

MILLENNIUM **Bulk Terminals—Longview**

EIS Environmental Impact Statement

State Environmental Policy Act Final Environmental Impact Statement

Volume III.c: Operations Technical Reports

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COWLITZ COUNTY WASHINGTON

DEPARTMENT OF ECOLOGY State of Washington

Volume III.c

Operations Technical Reports

Rail Transportation

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Coal: Coal Dust Emissions, Coal Spills Analysis, and Sulfur Dioxide And Mercury Emissions Analysis

Greenhouse Gas Emission

Coal Market Analysis

Climate Change

MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA RAIL TRANSPORTATION TECHNICAL REPORT

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Contents

List of Tables i
List of Figures ii
List of Acronyms and Abbreviations iii

Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-6
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-1
2.1.2 Impact Analysis 2-2
2.1.3 Train Routes 2-7
2.2 Existing Conditions 2-9
2.2.1 BNSF Spur and Reynolds Lead 2-10
2.2.2 Existing Rail Traffic in Washington State 2-13
2.2.3 Existing Rail Traffic Outside of Washington State 2-17
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Construction: Direct Impacts 3-1
3.1.2 Construction: Indirect Impacts 3-1
3.1.3 Operations: Direct Impacts 3-2
3.1.4 Operations: Indirect Impacts 3-2
3.2 No-Action Alternative 3-10
Chapter 4 **Required Permits** **4-1**
Chapter 5 **References** **5-1**
5.1 Written References 5-1
5.2 Personal Communications 5-2

Appendix A. Potential Coal Train Operating Plans

Tables

Table 1. Regulations, Statutes, and Guidelines for Rail Transportation 1-5
Table 2. Proposed Action-Related Train Parameters 2-4
Table 3. Average Capacities of Typical Rail Freight Corridors (trains per day) 2-6
Table 4. Representative Mine Origins Selected for Analysis 2-9
Table 5. Baseline Rail Traffic on the BNSF Spur and Reynolds Lead 2-11
Table 6. Route Infrastructure and Rail Traffic 2-14
Table 7. Route Segments between the Powder River Basin and Washington Statea 2-17
Table 8. Loaded Train and Volume Forecast 3-2
Table 9. BNSF Spur and Reynolds Lead Operations Detail—Incoming and Outgoing Proposed Action-Related Trainsa 3-4
Table 10. Infrastructure Capacity and Projected Rail Traffic, Including Proposed Action-Related Trains (trains per day) 3-5

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. BNSF and Union Pacific Routes to and from Longview, Washington 2-8
Figure 4. BNSF Spur and Reynolds Lead 2-12
Figure 5. Estimated Washington Rail Network Daily Track Utilization (2015) 2-15
Figure 6. Projected Washington Rail Network Daily Track Utilization, 2028 Baseline Conditions with Proposed Action-Related Trains 3-7
Figure 7. Projected Washington Rail Network Daily Track Utilization, 2028 Baseline Conditions (without Proposed Action-Related Trains) 3-11

Acronyms and Abbreviations

ABS	Automatic Block Signals
Applicant	Millennium Bulk Terminals—Longview, LLC
BNSF	BNSF Railway Company
Btu	British thermal unit
CFR	Code of Federal Regulations
CLC	Columbia and Cowlitz Railway
CTC	Centralized Traffic Control
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
LVSW	Longview Switching Company
mph	miles per hour
NEPA	National Environmental Policy Act
PTC	Positive Train Control
RCW	Revised Code of Washington
SEPA	Washington State Environmental Policy Act
TCS	Traffic Control Systems
TWC	Track Warrant Control
UP	Union Pacific Railroad
USC	United States Code
USDOT	U.S. Department of Transportation
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WUTC	Washington Utilities and Transportation Commission

Chapter 1
Introduction

This technical report assesses the potential rail transportation impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. For this assessment, rail transportation refers to the Proposed Action-related trains that would service the project area as well as the type and volume of other rail traffic using the same rail lines. This report describes the regulatory setting, establishes the methods for assessing potential rail transportation impacts, presents the historical and current rail transportation conditions in the study area, and assesses potential impacts.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east

in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

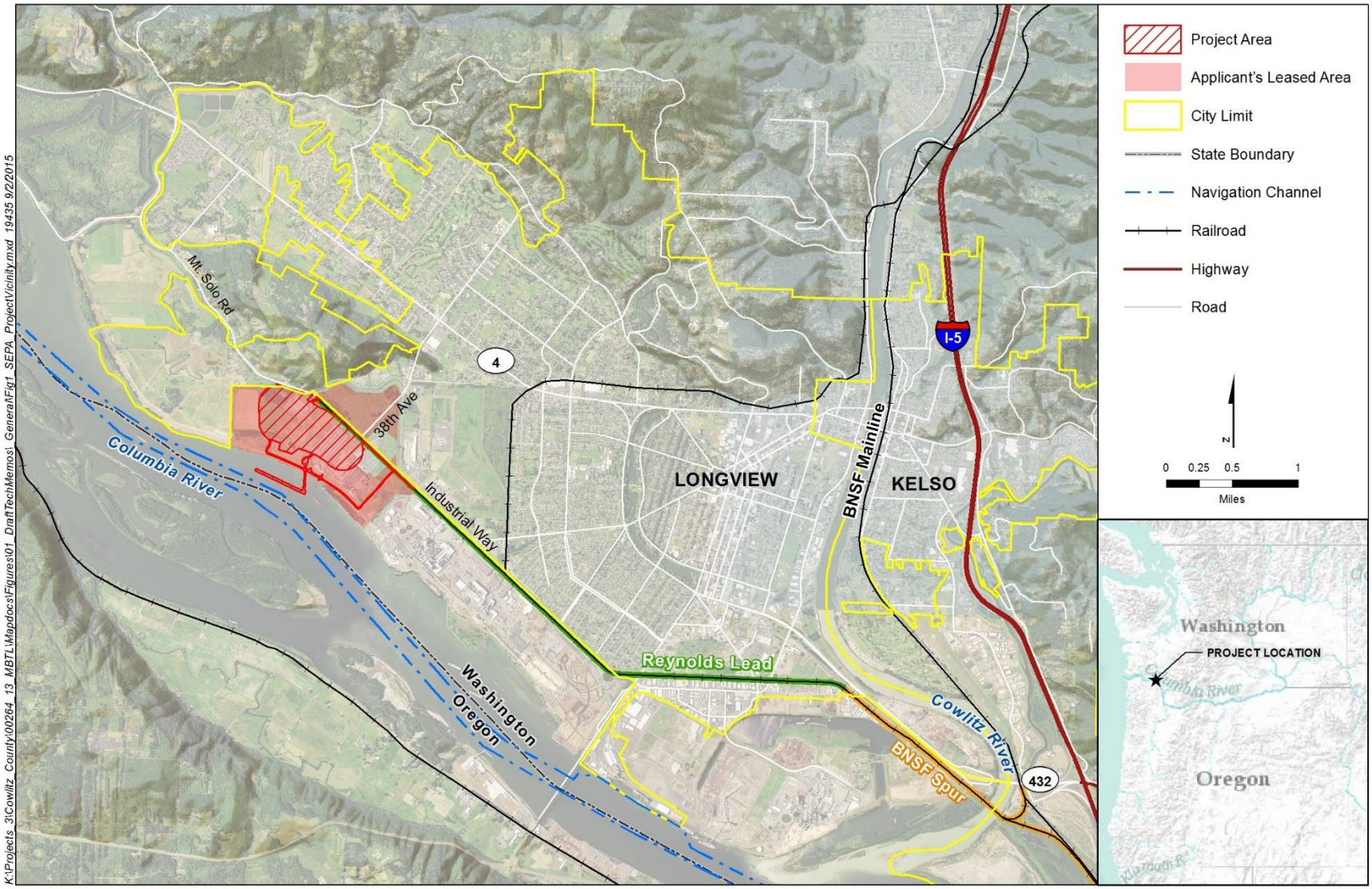
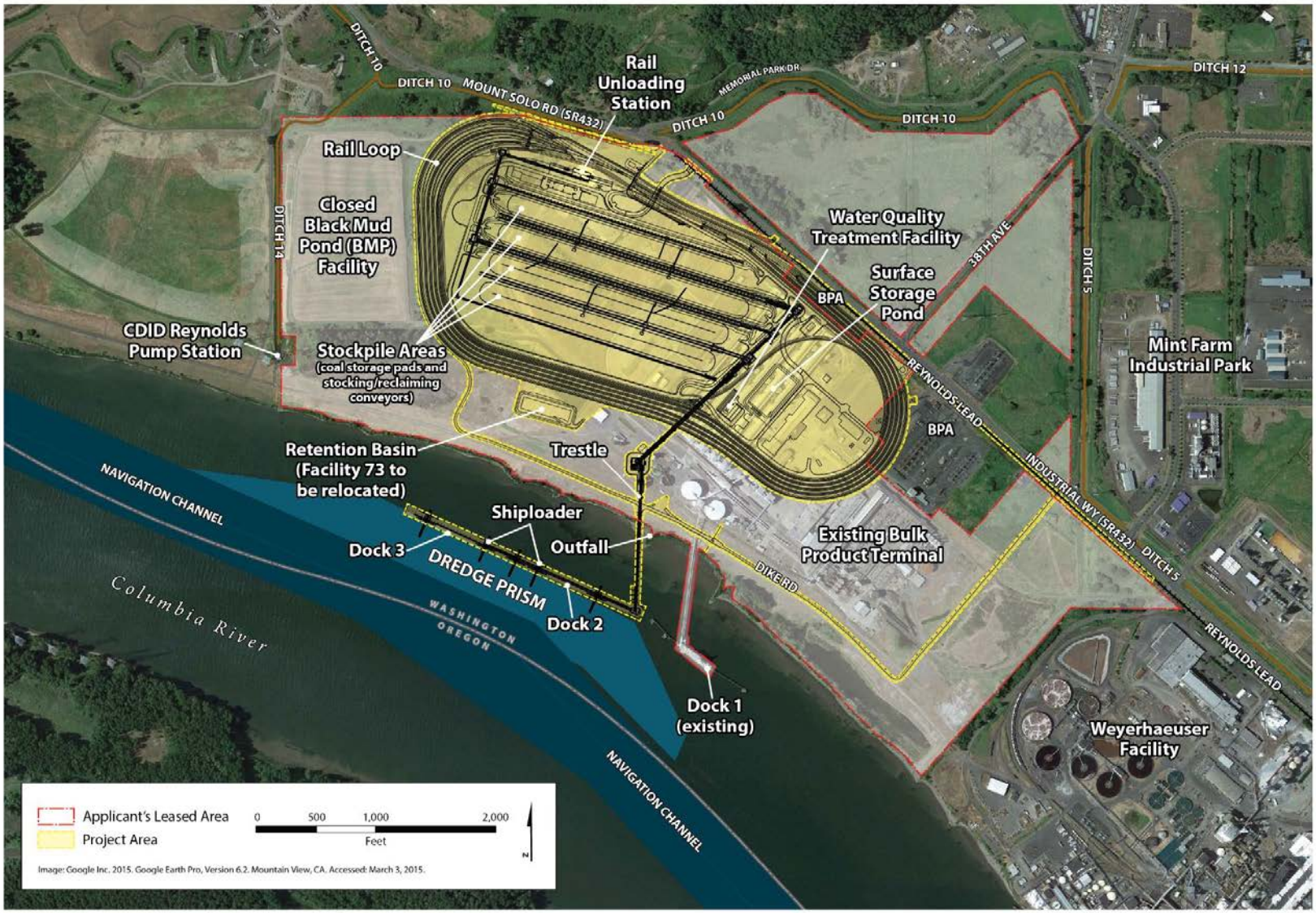


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

The jurisdictional authorities and corresponding regulations, statutes, and guidance for determining potential impacts on rail transportation are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidelines for Rail Transportation

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Federal Railroad Safety Act of 1970	Gives FRA rulemaking authority over all areas of rail line safety. FRA has designated that state and local law enforcement agencies have jurisdiction over most aspects of highway/rail grade crossings, including warning devices and traffic law enforcement.
Highway Safety Act and the Federal Railroad Safety Act	Gives FHWA and FRA regulatory jurisdiction over safety at federal highway/rail grade crossings. USDOT has promulgated rules addressing grade-crossing safety and provides funding for installation and improvement of warning devices. FRA has issued rules that impose minimum maintenance, inspection, and testing standards for at-grade crossing warning devices for highway/rail grade crossings on federal highways and state and local roads (49 CFR Parts 234–236).

Regulation, Statute, Guideline	Description
Federal Railroad Administration general regulations (49 CFR Parts 200–299)	Regulates safety, including operations, engineers, and crew (e.g., control of alcohol and drug use), track, signaling, and rolling stock (e.g., locomotives and passenger and freight cars) for common carrier rail lines that are part of the general rail line system of transportation.
ICC Termination Act of 1995 (49 USC 101)	Establishes the STB and upholds the common carrier obligations of railroads; requires railroads to provide service upon reasonable request.
State	
Washington State Environmental Policy Act (197-11 WAC, RCW 43.21C)	Requires state and local agencies in Washington State to identify potential environmental impacts that could result from governmental decisions.
Washington Utilities and Transportation Commission	Inspects and issues violations for hazardous materials, tracks, signal and train control, and rail operations. WUTC regulates the construction, closure, or modification of public railroad crossings. In addition, WUTC inspects and issues defect notices if a crossing does not meet minimum standards. However, WUTC has no jurisdiction over public crossings in first-class cities.[a]
WSDOT Local Agency Guidelines M 36-63.28, June 2015, Chapter 32, Railroad/Highway Crossing Program	Focuses on adding protection that improves safety and efficiency of railroad/highway crossings. Provides a process for investigating alternatives for improving grade-crossing safety, such as closure, consolidation, and installation of warning devices.
WSDOT Design Manual M 22.01.10, November 2015, Chapter 1350, Railroad Grade Crossings	Provides specific guidance for the design of at-grade railroad crossings.
Rail Companies—Operation (480-62 WAC)	Establishes operating procedures for railroad companies operating in Washington State. Includes general and procedural rules, safety rules, reporting requirement rules, and the establishment and distribution of a grade-crossing protective fund.
Local	
Longview Municipal Code 11.40.080 (Trains Not to Block Streets)	Prohibits trains from using any street or highway for a longer than five minutes, except trains or cars in motion other than those engaged in switching activities.
Cowlitz County SEPA Regulations (CCC 19.11)	Provides for the implementation of SEPA in Cowlitz County.

Notes:

[a] Per RCW 35.01.01, a first-class city is a city with a population of 10,000 or more at the time of organization or reorganization that has adopted a charter.

USC = United States Code; NEPA = National Environmental Policy Act; CFR = Code of Federal Regulations; FRA = Federal Railroad Administration; FHWA = Federal Highway Administration; USDOT = U.S. Department of Transportation; STB = Surface Transportation Board; WAC = Washington Administrative Code; RCW = Revised Code of Washington; WUTC = Washington Utilities and Transportation Commission; WSDOT = Washington State Department of Transportation; SEPA = Washington State Environmental Policy Act; CCC = Cowlitz County Code

1.3 Study Area

The study area for direct impacts on rail transportation is the project area for the Proposed Action. The study area for indirect impacts on rail transportation includes the rail routes expected to be

used by Proposed Action-related trains between the project area and the Powder River Basin in Montana and Wyoming and the Uinta Basin in Utah and Colorado. The indirect impacts analysis focuses on the Reynolds Lead and BNSF Spur and the BNSF main line in Cowlitz County. A qualitative assessment along the BNSF main line in Washington State and to and from the Powder River Basin and Uinta Basin is also presented.

Chapter 2
Existing Conditions

This chapter describes the methods for identifying existing conditions and determining impacts, and the existing conditions in the study area as they pertain to rail transportation.

2.1 Methods

This section describes the sources of information and methods used to characterize the affected environment and assess the potential impacts of the Proposed Action and No-Action Alternative on rail transportation.

2.1.1 Data Sources

The following sources of information were used to define the existing conditions relevant to rail transportation and identify the potential impacts of the Proposed Action and No-Action Alternative on rail transportation in the study areas.

2.1.1.1 Existing and Projected Rail Traffic

Existing and projected rail traffic for the Reynolds Lead and BNSF Spur were based on information from LVSW as operator of the Reynolds Lead and BNSF Spur and field observations. Existing and projected rail traffic for routes within Washington State was based on the *Washington State Rail Plan* (Washington State Department of Transportation 2014a). Existing and projected rail traffic on main line routes outside of Washington State were based on state rail planning documents, Federal Railroad Administration (FRA) data, and a Surface Transportation Board study (Surface Transportation Board 2015). The Applicant provided estimates of rail traffic under the No-Action Alternative (approximately 2 trains per day in 2028 on the Reynolds Lead and BNSF Spur).

2.1.1.2 Rail Operations

The following information sources were used for Proposed Action-related rail operations.

- **Volumes.** Proposed Action-related rail traffic to the project area at full terminal operations would include 8 loaded trains per day and 8 empty trains per day.
    - The types and number of trains from Longview Junction to the project area for 2015 and 2028 were developed from meetings with LVSW and the Port of Longview. The types and number of baseline train traffic beyond Longview Junction on main line routes were developed from the *Washington State Rail Plan* using linear extrapolation of 2010 and 2035 projected train traffic to 2015 and 2028. The type and number of baseline train traffic on main line routes outside Washington State were developed from the state rail

planning documents.[1] FRA crossing inventory reports (Federal Railroad Administration 2016) and a Surface Transportation Board study (Surface Transportation Board 2015) were also used to develop existing rail traffic estimates.

- **Capacity.** The *Washington State Rail Plan* was used to estimate rail segment capacity on BNSF main line routes in Washington State. The capacity of main line routes outside Washington State were estimated from the state rail planning documents.
- **Routes.** Representative coal mines were selected to identify rail routes outside of Washington State. Routes to and from the project area within Washington State were based on existing BNSF and UP operational practices and Washington State Department of Transportation (WSDOT) documents including the *Washington State Rail Plan* and *Washington State Freight Mobility Plan* (Washington State Department of Transportation 2014b).
- **Train parameters.** Train parameters including the number of rail cars per unit train (125 rail cars for each train) and number of locomotives (four per unit train) were based on information provided by the Applicant, input from BNSF, and existing BNSF coal train operations (BNSF Railway Company 2016).
- **Reynolds Lead, BNSF Spur, and project area operations**. Operations of the Reynolds Lead, BNSF Spur, and the project area was based on information provided by LVSW and the Applicant.

2.1.2 Impact Analysis

The following methods and assumptions were used to evaluate the potential impacts of the Proposed Action and No-Action Alternative on rail transportation.

No rail construction or infrastructure improvements outside of the project area are proposed by the Applicant. However, LVSW plans to upgrade the Reynolds Lead and part of the BNSF Spur as a separate action should it be warranted by increased rail traffic resulting from existing and future customers. Upgrades to the track would include adding ballast, replacing ties, and upgrading rail. These improvements would provide for safer operations and increased speed over the BNSF Spur and Reynolds Lead. LVSW would also install signals and upgrade the traffic control system to Centralized Traffic Control (CTC) and add an electric remotely operated switch from the BNSF Spur to the Reynolds Lead. The signaling would add capacity to the line, allowing trains to be spaced closer together and the electronic switch would eliminate the need for loaded and empty trains to stop while a train crewmember operates the switch (Wolter pers. comm.). Construction of these improvements would take approximately 6 months. Because these improvements are not certain, the impact analysis considers infrastructure with and without these planned improvements.

For the purposes of this analysis, potential operations impacts are based on the Applicant's planned throughput capacity (up to 44 million metric tons of coal per year).

Train speed and travel time from Longview Junction to project area. The operating plan (Appendix A, *Potential Coal Train Operating Plans*) assumes that the maximum speed over the

[1] State rail planning documents include the *Montana State Rail Plan, Final Report* (Cambridge Systematics, Inc. 2010); *Wyoming Statewide Rail Plan* (Wyoming Department of Transportation 2015); *Idaho Statewide Rail Plan* (David Evans and Associates 2013); and *Oregon State Rail Plan Freight and Passenger Rail System Inventory Draft Report* (Cambridge Systematics, Inc. 2014).

Reynolds Lead could increase from 10 miles per hour (mph) to up to 25 mph if track improvements are made by LVSW, which would reduce the train travel time from the BNSF main line to the project area from approximately 49 minutes to approximately 32 minutes. For this analysis, it is assumed that Proposed Action-related trains would reach a maximum speed of 20 mph if the planned improvements were made, with an average speed of approximately 11 mph.

However, also included is an analysis of train speeds and transit time over each road crossing assuming the planned improvements are not made. Trains would accelerate or decelerate at various points along the route approaching switches. Estimates of the train speeds at various points on the route were used to estimate the time that trains would transit each road crossing. The analysis assumes that none of the improvements would be made to the road crossings as proposed in WSDOT's *State Route 432 Rail Realignment and Highway Improvements Project* (Parsons Brinckerhoff 2014).

Proposed Action-related train parameters. The number of cars per train and number of locomotives are based on information provided by the Applicant. The coal car type, tare weight,[2] length, and capacity are based on a typical aluminum rotary coal gondola. The parameters of Proposed Action-related trains that would service the project area are summarized in Table 2. For purposes of this analysis, all Proposed Action-related trains are assumed to have the characteristics shown in Table 2.

According to the Applicant, rail operations would support coal export terminal throughput of 40 million metric tons of coal per year. The Applicant assumes a 10% increase in throughput (4 million metric tons of coal per year) is possible with rail car capacity increases, achieved with process efficiencies and technological improvements, by 2028.

[2] Weight of the empty railcar.

Table 2. Proposed Action-Related Train Parameters

Rail Cars	
Type	Alum Rotary Gondola
Gross rail load (tons)	143
Tare weight (tons)	20.9
Lading per car (tons)	122.1
Coupled Length (feet)	53
Locomotives	
Type	4400 HP AC
Weight (tons)	216
Length (feet)	73
Number in train	4
Configuration[a]	3-0-1
Total Train	
Cars per train[b]	125
Total lading weight (tons)	15,263
Total tare weight of cars (tons)	2,613
Weight locomotives (tons)	648
Total train weight (tons)	18,780
Total train length (feet)	6,917

[a] Locomotives are distributed through trains (distributed power) in various configurations. Proposed Action-related trains would likely have three locomotives at the head and one at the rear of the train.

Rail line capacity. The capacity of a rail line is generally determined by the number of main tracks, type of traffic control system, and types of trains moving over the segment. Train speed on the Reynolds Lead and BNSF Spur was estimated using a simulation model.[3] The assumptions for the contribution of each of these factors and the basis for assumptions are described in Section 2.1.1, *Data Sources.*

- **Longview Junction to project area.** The theoretical capacity[4] for the Reynolds Lead and BNSF Spur was calculated based on the number of main tracks, train parameters, speed, and distance. The track segment from Longview Junction to the project area is currently not signaled. Permission to occupy this track is controlled by the LVSW yardmaster. Along with upgrading the track to increase speeds, LVSW plans to upgrade the signal system to CTC.
- **Beyond Longview Junction.** Beyond Longview Junction, the number of main tracks and traffic control systems were developed from the *Washington State Rail Plan*. As described in Technical Note 4a of the *Washington State Rail Plan*, this approach involves estimating maximum practical capacity in number of trains per day, determined by signal type, number of tracks, and geometric limitations.

Routes. The BNSF route for loaded Proposed Action-related trains from the Powder River Basin would run through Montana and Sandpoint, Idaho, to Spokane and Pasco, Washington. Trains

[3] Inputs to the model were locomotive horsepower, train length and weight, number of axles, cross section, air brake pounds per square inch, a resistance factor, track grade, and track curvature.

[4] Theoretical capacity is the number of trains that could run over a route in a mathematically generated environment at minimum spacing between trains.

would then travel along the Columbia River Gorge to Vancouver, Washington, then north to Longview. Empty trains are expected to travel north from Longview Junction to Auburn and over Stampede Pass to Pasco. The UP route for Proposed Action-related trains originating in the Uinta Basin or Powder River Basin would run through Oregon to the North Portland Junction. From there, Proposed Action-related UP trains would cross into Washington at Vancouver and run over the BNSF Seattle Subdivision to the project area. This same track would be used by Proposed Action-related BNSF trains going to the project area. Alternative routes and additional information on Proposed Action-related train routes is provided in Section 2.1.3, *Train Routes*. Most of the route segments in this analysis have one main track with multiple sidings for trains to meet or pass, but there are several segments with two or three main tracks.

Baseline rail traffic. The types and number of trains from Longview Junction to the project area for the existing year and 2028 were developed from meetings with LVSW and the Port of Longview. The types and number of baseline trains on main line routes in Washington State were developed using linear extrapolation of 2010 and 2035 projected train traffic to 2015 and 2028.[5] The freight demands analysis methods in the *Washington State Rail Plan* used an economic forecast to estimate the future freight rail demand. These rail traffic estimates do not include the rail traffic for proposed coal or crude oil projects in Washington State. Therefore, Proposed Action-related rail traffic was added to 2028 baseline rail traffic estimates for the purposes of this analysis. Rail traffic information derived from state rail planning documents was used to determine potential impacts of Proposed Action-related trains on rail capacity outside of Washington State in Idaho, Montana, Oregon, Utah, and Wyoming where sufficient publicly available data were available.

Proposed Action-related rail traffic. The Applicant estimates that, at full capacity, operation of the Proposed Action would move up to 44 million metric ton of coal per year, requiring the receipt and return of 8 Proposed Action-related trains per day, or 16 daily trains. Train parameters are outlined in Table 2.

2.1.2.1 Traffic Control Systems

Traffic control systems help maintain a safe distance between trains passing or meeting on the same track. There are three basic types of systems.

Automatic Block Signals (ABS). ABS is an electronic signal system that can control when a train can advance into the next block. A block is a section of track with signals at each end. Only 1 train can occupy a block at one time at normal speed. Trains may enter a block occupied by another train in the same direction, but must be prepared to stop within half the range of vision. The signals provide information to the train crew about some speed restrictions and they provide information about the occupancy of the blocks ahead.

Track Warrant Control (TWC). Under this basic control system, train crews obtain authority to occupy and move on a main track from the dispatcher in the form of a completed track warrant form. Usually the track warrant information is transmitted to the train crew by phone, radio, or

[5] The rail traffic estimates in the *Washington State Rail Plan* are based on data collected between 2010 and 2013. Rail traffic is highly dynamic and fluctuates because of changing demand. The 2028 rail traffic estimates are intended to provide a "snapshot" of estimated rail traffic volumes; the rail traffic estimates do not represent actual volumes for 2028.

electronic transmission to the locomotive. It is the least costly system and is generally used on the low-density track where capacity is generally not an issue. Track warrant authority may be used in combination with ABS or on track that has no block signals.

Centralized Traffic Control (CTC) and Traffic Control Systems (TCS). With CTC, electrical circuits monitor the location of trains, allowing dispatchers to control train movements from a remote location, usually a central dispatching office. The signal system prevents trains from being authorized to enter sections of track occupied by other trains moving in the opposite direction. The dispatcher controls traffic by controlling the signals. If the signal is at stop, the approaching train is not authorized to proceed. If the signal is not at stop, the train is authorized to continue to the next controlled signal.

In 2008, Congress passed the Rail Safety Improvement Act of 2008, which requires all passenger railroads and Class I freight railroads to install Positive Train Control (PTC) on all lines that carry passengers or toxic-by-inhalation commodities.[6] PTC automatically stops a train if the engineer does not respond properly to a signal indication. PTC is designed to reduce the number of train accidents caused by human error. While future generations of PTC may help railroads increase capacity on individual corridors, the PTC technology currently being installed on U.S. railroads is not expected to have a meaningful impact on corridor capacity (Association of American Railroads 2014).

Table 3 summarizes estimated capacity based on the number of main tracks and traffic control systems.

Table 3. Average Capacities of Typical Rail Freight Corridors (trains per day)

Number of Tracks	Type of Control	Practical Maximum if Multiple Train Types use Corridor[a]
1	N/S or TWC	16
1	ABS	18
2	N/S or TWC	28
1	CTC or TCS	30
2	ABS	53
2	CTC or TCS	75
3	CTC or TCS	133
4	CTC or TCS	173
5	CTC or TCS	248
6	CTC or TCS	360

Notes:
[a] For example, a mix of merchandise, intermodal, and passenger trains.
Source: Cambridge Systematics 2007: 4–7
N/S = No Signal; TWC = Track Warrant Control; ABS = Automatic Block Signaling; CTC = Centralized Traffic Control; TCS = Traffic Control System

[6] Toxic-by-inhalation commodities are gases or liquids such as chlorine or anhydrous ammonia that are especially hazardous when released into the atmosphere.

2.1.2.2 Train Types and Operations

Different train types such as passenger, intermodal, automotive, coal unit, and general manifest trains operate at different speeds. Trains operating at different speeds require a larger separation than trains of the same type operating on the same segment. For the purpose of this analysis, multiple train types were assumed. Capacity on a single-track segment can also be increased by running trains in only one direction over that segment. Two single-track routes can be combined to function essentially as double track. This strategy, known is directional running is described in Section 2.1.3, *Train Routes*.

2.1.3 Train Routes

The routes from the selected representative mines to the project area were assumed the same as current BNSF and UP routes and as documented in WSDOT publications, including the *Washington State Rail Plan* and *Washington State Freight Mobility Plan*.

In 2012, BNSF changed its train operations protocol to enhance use of existing capacity using directional running. This strategy routes all westbound loaded unit trains[7] (including coal trains) from Pasco via the Columbia River Gorge to Vancouver, where they continue north on the BNSF main line to their final destinations. Empty unit bulk trains from north of Vancouver, including Cowlitz County, return to Pasco and to points east via Stampede Pass.

However, each railroad company has alternative routes. As volume increases on any one-line segment, each railroad company may revise its operations to distribute traffic over existing infrastructure. Railroad companies may also expand their infrastructure, which occurs on an ongoing basis based on demand. Figure 3 displays the routes used for this analysis.

Loaded and empty BNSF trains would travel on the same route from the Powder River Basin to Pasco, Washington.[8] West of Pasco, westbound loaded trains would be expected to move to the project area on the Columbia River Gorge route through Vancouver to Longview Junction, Washington. Empty trains would be expected to move from Longview Junction on the BNSF Stampede Pass route through Auburn and Yakima to Pasco, Washington.

The UP route is largely outside of Washington State. Proposed Action-related trains would move from the Uinta Basin and Powder River Basin through Pocatello, Idaho; Boise, Idaho; and Hinkle, Oregon. From Hinkle, the route parallels the Columbia River on the Oregon side to Portland, Oregon. Between Portland, Oregon, and Longview Junction, Washington, UP operates over the same track that carries BNSF trains. Empty UP Proposed Action-related trains would return to the Uinta Basin or Powder River Basin via the same route.

Between Longview Junction and the project area, both BNSF and UP Proposed Action-related trains would move over the LVSW rail line (Reynolds Lead and BNSF Spur).

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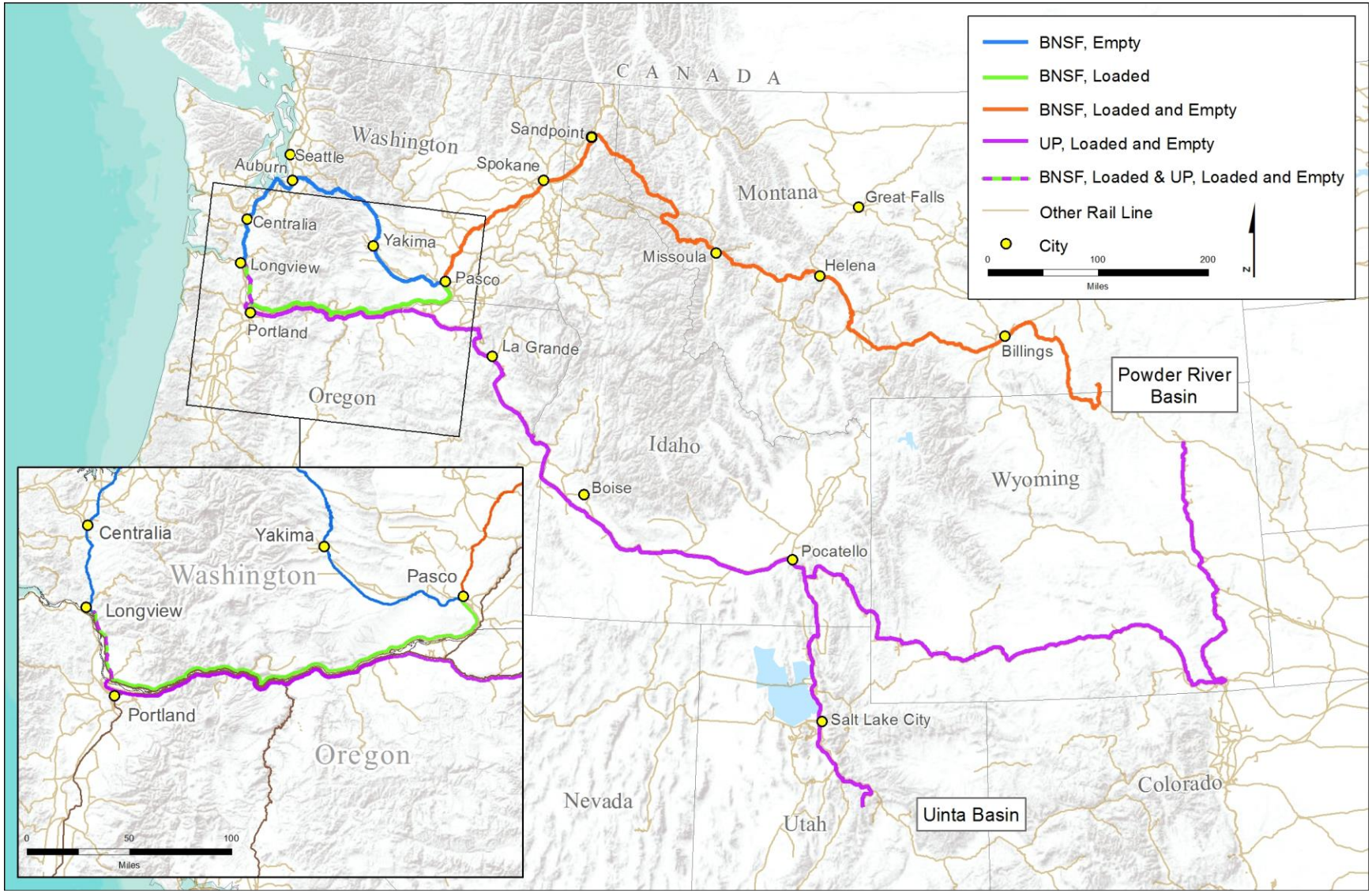
[7] Unit trains consist of rail cars that carry the same commodity shipped from the same origin to the same destination. Manifest trains consist of rail cars c different commodities originating in different locations and delivered to different locations.

[8] In late 2014, the BNSF constructed and began operation of a respray facility along their main line in Pasco, Washington. Before coal trains continue their route west along the Columbia River Gorge, BNSF resprays the coal rail cars with a surfactant to ensure coal dust release is further mitigated.

Figure 3. BNSF and Union Pacific Routes to and from Longview, Washington



2.1.3.1 Train Origins

Two types of coal could be exported from the coal export terminal.

- Subbituminous coal (approximately 8,800 to 9,200 British thermal units [Btu] per pound), originating in the Powder River Basin in Montana or Wyoming.
- Bituminous coal (approximately 11,700 Btu per pound), originating in the Uinta Basin in Utah or Colorado.

For purposes of this analysis, an example mine was used from each of these origin areas (Table 4) to estimate rail miles and routes. Rail routes would be similar for other mines from these regions to the coal export terminal. Given market economics, most of the coal that would be exported would be expected to come from Powder River Basin mines in Montana and Wyoming and would move via the BNSF routes.

Table 4. Representative Mine Origins Selected for Analysis

Coal Supply Region	Representative Mine	Rail Station	Railroad
Powder River Basin	Spring Creek Mine	Spring Creek Mine, Montana	BNSF
Utah	Skyline Mine	Skyline, Utah	UP

Notes:
BNSF = BNSF Railway Company; UP = Union Pacific Railroad

2.2 Existing Conditions

The existing conditions related to rail transportation in the study area are described below.

As described in Section 1.1.1, *Proposed Action,* the project area is located on 190 acres primarily within a 540-acre existing industrial site near Longview, Washington. The project area is located on the Reynolds Lead, an existing rail line that serves several industries and connects via the BNSF Spur to the rail network approximately 6 miles away in Longview Junction. The track and rail infrastructure leading to the project area are described as follows.

- The BNSF Spur consists of a track through Longview Junction yard, across the Cowlitz River Bridge,[9] and through the LVSW yard. Figure 1 illustrates the BNSF Spur.
- The Reynolds Lead consists of a track from the LVSW yard to the project area. The Reynolds Lead covers the majority of the distance between the project area and the BNSF main line. Figure 1 illustrates the Reynolds Lead.

The route has a single main track with TWC (no signals). Two sidings on the Reynolds Lead are currently used to interchange cars with the Columbia and Cowlitz Railway (CLC).[10] Speed limit on

[9] The Cowlitz Bridge is a manually operated drawbridge controlled by LVSW. The bridge only opens once every 4 or 5 years to allow passage of river-dredging vessels.

[10] CLC is owned by Patriot Rail. It primarily provides switching service inside the Weyerhaeuser plant and serves a few industries. All cars to or from CLC are handled by LVSW for interchange to BNSF and UP. CLC interchanges with LVSW at two sidings on the Reynolds Lead near the LVSW yard.

the line is 10 mph. At an average speed of 9 mph (allowing for slowing and accelerating at various locations), train travel time from Longview Junction to the project area under current conditions would be approximately 49 minutes.

2.2.1 BNSF Spur and Reynolds Lead

Table 5 summarizes current baseline traffic data for the BNSF Spur and Reynolds Lead to and from the Port of Longview or other industrial customers. The table also includes the estimated train size and average passing time over a road crossing for those trains. The table also includes a weighted average of baseline trains per day passing each road crossing. The train counts include both loaded and empty trains.[11] For purposes of describing baseline traffic, the LVSW rail line is divided into two parts, the BNSF Spur and the Reynolds Lead, as shown in Figure 4.

Between Longview Junction and the project area there are five public at-grade road crossings (Figure 4). These road crossings experience rail traffic from current train operations to and from the Port of Longview and/or from industrial switching activities at locations along the Reynolds Lead. Each Proposed Action-related train, loaded and empty, would also cross roads at these locations. This section analyzes the train volume and train crossing times at each of these road crossings. The analysis assumes no improvements would be made to the crossings.

BNSF Spur

The BNSF Spur runs from the BNSF Seattle Subdivision mainline switch at Longview Junction, across the Cowlitz River Bridge, to the LVSW yard. Baseline traffic on the BNSF Spur is about 7 trains (or switch movements) per day. The 7 trains average 78 rail cars per train and 4,920 feet in length. The Port Industrial Rail Corridor connects with the BNSF Spur just east of the LVSW yard. Trains to or from the EGT, LLC, and other Port of Longview facilities leave or enter the BNSF Spur at the Industrial Rail Corridor switch. Other trains originate or terminate in the LVSW yard. Dike Road is the only at-grade road crossing on the BNSF Spur and there are no private crossings. All 7 trains per day (on average) on the BNSF Spur cross Dike Road.

The switch from the BNSF Spur to the Port Industrial Rail Corridor is a remotely controlled switch operated by the BNSF dispatcher. The speed limit on the BNSF Spur is 10 mph because of speed restrictions on the bridge. There is one main track, and traffic control is TWC. Capacity through this area currently is approximately 24 trains per day (12 trains in each direction), which supports the current volume. The SEPA co-lead agencies obtained the Cowlitz River Bridge public bridge inspection report generated by BNSF from FRA on January 4, 2017. The Condition of Bridge subsection of the report states: “Bridge confirmed to have the capacity to carry traffic operated over the bridge.”

[11] Train count and train size estimates include both loaded and empty cars based LVSW (pers. comm.) and Port of Longview (pers. comm.). These estimates are similar to those reported in Parsons Brinckerhoff (2014), which shows 450 loaded cars per day.

Table 5. Baseline Rail Traffic on the BNSF Spur and Reynolds Lead

	Trains/ Day	Days/ Week	Trains/ Year	Cars/ Train	Locomotives/ Train	Train Length (Feet)[d]	Estimated Passing Time (Minutes)[e]	Weighted Average Trains per Day over Road Crossings				
								BNSF Spur crossing of Dike Road	Reynolds Lead crossing of 3rd Avenue (SR 432)	Reynolds Lead crossing of California Way	Reynolds Lead crossing of Oregon Way	Reynolds Lead crossing of Industrial Way
CLC trains interchange to/from LVSW rail line[a,b]	2	5	520	15	2	1,065	1.2				1.42	1.42
LVSW rail line interchange to/from CLC[a,b]	2	5	520	15	2	1,093	1.2		1.42	1.42		
Reynolds Lead Industry local crew[a,c]	2	3	312	30	2	2,068	2.4		0.85	0.85	0.85	0.85
Manifest trains from Longview Junction yard to LVSW yard[a,f]	4	5	1,040	30	2	2,068	2.4	2.85				
Grain unit trains to/from EGT[a,g]	4	7	1,456	110	3	6,819	7.7	3.99				
Clay, soda ash and other Port unit trains[a,h]	2	1	104	110	3	6,819	7.7	0.28				
Weighted Average Trains/day								7.12	2.28	2.28	2.28	2.28
Weighted Average Length (feet)								4,919	1,459	1,459	1,441	1,441
Weighted Average Cars/train								78	21	21	21	21

[a] Source: Wolter pers. comm.

[b] CLC switch crew from Weyerhaeuser plant delivers and picks up cars to/from interchange sidings just west of California Way. LVSW switch crew from LVSW yard delivers and picks up cars to/from interchange sidings just west of California Way.

[c] Crew works afternoon shift 5 days/week but serves Reynolds Lead 3 days/week. Cars per train range from 5 to 30 depending on whether train is delivering coal or alumina or to the Port of Longview.

[d] Car length is average of car types handled (Wolter pers. comm.) and Hellerworx observations, December 3, 2014. Locomotive type based on Hellerworx observations, December 3, 2014.

[e] Based on 10 mph average speed.

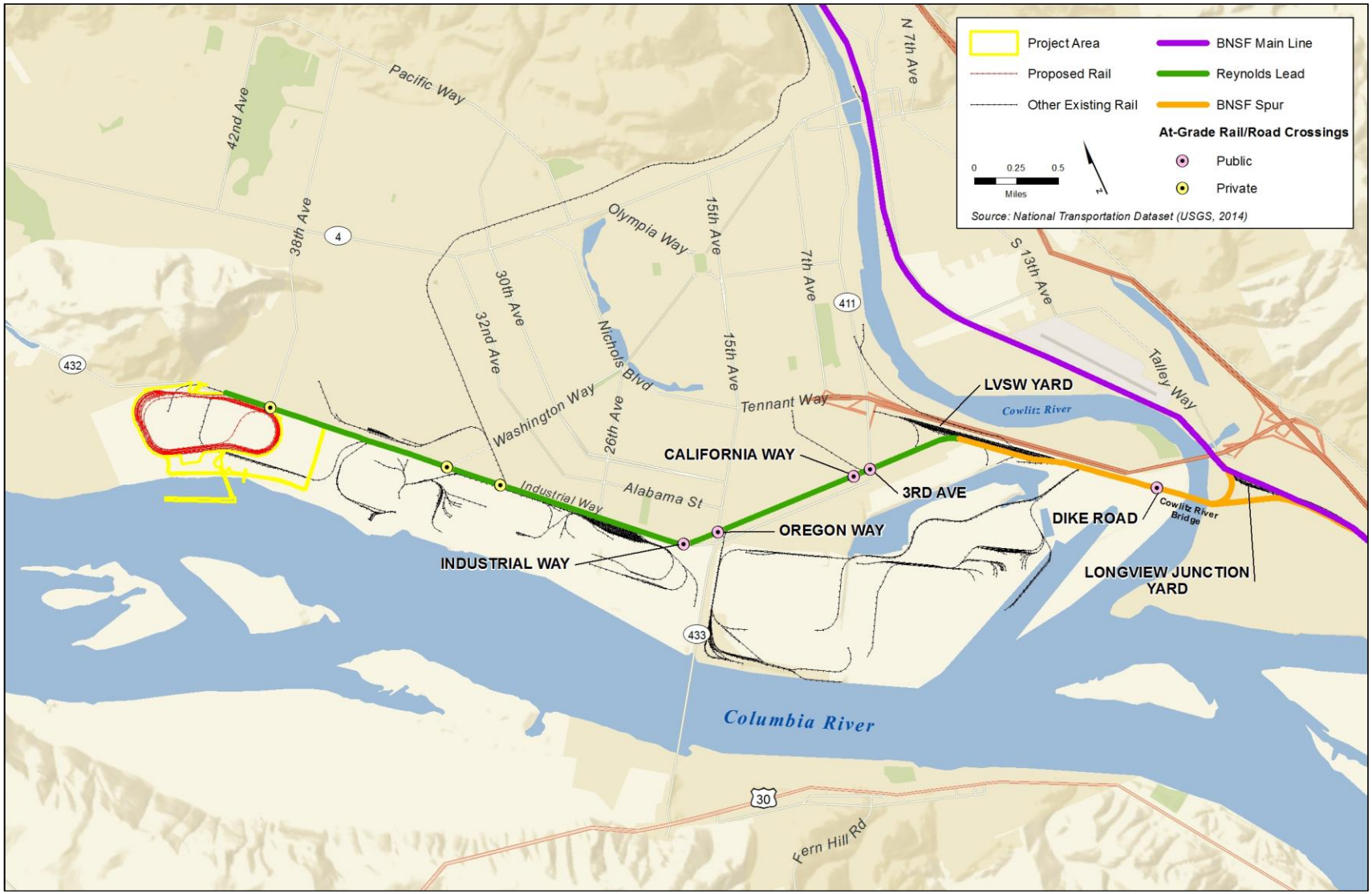
[f] Manifest movements between Longview Junction yard and LVSW yard across bridge are generally cuts of cars moving as a yard transfer (Wolter pers. comm.). Occasionally LVSW yardmaster will direct BNSF or UP road crew to bring a manifest train off BNSF main line into the LVSW yard instead of switching it in Longview Junction yard because most of the cars on the train are destined to the Port of Longview.

[g] EGT capacity for 4 trains per day but current volume is 2 (Wolter pers. comm.). Train size is BNSF standard grain unit shuttle train, 110 cars. Number of locomotives on grain unit trains and locomotive configuration (Wolter pers. comm.). Locomotive specs same as projected coal trains 3 GE AC 4400 units; 2 loaded and 2 empty trains per day.

[h] Miscellaneous Port of Longview unit trains carry the following products: clay,1 train per month; soda ash, 2 or 3 trains per month; a few unit trains per year of potash and urea (Port of Longview pers. comm.) Volume estimates provided by Wolter (pers. comm.), LVSW (pers. comm.), and Port of Longview (pers. comm.). Estimated train length and locomotives provided by Wolter (pers. comm.), LVSW (pers. comm.), and Hellerworx experience. Port of Longview manifest traffic crossing the dike road is included in manifest traffic between the Longview Junction yard and LVSW yard.

CLC = Columbia and Cowlitz Railway; LVSW = Longview Switching Company; mph = miles per hour

Figure 4. BNSF Spur and Reynolds Lead



Reynolds Lead

The Reynolds Lead runs from the west end of the LVSW yard to the project area. There is one main track with TWC traffic control. The current speed limit is 10 mph, and capacity is approximately 24 trains per day (12 trains in each direction). Baseline traffic is just more than 2 trains per day, on average. Trains operating on the Reynolds Lead include an LVSW local crew that places and pulls cars at industrial facilities located along the Reynolds Lead 3 days per week and a local crew that delivers and picks up cars that are interchanged to and from the CLC at two sidings just west of California Way. CLC also operates on the Reynolds Lead between the Weyerhaeuser plant near Industrial Way and these sidings to deliver and pick up interchange cars to or from the LVSW rail line.

The Reynolds Lead ends at the project area. There are four public at-grade road crossings on the Reynolds Lead between the LVSW yard and the project area (Figure 4). Not all of the trains cross each of these roads. The LVSW local crew switching industries on the Reynolds Lead crosses all four roads twice. The LVSW crew that interchanges cars to the CLC on the sidings crosses 3rd Avenue and California Way twice. The CLC crew interchanging cars to the LVSW rail line crosses twice over Oregon Way and Industrial Way on the way to the sidings.

2.2.2 Existing Rail Traffic in Washington State

Within Washington State, Proposed Action-related trains would travel mostly on BNSF track. Table 6 summarizes infrastructure and traffic data for each major segment of the BNSF route in Washington State. These major segments and the rail traffic they support are described below. Figure 5 illustrates 2015 rail traffic and capacity along the major rail segments using the *Washington State Rail Plan*.[12]

- **Idaho/Washington State Line–Spokane.** This segment covers 18.6 miles and is part of BNSF's Kootenai River Subdivision. It is a double track with CTC. Capacity is approximately 76 trains per day and volume is approximately 70 trains per day. All BNSF trains between the eastern part of BNSF's system and points in Washington State move over this corridor. Train traffic includes intermodal, grain, coal, and general manifest trains. Amtrak's Empire Builder passenger service between Chicago, Illinois; Seattle, Washington; and Portland, Oregon also uses this segment.
- **Spokane–Pasco.** This corridor covers 145.5 miles and is part of BNSF's Lakeside Subdivision. This line is mostly single track with CTC. Capacity is approximately 37 trains per day and volume is approximately 39 trains per day. Train traffic on this segment includes intermodal, grain, coal, and general manifest trains. The Portland section of Amtrak's Empire Builder passenger service uses this segment. BNSF is currently making upgrades to this segment, including adding a second main line in some areas. .

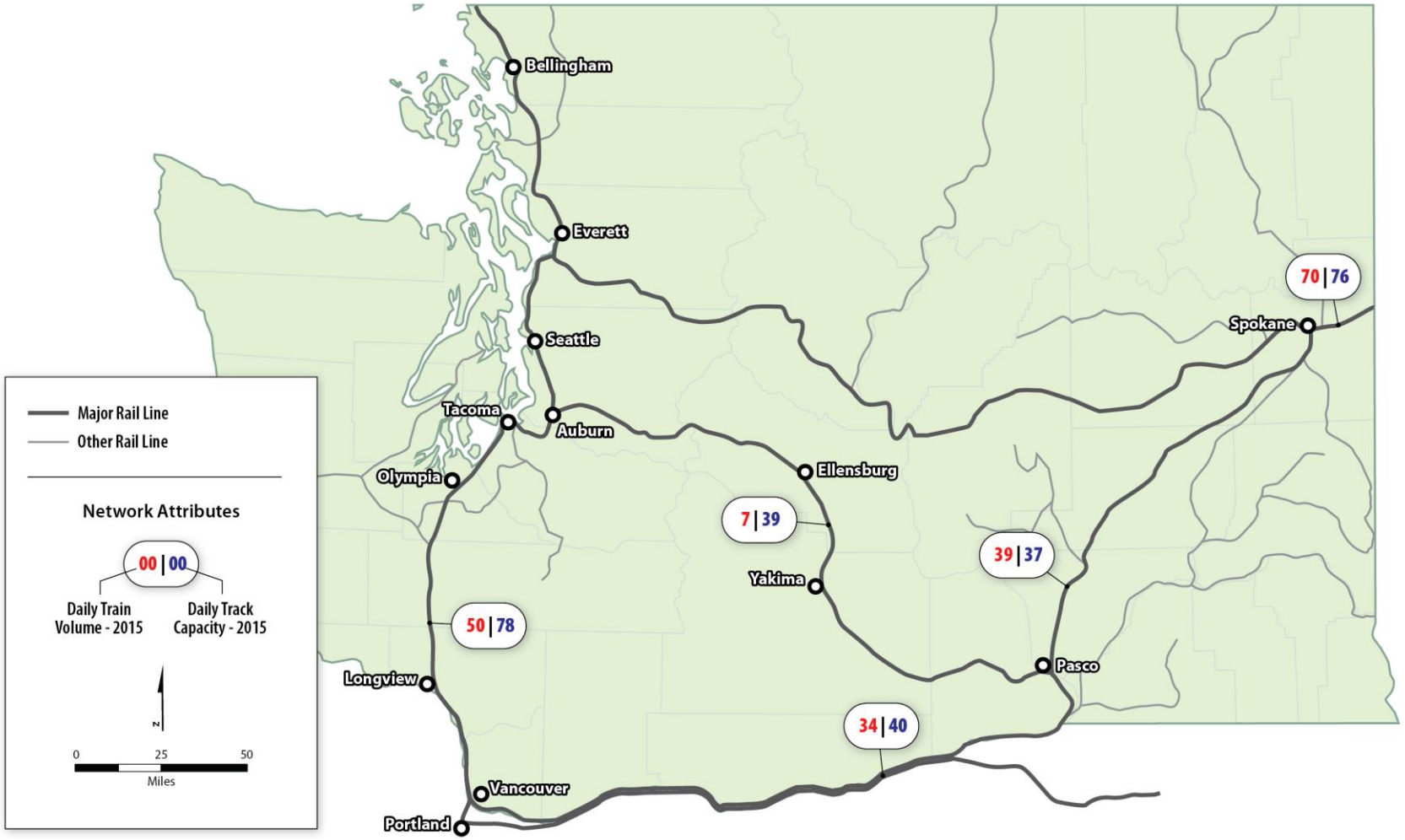
[12] Rail traffic estimates provided in the *Washington State Rail Plan* do not include the rail traffic for proposed coal or crude oil projects in Washington State.

Table 6. Route Infrastructure and Rail Traffic

Route Segment	Railroad	Subdivision	Current Traffic Control System[a]	Current Main Tracks[a]	Current Passenger Train Route[a]	Future Passenger Train Route[a]	Estimated Current Capacity (Trains/day)[b]	Miles[c]	Estimated Baseline (2015) Trains Per Day[d]	Projected 2035 Trains per Day[a]
Idaho/ Washington State Line–Spokane	BNSF	Spokane	CTC	2	Yes	Yes	76	18.6	70	125
Spokane–Pasco	BNSF	Lakeside	CTC	1	Yes	Yes	37	145.5	39	66
Pasco–Vancouver	BNSF	Fallbridge	CTC	1	Yes	Yes	40	221.4	34	56
Vancouver–Longview Junction	BNSF	Seattle	CTC	2	Yes	Yes	78	34.8	50	85
Longview Junction–LVSW Yard (BNSF Spur)	BNSF	LVSW	TWC	1	No	No	24	2.1	7	N/A
LVSW Yard–Project Area (Reynolds Lead)	BNSF	LVSW	TWC	1	No	No	24	5.0	2	N/A
Longview Junction–Auburn	BNSF	Seattle	CTC	2	Yes	Yes	78	118.6	50	85
Auburn–Yakima	BNSF	Stampede	TWC	1	No	No	39	139.6	7	13
Yakima–Pasco	BNSF	Yakima Valley	TWC	1	No	No	39	89.4	7	13

[a] Source: Washington State Department of Transportation 2014b.
[b] Source: Washington State Department of Transportation 2014b; LVSW rai line segments were estimated from Table 5.
[c] Source: Estimated based on GIS measurements.
[d] Source: Washington State Department of Transportation 2014b; Wolter pers. comm.; Port of Longview pers. comm.
LVSW = Longview Switching Company; CTC = Centralized Traffic Control; TWC = Track Warrant Control; N/A = No projection is available.

Figure 5. Estimated Washington Rail Network Daily Track Utilization (2015)



- **Pasco–Vancouver.** This segment covers 221.4 miles and is BNSF's Fallbridge Subdivision, also known as the Columbia River Gorge route. It is mostly single track with CTC. Capacity is approximately 40 trains per day and volume is approximately 34 trains per day. Train traffic on this segment includes intermodal, grain, coal, and manifest. The Portland section of Amtrak's Empire Builder passenger service also uses this route. BNSF uses directional operations on this segment, which increases capacity by running westbound loaded unit trains on this segment and eastbound empty unit trains via Stampede Pass.

  Vancouver–Longview Junction. This segment covers 34.8 miles of BNSF's Seattle Subdivision. It is double track with CTC. About 21 miles of this segment is in Cowlitz County. Capacity is approximately 78 trains per day and volume is approximately 50 trains per day. This line also carries all UP trains between Portland, Oregon and Tacoma. Traffic includes intermodal, grain, coal and other unit trains along with manifest trains. This section of the BNSF line is also a key route for passenger trains. Amtrak's Coast Starlight trains to and from California and Amtrak Cascades trains between Eugene, Oregon and Seattle use this segment.

  WSDOT is constructing 3.7 miles of a third main track on the BNSF Seattle Subdivision main line between Longview Junction and Kelso, scheduled to be completed in 2017. The purpose of the third main track is to enable 2 trains to pass while a train is simultaneously moving into or out of the Longview Junction yard (Washington State Department of Transportation 2014c). This would reduce the potential for delays to passenger and freight trains running through the area.

- **Longview Junction–Auburn.** This segment includes 118.6 miles of BNSF's Seattle Subdivision. About 18 miles of this segment are in Cowlitz County. There are two main tracks and traffic control is CTC. Current capacity is approximately 78 trains per day and volume is about 50 trains per day. Traffic on this line includes intermodal, empty coal, and grain trains returning to the east and manifest trains. This segment is also a key section for passenger trains. Amtrak's Coast Starlight trains to/from California and Amtrak Cascades trains use this route as do Sound Transit Sounder commuter trains on the section between Tacoma and Auburn.

- **Auburn–Yakima.** This segment is known as BNSF's Stampede Pass route. The Auburn–Yakima segment covers 139.6 miles and make up BNSF's Stampede Subdivision. The track structure is mostly single track and traffic control is mostly TWC with some segments of CTC. Current capacity is approximately 39 trains per day and volume is approximately 7 trains per day. Traffic volume consists largely of empty coal and grain trains. BNSF uses directional operations on this segment, which increases capacity by running eastbound unit trains on this segment and westbound loaded unit trains via the Columbia River Gorge.

- **Yakima–Pasco.** This segment covers 89.4 miles. It makes up BNSF's Yakima Valley Subdivision. The track structure is mostly single track and traffic control is mostly TWC with some segments of CTC. Current capacity is approximately 39 trains per day and volume is approximately 7 trains per day. Traffic volume consists largely of empty coal and grain trains returning to the east and some manifest trains.

West of Pasco, BNSF uses directional running, which increases capacity by running trains in different directions on different routes. From Pasco, westbound rail traffic moves via BNSF's Fallbridge Subdivision to Vancouver. This route services the Portland, Oregon section of Amtrak's Empire Builder passenger train and unit trains carrying grain, crude oil, and other commodities and general manifest trains. These trains then move north on the Seattle Subdivision. The Seattle

Subdivision handles many Amtrak passenger trains and commuter trains per day in addition to intermodal, grain, and general manifest BNSF and UP trains.

2.2.3 Existing Rail Traffic Outside of Washington State

From Wyoming or Montana Powder River Basin mines, Proposed Action-related trains operating on BNSF rail lines would move west to Huntley, Montana. From Huntley, Montana to Sandpoint, Idaho, BNSF typically operates coal and other trains over Montana Rail Link tracks. This route is mostly single track with primarily CTC traffic control; however, some sections have two main tracks. From Sandpoint, Idaho, trains would move back to BNSF tracks and cross into Washington moving toward Spokane. Capacity along the route is approximately 18 to 75 trains per day, depending upon the specific location and track characteristics, and volume is 17 to 54 trains per day depending upon the specific location (Surface Transportation Board 2015). Table 6 provides a snapshot of existing traffic and capacity along main line rail segments between the Powder River Basin and Washington State.

Table 7. Route Segments between the Powder River Basin and Washington State[a]

Route Segment	Current Traffic Control System	Current Mainline Tracks	Estimated Existing Capacity [b]	Estimated Trains per Day (2018)[b]
Spring Creek, Montana–Dutch, Wyoming	CTC	1	30	17
Dutch, Wyoming–Huntley, Montana	CTC	2	75	26
Huntley, Montana–Mossmain, Montana	ABS	1	18	23
Mossmain, Montana–Sandpoint, Idaho	CTC	1	30	28
Sandpoint, Idaho–Idaho/Washington State Line	CTC	2	75	54

Notes:
[a] Unless otherwise noted, data sourced from Surface Transportation Board 2015.
[b] Based on 2007 data from the American Association of Railroads as reported in the 2010 Montana State Rail Plan, Final Report (Cambridge Systematics, Inc. 2010)
CTC = Centralized Traffic Control; ABS = Automatic Block Signals

From Utah and Colorado Uinta Basin mines or Wyoming Powder River Basin mines, Proposed Action-related trains would transit through Pocatello and Boise, Idaho; then along the Oregon side of the Columbia River to the North Portland Junction. There, UP trains would operate on BNSF tracks, crossing the Columbia River to Vancouver and heading north on the BNSF Seattle Subdivision to Longview Junction. Most of these routes have one main track with CTC or ABS, although some segments have four main tracks and other traffic control system types. Capacity is approximately 16 to 173 trains per day, depending on the specific location and track characteristics, and volume is 20 to 60 trains per day.

Chapter 3
Impacts

This chapter describes the potential impacts on rail transportation that would result from construction and operation of Proposed Action and under the No-Action Alternative.

3.1 Proposed Action

This section describes the potential impacts that could occur in the study area as a result of construction and operation of the Proposed Action.

At full operation, Proposed Action-related trains would add 8 loaded and 8 empty Proposed Action-related trains per day (16 total trains per day) to the rail lines between the Powder River Basin or the Uinta Basin and the project area.

3.1.1 Construction: Direct Impacts

The Reynolds Lead would be modified within the project area to accommodate unit train access to and from the coal export terminal. Because the project area is at the terminus (end) of the Reynolds Lead, this construction would not affect existing rail traffic on the Reynolds Lead. Under the rail scenario, trains transporting construction materials would travel to and from the project area. The unloading and maneuvering of these trains during construction within the project area would not affect the operations of existing rail traffic on the Reynolds Lead.

3.1.2 Construction: Indirect Impacts

Construction of the Proposed Action would result in the following indirect impact.

Add Temporary Rail Traffic for Transport of Construction Materials

The Applicant has stated that 2.1 million yards of suitable material would be needed for construction. This material would be transported to the project area by truck or rail. The Applicant estimates approximately two-thirds of the volume (1.4 million yards) would move during the first year of construction. The Applicant has further stated that moving the suitable material by rail would require an estimated 350 loaded trains of 100 cars each, equivalent to 700 trains (loaded and empty) over the construction period. During the first year of construction, when two–thirds of the volume would be transported, this would amount to approximately 467 trains or an average of 1.3 trains per day.

The baseline rail traffic from Longview Junction to the LVSW yard in 2018 is an average of 7 trains per day. Baseline trains consist of approximately 4 grain trains per day (2 loaded and 2 empty) to/from the EGT grain terminal at the Port of Longview, 2 to 3 manifest trains per day from the BNSF main line to the LVSW yard, and an occasional unit train of clay, soda ash, or other trains destined to or from the Port of Longview. From the LVSW yard to the project area, the baseline volume is approximately 2 trains per day. The current capacity over these segments

is approximately 24 trains per day. Transport of suitable material for construction would not be expected to disrupt current rail traffic.

This construction rail traffic would use BNSF main line routes in Washington State in 2018. Due to the low number of trains per day compared to existing rail traffic volumes and the daily variability of rail traffic volumes, Proposed Action-related construction trains would have a low impact on rail capacity and operations on BNSF main line routes.

3.1.3 Operations: Direct Impacts

During operations, 8 loaded trains would travel to the project area daily, and 8 empty trains would travel from the project area daily. These trains would maneuver along the rail loop in the project area. Rail traffic operations within the project area would not affect rail traffic on the Reynolds Lead because rail operations would be limited to the project area.

3.1.4 Operations: Indirect Impacts

Operation of the Proposed Action would result in indirect impacts on rail transportation. Impacts were determined by comparing the baseline rail traffic in 2028 with the projected rail capacity in 2028 and evaluating if the addition of Proposed Action-related trains could contribute to the capacity of a segment being exceeded. As noted in Section 2.1.2, *Impact Analysis,* 2028 baseline rail traffic estimates are based on linear extrapolation of data collected between 2010 and 2013 for the *Washington State Rail Plan*. Rail traffic is highly dynamic and fluctuates because of changing demand. The projected 2028 rail traffic volumes are intended to provide a "snapshot" of rail traffic volumes. The rail traffic volumes do not represent actual volumes for 2028 because uncertainties exist and the actual volume of freight rail traffic in 2028 cannot be predicted with precision. The impacts are identified as follows.

Add Rail Traffic on the BNSF Spur and Reynolds Lead

Operation of the Proposed Action would require moving loaded Proposed Action-related trains from the Longview Junction yard to the project area and the reverse (moving empty trains from the project area to Longview Junction). This movement would add train traffic to existing rail lines. Each Proposed Action-related train is assumed to move empty back to the representative mine, which is typical of unit train coal service. Figure 4 shows the routes. The step-by-step work activities are described in Appendix A, *Potential Coal Train Operating Plans.*

The Applicant has projected shipping tonnage for three phases of operation: Start Up, Stage 1 and Stage 2. Projected average coal volumes per year and per month and the corresponding number of loaded trains per month and per day are shown in Table 7. At full capacity, the coal export terminal would receive an average of 8 loaded trains and return an average of 8 empty Proposed Action-related trains per day (16 trains would operate on the incoming/outgoing rail line).

Table 8. Loaded Train and Volume Forecast

	Start Up	Stage 1	Stage 2
Throughput (metric tons/year)	10,000,000	25,000,000	44,000,000
Average train loaded trains/day	2	5	8

The projected 2028 capacity assumes no railroad investments would be made to increase capacity and no substantial changes in existing operation would occur. Between Longview Junction and the project area, there are two route segments: Longview Junction to the LVSW yard (BNSF Spur) and LVSW yard to the project area (Reynolds Lead).

Both of these segments have one main track and TWC. Capacity is approximately 24 trains per day and baseline volume is 7 trains per day on the BNSF Spur and 4 trains per day on the Reynolds Lead. At full terminal operations, Proposed Action-related trains would add 16 trains per day (8 loaded and 8 empty) on each of these segments for 23 on the BNSF Spur and 20 on the Reynolds Lead. The Reynolds Lead and BNSF Spur have the capacity to handle baseline rail traffic plus future Proposed Action-related rail traffic.

As discussed in Chapter 2, *Existing Conditions*, LVSW has indicated that it would upgrade the traffic control technology on both the BNSF Spur and the Reynolds Lead from TWC to CTC. The upgrade in traffic control technology would increase capacity on both segments. This improvement would provide sufficient capacity to handle both the Proposed Action-related trains and the projected growth in baseline traffic.

In addition to converting to the CTC system, LVSW indicated it would upgrade the track on the Reynolds Lead and BNSF Spur. Upgrades would include additional ballast, replacing ties, and upgrading the rails. These improvements would provide for a safer operation and allow for an increase in maximum speed from 10 mph to 25 mph on the Reynolds Lead. LVSW would also install a remotely operated electric switch from the BNSF Spur to the Reynolds Lead to allow for continuous movement and consistent operation. The speed limit on the BNSF Spur is largely governed by the speed limit across the Cowlitz River Bridge, which would remain at 10 mph. LVSW would also install a remotely operated electric switch connecting the BNSF Spur to the Reynolds Lead to allow continuous movement and more consistent operation. The electronic switch would eliminate the need for loaded and empty trains to stop while a train crewmember operates the switch.

While LVSW has developed upgrade plans, it has not begun work or applied for permits. LVSW would start the permit and funding processes when future volume increases become reasonably certain. This approach is consistent with typical railroad capital investment policy.

Table 8 provides additional information on anticipated operations over the Reynolds Lead and BNSF Spur, including the expected average time for the Proposed Action-related trains to cross each of the road crossings with current and planned infrastructure improvements. Trains would accelerate or decelerate at various points along the route and estimates of the time that trains would transit each road crossing considered this acceleration and deceleration. Table 9 provides information on route capacity for mainline services from Longview Junction to the Powder River Basin.

Table 9. BNSF Spur and Reynolds Lead Operations Detail—Incoming and Outgoing Proposed Action-Related Trains[a]

	West end of Cowlitz River Bridge, crossing of Dike Road	Port of Longview Central Corridor Switch	Reynolds Lead Switch	Reynolds Lead Crossing of 3rd Avenue	Reynolds Lead Crossing of California Way (Loaded/Empty)	CCR Interchange Sidings (Loaded/Empty)	Reynolds Lead Crossing of Oregon Way	Reynolds Lead Crossing of Industrial Way	Project Area Clear of Reynolds Lead
Segment miles	1.50	0.38	0.84	0.56	0.11	0.07	0.80	0.22	2.90
Estimated mph with planned track improvements	10	10	10	15	15/20	18/20	20	20	5
Cumulative miles from BNSF main line switch at Longview Junction	1.50	1.88	2.72	3.28	3.39	3.46	4.26	4.48	7.38
Estimated passing time with planned track improvements (minutes)[a,b]	8	8	8	5	5/4	4	4	4	16
Estimated mph with current track infrastructure[c]	10	10	5	8	8/10	8/10	10	10	5
Estimated passing time with current track infrastructure (minutes)[a,c]	8	8	16	10	10/8	10/8	8	8	16

Notes:

[a] Estimated coal train length, 125 cars, 3 GE AC; 4400 locomotives = 6,844 feet.

[b] Track improvements include upgrading Reynolds Lead to speed limit of 25 mph, new bypass track around LVSW yard, and electronic switches onto Reynolds Lead. Train operation is estimated based on existing operations (Wolter, LVSW pers. comm.).

[c] Train operation with current infrastructure is estimate based on existing operations and LVSW pers. comm.

mph = miles per hour; LVSW = Longview Switching Company

Table 10. Infrastructure Capacity and Projected Rail Traffic, Including Proposed Action-Related Trains (trains per day)

Route Segment	Railroad	Subdivision	Current Traffic Control System[a]	Current Main Tracks[a]	Projected 2028 Capacity (trains/day)[b]	Miles[c]	Estimated Baseline 2015 (trains/day)[b,d]	Projected 2028 Capacity Surplus (Deficit)[f]	2028 with Proposed Action (trains/ day)	Projected 2028 Capacity Surplus (Deficit) with Proposed Action-Related Trains[f]
Idaho/Washington State Line–Spokane	BNSF	Spokane	CTC	2	76	18.6	70	(30)	122	(46)
Spokane–Pasco	BNSF	Lakeside	CTC	1	38	145.5	39	(18)	72	(34)
Pasco–Vancouver	BNSF	Fallbridge	CTC	1	41	221.4	34	(7)	56	(15)
Vancouver–Longview Junction	BNSF	Seattle	CTC	2	80	34.8	50	7	81	(1)
Longview Junction–LVSW Yard (BNSF Spur)	BNSF	LVSW	TWC	1	24	2.1	7	17	23	1
LVSW Yard–Project Area (Reynolds Lead)	BNSF	LVSW	TWC	1	24	5.0	2	20	20	4
Longview Junction–Auburn	BNSF	Seattle	CTC	2	80	118.6	50	7	81	(1)
Auburn–Yakima	BNSF	Stampede	TWC	1	39	139.6	7	28	19	20
Yakima–Pasco	BNSF	Yakima Valley	TWC	1	39	89.4	7	28	19	20

Notes:

[a] Source: Washington State Department of Transportation 2014a, Technical Note 2

[b] Source: Washington State Department of Transportation 2014ba Technical Note 4a, except LVSW rail line segments

[c] Source: Estimated based on GIS measurements.

[d] Source: Washington State Department of Transportation 2014ba Wolter pers. comm.; Port of Longview pers. comm.

[e] Source: Washington State Department of Transportation 2014a; Parsons Brinckerhoff 2014

[f] Projected capacity surplus/deficit without infrastructure improvements or changes in operations. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic, but it is unknown when these actions would be taken or permitted.

CTC = Centralized Traffic Control; TWC = Track Warrant Control

Add Rail Traffic on the BNSF Main Line To and From Longview Junction within Cowlitz County

As shown in Table 9, this segment is part of the BNSF Seattle Subdivision and has two main tracks with CTC. As shown in Figure 6, projected 2028 capacity without improvements or operating changes is approximately 80 trains per day. Projected 2028 volume with Proposed Action-related trains is approximately 81 trains per day; therefore, projected volume approximately equal the projected capacity.

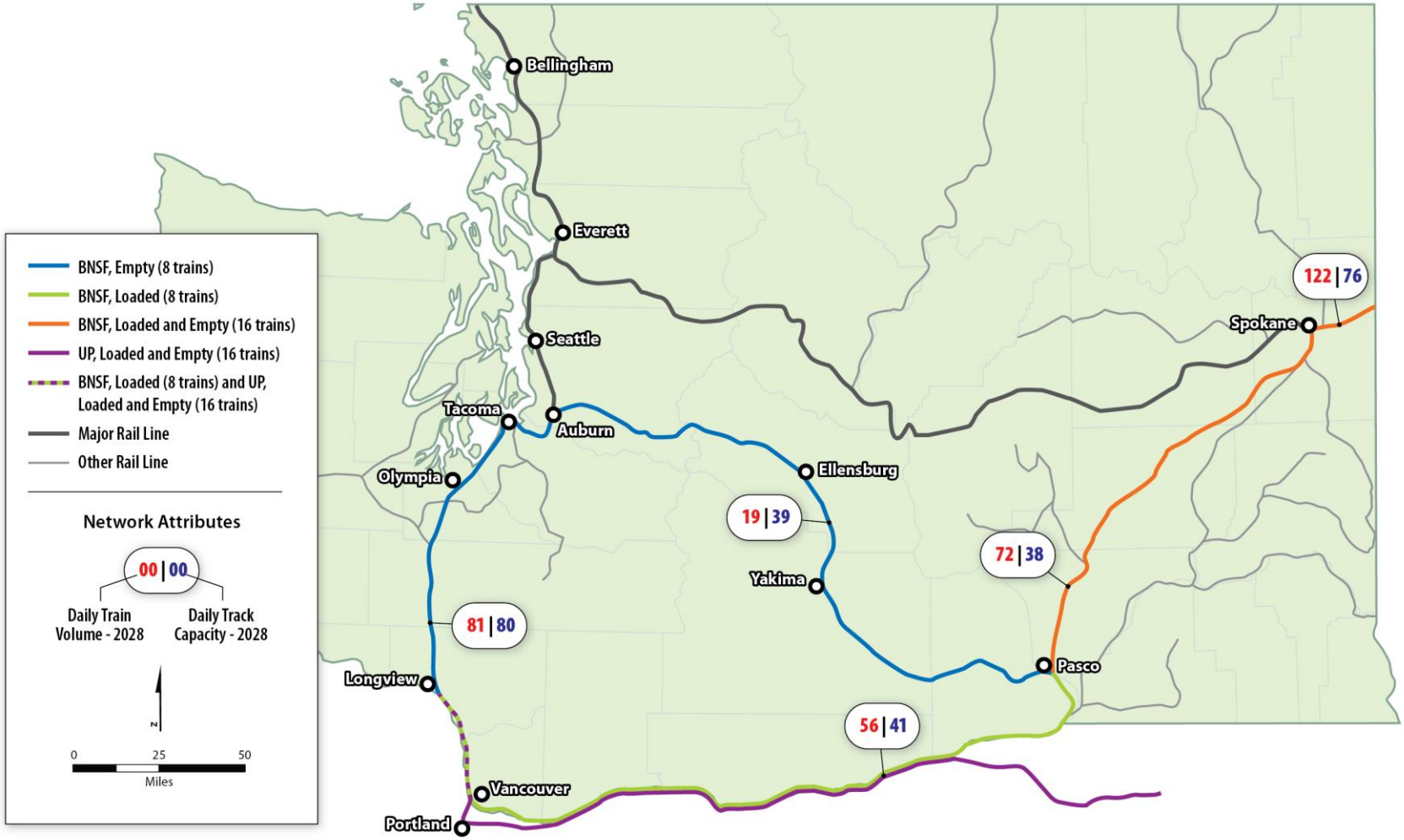
If UP (between Vancouver and Longview Junction) serves most of the volume, then all 16 Proposed Action-related trains (8 loaded and 8 empty) would use the segment from Vancouver, Washington to Longview, Washington, increasing volume beyond current capacity without improvements. Impacts of exceeding the capacity would include congestion and delays to both passenger and freight trains. Without improvements or operating changes, this segment would exceed capacity and Proposed Action-related trains would contribute to congestion or delays on this segment, or an inability of BNSF to handle all of the volume. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic.

Add Rail Traffic to Existing BNSF Rail Infrastructure in Washington State beyond Cowlitz County

The Proposed Action would add rail traffic to the BNSF main lines in Washington State, affecting capacity on all segments, as summarized in Table 9. The projected rail traffic assumes that directional running continues on the Columbia River Gorge route (primarily westbound trains) and Stampede Pass route (primarily eastbound trains)(Washington State Department of Transportation 2014a). The projected increase in rail traffic relative to capacity are described for segments in Washington State and beyond Cowlitz County below.

- **Idaho/Washington State Line–Spokane**. All Proposed Action-related trains to and from the Powder River Basin on BNSF would move over this segment. This segment has two main tracks with CTC. Projected 2028 capacity without improvements is 76 trains per day. The projected rail traffic in 2028 with Proposed Action-related trains would be 122 trains per day. Without improvements or operating changes, the projected volume on this segment would exceed the existing capacity of 76 trains per day. Proposed Action-related trains would contribute to congestion or delays on this segment, or the inability of BNSF to handle all of the volume. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic. The capacity concerns for this segment extend beyond Washington State to Sandpoint, Idaho. This potential constraint is identified in the *Washington State Rail Plan* as a key potential chokepoint.

Figure 6. Projected Washington Rail Network Daily Track Utilization, 2028 Baseline Conditions with Proposed Action-Related Trains



- **Spokane–Pasco**. All Proposed Action-related trains to and from the Powder River Basin on BNSF would move over this segment under current BNSF operations. At Spokane, BNSF's Stevens Pass route to Seattle, Washington via Wenatchee, Washington splits off. All BNSF trains moving from Spokane to the west via the Columbia River Gorge route or Stampede Pass route move over this segment from Spokane to Pasco. This segment has one main track and CTC. Projected 2028 capacity without improvements or operating changes is 38 trains per day. Projected 2028 volume with Proposed Action-related trains is 72 trains per day. Without improvements or operating changes, this segment would also exceed capacity and Proposed Action-related trains would contribute congestion or delays on this segment, or an inability of BNSF to handle all of the volume. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic. This potential constraint is identified in the *Washington State Rail Plan* as a key potential chokepoint.

- **Pasco–Vancouver**. Loaded Proposed Action-related trains on BNSF from the Powder River Basin to the coal export terminal would move over this segment. The segment has one main track with CTC. Projected volume with Proposed Action-related trains is 56 trains per day. Without improvements or operating changes, the projected traffic on this segment would exceed the existing capacity of 41 trains per day. Proposed Action-related trains would contribute to congestion or delays on this segment, or the inability to handle all of the volume. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic. This potential constraint is identified in the *Washington State Rail Plan* as a significant capacity concern.

- **Vancouver–Longview Junction and Longview Junction–Auburn (outside Cowlitz County)**. This is the same segment described for Cowlitz County. This segment has two main tracks with CTC. Projected 2028 capacity without improvements or operating changes is approximately 80 trains per day. Projected 2028 volume with Proposed Action-related BNSF trains to and from the Powder River Basin is 81 trains per day; therefore, the projected volume on this segment with Proposed Action-related trains would be approximately equal to capacity (80 trains per day).

  If all 16 Proposed Action-related trains use the segment between Vancouver and Longview Junction (UP trains), the 2028 volume on this segment would be 89 trains daily and would exceed capacity without improvements (80 trains daily). Proposed Action-related trains would contribute to congestion or delays on this segment, or the inability to handle all of the volume. It is expected that BNSF would make the necessary investments or operating changes to accommodate the growth in rail traffic.

- **Auburn–Yakima and Yakima–Pasco.** Empty trains returning to the Powder River Basin on BNSF would move over these segments. The projected rail traffic in 2028 would be 11 trains per day. Projected 2028 capacity is 39 trains per day, and therefore, these segments would not have capacity issues in 2028.

Add Rail Traffic to Existing BNSF and UP Rail Infrastructure Outside Washington State

Operation of the Proposed Action would add 8 loaded and 8 empty Proposed Action-related trains per day (16 trains) to existing rail traffic beyond Washington State (Figure 3). The rail infrastructure is described in Section 2.2, *Existing Conditions.* The current rail traffic on the BNSF main lines between Washington State and the Powder River Basin is approximately 17 to 54

trains per day and the capacity is approximately 18 to 75 trains per day, depending on location and track characteristics. Along some segments, existing rail traffic is near capacity.

The current rail traffic on the UP routes between Washington State and the Uinta Basin and the Powder River Basin is approximately 20 to 60 trains per day and a capacity of 16 to 173 trains per day, depending on location and track characteristics.

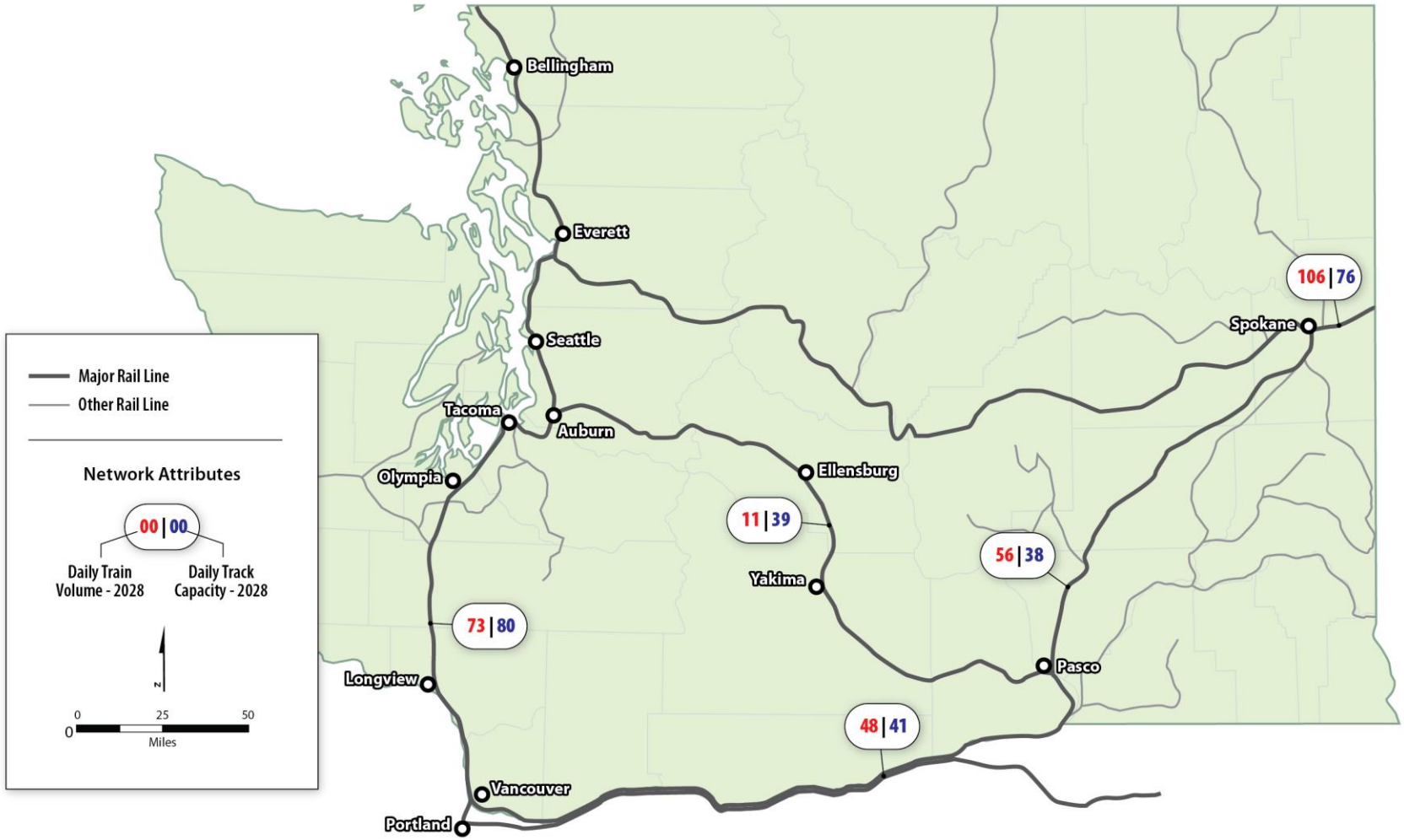
Along the BNSF and UP routes outside Washington State, without improvements or operating changes, Proposed Action-related trains would contribute to congestion or delays on certain segments or the inability of BNSF or UP to handle its rail traffic. It is expected that BNSF and UP would make the necessary investments or operating changes to accommodate the growth in rail traffic.

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal. The Applicant would continue with current and future increased operations in the project area. The project area could be developed for other industrial uses including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement.

The Applicant's anticipated growth under the No-Action Alternative would require approximately 2 trains per day on the Reynolds Lead, BNSF Spur, and BNSF main line in Cowlitz County. The existing infrastructure on the Reynolds Lead, BNSF Spur, and BNSF main line would provide sufficient capacity to handle the projected growth in baseline traffic and investments to increase capacity would not be necessary. Some BNSF main line segments would exceed capacity in 2028 if BNSF does not make capital investments or operating changes to expand capacity. Figure 7 shows the projected traffic and capacity without the Proposed Action.

Figure 7. Projected Washington Rail Network Daily Track Utilization, 2028 Baseline Conditions (without Proposed Action-Related Trains)



Chapter 4
Required Permits

No permits related to rail transportation would be required for the construction or operation of the Proposed Action.

Chapter 5
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5.1 Written References

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5.2 Personal Communications

Port of Longview. December 3, 2014—Meeting regarding estimated trains per day.

Wolter, David. Longview Switching Company. December 3, 2014—Meeting regarding coal train configurations on the BNSF, current and projected operations on LVSW.

Appendix A

Potential Coal Train Operating Plans

Appendix A
Potential Coal Train Operating Plans

Table A-1. Potential BNSF Coal Train Operating Plan[a]

Activity	Event	City	State	Miles[b]	Running Time or Dwell Time[c]		MPH[d]	Work Activities[e]	Comments
Loaded trains from WA state line to Longview Junction	Depart	ID/WA Line	WA						
	Arrive	Spokane	WA	18.3	1:00	1.00	18		
	Arrive	Pasco	WA	142.8	8:00	8.00	18		BNSF current project to double track
	Arrive	Vancouver	WA	226.2	12:00	13.00	18	Crew change	
	Arrive	Longview Junction	WA	35.2	2:00	2.00	18		Possible construction of 3rd main track through Longview/Kalama
Loaded movement within port	Depart	Longview Junction	WA	Dwell	0:00		-	BNSF dispatcher requests permission from LVSW yardmaster to access LVSW track through to MBTL. LVSW yardmaster lines switches and signals through to MBTL then provides authority to BNSF dispatcher. BNSF dispatcher lines switches and signals off BNSF main into Longview Junction yard. Trains proceeds via south leg of Longview Junction Y across Cowlitz River bride. Train does not stop until MBTL switch unless	BNSF plans to upgrade LVSW route from west side of Cowlitz River bridge to MBTL with CTC and remote control switches which would increase speed to 25 MPH. Speed over Cowlitz River bridge would remain at 10 MPH.

Activity	Event	City	State	Miles[b]	Running Time or Dwell Time[c]		MPH[d]	Work Activities[e]	Comments
								LVSW or MBTL cannot take train. If LVSW or MBTL cannot take train - it will wait on BNSF main at signal until it can proceed to MBTL.	
	Arrive	MBTL Loop	WA	7.4	0:32	0.74	10	Train stops, conductor operates switch into MBTL, BNSF or UP crews handle unit train to MBTL. Proceed into MBTL track designated by MBTL yardmaster	6 miles Longview Junction to MBTL switch. About 1.4 miles to pull entire train onto MBTL storage track.
	Secure Train	MBTL Loop	WA	Dwell	0:00		-	BNSF or UP crew secures train and either transported by automobile back to Vancouver, WA (BNSF) or Albina (UP) or board outbound train for return to Vancouver, WA or Albina	BNSF or UP crew may remain on duty to unload train or to move an empty train direct to dumper
Unloading	Prep for dumping	MBTL Loop	WA	Dwell	2:30		-	Mechanical inspection, train then waits on storage track until MBTL ready to unload.	Dwell time waiting to unload - Hellerworx estimate
	Begin Dumping	MBTL Loop	WA	0			1	MBTL crew positions train with first 2 cars positioned at dumper, indexer would move train through dumper stopping every 2 cars to dump,	
	Dumping Completed	MBTL Loop	WA	1	1:20		1	From dumper, train proceeds into storage track awaiting outbound train crew	

Activity	Event	City	State	Miles[b]	Running Time or Dwell Time[c]		MPH[d]	Work Activities[e]	Comments
Empty Movement within Port	Empty train prep	MBTL Loop	WA	Dwell	3:00		-	Mechanical inspection, Bad Order (cars with defects) repaired in place or switched out of train to Bad Order track. Train waits for outbound train slot. BNSF crew taxi from Vancouver, WA or crew from inbound train boards outbound.	Mechanical inspection and switching out Bad Orders about 1 hour, balance of time waiting crew/train slot to depart, all Hellerworx estimates.
	Depart	MBTL Loop	WA	Dwell	0:00		-	Crew obtains authority from BNSF dispatcher to proceed on BNSF main line. BNSF dispatcher lines switches from Longview Junction --North leg of Y from Cowlitz River bridge. LVSW yard master lines switches and signals over LVSW to Longview Junction yard. Train stops at MBTL switch, conductor operates switch to line movement onto Reynolds Lead, transported by road to lead locomotive when switch closed	
	Arrive	Longview Junction	WA	7.4	0:32	0.74	10	Train moves directly from MBTL over LVSW track and across Cowlitz River bridge over north leg of Y onto BNSF main line at Longview Junction heading north toward Auburn	BNSF currently improving northbound leg of Y at Longview Junction to increase radius- current tight curve sometimes causes empties to derail. Train does not depart MBTL until authority to proceed on BNSF main line is obtained from BNSF dispatcher. It would not typically stop at any point on LVSW between MBTL and Longview Junction

Activity	Event	City	State	Miles[b]	Running Time or Dwell Time[c]	MPH[d]	Work Activities[e]	Comments
	Depart	Longview Junction	WA	0	0:00		Train moves directly onto BNSF main line heading north toward Auburn	
Empty trains port to WA state line	Arrive	Auburn	WA	119.9	7:00	6.66	18	Crew change location and dwell times are Hellerworx estimates. Empty return route via Stampede Pass, Hellerworx estimate.
	Arrive	Yakima	WA	139	8:00	7.72	18	
	Arrive	Pasco	WA	89.5	5:00	4.97	18	
	Arrive	Spokane	WA	142.8	8:00	7.93	18	
	Arrive	ID/WA Line	WA	18.3	1:00	1.02	18	

Notes

[a] Potential operating plans were not developed nor provided by the Applicant.

[b] BNSF and UP Route miles from PC Rail 21 Coal/Bulk Familized Reynolds Lead miles from meeting with David Wolter 12.03.14 and Hellerworx estimate from Google Earth

[c] Hellerworx estimate

[d] MPH for main line movements - Hellerworx estimate based on BNSF coal unit train performance 53 week average reported to AAR, less Hellerworx estimated dwell time en route
MPH for port area movements from Noise Report Sept 2014 P20 and Hellerworx estimate
Meeting with LVSW David Wolter 12.03.14

[e] Work activities from BNSF, UP and LVSW work activity from Hellerworx experience and Meeting with LVSW David Wolter 12.03.14

Table A-2. Potential UP Coal Train Operating Plan[a]

Activity	Event	City	State	Miles[b]	Running Time or Dwell Time[c]	MPH[d]	Work Activities[e]	Comments
Loaded trains from WA state line to Longview Junction	Depart	OR/WA Line	WA				UP trains, crew change Albina Yard (Portland), enter BNSF trackage at Albina Yard, proceed across Columbia River bridge to Vancouver, WA	
	Arrive	Vancouver	WA	0.7	0:30	1		
	Arrive	Longview	WA	35.2	2:00	18		Possible construction of 3rd main track through Longview/Kalama
Loaded movement within port	Depart	Longview Junction	WA	Dwell	0:00	-	BNSF dispatcher requests permission from LVSW yardmaster to access LVSW track through to MBTL. LVSW yardmaster lines switches and signals through to MBTL then provides authority to BNSF dispatcher. BNSF dispatcher lines switches and signals off BNSF main into Longview Junction yard. Trains proceeds via south leg of Y across Cowlitz River bride. Train does not stop until MBTL switch unless LVSW or MBTL cannot take train. If LVSW or MBTL cannot take train - it will wait on BNSF main at signal until it can proceed to MBTL.	BNSF plans to upgrade LVSW route from west side of Cowlitz River bridge to MBTL with CTC and remote control switches which would increase speed to 25 MPH. Speed over Cowlitz River bridge would remain at 10 MPH.
	Arrive	MBTL Loop	WA	7.4	0:32	10	Train stops, conductor operates switch into MBTL, BNSF or UP crews handle unit train to MBTL. Proceed into MBTL track designated by MBTL yardmaster	6 miles Longview Junction to MBTL switch. About 1.4 miles to pull entire train onto MBTL storage track.
	Secure Train	MBTL Loop	WA	Dwell	0:00		BNSF or UP crew secures train and either transported by automobile back to Vancouver, WA (BNSF) or Albina (UP) or board outbound train for return to Vancouver, WA or Albina	BNSF or UP crew may remain on duty to unload train or to move an empty train direct to dumper

Activity	Event	City	State	Miles [b]	Running Time or Dwell Time [c]	MPH [d]	Work Activities[e]	Comments
Unloading	Prep for dumping	MBTL Loop	WA	Dwell	2:30		Mechanical inspection, train then waits on storage track until MBTL ready to unload.	Dwell time waiting to unload - Hellerworx estimate
	Begin Dumping	MBTL Loop	WA	0	0:00		MBTL crew positions train with first 2 cars positioned at dumper, indexer would move train through dumper stopping every 2 cars to dump,	
	Dumping Completed	MBTL Loop	WA	1	1:20	1	MBTL crew takes lead locomotives to end of loading loop, couple to empty train when unloading completed. From dumper, train proceeds into storage track awaiting outbound train crew	
Empty Movement within Port	Empty train prep	MBTL Loop	WA	Dwell	3:00		Mechanical inspection, Bad Order (cars with defects) repaired in place or switched out of train to Bad Order track. Train waits for outbound train slot. UP crew taxi from Albina or crew from inbound train boards outbound.	Mechanical inspection and switching out Bad Orders about 1 hour, balance of time waiting crew/train slot to depart, all Hellerworx estimates.
	Depart	MBTL Loop	WA	Dwell	0:00		Crew obtains authority from BNSF dispatcher to proceed on BNSF main line. BNSF dispatcher lines switches form Longview Junction - South leg of Y from Cowlitz River bridge. LVSW yard master lines switches and signals over LVSW to Longview Junction yard	
	Arrive	Longview Junction	WA	7.4	0:32	10	Train moves directly from MBTL over LVSW track and across Cowlitz River bridge over south leg of Y onto BNSF main line at Longview Junction	BNSF currently improving northbound leg of Y at Longview Junction to increase radius- current tight curve sometimes causes empties to derail. Train does not depart MBTL until authority to proceed on BNSF main line is obtained from BNSF dispatcher. It would not typically stop at any point

Activity	Event	City	State	Miles [b]	Running Time or Dwell Time [c]	MPH [d]	Work Activities[e]	Comments
								on LVSW between MBTL and Longview Junction
	Depart	Longview Junction	WA	0	0:00		Train moves directly onto BNSF main line heading south toward Vancouver, WA	
Empty trains port to WA state line	Arrive	Vancouver	WA	35.2	2:00	20		
	Arrive	OR/WA Line	WA	0.7	0:30	1	Train moves on BNSF trackage rights to Albina Yard then back on UP, crew change	

Notes

[a] Potential operating plans were not developed nor provided by the Applicant.

[b] BNSF and UP Route miles from PC Rail 21 Coal/Bulk Familized. Reynolds Lead miles from meeting with David Wolter 12.03.14 and Hellerworx estimate from Google Earth

[c] Hellerworx estimate

[d] MPH for main line movements - Hellerworx estimate based on BNSF coal unit train performance 53 week average reported to AAR, less Hellerworx estimated dwell time en route
MPH for port area movements from Noise Report Sept 2014 P20 and Hellerworx estimate
Meeting with LVSW David Wolter 12.03.14

[e] Work activities from BNSF, UP and LVSW work activity from Hellerworx experience and Meeting with LVSW David Wolter 12.03.14

MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA RAIL SAFETY TECHNICAL REPORT

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Kelso, WA 98626
Contact: Elaine Placido, Director of Building and Planning

IN COOPERATION WITH:
Washington State Department of Ecology, Southwest Region

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April 2017

ICF. 2017. *Millennium Bulk Terminals—Longview, SEPA Environmental Impact Statement, SEPA Rail Safety Technical Report*. April. (ICF 00264.13.) Seattle, WA. Prepared for Cowlitz County, Kelso, WA, in cooperation with Washington State Department of Ecology, Southwest Region.

Contents

List of Tables ii
List of Figures ii
List of Acronyms and Abbreviations iii

Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-6
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-1
2.1.2 Impact Analysis 2-2
2.2 Existing Conditions 2-5
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-3
3.1.1 Construction: Direct Impacts 3-3
3.1.2 Operations: Direct Impacts 3-4
3.1.3 Operations: Indirect Impacts 3-4
3.2 No-Action Alternative 3-7
Chapter 4 **Permits** **4-1**
Chapter 5 **References** **5-1**

Appendix A Rail Safety Data

Tables

Table 1. Regulations, Statutes, and Guidelines for Rail Safety 1-5
Table 2. Nationwide Train Accident Rates 2-3
Table 3. Railroad Track Classes 2-4
Table 4. Key Segment Parameters for Existing Traffic on BNSF lines in Washington State 2-6
Table 5. 2018 Predicted Train Accidents during Peak Year of Construction 3-4
Table 6. Predicted Train Accidents per Year[a] 3-5

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. BNSF and Union Pacific Routes to and from the Project Area 3-2

Acronyms and Abbreviations

Applicant	Millennium Bulk Terminals—Longview, LLC
BNSF	BNSF Railway Company
CFR	Code of Federal Regulations
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
LVSW	Longview Switching Company
mph	miles per hour
Port	Port of Longview
RCW	Revised Code of Washington
SEPA	Washington State Environmental Policy Act
UP	Union Pacific Railroad
USDOT	U.S. Department of Transportation
WAC	Washington Administrative Code
WUTC	Washington Utilities and Transportation Commission

Chapter 1
Introduction

This technical report assesses the potential rail safety impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. This technical report describes the regulatory setting, establishes the methods for assessing potential rail safety impacts, presents the historical and current rail safety conditions in the study area, and assesses potential impacts. The SEPA Vehicle Transportation Technical Report (ICF and DKS Associates 2017) addresses grade crossing safety.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

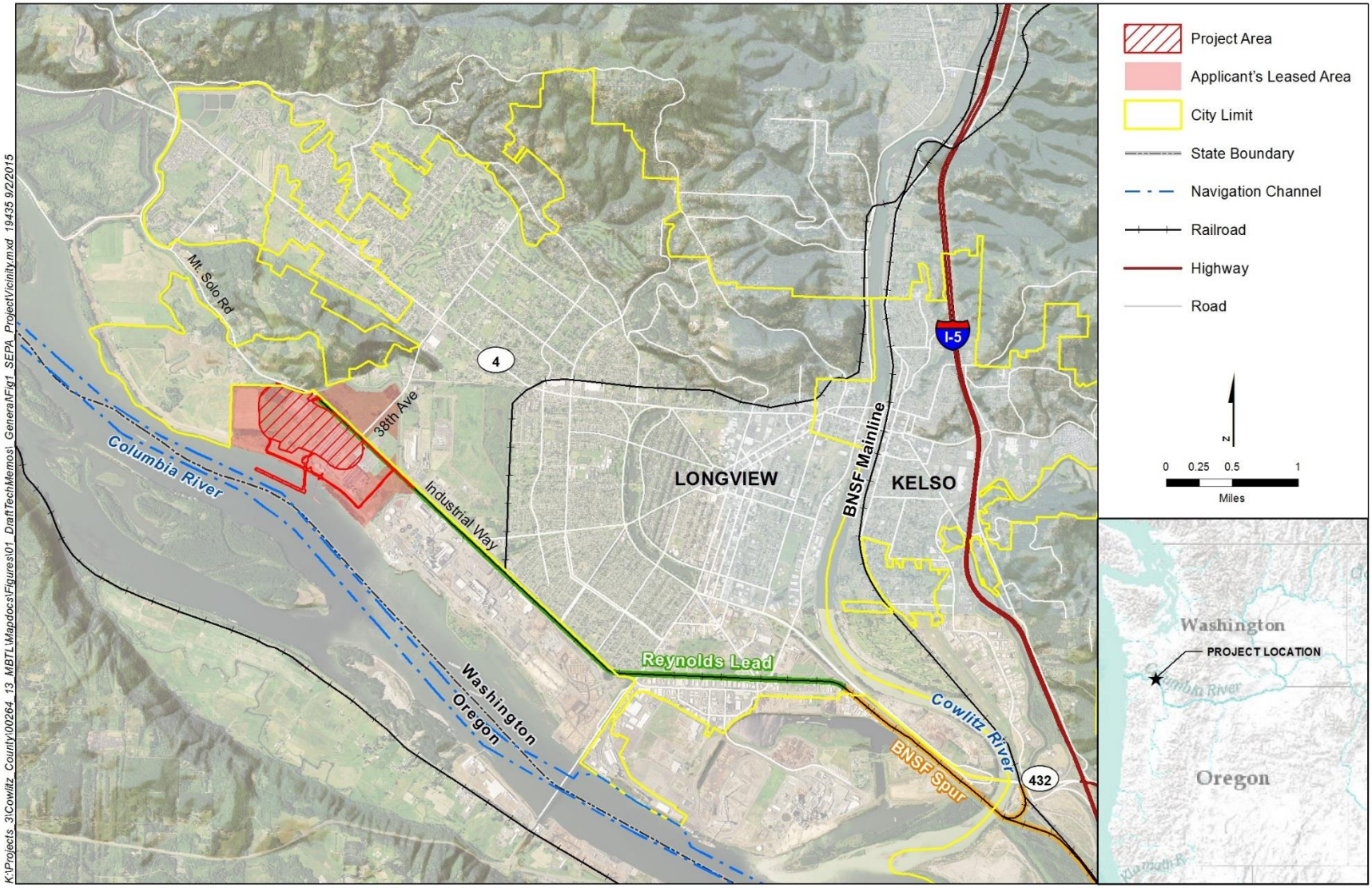
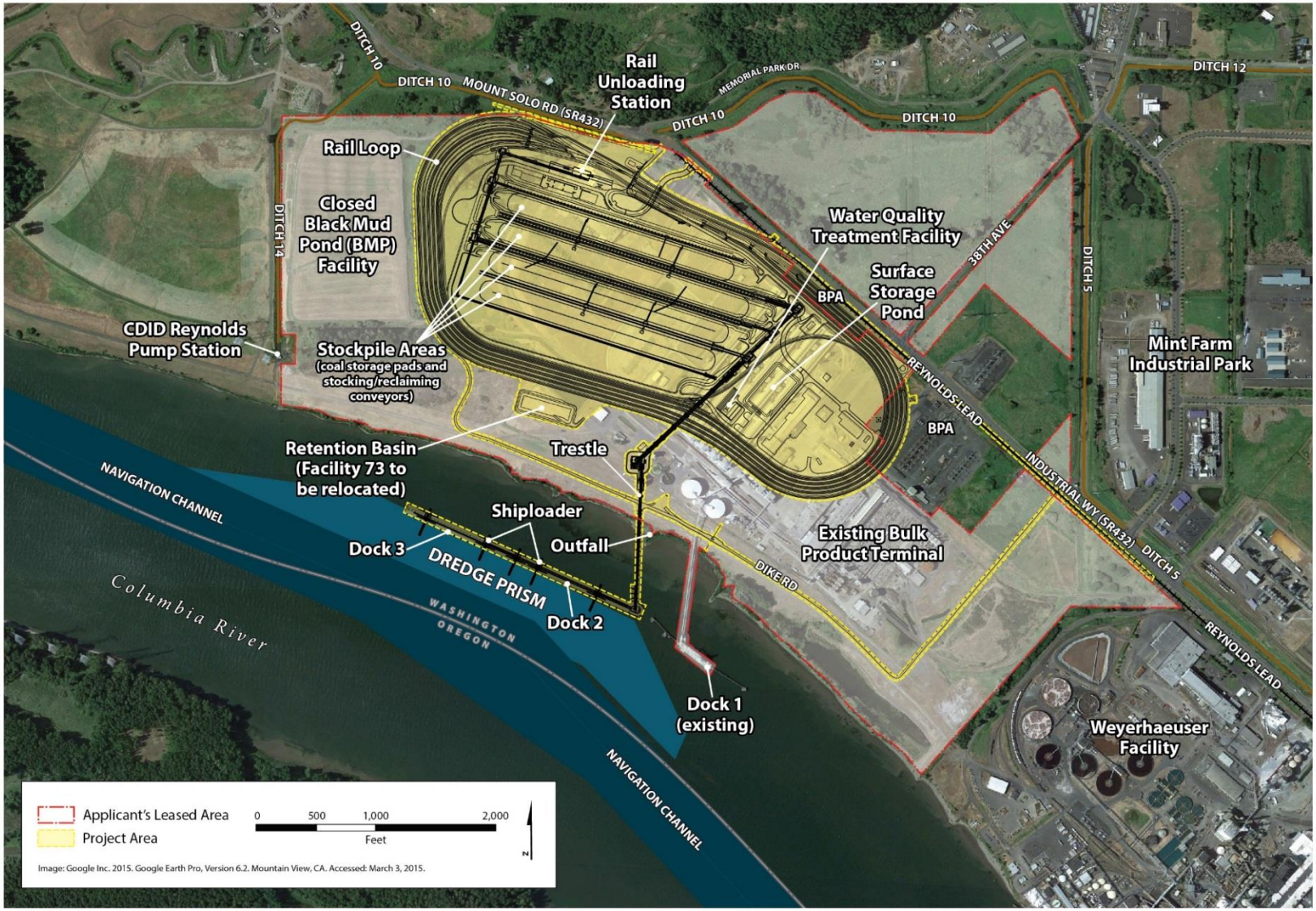


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

The jurisdictional authorities and corresponding regulations, statutes, and guidance for determining potential impacts on rail safety are summarized in Table 1. Those regulations pertaining to at-grade rail crossings are used in the SEPA Vehicle Transportation Technical Report (ICF and DKS Associates 2017).

Table 1. Regulations, Statutes, and Guidelines for Rail Safety

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Federal Railroad Safety Act of 1970	Gives FRA rulemaking authority over all areas of rail line safety. FRA has designated that state and local law enforcement agencies have jurisdiction over most aspects of highway/rail at-grade crossings, including warning devices and traffic law enforcement.
Highway Safety Act and the Federal Railroad Safety Act	Gives FHWA and FRA regulatory jurisdiction over safety at federal highway/ rail at-grade crossings. USDOT has promulgated rules addressing grade-crossing safety and provides funding for installation and improvement of warning devices. FRA has issued rules that impose minimum maintenance, inspection, and testing standards for at-grade crossing warning devices for highway/rail at-grade crossings on federal highways and state and local roads.

Regulation, Statute, Guideline	Description
Federal Railroad Administration General Regulations (49 CFR 200–299)	Regulates safety, including operations, engineers, and crew (e.g., control of alcohol and drug use), track, signaling, and rolling stock (e.g., locomotives and passenger and freight cars) for common carrier rail lines that are part of the general rail line system of transportation.
State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Title 81, Transportation—Railroads, Employee Requirements and Regulations (RCW 81.40)	Establishes general requirements for railroad employee environment and working conditions, the minimum crew size for passenger trains, and requirements for flaggers.
Rail Companies—Clearances (WAC 480-60)	Establishes operating procedures for railroad companies operating in Washington State. Includes rules of practice and procedure, walkway clearances, side clearances, track clearances, side clearances, track clearances, and rules for operation of excess dimension loads.
Rail Companies—Operation (WAC 480-62)	Establishes railroad operating procedures in Washington State. Includes general and procedural rules, safety rules, reporting requirement rules, and the establishment and distribution of a grade-crossing protective fund.
Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provides for the implementation of SEPA in Cowlitz County.

USC = United States Code; NEPA = National Environmental Policy Act; CFR = Code of Federal Regulations; FRA = Federal Railroad Administration; FHWA = Federal Highway Administration; USDOT = U.S. Department of Transportation; RCW = Revised Code of Washington; WAC = Washington Administrative Code; CCC = Cowlitz County Code; SEPA = State Environmental Policy Act

1.3 Study Area

The study area for direct impacts on rail safety is the project area. The study area for indirect impacts on rail safety is the expected rail routes of Proposed Action-related trains within Washington State.

Chapter 2
Existing Conditions

This chapter describes the methods for assessing the existing conditions and determining impacts in the study area as they pertain to rail safety and existing conditions.

2.1 Methods

This section describes the sources of information and methods used to characterize the existing conditions and assess the potential impacts of the Proposed Action and No-Action Alternative on rail safety.

The analysis used the definition of a rail accident from the Federal Railroad Administration (FRA):[1]

> Collisions, derailments, fires, explosions, acts of God, or other events involving the operation of railroad on-track equipment (standing or moving) and causing reportable damages greater than the reporting threshold for the year in which the accident/incident occurred.

The FRA reporting threshold was $10,500 in 2016. Therefore, accidents include a wide variety of incidents and are not limited to collisions or derailments.

The analysis used existing rail accident data from FRA as the basis for the rail safety and accident analysis. While the Washington Utilities and Transportation Commission (WUTC) gathers information on accidents that occur in Washington State, WUTC does not have the corresponding data on train miles within the state for determining accidents per million train miles. Such accident rates provided by FRA, broken down by track class, are the basis of the rail safety analysis. Appendix A, *Rail Safety Data,* describes the observed data on accident rates nationwide and accident counts specific to Washington State and Cowlitz County.[2]

Historically, accident rates (accidents per train mile) do not change dramatically from one year to the next, but generally trend downward over time due to improved control systems, communications, and inspection practices. As a result, using current data for future projections is conservative. Typically, year-to-year accident rates are more consistent than year-to-year traffic volumes on any specific route, which may vary substantially as new projects are added or demands change.

2.1.1 Data Sources

The following sources of information were used to evaluate the rail safety characteristics of the study area.

[1] The Federal Railroad Administration (FRA) was created by the U.S. Department of Transportation Act of 1966. It is one of 10 agencies within the U.S. Department of Transportation concerned with intermodal transportation. FRA's mission is to enable the safe, reliable, and efficient movement of people and goods. FRA has established federal regulations pertaining to the safety of interstate commerce. These regulations set standards for all railroads dealing with the interchange of railroad cars and equipment.

[2] Appendix A, *Rail Safety Data,* is based on the most recent data available when the analysis was completed.

- **Train parameters** including the number of rail cars (125 rail cars per unit trains) were based on information provided by the Applicant and existing BNSF train operations.
- **Baseline train volumes** for the Reynolds Lead and BNSF Spur were collected from LVSW and field observations. BNSF main line volumes were collected from the *Washington State Rail Plan* (Washington State Department of Transportation 2014a). Year 2015 and 2028 projected volumes were estimated using a linear extrapolation based on 2010 volumes and 2035 projected volumes.
- **Future project-related train traffic** from the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017), notably 8 loaded and 8 empty trains per day if the coal export terminal is constructed and operated at full terminal throughput in 2028.
- **Future train routes** compiled from the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017), which used information from the *Washington State Rail Plan* (Washington State Department of Transportation 2014a) and *Washington State Freight Mobility Plan* (Washington State Department of Transportation 2014b).[3]
- **Accident rates** compiled by FRA for year 2012 through year 2014,[4] along with analyses by Liu et al. (2011), and Anderson and Barkan (2004) giving derailment rates by track class and discussing the impacts of track class, train length, and signal systems.

2.1.2 Impact Analysis

The following methods were used to evaluate the potential rail safety impacts of the Proposed Action and No-Action Alternative. For the purposes of this analysis, construction impacts are based on peak construction period, assumed to be in 2018, which would average 1.3 trains per day. Operations impacts are based on the maximum coal export terminal throughput capacity (up to 44 million metric tons of coal per year), which would result in 8 loaded and 8 empty trains per day by 2028.

2.1.2.1 Accident Frequency

The analysis considered one construction scenario and two operations scenarios.

- **2018 Construction:** Average of 1.3 train trips per day
- **2028 Baseline Conditions:** 2028 conditions without the Proposed Action
- **2028 Proposed Action:** Full train operations in 2028 (8 loaded and 8 empty trains per day on the Reynolds Lead, BNSF Spur, and BNSF main line)

Train accident rates are generally distinguished only by freight versus passenger service, not by specific cargoes. Both loaded and unloaded Proposed Action-related trains were evaluated, as well as other existing rail traffic where appropriate. Given that the project would operate *unit trains* of

[3] In 2012, BNSF introduced a train operations protocol change to enhance the use of existing capacity by a directional running agreement using Stampede Pass for eastbound empty bulk trains. The strategy of directional running is to route all westbound-loaded unit trains (including coal) from Pasco to Vancouver via the Columbia River Gorge. Empty unit bulk trains (including coal) generated north of Vancouver including Cowlitz County are destined to return to Pasco and to points east via Stampede Pass.

[4] 2014 data were the most recent available data when the analysis was completed.

approximately 125 rail cars that would travel from the mines to the project area without being split up, trains would generally pass around or straight through yards without switching.

This analysis used both qualitative and quantitative methods to estimate accident rates for the scenarios. The number of accidents (primarily collisions and derailments) resulting from train operations based on accident rates from FRA were estimated. Rates, in combination with the specifics of the operations (e.g., number of trains, route length, track class), were analyzed to estimate the number of accidents per year. The analysis compared predicted rates (in accidents per million train miles) for all railroads with rates specific to BNSF and UP (as co-owners of LVSW) as the first step in determining the appropriate accident rates with Proposed Action-related trains (Table 2).

Table 2. Nationwide Train Accident Rates

	Accident Rate per Million Train Miles		
Year	All Railroads (Passenger and Freight Trains)	BNSF (Freight Trains)	UP (Freight Trains)
2012	2.41	2.20	3.04
2013	2.43	2.11	3.02
2014	2.27	1.89	2.82

Notes:
Source: Federal Railroad Administration (2015).
BNSF = BNSF Railway Company; UP = Union Pacific Railroad

BNSF's accident rates are similar to but less frequent than the average for all railroads. UP has a slightly higher accident rate. LVSW did not have any reported train accident data in the FRA database for 2012 to 2014; that is, there were no train accidents experienced in this period on the Reynolds Lead or BNSF Spur. Given the rail transportation associated with the Proposed Action within Washington State would be on BNSF lines, a rate of 2 accidents per million train miles (the national average for BNSF over the last 2 years) was used as the starting point of the accident analysis. Specific train accident rates for BNSF in Washington State were not available because FRA data do not include train accident rates by state, only nationally. In addition, WUTC does not collect data for a Washington State accident rate to be calculated. For these reasons, the national average for BNSF over the last 2 years was used. FRA data include accident count by state (Appendix A) but does not include accident rate data by state.

The predicted number of accidents per year was calculated by multiplying segment length by the number of trains per year by the applicable accident rate. Thus, the derivation of accident rates is an important part of the overall analysis. Accident rates have been shown to vary considerably by track class, with higher accident rates (i.e., yielding more accidents for a given number of train miles) occurring on lower track classes. Lower track classes have lower maximum operating speeds, which can reduce the consequences of those accidents which occur (Table 3).[5]

[5] Train accidents are more likely to occur on lower track classes (which have lower maximum allowable speeds) because lower track classes are not designed and maintained to the same standards as higher track classes. Track Class 1 is restricted to 10 miles per hour (mph) for freight trains. Rail yards, branch lines, many short lines, and industrial track are typical places to see Track Class 1 track. Track Class 2 may have travel up to 25 mph for freight trains. Secondary main lines, branch lines, and many regional railroads may have track in this category.

Liu et al. (2011) derived derailment rates by track class,[6] using the baseline rates provided by Anderson and Barkan (2004). They found the derailment rates for Track Class 3 were twice the average across all track classes. Derailment rates for Track Class 2 were six times the average for all track classes (accident rates increase with lower track classes generally due to lower track quality). Conversely, derailment rates for Track Class 5 were roughly a third of the overall average rates (accident rates decrease with higher track classes due to higher track quality and other factors).

Table 3. Railroad Track Classes

	Maximum Allowable Speed (mph)	
Class	**Freight Rail**	**Passenger Rail**
Excepted (X)	10	NA
1	10	15
2	25	30
3	40	60
4	60	80
5	80	90
6	NA	110
7	NA	125
8	NA	150
9	NA	200

Notes:
Source: 49 CFR Part 213.9 Classes of track: operating speed limits
mph = miles per hour; NA = not applicable

Anderson and Barkan (2004) found that the overall accident rate (collisions, derailments, and other types) on Track Class 3 was roughly twice the total rate for all track classes (the same pattern seen for just derailments), and the overall rate on Track Classes 4 and higher was roughly half the total rate for all track classes.

Data on accident rates by track class was used to generate a base accident rate for each segment. The Reynolds Lead and BNSF Spur are currently maintained in accordance with the Track Class 1 standard. LVSW plans to upgrade the Reynolds Lead and BNSF Spur to Track Class 2 designation for full capacity operation of the Proposed Action or other future action (ICF and Hellerworx 2017). The Reynolds Lead and BNSF Spur would be maintained as Track Class 1 if planned improvements are not made.

Using the base rate of two accidents per million train miles, a multiplier of six was then applied as an adjustment to better represent Track Class 2, as indicated by Anderson and Barkan (2004) and Liu et al. (2011), resulting in a rate of 12.0 accidents per million train miles for the Reynolds Lead and the BNSF Spur if improvements are made to Track Class 2. For the other segments in Washington

[6] FRA's track safety standards establish nine specific classes of track (Class 1 to Class 9). Class of Track is based on standards for track structure and geometry, and inspection frequency. Each Class of Track has a maximum allowable operating speed for both freight and passenger trains. The higher the Class of Track, the greater the allowable track speed and the more stringent the applicable track safety standards.

State, it was assumed the track was Track Class 3, giving an accident rate of 4.0 accidents per million train miles when the multiplier of two is applied to the base rate.[7]

Accident rates for Track Class 1, which includes the Reynolds Lead and BNSF Spur (without planned improvements), are more uncertain, given the small percentage of train miles that occur on such track. Moreover, many sources group Excepted Track (Class X) and Track Class 1 in their data collection making it harder to obtain accident rates specific to just Track Class 1. (Track Class X is exempted from many of the stated geometry and structural requirements and is thus limited to extremely low speeds.) As such, it is hard to predict accident rates for Track Class 1, but they could be 10 to 20 or more times higher than the base (total) accident rate. Thus, if the Reynolds Lead and the BNSF Spur are not improved, the estimates for the Reynolds Lead and the BNSF Spur presented in this report would increase by roughly a factor of 1.5 to 3 times higher than Track Class 2.

2.1.2.2 Accident Severity

Main line train accidents in Cowlitz County and Washington State with and without injuries and fatalities as an indicator of potential accident severity were reviewed. Based on FRA data (2015) as shown in Appendix A, there were two accidents in Cowlitz County in 2014, and neither one resulted in an injury or fatality. One incident was in a yard with no derailment and the other involved a derailment of 11 rail cars on main line track. In Washington State, there were 36 accidents in 2014, two of which involved an injury. Thirteen accidents were on main line track, and the remainders were in rail yards or on industry track. Derailments (main line and industry track) involved from 0 to 11 rail cars.

2.2 Existing Conditions

As described in Section 1.1.1, *Proposed Action*, the project area is primarily located on 190 acres (project area) of a 540-acre existing industrial site (Applicant's leased area) near Longview, Washington. As shown in Figure 1, the project area is connected to the BNSF main line and Longview Junction (approximately 7.1 miles away) via the Reynolds Lead and the BNSF Spur. The Reynolds Lead currently serves several industries including Weyerhaeuser and North Pacific Paper Corporation, and existing operations in the Applicant's leased area.

The follow describes the BNSF Spur and Reynolds Lead.

- **BNSF Spur.** This section of track runs from the BNSF Seattle Subdivision main line switch at Longview Junction, across the Cowlitz River Bridge to the LVSW yard (Figure 1). Baseline traffic on the BNSF Spur is about 7 trains per day. The Port Industrial Rail Corridor connects with the BNSF Spur just east of the LVSW yard. Trains to or from various port facilities leave or enter the BNSF Spur at the Industrial Rail Corridor switch. The rest of the trains originate or terminate in the yard.
- **Reynolds Lead.** This section runs from the west end of the yard to the existing bulk product terminal (Figure 1). Baseline traffic is just over 2 trains per day, on average. Trains operating on the Reynolds Lead include an LVSW local crew switching industries along the Reynolds Lead 3

[7] Certain rail segments are Track Class 4, which has a much lower accident rate than Track Class 3, thus, making the assumption of Track Class 3 a conservative analysis.

days per week and a local crew that delivers and picks up rail cars that are interchanged at two sidings west of California Way.

Table 4 provides key parameters of the BNSF Spur and Reynolds Lead, based on the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017).

Table 4. Key Segment Parameters for Existing Traffic on BNSF lines in Washington State

Segment	Miles	Track Class	Estimated Baseline Trains per Day (2015)
Idaho/Washington State Line–Spokane	18.6	3[a]	70
Spokane–Pasco	145.5	3[a]	39
Pasco–Vancouver	221.4	3[a]	34
Vancouver–Longview Junction	34.8	3[a]	50
Longview Junction–LVSW Yard (BNSF Spur)	2.1	1	7
LVSW Yard–Project Area (Reynolds Lead)	5.0	1	2
Longview Junction–Auburn	118.6	3[a]	50
Auburn–Yakima	139.6	3[a]	7
Yakima–Pasco	89.4	3[a]	7

Notes:
[a] Track class for other segments in Washington State conservatively assumed to be Track Class 3 for the analysis.

Chapter 3
Impacts

This chapter describes the potential direct and indirect impacts on rail safety (train accidents) that would result from construction and operation of the Proposed Action and ongoing operations under the No-Action Alternative.

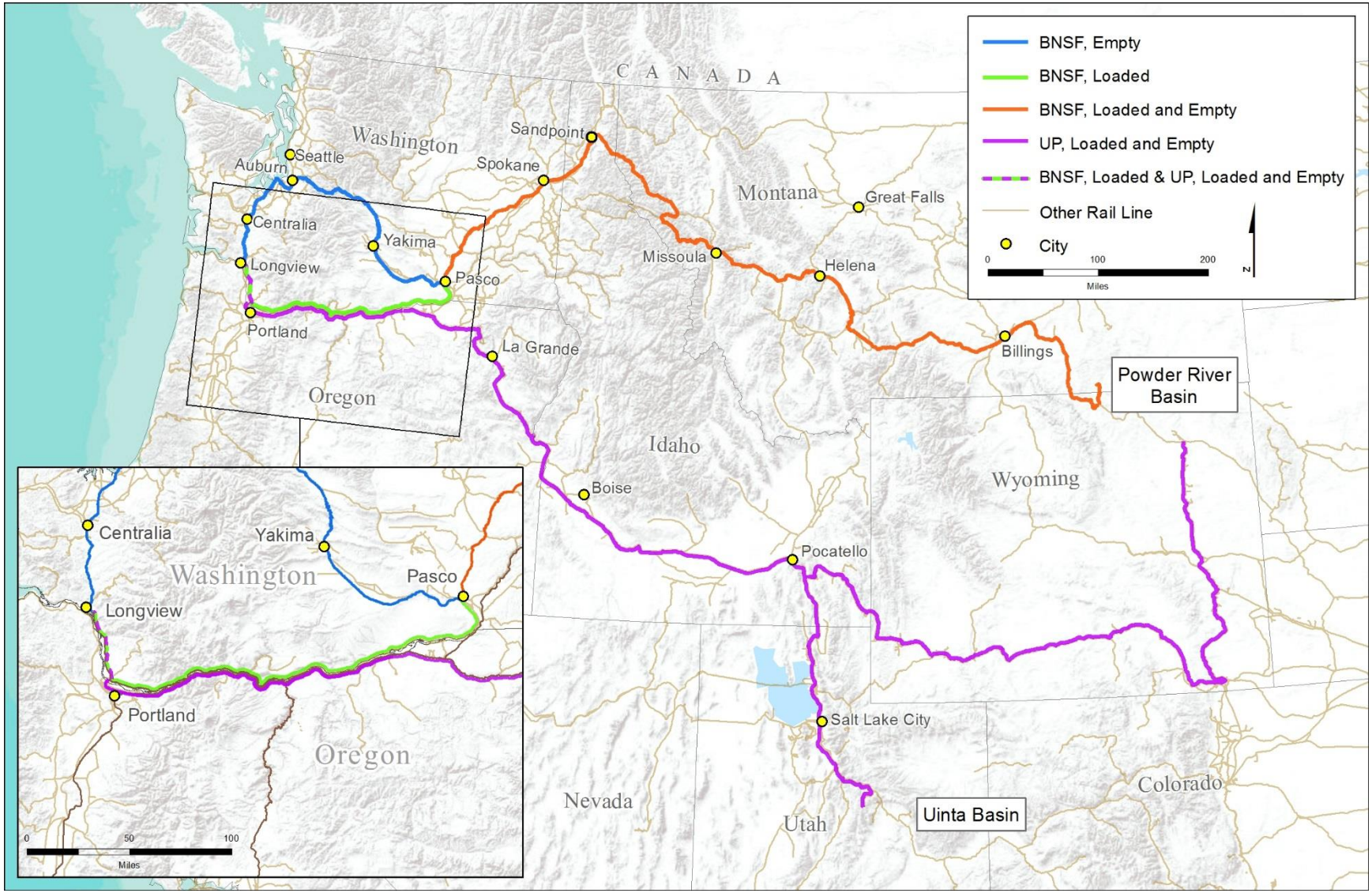
Under the Proposed Action, trains would travel along the Reynolds Lead and BNSF Spur as described in Chapter 2, *Existing Conditions*. Beyond Longview Junction, the main rail lines to and from the potential sources for the coal already exist and are currently in operation as illustrated in Figure 3.

Based on current operating practices, BNSF loaded and empty Proposed Action-related trains would travel via the same route between the coal mines in the Powder River Basin and Pasco, Washington. West of Pasco, loaded trains would move to the project area via BNSF's Columbia River Gorge route through Vancouver, Washington to Longview Junction. Empty trains would return from Longview Junction via BNSF's Stampede Pass route through Auburn, Washington, and Yakima, Washington, to Pasco. These routes are analyzed in this section. Estimates on a per-mile basis have also been developed so that they can be applied to other routes, if applicable.

Both loaded and empty Proposed Action-related trains on the UP would move via the same route between the Uinta Basin and Powder River Basin and the project area. Between Vancouver and Longview Junction, UP operates over the same track that carries BNSF trains, so no additional analysis was required for Proposed Action-related UP trains within Washington State.

As described previously, a train accident for this analysis is defined as involving one or more railroads that have sustained combined track, equipment, and/or structural damage in excess of the reporting threshold. The FRA reporting threshold was $10,500 in 2016. Therefore, an accident includes a wide a variety of incident types and severity and is not limited to collisions or derailments.

Figure 3. BNSF and Union Pacific Routes to and from the Project Area



3.1 Proposed Action

Potential impacts on rail safety from the Proposed Action are described below.

3.1.1 Construction: Direct Impacts

As described previously under the rail construction scenario, trains transporting construction materials would travel to and from the project area. Under this scenario, an average of 1.3 construction trains would travel to and from the project area per day. Construction impacts are based on the peak construction period, assumed to be in 2018. Any accidents would be related to construction activities in the project area and would not result in a rail safety direct impact on the Reynolds Lead, BNSF Spur, or BNSF main line routes. Construction: Indirect Impacts

Construction of would result in the following indirect impacts.

Increase the Potential for Train Accidents

The Applicant has indicated materials needed for construction could be delivered by rail. This would require an estimated 350 loaded trains of 100 rail cars each to deliver construction materials. There would also be the same number of empty trains returning. All rail traffic would use the Reynolds Lead and BNSF Spur. Because the specific routes that would be used by Proposed Action-related trains are not known, a conservative estimate was used. The expected routes in Washington State for Proposed Action-related trains during operations were used to illustrate the possible range of accident frequencies for rail transportation of construction materials.

It is anticipated two-thirds of the construction materials would be transported during the first year of construction (2018), which would amount to approximately 467 one-way train trips (half loaded, half empty; an average of 1.3 trains per day). The numbers of accidents were predicted using the rates described in Section 2.1.2.1, *Accident Frequency,* and are presented in Table 5 for the major route segments.

Table 5. 2018 Predicted Train Accidents during Peak Year of Construction

Segment	Length (miles)	Predicted Proposed Action-Related Construction Train Accidents[a]
Loaded Trains (Inbound Route)		
Idaho/Washington State Line–Spokane	18.6	0.03
Spokane–Pasco	145.5	0.27
Pasco–Vancouver	221.4	0.41
Vancouver–Longview Junction	34.8	0.07
Longview Junction–LVSW Yard (BNSF Spur)	2.1	0.01
LVSW Yard–Project Area (Reynolds Lead)	5.0	0.03
Empty Trains (Outbound Route)		
Project Area–LVSW Yard (Reynolds Lead)	5.0	0.03
LVSW Yard–Longview Junction (BNSF Spur)	2.1	0.01
Longview Junction–Auburn	118.6	0.22
Auburn–Yakima	139.6	0.26
Yakima–Pasco	89.4	0.17
Pasco–Spokane	145.5	0.27
Spokane–Idaho/Washington State Line	18.6	0.03

Notes:
[a] Accidents related to the construction of the Proposed Action; these would be additive to the baseline results.

Proposed Action-related construction rail traffic would contribute to relatively small increase in predicted train accidents.

3.1.2 Operations: Direct Impacts

At full terminal operations, 8 loaded trains would travel to the project area, and 8 empty trains would travel from the project area daily. These trains would maneuver along the rail loop in the project area. The accident rates described previously are not applicable to the project area. Any rail accidents in the project area would be related to overall operations of the coal export terminal and would not affect rail safety on the Reynolds Lead, BNSF Spur, or BNSF main line.

3.1.3 Operations: Indirect Impacts

Operation of the Proposed Action would result in the following indirect impacts.

Increase the Potential for Train Accidents

The Proposed Action would yield predicted accidents per year. The predicted numbers are based on nationwide accident rates as described in Section 2.1, *Methods*; however, only inbound accidents would involve loaded trains. In addition, some accidents might involve standing derailments of a few rail cars.

The predicted accident frequencies on the Reynolds Lead and BNSF Spur in 2028 are shown in Table 6. The analysis is based on 8 loaded inbound trains per day and 8 empty outbound trains per day. As described previously, if the Reynolds Lead and BNSF Spur are not improved to Class

2 standards, the estimates for the Reynolds Lead and BNSF Spur would increase by roughly a factor of 1.5 to 3.

Table 6. Predicted Train Accidents per Year[a]

Segment	Length (miles)	Proposed Action-Related Trains 2028	Baseline 2028
Loaded Trains (Inbound Route)			
Idaho/Washington State Line–Spokane	18.6	0.22	2.88
Spokane–Pasco	145.5	1.70	11.90
Pasco–Vancouver	221.4	2.59	15.52
Vancouver–Longview Junction	34.8	0.41	3.71
Longview Junction–LVSW (BNSF Spur)	2.1	0.07	0.06
LVSW Yard–Project Area (Reynolds Lead)	5.0	0.18	0.04
Empty Trains (Outbound Route)			
Project area–LVSW Yard (Reynolds Lead)	5.0	0.18	0.04[b]
LVSW Yard–Longview Junction (BNSF Spur)	2.1	0.07	0.06[b]
Longview Junction–Auburn	118.6	1.39	12.64
Auburn–Yakima	139.6	1.63	2.24
Yakima–Pasco	89.4	1.04	1.44
Pasco–Spokane	145.5	1.70	11.90[c]
Spokane–Idaho/Washington State Line	18.6	0.22	2.88[c]

Notes:

[a] Assumes the Reynolds Lead and BNSF Spur would be improved to Class 2 standards by LVSW. If the Reynolds Lead and BNSF Spur are not improved to Class 2 standards, the predicted train accidents per year would increase to approximately 1.5 to 3 times more than the Class 2 accident rate.

[b] Due to overlap of inbound and outbound routes on these segments, avoid double counting Baseline 2028 results in totals.

The predicted number of accidents on the Reynolds Lead and BNSF Spur is 0.25 accident per year for the loaded Proposed Action-related trains and 0.25 accident per year for empty Proposed Action-related trains. This is roughly one accident for each type of train (inbound and outbound) every 4 years. When added to the estimated 2028 baseline results, this suggests the Proposed Action–related traffic would increase the chance of an accident from 0.11 accident per year to 0.61 accident per year for all traffic, inbound and outbound.

If a different route than those analyzed in this report were to be used, the number of estimated accidents per year could be calculated based on the trains per year on a particular segment multiplied by the length of the segment multiplied by the Track Class 3 accident rate of four per million train miles. If all inbound and outbound Proposed Action-related trains traveled through the Columbia River Gorge, the outbound accident frequencies would be the same as the inbound accident frequencies shown in Table 6 for the Proposed Action. If all inbound and outbound Proposed Action-related trains traveled across Stampede Pass, the inbound accidents frequencies would be the same as the outbound accident frequencies shown in Table 6 for the Proposed Action.

Not every accident of a loaded Proposed Action-related train would result in a coal spill, and spills that would occur would vary in size. A collision or derailment could involve only a few rail

cars or lead to a greater number of rail cars being derailed in certain circumstances. Not all rail cars that derail would end up in a position where some or all of their contents could be spilled, depending on the nature of the accident (such as size, speed, and terrain). In addition, spills on the Reynolds Lead or BNSF Spur would be expected to be small given the lower operating speeds, which yield less energetic collisions and derailments, and therefore fewer rail cars derailing and even fewer releasing cargo.

Available data (Liu et al. 2012) indicate that while the average number of rail cars derailed on main line track (all classes and speeds) for 2001 through 2010 was 8.4 cars, the number of rail cars on yard, siding, and industry track ranged from 4.3 to 5.7 rail cars. These types of track provide an indication of the consequences of derailments at very low speeds.

3.1.3.1 Cowlitz County Operations Impacts

Table 6 can also be used to determine the predicted frequency of accidents within Cowlitz County. In addition to the Reynolds Lead and BNSF Spur track, 51.6% of the route from Vancouver to Longview Junction, and 18% of the route from Longview Junction to Auburn are within Cowlitz County. The predicted numbers of annual accidents described below include all the track within Cowlitz County, including the Reynolds Lead and BNSF Spur track.

The predicted number of loaded Proposed Action-related train accidents is 0.46 per year, or roughly one every 2 years, recognizing that accidents do not necessarily involve spills. The predicted number of empty Proposed Action-related train accidents is slightly higher, at 0.50 per year, due to the greater number of miles within Cowlitz County on the return route.

The 2028 baseline traffic for the inbound and outbound routes in Cowlitz County has roughly 4.30 predicted accidents per year. The number of predicted accidents per year increases to 5.25 with Proposed Action-related trains, showing the smaller relative contribution of the project trains to overall rail safety when the other rail shipments on the routes are included.

3.1.3.2 Statewide Operations Impacts

Table 6 can also be used to determine the predicted frequency of accidents on the rail lines within Washington State, including Cowlitz County and the Reynolds Lead and BNSF Spur. When looking at outbound trains, the first two inbound segments within the state are also traveled, albeit in the opposite direction; the associated accident frequencies should not be double counted.

The predicted number of operations-related loaded Proposed Action-related train accidents within Washington State is 5.16 per year, again recognizing that not all accidents involve spills. The number of empty Proposed Action-related train accidents is higher, at 6.23 per year, due to the greater length of the return route.

When inbound and outbound accidents related to the Proposed Action are added to the total baseline traffic (for 2028), predicted accidents increase from 50.43 accidents per year to 61.81 accidents per year, showing the smaller relative contribution of Proposed Action-related trains to overall rail safety when the other shipments on the routes are included.

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal. The Applicant would continue with current and proposed future increased operations in the project area. The project area could be developed for other industrial uses including an expanded bulk product terminal. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement.

The Applicant anticipates that planned growth under the No-Action Alternative would require approximately 2 trains per day; therefore, the predicted number of accidents would be lower than the Proposed Action and higher than the baseline conditions (Table 6). Various types of rail cars would be needed for the range of expected cargoes. No-Action Alternative-related rail traffic would have various cargoes (mixed-load train). The potential for a mixed-load train derailment or accident on the Reynolds Lead or BNSF Spur would presumably be lower than for a unit train because mixed-load trains would not have as many rail cars as a unit train.

Chapter 4
Permits

No permits related to rail safety would be required for the construction or operation of the Proposed Action.

Chapter 5
References

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Appendix A

Rail Safety Data

Appendix A
Rail Safety Data

This appendix summarizes the rail accident data used in the rail safety analysis.

Observed Accident Rates

Rail accident data available from the Federal Railroad Administration (FRA) were used as the initial basis for the rail safety and accident analysis. The specific data analyzed were for 2012 through 2014, with the data compiled in 2015 (Federal Railroad Administration 2015), the most recent available data when the analysis was completed.

The following image shows the raw data as it appears in the FRA database for all railroads. FRA data includes accident counts at the state and county levels, but accident rates are calculated on a nationwide basis. The data of interest to the analysis are the total year rates for 2012, 2013, and 2014. The rates are per million train miles.

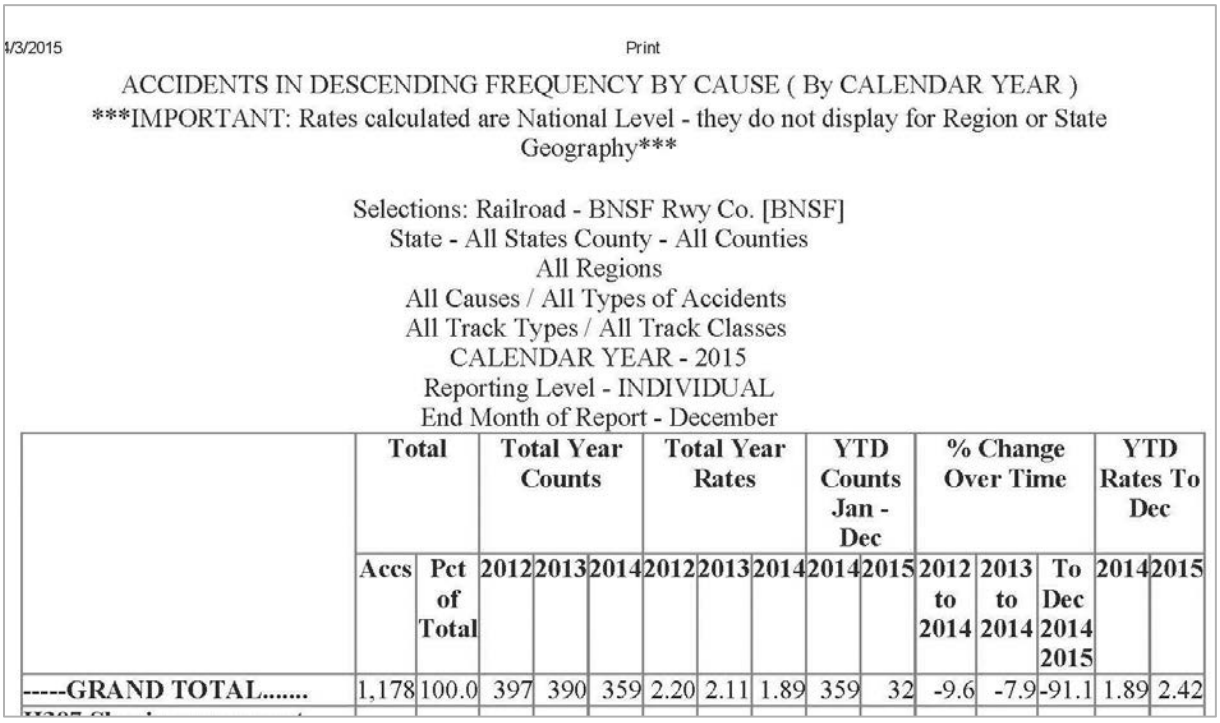
4/8/2015 Print

ACCIDENTS IN DESCENDING FREQUENCY BY CAUSE (By CALENDAR YEAR)
IMPORTANT: Rates calculated are National Level - they do not display for Region or State Geography

Selections: Railroad - All Railroads
State - All States County - All Counties
All Regions
All Causes / All Types of Accidents
All Track Types / All Track Classes
CALENDAR YEAR - 2015
Reporting Level - ALL
End Month of Report - December

	Total		Total Year Counts			Total Year Rates			YTD Counts Jan - Dec		% Change Over Time			YTD Rates To Dec	
	Accs	Pct of Total	2012	2013	2014	2012	2013	2014	2014	2015	2012 to 2014	2013 to 2014	To Dec 2014 2015	2014	2015
-----GRAND TOTAL.....	5,480	100.0	1,760	1,822	1,736	2.41	2.43	2.27	1,736	162	-1.4	-4.7	-90.7	2.27	2.58

The following two figures show the extracted data for BNSF Railway Company (BNSF) and Union Pacific Railroad (UP) for all track classes.

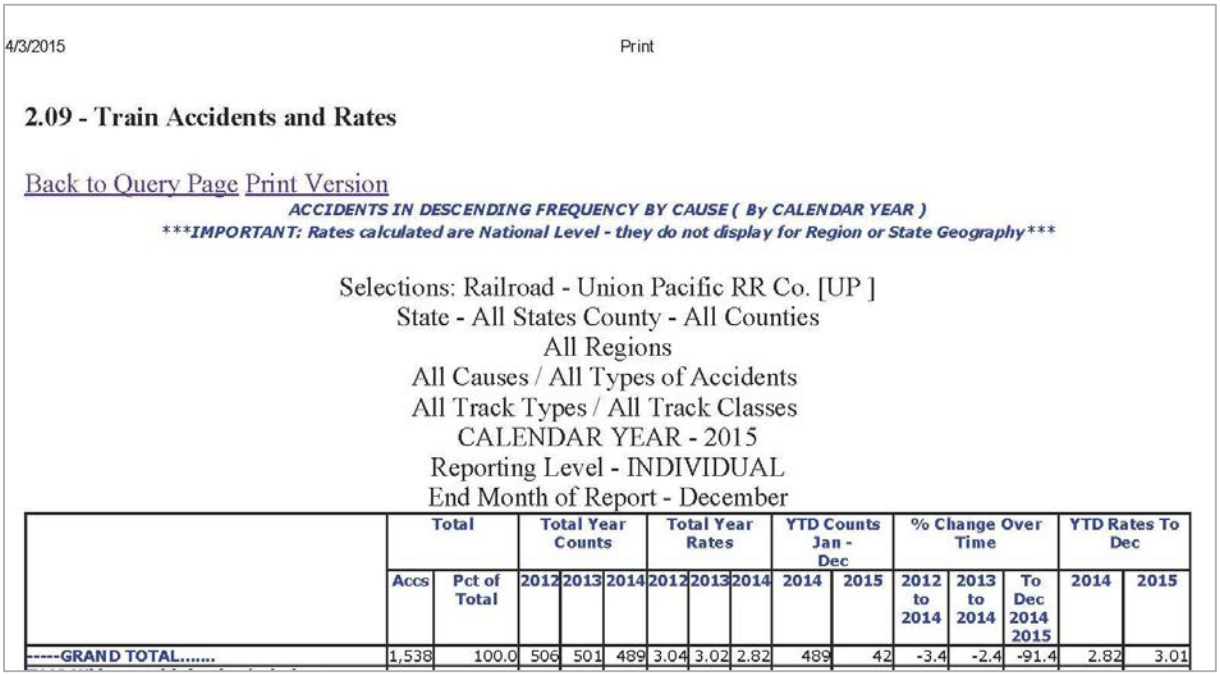


4/3/2015 Print

ACCIDENTS IN DESCENDING FREQUENCY BY CAUSE (By CALENDAR YEAR)
IMPORTANT: Rates calculated are National Level - they do not display for Region or State Geography

Selections: Railroad - BNSF Rwy Co. [BNSF]
State - All States County - All Counties
All Regions
All Causes / All Types of Accidents
All Track Types / All Track Classes
CALENDAR YEAR - 2015
Reporting Level - INDIVIDUAL
End Month of Report - December

	Total		Total Year Counts			Total Year Rates			YTD Counts Jan - Dec		% Change Over Time			YTD Rates To Dec	
	Accs	Pct of Total	2012	2013	2014	2012	2013	2014	2014	2015	2012 to 2014	2013 to 2014	To Dec 2014 2015	2014	2015
-----GRAND TOTAL.....	1,178	100.0	397	390	359	2.20	2.11	1.89	359	32	-9.6	-7.9	-91.1	1.89	2.42



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2.09 - Train Accidents and Rates

Back to Query Page Print Version

ACCIDENTS IN DESCENDING FREQUENCY BY CAUSE (By CALENDAR YEAR)
****IMPORTANT: Rates calculated are National Level - they do not display for Region or State Geography****

Selections: Railroad - Union Pacific RR Co. [UP]
State - All States County - All Counties
All Regions
All Causes / All Types of Accidents
All Track Types / All Track Classes
CALENDAR YEAR - 2015
Reporting Level - INDIVIDUAL
End Month of Report - December

	Total		Total Year Counts			Total Year Rates			YTD Counts Jan - Dec		% Change Over Time			YTD Rates To Dec	
	Accs	Pct of Total	2012	2013	2014	2012	2013	2014	2014	2015	2012 to 2014	2013 to 2014	To Dec 2014 2015	2014	2015
-----GRAND TOTAL.....	1,538	100.0	506	501	489	3.04	3.02	2.82	489	42	-3.4	-2.4	-91.4	2.82	3.01

The analysis compared the historic rates (in accidents per million train miles) for all railroads with rates specific to BNSF and UP as the first step in determining the appropriate accident rates for the Proposed Action (Table 1). The data Table 1 summarize the outputs from the FRA database.

Table 1. Train Accident Rates

	Accident Rate per Million Train Miles (FRA 2015)		
Year	**All Railroads**	**BNSF**	**UP**
2012	2.41	2.20	3.04
2013	2.43	2.11	3.02
2014	2.27	1.89	2.82

As shown in Table 1, BNSF's accident rates are similar to but lower (less frequent) than the average for all railroads. UP had slightly higher accident rates than BNSF. The Longview Switching Company (operator of the Reynolds Lead and BNSF Spur) did not have any data in the FRA database for 2012 through 2014; that is there were no train accidents experienced in this period on the Reynolds Lead or BNSF Spur. Because Proposed Action-related rail traffic in Washington State would be on BNSF lines, a rate of 2 accidents per million train miles (the national average for BNSF over the last 2 years) was used as the starting point of the accident analysis. Specific accident rates for BNSF in Washington State were not available. These data were then supplemented with data from analyses by Liu et al. (2011) and Anderson and Barkan (2004), as these give derailment rates by track class.

Observed Accident Counts

In addition to extracting the nationwide accident rates from the FRA database, the analysis also included data on mainline accidents in Cowlitz County and Washington State with and without injuries and fatalities as an indicator of potential accident severity. The data extracted from the database are presented in Figure 1.

Figure 1. Washington State Accident Counts—All Railroads (2014)

Acc Nbr	Rpt RR	Report Number	Kld/Inj	Mo	Day	ST	County	Type Track	Trk Maint	Type Acc	Pri Cause	Cont Cause	Equip Damage	Track Damage	Kld	Inj	RR Equip	Spd Mph	Locos Der	Cars Der
1	ATK	131208	55A	01	06	WA	KING	Main	ATK	Der	T311		28,765	3,000	0	0	PASSENGER TRAIN	012	1	0
2	BNSF	NW0114106	55A	01	13	WA	KING	Main	BNSF	Der	E62C		10,296	125,161	0	0	FREIGHT TRAIN	058	0	2
3	TMBL	02042014A	55A	02	04	WA	PIERCE	Yard	PTOZ	Oth	M402	H307	15,000	0	0	0	YARD/SWITCHING	010	0	0
4	BNSF	NW0214105	55A	02	10	WA	KING	Industry	BNSF	Der	H307	H702	13,432	2,500	0	0	YARD/SWITCHING	005	0	1
5	BNSF	NW0214110	55A	02	16	WA	SPOKANE	Yard	BNSF	Der	H312		9,606	3,672	0	0	YARD/SWITCHING	004	0	1
6	TMBL	03012014A	55A	03	01	WA	PIERCE	Yard	TMBL	Oth	H021	H318	15,000	0	0	0	YARD/SWITCHING	002	0	0
7	BNSF	NW0314104	55A	03	10	WA	DOUGLAS	Main	BNSF	Der	E69C		4,278	280,000	0	0	FREIGHT TRAIN	054	0	1
8	BNSF	NW0414101	55A	04	03	WA	COWLITZ	Main	BNSF	Oth	S011		0	17,200	0	0	FREIGHT TRAIN	005	0	0
9	PSAP	PSA558914D	55A	04	29	WA	GRAYS HARBOR	Main	PSAP	Der	T110		126,000	26,000	0	0	FREIGHT TRAIN	005	0	6
10	PSAP	PSA563914D	55A	05	09	WA	GRAYS HARBOR	Main	PSAP	Der	T111		44,700	60,000	0	0	FREIGHT TRAIN	005	0	7
11	BNSF	NW0514106	55A	05	11	WA	COWLITZ	Yard	BNSF	Der	H704		2,200	14,812	0	0	FREIGHT TRAIN	010	0	11
12	PSAP	PSA567314D	55A	05	15	WA	GRAYS HARBOR	Main	PSAP	Der	T109		350,000	189,450	0	0	FREIGHT TRAIN	010	0	11
13	PSAP	PSA570414D	55A	05	21	WA	LEWIS	Yard	PSAP	Der	M599		5,000	69,000	0	0	YARD/SWITCHING	004	0	11
14	BNSF	NW0614102	55A	06	06	WA	PIERCE	Yard	BNSF	Coll	H307		20,559	0	0	0	YARD/SWITCHING	005	0	0
14	BNSF	NW0614102	55A	06	06	WA	PIERCE	Yard	BNSF	Coll	H307		500	0	0	0	YARD/SWITCHING	000	0	0
15	ATK	133106	55A	06	09	WA	LEWIS	Main	BNSF	Oth	M308		1,632	0	0	1	PASSENGER TRAIN	053	0	0
15	BNSF	NW0614200	55A	06	09	WA	LEWIS	Main	BNSF	Oth	M308		0	10,000	0	0	NOT RPD OR N/A	000	0	0
16	BNSF	NW0614109	55A	06	13	WA	KING	Yard	BNSF	Coll	H607		80,000	0	0	0	YARD/SWITCHING	007	1	0
16	BNSF	NW0614109	55A	06	13	WA	KING	Yard	BNSF	Coll	H607		45,514	20,500	0	0	YARD/SWITCHING	008	0	1
17	BNSF	NW0614123	55A	06	27	WA	CLARK	Yard	BNSF	Coll	H318		31,646	0	0	0	YARD/SWITCHING	010	0	0
17	BNSF	NW0614123	55A	06	27	WA	CLARK	Yard	BNSF	Coll	H318		25,143	0	0	0	YARD/SWITCHING	005	0	1
18	BNSF	NW0714105	55A	07	06	WA	SPOKANE	Yard	BNSF	Der	H524	H523	8,412	1,000	0	0	YARD/SWITCHING	010	0	8
18	BNSF	NW0714105	55A	07	06	WA	SPOKANE	Yard	BNSF	Der	H524	H523	2,576	0	0	0	CUT OF CARS	000	0	2
19	BNSF	NW0714109	55A	07	09	WA	BENTON	Main	BNSF	Der	T109		101,465	56,000	0	0	FREIGHT TRAIN	037	0	3
20	BNSF	NW0714102	55A	07	17	WA	SNOHOMISH	Yard	BNSF	Der	H607	H702	6,500	7,100	0	0	YARD/SWITCHING	005	0	4
21	BNSF	NW0714116	55A	07	24	WA	KING	Main	BNSF	Der	E65L		62,316	143,500	0	0	FREIGHT TRAIN	005	1	4
22	BNSF	NW0814106	55A	08	01	WA	SPOKANE	Yard	BNSF	Coll	H021		5,360	0	0	0	FREIGHT TRAIN	003	0	4
22	BNSF	NW0814106	55A	08	01	WA	SPOKANE	Yard	BNSF	Coll	H021		5,156	0	0	0	CUT OF CARS	005	0	1
23	TMBL	08152014A	55A	08	15	WA	THURSTON	Main	TMBL	Oth	M503		14,599	25,000	0	0	FREIGHT TRAIN	008	0	0
24	BNSF	NW0814122	55A	08	29	WA	PIERCE	Yard	BNSF	Oth	H318		9,305	0	0	0	CUT OF CARS	002	0	0
24	BNSF	NW0814122	55A	08	29	WA	PIERCE	Yard	BNSF	Oth	H318		2,200	0	0	0	YARD/SWITCHING	005	0	0
25	BNSF	NW0914101	55A	09	13	WA	CLARK	Yard	BNSF	Coll	H307		10,366	0	0	0	YARD/SWITCHING	008	0	0
25	BNSF	NW0914101	55A	09	13	WA	CLARK	Yard	BNSF	Coll	H307		10,200	0	0	0	LIGHT LOCO(S)	004	0	0
26	BNSF	NW0914107	55A	09	21	WA	FRANKLIN	Yard	BNSF	Coll	H306		77,159	11,156	0	0	FREIGHT TRAIN	010	0	0
26	BNSF	NW0914107	55A	09	21	WA	FRANKLIN	Yard	BNSF	Coll	H306		40,000	0	0	0	YARD/SWITCHING	002	0	0
27	BNSF	NW1114103	55A	11	04	WA	CHELAN	Yard	BNSF	Der	T207		11,726	5,000	0	0	FREIGHT TRAIN	008	0	5
28	BNSF	NW1114111	55A	11	11	WA	KING	Yard	BNSF	Der	M411		7,818	3,000	0	0	YARD/SWITCHING	010	0	3
29	BNSF	NW1114114	55A	11	13	WA	SPOKANE	Yard	BNSF	Der	H525		20,979	7,000	0	0	FREIGHT TRAIN	004	0	4
30	BNSF	NW1114200	55A	11	20	WA	LEWIS	Main	BNSF	Oth	M304		15,000	1,100	0	0	FREIGHT TRAIN	038	0	0
31	BNSF	NW1114201	55A	11	24	WA	SPOKANE	Main	BNSF	Oth	M303		15,000	0	0	1	MAINTENANCE CAR	005	0	0
32	BNSF	NW1214100	55A	12	03	WA	KING	Industry	XGNW	Der	M101		15,043	1,000	0	0	YARD/SWITCHING	004	0	6
33	BNSF	NW1214104	55A	12	07	WA	SPOKANE	Yard	BNSF	Coll	H306		8,295	0	0	0	YARD/SWITCHING	003	0	0
33	BNSF	NW1214104	55A	12	07	WA	SPOKANE	Yard	BNSF	Coll	H306		3,202	0	0	0	YARD/SWITCHING	003	0	0
34	BNSF	NW1214105	55A	12	09	WA	CLARK	Yard	BNSF	Oth	H702		0	40,945	0	0	LIGHT LOCO(S)	002	0	0
35	BNSF	NW1214107	55A	12	12	WA	KING	Yard	BNSF	Der	H318		17,124	1,000	0	0	YARD/SWITCHING	010	0	3
36	BNSF	NW1214109	55A	12	12	WA	SPOKANE	Yard	BNSF	Der	H312		19,199	0	0	0	YARD/SWITCHING	004	0	2

Based on the FRA data (2015), there were two accidents in Cowlitz County in 2014 (accidents 8 and 11 in Figure 1) and neither involved an injury or fatality. One incident was in a yard and the other involved a derailment of 11 rail cars on main line track. For Washington State, there were 36 accidents in 2014, two of which had an injury involved. Thirteen accidents were on main line track, the rest were in yards or on industry track. Derailments had 0 to 11 rail cars involved. Table 2 illustrates UTC data for crashes that occurred at highway rail grade crossings and along railroad rights-of-way in Washington State.

Table 2. Washington State Rail Crash Statistics

Year	Crossing Collisions	Crossing Injuries	Crossing Fatalities	Trespass Fatalities
2012	33	18	2	10
2013	20	10	4	17
2014	35	10	5	9

References

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MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA VEHICLE TRANSPORTATION TECHNICAL REPORT

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April 2017

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Contents

List of Tables ii
List of Figures iii
List of Acronyms and Abbreviations iv
Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-6
1.3.1 Study Crossings 1-6
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-1
2.1.2 Impact Analysis 2-1
2.2 Existing Conditions 2-16
2.2.1 Emergency Services 2-16
2.2.2 Washington State 2-21
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Construction: Direct and Indirect Impacts 3-1
3.1.2 Operations: Direct Impacts 3-11
3.1.3 Operations: Indirect Impacts 3-12
3.1.4 Washington State Study Area 3-23
3.2 No-Action Alternative 3-32
Chapter 4 **Required Permits** **4-1**
Chapter 5 **References** **5-1**
5.1 Written References 5-1
5.2 Personal Communications 5-2

Appendix A Vehicle Transportation Technical Data
Appendix B Data for Selected Crossings Outside of Cowlitz County

Tables

Table 1. Regulations, Statutes, and Guidelines for Highway/Rail Grade Crossings 1-5

Table 2. Motor Vehicle and Train Volumes at Study Crossings 2-8

Table 3. Grade Crossing Level of Service 2-12

Table 4. Estimated Vehicle Storage Lengths 2-14

Table 5. At-Grade Crossing and Roadway Characteristics 2-17

Table 6. Existing Conditions at Selected Study Crossings Outside of Cowlitz County 2-22

Table 7. Study Crossing Characteristics—2018 Construction Scenario 3-2

Table 8. Estimated Vehicle Delay and LOS—2018 Construction Scenario (PM Peak Hour) 3-5

Table 9. Estimated Vehicle Delay and LOS—2018 Construction Scenario (24-Hour Average) 3-7

Table 10. Estimated Vehicle Queue Lengths—2018 Construction Scenario (PM Peak Hour) 3-9

Table 11. Study Crossing Characteristics—2028 Operations 3-13

Table 12. Estimated Vehicle Delay and LOS—2028 Operations (PM Peak Hour) 3-16

Table 13. Estimated Vehicle Delay and LOS—2028 Operations (24-Hour Average) 3-18

Table 14. Estimated Vehicle Queue Lengths—2028 Operations (PM Peak Hour) 3-20

Table 15. At-Grade Crossing Safety Assessment 3-24

Table 16. 2028 Conditions at Selected Statewide Study Crossings 3-25

Table 17. 2028 Statewide At-Grade Crossing Safety Assessment 3-31

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. Reynolds Lead and BNSF Spur Study Crossings 2-4
Figure 4. BNSF Main Line Study Crossings 2-6
Figure 5. Fire Stations in the Kelso-Longview Area 2-19
Figure 6. Selected At-Grade Crossings Beyond Cowlitz County 3-28

Acronyms and Abbreviations

AADT	annual average daily traffic
ADT	average daily traffic
AMR	American Medical Response
Applicant	Millennium Bulk Terminals—Longview, LLC
BNSF	BNSF Railway Company
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
County	Cowlitz County
EMS	emergency medical services
EMT	emergency medical technician
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
LOS	level of service
LVSW	Longview Switching Company
mph	miles per hour
NEPA	National Environmental Policy Act
NORPAC	North Pacific Paper Corporation
RCW	Revised Code of Washington
Reynolds facility	Reynolds Metal Company facility
SEPA	Washington State Environmental Policy Act
SR	State Route
UP	Union Pacific Railroad
USC	United States Code
USDOT	U.S. Department of Transportation
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WUTC	Washington Utilities and Transportation Commission

Chapter 1
Introduction

This technical report assesses the potential vehicle transportation impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. This report describes the regulatory setting, establishes the methods for assessing potential vehicle transportation impacts, presents the historical and current vehicle transportation conditions in the study area, and assesses potential impacts.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

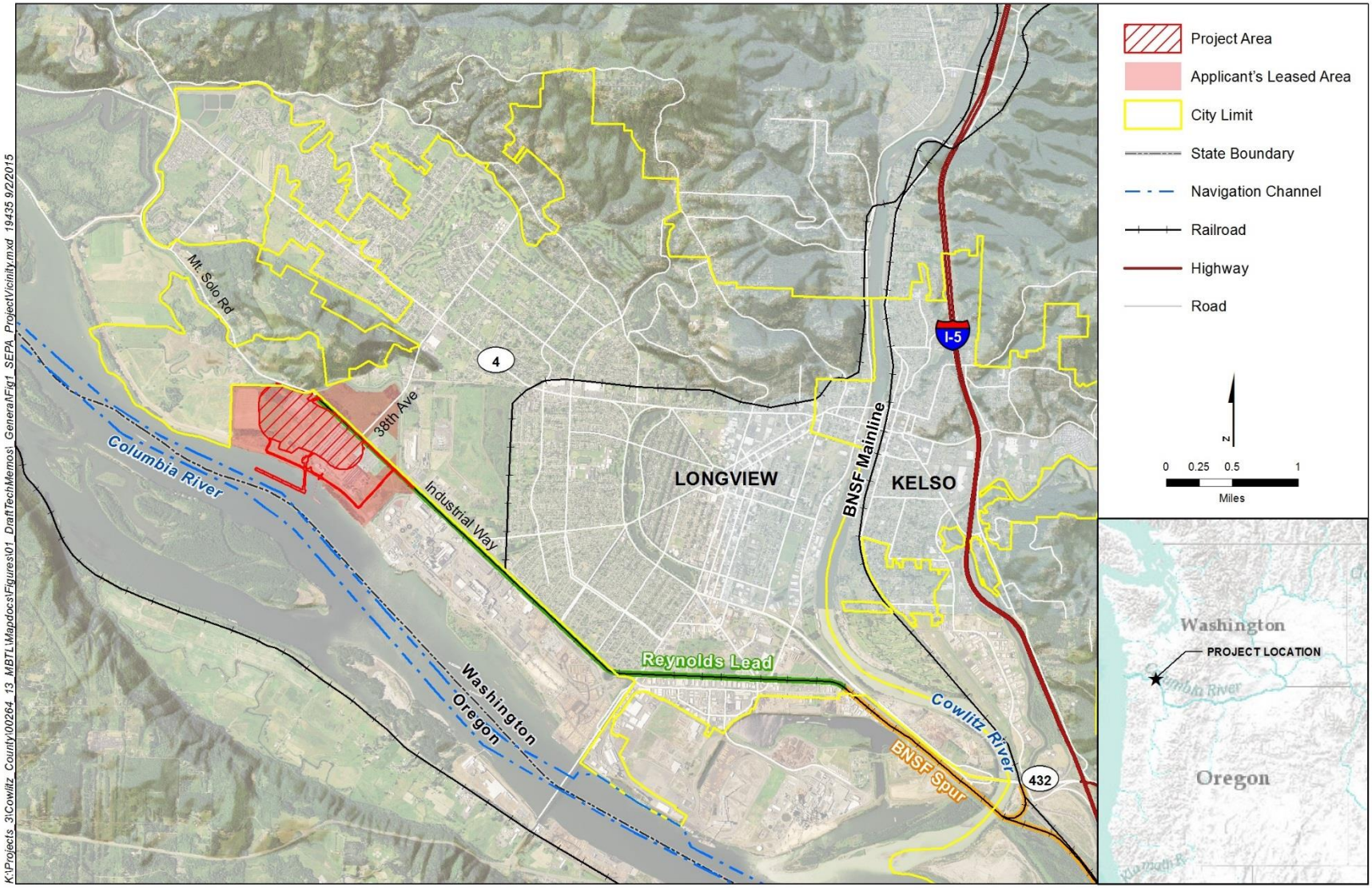
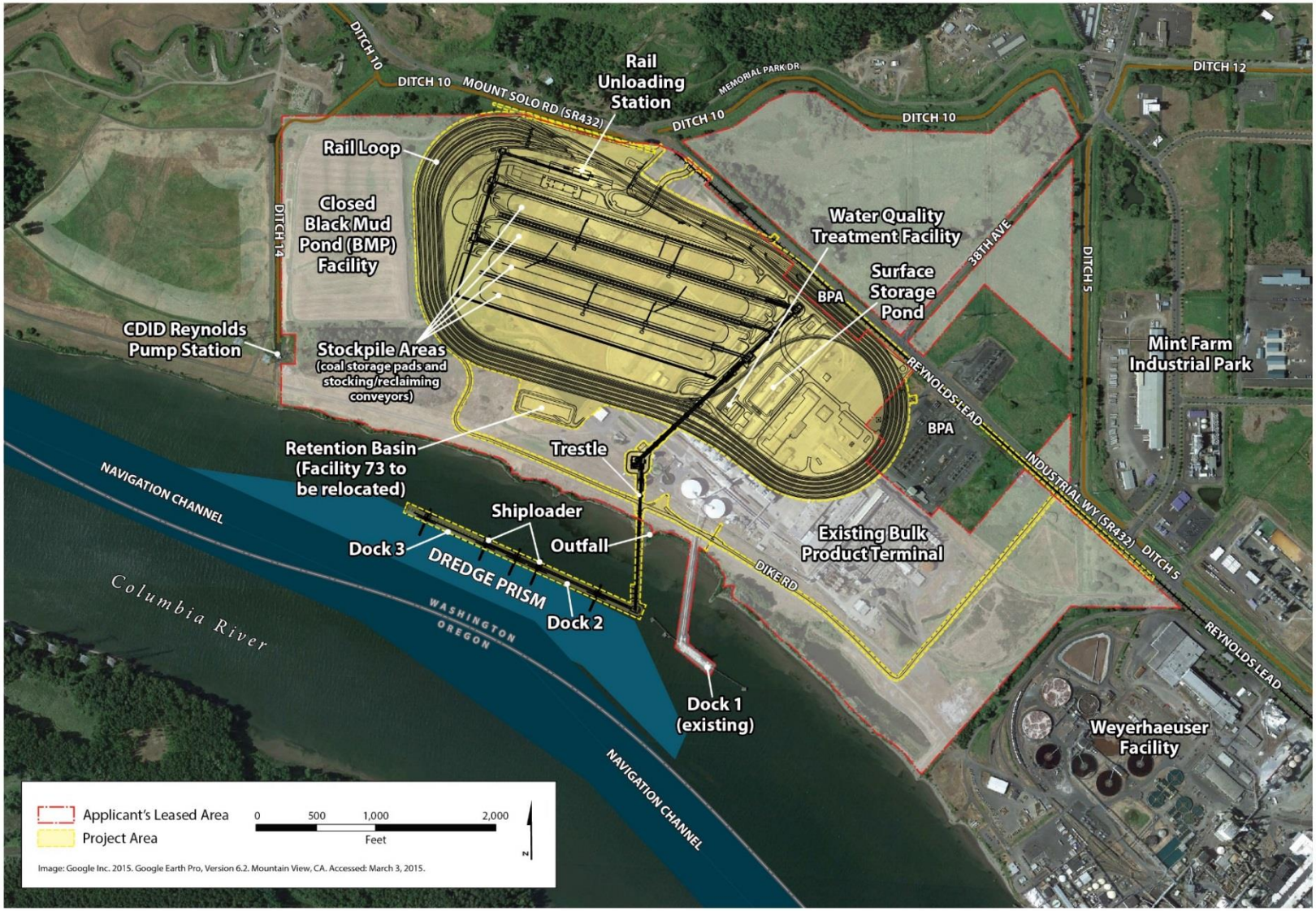


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

Different jurisdictions are responsible for the regulation of highway/rail grade crossings. These jurisdictions and their regulations, statutes, and guidance that apply to grade crossings are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidelines for Highway/Rail Grade Crossings

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Federal Railroad Safety Act of 1970	Gives FRA rulemaking authority over all areas of rail line safety. FRA has designated that state and local law enforcement agencies have jurisdiction over most aspects of highway/rail grade crossings, including warning devices and traffic law enforcement.
Highway Safety Act and the Federal Railroad Safety Act	Gives FHWA and FRA regulatory jurisdiction over safety at federal highway/rail grade crossings. USDOT has promulgated rules addressing grade-crossing safety and provides funding for installation and improvement of warning devices. FRA has issued rules that impose minimum maintenance, inspection, and testing standards for at-grade crossing warning devices for highway/rail grade crossings on federal highways and state and local roads (49 CFR 234–236).

Regulation, Statute, Guideline	Description
Railroad-Highway Grade Crossing Handbook (Federal Highway Administration 2007); *Manual on Uniform Traffic Control Devices* (23 USC 109(d))	Guidance document on grade-crossing safety issues, including the selection and placement of warning devices and enforcement of traffic laws. Provides guidelines for traffic control devices that consider delay, roadway classification, average daily traffic, number of trains per day, and train speed at grade crossings.
State	
Washington State Environmental Policy Act (197-11 WAC, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Washington State Department of Transportation, Design Manual M 22.01.10, November 2015, Chapter 1350, Railroad Grade Crossings	Sets forth requirements and guidance on the design and treatment of state highway-rail grade crossings.
Motor Vehicles, Rules of the Road (RCW 46.61.340)	Sets forth that train traffic has the right-of-way at grade crossings.
Washington Utilities and Transportation Commission	Inspects and issues violations for hazardous materials shipments; track, signal, and train control; and rail operations. WUTC also regulates the construction, closure, or modification of public railroad crossings. In addition, WUTC inspects and issues defect notices if a crossing does not meet minimum standards. However, WUTC has no jurisdiction over public crossings in first-class cities.[a]
Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provide for the implementation of SEPA in Cowlitz County.
Railroad Trains Not to Block Streets (LMC 11.40.080)	Prohibits trains from using any street or highway for a period longer than 5 minutes, except trains or cars in motion other than those engaged in switching activities.

Notes:

[a] Per RCW 35.01.01, a first-class city is a city with a population of 10,000 or more at the time of organization or reorganization that has adopted a charter.

USC = United States Code; NEPA = National Environmental Policy Act; CFR = Code of Federal Regulations; Corps = U.S. Army Corps of Engineers; FRA = Federal Railroad Administration; FHWA = Federal Highway Administration; USDOT = U.S. Department of Transportation; WAC = Washington Administrative Code; RCW = Revised Code of Washington; WUTC = Washington Utilities and Transportation Commission; SEPA = Washington State Environmental Policy Act; CCC = Cowlitz County Code; LMC = Longview Municipal Code

1.3 Study Area

The study area for direct impacts is the project area. The study area for indirect impacts is active public and private at-grade crossings within Cowlitz County on the Reynolds Lead and BNSF Spur, and all at-grade public crossings on the BNSF main line. At-grade crossings of interest along the BNSF main line in Washington State are also considered.

1.3.1 Study Crossings

The analysis focused on 17 at-grade railroad crossings along the Reynolds Lead, BNSF Spur, and BNSF main line in Cowlitz County.

1.3.1.1 Reynolds Lead and BNSF Spur Study Crossings

The following identifies the study crossings along the Reynolds Lead and BNSF Spur in the study area.[1] Although the project area is in Cowlitz County, all of the at-grade crossings are in the City of Longview. The U.S. Department of Transportation (USDOT) Crossing Identification Number for the public at-grade crossings is also provided.

- Project area access at 38th Avenue, just south of Industrial Way (SR 432), milepost 3.30.
- Weyerhaeuser Access at Washington Way, just south of SR 432 milepost 4.43.
- Weyerhaeuser North Pacific Paper Corporation (NORPAC) Access, just south of SR 432 milepost 4.76.
- Industrial Way (SR 432), milepost 5.90, just west of Oregon Way (SR 433) (101806G)
- Oregon Way, 300 feet north of the Industrial Way/Oregon Way intersection (401805A)
- California Way, 460 feet north of Industrial Way (101821J)
- 3rd Avenue (SR 432), milepost 7.19, just north of the 3rd Avenue/Industrial Way intersection (101826T)
- Dike Road, just south of Tennant Way (SR 432) (101791U)

1.3.1.2 BNSF Main Line Study Crossings

The following identifies the study crossings along the BNSF main line in Cowlitz County (all public road/rail at-grade crossings along the BNSF main line in Cowlitz County). The USDOT Crossing Identification Number is also provided.

- Taylor Crane Road, 50 feet west of Barnes Drive in Castle Rock (092481X)
- Cowlitz Street, 350 feet west of Pioneer Avenue in Castle Rock (092476B)
- Cowlitz Gardens Road, west of Pacific Avenue in Kelso (092466V)
- Mill Street, west of 1st Avenue in Kelso (092458D)
- S River Road, west of Pacific Avenue in Kelso (092457W)
- Toteff Road/Port Road in Kalama (092446J)
- W Scott Avenue, 650 feet east of Pekin Road in Woodland (092437K)
- Davidson Avenue, east of Pekin Road in Woodland (092435W)
- Whalen Road, east of Kuhnis Road in Woodland (092434P)

1.3.1.3 Statewide Crossings

A review of at-grade rail crossings of interest identified by the Washington State Department of Transportation (WSDOT) on the BNSF main line beyond Cowlitz County was also conducted. These statewide study crossings are at-grade state highway crossings or at-grade crossings near state highways.

[1]The intersections upstream from each of the eight at-grade railroad crossings along the Reynolds Lead and BNSF Spur were also analyzed during the peak vehicle traffic hour.

Chapter 2
Existing Conditions

This chapter describes the methods for assessing the existing conditions and determining impacts in the study area as they pertain to vehicle transportation.

2.1 Methods

This section describes the sources of information and methods used to characterize the existing conditions and assess the potential impacts of the Proposed Action and No-Action Alternative on vehicle transportation.

2.1.1 Data Sources

The following sources of information were used to evaluate the vehicle transportation characteristics of the study area.

- USDOT Grade Crossing Inventory, Federal Railroad Administration (FRA).
- Data provided by the Washington Utilities and Transportation Commission (WUTC).
- *SR 432 Highway Improvements and Rail Realignment Study* (Cowlitz-Wahkiakum Council of Governments 2014).
- *Traffic and Transportation Resource Report* (URS Corporation 2014) provided by the Applicant.
- Traffic volume data provided in local studies and field-collected data.

2.1.2 Impact Analysis

The following methods were used to evaluate the potential impacts of the Proposed Action and No-Action Alternative on vehicle transportation. For the purposes of this analysis, construction impacts are based on the peak construction period and operations impacts are based on maximum throughput capacity (44 million metric tons of coal per year).

2.1.2.1 No-Action Alternative Analysis

Regardless of whether the coal export terminal is built, the Applicant would continue to operate approximately 350 acres of the project area as a bulk product terminal, and increase commodity storage and shipment as described in Section 1.1.2, *No-Action Alternative*. The Applicant could expand the existing bulk product terminal onto the 190-acre project area, developing storage and shipment facilities to increase existing coal and alumina operations under current permits.

By 2018, the planned bulk product terminal activities would increase the average length of trains up to 575 feet along the Reynolds Lead and the BNSF Spur. By 2028, potential bulk product terminal activities would add 1.71 daily train trips to the Reynolds Lead (each train trip approximately 2,068 feet long).

2.1.2.2 Construction Impact Analysis

The Applicant has identified three construction scenarios.

- **Truck.** If material is delivered by truck, it is assumed approximately 88,000 truck trips would be required over the construction period. Approximately 56,000 loaded truck trips would be needed during the peak construction year.
- **Rail.** If material is delivered by rail, it is assumed approximately 700 train trips (35,000 loaded rail cars) would be required over the construction period. Approximately two-thirds of the rail trips would occur during the peak construction year.
- **Barge.** If material is delivered by barge, it is assumed approximately 1,130 barge trips would be required over the construction period. Approximately two-thirds of the barge trips would occur during the peak construction year. Because the project area does not have an existing barge dock, the material would be unloaded at an existing dock elsewhere on the Columbia River and transported to the project area by truck.

The analysis analyzed all three scenarios.[2] Potential impacts on vehicle transportation during construction could occur because of construction-worker vehicle traffic and additional trucks or trains bringing preload materials to the project area. This analysis of potential impacts assumes the following, based primarily on information provided by the Applicant.

- Approximately 1.4 million cubic yards of material would be imported to the project area during the first year of construction.[3] No exporting of material would occur during the first year of construction.
- Approximately 200 construction workers would be on site daily in 2018, with the work shift ending at 5:00 p.m., and approximately 90% of the construction workers traveling in a single-occupancy vehicle. This would result in 180 outbound trips during the PM peak hour (AECOM 2015).
- If construction materials are delivered by truck (truck or barge construction scenario), approximately 56,000 trucks, or a maximum of 330 per day, would be required to deliver the preload material to the site during the first year of construction, which is assumed to be 2018. This estimate is based on a combination of the amount of space likely available on site for unloading material and the anticipated number of trucks available in the area capable of hauling preload material. Given that 56,000 trucks would be required to deliver the preload material in 2018, it would take approximately 170 working days for delivery. This would result in 42 inbound and 42 outbound trucks per hour (assuming deliveries occur evenly over an 8-hour workday) (AECOM 2015).
- If construction material is delivered by rail (rail construction scenario), approximately 23,333 loaded rail cars would be required to deliver the preload material to the site in 2018. Assuming 100-car rail trains, this would result in approximately 233 inbound and 233 outbound trains or an average of 1.3 trains per day (each approximately 6,219 feet long), in 2018 (URS Corporation 2014).

[2] The barge scenario includes the same assumptions as the truck scenario because materials would be transferred from barge to truck and delivered to the project area.

[3] A total of 2.1 million cubic yards of construction material is expected to be imported over the duration of the construction period. For the purposes of the vehicle transportation analysis, the first year of construction was used because two-thirds of the volume is expected to be transported during the first year and represents the peak year.

2.1.2.3 Operations Impact Analysis

It is assumed the coal export terminal would be operating in 2028 at the planned capacity of 44 million metric tons per year of coal. Full operations of the coal export terminal would add 16 new daily train trips (8 loaded and 8 empty), each an average of 6,917 feet (approximately 1.3 miles) long. Based primarily on estimates provided by the Applicant, approximately 135 employees would be needed to operate the coal export terminal. Operations would occur 24 hours per day, 7 days per week, and 50% of the employees would exit and 30% would enter the site during the PM peak hour. This would result in 41 inbound and 68 outbound trips during the PM peak hour (URS Corporation 2014).

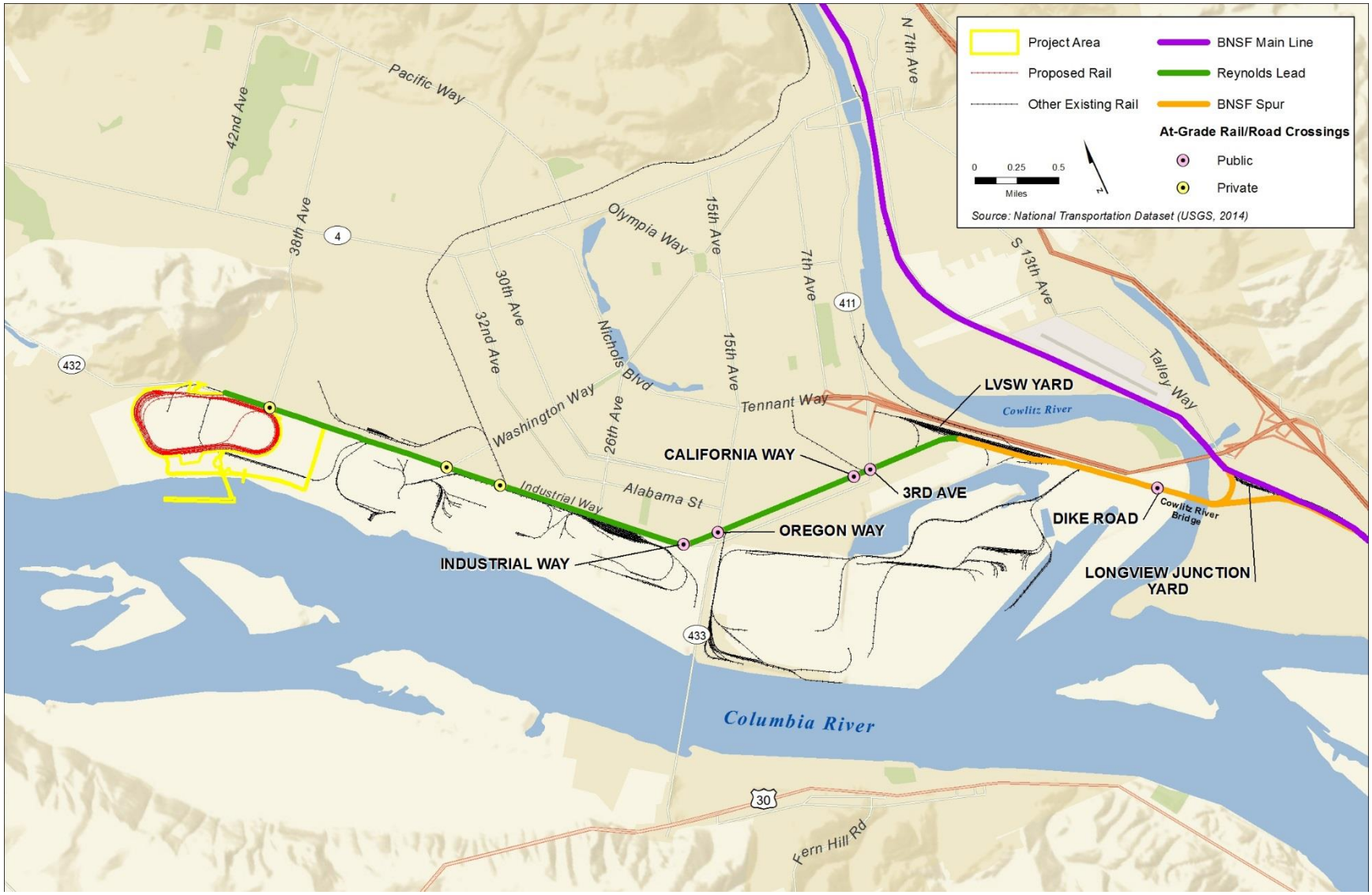
Reynolds Lead and BNSF Spur

The types and number of trains from Longview Junction to the project area for existing year and 2028 were developed from meetings with LVSW and the Port of Longview. As described in the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017), LVSW plans to upgrade the Reynolds Lead and part of the BNSF Spur as a separate action should it be warranted by increased rail traffic resulting from existing and future customers. Upgrades to the track would include adding ballast, replacing ties, and upgrading rail. These improvements would provide for safer operations and increased speed over the BNSF Spur and Reynolds Lead. LVSW would also install signals, upgrade the traffic control system to Centralized Traffic Control, and add an electric, remotely operated switch from the BNSF Spur to the Reynolds Lead. Construction of these improvements would take approximately 6 months. Because these improvements are not certain, the vehicle transportation impact analysis analyzes current track infrastructure and with these planned track improvements. Figure 3 illustrates the Reynolds Lead and BNSF Spur, and the study crossings along the Reynolds Lead and BNSF Spur.

The vehicle transportation analysis does not include the improvements identified in the *SR 432 Highway Improvements and Rail Realignment Study* completed in September 2014 (Cowlitz-Wahkiakum Council of Governments 2014). This study identified various design concepts to address safety, traffic congestion, system mobility and freight capacity issues where the rail and roadway systems overlap along the SR 432 corridor. Various design concepts were developed and evaluated for rail and highway improvements to improve safety, mobility, congestion, and freight capacity.

The top concept that emerged from this study was a grade-separated intersection at SR 432/SR 433. This project, called the Industrial Way/Oregon Way Intersection Project and led by Cowlitz County Public Works, is currently in the preliminary design and National Environmental Policy Act (NEPA) and Washington State Environmental Policy Act (SEPA) environmental compliance phase to address traffic congestion, freight mobility and safety issues at this intersection. Grade separating the Industrial Way and Oregon Way at-grade rail crossings on the Reynolds Lead would eliminate motor vehicle delay and vehicle queuing at these two crossings. Trains on the Reynolds Lead would travel beneath these roadways without delaying motor vehicle traffic at these crossings. However, this project was not included in the vehicle transportation analysis because a preferred alternative for the intersection has not been identified and implementation by 2028 is not certain. The other concepts identified in the *Highway Improvements and Rail Realignment Study* were not included in the vehicle transportation analysis for the Proposed Action because funding for implementation has not been secured.

Figure 3. Reynolds Lead and BNSF Spur Study Crossings



BNSF Main Line in Cowlitz County

The types and number of baseline train traffic beyond Longview Junction were developed from the *Washington State Rail Plan* (WSDOT Rail Plan) (Washington State Department of Transportation 2014a) using linear extrapolation of 2010 and 2035 projected train traffic to 2018 and 2028. The analysis assumes 8 full inbound trains arrive at Longview Junction from the south on the BNSF main line and 8 empty trains travel north from Longview Junction on the BNSF main line. Other potential options could include all trains traveling to the north and all trains traveling to the south. Figure 4 illustrates the study crossings along the BNSF main line in Cowlitz County.

The analysis assumed that up to 2 Proposed Action-related trains could arrive during the PM peak hour by 2028 on the BNSF main line in Cowlitz County, meaning no more than 2 trains would be expected at the study crossings, regardless of the route. Therefore, to account for motor vehicle impacts associated with each of the train route, the analysis assumes 2 Proposed Action-related trains at each crossing along the BNSF main line during the PM peak hour. If all 16 daily train trips were routed to arrive and leave from the same direction, it would increase the weighted average train length by about 150 feet and increase the overall daily gate downtime between 14 and 20 minutes at BNSF main line study crossings.

Washington State

For the Washington State study area analysis, it was assumed that the rail routes would be the same as current BNSF and UP routes and as documented in WSDOT publications, including the WSDOT Rail Plan and *Washington State Freight Mobility Plan* (Washington State Department of Transportation 2014b). In 2012, BNSF changed its train operations protocol to enhance use of existing capacity using directional running. This strategy routes all westbound-loaded unit trains (including coal) from Pasco via the Columbia River Gorge to Vancouver, Washington, where it continues on the BNSF north-south main line to its final destination. Empty unit bulk trains from north of Vancouver, including Cowlitz County, return to Pasco and to points east via Stampede Pass. The types and number of baseline train traffic were developed from the WSDOT Rail Plan using linear extrapolation of 2010 and 2035 projected train traffic.

2.1.2.4 Years and Scenarios

The years selected for analysis are 2018 and 2028, which allows the identification of potential impacts at rail-crossings associated with construction and operation of the Proposed Action, and helps determine if improvements would be necessary at study crossings. The following scenarios were analyzed.

- **2018 No-Action.** Assumes that the coal export terminal would not be constructed and that activities currently ongoing and planned for the existing bulk materials terminal within the Applicant's leased area would occur (summarized in Section 2.1.2.1, *No-Action Alternative Analysis*). It includes the motor vehicle and train volumes in Table 2.
- **2018 Proposed Action (Construction).** Represents conditions during the construction of the coal export terminal. It assumes the motor vehicle and train volumes from the 2018 No-Action scenario, but with the added traffic and rail growth related to construction of the Proposed Action discussed in Section 2.1.2.2, *Construction Impact Analysis*.

Figure 4. BNSF Main Line Study Crossings



It also assumes the planned project area activities included in the 2018 No-Action scenario. As discussed in Section 2.1.2.2, *Construction Impact Analysis*, this analysis considers construction materials delivered by truck, or construction materials delivered by rail.

- **2028 No-Action.** Assumes that the coal export terminal would not be constructed, and includes the motor vehicle and train volumes from the 2018 No-Action scenario, but with 10 years of added vehicle traffic growth. It also assumes the planned bulk product terminal activities included in the 2018 No-Action scenario, and the potential future activities for the existing bulk product terminal discussed in Section 2.1.2.1, *No-Action Alternative Analysis*.
- **2028 Proposed Action.** Represents conditions during full operation of the Proposed Action. It includes the motor vehicle and train volumes from the 2028 No-Action scenario, but with the added traffic and train growth related to full operation of the coal export terminal discussed in Section 2.1.2.3, *Operations Impact Analysis.* It also assumes the planned and potential expansion of bulk product terminal activities included in the 2028 No-Action scenario. This analysis considers the following circumstances: 1) current track infrastructure improvements along the Reynolds Lead, and 2) planned track infrastructure improvements along the Reynolds Lead that would increase the average train speed from 8 miles per hour (mph) to 10 mph at the Weyerhaeuser access crossing—opposite Washington Way, from 10 mph to 15 mph at the Weyerhaeuser NORPAC access crossing, from 10 mph to 20 mph at the Industrial Way and Oregon Way crossings, and from 8 mph to 15 mph at the California Way and 3rd Avenue crossings. No changes in train speed would be expected at the existing site access—opposite 38th Avenue, and at the Dike Road crossings.

2.1.2.5 Trip Distribution Analysis

The construction- and employee-related traffic was distributed onto the transportation network based on current traffic patterns near the project area. For the construction workers and full operation employees (Section 2.1.2.2, *Construction Impact Analysis,* and Section 2.1.2.3, *Operations Impact Analysis*), it is assumed that 60% of the traffic would arrive from the north using Washington Way (35%) and Oregon Way (25%), 15% from the south along Oregon Way, 20% from the east along 3rd Avenue, and 5% from the west along Industrial Way. For the construction materials delivered to the project area by truck (Section 2.1.2.2, *Construction Impact Analysis*) it is assumed that 75% of the trucks would arrive from the east using 3rd Avenue, and 25% from the south along Oregon Way.

2.1.2.6 Analysis of Baseline and Future Volumes at Railroad Crossings

Motor Vehicles

Table 2 includes the average daily traffic (ADT) and PM peak hour count data for all study crossings. Hourly traffic volumes over the course of 3 days were compared at select locations[4] to identify a peak hour. The analysis identified a peak hour between 4:00 and 5:00 p.m., with evening peak period traffic volumes more than 25% greater than those in the morning and afternoon.

[4] The hourly traffic volumes were based on volumes collected between March 5, 2013 and Marcy 7, 2013, at the following locations: 1) Industrial Way, west of Oregon Way; 2) Industrial Way, between Oregon Way and California Way; 3) 3rd Avenue, north of Industrial Way; and 4) Oregon Way, north of Industrial Way.

Table 2. Motor Vehicle and Train Volumes at Study Crossings

Crossing Name (USDOT Crossing ID)	Time Period	2018 No-Action Scenario		2018 Proposed Action (Construction - Truck Delivery) Scenario		2018 Proposed Action (Construction - Rail Delivery) Scenario		2028 No-Action Scenario		2028 Proposed Action (Operations) Scenario	
		Vehicle	Train	Vehicle	Train	Vehicle	Train	Vehicle	Train	Vehicle	Train
Study Crossings along the Reynolds Lead and BNSF Spur											
Project area at 38th Avenue	Per Day	400	2.3	3,050	2.3	2,200	3.6	600	4.0	1,700	20.0
	PM Peak	40	1	305	1	220	1	60	1	170	1 or 2
Weyerhaeuser access at Washington Way	Per Day	3,200	2.3	3,200	2.3	3,200	3.6	3,800	4.0	3,800	20.0
	PM Peak	320	1	320	1	320	1	380	1	380	1 or 2
Weyerhaeuser NORPAC access	Per Day	700	2.3	700	2.3	700	3.6	950	4.0	950	20.0
	PM Peak	70	1	70	1	70	1	95	1	95	1 or 2
Industrial Way-SR 432 (101806G)	Per Day	9,600	2.3	11,500	2.3	10,700	3.6	10,800	4.0	11,450	20.0
	PM Peak	960	1	1,150	1	1,070	1	1,080	1	1,145	1 or 2
Oregon Way-SR 433 (101805A)	Per Day	13,400	2.3	13,850	2.3	13,850	3.6	16,750	4.0	17,000	20.0
	PM Peak	1,340	1	1,385	1	1,385	1	1,675	1	1,700	1 or 2
California Way (101821J)	Per Day	3,750	2.3	3,750	2.3	3,750	3.6	5,450	4.0	5,450	20.0
	PM Peak	375	1	375	1	375	1	545	1	545	1 or 2
3rd Avenue-SR 432 (101826T)	Per Day	16,300	2.3	17,300	2.3	16,650	3.6	20,000	4.0	20,200	20.0
	PM Peak	1,630	1	1,730	1	1,665	1	2,000	1	2,020	1 or 2
Dike Road (101791U)	Per Day	400	7.1	400	7.1	400	8.4	400	7.1	400	23.1
	PM Peak	40	1	40	1	40	1	40	1	40	1 or 2

Crossing Name (USDOT Crossing ID)	Time Period	2018 No-Action Scenario		2018 Proposed Action (Construction - Truck Delivery) Scenario		2018 Proposed Action (Construction - Rail Delivery) Scenario		2028 No-Action Scenario		2028 Proposed Action (Operations) Scenario	
		Vehicle	Train	Vehicle	Train	Vehicle	Train	Vehicle	Train	Vehicle	Train
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County											
Taylor Crane Road in Castle Rock (092481X)	Per Day	50	55.1	50	55.1	50	56.1	50	72.7	50	80.7
	PM Peak	5	3.9	5	3.9	5	4.9	5	4.6	5	6.6
Cowlitz Street in Castle Rock (092476B)	Per Day	1,200	55.1	1,200	55.1	1,200	56.1	1,450	72.7	1,450	80.7
	PM Peak	120	3.9	120	3.9	120	4.9	145	4.6	145	6.6
Cowlitz Gardens Road in Kelso (092466V)	Per Day	700	55.1	700	55.1	700	56.1	850	72.7	850	80.7
	PM Peak	70	3.9	70	3.9	70	4.9	85	4.6	85	6.6
Mill Street in Kelso (092458D)	Per Day	2,550	55.1	2,550	55.1	2,550	56.1	3,000	72.7	3,000	80.7
	PM Peak	255	3.9	255	3.9	255	4.9	300	4.6	300	6.6
S River Road in Kelso (092457W)	Per Day	1,850	55.1	1,850	55.1	1,850	56.1	2,200	72.7	2,200	80.7
	PM Peak	185	3.9	185	3.9	185	4.9	220	4.6	220	6.6
Toteff Road/ Port Road in Kalama (092446J)	Per Day	1,200	55.1	1,200	55.1	1,200	56.1	1,450	72.7	1,450	80.7
	PM Peak	120	3.9	120	3.9	120	4.9	145	4.6	145	6.6
W Scott Avenue in Woodland (092437K)	Per Day	2,650	55.1	2,650	55.1	2,650	56.1	3,100	72.7	3,100	80.7
	PM Peak	265	3.9	265	3.9	265	4.9	310	4.6	310	6.6
Davidson Avenue in Woodland (092435W)	Per Day	2,000	55.1	2,000	55.1	2,000	56.1	2,350	72.7	2,350	80.7
	PM Peak	200	4	200	3.9	200	4.9	235	4.6	235	6.6
Whalen Road in Woodland (092434P)	Per Day	1,550	55.1	1,550	55.1	1,550	56.1	1,800	72.7	1,800	80.7
	PM Peak	155	3.9	155	3.9	155	4.9	180	4.6	180	6.6

The data also indicated that the PM peak hour represents approximately 10% of the daily traffic volumes at these locations. This factor was used to covert count data from peak hour to ADT or vice versa.

PM peak hour vehicle turn movement counts were conducted at the eight study intersections along the Reynolds Lead and BNSF Spur during the weekday evening peak period (4 to 6 p.m.).[5] These collected counts were also used for the eight adjacent study crossings. PM peak hour vehicle turn movement counts at five of the study crossings along the BNSF main line in Cowlitz County were obtained from recent studies (Washington State Department of Transportation 2014c; DKS Associates 2013). Where recent traffic count data were unavailable (at the Taylor Crane Road, Cowlitz Street, Cowlitz Gardens Road, and Whalen Road study crossings), average daily traffic volumes were obtained from the FRA or WUTC databases (as a conservative approach, the database with the higher volume was used for each study crossing), and converted to PM peak hour with the 10% factor.

Future traffic volumes for the analysis years included a combination of background traffic, as well as growth associated with the Proposed Action as discussed in Section 2.1.2.2, *Construction Impact Analysis,* and Section 2.1.2.3, *Operations Impact Analysis*. Background traffic was estimated by developing a linear growth rate between existing and forecast traffic volumes at study intersections and crossings along the Reynolds Lead and BNSF Spur in the immediate area (Cowlitz-Wahkiakum Council of Governments 2014). The derived growth rates were applied to the collected count data to develop 2018 No-Action scenario traffic volumes and to the 2018 No-Action scenario traffic volumes for 10 years to develop year 2028 No-Action scenario traffic volumes. At study crossings along the BNSF main line in Cowlitz County where forecast traffic volumes are unavailable, these data suggest that traffic volumes are forecast to increase at a rate of 2% annually. For comparison purposes, a 2% annual growth rate was applied to expand older count data to reflect baseline traffic conditions in the *SR 432 Highway Improvements and Rail Realignment Study* (Cowlitz-Wahkiakum Council of Governments 2014). Therefore, at study crossings along the BNSF main line in Cowlitz County the 2% annual growth rate was applied to the collected count data to develop 2018 and 2028 No-Action scenario traffic volumes.

Trains

Estimated freight train volume and operational information for the No-Action scenario along the Reynolds Lead and BNSF Spur was provided by LVSW (Wolter pers. comm.). Freight train volumes along the BNSF main line for the No-Action scenario were extrapolated linearly from the WSDOT Rail Plan, and evenly distributed throughout the day (daily freight train volume per 24 hours). Passenger rail volumes were from existing Amtrak schedules (10 trains per day, including 8 Cascades trains, and 2 Coast Starlight trains), with 2 trains passing during the PM peak hour (1 Cascades train, and 1 Coast Starlight train per existing schedules). No increase in passenger rail service was assumed in the future. Unlike passenger trains, freight trains do not run on a schedule. Railroad companies evaluate each situation and dispatch trains based on a number of criteria, including available crew, number of cars, cost of fuel, and overall revenue. Analysis and projection of rail impact operations requires analyzing the rail traffic and developing typical operations. To analyze the highest potential vehicle delay impacts that could occur related to the Proposed Action, an analysis of vehicle delay during the PM peak traffic hour was completed.

[5] Based on traffic counts conducted on Tuesday, November 15, 2016.

An average of 2 non-Proposed Action-related trains per day would be expected over study crossings on the Reynolds Lead, and 7 at the Dike Road study crossing (along the BNSF Spur) under the 2018 No-Action and 2018 Construction (truck delivery) scenarios. One non-Proposed Action-related train could travel along the BNSF Spur and Reynolds Lead during the PM peak hour. The BNSF main line would have around 55 non-Proposed Action-related trains per day by 2018. It was assumed that 4 non-Proposed Action-related trains would travel during the PM peak hour.

The 2018 Construction (rail delivery) scenario would add an average of 1.3 train trips per day, as documented in Section 2.1.2.2, *Construction Impact Analysis*. It was assumed that this train could travel during the PM peak hour.

The 2028 No-Action scenario would include approximately 2 additional non-Proposed Action-related trains per day on the Reynolds Lead, as documented in Section 2.1.2.1, *No-Action Alternative Analysis.* Overall, approximately 4 trains per day would be expected along the Reynolds Lead, and approximately 7 at the Dike Road study crossing (along the BNSF Spur) in the 2028 No-Action scenario. One non-Proposed Action-related train could travel along the BNSF Spur and Reynolds Lead during the PM peak hour. The BNSF main line would include approximately 18 additional non-Proposed Action-related trains per day in the 2028 No-Action scenario, with 73 non-Proposed Action-related trains expected per day in the 2028 No-Action scenario. It was assumed that 5 non-Proposed Action-related trains would travel during the PM peak hour.

The Proposed Action would add approximately 16 additional trains per day, as documented in Section 2.1.2.3, *Operations Impact Analysis*. Up to 2 Proposed Action-related trains could travel along the Reynolds Lead, BNSF Spur, and BNSF main line with planned track infrastructure during the PM peak hour. Table 2 includes the daily and PM peak train crossings for 2018 and 2028.

2.1.2.7 Railroad Crossing Performance Measures

The following performance measures were used to identify impacts at the railroad crossings.

Level of Service

A vehicle level of service (LOS) impact was defined as a study crossing or upstream intersection that operates below LOS D under the Proposed Action that would not otherwise operate below LOS D under the No-Action scenario for the same year. LOS represents a "report card" rating (A through F) based on the delay experienced by vehicles at an intersection, or in this case, a railroad crossing, as shown in Table 3. LOS A, B, and C indicate conditions where traffic moves without substantial delays. LOS D and E represent progressively worse operating conditions. LOS F represents conditions where average vehicle delay has become excessive and demand has exceeded capacity.

Table 3. Grade Crossing Level of Service

Level of Service (LOS)	Average Total Delay (seconds/vehicle)
A	<= 10
B	> 10 and <= 20
C	> 20 and <= 35
D	> 35 and <= 55
E	> 55 and <= 80
F	> 80

Notes:
Source: Transportation Resource Board 2000:Exhibit 16-2

The Cities of Kelso (2015), Longview, Woodland (2005), and the WSDOT (2010) use a peak hour standard of LOS D or better. The transportation element of the *City of Longview Comprehensive Plan* (December 2006) defines a capacity deficiency on arterial segments as a volume-to-capacity ratio of 0.85 or higher (representing a generalized LOS D or worse). As a conservative approach, the LOS D average delay for all vehicles equal to or less than 55 seconds was applied as a standard to all of the at-grade railroad crossings and upstream intersections, regardless of the street functional classification or jurisdiction.

For the PM peak hour analysis, traffic operating conditions at study crossings were determined based on the *2000 Highway Capacity Manual* (Transportation Research Board 2000) methodology for signalized intersections (the railroad crossings were assumed to be pre-timed traffic signals). The conditions reported include the estimated average vehicle delay, and LOS of the roadway approaches to the study crossings. Available signal timing information for the intersections adjacent to the rail crossings were incorporated into this analysis. For the 24-hour analysis, similar delay thresholds, based on the LOS definitions found in the *2000 Highway Capacity Manual* methodology for signalized intersections, were used to assess the average delay experienced per vehicle at each rail crossing. The average delay per vehicle in a 24-hour period (in seconds) for a rail crossing was determined based on the average number of daily trains, average train length, train speed, and average daily traffic volumes in both directions.

For the study intersections, traffic-operating conditions for the PM peak hour were determined based on the *2010 Highway Capacity Manual* (Transportation Research Board 2010) method for signalized and unsignalized intersections. At signalized locations, the LOS and delay are reported as the intersection average and as the worst stop controlled approach at unsignalized locations.

Queue

A vehicle queuing impact was defined as a queue extending from a study crossing or upstream intersection that exceeds available storage length (to the nearest intersection) under the Proposed Action that would not otherwise exceed the available storage under the No-Action scenario from the same year. The available storage along the roadways approaching the study crossings and at nearby intersections is shown in Table 4.

Queuing analysis was conducted using SimTraffic 8, which estimates the 95th percentile vehicle queue lengths, or the queue length that would not be exceeded in 95% of the queues formed during the PM peak hour.[6]

Accident Probability

Vehicle safety at the study crossings in Cowlitz County and statewide crossings was analyzed by estimating future accident frequency and the corresponding predicted interval between accidents with and without the addition of proposed action rail traffic. The FRA GradeDec.Net model was used to analyze the crossings (Federal Railroad Administration 2016). This model accounts for accident history and frequency of trains at existing at-grade crossings, volume of vehicle traffic, existing safety devices at the at-grade crossings, and other factors to determine the potential impacts of an increase in rail traffic. Other physical factors that affect the frequency of collisions at a crossing, such as available sight distance, approach grade, or vehicle storage between adjacent intersections, are not captured in this model. This analysis provides a frame of reference for crossings by estimating accident probability, but does not identify these crossings as safe or unsafe. The Railroad-Highway Grade Crossing Handbook–Revised Second Edition (Federal Highway Administration 2007) indicates that active devices with automatic gates or grade separation should be considered as options when certain criteria are met. One criterion is if the expected accident frequency, as calculated by the USDOT Accident Prediction formula, exceeds 0.075 for active devices with automatic gates and 0.50 for grade separation. For the purpose of this analysis, a vehicle safety impact was defined as a study crossing that would have an expected accident frequency of more than 0.075 accidents per year under the Proposed Action that would be at or fewer than 0.075 accidents under the No-Action scenario.

[6] SimTraffic 8 was unable to be fully calibrated and verified based on field conditions because no trains were observed crossing during the PM peak hour. However, estimated queues were verified based on the relationship between observed queues during nonpeak conditions, and traffic volumes at that time. This relationship was compared to PM peak hour traffic volumes to help verify the estimated baseline queue lengths.

Table 4. Estimated Vehicle Storage Lengths

Crossing Name (USDOT Crossing ID)	Roadway Movement	Available Storage before Impacting nearby Intersection (feet)	Intersection Affected by Queue from Crossing	Intersection Movement	Available Storage (feet)
Project area access at 38th Avenue	NB	>1,000 (private driveway)	Industrial Way/ 38th Avenue	WBL	180
	SB	<20		EBR	180
Weyerhaeuser access at Washington Way	NB	>1,000 (private driveway)	Industrial Way/ Washington Way	WBL	180
				EBR	20
	SB	<20		SBT	150
Weyerhaeuser NORPAC access	NB	>1,000 (private driveway)	Industrial Way/ NORPAC access	WBL	80
	SB	<20		EBR	200
Industrial Way-SR 432 (101806G)	NB	120	Industrial Way/ Weyerhaeuser	EBL	>1,000 (private driveway)
	SB	>1,000		NBT	730
Oregon Way-SR 433 (101805A)	NB	220	Industrial Way/ Oregon Way	NBT	>1,000
				EBL	85
				WBR	0
	SB	700	Oregon Way/ Alabama Street	EBR	N/A
				WBL	
				SBT	
California Way (101821J)	NB	400	Industrial Way/ California Way	N/A	N/A
	SB	>1,000			
3rd Avenue-SR 432 (101826T)	NB	400	3rd Avenue/ Industrial Way	WBR	170
				NBT	240
			Industrial Way/ California Way	SBL	140
	SB	>1,000		NBR	100
				EBT	>1,000
Dike Road (101791U)	NB	>1,000	None	N/A	N/A
	SB	200			

Crossing Name (USDOT Crossing ID)	Roadway Movement	Available Storage before Impacting nearby Intersection (feet)	Intersection Affected by Queue from Crossing	Intersection Movement	Available Storage (feet)
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County					
Taylor Crane Road in Castle Rock (092481X)	EB	300	None	N/A	N/A
	WB	50			
Cowlitz Street in Castle Rock (092476B)	EB	440	None	N/A	N/A
	WB	260			
Cowlitz Gardens Road in Kelso (092466V)	EB	50	None	N/A	N/A
	WB	50			
Mill Street in Kelso (092458D)	EB	>1,000	None	N/A	N/A
	WB	250			
S River Road in Kelso (092457W)	EB	120	Pacific Avenue/ S River Road	SBR	0
	WB	60		NBL	0
Toteff Road/ Port Road in Kalama (092446J)	EB	>1,000	None	N/A	N/A
	WB	900			
W Scott Avenue in Woodland (092437K)	EB	580	None	N/A	N/A
	WB	720			
Davidson Avenue in Woodland (092435W)	EB	120	None	N/A	N/A
	WB	330			
Whalen Road in Woodland (092434P)	EB	180	None	N/A	N/A
	WB	800			

Notes:
USDOT = U.S. Department of Transportation; NB = northbound; SB = southbound; EB = eastbound; WB = westbound; WBT= westbound through; EBR= eastbound right; SBT = southbound through; EBL= eastbound left; NBT = northbound through; SBL = southbound left; NBR = northbound right; EBT= eastbound through; N/A = not applicable

2.2 Existing Conditions

The existing environmental conditions related to vehicle transportation in the study area are described below.

Table 5 provides vehicle and train traffic information at the five public at-grade crossings on the Reynolds Lead and BNSF Spur, and three private crossings on the Reynolds Lead, including the entrance to the project area and the traffic associated with these crossings. Table 5 also presents information for vehicle and train traffic at all nine public at-grade crossings on the BNSF main line in Cowlitz County that would be used by Proposed Action-related train traffic to and from the project area. Relevant roadway characteristics also are listed, including roadway functional classifications and number of lanes at the crossing. Information on at-grade crossing and roadway performance is presented in Chapter 3, *Impacts*.

Ten years of collision records (2003 to 2013) for the at-grade railroad crossings along the BNSF main line, Reynolds Lead, and BNSF Spur in Cowlitz County were obtained from FRA and WSDOT databases. The data identified one collision involving a train near the project area, at the Washington Way crossing, just south of the Industrial Way intersection. The crossing is ungated, and located less than 50 feet from Industrial Way. The collision involved a vehicle stopped at the traffic signal, beyond the stop bar and on the track and being struck by a train. The collision resulted in property damage only.

A collision involving a train also occurred at the Cowlitz Gardens Road crossing on the BNSF main line. This crossing is gated and fewer than 75 feet from Pacific Avenue. The collision involved an inoperable vehicle stopped on the tracks and being struck by a train. The collision resulted in property damage only.

2.2.1 Emergency Services

The Cowlitz 2 Fire & Rescue District, the Longview Fire Department, and American Medical Response (AMR) provide emergency medical services (EMS) and fire protection for the project area. Figure 5 illustrates the location of fire stations near the project area.

Cowlitz 2 Fire & Rescue

Cowlitz 2 Fire & Rescue serves approximately 34,000 citizens in the City of Kelso and unincorporated Cowlitz County and responds to approximately 4,100 calls per year (Cowlitz 2 Fire & Rescue 2015). The district is staffed by approximately 120 full-time and volunteer members in five active fire stations, two of which are staffed with full-time emergency medical technicians (EMTs) and paramedic firefighters. Volunteer firefighter EMTs also respond on an on-call basis.

Table 5. At-Grade Crossing and Roadway Characteristics

	Roadway			Railroad (Trains)		
Crossing Name (USDOT Crossing ID)	**2018 ADT**	**Functional Classification[a]**	**Lanes**	**Protection[b]**	**2018 Crossings per day**	**Average Speed (mph)[c]**
Study Crossings along the Reynolds Lead and BNSF Spur						
Project area access at 38th Avenue	400	Private	2	None	2.3	5 (freight)
Weyerhaeuser access at Washington Way	3,200	Private	4	None	2.3	8 (freight)
Weyerhaeuser NORPAC access	700	Private	2	None	2.3	10 (freight)
Industrial Way- SR 432 (101806G)	9,600	Principal Arterial	2	Overhead Lights	2.3	10 (freight)
Oregon Way- SR 433 (101805A)	13,400	Principal Arterial	4	Gates/ Overhead Lights	2.3	10 (freight)
California Way (101821J)	3,750	Minor Arterial	2	Overhead Lights	2.3	8 (freight)
3rd Avenue- SR 432 (101826T)	16,300	Principal Arterial	4	Gates/ Overhead Lights	2.3	8 (freight)
Dike Road (101791U)	400	Local	2	Overhead Lights	7.1	10 (freight)
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County						
Taylor Crane Road in Castle Rock (092481X)	50	Local	2	None	55.1	50 (freight); 50 (passenger)
Cowlitz Street in Castle Rock (092476B)	1,200	Minor Collector	2	Gates/ Overhead Lights	55.1	50 (freight); 50 (passenger)
Cowlitz Gardens Road in Kelso (092466V)	700	Local	2	Gates	55.1	60 (freight); 75 (passenger)
Mill Street in Kelso (092458D)	2,550	Local	2	Gates	55.1	40 (freight); 40 (passenger)
S River Road in Kelso (092457W)	1,850	Local	2	Gates	55.1	40 (freight); 40 (passenger)
Toteff Road/ Port Road in Kalama (092446J)	1,200	Local	2	Gates/ Overhead Lights	55.1	60 (freight); 79 (passenger)
W Scott Avenue in Woodland (092437K)	2,650	Minor Arterial	2	Gates	55.1	60 (freight); 75 (passenger)

Crossing Name (USDOT Crossing ID)	Roadway				Railroad (Trains)	
	2018 ADT	Functional Classification[a]	Lanes	Protection[b]	2018 Crossings per day	Average Speed (mph)[c]
Davidson Avenue in Woodland (092435W)	2,000	Minor Arterial	2	Gates	55.1	60 (freight); 75 (passenger)
Whalen Road in Woodland (092434P)	1,550	Minor Arterial	2	Gates	55.1	60 (freight); 75 (passenger)

Notes:

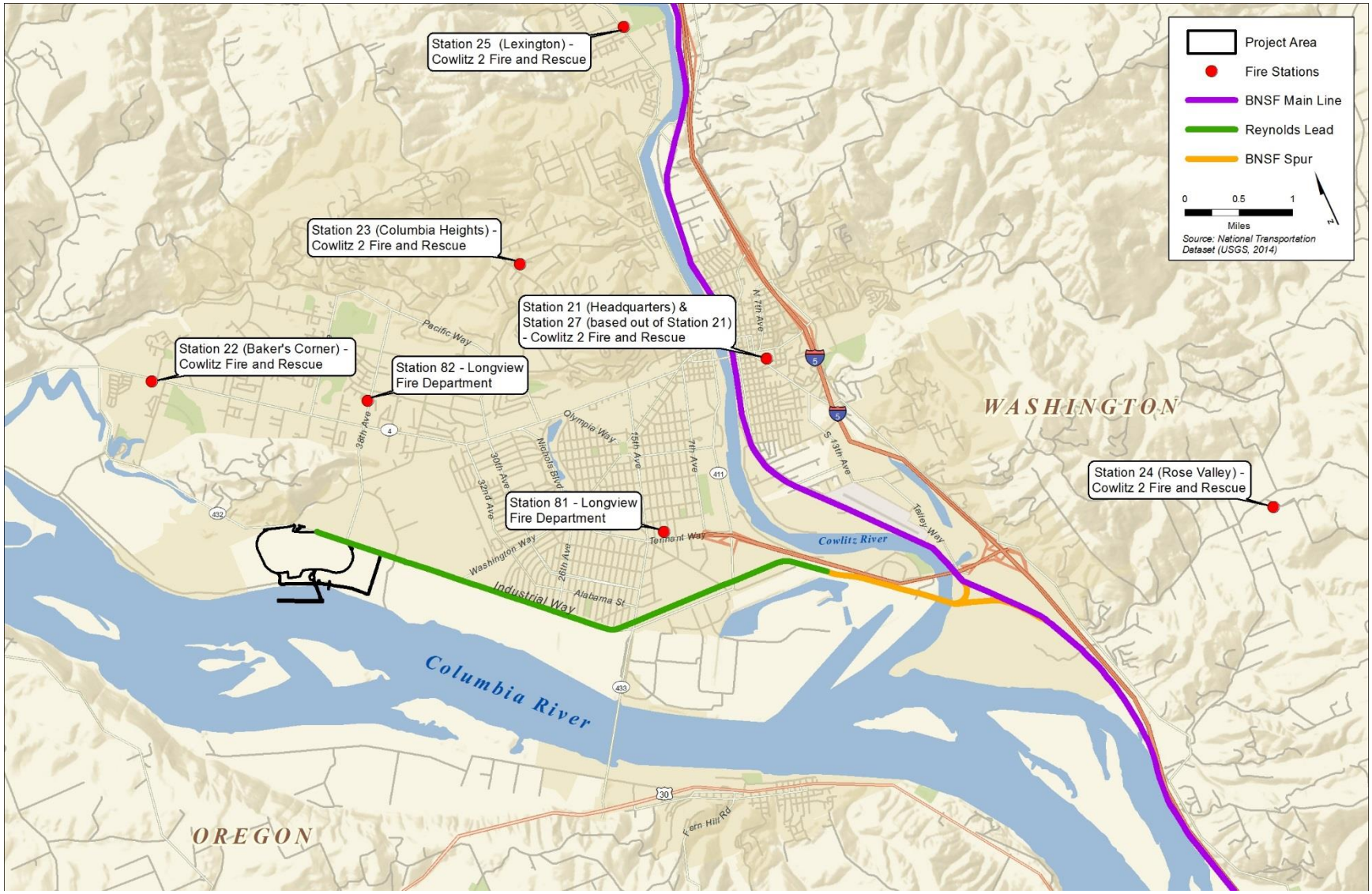
[a] Source: City of Longview 2015; City of Kelso 2006; City of Castle Rock 2006; City of Woodland 2005

[b] Source: Field observations

[c] Source: SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017) and Washington Utilities and Transportation Commission 2015.

ADT = average daily traffic; mph = miles per hour

Figure 5. Fire Stations in the Kelso-Longview Area



The district includes the following stations and equipment.

- Station 21 (Headquarters for Cowlitz 2 Fire & Rescue) is staffed with 27 full-time personnel and includes a main response fire engine, a volunteer/reserve-ready fire engine, an advanced life support ambulance, and a reserve-ready advanced life support ambulance. This station includes three rotating shifts 24 hours a day, 7 days a week, 365 days a year. During each shift, at least eight personnel staff a variety of equipment.
- Station 22 (Baker's Corner) is a volunteer station and includes a main response fire engine, a 3,000-gallon water supply, an EMS/wildland response vehicle, and an EMS response ambulance. This all-volunteer station serves as crucial first response before additional help arrives.
- Station 23 (Columbia Heights) is staffed full time by firefighter/EMT, firefighter/paramedic, and volunteer personnel and includes a main response fire engine, an EMS/wildland response vehicle, an advanced life support ambulance, a basic life support ambulance, and a hazardous materials response apparatus.
- Station 24 (Rose Valley) is a volunteer station and includes a main response fire engine and an EMS/wildland response vehicle. This all-volunteer station serves as crucial first response before additional help arrives.
- Station 25 (Lexington) Station 25 is a volunteer station and includes an initial response fire engine, a 2,000-gallon water supply, and an EMS/wildland response vehicle. This all-volunteer station serves as crucial first response before additional help arrives.
- Station 27 (Kelso) is a volunteer station and includes a main response fire engine and a 3,000-gallon water supply. This all-volunteer station backs up personnel at Station 21 (Headquarters) when they are on calls.

Longview Fire Department

The Longview Fire Department serves approximately 36,000 citizens spread over 14.7 square miles of urban/suburban development. The department is staffed with 39 full-time EMT/firefighters, and four paramedic/firefighters. Paramedic transport service is provided within the City of Longview by AMR, a private provider. The Longview Fire Department responds to approximately 4,500 calls per year from two fire stations (City of Longview 2015). The department includes the following stations and equipment.

- Station 81 is located at 740 Commerce Avenue in Longview. A minimum of six line firefighters and one battalion chief are on duty 24 hours a day. The station includes an aerial ladder truck and a fire engine.
- Station 82 is located at 2355 38th Avenue in Longview. This station has a minimum of three line firefighters on duty 24 hours a day, with a maximum of five firefighters. The station primarily responds to the west end of Longview; however, it responds as backup to Station 81, as needed. The station includes one fire engine.

American Medical Response

AMR is a private ambulance company that provides emergency and nonemergency medical transport service for the project area. AMR includes approximately 35 paramedics and EMTs, and handles an average of 7,500 calls annually (American Medical Response 2015). The medical transport vehicles are based out of the facility near the Cowlitz Highway intersection with Long Avenue.

2.2.2 Washington State

As described in Section 2.1.2.3, *Operations Impact Analysis*, Proposed Action-related BNSF trains from the Powder River Basin would cross Washington State from east of Spokane (Washington State–Idaho border) to the project area in Cowlitz County via Pasco, the Columbia River Gorge, and Vancouver. Empty Proposed Action-related trains area expected to return via Stampede Pass, Pasco, and Spokane. WSDOT provided a list of statewide crossings of interest during the project's SEPA scoping process for crossings along the proposed rail routes. These study crossings are at-grade state highway crossings or at-grade crossings near state highways. Table 6 summarizes the existing conditions at these study crossings, including existing estimated annual average daily traffic (AADT), freight and passenger train speed at the crossings, and estimated number of trains per day.[7]

[7] The geographic locations of these crossings are illustrated in Chapter 3, *Impacts,* Figure 6.

Table 6. Existing Conditions at Selected Study Crossings Outside of Cowlitz County

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Railroad Milepost[b]	Estimated 2015 AADT[c]	Estimated Freight Train Speed (mph)[b]	Estimated Passenger Train Speed (mph)[b]	Estimated 2015 Trains per Day[d]
Spokane County							
1	Idaho Road	066236B	53.4	2,650	60	70	70
2	McKinzey Road	066239W	56.2	2,600	60	79	70
3	Harvard Road	066240R	56.8	8,400	60	79	70
4	Barker Road	066244T	58.9	13,900	60	79	70
5	Flora Road	066245A	59.9	6,600	60	79	70
6	Pines Road-SR 27	066367E	62.9	29,700	60	79	70
7	University Road	066371U	64.0	2,450	60	79	70
8	Park Road	066377K	66.1	16,400	60	79	70
9	Pine Street	066315M	15.8	750	35	35	39
10	F Street/Cheney-Spangle	065970L	16.4	3,650	35	35	39
11	Cheney-Plaza Road	065971T	16.8	1,050	35	35	39
Adams County							
12	Paha Packard Road	089665U	74.2	100	60	79	39
13	Kahlotus Road	089670R	80.6	300	60	79	39
14	1st Street	089672E	81.8	500	50	60	39
15	Wilbur/City Road	089673L	82.1	550	50	60	39
Franklin County							
16	Eltopia Road W	089699N	129.1	350	60	79	39
17	Sagemoor Road	089700F	134.2	450	60	79	39
Benton County							
18	East 3rd Avenue	090031U	229.2	2,800	35	35	34
19	Dague Road-East 25th Avenue	090035W	227.5	800	60	60	34
20	Perkins Road	090036D	226.4	700	60	60	34
21	Bowles Road	090038S	225.7	2,450	60	60	34

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Railroad Milepost[b]	Estimated 2015 AADT[c]	Estimated Freight Train Speed (mph)[b]	Estimated Passenger Train Speed (mph)[b]	Estimated 2015 Trains per Day[d]
22	Cochran Road	090039Y	225.0	100	60	60	34
23	Finley Road	090040T	224.5	3,100	60	60	34
24	Whitcomb Island	090061L	171.9	50	60	60	34
Klickitat County							
25	Maple Street	090169V	75.7	850	45	45	34
26	Walnut Street	090168N	75.5	1,400	45	45	34
27	South Dock Grade Road	090164L	74.2	100	55	60	34
Skamania County							
28	Indian Crossing	090159P	65.9	100	55	60	34
29	Home Valley Park	090155M	59.6	50	55	60	34
30	Cemetery Xing	090151K	54.7	50	N/A	N/A	34
31	Russell Avenue	090148C	53.9	350	20	20	34
32	Skamania Landing/Butler Road	090135B	43.3	100	60	60	34
33	Walker/Skamania Landing	090134U	42.6	150	60	60	34
34	St Cloud Road	090133M	39.7	N/A	N/A	N/A	34
Lewis County							
35	SR 506-7th Street	092484T	77.8	1,400	50	75	50
36	Walnut Street – SR 505/603	092493S	71.6	2,850	50	50	50
37	E Locust Street	092519S	54.2	2,800	40	40	50
38	Main Street	092520L	54.1	2,650	40	40	50
39	Maple Street	092521T	53.8	3,500	40	40	50
40	Big Hanaford Road	092524N	51.8	2,550	10	N/A	50

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Railroad Milepost[b]	Estimated 2015 AADT[c]	Estimated Freight Train Speed (mph)[b]	Estimated Passenger Train Speed (mph)[b]	Estimated 2015 Trains per Day[d]
Yakima County							
41	Jones Road East	099178A	79.4	1,600	55	40	7
42	Indian Church	104523U	63.8	2,450	55	40	7
43	SR241/Reservation	104534G	52.2	2,850	55	40	7
44	Gulden Road	104536V	51.1	300	55	40	7

Notes:

[a] See Chapter 3, *Impacts,* Figure 6, for crossing location.

[b] Source: Washington Utilities Transportation Commission 2015.

[c] Source: Washington Utilities Transportation Commission 2015; Federal Railroad Administration 2015. The data source with the most recent AADT was used and a 2% growth rate was applied to adjust to 2015.

[d] Washington State Department of Transportation 2014b. Linear extrapolation of 2010 and 2035 projected train traffic to 2015 volumes.

USDOT = U.S. Department of Transportation; FRA = Federal Railroad Administration; AADT = annual average daily traffic; mph = miles per hour; N/A = data not available

Chapter 3
Impacts

This chapter describes the impacts on vehicle transportation that would result from construction and operation of the Proposed Action and the No-Action Alternative.

As described previously, railroad companies evaluate each situation and dispatch trains based on various criteria. The analysis analyzes a 24-hour average delay to illustrate the delay for the average vehicle. To analyze the highest potential vehicle delay impacts that could occur related to the Proposed Action, an analysis of vehicle delay during the PM peak traffic hour was completed. The PM peak hour analysis assumes Proposed Action-related trains would pass during the peak hour, and represents a worst-case analysis and a scenario that would likely not occur daily. See Appendix A, *Vehicle Transportation Technical Data*, for the analysis data.

3.1 Proposed Action

Potential impacts on vehicle transportation from the Proposed Action are described below.

3.1.1 Construction: Direct and Indirect Impacts

An estimated 180 PM peak hour motor vehicle trips are estimated as a result of peak construction activities with the rail construction scenario, or an estimated 260 PM peak hour motor vehicle trips with the truck or barge construction scenario. These vehicles would access the project area via the private driveway opposite 38th Avenue or a new driveway on Industrial Way. Parking would be provided for construction workers in the Applicant's leased area. All vehicle transportation impacts during construction would occur outside the project area and, therefore, would be considered indirect impacts. Construction of the Proposed Action would result in the following indirect impacts.

Cause Vehicle Delays from Rail Construction Traffic

An average of 2 non-Proposed Action-related trains per day would be expected over study crossings on the Reynolds Lead, and 7 at the Dike Road study crossing (along the BNSF Spur) in the 2018 No-Action and 2018 Construction (truck delivery) scenarios. One non-Proposed Action-related train could pass during the PM peak hour. The weighted average length of these trains would be approximately 2,000 feet along the Reynolds Lead, and 5,000 feet along the BNSF Spur. The BNSF main line would have around 55 non-Proposed Action-related trains per day by 2018, with a weighted average length of more than 5,100 feet. It is assumed that 4 non-Proposed Action-related trains could pass during the PM peak hour. Table 7 shows the anticipated weighted average train lengths and total gate downtime at the study crossings for 2018.

Table 7. Study Crossing Characteristics—2018 Construction Scenario

Crossing Name (USDOT Crossing ID)	Time Period	2018 No-Action		2018 Proposed Action (Truck Delivery)		2018 Proposed Action (Rail Delivery)	
		Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)
Study Crossings along the Reynolds Lead and BNSF Spur							
Project area access at 38th Avenue	Per Day	2,024	11.6	2,024	11.6	3,530	30.3
	PM Peak		5.1		5.1	6,219	14.6
Weyerhaeuser access at Washington Way	Per Day	2,024	7.7	2,024	7.7	3,530	19.6
	PM Peak		3.4		3.4	6,219	9.3
Weyerhaeuser NORPAC access	Per Day	2,024	6.4	2,024	6.4	3,530	16.0
	PM Peak		2.8		2.8	6,219	7.6
Industrial Way-SR 432 (101806G)	Per Day	2,024	6.4	2,024	6.4	3,530	16.0
	PM Peak		2.8		2.8	6,219	7.6
Oregon Way-SR 433 (101805A)	Per Day	2,024	6.4	2,024	6.4	3,530	16.0
	PM Peak		2.8		2.8	6,219	7.6
California Way (101821J)	Per Day	2,041	7.8	2,041	7.8	3,541	19.7
	PM Peak		3.4		3.4	6,219	9.3
3rd Avenue-SR 432 (101826T)	Per Day	2,041	7.8	2,041	7.8	3,541	19.7
	PM Peak		3.4		3.4	6,219	9.3
Dike Road (101791U)	Per Day	4,919	43.4	4,919	43.4	5,116	53.0
	PM Peak		6.1		6.1	6,219	7.6
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County							
Taylor Crane Road in Castle Rock (092481X)	Per Day	5,160	92.2	5,160	92.2	5,178	94.1
	PM Peak	3,425	5.0	3,425	5.0	3,995	6.9
Cowlitz Street in Castle Rock (092476B)	Per Day	5,160	92.2	5,160	92.2	5,178	94.1
	PM Peak	3,425	5.0	3,425	5.0	3,995	6.9
Cowlitz Gardens Road in Kelso (092466V)	Per Day	5,160	79.1	5,160	79.1	5,178	80.7
	PM Peak	3,425	4.4	3,425	4.4	3,995	6.1

Crossing Name (USDOT Crossing ID)	Time Period	2018 No-Action		2018 Proposed Action (Truck Delivery)		2018 Proposed Action (Rail Delivery)	
		Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)
Mill Street in Kelso (092458D)	Per Day	5,160	108.3	5,160	108.3	5,178	110.6
	PM Peak	3,425	5.7	3,425	5.7	3,995	8.0
S River Road in Kelso (092457W)	Per Day	5,160	108.3	5,160	108.3	5,178	110.6
	PM Peak	3,425	5.7	3,425	5.7	3,995	8.0
Toteff Road/ Port Road in Kalama (092446J)	Per Day	5,160	78.5	5,160	78.5	5,178	80.1
	PM Peak	3,425	4.4	3,425	4.4	3,995	6.1
W Scott Avenue in Woodland (092437K)	Per Day	5,160	79.1	5,160	79.1	5,178	80.7
	PM Peak	3,425	4.4	3,425	4.4	3,995	6.1
Davidson Avenue in Woodland (092435W)	Per Day	5,160	79.1	5,160	79.1	5,178	80.7
	PM Peak	3,425	4.4	3,425	4.4	3,995	6.1
Whalen Road in Woodland (092434P)	Per Day	5,160	79.1	5,160	79.1	5,178	80.7
	PM Peak	3,425	4.4	3,425	4.4	3,995	6.1

Total gate downtime would be up to 8 minutes per day (3 minutes during the PM peak hour) at public crossings along the Reynolds Lead, 12 minutes per day (5 minutes during the PM peak hour) at private crossings along the Reynolds Lead, 43 minutes per day (6 minutes during the PM peak hour) at the Dike Road crossing along the BNSF Spur, and up to 108 minutes per day (6 minutes during the PM peak hour) along the BNSF main line in the 2018 No-Action and 2018 Construction (truck delivery) scenarios.

The 2018 Construction (rail delivery) scenario would add approximately 1 additional train per day, as documented in Section 2.1.2.2, *Construction Impact Analysis*. This train could pass during the PM peak hour. The additional train would take between 8 and 9 minutes to pass through the public street study crossings along the Reynolds Lead and BNSF Spur, and around 2 minutes to pass through the study crossings along the BNSF main line. This would increase the total gate downtime up to 12 minutes during an average day for the public study crossings along the Reynolds Lead, up to 19 minutes during an average day for the private study crossings along the Reynolds Lead, and up to 2 minutes during an average day along the BNSF main line during the first year of construction of the Proposed Action.

Table 8 shows the estimated average delay per vehicle and LOS that would be experienced during the PM peak hour at each of the study crossings and upstream intersections for the 2018 Construction scenario for preload material delivery by truck or by rail, with the estimated 2018 No-Action scenario conditions provided for reference.

As shown, construction activities would not result in any material change in vehicle delay at the study crossings on the Reynolds Lead, BNSF Spur, and BNSF main line and upstream materials if preload material is delivered by truck. Should delivery of preload material by rail occur during the PM peak hour, the average delay per vehicle would increase at study crossings, with forecast LOS dropping below LOS D at three of the at-grade crossings on the Reynolds Lead. The length of the construction preload material train, estimated at 6,219 feet, and the slow track speeds at the California Way, 3rd Avenue (SR 432) and project area access (opposite 38th Avenue) study crossings (between 5 and 8 mph), would contribute to the vehicle LOS impacts. No vehicle LOS impacts are forecast at study crossings along the BNSF main line.

Table 9 shows the estimated average delay per vehicle and LOS that would be experienced during a 24-hour period at each of the study crossings in 2018. As shown, the average delay per vehicle expected over a 24-hour period is very low under each of the 2018 scenarios, illustrating that most drivers over the course of a day would not be delayed by a train at the study crossings. However, if a train crosses during the PM peak hour, it could cause substantial delay to drivers, as indicated in Table 8.

Table 8. Estimated Vehicle Delay and LOS—2018 Construction Scenario (PM Peak Hour)

USDOT Crossing ID	Study Crossing/Intersection Name	2018 No-Action		2018 Proposed Action (Truck Delivery)		2018 Proposed Action (Rail Delivery)	
		Delay (seconds)	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS[a]
Study Crossings along the Reynolds Lead and BNSF Spur*							
Private	Project area access at 38th Avenue	15.0	B	15.7	B	126.7	**F**
Private	Weyerhaeuser access at Washington Way	6.9	A	6.9	A	51.9	D
Private	Weyerhaeuser NORPAC access	4.8	A	4.8	A	38.0	D
101806G	Industrial Way (SR 432)	7.4	A	7.8	A	49.8	D
101805A	Oregon Way (SR 433)	6.1	A	6.2	A	43.3	D
101821J	California Way	7.5	A	7.5	A	56.1	**E**
101826T	3rd Avenue (SR 432)	10.4	B	10.8	B	78.2	**E**
101791U	Dike Road	21.8	C	21.8	C	32.9	C
Study Intersection adjacent to the Reynolds Lead and BNSF Spur**							
N/A	Industrial Way/ 38th Avenue	9.7	A	13.3	B	12.2	B
N/A	Industrial Way/ Washington Way	15.1	B	16.4	B	16.0	B
N/A	Industrial Way/ NORPAC access	15.3	C	19.1	C	17.5	C
N/A	Industrial Way/ Weyerhaeuser access	16.1	C	20.5	C	18.7	C
N/A	Industrial Way/ Oregon Way	34.0	C	39.3	D	37.0	D
N/A	Industrial Way/ California Way	22.6	C	22.4	C	22.3	C
N/A	3rd Avenue/ Industrial Way	18.2	B	17.6	B	17.2	B
N/A	Dike Road/ Frontage Road	8.9	A	8.9	A	8.9	A
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County*							
092481X	Taylor Crane Road (Castle Rock)	7.3	A	7.3	A	20.6	C
092476B	Cowlitz Street (Castle Rock)	7.7	A	7.7	A	21.6	C
092466V	Cowlitz Gardens Road (Kelso)	5.9	A	5.9	A	16.4	B
092458D	Mill Street (Kelso)	10.7	B	10.7	B	31.0	C
092457W	S River Road (Kelso)	10.4	B	10.4	B	30.1	C
092446J	Toteff Road/Port Road (Kalama)	5.9	A	5.9	A	16.8	B

USDOT Crossing ID	Study Crossing/Intersection Name	2018 No-Action Delay (seconds)	2018 No-Action LOS	2018 Proposed Action (Truck Delivery) Delay (seconds)	2018 Proposed Action (Truck Delivery) LOS	2018 Proposed Action (Rail Delivery) Delay (seconds)	2018 Proposed Action (Rail Delivery) LOS[a]
092437K	W Scott Avenue (Woodland)	6.6	A	6.6	A	18.3	B
092435W	Davidson Avenue (Woodland)	6.2	A	6.2	A	17.4	B
092434P	Whalen Road (Woodland)	6.1	A	6.1	A	17.0	B

Notes:

[a] **Bolded**, **shaded gray** values indicate a vehicle LOS impact (a study crossing or intersection that operates below LOS D under the Proposed Action that would not otherwise operate below LOS D under the No-Action scenario from the same year).

*Delay = average delay per vehicle at worst roadway approach to the crossing; LOS = level of service of worst roadway approach to the crossing

**At signalized study intersections, the LOS and delay are reported as the intersection average and as the worst stop controlled approach at un-signalized locations.

Table 9. Estimated Vehicle Delay and LOS—2018 Construction Scenario (24-Hour Average)

		2018 No-Action		2018 Proposed Action (Truck Delivery)		2018 Proposed Action (Rail Delivery)	
USDOT Crossing ID	Study Crossing Name	Delay (seconds)	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS
Study Crossings along the Reynolds Lead and BNSF Spur							
Private	Project area access at 38th Avenue	1.2	A	1.4	A	5.8	A
Private	Weyerhaeuser access at Washington Way	0.6	A	0.6	A	2.4	A
Private	Weyerhaeuser NORPAC access	0.4	A	0.4	A	1.5	A
101806G	Industrial Way (SR 432)	0.4	A	0.4	A	1.8	A
101805A	Oregon Way (SR 433)	0.4	A	0.4	A	1.7	A
101821J	California Way	0.6	A	0.6	A	2.5	A
101826T	3rd Avenue (SR 432)	0.6	A	0.6	A	2.6	A
101791U	Dike Road	5.6	A	5.6	A	7.1	A
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County							
092481X	Taylor Crane Road in Castle Rock	3.2	A	3.2	A	3.3	A
092476B	Cowlitz Street in Castle Rock	3.3	A	3.3	A	3.4	A
092466V	Cowlitz Gardens Road in Kelso	2.4	A	2.4	A	2.5	A
092458D	Mill Street in Kelso	4.8	A	4.8	A	4.9	A
092457W	S River Road in Kelso	4.7	A	4.7	A	4.8	A
092446J	Toteff Road/ Port Road in Kalama	2.4	A	2.4	A	2.5	A
092437K	W Scott Avenue in Woodland	2.5	A	2.5	A	2.6	A
092435W	Davidson Avenue in Woodland	2.5	A	2.5	A	2.5	A
092434P	Whalen Road in Woodland	2.5	A	2.5	A	2.5	A

Notes:
Delay = average delay per vehicle over 24-hour period, in seconds; LOS = level of service of railroad crossing

Table 10 shows the estimated vehicle queue lengths that would be experienced during the PM peak hour at each of the study crossings during construction in 2018 for preload material delivery by truck or by rail, with the estimated 2018 No-Action scenario conditions provided for reference.

As shown, vehicle queues extending from six study crossings (all along the Reynolds Lead) could affect seven nearby intersections with 2018 No-Action scenario trains during the PM peak hour. The affected intersections include Industrial Way/38th Avenue, Industrial Way/Washington Way, Industrial Way/NORPAC access, Industrial Way/Weyerhaeuser Access, Industrial Way/Oregon Way, 3rd Avenue/Industrial Way, and Industrial Way/California Way. Vehicle queues at these intersections could exceed available storage at four approaches, including the eastbound right turn from Industrial Way to the Weyerhaeuser Access (opposite Washington Way), the eastbound left turn and westbound right turn from Industrial Way to Oregon Way, and the northbound through movement at the 3rd Avenue/Industrial Way intersection. These queues could potentially block other movements at these intersections that would otherwise not be affected by train crossing events.

Construction activities would not result in any material change in vehicle queue lengths if preload material is delivered by truck. Should delivery of preload material by rail occur during the PM peak hour, the estimated vehicle queue lengths would increase at rail crossings along high volume roadways, with queues extending nearly 1,000 feet beyond those expected with 2018 No-Action and 2018 Construction (via truck) scenario trains at the Industrial Way (SR 432), Oregon Way (SR 433), and 3rd Avenue (SR 432) study crossings. The length of the construction preload material train, estimated at 6,219 feet, and the slow track speeds at the Industrial Way (SR 432), Oregon Way (SR 433), 3rd Avenue (SR 432) study crossings (between 8 and 10 mph), would contribute to the increased vehicle queue lengths.

Two additional intersections would be affected by vehicle queues extending from rail crossings with 2018 Construction (via rail) scenario trains during the PM peak hour (beyond those affected by 2018 No-Action scenario trains), including Oregon Way/Alabama Street, and Pacific Avenue/S River Road. However, vehicle queues at the nine affected intersections would not exceed available storage at any additional approach beyond those affected by 2018 No-Action scenario trains.

Table 10. Estimated Vehicle Queue Lengths—2018 Construction Scenario (PM Peak Hour)[a]

Study Crossing (USDOT Crossing ID)	Road MVMT[b]	2018 No-Action	2018 Truck	2018 Rail	Upstream Intersection Affected by Queue from Study Crossing	Intersection MVMT[c]	2018 No-Action	2018 Truck	2018 Rail
		Estimated Study Crossing Queue Length (feet)					Estimated Upstream Intersection Queue Length (feet)		
Study Crossings along the Reynolds Lead and BNSF Spur									
Project area access- opposite 38th Avenue	NB	40	1,180	1,640	Industrial Way/ 38th Avenue	WBL	20	80	60
	SB	40	80	60		EBR	20	20	60
Weyerhaeuser access- opposite Washington Way	NB	100	180	500	Industrial Way/ Washington Way	WBL	80	100	120
						EBR	120	160	40
	SB	140	160	120		SBT	40	40	80
Weyerhaeuser NORPAC access	NB	40	40	120	Industrial Way/ NORPAC access	WBL	20	20	20
	SB	20	20	20		EBR	20	20	20
Industrial Way- SR 432 (101806G)	NB	400	400	460	Industrial Way/ Weyerhaeuser	EBL	140	140	240
	SB	280	320	980		NBT	280	280	360
Oregon Way- SR 433 (101805A)	NB	800	1,180	1,760	Industrial Way/ Oregon Way	NBT	260	260	2,240
						EBL	180	240	240
						WBR	560	960	100
	SB	160	160	880	Oregon Way/ Alabama Street	EBR	N/A	N/A	100
						WBL			100
						SBT			180
California Way (101821J)	NB	80	80	220	Industrial Way/ California Way	N/A	N/A	N/A	N/A
	SB	120	140	520					
3rd Avenue- SR 432 (101826T)	NB	1,080	1,120	2,100	3rd Avenue/ Industrial Way	WBR	80	80	120
						NBT	720	760	1,740
					Industrial Way/ California Way	SBL	120	140	140
	SB	260	260	1,040		NBR	60	60	80
						EBT	480	520	1,500
Dike Road (101791U)	NB	40	40	60	None	N/A	N/A	N/A	N/A

Study Crossing (USDOT Crossing ID)	Road MVMT[b]	2018 No-Action Estimated Study Crossing Queue Length (feet)	2018 Truck Estimated Study Crossing Queue Length (feet)	2018 Rail Estimated Study Crossing Queue Length (feet)	Upstream Intersection Affected by Queue from Study Crossing	Intersection MVMT[c]	2018 No-Action Estimated Upstream Intersection Queue Length (feet)	2018 Truck Estimated Upstream Intersection Queue Length (feet)	2018 Rail Estimated Upstream Intersection Queue Length (feet)
	SB	40	40	40					
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County									
Taylor Crane Road in Castle Rock (092481X)	EB	20	20	20	None	N/A	N/A	N/A	N/A
	WB	20	20	20					
Cowlitz Street in Castle Rock (092476B)	EB	40	40	40	None	N/A	N/A	N/A	N/A
	WB	40	40	60					
Cowlitz Gardens Road in Kelso (092466V)	EB	20	20	20	None	N/A	N/A	N/A	N/A
	WB	20	20	20					
Mill Street in Kelso (092458D)	EB	80	80	100	None	N/A	N/A	N/A	N/A
	WB	100	100	120					
S River Road in Kelso (092457W)	EB	40	40	80	Pacific Avenue/ S River Road	SBR	N/A	N/A	40
	WB	60	60	100		NBL			40
Toteff Road/ Port Road in Kalama (092446J)	EB	40	40	40	None	N/A	N/A	N/A	N/A
	WB	40	40	60					
W Scott Avenue in Woodland (092437K)	EB	40	40	60	None	N/A	N/A	N/A	N/A
	WB	100	100	120					
Davidson Avenue in Woodland (092435W)	EB	60	60	60	None	N/A	N/A	N/A	N/A
	WB	40	40	40					
Whalen Road in Woodland (092434P)	EB	40	40	40	None	N/A	N/A	N/A	N/A
	WB	60	60	60					

Notes:

[a] Shaded gray values indicate a study crossing or intersection queue that exceeds available storage. Shaded black values indicate a project impact.

[b] MVMT = roadway movement approaching the rail crossing; NB = northbound; SB = southbound; EB = eastbound; WB = westbound

[c] MVMT = movement at nearby intersection affected by queue from rail crossing; NBL = northbound left; NBR = northbound right; NBT = northbound through; SBL = southbound left; SBR = southbound right; SBT = southbound through; EBL= eastbound left; EBR= eastbound right; EBT= eastbound through; WBL= westbound left; WBR= westbound right; WBT= westbound through

Cause Delay to Emergency Vehicle Response from Rail Traffic

EMS and fire protection response times would be affected by increased delay at at-grade crossings because of the Proposed Action. During construction, should delivery of preload material by rail occur during the PM peak hour, the average delay per stopped vehicle would be estimated at less than 80 seconds at public at-grade crossings along the Reynolds Lead and generally less than 30 seconds at public at-grade crossings along the BNSF Spur and BNSF main line. This corresponds to an increase by approximately 60 seconds or less at public at-grade crossings along the Reynolds Lead and less than 20 seconds along the BNSF Spur and BNSF main line compared to the 2018 No-Action scenario. Construction activities would not result in any material change in vehicle delay at at-grade crossings on the Reynolds Lead, BNSF Spur, and BNSF main line if preload material is delivered by truck.

Total gate downtime would be up to 8 minutes per day at public crossings along the Reynolds Lead, 43 minutes per day at the Dike Road crossing along the BNSF Spur, and up to 108 minutes per day along the BNSF main line under the 2018 No-Action and 2018 Construction (truck delivery) scenarios. If preload material is delivered by rail, total gate downtime would be up to 12 minutes longer per day at public crossings along the Reynolds Lead and BNSF Spur and up to 2 minutes longer per day along the BNSF main line compared to the 2018 No-Action scenario. Over the course of a day, a 1% increase in probability of EMS and fire protection response vehicles being delayed at study crossings along the Reynolds Lead, BNSF Spur, and BNSF main line is anticipated with 2018 Construction (via rail) scenario trains.

Increase Predicted Accident Probability

The accident probability analysis found none of the study crossings to have an expected accident frequency of more than 0.075 accidents per year with existing crossing safety protection. The increased rail activity during construction, should delivery of preload material by rail occur, could increase the frequency of accidents compared to the 2018 No-Action scenario. The predicted intervals between accidents at public crossings along the Reynolds Lead and BNSF Spur could decrease up to 15 years, and up to 40 years at private crossings along the Reynolds Lead. No material change to the frequency of accidents at crossings along the BNSF main line would be expected if preload material is delivered by rail. Construction activities would not result in any material change to the frequency of accidents at most crossings along the Reynolds Lead, BNSF Spur, and BNSF main line if preload material is delivered by truck. The exception would be the 38th Avenue project site access, where the predicted interval between accidents could decrease up to 35 years due to motor vehicle volume growth associated with the construction activities.

3.1.2 Operations: Direct Impacts

Approximately 109 PM peak hour motor vehicle trips are estimated because of operation of the Proposed Action. These vehicles would access the project area via the private driveway opposite 38th Avenue or at the existing driveway on Industrial Way approximately 0.5 mile west of the 38th Avenue driveway. Access roads in the project area would be designed to allow two-way traffic for standard vehicles. All roadways and parking areas would be designed and constructed to the standards appropriate for loading and capacity requirements. All regularly used roads accessing the buildings and facilities in the project area would be sealed with asphalt pavement. Paving would be

designed to accommodate mobile equipment loadings. Surfacing of unpaved areas would be used to control soil erosion by wind and water.

3.1.3 Operations: Indirect Impacts

All vehicle transportation impacts during operations would occur outside the project area and, therefore, would be considered indirect impacts. Full operation of the Proposed Action would result in the following indirect impacts.

Cause Vehicle Delays from Rail Traffic

The Proposed Action would add approximately 16 additional trains per day (up to 2 during the PM peak hour) in 2028, as documented in Section 2.1.2.3, *Operations Impact Analysis.* Analysis of the study crossings in 2028 was estimated both with and without planned track infrastructure along the Reynolds Lead. Planned track improvements would increase the average train speed from 8 mph to 10 mph at the Weyerhaeuser access crossing opposite Washington Way, from 10 mph to 15 mph at the Weyerhaeuser NORPAC access crossing, from 10 mph to 20 mph at the Industrial Way and Oregon Way crossings, and from 8 to 15 mph at the California Way and 3rd Avenue crossings. No changes in train speed would occur at the existing site access opposite 38th Avenue and Dike Road crossings. Table 11 shows study crossing characteristics in 2028.

A Proposed Action-related train would take between 8 and 10 minutes to pass through the public study crossings along the Reynolds Lead with current track infrastructure, and between 4 and 6 minutes with planned track infrastructure. Trains under full operation of the Proposed Action would take about 8 minutes to cross Dike Road along the BNSF Spur, and around 2 minutes to pass through the study crossings along the BNSF main line. Overall, the 16 additional Proposed Action-related trains would increase the total gate downtime more than 130 minutes during an average day for the public study crossings along the Reynolds Lead and BNSF Spur, up to 260 minutes during an average day for the private study crossings along the Reynolds Lead, and up to 20 minutes during an average day along the BNSF main line. The planned track infrastructure along the Reynolds Lead would reduce the total gate downtime at the Weyerhaeuser Washington Way access, Weyerhaeuser NORPAC access, Industrial Way-SR 432 (101806G), Oregon Way- SR 433 (101805A), California Way (101821J), and 3rd Avenue-SR 432 (101826T) study crossings.

Table 11. Study Crossing Characteristics—2028 Operations

Study Crossing (USDOT Crossing ID)	Time Period	2028 No-Action		2028 Operations (with Current Track Infrastructure)		2028 Operations (with Planned Track Infrastructure)	
		Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)
Study Crossings along the Reynolds Lead and BNSF Spur							
Project area access at 38th Avenue	Per Day	2,043	20.5	5,944	280.0	5,944	280.0
	PM Peak		5.1	6,917	16.2	6,917	16.2
Weyerhaeuser access at Washington Way	Per Day	2,043	13.6	5,944	178.8	5,944	145.0
	PM Peak		3.4	6,917	10.3	6,917	8.4
Weyerhaeuser NORPAC access	Per Day	2,043	11.2	5,944	145.0	5,944	100.0
	PM Peak		2.8	6,917	8.4	6,917	5.7
Industrial Way- SR 432 (101806G)	Per Day	2,043	11.2	5,944	145.0	5,944	77.5
	PM Peak		2.8	6,917	8.4	6,917	4.4
Oregon Way- SR 433 (101805A)	Per Day	2,043	11.2	5,944	145.0	5,944	77.5
	PM Peak		2.8	6,917	8.4	6,917	4.4
California Way (101821J)	Per Day	2,053	13.6	5,946	178.8	5,946	100.0
	PM Peak		3.4	6,917	10.3	6,917	5.7
3rd Avenue- SR 432 (101826T)	Per Day	2,053	13.6	5,946	178.8	5,946	100.0
	PM Peak		3.4	6,917	10.3	6,917	5.7
Dike Road (101791U)	Per Day	4,919	43.4	6,301	177.1	6,301	177.1
	PM Peak		6.1	6,917	8.4	6,917	8.4
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County							
Taylor Crane Road in Castle Rock (092481X)	Per Day	5,396	125.5	5,546	142.1	5,546	142.1
	PM Peak	3,837	6.3	4,770	10.5	4,770	10.5
Cowlitz Street in Castle Rock (092476B)	Per Day	5,396	125.5	5,546	142.1	5,546	142.1
	PM Peak	3,837	6.3	4,770	10.5	4,770	10.5
	Per Day	5,396	108.2	5,546	122.6	5,546	122.6

Study Crossing (USDOT Crossing ID)	Time Period	2028 No-Action		2028 Operations (with Current Track Infrastructure)		2028 Operations (with Planned Track Infrastructure)	
		Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)	Weighted Average Train Length (feet)	Total Gate Downtime (minutes)
Cowlitz Gardens Road in Kelso (092466V)	PM Peak	3,837	5.6	4,770	9.2	4,770	9.2
Mill Street in Kelso (092458D)	Per Day	5,396	147.8	5,546	167.5	5,546	167.5
	PM Peak	3,837	7.3	4,770	12.2	4,770	12.2
S River Road in Kelso (092457W)	Per Day	5,396	147.8	5,546	167.5	5,546	167.5
	PM Peak	3,837	7.3	4,770	12.2	4,770	12.2
Toteff Road/ Port Road in Kalama (092446J)	Per Day	5,396	107.5	5,546	121.9	5,546	121.9
	PM Peak	3,837	5.6	4,770	9.2	4,770	9.2
W Scott Avenue in Woodland (092437K)	Per Day	5,396	108.2	5,546	122.6	5,546	122.6
	PM Peak	3,837	5.6	4,770	9.2	4,770	9.2
Davidson Avenue in Woodland (092435W)	Per Day	5,396	108.2	5,546	122.6	5,546	122.6
	PM Peak	3,837	5.6	4,770	9.2	4,770	9.2
Whalen Road in Woodland (092434P)	Per Day	5,396	108.2	5,546	122.6	5,546	122.6
	PM Peak	3,837	5.6	4,770	9.2	4,770	9.2

Table 12 shows the estimated average delay per vehicle and LOS that would be experienced during the PM peak hour at each of the study crossings and intersections in 2028 with the Proposed Action, with the estimated 2028 No-Action scenario conditions provided for reference.

As shown, the increased rail activity associated with the Proposed Action would increase average delay per vehicle during the PM peak hour, with forecasted LOS dropping below D at six of the study crossings on the Reynolds Lead with existing track infrastructure. The length of the Proposed Action-related trains, estimated at 6,917 feet, and the slow track speeds (between 5 and 10 mph), would contribute to the vehicle LOS impacts.

The planned track infrastructure along the Reynolds Lead would address all of the vehicle LOS impacts at the public study crossings, assuming 1 Proposed Action-related train on the Reynolds Lead during the PM peak hour. Only the project area access (opposite 38th Avenue) study crossing would operate below LOS D. Vehicle LOS impacts are still forecasted at this study crossing since track speeds would not increase with the planned track infrastructure along the Reynolds Lead.

However, four of the study crossings would have vehicle LOS impacts with 2 Proposed Action-related trains on the Reynolds Lead during the PM peak hour, with planned track infrastructure. It should be noted that track speeds at two of these study crossings (project area access-opposite 38th Avenue, and Dike Road) would not be increased with the planned track infrastructure along the Reynolds Lead.

Vehicle LOS impacts are also forecasted at the Mill Street and S River Road study crossings in Kelso, along the BNSF main line. These crossings are forecast to be slightly over standard, mainly due to the slower track speeds for both freight and passenger trains (40 mph).

Table 13 shows the estimated average delay per vehicle and LOS that would be experienced during a 24-hour period at each of the study crossings in 2028. As shown, the average delay per vehicle expected over a 24-hour period is very low under the 2028 No-Action scenario and 2028 Proposed Action (with planned track infrastructure) scenario. However, the average delay per vehicle expected over a 24-hour period is higher under the 2028 Proposed Action (with existing track infrastructure) scenario, corresponding with the PM peak hour results.

Table 12. Estimated Vehicle Delay and LOS—2028 Operations (PM Peak Hour)[a]

Study Crossing/Intersection (USDOT Crossing ID)	2028 No-Action		2028 Operations (Current Track Infrastructure and 1 Peak Hour Proposed Action-Related Train)		2028 Operations (Planned Track Infrastructure[b] and 1 Peak Hour Proposed Action-Related Train)		2028 Operations (Planned Track Infrastructure[b] and 2 Peak Hour Proposed Action-Related Trains)	
	Delay	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS
Study Crossings along the Reynolds Lead and BNSF Spur*								
Project area access at 38th Ave	15.4	B	154.6	**F**	154.6	**F**	274.9	**F**
Weyerhaeuser access at Washington Way	7.1	A	64.3	**E**	42.2	D	75.0	**E**
Weyerhaeuser NORPAC access	4.8	A	41.6	**D**	19.6	B	34.9	C
Industrial Way- SR 432 (101806G)	7.8	A	64.4	**E**	18.7	B	32.8	C
Oregon Way- SR 433 (101805A)	6.6	A	56.0	**E**	16.0	B	28.3	C
California Way (101821J)	8.3	A	72.8	**E**	22.7	C	40.2	D
3rd Avenue- SR 432 (101826T)	12.1	B	106.3	**F**	33.2	C	58.8	**E**
Dike Road (101791U)	21.3	C	40.2	D	40.2	D	71.4	**E**
Study Intersection adjacent to the Reynolds Lead and BNSF Spur**								
Industrial Way/ 38th Avenue	10.0	B	11.3	B	11.3	B	11.3	B
Industrial Way/ Washington Way	16.6	B	17.3	B	17.3	B	17.3	B
Industrial Way/ NORPAC access	18.7	C	20.4	C	20.4	C	20.4	C
Industrial Way/ Weyerhaeuser	18.8	C	20.4	C	20.4	C	20.4	C
Industrial Way/ Oregon Way	50.4	D	52.3	D	52.3	D	52.3	D
Industrial Way/ California Way	24.5	C	24.6	C	24.6	C	24.6	C
3rd Avenue/ Industrial Way	22.2	C	22.4	C	22.4	C	22.4	C
Dike Road/ Frontage Road	8.9	A	8.9	A	8.9	A	8.9	A
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County*								
Taylor Crane Road in Castle Rock (092481X)	19.4	B	N/A	N/A	N/A	N/A	42.6	D
Cowlitz Street in Castle Rock (092476B)	20.5	C	N/A	N/A	N/A	N/A	45.0	D

Study Crossing/Intersection (USDOT Crossing ID)	2028 No-Action		2028 Operations (Current Track Infrastructure and 1 Peak Hour Proposed Action-Related Train)		2028 Operations (Planned Track Infrastructure[b] and 1 Peak Hour Proposed Action-Related Train)		2028 Operations (Planned Track Infrastructure[b] and 2 Peak Hour Proposed Action-Related Trains)	
	Delay	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS
Cowlitz Gardens Road in Kelso (092466V)	15.5	B	N/A	N/A	N/A	N/A	34.1	C
Mill Street in Kelso (092458D)	29.4	C	N/A	N/A	N/A	N/A	65.6	**E**
S River Road in Kelso (092457W)	28.4	C	N/A	N/A	N/A	N/A	63.5	**E**
Toteff Road/ Port Road in Kalama (092446J)	15.9	B	N/A	N/A	N/A	N/A	34.9	C
W Scott Avenue in Woodland (092437K)	17.6	B	N/A	N/A	N/A	N/A	39.0	D
Davidson Avenue in Woodland (092435W)	16.6	B	N/A	N/A	N/A	N/A	36.9	D
Whalen Road in Woodland (092434P)	16.1	B	N/A	N/A	N/A	N/A	35.8	D

Notes:

[a] **Bolded**, **shaded gray** values indicate a vehicle LOS impact (a study crossing or intersection that operates below LOS D under the Proposed Action that would not otherwise operate below LOS D under the No-Action scenario from the same year).

[b] Planned track infrastructure along the Reynolds Lead would increase the average train speed from 8 mph to 10 mph at the Weyerhaeuser access crossing—opposite Washington Way, from 10 mph to 15 mph at the Weyerhaeuser NORPAC access crossing, from 10 mph to 20 mph at the Industrial Way and Oregon Way crossings, and from 8 mph to 15 mph at the California Way and 3rd Avenue crossings. No changes in train speed would occur at the existing site access—opposite 38th Avenue and Dike Road crossings.

*Delay = average delay per vehicle at worst roadway approach to the crossing; LOS = level of service of worst roadway approach to the crossing.

**At signalized study intersections, the LOS and delay are reported as the intersection average and as the worst stop controlled approach at un-signalized locations.

Table 13. Estimated Vehicle Delay and LOS—2028 Operations (24-Hour Average)[a]

USDOT Crossing ID	Study Crossing	2028 No-Action		2028 Operations (with Current Track Infrastructure)		2028 Operations (with Planned Track Infrastructure[b])	
		Delay	LOS	Delay (seconds)	LOS	Delay (seconds)	LOS
Study Crossings along the Reynolds Lead and BNSF Spur							
Private	Project area access at 38th Ave	2.2	A	85.1	**F**	86.1	**F**
Private	Weyerhaeuser access at Washington Way	1.0	A	35.4	D	23.2	C
Private	Weyerhaeuser NORPAC access	0.7	A	22.5	C	10.7	B
101806G	Industrial Way (SR 432)	0.8	A	26.7	C	7.5	A
101805A	Oregon Way (SR 433)	0.8	A	25.5	C	7.2	A
101821J	California Way	1.1	A	37.5	D	11.9	B
101826T	3rd Avenue (SR 432)	1.1	A	39.4	D	12.3	B
101791U	Dike Road	5.7	A	29.2	C	28.6	C
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County							
092481X	Taylor Crane Road in Castle Rock	4.5	A	5.2	A	5.2	A
092476B	Cowlitz Street in Castle Rock	4.7	A	5.4	A	5.4	A
092466V	Cowlitz Gardens Road in Kelso	3.4	A	4.0	A	4.0	A
092458D	Mill Street in Kelso	6.9	A	8.0	A	8.0	A
092457W	S River Road in Kelso	6.7	A	7.8	A	7.8	A
092446J	Toteff Road/ Port Road in Kalama	3.5	A	4.0	A	4.0	A
092437K	W Scott Avenue in Woodland	3.6	A	4.2	A	4.2	A
092435W	Davidson Avenue in Woodland	3.5	A	4.1	A	4.1	A
092434P	Whalen Road in Woodland	3.5	A	4.0	A	4.0	A

Notes:

[a] **Bolded**, **shaded gray** values indicate a vehicle LOS impact (a study crossing that operates below LOS D under the Proposed Action that would not otherwise operate below LOS D under the No-Action scenario from the same year).

[b] Planned track infrastructure along the Reynolds Lead would increase the average train speed from 8 mph to 10 mph at the Weyerhaeuser access crossing—opposite Washington Way, from 10 mph to 15 mph at the Weyerhaeuser NORPAC access crossing, from 10 mph to 20 mph at the Industrial Way and Oregon Way crossings, and from 8 mph to 15 mph at the California Way and 3rd Avenue crossings. No changes in train speed would occur at the existing site access—opposite 38th Avenue and Dike Road crossings.

Delay = Average delay per vehicle over 24-hour period, in seconds; LOS = level of service of railroad crossing

Table 14 shows the estimated vehicle queue lengths that would be experienced during the PM peak hour at each of the study crossings in 2028. The increased rail activity associated with the Proposed Action (existing track infrastructure) would increase vehicle queues at rail crossings along high volume roadways, with queues similar to those estimated with 2018 Construction (via rail) scenario trains, extending nearly 1,000 feet beyond those expected with 2028 No-Action scenario trains at the Industrial Way (SR 432), Oregon Way (SR 433), and 3rd Avenue (SR 432) study crossings. The length of the Proposed Action-related trains, estimated at 6,917 feet, and the slow track speeds (between 8 and 10 mph), would contribute to the increased vehicle queue lengths.

One additional intersection would be affected by vehicle queues extending from rail crossings with Proposed Action-related trains (existing track infrastructure) during the PM peak hour (beyond those affected by 2028 No-Action scenario trains), Oregon Way/Alabama Street. Vehicle queues at the 9 affected intersections (all previously identified as being affected with 2018 trains) would exceed available storage at three additional approaches beyond those affected by 2028 No-Action scenario trains, the westbound left movement from Industrial Way to 38th Avenue, the westbound right movement from Industrial Way to 3rd Avenue, and the northbound right movement from California Way to Industrial Way. These queues could block other movements at the intersections that would otherwise not be affected by train crossing events.

The planned track infrastructure along the Reynolds Lead would reduce vehicle queues at the study crossings between the Weyerhaeuser access (opposite Washington Way) and 3rd Avenue (SR 432), assuming 1 Proposed Action-related train on the Reynolds Lead during the PM peak hour. Vehicle queues would be between 700 and 1,000 feet shorter than queue lengths estimated with the existing track infrastructure along the Reynolds Lead. However, vehicle queues would still exceed available storage at six of the eight approaches identified with the existing track infrastructure. Note that Table 14 shows estimated vehicle queue lengths with the planned track infrastructure and 1 Proposed Action-related train on the Reynolds Lead during the PM peak hour. With 2 Proposed Action-related trains on the Reynolds Lead during the PM peak hour, vehicle queues extending from study crossings would be similar to those estimated with the existing track infrastructure, despite the track improvements.

Table 14. Estimated Vehicle Queue Lengths—2028 Operations (PM Peak Hour)[a]

Study Crossing (USDOT Crossing ID)	Road MVMT[b]	2028 No-Action	2028 Current Infras.	2028 Planned Infras.	Intersection Affected by Queue from Crossing	Intersection MVMT[c]	2028 No-Action	2028 Exist. Infras.	2028 Plan. Infras.
		Estimated Queue Length at Study Crossing (feet)					Estimated Queue Length at Upstream Intersection (feet)		
Study Crossings along the Reynolds Lead and BNSF Spur									
Project area access at 38th Avenue	NB	40	1,380	1,180	Industrial Way/ 38th Avenue	WBL	20	**220**	**280**
	SB	40	220	300		EBR	20	80	60
Weyerhaeuser access-opposite Washington Way	NB	240	680	560	Industrial Way/ Washington Way	WBL	100	120	100
						EBR	160	660	540
	SB	160	660	540		SBT	40	140	90
Weyerhaeuser NORPAC access	NB	60	180	120	Industrial Way/ NORPAC access	WBL	20	20	20
	SB	20	40	20		EBR	20	20	20
Industrial Way- SR 432 (101806G)	NB	360	480	400	Industrial Way/ Weyerhaeuser	EBL	160	360	160
	SB	280	1,300	540		NBT	240	360	280
Oregon Way- SR 433 (101805A)	NB	1,180	2,200	1,620	Industrial Way/ Oregon Way	NBT	380	1,880	1,080
						EBL	320	400	340
						WBR	940	1,960	1,380
	SB	220	**1,160**	440	Oregon Way/ Alabama Street	EBR	N/A	260	N/A
						WBL		340	
						SBT		460	
California Way (101821J)	NB	100	260	260	Industrial Way/ California Way	N/A	N/A	N/A	N/A
	SB	160	820	420					
3rd Avenue- SR 432 (101826T)	NB	1,300	3,220	1,380	3rd Avenue/ Industrial Way	WBR	80	**240**	100
						NBT	920	2,860	1,020
					Industrial Way/ California Way	SBL	160	200	180
	SB	440	1,700	760		NBR	80	**140**	80
						EBT	700	2,620	780

Study Crossing (USDOT Crossing ID)	Road MVMT[b]	2028 No-Action	2028 Current Infras.	2028 Planned Infras.	Intersection Affected by Queue from Crossing	Intersection MVMT[c]	2028 No-Action	2028 Exist. Infras.	2028 Plan. Infras.
		Estimated Queue Length at Study Crossing (feet)					Estimated Queue Length at Upstream Intersection (feet)		
Dike Road (101791U)	NB	40	60	40	None	N/A	N/A	N/A	N/A
	SB	40	40	40					
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County									
Taylor Crane Road in Castle Rock (092481X)	EB	20	20	20	None	N/A	N/A	N/A	N/A
	WB	20	20	20					
Cowlitz Street in Castle Rock (092476B)	EB	40	60	60	None	N/A	N/A	N/A	N/A
	WB	80	80	80					
Cowlitz Gardens Road in Kelso (092466V)	EB	20	40	40	None	N/A	N/A	N/A	N/A
	WB	20	40	40					
Mill Street in Kelso (092458D)	EB	100	180	180	None	N/A	N/A	N/A	N/A
	WB	160	240	240					
S River Road in Kelso (092457W)	EB	80	120	120	Pacific Avenue/S River Road	SBR	60	100	100
	WB	120	180	180		NBL	40	40	40
Toteff Road/ Port Road in Kalama (092446J)	EB	40	60	60	None	N/A	N/A	N/A	N/A
	WB	60	80	80					
W Scott Avenue in Woodland (092437K)	EB	60	100	100	None	N/A	N/A	N/A	N/A
	WB	140	200	200					
Davidson Avenue in Woodland (092435W)	EB	100	120	120	None	N/A	N/A	N/A	N/A
	WB	60	80	80					
Whalen Road in Woodland (092434P)	EB	60	60	60	None	N/A	N/A	N/A	N/A
	WB	80	80	80					

Notes:

[a] Shaded gray values indicate a study crossing or intersection with a queue that exceeds available storage. Shaded black values indicate a project impact.

[b] MVMT= Roadway movement approaching the rail crossing; NB = northbound; SB = southbound; EB = eastbound; WB = westbound

[c] MVMT= Movement at nearby intersection affected by queue from rail crossing; NBL = northbound left; NBR = northbound right; NBT = northbound through; SBL = southbound left; SBR = southbound right; SBT = southbound through; EBL = eastbound left; EBR = eastbound right; EBT = eastbound through; WBL = westbound left; WBR = westbound right; WBT = westbound through; N/A = not available

Cause Delay to Emergency Vehicle Response from Rail Traffic

EMS and fire protection response times would be affected by increased delay at at-grade crossings as a result of the Proposed Action.

The average delay during the PM peak hour per stopped vehicle during operations in 2028 would be estimated at less than 110 seconds at public at-grade crossings along the Reynolds Lead, and generally less than 60 seconds at public at-grade crossings along the BNSF Spur and BNSF main line. This corresponds to an increase by approximately 90 seconds or less at public at-grade crossings along the Reynolds Lead, and less than 40 seconds along the BNSF Spur and BNSF main line compared to the 2028 No Action scenario. With the planned track infrastructure, the average delay during the PM peak hour per stopped vehicle would be estimated to increase by less than 50 seconds at public at-grade crossings along the Reynolds Lead.

Total gate downtime would be up to 14 minutes per day at public crossings along the Reynolds Lead, 43 minutes per day at the Dike Road crossing along the BNSF Spur, and up to 148 minutes per day along the BNSF main line in the 2028 No-Action scenario. Under full operations, trains would increase total gate downtime by more than 130 minutes during an average day for the public study crossings along the Reynolds Lead and BNSF Spur and up to 20 minutes during an average day along the BNSF main line compared to the 2028 No-Action scenario. The planned track infrastructure along the Reynolds Lead would reduce the total gate downtime at the Industrial Way (SR 432), Oregon Way (SR 433), California Way, and 3rd Avenue (SR 432) study crossings.

Over the course of a day, a 10% increase in probability of EMS and fire protection response vehicles being delayed at study crossings along the Reynolds Lead and BNSF Spur, and 1% increase at study crossings along the BNSF main line is anticipated with the Proposed Action (with existing track infrastructure) trains. The planned track infrastructure along the Reynolds Lead would reduce the probability of EMS and fire protection response vehicles of being delayed at the Industrial Way (SR 432), Oregon Way (SR 433), California Way, and 3rd Avenue (SR 432) study crossings by around 5%.

Overall, the Proposed Action could have an adverse impact on emergency vehicle response time, especially without planned track improvements, depending on the location of the origin and destination of the response incident in relation to the at-grade crossings that would be anticipated to experience increased gate downtime.

Increase Predicted Accident Probability

The predicted accident probability based on current safety protection for each at-grade study crossing is summarized in Table 15 for both construction and operations of the Proposed Action, with No-Action scenario conditions shown for reference.

The predicted interval between accidents could decrease up to 26 years at crossings along the Reynolds Lead and BNSF Spur, and up to 9 years at crossings along the BNSF main line in the 2028 No-Action scenario due to non-project related rail and motor vehicle traffic growth. Under full operations, trains could decrease the predicted interval between accidents up to 31 years at public crossings along the Reynolds Lead and BNSF Spur, 42 years at private crossings along the Reynolds Lead, and up to 2 years at crossings along the BNSF main line compared to the 2028 No-Action scenario. The public study crossings that would have the shortest predicted intervals

between accidents in 2028 would be the 3rd Avenue (SR 432) and Oregon Way (SR 433) crossings, at intervals of more than 24 years, due to the high motor vehicle volumes at the crossings. The private study crossings that would have the shortest predicted intervals between accidents in 2028 would be the Weyerhaeuser Washington Way access and the 38th Avenue project site access, at intervals of more than 22 years, due to the passive crossing protection.

The Railroad-Highway Grade Crossing Handbook–Revised Second Edition indicates that active devices with automatic gates or grade separation should be considered as options when certain criteria are met. One criterion is if the expected accident frequency, as calculated by the USDOT Accident Prediction formula, exceeds 0.075 for active devices with automatic gates, and 0.50 for grade separation. As shown in Table 15, no grade crossings would exceed these frequencies..

3.1.4 Washington State Study Area

As described in Section 2.1.2.3, *Operations Impact Analysis,* Proposed Action-related BNSF trains would cross Washington State from the Washington State–Idaho border (east of Spokane) to the project area in Cowlitz County. Loaded and empty UP trains to and from the Powder River Basin and Uinta Basin would travel north from Vancouver, Washington. Section 2.2.2, *Washington State,* identified a list of statewide crossings of interest during the project's SEPA scoping process for crossings along the proposed rail routes. Table 16 illustrates the 2028 estimated baseline trains per day at these study crossings and the estimated number of trains per day with the Proposed Action in 2028. Figure 6 illustrates the rail routes and the study crossings. Appendix B, Data for Selected Crossings Outside of Cowlitz County, provides additional data on the study crossings.

Table 15. At-Grade Crossing Safety Assessment

Crossing Name (USDOT Crossing ID)	Predicted Accidents (accidents/year)				
	2018 No-Action	2018 Proposed Action (Truck Delivery)	2018 Proposed Action (Rail Delivery)	2028 No-Action	2028 Operations
Study Crossings along the Reynolds Lead and BNSF Spur					
Project area access at 38th Avenue	0.010	0.019	0.022	0.014	0.037
Weyerhaeuser access at Washington Way	0.020	0.020	0.024	0.025	0.045
Weyerhaeuser NORPAC access	0.012	0.012	0.015	0.017	0.032
Industrial Way- SR 432 (101806G)	0.013	0.014	0.016	0.016	0.025
Oregon Way- SR 433 (101805A)	0.017	0.018	0.021	0.022	0.037
California Way (101821J)	0.010	0.010	0.011	0.013	0.021
3rd Avenue- SR 432 (101826T)	0.021	0.021	0.024	0.025	0.041
Dike Road (101791U)	0.010	0.010	0.011	0.010	0.015
At-Grade Public Crossings along the BNSF Main Line in Cowlitz County					
Taylor Crane Road in Castle Rock (092481X)	0.017	0.017	0.017	0.020	0.021
Cowlitz Street in Castle Rock (092476B)	0.027	0.027	0.028	0.031	0.032
Cowlitz Gardens Road in Kelso (092466V)	0.027	0.027	0.028	0.031	0.032
Mill Street in Kelso (092458D)	0.035	0.035	0.036	0.038	0.039
S River Road in Kelso (092457W)	0.033	0.033	0.033	0.037	0.039
Toteff Road/ Port Road in Kalama (092446J)	0.027	0.027	0.028	0.031	0.032
W Scott Avenue in Woodland (092437K)	0.032	0.032	0.032	0.036	0.037
Davidson Avenue in Woodland (092435W)	0.031	0.031	0.031	0.034	0.036
Whalen Road in Woodland (092434P)	0.029	0.029	0.029	0.033	0.034

Table 16. 2028 Conditions at Selected Statewide Study Crossings

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Estimated Freight Train Speed[b]	2015 Estimated Trains Per Day[c]	2028 Projected Baseline Trains Per Day[c]	2028 Projected Trains Per Day with Proposed Action	2028 Increase in Trains Per Day with Proposed Action	Estimated Daily Gate Downtime from Proposed Action-related Trains (minutes)
Spokane County								
1	Idaho Road	066236B	60	70	106	122	13%	32
2	McKinzey Road	066239W	60	70	106	122	13%	32
3	Harvard Road	066240R	60	70	106	122	13%	32
4	Barker Road	066244T	60	70	106	122	13%	32
5	Flora Road	066245A	60	70	106	122	13%	32
6	Pines Road-SR 27	066367E	60	70	106	122	13%	32
7	University Road	066371U	60	70	106	122	13%	32
8	Park Road	066377K	60	70	106	122	13%	32
9	Pine Street	066315M	35	39	56	72	22%	48
10	F Street/Cheney-Spangle	065970L	35	39	56	72	22%	48
11	Cheney-Plaza Road	065971T	35	39	56	72	22%	48
Adams County								
12	Paha Packard Road	089665U	60	39	56	72	22%	16
13	Kahlotus Road	089670R	60	39	56	72	22%	16
14	1st Street	089672E	50	39	56	72	22%	36
15	Wilbur/City Road	089673L	50	39	56	72	22%	36
Franklin County								
16	Eltopia Road W	089699N	60	39	56	72	22%	16
17	Sagemoor Road	089700F	60	39	56	72	22%	16
Benton County								
18	East 3rd Avenue	090031U	35	34	48	56	14%	24
19	Dague Road-East 25th Avenue	090035W	60	34	48	56	14%	16

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Estimated Freight Train Speed[b]	2015 Estimated Trains Per Day[c]	2028 Projected Baseline Trains Per Day[c]	2028 Projected Trains Per Day with Proposed Action	2028 Increase in Trains Per Day with Proposed Action	Estimated Daily Gate Downtime from Proposed Action-related Trains (minutes)
20	Perkins Road	090036D	60	34	48	56	14%	16
21	Bowles Road	090038S	60	34	48	56	14%	16
22	Cochran Road	090039Y	60	34	48	56	14%	16
23	Finley Road	090040T	60	34	48	56	14%	16
24	Whitcomb Island	090061L	60	34	48	56	14%	16
Klickitat County								
25	Maple Street	090169V	45	34	48	56	14%	20
26	Walnut Street	090168N	45	34	48	56	14%	20
27	South Dock Grade Road	090164L	55	34	48	56	14%	17
Skamania County								
28	Indian Crossing	090159P	55	34	48	56	14%	17
29	Home Valley Park	090155M	55	34	48	56	14%	17
30	Cemetery Xing	090151K	N/A	34	48	56	14%	N/A
31	Russell Avenue	090148C	20	34	48	56	14%	38
32	Skamania Landing/Butler Road	090135B	60	34	48	56	14%	16
33	Walker/Skamania Landing	090134U	60	34	48	56	14%	16
34	St Cloud Road	090133M	N/A	34	48	56	14%	N/A
Lewis County								
35	SR 506-7th Street	092484T	50	50	73	81	10%	18
36	Walnut Street – SR 505/603	092493S	50	50	73	81	10%	18
37	E Locust Street	092519S	40	50	73	81	10%	22
38	Main Street	092520L	40	50	73	81	10%	22
39	Maple Street	092521T	40	50	73	81	10%	22

#[a]	Study Crossing	USDOT/FRA Crossing ID[b]	Estimated Freight Train Speed[b]	2015 Estimated Trains Per Day[c]	2028 Projected Baseline Trains Per Day[c]	2028 Projected Trains Per Day with Proposed Action	2028 Increase in Trains Per Day with Proposed Action	Estimated Daily Gate Downtime from Proposed Action-related Trains (minutes)
40	Big Hanaford Road	092524N	10	50	73	81	10%	68
Yakima County								
41	Jones Road East	099178A	55	7	11	19	42%	17
42	Indian Church	104523U	55	7	11	19	42%	17
43	SR241/Reservation	104534G	55	7	11	19	42%	17
44	Gulden Road	104536V	55	7	11	19	42%	17

Notes:

[a] See Figure 6 for study crossing location.

[b] Source: Washington Utilities Transportation Commission 2015.

[c] Washington State Department of Transportation 2014b. Linear extrapolation of 2010 and 2035 projected train traffic to 2015 volumes.

N/A = data not available

Figure 6. Selected At-Grade Crossings Beyond Cowlitz County



Vehicle Delay

As illustrated in Table 16, the Proposed Action would add 16 trains per day to the study crossings in Spokane, Adams, and Franklin Counties (between the Washington State-Idaho border east of Spokane and Pasco, Washington) and would increase daily rail traffic by approximately 13% and 22%, depending on location. Between Pasco and Cowlitz County (study crossings in Benton, Klickitat, and Skamania Counties), the Proposed Action would add 8 trains per day and increase daily rail traffic by approximately 14%. At the Lewis County study crossings, the Proposed Action would add 8 trains per day and increase daily rail traffic by approximately 10%, and between Auburn and Pasco (Yakima County study crossings), the Proposed Action would increase daily rail traffic by approximately 44%.

Proposed Action-related trains would be approximately 1.3 miles long, and would take the following approximate times to pass at study crossings.[8]

- 10 mph: 8.5 minutes
- 20 mph: 4.75 minutes
- 30 mph: 3.25minutes
- 40 mph: 2.75 minutes
- 50 mph: 2.25 minutes
- 60 mph: 2.0 minutes

Vehicle delay would increase between the Washington State-Idaho border and Cowlitz County because the Proposed Action would add 8 or 16 trains daily (depending on location) to existing BNSF main line as shown in Figure 6. Proposed Action-related trains would also be longer (approximately 1.3 miles long) than the average BNSF freight train length (approximately 1.2 miles long). Assuming Proposed Action-related trains travel at the same freight train speeds identified in Table 16, the five study crossings with the largest increase in daily vehicle delay compared to baseline 2028 conditions would be the following.[9]

- Big Hanaford Road, Lewis County (8 Proposed Action-related trains daily, 10 mph)
- Pine Street, Spokane County (16 Proposed Action-related trains daily, 35 mph)
- F Street/Cheney-Spangle, Spokane County (16 Proposed Action-related trains daily, 35 mph)
- Cheney-Plaza Road, Spokane County (16 Proposed Action-related trains daily, 35 mph)
- Russel Avenue, Skamania County (8 Proposed Action-related trains daily, 20 mph)

When factoring in existing AADT, the five study crossings with the largest increase in vehicle delay compared to the baseline 2028 conditions would be the following.

- Pines Road-SR 27, Spokane County (16 Proposed Action-related trains daily)

[8] Assumes gate closing 30 seconds before a Proposed Action-related train would pass through the grade crossing and 12 seconds after the Proposed Action-related train passes the crossing. See Table 16 for existing freight train speeds.

[9] Calculated by multiplying the existing freight train speed at the study crossing (Table 16) by the number of daily Proposed Action-related trains.

- Park Road, Spokane County (16 Proposed Action-related trains daily)
- Barker Road, Spokane County (16 Proposed Action-related trains daily)
- Harvard Road, Spokane County (16 Proposed Action Proposed Action-related trains daily)
- Flora Road, Spokane County (16 Proposed Action-related trains daily)

The combination of high AADTs and 16 trains per day would cause these study crossings to have the highest increase in vehicle delay per vehicle of the study crossings.

Because the frequency of train traffic on BNSF routes would increase from Proposed Action-related trains, the probability of an increase in emergency response time at all at-grade crossings would also increase because crossings would be blocked more frequently. This vehicle delay impact would only occur if an emergency vehicle experienced a delay related to Proposed Action-related train that would occur on average 8 or 16 times a day, depending on location. The potential for the Proposed Action to affect emergency response would also depend on whether the dispatched emergency vehicle would need to cross the rail line and the availability of alternative routes if a Proposed Action-related train occupies the crossing at the time of the emergency call.

Vehicle Safety

The predicted accident probability based on current safety protection for each of the 44 at-grade statewide study crossings is summarized in Table 17 for the 2028 Proposed Action, with No-Action scenario conditions shown for reference. As shown in Table 17, the accident probability analysis found three of the statewide study crossings to have an expected accident frequency of more than 0.075 accidents per year with existing crossing safety protection under the 2028 No-Action scenario, including the Park Road, F Street/Cheney-Spangle and E Locust Street crossings. These crossings would have predicted intervals between accidents in the 2028 No-Action scenario between 8 and 11 years.

Under full operations in 2028, trains would decrease the predicted interval between accidents up to 9 years at statewide study crossings compared to the 2028 No-Action scenario. Proposed Action-related trains would slightly decrease the predicted interval between accidents at all at-grade crossings because 8 or 16 Proposed Action-related trains would pass at each crossing, depending on location, and the Proposed Action would not change crossing protection at the study crossings.

The Railroad-Highway Grade Crossing Handbook–Revised Second Edition indicates that active devices with automatic gates, or grade separation should be considered as options when certain criteria are met. One criterion is if the expected accident frequency, as calculated by the USDOT Accident Prediction formula, exceeds 0.075 for active devices with automatic gates and 0.50 for grade separation. As shown in Table 17, the accident probability analysis found the Park Road, F Street/Cheney-Spangle and E Locust Street crossings to be more than 0.075 accidents per year with existing crossing safety protection. None of the statewide study crossings would have an accident probability of more than 0.075 accidents per year with Proposed Action-related trains that would be at or fewer than 0.075 accidents per year under the No-Action scenario in 2028.

Table 17. 2028 Statewide At-Grade Crossing Safety Assessment

#[a]	Road Crossing	USDOT/FRA Crossing ID	Accident Probability (accidents/year)	
			2028 No-Action	2028 Proposed Action
Spokane County				
1	Idaho Road	066236B	0.041	0.042
2	McKenzie Road	066239W	0.041	0.042
3	Harvard Road	066240R	0.049	0.051
4	Barker Road	066244T	0.049	0.051
5	Flora Road	066245A	0.044	0.045
6	Pines Road-SR 27	066367E	0.061	0.062
7	University Road	066371U	0.037	0.038
8	Park Road	066377K	0.122	0.125
9	Pine Street	066315M	0.029	0.032
10	F Street/Cheney-Spangle	065970L	0.091	0.096
11	Cheney-Plaza Road	065971T	0.025	0.028
Adams County				
12	Paha Packard Road	089665U	0.015	0.016
13	Kahlotus Road	089670R	0.022	0.024
14	1st Street	089672E	0.021	0.024
15	Wilbur/City Road	089673L	0.025	0.027
Franklin County				
16	Eltopia Road W	089699N	0.020	0.022
17	Sagemoor Road	089700F	0.021	0.023
Benton County				
18	East 3rd Avenue	090031U	0.033	0.034
19	Dague Road-East 25th Avenue	090035W	0.023	0.024
20	Perkins Road	090036D	0.059	0.061
21	Bowles Road	090038S	0.029	0.030
22	Cochran Road	090039Y	0.014	0.015
23	Finley Road	090040T	0.030	0.032
24	Whitcomb Island	090061L	0.012	0.012
Klickitat County				
25	Maple Street	090169V	0.032	0.033
26	Walnut Street	090168N	0.025	0.026
27	South Dock Grade Road	090164L	0.014	0.015
Skamania County				
28	Indian Crossing	090159P	0.016	0.017
29	Home Valley Park	090155M	0.012	0.012
30	Cemetery Xing	090151K	0.019	0.020
31	Russell Avenue	090148C	0.024	0.025

#[a]	Road Crossing	USDOT/FRA Crossing ID	Accident Probability (accidents/year) 2028 No-Action	2028 Proposed Action
32	Skamania Landing/Butler Road	090135B	0.010	0.011
33	Walker/Skamania Landing	090134U	0.011	0.012
34	St Cloud Road	090133M	0.006	0.007
Lewis County				
35	SR 506-7th Street	092484T	0.033	0.034
36	Walnut Street – SR 505/603	092493S	0.037	0.038
37	E Locust Street	092519S	0.135	0.138
38	Main Street	092520L	0.037	0.038
39	Maple Street	092521T	0.039	0.039
40	Big Hanaford Road	092524N	0.037	0.038
Yakima County				
41	Jones Road East	099178A	0.015	0.019
42	Indian Church	104523U	0.017	0.021
43	SR241/Reservation	104534G	0.020	0.024
44	Gulden Road	104536V	0.010	0.012

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal vehicle transportation impacts related to construction and operation of the coal export terminal would not occur. The Applicant would continue with current and future increased operations in the project area. The project area could be developed for other industrial uses including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement. The Applicant's planned growth would require approximately 2 trains per day on the Reynolds Lead.

Anticipated No-Action Alternative conditions for vehicle LOS for 2018 are shown in Tables 8 and 9. As shown, all study crossings would operate with an LOS B or better along the Reynolds Lead, LOS C at the Dike Road crossing along the BNSF Spur, and LOS B or better along the BNSF main line during the PM peak hour. All study crossings would operate with an LOS A over a 24-hour period.

Table 10 shows the estimated vehicle queue lengths for the 2018 No-Action scenario. Vehicle queues extending from six study crossings (all along the Reynolds Lead) would affect seven nearby intersections with 2018 No-Action scenario trains during the PM peak hour. The affected intersections include Industrial Way/38th Avenue, Industrial Way/Washington Way, Industrial Way/ NORPAC access, Industrial Way/Weyerhaeuser Access, Industrial Way/Oregon Way, 3rd Avenue/Industrial Way, and Industrial Way/California Way. Vehicle queues at these intersections would exceed available storage at four approaches, including the eastbound right turn from Industrial Way to the Weyerhaeuser Access (opposite Washington Way), the eastbound left turn and westbound right turn from Industrial Way to Oregon Way, and the northbound through movement

at the 3rd Avenue/Industrial Way intersection. These queues could potentially block other movements at these intersections that would otherwise not be affected by train crossing events.

Table 11 shows the anticipated weighted average train lengths and total gate downtime at the study crossings for 2028. The 2028 No-Action scenario would include approximately 2 trains per day on the Reynolds Lead, as documented in Section 2.1.2.1, *No-Action Alternative Analysis.* Overall, 4 trains per day are expected along the Reynolds Lead (1 during the PM peak hour), and 7 (1 during the PM peak hour) at the Dike Road study crossing (along the BNSF Spur) under the 2028 No-Action scenario. The weighted average length of these trains would be around 2,000 feet along the Reynolds Lead, and 5,000 feet along the BNSF Spur. The BNSF main line would include approximately 16 additional non-Proposed Action-related trains per day under the 2028 No-Action scenario, as estimated from the WSDOT Rail Plan (Washington State Department of Transportation 2014a). The BNSF main line would have 73 non-Proposed Action-related trains per day (5 during the PM peak hour) under the 2028 No-Action scenario, with a weighted average length of nearly 5,400 feet.

Total gate downtime would be up to 14 minutes per day (3 minutes during the PM peak hour) at public crossings along the Reynolds Lead, 20 minutes per day (5 minutes during the PM peak hour) at private crossings along the Reynolds Lead, 43 minutes per day (6 minutes during the PM peak hour) at the Dike Road crossing along the BNSF Spur, and up to 148 minutes per day (7 minutes during the PM peak hour) along the BNSF main line under the 2028 No-Action scenario.

The predicted accident probability under 2018 No-Action scenario conditions are shown in Table 15. The predicted accident rate for the No-Action Alternative was found to be fewer than 0.075 accidents per year with existing crossing safety protection at the study crossings.

The 2028 No-Action scenario would include approximately 2 additional non-Proposed Action-related trains per day on the Reynolds Lead, as documented in Section 2.1.2.1, *No-Action Alternative Analysis.* The estimated conditions for vehicle LOS for 2028 No-Action scenario are shown in Tables 12 and 13. As shown, all study crossings would operate with an LOS B or better along the Reynolds Lead, and LOS C or better along the BNSF Spur and BNSF main line during the PM peak hour. All study crossings would operate with an LOS A over a 24-hour period.

Table 14 shows the estimated vehicle queue lengths for the 2028 No-Action scenario. Vehicle queues would be up to 400 feet longer beyond those identified with the 2018 No-Action scenario trains. Vehicle queues extending from seven study crossings (six along the Reynolds Lead and one along the BNSF main line) would affect eight nearby intersections with 2028 No-Action scenario trains during the PM peak hour. All of the affected intersections were previously identified as being affected with 2018 trains, including Industrial Way/38th Avenue, Industrial Way/Washington Way, Industrial Way/NORPAC access, Industrial Way/Weyerhaeuser Access, Industrial Way/Oregon Way, 3rd Avenue/Industrial Way, Industrial Way/California Way, and Pacific Avenue/S River Road. Vehicle queues at these intersections would exceed available storage at one additional approach beyond the four identified with the 2018 No-Action scenario trains, These include the eastbound right turn from Industrial Way to the Weyerhaeuser Access (opposite Washington Way), the eastbound left turn and westbound right turn from Industrial Way to Oregon Way, the northbound through movement at the 3rd Avenue/Industrial Way intersection, and the southbound left movement from California Way to Industrial Way. These queues could potentially block other movements at these intersections that would otherwise not be affected by train crossing events.

The predicted accident probability for the 2028 No-Action scenario conditions are shown in Table 15. The predicted accident rate for the No-Action Alternative was found to be fewer than 0.075 accidents per year with existing crossing safety protection at the study crossings.

Chapter 4
Required Permits

No permits related to vehicle transportation would be required for construction and operation of the Proposed Action.

Chapter 5
References

5.1 Written References

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5.2 Personal Communications

Wolter, Dave. General Manager. Longview Switching Company. December 3, 2014—In person meeting with ICF.

Appendix A

Vehicle Transportation Technical Data

Weighted Average Train Length

Spur Line		2018 No-Action Alternative	2018 Construction (Truck Delivery)	2018 Construction (Rail Delivery)	2028 No-Action Alternative (with current track infrastructure)	2028 On-Site Alternative (with current track infrastructure)	2028 On-Site Alternative (with planned track infrastructure)
Spur Line							
Project site access (opposite 38th Avenue)	Daily	2,024	2,024	3,530	2,043	5,944	5,944
	P.M. Peak	2,024	2,024	6,219	2,043	6,917	6,917
Weyerhaeuser access (opposite Washington Way)	Daily	2,024	2,024	3,530	2,043	5,944	5,944
	P.M. Peak	2,024	2,024	6,219	2,043	6,917	6,917
Weyerhaeuser Norpac Access	Daily	2,024	2,024	3,530	2,043	5,944	5,944
	P.M. Peak	2,024	2,024	6,219	2,043	6,917	6,917
Industrial Way (SR 432)	Daily	2,024	2,024	3,530	2,043	5,944	5,944
	P.M. Peak	2,024	2,024	6,219	2,043	6,917	6,917
Oregon Way (SR 433)	Daily	2,024	2,024	3,530	2,043	5,944	5,944
	P.M. Peak	2,024	2,024	6,219	2,043	6,917	6,917
California Way	Daily	2,041	2,041	3,541	2,053	5,946	5,946
	P.M. Peak	2,041	2,041	6,219	2,053	6,917	6,917
3rd Avenue (SR 432)	Daily	2,041	2,041	3,541	2,053	5,946	5,946
	P.M. Peak	2,041	2,041	6,219	2,053	6,917	6,917
Dike Road	Daily	4,919	4,919	5,116	4,919	6,301	6,301
	P.M. Peak	4,919	4,919	6,219	4,919	6,917	6,917
Mainline							
Taylor Crane Road (Castle Rock)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Cowlitz Avenue (Castle Rock)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Cowlitz Gardens Road (Kelso)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Mill Street (Kelso)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
S River Road/ Yew Street (Kelso)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Toteff Road/Port Road (Kalama)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
W Scott Avenue (Woodland)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Davidson Avenue (Woodland)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770
Whalen Road (Woodland)	Daily	5,160	5,160	5,178	5,396	5,546	5,546
	P.M. Peak	3,425	3,425	3,995	3,837	4,770	4,770

Weighted Average Speed

Spur Line	2018 No-Action Alternative	2018 Construction (Truck Delivery)	2018 Construction (Rail Delivery)	2028 No-Action Alternative (with current track infrastructure)	2028 On-Site Alternative (with current track infrastructure)	2028 On-Site Alternative (with planned track infrastructure)
Spur Line	Daily	Daily	Daily	Daily	Daily	Daily
Project site access (opposite 38th Avenue)	5	5	5	5	5	5
Weyerhaeuser access (opposite Washington Way)	8	8	8	8	8	10
Weyerhaeuser Norpac Access	10	10	10	10	10	15
Industrial Way (SR 432)	10	10	10	10	10	20
Oregon Way (SR 433)	10	10	10	10	10	20
California Way	8	8	8	8	8	15
3rd Avenue (SR 432)	8	8	8	8	8	15
Dike Road	10	10	10	10	10	10
Mainline	Daily	Daily	Daily	Daily	Daily	Daily
Taylor Crane Road (Castle Rock)	50	50	50	50	50	50
Cowlitz Avenue (Castle Rock)	50	50	50	50	50	50
Cowlitz Gardens Road (Kelso)	63	63	63	62	62	62
Mill Street (Kelso)	40	40	40	40	40	40
S River Road/ Yew Street (Kelso)	40	40	40	40	40	40
Toteff Road/Port Road (Kalama)	63	63	63	63	62	62
W Scott Avenue (Woodland)	63	63	63	62	62	62
Davidson Avenue (Woodland)	63	63	63	62	62	62
Whalen Road (Woodland)	63	63	63	62	62	62

Weighted Average Speed

Spur Line	2018 No-Action Alternative	2018 Construction (Truck Delivery)	2018 Construction (Rail Delivery)	2028 No-Action Alternative (with current track infrastructure)	2028 On-Site Alternative (with current track infrastructure)	2028 On-Site Alternative (with planned track infrastructure)
Spur Line	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak
Project site access (opposite 38th Avenue)	5	5	5	5	5	5
Weyerhaeuser access (opposite Washington Way)	8	8	8	8	8	10
Weyerhaeuser Norpac Access	10	10	10	10	10	15
Industrial Way (SR 432)	10	10	10	10	10	20
Oregon Way (SR 433)	10	10	10	10	10	20
California Way	8	8	8	8	8	15
3rd Avenue (SR 432)	8	8	8	8	8	15
Dike Road	10	10	10	10	10	10
Mainline	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak	P.M. Peak
Taylor Crane Road (Castle Rock)	50	50	50	50	50	50
Cowlitz Avenue (Castle Rock)	50	50	50	50	50	50
Cowlitz Gardens Road (Kelso)	68	68	66	67	65	65
Mill Street (Kelso)	40	40	40	40	40	40
S River Road/ Yew Street (Kelso)	40	40	40	40	40	40
Toteff Road/Port Road (Kalama)	70	70	68	68	66	66
W Scott Avenue (Woodland)	68	68	66	67	65	65
Davidson Avenue (Woodland)	68	68	66	67	65	65
Whalen Road (Woodland)	68	68	66	67	65	65

2018 No-Action Alternative Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	2.28	2,024	5	11.62	400	1.2	A
	Weyerhaeuser access (opposite Washington Way)	2.28	2,024	8	7.69	3200	0.6	A
	Weyerhaeuser Norpac Access	2.28	2,024	10	6.38	700	0.4	A
101806G	Industrial Way (SR 432)	2.28	2,024	10	6.38	9600	0.4	A
101805A	Oregon Way (SR 433)	2.28	2,024	10	6.38	13400	0.4	A
101821J	California Way	2.28	2,041	8	7.75	3750	0.6	A
101826T	3rd Avenue (SR 432)	2.28	2,041	8	7.75	16300	0.6	A
101791U	Dike Road	7.12	4,919	10	43.38	400	5.6	A
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	55.10	5160	50	92.16	50	3.2	A
092476B	Cowlitz Avenue (Castle Rock)	55.10	5160	50	92.16	1200	3.3	A
092466V	Cowlitz Gardens Road (Kelso)	55.10	5160	63	79.06	700	2.4	A
092458D	Mill Street (Kelso)	55.10	5160	40	108.31	2550	4.8	A
092457W	S River Road/ Yew Street (Kelso)	55.10	5160	40	108.31	1850	4.7	A
092446J	Toteff Road/Port Road (Kalama)	55.10	5160	63	78.47	1200	2.4	A
092437K	W Scott Avenue (Woodland)	55.10	5160	63	79.06	2650	2.5	A
092435W	Davidson Avenue (Woodland)	55.10	5160	63	79.06	2000	2.5	A
092434P	Whalen Road (Woodland)	55.10	5160	63	79.06	1550	2.5	A

2018 Construction (Truck Delivery) Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	2.28	2,024	5	11.62	3050	1.4	A
	Weyerhaeuser access (opposite Washington Way)	2.28	2,024	8	7.69	3200	0.6	A
	Weyerhaeuser Norpac Access	2.28	2,024	10	6.38	700	0.4	A
101806G	Industrial Way (SR 432)	2.28	2,024	10	6.38	11500	0.4	A
101805A	Oregon Way (SR 433)	2.28	2,024	10	6.38	13850	0.4	A
101821J	California Way	2.28	2,041	8	7.75	3750	0.6	A
101826T	3rd Avenue (SR 432)	2.28	2,041	8	7.75	17300	0.6	A
101791U	Dike Road	7.12	4,919	10	43.38	400	5.6	A
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	55.10	5160	50	92.16	50	3.2	A
092476B	Cowlitz Avenue (Castle Rock)	55.10	5160	50	92.16	1200	3.3	A
092466V	Cowlitz Gardens Road (Kelso)	55.10	5160	63	79.06	700	2.4	A
092458D	Mill Street (Kelso)	55.10	5160	40	108.31	2550	4.8	A
092457W	S River Road/ Yew Street (Kelso)	55.10	5160	40	108.31	1850	4.7	A
092446J	Toteff Road/Port Road (Kalama)	55.10	5160	63	78.47	1200	2.4	A
092437K	W Scott Avenue (Woodland)	55.10	5160	63	79.06	2650	2.5	A
092435W	Davidson Avenue (Woodland)	55.10	5160	63	79.06	2000	2.5	A
092434P	Whalen Road (Woodland)	55.10	5160	63	79.06	1550	2.5	A

2018 Construction (Rail Delivery) Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	3.56	3,530	5	30.31	2200	5.8	A
	Weyerhaeuser access (opposite Washington Way)	3.56	3,530	8	19.61	3200	2.4	A
	Weyerhaeuser Norpac Access	3.56	3,530	10	16.04	700	1.5	A
101806G	Industrial Way (SR 432)	3.56	3,530	10	16.04	10700	1.8	A
101805A	Oregon Way (SR 433)	3.56	3,530	10	16.04	13850	1.7	A
101821J	California Way	3.56	3,541	8	19.67	3750	2.5	A
101826T	3rd Avenue (SR 432)	3.56	3,541	8	19.67	16650	2.6	A
101791U	Dike Road	8.40	5,116	10	53.04	400	7.1	A
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	56.10	5178	50	94.07	50	3.3	A
092476B	Cowlitz Avenue (Castle Rock)	56.10	5178	50	94.07	1200	3.4	A
092466V	Cowlitz Gardens Road (Kelso)	56.10	5178	63	80.72	700	2.5	A
092458D	Mill Street (Kelso)	56.10	5178	40	110.58	2550	4.9	A
092457W	S River Road/ Yew Street (Kelso)	56.10	5178	40	110.58	1850	4.8	A
092446J	Toteff Road/Port Road (Kalama)	56.10	5178	63	80.13	1200	2.5	A
092437K	W Scott Avenue (Woodland)	56.10	5178	63	80.72	2650	2.6	A
092435W	Davidson Avenue (Woodland)	56.10	5178	63	80.72	2000	2.5	A
092434P	Whalen Road (Woodland)	56.10	5178	63	80.72	1550	2.5	A

2028 No-Action Alternative (with current track infrastructure) Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	3.99	2043	5	20.51	600	2.2	A
	Weyerhaeuser access (opposite Washington Way)	3.99	2043	8	13.57	3800	1.0	A
	Weyerhaeuser Norpac Access	3.99	2043	10	11.25	950	0.7	A
101806G	Industrial Way (SR 432)	3.99	2043	10	11.25	10800	0.8	A
101805A	Oregon Way (SR 433)	3.99	2043	10	11.25	16750	0.8	A
101821J	California Way	3.99	2053	8	13.63	5450	1.1	A
101826T	3rd Avenue (SR 432)	3.99	2053	8	13.63	20000	1.1	A
101791U	Dike Road	7.12	4919	10	43.38	400	5.6	A
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	72.70	5396	50	125.50	50	4.5	A
092476B	Cowlitz Avenue (Castle Rock)	72.70	5396	50	125.50	1450	4.7	A
092466V	Cowlitz Gardens Road (Kelso)	72.70	5396	62	108.17	850	3.4	A
092458D	Mill Street (Kelso)	72.70	5396	40	147.79	3000	6.9	A
092457W	S River Road/ Yew Street (Kelso)	72.70	5396	40	147.79	2200	6.7	A
092446J	Toteff Road/Port Road (Kalama)	72.70	5396	63	107.54	1450	3.5	A
092437K	W Scott Avenue (Woodland)	72.70	5396	62	108.17	3100	3.6	A
092435W	Davidson Avenue (Woodland)	72.70	5396	62	108.17	2350	3.5	A
092434P	Whalen Road (Woodland)	72.70	5396	62	108.17	1800	3.5	A

2028 On-Site Alternative (with current track infrastructure) Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	19.99	5,944	5	280.04	1690	86.1	F
	Weyerhaeuser access (opposite Washington Way)	19.99	5,944	8	178.77	3800	35.3	D
	Weyerhaeuser Norpac Access	19.99	5,944	10	145.02	950	22.6	C
101806G	Industrial Way (SR 432)	19.99	5,944	10	145.02	11450	26.4	C
101805A	Oregon Way (SR 433)	19.99	5,944	10	145.02	17020	25.1	C
101821J	California Way	19.99	5,946	8	178.83	5450	38.1	D
101826T	3rd Avenue (SR 432)	19.99	5,946	8	178.83	20220	39.2	D
101791U	Dike Road	23.12	6,301	10	177.14	400	28.6	C
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	80.70	5546	50	142.08	50	5.2	A
092476B	Cowlitz Avenue (Castle Rock)	80.70	5546	50	142.08	1450	5.4	A
092466V	Cowlitz Gardens Road (Kelso)	80.70	5546	62	122.58	850	4.0	A
092458D	Mill Street (Kelso)	80.70	5546	40	167.51	3000	8.0	A
092457W	S River Road/ Yew Street (Kelso)	80.70	5546	40	167.51	2200	7.8	A
092446J	Toteff Road/Port Road (Kalama)	80.70	5546	62	121.92	1450	4.0	A
092437K	W Scott Avenue (Woodland)	80.70	5546	62	122.58	3100	4.2	A
092435W	Davidson Avenue (Woodland)	80.70	5546	62	122.58	2350	4.1	A
092434P	Whalen Road (Woodland)	80.70	5546	62	122.58	1800	4.0	A

2028 On-Site Alternative (with planned track infrastructure) Daily

Crossing ID	Street	Number of Daily Trains	Average Train Length (feet)	Train Speed (mph)	Gate Down-Time per Day (min)	Average daily traffic in both directions (veh/day)	Average delay per vehicle in a 24-hour period (sec/veh)	Level of service
	Spur Line							
	Project site access (opposite 38th Avenue)	19.99	5,944	5	280.04	1690	86.1	F
	Weyerhaeuser access (opposite Washington Way)	19.99	5,944	10	145.02	3800	23.2	C
	Weyerhaeuser Norpac Access	19.99	5,944	15	100.01	950	10.7	B
101806G	Industrial Way (SR 432)	19.99	5,944	20	77.51	11450	7.5	A
101805A	Oregon Way (SR 433)	19.99	5,944	20	77.51	17020	7.2	A
101821J	California Way	19.99	5,946	15	100.04	5450	11.9	B
101826T	3rd Avenue (SR 432)	19.99	5,946	15	100.04	20220	12.3	B
101791U	Dike Road	23.12	6,301	10	177.14	400	28.6	C
	Mainline							
092481X	Taylor Crane Road (Castle Rock)	80.70	5546	50	142.08	50	5.2	A
092476B	Cowlitz Avenue (Castle Rock)	80.70	5546	50	142.08	1450	5.4	A
092466V	Cowlitz Gardens Road (Kelso)	80.70	5546	62	122.58	850	4.0	A
092458D	Mill Street (Kelso)	80.70	5546	40	167.51	3000	8.0	A
092457W	S River Road/ Yew Street (Kelso)	80.70	5546	40	167.51	2200	7.8	A
092446J	Toteff Road/Port Road (Kalama)	80.70	5546	62	121.92	1450	4.0	A
092437K	W Scott Avenue (Woodland)	80.70	5546	62	122.58	3100	4.2	A
092435W	Davidson Avenue (Woodland)	80.70	5546	62	122.58	2350	4.1	A
092434P	Whalen Road (Woodland)	80.70	5546	62	122.58	1800	4.0	A

2018 No-Action Alternative PM Peak Hour

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	1	0	0	0	0	1.00	5.10
	Weyerhaeuser access (opposite Washington Way)	1	0	0	0	0	1.00	3.37
	Weyerhaeuser Norpac Access	1	0	0	0	0	1.00	2.80
101806G	Industrial Way (SR 432)	1	0	0	0	0	1.00	2.80
101805A	Oregon Way (SR 433)	1	0	0	0	0	1.00	2.80
101821J	California Way	1	0	0	0	0	1.00	3.40
101826T	3rd Avenue (SR 432)	1	0	0	0	0	1.00	3.40
101791U	Dike Road	1	0	0	0	0	1.00	6.09
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	0	1.9	1	1	3.90	4.99
092476B	Cowlitz Avenue (Castle Rock)	0	0	1.9	1	1	3.90	4.99
092466V	Cowlitz Gardens Road (Kelso)	0	0	1.9	1	1	3.90	4.42
092458D	Mill Street (Kelso)	0	0	1.9	1	1	3.90	5.74
092457W	S River Road/ Yew Street (Kelso)	0	0	1.9	1	1	3.90	5.74
092446J	Toteff Road/Port Road (Kalama)	0	0	1.9	1	1	3.90	4.40
092437K	W Scott Avenue (Woodland)	0	0	1.9	1	1	3.90	4.42
092435W	Davidson Avenue (Woodland)	0	0	1.9	1	1	3.90	4.42
092434P	Whalen Road (Woodland)	0	0	1.9	1	1	3.90	4.42

2018 Construction PM Peak Hour (Truck Delivery)

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	1	0	0	0	0	1.00	5.10
	Weyerhaeuser access (opposite Washington Way)	1	0	0	0	0	1.00	3.37
	Weyerhaeuser Norpac Access	1	0	0	0	0	1.00	2.80
101806G	Industrial Way (SR 432)	1	0	0	0	0	1.00	2.80
101805A	Oregon Way (SR 433)	1	0	0	0	0	1.00	2.80
101821J	California Way	1	0	0	0	0	1.00	3.40
101826T	3rd Avenue (SR 432)	1	0	0	0	0	1.00	3.40
101791U	Dike Road	1	0	0	0	0	1.00	6.09
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	0	1.9	1	1	3.90	4.99
092476B	Cowlitz Avenue (Castle Rock)	0	0	1.9	1	1	3.90	4.99
092466V	Cowlitz Gardens Road (Kelso)	0	0	1.9	1	1	3.90	4.42
092458D	Mill Street (Kelso)	0	0	1.9	1	1	3.90	5.74
092457W	S River Road/ Yew Street (Kelso)	0	0	1.9	1	1	3.90	5.74
092446J	Toteff Road/Port Road (Kalama)	0	0	1.9	1	1	3.90	4.40
092437K	W Scott Avenue (Woodland)	0	0	1.9	1	1	3.90	4.42
092435W	Davidson Avenue (Woodland)	0	0	1.9	1	1	3.90	4.42
092434P	Whalen Road (Woodland)	0	0	1.9	1	1	3.90	4.42

2018 Construction PM Peak Hour (Rail Delivery)

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL Con	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	0	1.00	0	0	0	1.00	14.63
	Weyerhaeuser access (opposite Washington Way)	0	1.00	0	0	0	1.00	9.33
	Weyerhaeuser Norpac Access	0	1.00	0	0	0	1.00	7.57
101806G	Industrial Way (SR 432)	0	1.00	0	0	0	1.00	7.57
101805A	Oregon Way (SR 433)	0	1.00	0	0	0	1.00	7.57
101821J	California Way	0	1.00	0	0	0	1.00	9.33
101826T	3rd Avenue (SR 432)	0	1.00	0	0	0	1.00	9.33
101791U	Dike Road	0	1.00	0	0	0	1.00	7.57
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	1.00	1.9	1	1	4.90	6.90
092476B	Cowlitz Avenue (Castle Rock)	0	1.00	1.9	1	1	4.90	6.90
092466V	Cowlitz Gardens Road (Kelso)	0	1.00	1.9	1	1	4.90	6.09
092458D	Mill Street (Kelso)	0	1.00	1.9	1	1	4.90	8.01
092457W	S River Road/ Yew Street (Kelso)	0	1.00	1.9	1	1	4.90	8.01
092446J	Toteff Road/Port Road (Kalama)	0	1.00	1.9	1	1	4.90	6.08
092437K	W Scott Avenue (Woodland)	0	1.00	1.9	1	1	4.90	6.09
092435W	Davidson Avenue (Woodland)	0	1.00	1.9	1	1	4.90	6.09
092434P	Whalen Road (Woodland)	0	1.00	1.9	1	1	4.90	6.09

2028 No-Action Alternative PM Peak Hour (with current track infrastructure)

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	1	0	0	0	0	1.00	5.14
	Weyerhaeuser access (opposite Washington Way)	1	0	0	0	0	1.00	3.40
	Weyerhaeuser Norpac Access	1	0	0	0	0	1.00	2.82
101806G	Industrial Way (SR 432)	1	0	0	0	0	1.00	2.82
101805A	Oregon Way (SR 433)	1	0	0	0	0	1.00	2.82
101821J	California Way	1	0	0	0	0	1.00	3.42
101826T	3rd Avenue (SR 432)	1	0	0	0	0	1.00	3.42
101791U	Dike Road	1	0	0	0	0	1.00	6.09
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	0	2.6	1	1	4.60	6.31
092476B	Cowlitz Avenue (Castle Rock)	0	0	2.6	1	1	4.60	6.31
092466V	Cowlitz Gardens Road (Kelso)	0	0	2.6	1	1	4.60	5.58
092458D	Mill Street (Kelso)	0	0	2.6	1	1	4.60	7.31
092457W	S River Road/ Yew Street (Kelso)	0	0	2.6	1	1	4.60	7.31
092446J	Toteff Road/Port Road (Kalama)	0	0	2.6	1	1	4.60	5.57
092437K	W Scott Avenue (Woodland)	0	0	2.6	1	1	4.60	5.58
092435W	Davidson Avenue (Woodland)	0	0	2.6	1	1	4.60	5.58
092434P	Whalen Road (Woodland)	0	0	2.6	1	1	4.60	5.58

2028 On-Site Alternative PM Peak Hour (with current track infrastructure)

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	0	1	0	0	0	1.00	16.22
	Weyerhaeuser access (opposite Washington Way)	0	1	0	0	0	1.00	10.33
	Weyerhaeuser Norpac Access	0	1	0	0	0	1.00	8.36
101806G	Industrial Way (SR 432)	0	1	0	0	0	1.00	8.36
101805A	Oregon Way (SR 433)	0	1	0	0	0	1.00	8.36
101821J	California Way	0	1	0	0	0	1.00	10.33
101826T	3rd Avenue (SR 432)	0	1	0	0	0	1.00	10.33
101791U	Dike Road	0	1	0	0	0	1.00	8.36
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092476B	Cowlitz Avenue (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092466V	Cowlitz Gardens Road (Kelso)	0	2	2.6	1	1	6.60	9.20
092458D	Mill Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092457W	S River Road/ Yew Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092446J	Toteff Road/Port Road (Kalama)	0	2	2.6	1	1	6.60	9.19
092437K	W Scott Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092435W	Davidson Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092434P	Whalen Road (Woodland)	0	2	2.6	1	1	6.60	9.20

2028 On-Site Alternative PM Peak Hour (with planned track infrastructure)- 1 MBTL Train

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	0	1	0	0	0	1.00	16.22
	Weyerhaeuser access (opposite Washington Way)	0	1	0	0	0	1.00	8.36
	Weyerhaeuser Norpac Access	0	1	0	0	0	1.00	5.74
101806G	Industrial Way (SR 432)	0	1	0	0	0	1.00	4.43
101805A	Oregon Way (SR 433)	0	1	0	0	0	1.00	4.43
101821J	California Way	0	1	0	0	0	1.00	5.74
101826T	3rd Avenue (SR 432)	0	1	0	0	0	1.00	5.74
101791U	Dike Road	0	1	0	0	0	1.00	8.36
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092476B	Cowlitz Avenue (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092466V	Cowlitz Gardens Road (Kelso)	0	2	2.6	1	1	6.60	9.20
092458D	Mill Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092457W	S River Road/ Yew Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092446J	Toteff Road/Port Road (Kalama)	0	2	2.6	1	1	6.60	9.19
092437K	W Scott Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092435W	Davidson Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092434P	Whalen Road (Woodland)	0	2	2.6	1	1	6.60	9.20

2028 On-Site Alternative PM Peak Hour (with planned track infrastructure)- 2 MBTL Trains

Crossing ID	Street	Number of PM Peak Hour Trains					Total Number of PM Peak Hour Trains	Gate Down-Time PM Peak (min)
	Spur Line	Existing	MBTL	BNSF	Cascades	Coast Starlight		
	Project site access (opposite 38th Avenue)	0	2	0	0	0	2.00	32.44
	Weyerhaeuser access (opposite Washington Way)	0	2	0	0	0	2.00	16.72
	Weyerhaeuser Norpac Access	0	2	0	0	0	2.00	11.48
101806G	Industrial Way (SR 432)	0	2	0	0	0	2.00	8.86
101805A	Oregon Way (SR 433)	0	2	0	0	0	2.00	8.86
101821J	California Way	0	2	0	0	0	2.00	11.48
101826T	3rd Avenue (SR 432)	0	2	0	0	0	2.00	11.48
101791U	Dike Road	0	2	0	0	0	2.00	16.72
	Mainline							
092489X	Taylor Crane Road (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092476B	Cowlitz Avenue (Castle Rock)	0	2	2.6	1	1	6.60	10.46
092466V	Cowlitz Gardens Road (Kelso)	0	2	2.6	1	1	6.60	9.20
092458D	Mill Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092457W	S River Road/ Yew Street (Kelso)	0	2	2.6	1	1	6.60	12.24
092446J	Toteff Road/Port Road (Kalama)	0	2	2.6	1	1	6.60	9.19
092437K	W Scott Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092435W	Davidson Avenue (Woodland)	0	2	2.6	1	1	6.60	9.20
092434P	Whalen Road (Woodland)	0	2	2.6	1	1	6.60	9.20

Traffic Volumes- ADT					
	2018 No Action	2018 Construction, via truck	2018 Construction, via rail	2028 No Action	2028 Proposed Action
38th Avenue	400	3,050	2,200	600	1,690
Washington Way	3,200	3,200	3,200	3,800	3,800
Weyerhaeuser Norpac Entrance	700	700	700	950	950
Industrial Way/SR432	9,600	11,500	10,700	10,800	11,450
SR433-Oregon Way	13,400	13,850	13,850	16,750	17,020
California Way	3,750	3,750	3,750	5,450	5,450
3rd Ave-SR 432	16,300	17,300	16,650	20,000	20,220
Dike Rd	400	400	400	400	400
Taylor Crane Road	50	50	50	50	50
Cowlitz Ave	1,200	1,200	1,200	1,450	1,450
Cowlitz Garden	700	700	700	850	850
Mill St	2,550	2,550	2,550	3,000	3,000
S River St/Yew St	1,850	1,850	1,850	2,200	2,200
Toteff-Hendrick	1,200	1,200	1,200	1,450	1,450
W Scott Ave	2,650	2,650	2,650	3,100	3,100
Davidson Avenue	2,000	2,000	2,000	2,350	2,350
Whalen Rd	1,550	1,550	1,550	1,800	1,800

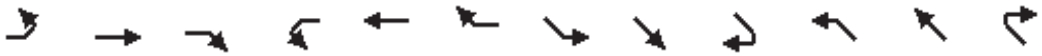
Traffic Volumes- PM Peak					
	2018 No Action	2018 Construction, via truck	2018 Construction, via rail	2028 No Action	2028 Proposed Action
38th Avenue	40	305	220	60	169
Washington Way	320	320	320	380	380
Weyerhaeuser Norpac Entrance	70	70	70	95	95
Industrial Way/SR432	960	1,150	1,070	1,080	1,145
SR433-Oregon Way	1,340	1,385	1,385	1,675	1,702
California Way	375	375	375	545	545
3rd Ave-SR 432	1,630	1,730	1,665	2,000	2,022
Dike Rd	40	40	40	40	40
Taylor Crane Road	5	5	5	5	5
Cowlitz Ave	120	120	120	145	145
Cowlitz Garden	70	70	70	85	85
Mill St	255	255	255	300	300
S River St/Yew St	185	185	185	220	220
Toteff-Hendrick	120	120	120	145	145
W Scott Ave	265	265	265	310	310
Davidson Avenue	200	200	200	235	235
Whalen Rd	155	155	155	180	180



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	755	0	0	585	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	821	0	0	636	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	821	0	0	636	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			3350			3350	
v/s Ratio Prot					c0.01			c0.23			0.18	
v/s Ratio Perm												
v/c Ratio					0.20			0.25			0.19	
Uniform Delay, d1					1453.7			5.9			5.5	
Progression Factor					0.02			1.00			1.00	
Incremental Delay, d2					4.6			0.2			0.1	
Delay (s)					39.4			6.1			5.6	
Level of Service					D			A			A	
Approach Delay (s)		0.0			39.4			6.1			5.6	
Approach LOS		A			D			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.3	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.24		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	30.9%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	190	0	0	185	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					200.0			2996.0			2996.0	
Effective Green, g (s)					200.0			2996.0			2996.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					118			1631			1727	
v/s Ratio Prot					c0.01			c0.12			0.11	
v/s Ratio Perm												
v/c Ratio					0.17			0.13			0.12	
Uniform Delay, d1					1421.3			7.4			7.3	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					3.1			0.2			0.1	
Delay (s)					12.4			7.5			7.4	
Level of Service					B			A			A	
Approach Delay (s)		0.0			12.4			7.5			7.4	
Approach LOS		A			B			A			A	

Intersection Summary			
HCM 2000 Control Delay	7.7	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	20.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

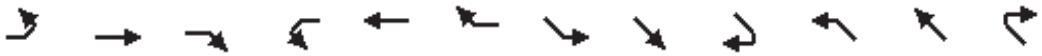
Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	420	0	0	540	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	457	0	0	587	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	457	0	0	587	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			1713			1650	
v/s Ratio Prot					c0.01			0.25			c0.34	
v/s Ratio Perm												
v/c Ratio					0.20			0.27			0.36	
Uniform Delay, d1					1453.7			6.0			6.8	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					4.6			0.4			0.6	
Delay (s)					4.8			6.4			7.4	
Level of Service					A			A			A	
Approach Delay (s)		0.0			4.8			6.4			7.4	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.9	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.35		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	38.4%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1000	0	0	630	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1124	0	0	708	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1124	0	0	708	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					200.0			2996.0			2996.0	
Effective Green, g (s)					200.0			2996.0			2996.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					118			2991			2913	
v/s Ratio Prot					c0.01			c0.35			0.23	
v/s Ratio Perm												
v/c Ratio					0.17			0.38			0.24	
Uniform Delay, d1					1421.3			10.0			8.4	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					3.1			0.4			0.2	
Delay (s)					1424.4			10.4			8.6	
Level of Service					F			B			A	
Approach Delay (s)		0.0			1424.4			10.4			8.6	
Approach LOS		A			F			B			A	

Intersection Summary			
HCM 2000 Control Delay	25.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.36		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	37.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	220	0	0	100	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2996.0			2996.0						200.0	
Effective Green, g (s)		2996.0			2996.0						200.0	
Actuated g/C Ratio		0.94			0.94						0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4670			3313						118	
v/s Ratio Prot		c0.05			0.03						c0.01	
v/s Ratio Perm												
v/c Ratio		0.05			0.03						0.17	
Uniform Delay, d1		6.8			6.7						1421.3	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						3.1	
Delay (s)		6.9			6.7						3.2	
Level of Service		A			A						A	
Approach Delay (s)		6.9			6.7			0.0			3.2	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.6	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	14.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	60	0	0	10	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			1764			1764	
v/s Ratio Prot					c0.01			c0.04			0.01	
v/s Ratio Perm												
v/c Ratio					0.20			0.04			0.01	
Uniform Delay, d1					1453.7			4.7			4.5	
Progression Factor					0.01			1.00			1.06	
Incremental Delay, d2					4.6			0.0			0.0	
Delay (s)					23.2			4.7			4.8	
Level of Service					C			A			A	
Approach Delay (s)		0.0			23.2			4.7			4.8	
Approach LOS		A			C			A			A	

Intersection Summary			
HCM 2000 Control Delay	8.5	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					304.0			2892.0			2892.0	
Effective Green, g (s)					304.0			2892.0			2892.0	
Actuated g/C Ratio					0.10			0.90			0.90	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					180			4148			1683	
v/s Ratio Prot					c0.01			0.00			c0.01	
v/s Ratio Perm												
v/c Ratio					0.11			0.00			0.01	
Uniform Delay, d1					1324.4			14.9			15.0	
Progression Factor					0.16			1.00			1.00	
Incremental Delay, d2					1.2			0.0			0.0	
Delay (s)					207.6			14.9			15.0	
Level of Service					F			B			B	
Approach Delay (s)		0.0			207.6			14.9			15.0	
Approach LOS		A			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	79.2	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.02		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		367.0			367.0			2829.0			2829.0	
Effective Green, g (s)		367.0			367.0			2829.0			2829.0	
Actuated g/C Ratio		0.11			0.11			0.88			0.88	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		108			108			1526			1526	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.19			0.19			0.01			0.01	
Uniform Delay, d1		1281.3			1281.3			21.8			21.8	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		3.7			3.7			0.0			0.0	
Delay (s)		1285.0			1285.0			21.8			21.8	
Level of Service		F			F			C			C	
Approach Delay (s)		1285.0			1285.0			21.8			21.8	
Approach LOS		F			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	653.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



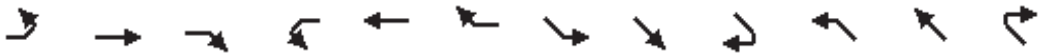
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	800	0	0	585	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	870	0	0	636	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	870	0	0	636	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			3350			3350	
v/s Ratio Prot					c0.01			c0.25			0.18	
v/s Ratio Perm												
v/c Ratio					0.20			0.26			0.19	
Uniform Delay, d1					1453.7			6.0			5.5	
Progression Factor					0.02			1.00			1.00	
Incremental Delay, d2					4.6			0.2			0.1	
Delay (s)					39.4			6.2			5.6	
Level of Service					D			A			A	
Approach Delay (s)		0.0			39.4			6.2			5.6	
Approach LOS		A			D			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.4	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.26		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	32.1%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	190	0	0	185	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					200.0			2996.0			2996.0	
Effective Green, g (s)					200.0			2996.0			2996.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					118			1631			1727	
v/s Ratio Prot					c0.01			c0.12			0.11	
v/s Ratio Perm												
v/c Ratio					0.17			0.13			0.12	
Uniform Delay, d1					1421.3			7.4			7.3	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					3.1			0.2			0.1	
Delay (s)					12.4			7.5			7.4	
Level of Service					B			A			A	
Approach Delay (s)		0.0			12.4			7.5			7.4	
Approach LOS		A			B			A			A	

Intersection Summary			
HCM 2000 Control Delay	7.7	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	20.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	570	0	0	582	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	620	0	0	633	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	620	0	0	633	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			1713			1650	
v/s Ratio Prot					c0.01			0.34			c0.36	
v/s Ratio Perm												
v/c Ratio					0.20			0.36			0.38	
Uniform Delay, d1					1453.7			6.9			7.1	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					4.6			0.6			0.7	
Delay (s)					4.8			7.5			7.8	
Level of Service					A			A			A	
Approach Delay (s)		0.0			4.8			7.5			7.8	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	7.6	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.37		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	40.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1067	0	0	661	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1199	0	0	743	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1199	0	0	743	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					200.0			2996.0			2996.0	
Effective Green, g (s)					200.0			2996.0			2996.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					118			2991			2913	
v/s Ratio Prot					c0.01			c0.38			0.24	
v/s Ratio Perm												
v/c Ratio					0.17			0.40			0.26	
Uniform Delay, d1					1421.3			10.4			8.5	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					3.1			0.4			0.2	
Delay (s)					1424.4			10.8			8.8	
Level of Service					F			B			A	
Approach Delay (s)		0.0			1424.4			10.8			8.8	
Approach LOS		A			F			B			A	

Intersection Summary			
HCM 2000 Control Delay	24.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.39		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	39.5%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	220	0	0	100	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2996.0			2996.0						200.0	
Effective Green, g (s)		2996.0			2996.0						200.0	
Actuated g/C Ratio		0.94			0.94						0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4670			3313						118	
v/s Ratio Prot		c0.05			0.03						c0.01	
v/s Ratio Perm												
v/c Ratio		0.05			0.03						0.17	
Uniform Delay, d1		6.8			6.7						1421.3	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						3.1	
Delay (s)		6.9			6.7						3.2	
Level of Service		A			A						A	
Approach Delay (s)		6.9			6.7			0.0			3.2	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.6	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	14.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	60	0	0	10	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					166.0			3030.0			3030.0	
Effective Green, g (s)					166.0			3030.0			3030.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					98			1764			1764	
v/s Ratio Prot					c0.01			c0.04			0.01	
v/s Ratio Perm												
v/c Ratio					0.20			0.04			0.01	
Uniform Delay, d1					1453.7			4.7			4.5	
Progression Factor					0.01			1.00			1.06	
Incremental Delay, d2					4.6			0.0			0.0	
Delay (s)					23.2			4.7			4.8	
Level of Service					C			A			A	
Approach Delay (s)		0.0			23.2			4.7			4.8	
Approach LOS		A			C			A			A	

Intersection Summary			
HCM 2000 Control Delay	8.5	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	242	0	0	62	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	247	0	0	63	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	247	0	0	63	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					304.0			2892.0			2892.0	
Effective Green, g (s)					304.0			2892.0			2892.0	
Actuated g/C Ratio					0.10			0.90			0.90	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					180			4148			1683	
v/s Ratio Prot					c0.01			c0.05			0.03	
v/s Ratio Perm												
v/c Ratio					0.11			0.06			0.04	
Uniform Delay, d1					1324.4			15.7			15.3	
Progression Factor					0.16			1.00			1.00	
Incremental Delay, d2					1.2			0.0			0.0	
Delay (s)					207.6			15.7			15.4	
Level of Service					F			B			B	
Approach Delay (s)		0.0			207.6			15.7			15.4	
Approach LOS		A			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	27.3	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	14.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		367.0			367.0			2829.0			2829.0	
Effective Green, g (s)		367.0			367.0			2829.0			2829.0	
Actuated g/C Ratio		0.11			0.11			0.88			0.88	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		108			108			1526			1526	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.19			0.19			0.01			0.01	
Uniform Delay, d1		1281.3			1281.3			21.8			21.8	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		3.7			3.7			0.0			0.0	
Delay (s)		1285.0			1285.0			21.8			21.8	
Level of Service		F			F			C			C	
Approach Delay (s)		1285.0			1285.0			21.8			21.8	
Approach LOS		F			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	653.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	800	0	0	585	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	870	0	0	636	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	870	0	0	636	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					452.0			2744.0			2744.0	
Effective Green, g (s)					452.0			2744.0			2744.0	
Actuated g/C Ratio					0.14			0.86			0.86	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					268			3034			3034	
v/s Ratio Prot					c0.01			c0.25			0.18	
v/s Ratio Perm												
v/c Ratio					0.07			0.29			0.21	
Uniform Delay, d1					1192.5			43.1			39.6	
Progression Factor					0.07			1.00			1.00	
Incremental Delay, d2					0.5			0.2			0.2	
Delay (s)					86.5			43.3			39.8	
Level of Service					F			D			D	
Approach Delay (s)		0.0			86.5			43.3			39.8	
Approach LOS		A			F			D			D	

Intersection Summary			
HCM 2000 Control Delay	42.4	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.26		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	32.1%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	190	0	0	185	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	204	0	0	199	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					558.0			2638.0			2638.0	
Effective Green, g (s)					558.0			2638.0			2638.0	
Actuated g/C Ratio					0.17			0.82			0.82	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					331			1436			1520	
v/s Ratio Prot					c0.01			c0.12			0.11	
v/s Ratio Perm												
v/c Ratio					0.06			0.14			0.13	
Uniform Delay, d1					1102.3			55.9			55.3	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					0.3			0.2			0.2	
Delay (s)					8.5			56.1			55.5	
Level of Service					A			E			E	
Approach Delay (s)		0.0			8.5			56.1			55.5	
Approach LOS		A			A			E			E	

Intersection Summary			
HCM 2000 Control Delay	53.6	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	20.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	528	0	0	540	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	574	0	0	587	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	574	0	0	587	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					452.0			2744.0			2744.0	
Effective Green, g (s)					452.0			2744.0			2744.0	
Actuated g/C Ratio					0.14			0.86			0.86	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					268			1552			1494	
v/s Ratio Prot					c0.01			0.32			c0.34	
v/s Ratio Perm												
v/c Ratio					0.07			0.37			0.39	
Uniform Delay, d1					1192.5			47.6			49.0	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					0.5			0.7			0.8	
Delay (s)					0.8			48.3			49.8	
Level of Service					A			D			D	
Approach Delay (s)		0.0			0.8			48.3			49.8	
Approach LOS		A			A			D			D	

Intersection Summary			
HCM 2000 Control Delay	48.2	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.35		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	38.4%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1036	0	0	630	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1164	0	0	708	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1164	0	0	708	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					558.0			2638.0			2638.0	
Effective Green, g (s)					558.0			2638.0			2638.0	
Actuated g/C Ratio					0.17			0.82			0.82	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					331			2633			2565	
v/s Ratio Prot					c0.01			c0.36			0.23	
v/s Ratio Perm												
v/c Ratio					0.06			0.44			0.28	
Uniform Delay, d1					1102.3			77.6			63.9	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					0.3			0.5			0.3	
Delay (s)					1102.6			78.2			64.2	
Level of Service					F			E			E	
Approach Delay (s)		0.0			1102.6			78.2			64.2	
Approach LOS		A			F			E			E	

Intersection Summary			
HCM 2000 Control Delay	83.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.38		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	38.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	220	0	0	100	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	244	0	0	111	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2638.0			2638.0						558.0	
Effective Green, g (s)		2638.0			2638.0						558.0	
Actuated g/C Ratio		0.82			0.82						0.17	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4111			2917						331	
v/s Ratio Prot		c0.05			0.03						c0.01	
v/s Ratio Perm												
v/c Ratio		0.06			0.04						0.06	
Uniform Delay, d1		51.9			50.9						1102.3	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						0.3	
Delay (s)		51.9			51.0						0.5	
Level of Service		D			D						A	
Approach Delay (s)		51.9			51.0			0.0			0.5	
Approach LOS		D			D			A			A	

Intersection Summary			
HCM 2000 Control Delay	48.9	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	14.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	60	0	0	10	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	67	0	0	11	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					452.0			2744.0			2744.0	
Effective Green, g (s)					452.0			2744.0			2744.0	
Actuated g/C Ratio					0.14			0.86			0.86	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					268			1597			1597	
v/s Ratio Prot					c0.01			c0.04			0.01	
v/s Ratio Perm												
v/c Ratio					0.07			0.04			0.01	
Uniform Delay, d1					1192.5			33.7			32.7	
Progression Factor					0.02			1.00			1.16	
Incremental Delay, d2					0.5			0.0			0.0	
Delay (s)					26.5			33.8			38.0	
Level of Service					C			C			D	
Approach Delay (s)		0.0			26.5			33.8			38.0	
Approach LOS		A			C			C			D	

Intersection Summary			
HCM 2000 Control Delay	32.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	200	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	204	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	204	0	0	20	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					876.0			2320.0			2320.0	
Effective Green, g (s)					876.0			2320.0			2320.0	
Actuated g/C Ratio					0.27			0.72			0.72	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					520			3327			1350	
v/s Ratio Prot					c0.01			c0.04			0.01	
v/s Ratio Perm												
v/c Ratio					0.04			0.06			0.01	
Uniform Delay, d1					852.9			126.6			122.3	
Progression Factor					0.22			1.00			1.00	
Incremental Delay, d2					0.1			0.0			0.0	
Delay (s)					190.8			126.7			122.3	
Level of Service					F			F			F	
Approach Delay (s)		0.0			190.8			126.7			122.3	
Approach LOS		A			F			F			F	

Intersection Summary			
HCM 2000 Control Delay	131.6	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		452.0			452.0			2744.0			2744.0	
Effective Green, g (s)		452.0			452.0			2744.0			2744.0	
Actuated g/C Ratio		0.14			0.14			0.86			0.86	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		134			134			1480			1480	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.15			0.15			0.01			0.01	
Uniform Delay, d1		1205.3			1205.3			32.9			32.9	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		2.3			2.3			0.0			0.0	
Delay (s)		1207.7			1207.7			32.9			32.9	
Level of Service		F			F			C			C	
Approach Delay (s)		1207.7			1207.7			32.9			32.9	
Approach LOS		F			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	620.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



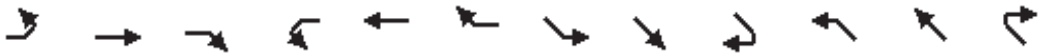
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	920	0	0	755	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	1000	0	0	821	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1000	0	0	821	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					167.0			3029.0			3029.0	
Effective Green, g (s)					167.0			3029.0			3029.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					99			3349			3349	
v/s Ratio Prot					c0.01			c0.28			0.23	
v/s Ratio Perm												
v/c Ratio					0.20			0.30			0.25	
Uniform Delay, d1					1452.7			6.4			5.9	
Progression Factor					0.02			1.00			1.00	
Incremental Delay, d2					4.5			0.2			0.2	
Delay (s)					39.8			6.6			6.1	
Level of Service					D			A			A	
Approach Delay (s)		0.0			39.8			6.6			6.1	
Approach LOS		A			D			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.7	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.29		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	35.4%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	260	0	0	285	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					203.0			2993.0			2993.0	
Effective Green, g (s)					203.0			2993.0			2993.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					120			1630			1725	
v/s Ratio Prot					c0.01			0.16			c0.17	
v/s Ratio Perm												
v/c Ratio					0.17			0.17			0.18	
Uniform Delay, d1					1418.4			8.0			8.0	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					3.0			0.2			0.2	
Delay (s)					12.4			8.2			8.3	
Level of Service					B			A			A	
Approach Delay (s)		0.0			12.4			8.2			8.3	
Approach LOS		A			B			A			A	

Intersection Summary			
HCM 2000 Control Delay	8.4	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.18		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	25.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	505	0	0	575	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	549	0	0	625	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	549	0	0	625	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					167.0			3029.0			3029.0	
Effective Green, g (s)					167.0			3029.0			3029.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					99			1713			1649	
v/s Ratio Prot					c0.01			0.30			c0.36	
v/s Ratio Perm												
v/c Ratio					0.20			0.32			0.38	
Uniform Delay, d1					1452.7			6.6			7.1	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					4.5			0.5			0.7	
Delay (s)					4.5			7.1			7.8	
Level of Service					A			A			A	
Approach Delay (s)		0.0			4.5			7.1			7.8	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	7.4	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.37		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	40.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1200	0	0	800	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1348	0	0	899	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1348	0	0	899	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					203.0			2993.0			2993.0	
Effective Green, g (s)					203.0			2993.0			2993.0	
Actuated g/C Ratio					0.06			0.94			0.94	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					120			2988			2910	
v/s Ratio Prot					c0.01			c0.42			0.29	
v/s Ratio Perm												
v/c Ratio					0.17			0.45			0.31	
Uniform Delay, d1					1418.4			11.6			9.4	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					3.0			0.5			0.3	
Delay (s)					1421.4			12.1			9.7	
Level of Service					F			B			A	
Approach Delay (s)		0.0			1421.4			12.1			9.7	
Approach LOS		A			F			B			A	

Intersection Summary			
HCM 2000 Control Delay	23.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.43		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	43.2%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	265	0	0	115	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2994.0			2994.0						202.0	
Effective Green, g (s)		2994.0			2994.0						202.0	
Actuated g/C Ratio		0.94			0.94						0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4666			3311						119	
v/s Ratio Prot		c0.06			0.04						c0.01	
v/s Ratio Perm												
v/c Ratio		0.06			0.04						0.17	
Uniform Delay, d1		7.0			6.9						1419.4	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						3.0	
Delay (s)		7.1			6.9						3.1	
Level of Service		A			A						A	
Approach Delay (s)		7.1			6.9			0.0			3.1	
Approach LOS		A			A			A			A	

Intersection Summary			
HCM 2000 Control Delay	6.8	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	15.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	75	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					167.0			3029.0			3029.0	
Effective Green, g (s)					167.0			3029.0			3029.0	
Actuated g/C Ratio					0.05			0.95			0.95	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					99			1763			1763	
v/s Ratio Prot					c0.01			c0.05			0.01	
v/s Ratio Perm												
v/c Ratio					0.20			0.05			0.01	
Uniform Delay, d1					1452.7			4.8			4.6	
Progression Factor					0.01			1.00			1.02	
Incremental Delay, d2					4.5			0.1			0.0	
Delay (s)					25.2			4.8			4.7	
Level of Service					C			A			A	
Approach Delay (s)		0.0			25.2			4.8			4.7	
Approach LOS		A			C			A			A	

Intersection Summary			
HCM 2000 Control Delay	8.1	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	30	0	0	30	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	31	0	0	31	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	31	0	0	31	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					307.0			2889.0			2889.0	
Effective Green, g (s)					307.0			2889.0			2889.0	
Actuated g/C Ratio					0.10			0.90			0.90	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					182			4143			1681	
v/s Ratio Prot					c0.01			0.01			c0.02	
v/s Ratio Perm												
v/c Ratio					0.11			0.01			0.02	
Uniform Delay, d1					1321.7			15.2			15.4	
Progression Factor					0.15			1.00			1.00	
Incremental Delay, d2					1.2			0.0			0.0	
Delay (s)					205.4			15.2			15.4	
Level of Service					F			B			B	
Approach Delay (s)		0.0			205.4			15.2			15.4	
Approach LOS		A			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	61.7	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		363.0			363.0			2833.0			2833.0	
Effective Green, g (s)		363.0			363.0			2833.0			2833.0	
Actuated g/C Ratio		0.11			0.11			0.89			0.89	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		107			107			1528			1528	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.19			0.19			0.01			0.01	
Uniform Delay, d1		1284.8			1284.8			21.3			21.3	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		3.8			3.8			0.0			0.0	
Delay (s)		1288.7			1288.7			21.3			21.3	
Level of Service		F			F			C			C	
Approach Delay (s)		1288.7			1288.7			21.3			21.3	
Approach LOS		F			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	655.0	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



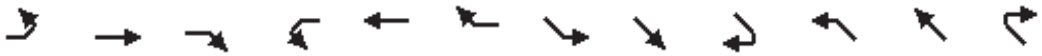
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	937	0	0	766	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					500.0			2696.0			2696.0	
Effective Green, g (s)					500.0			2696.0			2696.0	
Actuated g/C Ratio					0.16			0.84			0.84	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					296			2981			2981	
v/s Ratio Prot					c0.01			c0.29			0.24	
v/s Ratio Perm												
v/c Ratio					0.07			0.34			0.28	
Uniform Delay, d1					1151.2			55.7			51.9	
Progression Factor					0.08			1.00			1.00	
Incremental Delay, d2					0.4			0.3			0.2	
Delay (s)					96.1			56.0			52.1	
Level of Service					F			E			D	
Approach Delay (s)		0.0			96.1			56.0			52.1	
Approach LOS		A			F			E			D	

Intersection Summary			
HCM 2000 Control Delay	54.7	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.30		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	35.9%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	260	0	0	285	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					618.0			2578.0			2578.0	
Effective Green, g (s)					618.0			2578.0			2578.0	
Actuated g/C Ratio					0.19			0.81			0.81	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					366			1404			1486	
v/s Ratio Prot					c0.01			0.16			c0.17	
v/s Ratio Perm												
v/c Ratio					0.05			0.20			0.21	
Uniform Delay, d1					1052.8			72.0			72.5	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					0.3			0.3			0.3	
Delay (s)					8.2			72.3			72.8	
Level of Service					A			E			E	
Approach Delay (s)		0.0			8.2			72.3			72.8	
Approach LOS		A			A			E			E	

Intersection Summary			
HCM 2000 Control Delay	70.5	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.18		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	25.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



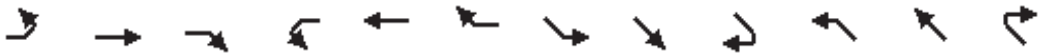
Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	546	0	0	600	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					500.0			2696.0			2696.0	
Effective Green, g (s)					500.0			2696.0			2696.0	
Actuated g/C Ratio					0.16			0.84			0.84	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					296			1524			1468	
v/s Ratio Prot					c0.01			0.33			c0.37	
v/s Ratio Perm												
v/c Ratio					0.07			0.39			0.44	
Uniform Delay, d1					1151.2			59.0			63.4	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					0.4			0.8			1.0	
Delay (s)					0.6			59.8			64.4	
Level of Service					A			E			E	
Approach Delay (s)		0.0			0.6			59.8			64.4	
Approach LOS		A			A			E			E	

Intersection Summary			
HCM 2000 Control Delay	61.2	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.39		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	41.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1214	0	0	808	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					618.0			2578.0			2578.0	
Effective Green, g (s)					618.0			2578.0			2578.0	
Actuated g/C Ratio					0.19			0.81			0.81	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					366			2573			2507	
v/s Ratio Prot					c0.01			c0.43			0.29	
v/s Ratio Perm												
v/c Ratio					0.05			0.53			0.36	
Uniform Delay, d1					1052.8			105.5			85.4	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					0.3			0.8			0.4	
Delay (s)					1053.1			106.3			85.8	
Level of Service					F			F			F	
Approach Delay (s)		0.0			1053.1			106.3			85.8	
Approach LOS		A			F			F			F	

Intersection Summary			
HCM 2000 Control Delay	106.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.44		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	43.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	265	0	0	115	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2578.0			2578.0						618.0	
Effective Green, g (s)		2578.0			2578.0						618.0	
Actuated g/C Ratio		0.81			0.81						0.19	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4018			2851						366	
v/s Ratio Prot		c0.06			0.04						c0.01	
v/s Ratio Perm												
v/c Ratio		0.07			0.04						0.05	
Uniform Delay, d1		64.2			62.7						1052.8	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						0.3	
Delay (s)		64.3			62.7						0.4	
Level of Service		E			E						A	
Approach Delay (s)		64.3			62.7			0.0			0.4	
Approach LOS		E			E			A			A	

Intersection Summary			
HCM 2000 Control Delay	60.9	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	15.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	75	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					500.0			2696.0			2696.0	
Effective Green, g (s)					500.0			2696.0			2696.0	
Actuated g/C Ratio					0.16			0.84			0.84	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					296			1569			1569	
v/s Ratio Prot					c0.01			c0.05			0.01	
v/s Ratio Perm												
v/c Ratio					0.07			0.05			0.01	
Uniform Delay, d1					1151.2			41.6			40.2	
Progression Factor					0.02			1.00			1.02	
Incremental Delay, d2					0.4			0.1			0.0	
Delay (s)					25.9			41.6			40.9	
Level of Service					C			D			D	
Approach Delay (s)		0.0			25.9			41.6			40.9	
Approach LOS		A			C			D			D	

Intersection Summary			
HCM 2000 Control Delay	39.0	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	98	0	0	71	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					971.0			2225.0			2225.0	
Effective Green, g (s)					971.0			2225.0			2225.0	
Actuated g/C Ratio					0.30			0.70			0.70	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					576			3191			1295	
v/s Ratio Prot					c0.01			0.02			c0.04	
v/s Ratio Perm												
v/c Ratio					0.03			0.03			0.06	
Uniform Delay, d1					784.6			151.8			154.5	
Progression Factor					0.23			1.00			1.00	
Incremental Delay, d2					0.1			0.0			0.1	
Delay (s)					184.3			151.9			154.6	
Level of Service					F			F			F	
Approach Delay (s)		0.0			184.3			151.9			154.6	
Approach LOS		A			F			F			F	

Intersection Summary			
HCM 2000 Control Delay	156.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		500.0			500.0			2696.0			2696.0	
Effective Green, g (s)		500.0			500.0			2696.0			2696.0	
Actuated g/C Ratio		0.16			0.16			0.84			0.84	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		148			148			1454			1454	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.14			0.14			0.01			0.01	
Uniform Delay, d1		1163.6			1163.6			40.2			40.2	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		1.9			1.9			0.0			0.0	
Delay (s)		1165.5			1165.5			40.2			40.2	
Level of Service		F			F			D			D	
Approach Delay (s)		1165.5			1165.5			40.2			40.2	
Approach LOS		F			F			D			D	

Intersection Summary			
HCM 2000 Control Delay	602.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	937	0	0	766	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					264.0			2932.0			2932.0	
Effective Green, g (s)					264.0			2932.0			2932.0	
Actuated g/C Ratio					0.08			0.92			0.92	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					156			3242			3242	
v/s Ratio Prot					c0.01			c0.29			0.24	
v/s Ratio Perm												
v/c Ratio					0.13			0.31			0.26	
Uniform Delay, d1					1361.3			15.8			14.7	
Progression Factor					0.15			1.00			1.00	
Incremental Delay, d2					1.7			0.3			0.2	
Delay (s)					203.8			16.0			14.9	
Level of Service					F			B			B	
Approach Delay (s)		0.0			203.8			16.0			14.9	
Approach LOS		A			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	17.5	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.30		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	35.9%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	260	0	0	285	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					500.0			2696.0			2696.0	
Effective Green, g (s)					500.0			2696.0			2696.0	
Actuated g/C Ratio					0.16			0.84			0.84	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					296			1468			1554	
v/s Ratio Prot					c0.01			0.16			c0.17	
v/s Ratio Perm												
v/c Ratio					0.07			0.19			0.20	
Uniform Delay, d1					1151.2			47.3			47.6	
Progression Factor					0.00			1.00			1.00	
Incremental Delay, d2					0.4			0.3			0.3	
Delay (s)					1.2			47.6			47.9	
Level of Service					A			D			D	
Approach Delay (s)		0.0			1.2			47.6			47.9	
Approach LOS		A			A			D			D	

Intersection Summary			
HCM 2000 Control Delay	46.2	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.18		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	25.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (vph)	0	0	0	0	20	0	0	546	0	0	600	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					264.0			2932.0			2932.0	
Effective Green, g (s)					264.0			2932.0			2932.0	
Actuated g/C Ratio					0.08			0.92			0.92	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					156			1658			1597	
v/s Ratio Prot					c0.01			0.33			c0.37	
v/s Ratio Perm												
v/c Ratio					0.13			0.36			0.41	
Uniform Delay, d1					1361.3			16.7			17.9	
Progression Factor					0.03			1.00			1.00	
Incremental Delay, d2					1.7			0.6			0.8	
Delay (s)					36.8			17.3			18.7	
Level of Service					D			B			B	
Approach Delay (s)		0.0			36.8			17.3			18.7	
Approach LOS		A			D			B			B	

Intersection Summary			
HCM 2000 Control Delay	18.3	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.39		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	41.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1214	0	0	808	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					342.0			2854.0			2854.0	
Effective Green, g (s)					342.0			2854.0			2854.0	
Actuated g/C Ratio					0.11			0.89			0.89	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					203			2849			2775	
v/s Ratio Prot					c0.01			c0.43			0.29	
v/s Ratio Perm												
v/c Ratio					0.10			0.48			0.33	
Uniform Delay, d1					1289.9			32.6			26.4	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					1.0			0.6			0.3	
Delay (s)					1290.8			33.2			26.7	
Level of Service					F			C			C	
Approach Delay (s)		0.0			1290.8			33.2			26.7	
Approach LOS		A			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	41.6	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.44		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	43.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	265	0	0	115	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		2696.0			2696.0						500.0	
Effective Green, g (s)		2696.0			2696.0						500.0	
Actuated g/C Ratio		0.84			0.84						0.16	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		4202			2981						296	
v/s Ratio Prot		c0.06			0.04						c0.01	
v/s Ratio Perm												
v/c Ratio		0.07			0.04						0.07	
Uniform Delay, d1		42.2			41.2						1151.2	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						0.4	
Delay (s)		42.2			41.2						0.4	
Level of Service		D			D						A	
Approach Delay (s)		42.2			41.2			0.0			0.4	
Approach LOS		D			D			A			A	

Intersection Summary			
HCM 2000 Control Delay	40.0	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	15.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	75	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					342.0			2854.0			2854.0	
Effective Green, g (s)					342.0			2854.0			2854.0	
Actuated g/C Ratio					0.11			0.89			0.89	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					203			1661			1661	
v/s Ratio Prot					c0.01			c0.05			0.01	
v/s Ratio Perm												
v/c Ratio					0.10			0.05			0.01	
Uniform Delay, d1					1289.9			19.6			18.9	
Progression Factor					2.07			1.00			1.02	
Incremental Delay, d2					1.0			0.1			0.0	
Delay (s)					2665.5			19.6			19.4	
Level of Service					F			B			B	
Approach Delay (s)		0.0			2665.5			19.6			19.4	
Approach LOS		A			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	439.6	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	98	0	0	71	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					971.0			2225.0			2225.0	
Effective Green, g (s)					971.0			2225.0			2225.0	
Actuated g/C Ratio					0.30			0.70			0.70	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					576			3191			1295	
v/s Ratio Prot					c0.01			0.02			c0.04	
v/s Ratio Perm												
v/c Ratio					0.03			0.03			0.06	
Uniform Delay, d1					784.6			151.8			154.5	
Progression Factor					0.01			1.00			1.00	
Incremental Delay, d2					0.1			0.0			0.1	
Delay (s)					4.2			151.9			154.6	
Level of Service					A			F			F	
Approach Delay (s)		0.0			4.2			151.9			154.6	
Approach LOS		A			A			F			F	

Intersection Summary			
HCM 2000 Control Delay	137.5	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		500.0			500.0			2696.0			2696.0	
Effective Green, g (s)		500.0			500.0			2696.0			2696.0	
Actuated g/C Ratio		0.16			0.16			0.84			0.84	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		148			148			1454			1454	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.14			0.14			0.01			0.01	
Uniform Delay, d1		1163.6			1163.6			40.2			40.2	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		1.9			1.9			0.0			0.0	
Delay (s)		1165.5			1165.5			40.2			40.2	
Level of Service		F			F			D			D	
Approach Delay (s)		1165.5			1165.5			40.2			40.2	
Approach LOS		F			F			D			D	

Intersection Summary			
HCM 2000 Control Delay	602.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	3200.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



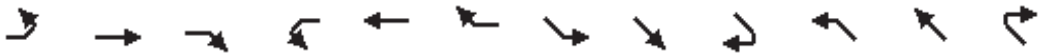
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	937	0	0	766	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frpb, ped/bikes					1.00			1.00			1.00	
Flpb, ped/bikes					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3539			3539	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3539			3539	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1018	0	0	833	0
Confl. Bikes (#/hr)									766			
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					264.0			1532.0			1532.0	
Effective Green, g (s)					264.0			1532.0			1532.0	
Actuated g/C Ratio					0.15			0.85			0.85	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					278			3012			3012	
v/s Ratio Prot					c0.01			c0.29			0.24	
v/s Ratio Perm												
v/c Ratio					0.07			0.34			0.28	
Uniform Delay, d1					662.3			28.0			26.1	
Progression Factor					0.27			1.00			1.00	
Incremental Delay, d2					0.5			0.3			0.2	
Delay (s)					179.4			28.3			26.3	
Level of Service					F			C			C	
Approach Delay (s)		0.0			179.4			28.3			26.3	
Approach LOS		A			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	29.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.30		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	35.9%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	260	0	0	285	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1743			1845	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1743			1845	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	280	0	0	306	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	9%	9%	9%	3%	3%	3%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					342.0			1454.0			1454.0	
Effective Green, g (s)					342.0			1454.0			1454.0	
Actuated g/C Ratio					0.19			0.81			0.81	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					361			1407			1490	
v/s Ratio Prot					c0.01			0.16			c0.17	
v/s Ratio Perm												
v/c Ratio					0.06			0.20			0.21	
Uniform Delay, d1					596.8			39.6			39.9	
Progression Factor					0.02			1.00			1.00	
Incremental Delay, d2					0.3			0.3			0.3	
Delay (s)					10.7			39.9			40.2	
Level of Service					B			D			D	
Approach Delay (s)		0.0			10.7			39.9			40.2	
Approach LOS		A			B			D			D	

Intersection Summary			
HCM 2000 Control Delay	39.1	HCM 2000 Level of Service	D
HCM 2000 Volume to Capacity ratio	0.18		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	25.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	546	0	0	600	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1810			1743	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1810			1743	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	593	0	0	652	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	5%	5%	5%	9%	9%	9%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					264.0			1532.0			1532.0	
Effective Green, g (s)					264.0			1532.0			1532.0	
Actuated g/C Ratio					0.15			0.85			0.85	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					278			1540			1483	
v/s Ratio Prot					c0.01			0.33			c0.37	
v/s Ratio Perm												
v/c Ratio					0.07			0.39			0.44	
Uniform Delay, d1					662.3			29.7			31.9	
Progression Factor					0.05			1.00			1.00	
Incremental Delay, d2					0.5			0.7			0.9	
Delay (s)					34.3			30.4			32.8	
Level of Service					C			C			C	
Approach Delay (s)		0.0			34.3			30.4			32.8	
Approach LOS		A			C			C			C	

Intersection Summary			
HCM 2000 Control Delay	31.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.39		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	41.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑↑			↑↑	
Volume (vph)	0	0	0	0	20	0	0	1214	0	0	808	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.95			0.95	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			3195			3112	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			3195			3112	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	1364	0	0	908	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	16%	16%	16%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					342.0			1454.0			1454.0	
Effective Green, g (s)					342.0			1454.0			1454.0	
Actuated g/C Ratio					0.19			0.81			0.81	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					361			2580			2513	
v/s Ratio Prot					c0.01			c0.43			0.29	
v/s Ratio Perm												
v/c Ratio					0.06			0.53			0.36	
Uniform Delay, d1					596.8			58.0			47.0	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					0.3			0.8			0.4	
Delay (s)					597.1			58.8			47.4	
Level of Service					F			E			D	
Approach Delay (s)		0.0			597.1			58.8			47.4	
Approach LOS		A			F			E			D	

Intersection Summary			
HCM 2000 Control Delay	59.0	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.44		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	43.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑↑↑			↑↑			↑			↑	
Volume (vph)	0	265	0	0	115	0	0	0	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		0.91			0.95						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		4988			3539						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		4988			3539						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	294	0	0	128	0	0	0	0	0	20	0
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3			1 3			2			2	
Permitted Phases												
Actuated Green, G (s)		1296.0			1296.0						500.0	
Effective Green, g (s)		1296.0			1296.0						500.0	
Actuated g/C Ratio		0.72			0.72						0.28	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		3591			2548						527	
v/s Ratio Prot		c0.06			0.04						c0.01	
v/s Ratio Perm												
v/c Ratio		0.08			0.05						0.04	
Uniform Delay, d1		75.0			73.2						474.4	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.0			0.0						0.1	
Delay (s)		75.0			73.2						0.1	
Level of Service		E			E						A	
Approach Delay (s)		75.0			73.2			0.0			0.1	
Approach LOS		E			E			A			A	

Intersection Summary			
HCM 2000 Control Delay	71.1	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	15.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	20	0	0	75	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	84	0	0	22	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					342.0			1454.0			1454.0	
Effective Green, g (s)					342.0			1454.0			1454.0	
Actuated g/C Ratio					0.19			0.81			0.81	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					361			1504			1504	
v/s Ratio Prot					c0.01			c0.05			0.01	
v/s Ratio Perm												
v/c Ratio					0.06			0.06			0.01	
Uniform Delay, d1					596.8			34.8			33.7	
Progression Factor					2.13			1.00			1.02	
Incremental Delay, d2					0.3			0.1			0.0	
Delay (s)					1272.2			34.9			34.4	
Level of Service					F			C			C	
Approach Delay (s)		0.0			1272.2			34.9			34.4	
Approach LOS		A			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	231.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.06		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑↑↑			↑	
Volume (vph)	0	0	0	0	20	0	0	98	0	0	71	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			0.91			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			4590			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			4590			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	0.98
Adj. Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	20	0	0	100	0	0	72	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	13%	13%	13%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)					971.0			825.0			825.0	
Effective Green, g (s)					971.0			825.0			825.0	
Actuated g/C Ratio					0.54			0.46			0.46	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)					1024			2103			853	
v/s Ratio Prot					c0.01			0.02			c0.04	
v/s Ratio Perm												
v/c Ratio					0.02			0.05			0.08	
Uniform Delay, d1					192.9			269.9			274.7	
Progression Factor					0.10			1.00			1.00	
Incremental Delay, d2					0.0			0.0			0.2	
Delay (s)					20.2			270.0			274.9	
Level of Service					C			F			F	
Approach Delay (s)		0.0			20.2			270.0			274.9	
Approach LOS		A			C			F			F	

Intersection Summary			
HCM 2000 Control Delay	245.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		950			950			1727			1727	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		950			950			1727			1727	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	20	0	0	20	0	0	20	0	0	20	0
Heavy Vehicles (%)	100%	100%	100%	100%	100%	100%	10%	10%	10%	10%	10%	10%
Turn Type		NA			NA			NA			NA	
Protected Phases		2			2			1 3			1 3	
Permitted Phases												
Actuated Green, G (s)		500.0			500.0			1296.0			1296.0	
Effective Green, g (s)		500.0			500.0			1296.0			1296.0	
Actuated g/C Ratio		0.28			0.28			0.72			0.72	
Clearance Time (s)		2.0			2.0							
Lane Grp Cap (vph)		263			263			1243			1243	
v/s Ratio Prot		0.02			c0.02			c0.01			0.01	
v/s Ratio Perm												
v/c Ratio		0.08			0.08			0.02			0.02	
Uniform Delay, d1		479.6			479.6			71.4			71.4	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.6			0.6			0.0			0.0	
Delay (s)		480.1			480.1			71.4			71.4	
Level of Service		F			F			E			E	
Approach Delay (s)		480.1			480.1			71.4			71.4	
Approach LOS		F			F			E			E	

Intersection Summary			
HCM 2000 Control Delay	275.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	6.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.4

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	410	10	30	530	10	65
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	446	11	33	576	11	73

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	457	0	1092	451
Stage 1	-	-	-	-	451	-
Stage 2	-	-	-	-	641	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	1073	-	186	507
Stage 1	-	-	-	-	539	-
Stage 2	-	-	-	-	432	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1073	-	180	507
Mov Cap-2 Maneuver	-	-	-	-	180	-
Stage 1	-	-	-	-	539	-
Stage 2	-	-	-	-	419	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	16.1
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	408	1073	-	-	-
HCM Lane V/C Ratio	0.207	0.03	-	-	-
HCM Control Delay (s)	16.1	8.5	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.8	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	115	240	120	360	305	155	170	485	405	70	430	85
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1872	1900
Adj Flow Rate, veh/h	128	267	0	400	339	172	189	539	450	78	478	94
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	161	468	240	471	451	417	229	1258	527	116	878	172
Arrive On Green	0.09	0.16	0.00	0.19	0.26	0.26	0.13	0.36	0.36	0.07	0.30	0.30
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	2968	580
Grp Volume(v), veh/h	128	267	0	400	339	172	189	539	450	78	285	287
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1778	1770
Q Serve(g_s), s	6.4	7.7	0.0	14.4	16.4	8.1	9.3	10.5	25.4	4.0	12.2	12.3
Cycle Q Clear(g_c), s	6.4	7.7	0.0	14.4	16.4	8.1	9.3	10.5	25.4	4.0	12.2	12.3
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.33
Lane Grp Cap(c), veh/h	161	468	240	471	451	417	229	1258	527	116	526	523
V/C Ratio(X)	0.80	0.57	0.00	0.85	0.75	0.41	0.83	0.43	0.85	0.67	0.54	0.55
Avail Cap(c_a), veh/h	311	709	364	778	664	614	417	1333	558	284	552	549
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	40.2	35.0	0.0	35.1	30.5	27.5	38.4	22.1	26.9	41.1	26.7	26.7
Incr Delay (d2), s/veh	8.7	1.6	0.0	4.8	3.8	0.9	7.4	0.3	12.1	6.6	1.2	1.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.5	3.2	0.0	5.1	8.2	3.6	5.0	5.1	12.0	2.1	6.1	6.1
LnGrp Delay(d),s/veh	48.9	36.6	0.0	39.8	34.3	28.4	45.8	22.4	39.0	47.7	27.8	27.9
LnGrp LOS	D	D		D	C	C	D	C	D	D	C	C
Approach Vol, veh/h		395			911			1178			650	
Approach Delay, s/veh		40.6			35.6			32.5			30.3	
Approach LOS		D			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	16.5	31.7	13.3	28.8	11.1	37.1	22.6	19.5
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	21.0	28.0	16.0	35.0	15.0	34.0	29.0	22.0
Max Q Clear Time (g_c+I1), s	11.3	14.3	8.4	18.4	6.0	27.4	16.4	9.7
Green Ext Time (p_c), s	0.3	8.3	0.2	5.4	0.1	4.7	1.2	4.6

Intersection Summary	
HCM 2010 Ctrl Delay	34.0
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	35	110	75	50	50	175	75	290	30	20	395	105
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	39	122	83	56	56	0	83	322	33	22	439	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	197	207	176	126	132	112	102	714	607	37	646	0
Arrive On Green	0.11	0.11	0.11	0.07	0.07	0.00	0.06	0.40	0.40	0.02	0.36	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	39	122	83	56	56	0	83	322	33	22	439	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	0.8	2.6	2.0	1.2	1.2	0.0	1.9	5.3	0.5	0.5	8.4	0.0
Cycle Q Clear(g_c), s	0.8	2.6	2.0	1.2	1.2	0.0	1.9	5.3	0.5	0.5	8.4	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	197	207	176	126	132	112	102	714	607	37	646	0
V/C Ratio(X)	0.20	0.59	0.47	0.45	0.42	0.00	0.81	0.45	0.05	0.60	0.68	0.00
Avail Cap(c_a), veh/h	344	361	307	351	369	313	296	1507	1281	169	1374	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	16.3	17.0	16.8	18.0	18.0	0.0	18.8	8.9	7.5	19.6	11.0	0.0
Incr Delay (d2), s/veh	0.5	2.7	2.0	2.5	2.2	0.0	14.0	0.4	0.0	14.3	1.3	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.4	1.4	0.9	0.7	0.7	0.0	1.3	2.7	0.2	0.4	4.3	0.0
LnGrp Delay(d),s/veh	16.7	19.7	18.8	20.5	20.2	0.0	32.7	9.4	7.5	33.9	12.2	0.0
LnGrp LOS	B	B	B	C	C		C	A	A	C	B	
Approach Vol, veh/h		244			112			438			461	
Approach Delay, s/veh		18.9			20.3			13.7			13.3	
Approach LOS		B			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	6.4	18.6		8.6	4.9	20.1		6.9
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	7.0	31.0		8.0	4.0	34.0		8.0
Max Q Clear Time (g_c+I1), s	3.9	10.4		4.6	2.5	7.3		3.2
Green Ext Time (p_c), s	0.0	4.2		0.3	0.0	4.4		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	15.1
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	145	880	10	20	600	30	15	10	25	60	10	120
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3144		1456	3077		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3144		1456	3077		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	156	946	11	22	645	32	16	11	27	65	11	129
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	21	0	0	80
Lane Group Flow (vph)	156	956	0	22	674	0	16	11	6	65	11	49
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	21.0	61.0		25.0	69.0		28.0	28.0	28.0	28.0	28.0	49.0
Effective Green, g (s)	21.0	61.0		25.0	69.0		28.0	28.0	28.0	28.0	28.0	49.0
Actuated g/C Ratio	0.16	0.47		0.19	0.53		0.22	0.22	0.22	0.22	0.22	0.38
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	283	1475		280	1633		219	409	269	264	272	633
v/s Ratio Prot	c0.09	c0.30		0.02	c0.22			0.01			0.01	0.01
v/s Ratio Perm							0.02		0.00	c0.05		0.02
v/c Ratio	0.55	0.65		0.08	0.41		0.07	0.03	0.02	0.25	0.04	0.08
Uniform Delay, d1	50.2	26.3		43.1	18.3		40.7	40.2	40.2	42.3	40.4	26.0
Progression Factor	1.00	1.00		1.17	0.01		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	7.5	2.2		0.4	0.6		0.6	0.1	0.1	2.2	0.3	0.2
Delay (s)	57.7	28.5		50.7	0.8		41.3	40.4	40.4	44.5	40.6	26.2
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		32.6			2.3			40.6			32.8	
Approach LOS		C			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	22.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.52		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	48.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	410	5	5	500	20	40
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	461	6	6	562	22	45

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	461	0	1034	461
Stage 1	-	-	-	-	461	-
Stage 2	-	-	-	-	573	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	1095	-	259	605
Stage 1	-	-	-	-	639	-
Stage 2	-	-	-	-	568	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1095	-	258	605
Mov Cap-2 Maneuver	-	-	-	-	258	-
Stage 1	-	-	-	-	639	-
Stage 2	-	-	-	-	565	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	15.3
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	418	1095	-	-	-
HCM Lane V/C Ratio	0.161	0.005	-	-	-
HCM Control Delay (s)	15.3	8.3	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.6	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	25	185	5	10	290	110	5	5	10	35	5	35
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	26	189	5	10	296	0	5	5	10	36	5	36
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	43	517	440	19	523	445	9	92	83	64	160	136
Arrive On Green	0.03	0.30	0.30	0.01	0.28	0.00	0.01	0.05	0.06	0.04	0.08	0.08
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	26	189	5	10	296	0	5	5	10	36	5	36
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.4	2.3	0.1	0.2	3.6	0.0	0.1	0.1	0.2	0.5	0.1	0.6
Cycle Q Clear(g_c), s	0.4	2.3	0.1	0.2	3.6	0.0	0.1	0.1	0.2	0.5	0.1	0.6
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	43	517	440	19	523	445	9	92	83	64	160	136
V/C Ratio(X)	0.60	0.37	0.01	0.53	0.57	0.00	0.57	0.05	0.12	0.57	0.03	0.26
Avail Cap(c_a), veh/h	370	1815	1542	264	1799	1529	240	1009	863	407	1283	1091
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	12.8	7.3	6.6	13.1	8.1	0.0	13.2	11.9	11.9	12.7	11.2	11.4
Incr Delay (d2), s/veh	4.9	0.2	0.0	8.4	0.4	0.0	20.0	0.1	0.2	2.9	0.0	0.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.2	1.1	0.0	0.1	1.9	0.0	0.1	0.0	0.1	0.3	0.0	0.3
LnGrp Delay(d),s/veh	17.7	7.5	6.6	21.5	8.5	0.0	33.2	12.0	12.1	15.6	11.2	11.8
LnGrp LOS	B	A	A	C	A		C	B	B	B	B	B
Approach Vol, veh/h		220			306			20			77	
Approach Delay, s/veh		8.7			8.9			17.4			13.5	
Approach LOS		A			A			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.7	11.6	4.9	5.5	4.3	12.0	4.1	6.2
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	6.0	26.0	6.0	16.0	4.0	28.0	4.0	18.0
Max Q Clear Time (g_c+I1), s	2.4	6.1	2.5	2.2	2.2	4.3	2.1	2.6
Green Ext Time (p_c), s	0.0	1.4	0.0	0.0	0.0	1.5	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	9.7
HCM 2010 LOS	A



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	35	50	950	15	15	615
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3148		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3148		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	39	56	1067	17	17	691
RTOR Reduction (vph)	0	45	1	0	0	0
Lane Group Flow (vph)	39	11	1083	0	17	691
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	18.0	25.0	89.0		7.0	47.0
Effective Green, g (s)	18.0	25.0	89.0		7.0	47.0
Actuated g/C Ratio	0.14	0.19	0.68		0.05	0.36
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	213	298	2155		67	1125
v/s Ratio Prot	c0.03	0.01	c0.34		c0.01	c0.22
v/s Ratio Perm						
v/c Ratio	0.18	0.04	0.50		0.25	0.61
Uniform Delay, d1	49.5	42.7	9.9		59.0	34.1
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	1.9	0.2	0.7		8.9	2.5
Delay (s)	51.4	42.9	3.2		67.9	36.6
Level of Service	D	D	A		E	D
Approach Delay (s)	46.4		3.2			37.3
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	18.2	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.47		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	36.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	2.1

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	25	10	10	55	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	27	11	11	60	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	38	0	115	33
Stage 1	-	-	-	-	33	-
Stage 2	-	-	-	-	82	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1572	-	881	1041
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	941	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1572	-	875	1041
Mov Cap-2 Maneuver	-	-	-	-	875	-
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	934	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1.1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	951	-	-	1572	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.5

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	560	10	30	572	10	65
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	609	11	33	622	11	73

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	620	0	1301	614
Stage 1	-	-	-	-	614	-
Stage 2	-	-	-	-	687	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	932	-	136	403
Stage 1	-	-	-	-	446	-
Stage 2	-	-	-	-	410	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	932	-	131	403
Mov Cap-2 Maneuver	-	-	-	-	131	-
Stage 1	-	-	-	-	446	-
Stage 2	-	-	-	-	395	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.4	20.5
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	316	932	-	-	-
HCM Lane V/C Ratio	0.267	0.035	-	-	-
HCM Control Delay (s)	20.5	9	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1.1	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	160	307	158	360	336	155	181	485	405	70	430	85
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1872	1900
Adj Flow Rate, veh/h	178	341	0	400	373	172	201	539	450	78	478	94
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	213	592	304	465	469	434	238	1179	494	113	791	155
Arrive On Green	0.12	0.20	0.00	0.19	0.27	0.27	0.13	0.33	0.33	0.07	0.27	0.27
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	2968	580
Grp Volume(v), veh/h	178	341	0	400	373	172	201	539	450	78	285	287
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1778	1770
Q Serve(g_s), s	9.6	10.3	0.0	15.5	19.7	8.6	10.7	11.7	28.3	4.4	13.6	13.8
Cycle Q Clear(g_c), s	9.6	10.3	0.0	15.5	19.7	8.6	10.7	11.7	28.3	4.4	13.6	13.8
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.33
Lane Grp Cap(c), veh/h	213	592	304	465	469	434	238	1179	494	113	474	472
V/C Ratio(X)	0.84	0.58	0.00	0.86	0.80	0.40	0.85	0.46	0.91	0.69	0.60	0.61
Avail Cap(c_a), veh/h	343	688	353	722	580	537	368	1200	502	263	512	509
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	41.8	35.0	0.0	38.1	32.8	28.8	41.2	25.5	31.1	44.5	31.2	31.2
Incr Delay (d2), s/veh	9.4	1.3	0.0	6.5	7.0	0.8	10.4	0.3	20.9	7.3	2.0	2.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.3	4.2	0.0	5.6	10.2	3.9	6.0	5.7	14.4	2.3	6.9	7.0
LnGrp Delay(d),s/veh	51.2	36.3	0.0	44.5	39.8	29.6	51.6	25.9	52.0	51.8	33.1	33.3
LnGrp LOS	D	D		D	D	C	D	C	D	D	C	C
Approach Vol, veh/h		519			945			1190			650	
Approach Delay, s/veh		41.4			39.9			40.1			35.5	
Approach LOS		D			D			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	17.9	30.9	16.8	31.7	11.4	37.4	23.7	24.8
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	20.0	28.0	19.0	33.0	15.0	33.0	29.0	23.0
Max Q Clear Time (g_c+I1), s	12.7	15.8	11.6	21.7	6.4	30.3	17.5	12.3
Green Ext Time (p_c), s	0.3	7.6	0.2	5.0	0.1	2.1	1.1	4.8

Intersection Summary	
HCM 2010 Ctrl Delay	39.3
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	35	110	75	50	50	175	138	440	30	20	437	105
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	39	122	83	56	56	0	153	489	33	22	486	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	184	193	164	115	120	102	194	852	724	36	686	0
Arrive On Green	0.11	0.11	0.11	0.06	0.06	0.00	0.11	0.48	0.48	0.02	0.38	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	39	122	83	56	56	0	153	489	33	22	486	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	1.0	3.1	2.4	1.5	1.4	0.0	4.2	9.4	0.6	0.6	11.0	0.0
Cycle Q Clear(g_c), s	1.0	3.1	2.4	1.5	1.4	0.0	4.2	9.4	0.6	0.6	11.0	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	184	193	164	115	120	102	194	852	724	36	686	0
V/C Ratio(X)	0.21	0.63	0.51	0.49	0.47	0.00	0.79	0.57	0.05	0.61	0.71	0.00
Avail Cap(c_a), veh/h	254	266	226	259	272	231	320	1344	1142	142	1157	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	19.6	20.6	20.3	21.7	21.7	0.0	20.7	9.1	6.8	23.3	12.5	0.0
Incr Delay (d2), s/veh	0.6	3.4	2.4	3.2	2.8	0.0	6.9	0.6	0.0	15.4	1.4	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	1.7	1.1	0.8	0.8	0.0	2.3	4.8	0.2	0.4	5.7	0.0
LnGrp Delay(d),s/veh	20.2	24.0	22.7	24.9	24.4	0.0	27.6	9.7	6.8	38.7	13.9	0.0
LnGrp LOS	C	C	C	C	C		C	A	A	D	B	
Approach Vol, veh/h		244			112			675			508	
Approach Delay, s/veh		22.9			24.7			13.6			15.0	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	9.5	22.4		9.1	5.0	26.8		7.1
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	9.0	31.0		7.0	4.0	36.0		7.0
Max Q Clear Time (g_c+I1), s	6.2	13.0		5.1	2.6	11.4		3.5
Green Ext Time (p_c), s	0.1	5.4		0.2	0.0	5.9		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	16.4
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	145	947	10	20	631	30	15	10	25	60	10	120
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3146		1456	3078		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3146		1456	3078		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	156	1018	11	22	678	32	16	11	27	65	11	129
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	21	0	0	81
Lane Group Flow (vph)	156	1028	0	22	707	0	16	11	6	65	11	48
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	21.0	63.0		24.0	70.0		27.0	27.0	27.0	27.0	27.0	48.0
Effective Green, g (s)	21.0	63.0		24.0	70.0		27.0	27.0	27.0	27.0	27.0	48.0
Actuated g/C Ratio	0.16	0.48		0.18	0.54		0.21	0.21	0.21	0.21	0.21	0.37
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	283	1524		268	1657		211	394	260	255	263	621
v/s Ratio Prot	c0.09	c0.33		0.02	c0.23			0.01			0.01	0.01
v/s Ratio Perm							0.02		0.00	c0.05		0.02
v/c Ratio	0.55	0.67		0.08	0.43		0.08	0.03	0.02	0.25	0.04	0.08
Uniform Delay, d1	50.2	25.7		43.9	18.0		41.5	41.0	41.0	43.1	41.2	26.6
Progression Factor	1.00	1.00		1.18	0.01		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	7.5	2.4		0.5	0.6		0.7	0.1	0.2	2.4	0.3	0.2
Delay (s)	57.7	28.1		52.0	0.8		42.2	41.2	41.1	45.5	41.5	26.9
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		32.0			2.3			41.4			33.5	
Approach LOS		C			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	22.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.55		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	49.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	560	5	5	542	20	40
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	629	6	6	609	22	45

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	629	0	1249	629
Stage 1	-	-	-	-	629	-
Stage 2	-	-	-	-	620	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	948	-	193	486
Stage 1	-	-	-	-	535	-
Stage 2	-	-	-	-	540	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	948	-	192	486
Mov Cap-2 Maneuver	-	-	-	-	192	-
Stage 1	-	-	-	-	535	-
Stage 2	-	-	-	-	537	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	19.1
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	322	948	-	-	-
HCM Lane V/C Ratio	0.209	0.006	-	-	-
HCM Control Delay (s)	19.1	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.8	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	25	185	5	52	290	110	14	5	223	35	5	35
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	26	189	5	53	296	0	14	5	228	36	5	36
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	42	412	350	82	478	406	23	334	288	62	414	352
Arrive On Green	0.03	0.24	0.24	0.05	0.26	0.00	0.01	0.20	0.20	0.03	0.22	0.22
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	26	189	5	53	296	0	14	5	228	36	5	36
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.5	3.1	0.1	1.0	4.7	0.0	0.3	0.1	5.0	0.7	0.1	0.6
Cycle Q Clear(g_c), s	0.5	3.1	0.1	1.0	4.7	0.0	0.3	0.1	5.0	0.7	0.1	0.6
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	42	412	350	82	478	406	23	334	288	62	414	352
V/C Ratio(X)	0.62	0.46	0.01	0.65	0.62	0.00	0.60	0.01	0.79	0.58	0.01	0.10
Avail Cap(c_a), veh/h	248	1407	1196	212	1446	1230	193	913	780	273	1089	925
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	16.0	10.8	9.7	15.5	10.8	0.0	16.2	10.7	12.6	15.8	10.2	10.4
Incr Delay (d2), s/veh	5.3	0.4	0.0	3.2	0.5	0.0	8.8	0.0	1.9	3.2	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.5	0.0	0.5	2.4	0.0	0.2	0.0	2.1	0.4	0.0	0.3
LnGrp Delay(d),s/veh	21.3	11.2	9.7	18.7	11.3	0.0	25.0	10.7	14.4	19.0	10.2	10.4
LnGrp LOS	C	B	A	B	B		C	B	B	B	B	B
Approach Vol, veh/h		220			349			247			77	
Approach Delay, s/veh		12.3			12.4			15.0			14.4	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.9	12.6	5.1	10.6	5.5	11.9	4.5	11.2
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	5.0	26.0	5.0	18.0	4.0	27.0	4.0	19.0
Max Q Clear Time (g_c+I1), s	2.5	7.2	2.7	7.0	3.0	5.1	2.3	2.6
Green Ext Time (p_c), s	0.0	1.4	0.0	0.1	0.0	1.4	0.0	0.1

Intersection Summary	
HCM 2010 Ctrl Delay	13.3
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	35	50	1017	15	15	646
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3150		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3150		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	39	56	1143	17	17	726
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	39	10	1159	0	17	726
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	49.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	49.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.38
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2180		67	1172
v/s Ratio Prot	c0.03	0.01	c0.37		c0.01	c0.23
v/s Ratio Perm						
v/c Ratio	0.19	0.04	0.53		0.25	0.62
Uniform Delay, d1	50.4	43.5	9.7		59.0	32.9
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	2.1	0.2	0.7		8.9	2.5
Delay (s)	52.5	43.7	3.3		67.9	35.4
Level of Service	D	D	A		E	D
Approach Delay (s)	47.4		3.3			36.1
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	17.6	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.49		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	38.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	2.1

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	25	10	10	55	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	27	11	11	60	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	38	0	115	33
Stage 1	-	-	-	-	33	-
Stage 2	-	-	-	-	82	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1572	-	881	1041
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	941	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1572	-	875	1041
Mov Cap-2 Maneuver	-	-	-	-	875	-
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	934	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1.1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	951	-	-	1572	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.5

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	518	10	30	530	10	65
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	563	11	33	576	11	73

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	574	0	1209	568
Stage 1	-	-	-	-	568	-
Stage 2	-	-	-	-	641	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	970	-	157	430
Stage 1	-	-	-	-	471	-
Stage 2	-	-	-	-	432	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	970	-	152	430
Mov Cap-2 Maneuver	-	-	-	-	152	-
Stage 1	-	-	-	-	471	-
Stage 2	-	-	-	-	417	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	18.7
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	346	970	-	-	-
HCM Lane V/C Ratio	0.244	0.034	-	-	-
HCM Control Delay (s)	18.7	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.9	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	160	276	147	360	305	155	170	485	405	70	430	85
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1872	1900
Adj Flow Rate, veh/h	178	307	0	400	339	172	189	539	450	78	478	94
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	214	546	281	468	443	410	227	1204	504	114	833	163
Arrive On Green	0.12	0.19	0.00	0.19	0.26	0.26	0.13	0.34	0.34	0.07	0.28	0.28
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	2968	580
Grp Volume(v), veh/h	178	307	0	400	339	172	189	539	450	78	285	287
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1778	1770
Q Serve(g_s), s	9.3	9.0	0.0	15.0	17.3	8.5	9.7	11.2	27.1	4.2	13.0	13.1
Cycle Q Clear(g_c), s	9.3	9.0	0.0	15.0	17.3	8.5	9.7	11.2	27.1	4.2	13.0	13.1
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.33
Lane Grp Cap(c), veh/h	214	546	281	468	443	410	227	1204	504	114	499	497
V/C Ratio(X)	0.83	0.56	0.00	0.86	0.77	0.42	0.83	0.45	0.89	0.68	0.57	0.58
Avail Cap(c_a), veh/h	354	710	365	746	599	554	380	1239	519	272	528	526
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	40.4	34.8	0.0	36.8	32.3	29.0	40.2	24.2	29.5	43.0	29.1	29.1
Incr Delay (d2), s/veh	8.3	1.3	0.0	5.7	5.0	1.0	7.8	0.3	17.5	7.0	1.5	1.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.0	3.7	0.0	5.4	8.7	3.8	5.3	5.5	13.5	2.2	6.6	6.6
LnGrp Delay(d),s/veh	48.7	36.1	0.0	42.5	37.3	30.0	48.0	24.5	47.0	50.0	30.6	30.7
LnGrp LOS	D	D		D	D	C	D	C	D	D	C	C
Approach Vol, veh/h		485			911			1178			650	
Approach Delay, s/veh		40.7			38.2			36.8			33.0	
Approach LOS		D			D			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	16.9	31.4	16.5	29.4	11.3	37.1	23.2	22.7
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	20.0	28.0	19.0	33.0	15.0	33.0	29.0	23.0
Max Q Clear Time (g_c+I1), s	11.7	15.1	11.3	19.3	6.2	29.1	17.0	11.0
Green Ext Time (p_c), s	0.3	7.9	0.3	5.1	0.1	3.0	1.2	4.7

Intersection Summary	
HCM 2010 Ctrl Delay	37.0
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	35	110	75	50	50	175	138	398	30	20	395	105
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	39	122	83	56	56	0	153	442	33	22	439	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	187	196	167	118	124	106	195	810	689	36	644	0
Arrive On Green	0.11	0.11	0.11	0.07	0.07	0.00	0.11	0.45	0.45	0.02	0.36	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	39	122	83	56	56	0	153	442	33	22	439	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	0.9	2.9	2.3	1.4	1.3	0.0	4.0	8.1	0.6	0.6	9.4	0.0
Cycle Q Clear(g_c), s	0.9	2.9	2.3	1.4	1.3	0.0	4.0	8.1	0.6	0.6	9.4	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	187	196	167	118	124	106	195	810	689	36	644	0
V/C Ratio(X)	0.21	0.62	0.50	0.47	0.45	0.00	0.79	0.55	0.05	0.60	0.68	0.00
Avail Cap(c_a), veh/h	268	282	239	274	287	244	338	1421	1208	150	1224	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	18.5	19.4	19.1	20.4	20.4	0.0	19.6	9.0	7.0	22.0	12.3	0.0
Incr Delay (d2), s/veh	0.5	3.2	2.3	2.9	2.5	0.0	6.8	0.6	0.0	15.0	1.3	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	1.6	1.1	0.8	0.8	0.0	2.2	4.1	0.2	0.4	4.9	0.0
LnGrp Delay(d),s/veh	19.0	22.6	21.4	23.3	22.9	0.0	26.4	9.6	7.0	37.0	13.6	0.0
LnGrp LOS	B	C	C	C	C		C	A	A	D	B	
Approach Vol, veh/h		244			112			628			461	
Approach Delay, s/veh		21.6			23.1			13.6			14.7	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	9.2	20.3		8.9	5.0	24.5		7.0
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	9.0	31.0		7.0	4.0	36.0		7.0
Max Q Clear Time (g_c+I1), s	6.0	11.4		4.9	2.6	10.1		3.4
Green Ext Time (p_c), s	0.1	4.9		0.2	0.0	5.3		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	16.0
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	145	916	10	20	600	30	15	10	25	60	10	120
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3145		1456	3077		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3145		1456	3077		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	156	985	11	22	645	32	16	11	27	65	11	129
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	21	0	0	81
Lane Group Flow (vph)	156	995	0	22	674	0	16	11	6	65	11	48
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	21.0	63.0		24.0	70.0		27.0	27.0	27.0	27.0	27.0	48.0
Effective Green, g (s)	21.0	63.0		24.0	70.0		27.0	27.0	27.0	27.0	27.0	48.0
Actuated g/C Ratio	0.16	0.48		0.18	0.54		0.21	0.21	0.21	0.21	0.21	0.37
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	283	1524		268	1656		211	394	260	255	263	621
v/s Ratio Prot	c0.09	c0.32		0.02	c0.22			0.01			0.01	0.01
v/s Ratio Perm							0.02		0.00	c0.05		0.02
v/c Ratio	0.55	0.65		0.08	0.41		0.08	0.03	0.02	0.25	0.04	0.08
Uniform Delay, d1	50.2	25.3		43.9	17.7		41.5	41.0	41.0	43.1	41.2	26.6
Progression Factor	1.00	1.00		1.20	0.01		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	7.5	2.2		0.5	0.6		0.7	0.1	0.2	2.4	0.3	0.2
Delay (s)	57.7	27.5		53.2	0.7		42.2	41.2	41.1	45.5	41.5	26.9
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		31.6			2.4			41.4			33.5	
Approach LOS		C			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	22.3	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.53		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	49.0%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	518	5	5	500	20	40
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	582	6	6	562	22	45

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	582	0	1155	582
Stage 1	-	-	-	-	582	-
Stage 2	-	-	-	-	573	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	987	-	220	517
Stage 1	-	-	-	-	563	-
Stage 2	-	-	-	-	568	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	987	-	219	517
Mov Cap-2 Maneuver	-	-	-	-	219	-
Stage 1	-	-	-	-	563	-
Stage 2	-	-	-	-	565	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	17.5
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	356	987	-	-	-
HCM Lane V/C Ratio	0.189	0.006	-	-	-
HCM Control Delay (s)	17.5	8.7	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.7	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	25	185	5	10	290	110	14	5	181	35	5	35
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	26	189	5	10	296	0	14	5	185	36	5	36
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	43	483	411	19	488	415	23	280	242	62	353	300
Arrive On Green	0.03	0.28	0.28	0.01	0.26	0.00	0.01	0.17	0.17	0.03	0.19	0.19
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	26	189	5	10	296	0	14	5	185	36	5	36
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.5	2.8	0.1	0.2	4.4	0.0	0.3	0.1	3.9	0.6	0.1	0.6
Cycle Q Clear(g_c), s	0.5	2.8	0.1	0.2	4.4	0.0	0.3	0.1	3.9	0.6	0.1	0.6
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	43	483	411	19	488	415	23	280	242	62	353	300
V/C Ratio(X)	0.61	0.39	0.01	0.53	0.61	0.00	0.60	0.02	0.76	0.58	0.01	0.12
Avail Cap(c_a), veh/h	262	1483	1261	223	1525	1296	204	962	823	288	1148	976
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	15.2	9.2	8.2	15.5	10.1	0.0	15.4	11.0	12.5	15.0	10.4	10.7
Incr Delay (d2), s/veh	5.2	0.2	0.0	8.5	0.5	0.0	8.7	0.0	1.9	3.1	0.0	0.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.3	0.0	0.1	2.3	0.0	0.2	0.0	1.6	0.4	0.0	0.3
LnGrp Delay(d),s/veh	20.3	9.4	8.2	24.0	10.6	0.0	24.1	11.0	14.3	18.1	10.5	10.7
LnGrp LOS	C	A	A	C	B		C	B	B	B	B	B
Approach Vol, veh/h		220			306			204			77	
Approach Delay, s/veh		10.7			11.0			14.9			14.2	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.8	12.3	5.1	9.2	4.3	12.8	4.5	9.9
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	5.0	26.0	5.0	18.0	4.0	27.0	4.0	19.0
Max Q Clear Time (g_c+I1), s	2.5	6.9	2.6	5.9	2.2	4.8	2.3	2.6
Green Ext Time (p_c), s	0.0	1.4	0.0	0.0	0.0	1.4	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	12.2
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	35	50	986	15	15	615
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3149		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3149		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	39	56	1108	17	17	691
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	39	10	1124	0	17	691
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	49.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	49.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.38
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2180		67	1172
v/s Ratio Prot	c0.03	0.01	c0.36		c0.01	c0.22
v/s Ratio Perm						
v/c Ratio	0.19	0.04	0.52		0.25	0.59
Uniform Delay, d1	50.4	43.5	9.6		59.0	32.4
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	2.1	0.2	0.7		8.9	2.2
Delay (s)	52.5	43.7	3.2		67.9	34.6
Level of Service	D	D	A		E	C
Approach Delay (s)	47.4		3.2			35.4
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	17.2	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.47		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	37.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	2.1

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	25	10	10	55	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	27	11	11	60	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	38	0	115	33
Stage 1	-	-	-	-	33	-
Stage 2	-	-	-	-	82	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1572	-	881	1041
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	941	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1572	-	875	1041
Mov Cap-2 Maneuver	-	-	-	-	875	-
Stage 1	-	-	-	-	989	-
Stage 2	-	-	-	-	934	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1.1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	951	-	-	1572	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.8

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	495	10	35	565	10	85
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	538	11	38	614	11	96

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	549	0	1233	543
Stage 1	-	-	-	-	543	-
Stage 2	-	-	-	-	690	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	991	-	151	446
Stage 1	-	-	-	-	484	-
Stage 2	-	-	-	-	408	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	991	-	145	446
Mov Cap-2 Maneuver	-	-	-	-	145	-
Stage 1	-	-	-	-	484	-
Stage 2	-	-	-	-	392	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	18.8
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	366	991	-	-	-
HCM Lane V/C Ratio	0.292	0.038	-	-	-
HCM Control Delay (s)	18.8	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1.2	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	120	315	145	485	340	190	175	610	490	80	590	85
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1874	1900
Adj Flow Rate, veh/h	133	350	0	539	378	211	194	678	544	89	656	94
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	161	450	231	594	527	488	226	1209	506	121	895	128
Arrive On Green	0.09	0.15	0.00	0.25	0.31	0.31	0.13	0.34	0.34	0.07	0.29	0.29
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	3128	448
Grp Volume(v), veh/h	133	350	0	539	378	211	194	678	544	89	373	377
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1781	1795
Q Serve(g_s), s	7.9	12.3	0.0	23.0	20.9	11.3	11.3	16.6	36.4	5.4	20.2	20.2
Cycle Q Clear(g_c), s	7.9	12.3	0.0	23.0	20.9	11.3	11.3	16.6	36.4	5.4	20.2	20.2
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.25
Lane Grp Cap(c), veh/h	161	450	231	594	527	488	226	1209	506	121	510	514
V/C Ratio(X)	0.82	0.78	0.00	0.91	0.72	0.43	0.86	0.56	1.07	0.74	0.73	0.73
Avail Cap(c_a), veh/h	198	492	253	705	595	550	286	1209	506	240	568	573
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	47.5	43.3	0.0	39.0	32.7	29.4	45.6	28.6	35.1	48.5	34.3	34.3
Incr Delay (d2), s/veh	20.2	7.8	0.0	14.0	4.2	0.9	18.6	0.7	61.6	8.4	4.6	4.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.7	5.4	0.0	8.9	10.5	5.1	6.8	8.2	23.4	2.9	10.6	10.7
LnGrp Delay(d),s/veh	67.8	51.0	0.0	53.0	36.9	30.3	64.2	29.2	96.7	56.9	38.9	38.9
LnGrp LOS	E	D		D	D	C	E	C	F	E	D	D
Approach Vol, veh/h		483			1128			1416			839	
Approach Delay, s/veh		55.6			43.3			59.9			40.8	
Approach LOS		E			D			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.4	35.5	14.8	37.8	12.5	41.4	31.1	21.5
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	17.0	34.0	12.0	37.0	15.0	36.0	31.0	18.0
Max Q Clear Time (g_c+I1), s	13.3	22.2	9.9	22.9	7.4	38.4	25.0	14.3
Green Ext Time (p_c), s	0.2	8.3	0.1	6.0	0.1	0.0	1.1	2.2

Intersection Summary	
HCM 2010 Ctrl Delay	50.4
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	40	135	90	60	60	210	95	370	35	20	445	115
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	44	150	100	67	67	0	106	411	39	22	494	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	217	228	194	125	131	112	134	791	673	36	689	0
Arrive On Green	0.12	0.12	0.12	0.07	0.07	0.00	0.08	0.44	0.44	0.02	0.38	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	44	150	100	67	67	0	106	411	39	22	494	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	1.1	3.7	2.8	1.7	1.6	0.0	2.9	7.8	0.7	0.6	11.0	0.0
Cycle Q Clear(g_c), s	1.1	3.7	2.8	1.7	1.6	0.0	2.9	7.8	0.7	0.6	11.0	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	217	228	194	125	131	112	134	791	673	36	689	0
V/C Ratio(X)	0.20	0.66	0.52	0.54	0.51	0.00	0.79	0.52	0.06	0.61	0.72	0.00
Avail Cap(c_a), veh/h	298	312	266	265	279	237	255	1341	1140	146	1226	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	18.4	19.5	19.1	21.0	21.0	0.0	21.2	9.5	7.5	22.7	12.2	0.0
Incr Delay (d2), s/veh	0.5	3.2	2.1	3.5	3.0	0.0	10.1	0.5	0.0	15.2	1.4	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	2.0	1.3	1.0	0.9	0.0	1.7	3.9	0.3	0.4	5.6	0.0
LnGrp Delay(d),s/veh	18.8	22.7	21.3	24.5	24.0	0.0	31.3	10.0	7.5	37.9	13.6	0.0
LnGrp LOS	B	C	C	C	C		C	A	A	D	B	
Approach Vol, veh/h		294			134			556			516	
Approach Delay, s/veh		21.7			24.3			13.9			14.7	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	7.7	22.0		9.8	5.0	24.6		7.3
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	7.0	32.0		8.0	4.0	35.0		7.0
Max Q Clear Time (g_c+I1), s	4.9	13.0		5.7	2.6	9.8		3.7
Green Ext Time (p_c), s	0.0	5.0		0.3	0.0	5.5		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	16.6
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	230	1050	10	25	760	45	20	10	30	90	10	160
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3148		1456	3076		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3148		1456	3076		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	247	1129	11	27	817	48	22	11	32	97	11	172
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	25	0	0	79
Lane Group Flow (vph)	247	1139	0	27	862	0	22	11	7	97	11	93
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Effective Green, g (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Actuated g/C Ratio	0.19	0.48		0.18	0.51		0.21	0.21	0.21	0.21	0.21	0.40
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	336	1525		268	1561		211	394	260	255	263	668
v/s Ratio Prot	c0.14	c0.36		0.02	c0.28			0.01			0.01	0.03
v/s Ratio Perm							0.02		0.01	c0.08		0.03
v/c Ratio	0.74	0.75		0.10	0.55		0.10	0.03	0.03	0.38	0.04	0.14
Uniform Delay, d1	49.4	27.1		44.0	21.9		41.7	41.0	41.0	44.3	41.2	24.8
Progression Factor	1.00	1.00		0.93	0.00		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	13.4	3.4		0.4	0.8		1.0	0.1	0.2	4.3	0.3	0.4
Delay (s)	62.8	30.5		41.5	0.9		42.7	41.2	41.2	48.6	41.5	25.2
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		36.2			2.1			41.7			34.0	
Approach LOS		D			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	24.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.66		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	56.8%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.3

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	505	15	5	555	25	50
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	567	17	6	624	28	56

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	567	0	1202	567
Stage 1	-	-	-	-	567	-
Stage 2	-	-	-	-	635	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	1000	-	206	527
Stage 1	-	-	-	-	572	-
Stage 2	-	-	-	-	532	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1000	-	205	527
Mov Cap-2 Maneuver	-	-	-	-	205	-
Stage 1	-	-	-	-	572	-
Stage 2	-	-	-	-	529	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	18.7
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	346	1000	-	-	-
HCM Lane V/C Ratio	0.244	0.006	-	-	-
HCM Control Delay (s)	18.7	8.6	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	0.9	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	30	230	10	10	325	125	10	10	10	40	10	40
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	31	235	10	10	332	0	10	10	10	41	10	41
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	50	554	471	19	555	472	17	112	100	70	180	153
Arrive On Green	0.03	0.32	0.32	0.01	0.30	0.00	0.01	0.07	0.07	0.04	0.09	0.09
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	31	235	10	10	332	0	10	10	10	41	10	41
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.5	3.0	0.1	0.2	4.4	0.0	0.2	0.2	0.2	0.6	0.1	0.7
Cycle Q Clear(g_c), s	0.5	3.0	0.1	0.2	4.4	0.0	0.2	0.2	0.2	0.6	0.1	0.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	50	554	471	19	555	472	17	112	100	70	180	153
V/C Ratio(X)	0.62	0.42	0.02	0.53	0.60	0.00	0.58	0.09	0.10	0.58	0.06	0.27
Avail Cap(c_a), veh/h	347	1702	1447	247	1688	1435	225	947	810	382	1204	1023
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	13.6	7.6	6.6	14.0	8.5	0.0	14.0	12.5	12.4	13.4	11.7	11.9
Incr Delay (d2), s/veh	4.5	0.2	0.0	8.4	0.4	0.0	11.2	0.1	0.2	2.8	0.0	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.5	0.1	0.1	2.3	0.0	0.1	0.1	0.1	0.4	0.1	0.3
LnGrp Delay(d),s/veh	18.1	7.8	6.6	22.4	8.9	0.0	25.2	12.6	12.5	16.2	11.8	12.3
LnGrp LOS	B	A	A	C	A		C	B	B	B	B	B
Approach Vol, veh/h		276			342			30			92	
Approach Delay, s/veh		8.9			9.2			16.8			14.0	
Approach LOS		A			A			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.9	12.6	5.1	5.9	4.3	13.1	4.3	6.7
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	6.0	26.0	6.0	16.0	4.0	28.0	4.0	18.0
Max Q Clear Time (g_c+I1), s	2.5	6.9	2.6	2.2	2.2	5.0	2.2	2.7
Green Ext Time (p_c), s	0.0	1.7	0.0	0.0	0.0	1.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	10.0
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	45	50	1150	20	15	785
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3147		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3147		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	51	56	1292	22	17	882
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	51	10	1313	0	17	882
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	45.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	45.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.35
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2178		67	1077
v/s Ratio Prot	c0.03	0.01	c0.42		c0.01	c0.28
v/s Ratio Perm						
v/c Ratio	0.25	0.04	0.60		0.25	0.82
Uniform Delay, d1	50.8	43.5	10.6		59.0	38.8
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	3.0	0.2	0.9		8.9	7.0
Delay (s)	53.8	43.7	3.7		67.9	45.7
Level of Service	D	D	A		E	D
Approach Delay (s)	48.5		3.7			46.2
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	22.2	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.60		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	42.4%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.9

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	30	10	10	65	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	33	11	11	71	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	43	0	130	38
Stage 1	-	-	-	-	38	-
Stage 2	-	-	-	-	92	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1566	-	864	1034
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	932	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1566	-	858	1034
Mov Cap-2 Maneuver	-	-	-	-	858	-
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	925	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	938	-	-	1566	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.8

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	536	10	35	590	10	85
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	583	11	38	641	11	96

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	593	0	1305	588
Stage 1	-	-	-	-	588	-
Stage 2	-	-	-	-	717	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	954	-	135	418
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	395	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	954	-	130	418
Mov Cap-2 Maneuver	-	-	-	-	130	-
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	379	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	339	954	-	-	-
HCM Lane V/C Ratio	0.315	0.04	-	-	-
HCM Control Delay (s)	20.4	8.9	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1.3	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	137	329	155	485	348	190	181	610	490	80	590	96
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1873	1900
Adj Flow Rate, veh/h	152	366	0	539	387	211	201	678	544	89	656	107
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	182	472	242	594	519	480	233	1186	497	121	846	138
Arrive On Green	0.10	0.16	0.00	0.25	0.30	0.30	0.13	0.34	0.34	0.07	0.28	0.28
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	3066	499
Grp Volume(v), veh/h	152	366	0	539	387	211	201	678	544	89	380	383
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1780	1785
Q Serve(g_s), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Cycle Q Clear(g_c), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.28
Lane Grp Cap(c), veh/h	182	472	242	594	519	480	233	1186	497	121	491	493
V/C Ratio(X)	0.83	0.78	0.00	0.91	0.75	0.44	0.86	0.57	1.10	0.74	0.77	0.78
Avail Cap(c_a), veh/h	263	517	266	703	544	504	285	1186	497	239	549	551
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	47.0	42.9	0.0	39.2	33.5	29.9	45.6	29.2	35.5	48.7	35.6	35.7
Incr Delay (d2), s/veh	14.1	7.3	0.0	14.1	5.8	0.9	19.9	0.7	68.9	8.4	6.5	6.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.1	5.7	0.0	8.9	11.0	5.1	7.1	8.3	24.1	2.9	11.2	11.3
LnGrp Delay(d),s/veh	61.1	50.3	0.0	53.3	39.3	30.8	65.5	30.0	104.5	57.1	42.1	42.2
LnGrp LOS	E	D		D	D	C	E	C	F	E	D	D
Approach Vol, veh/h		518			1137			1423			852	
Approach Delay, s/veh		53.4			44.4			63.5			43.7	
Approach LOS		D			D			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.9	34.5	16.1	37.4	12.6	40.8	31.2	22.3
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	17.0	33.0	16.0	34.0	15.0	35.0	31.0	19.0
Max Q Clear Time (g_c+I1), s	13.8	23.1	11.1	23.8	7.5	37.8	25.1	14.9
Green Ext Time (p_c), s	0.2	6.4	0.1	5.0	0.1	0.0	1.1	2.4

Intersection Summary	
HCM 2010 Ctrl Delay	52.3
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	40	135	90	60	60	224	119	411	35	20	470	115
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	212	223	190	120	126	107	169	838	712	36	699	0
Arrive On Green	0.12	0.12	0.12	0.07	0.07	0.00	0.10	0.47	0.47	0.02	0.39	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Cycle Q Clear(g_c), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	212	223	190	120	126	107	169	838	712	36	699	0
V/C Ratio(X)	0.21	0.67	0.53	0.56	0.53	0.00	0.78	0.55	0.05	0.61	0.75	0.00
Avail Cap(c_a), veh/h	280	294	250	249	262	223	343	1260	1071	137	1044	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	19.7	20.9	20.5	22.5	22.4	0.0	21.9	9.5	7.2	24.2	13.1	0.0
Incr Delay (d2), s/veh	0.5	3.8	2.3	4.0	3.4	0.0	7.7	0.6	0.0	15.6	1.6	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.6	2.2	1.4	1.0	1.0	0.0	2.1	4.6	0.3	0.4	6.4	0.0
LnGrp Delay(d),s/veh	20.2	24.7	22.8	26.5	25.9	0.0	29.6	10.0	7.3	39.8	14.7	0.0
LnGrp LOS	C	C	C	C	C		C	B	A	D	B	
Approach Vol, veh/h		294			134			628			544	
Approach Delay, s/veh		23.3			26.2			14.0			15.7	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	8.9	23.4		10.1	5.0	27.3		7.4
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	10.0	29.0		8.0	4.0	35.0		7.0
Max Q Clear Time (g_c+I1), s	5.8	14.5		5.9	2.6	11.1		3.8
Green Ext Time (p_c), s	0.1	4.9		0.3	0.0	6.0		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	17.3
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	230	1064	10	25	768	45	20	10	30	90	10	160
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3148		1456	3076		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3148		1456	3076		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	247	1144	11	27	826	48	22	11	32	97	11	172
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	25	0	0	76
Lane Group Flow (vph)	247	1154	0	27	871	0	22	11	7	97	11	96
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Effective Green, g (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Actuated g/C Ratio	0.19	0.48		0.18	0.51		0.21	0.21	0.21	0.21	0.21	0.40
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	336	1525		268	1561		211	394	260	255	263	668
v/s Ratio Prot	c0.14	c0.37		0.02	c0.28			0.01			0.01	0.03
v/s Ratio Perm							0.02		0.01	c0.08		0.03
v/c Ratio	0.74	0.76		0.10	0.56		0.10	0.03	0.03	0.38	0.04	0.14
Uniform Delay, d1	49.4	27.3		44.0	22.0		41.7	41.0	41.0	44.3	41.2	24.8
Progression Factor	1.00	1.00		0.94	0.00		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	13.4	3.6		0.4	0.8		1.0	0.1	0.2	4.3	0.3	0.5
Delay (s)	62.8	30.8		41.8	0.9		42.7	41.2	41.2	48.6	41.5	25.3
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		36.5			2.1			41.7			34.0	
Approach LOS		D			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	24.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.66		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	57.1%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.3

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	546	15	5	580	25	50
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	613	17	6	652	28	56

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	613	0	1276	613
Stage 1	-	-	-	-	613	-
Stage 2	-	-	-	-	663	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	961	-	186	496
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	516	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	961	-	185	496
Mov Cap-2 Maneuver	-	-	-	-	185	-
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	513	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	318	961	-	-	-
HCM Lane V/C Ratio	0.265	0.006	-	-	-
HCM Control Delay (s)	20.4	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	30	230	12	49	325	125	13	10	75	40	10	40
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	50	486	413	80	546	464	22	161	142	70	230	195
Arrive On Green	0.03	0.28	0.28	0.05	0.30	0.00	0.01	0.10	0.10	0.04	0.12	0.12
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Cycle Q Clear(g_c), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	50	486	413	80	546	464	22	161	142	70	230	195
V/C Ratio(X)	0.62	0.48	0.03	0.63	0.61	0.00	0.59	0.06	0.54	0.59	0.04	0.21
Avail Cap(c_a), veh/h	277	1629	1384	237	1677	1426	216	963	823	305	1152	979
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	14.2	8.9	7.7	13.9	9.0	0.0	14.6	12.2	12.7	14.0	11.5	11.8
Incr Delay (d2), s/veh	4.6	0.3	0.0	3.0	0.4	0.0	9.1	0.1	1.2	2.9	0.0	0.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.6	0.1	0.5	2.4	0.0	0.2	0.1	0.6	0.4	0.1	0.3
LnGrp Delay(d),s/veh	18.8	9.2	7.8	16.9	9.4	0.0	23.7	12.3	13.9	16.9	11.6	12.0
LnGrp LOS	B	A	A	B	A		C	B	B	B	B	B
Approach Vol, veh/h		278			382			100			92	
Approach Delay, s/veh		10.2			10.4			15.0			14.1	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.9	12.8	5.1	6.8	5.4	12.3	4.4	7.6
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	5.0	27.0	5.0	17.0	4.0	28.0	4.0	18.0
Max Q Clear Time (g_c+I1), s	2.6	7.1	2.7	3.5	2.8	5.4	2.2	2.7
Green Ext Time (p_c), s	0.0	1.7	0.0	0.0	0.0	1.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	11.3
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	45	50	1164	20	15	793
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3147		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3147		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	51	56	1308	22	17	891
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	51	10	1329	0	17	891
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	45.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	45.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.35
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2178		67	1077
v/s Ratio Prot	c0.03	0.01	c0.42		c0.01	c0.29
v/s Ratio Perm						
v/c Ratio	0.25	0.04	0.61		0.25	0.83
Uniform Delay, d1	50.8	43.5	10.7		59.0	38.9
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	3.0	0.2	0.9		8.9	7.3
Delay (s)	53.8	43.7	3.7		67.9	46.3
Level of Service	D	D	A		E	D
Approach Delay (s)	48.5		3.7			46.7
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	22.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.61		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	42.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.9

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	30	10	10	65	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	33	11	11	71	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	43	0	130	38
Stage 1	-	-	-	-	38	-
Stage 2	-	-	-	-	92	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1566	-	864	1034
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	932	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1566	-	858	1034
Mov Cap-2 Maneuver	-	-	-	-	858	-
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	925	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	938	-	-	1566	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.8

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	536	10	35	590	10	85
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	583	11	38	641	11	96

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	593	0	1305	588
Stage 1	-	-	-	-	588	-
Stage 2	-	-	-	-	717	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	954	-	135	418
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	395	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	954	-	130	418
Mov Cap-2 Maneuver	-	-	-	-	130	-
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	379	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	339	954	-	-	-
HCM Lane V/C Ratio	0.315	0.04	-	-	-
HCM Control Delay (s)	20.4	8.9	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1.3	0.1	-	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	137	329	155	485	348	190	181	610	490	80	590	96
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1873	1900
Adj Flow Rate, veh/h	152	366	0	539	387	211	201	678	544	89	656	107
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	182	472	242	594	519	480	233	1186	497	121	846	138
Arrive On Green	0.10	0.16	0.00	0.25	0.30	0.30	0.13	0.34	0.34	0.07	0.28	0.28
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	3066	499
Grp Volume(v), veh/h	152	366	0	539	387	211	201	678	544	89	380	383
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1780	1785
Q Serve(g_s), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Cycle Q Clear(g_c), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.28
Lane Grp Cap(c), veh/h	182	472	242	594	519	480	233	1186	497	121	491	493
V/C Ratio(X)	0.83	0.78	0.00	0.91	0.75	0.44	0.86	0.57	1.10	0.74	0.77	0.78
Avail Cap(c_a), veh/h	263	517	266	703	544	504	285	1186	497	239	549	551
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	47.0	42.9	0.0	39.2	33.5	29.9	45.6	29.2	35.5	48.7	35.6	35.7
Incr Delay (d2), s/veh	14.1	7.3	0.0	14.1	5.8	0.9	19.9	0.7	68.9	8.4	6.5	6.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.1	5.7	0.0	8.9	11.0	5.1	7.1	8.3	24.1	2.9	11.2	11.3
LnGrp Delay(d),s/veh	61.1	50.3	0.0	53.3	39.3	30.8	65.5	30.0	104.5	57.1	42.1	42.2
LnGrp LOS	E	D		D	D	C	E	C	F	E	D	D
Approach Vol, veh/h		518			1137			1423			852	
Approach Delay, s/veh		53.4			44.4			63.5			43.7	
Approach LOS		D			D			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.9	34.5	16.1	37.4	12.6	40.8	31.2	22.3
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	17.0	33.0	16.0	34.0	15.0	35.0	31.0	19.0
Max Q Clear Time (g_c+I1), s	13.8	23.1	11.1	23.8	7.5	37.8	25.1	14.9
Green Ext Time (p_c), s	0.2	6.4	0.1	5.0	0.1	0.0	1.1	2.4

Intersection Summary	
HCM 2010 Ctrl Delay	52.3
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	40	135	90	60	60	224	119	411	35	20	470	115
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	212	223	190	120	126	107	169	838	712	36	699	0
Arrive On Green	0.12	0.12	0.12	0.07	0.07	0.00	0.10	0.47	0.47	0.02	0.39	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Cycle Q Clear(g_c), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	212	223	190	120	126	107	169	838	712	36	699	0
V/C Ratio(X)	0.21	0.67	0.53	0.56	0.53	0.00	0.78	0.55	0.05	0.61	0.75	0.00
Avail Cap(c_a), veh/h	280	294	250	249	262	223	343	1260	1071	137	1044	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	19.7	20.9	20.5	22.5	22.4	0.0	21.9	9.5	7.2	24.2	13.1	0.0
Incr Delay (d2), s/veh	0.5	3.8	2.3	4.0	3.4	0.0	7.7	0.6	0.0	15.6	1.6	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.6	2.2	1.4	1.0	1.0	0.0	2.1	4.6	0.3	0.4	6.4	0.0
LnGrp Delay(d),s/veh	20.2	24.7	22.8	26.5	25.9	0.0	29.6	10.0	7.3	39.8	14.7	0.0
LnGrp LOS	C	C	C	C	C		C	B	A	D	B	
Approach Vol, veh/h		294			134			628			544	
Approach Delay, s/veh		23.3			26.2			14.0			15.7	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	8.9	23.4		10.1	5.0	27.3		7.4
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	10.0	29.0		8.0	4.0	35.0		7.0
Max Q Clear Time (g_c+I1), s	5.8	14.5		5.9	2.6	11.1		3.8
Green Ext Time (p_c), s	0.1	4.9		0.3	0.0	6.0		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	17.3
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	230	1064	10	25	768	45	20	10	30	90	10	160
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3148		1456	3076		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3148		1456	3076		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	247	1144	11	27	826	48	22	11	32	97	11	172
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	25	0	0	76
Lane Group Flow (vph)	247	1154	0	27	871	0	22	11	7	97	11	96
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Effective Green, g (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Actuated g/C Ratio	0.19	0.48		0.18	0.51		0.21	0.21	0.21	0.21	0.21	0.40
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	336	1525		268	1561		211	394	260	255	263	668
v/s Ratio Prot	c0.14	c0.37		0.02	c0.28			0.01			0.01	0.03
v/s Ratio Perm							0.02		0.01	c0.08		0.03
v/c Ratio	0.74	0.76		0.10	0.56		0.10	0.03	0.03	0.38	0.04	0.14
Uniform Delay, d1	49.4	27.3		44.0	22.0		41.7	41.0	41.0	44.3	41.2	24.8
Progression Factor	1.00	1.00		0.94	0.00		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	13.4	3.6		0.4	0.8		1.0	0.1	0.2	4.3	0.3	0.5
Delay (s)	62.8	30.8		41.8	0.9		42.7	41.2	41.2	48.6	41.5	25.3
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		36.5			2.1			41.7			34.0	
Approach LOS		D			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	24.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.66		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	57.1%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.3

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	546	15	5	580	25	50
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	613	17	6	652	28	56

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	613	0	1276	613
Stage 1	-	-	-	-	613	-
Stage 2	-	-	-	-	663	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	961	-	186	496
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	516	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	961	-	185	496
Mov Cap-2 Maneuver	-	-	-	-	185	-
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	513	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	318	961	-	-	-
HCM Lane V/C Ratio	0.265	0.006	-	-	-
HCM Control Delay (s)	20.4	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	30	230	12	49	325	125	13	10	75	40	10	40
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	50	486	413	80	546	464	22	161	142	70	230	195
Arrive On Green	0.03	0.28	0.28	0.05	0.30	0.00	0.01	0.10	0.10	0.04	0.12	0.12
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Cycle Q Clear(g_c), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	50	486	413	80	546	464	22	161	142	70	230	195
V/C Ratio(X)	0.62	0.48	0.03	0.63	0.61	0.00	0.59	0.06	0.54	0.59	0.04	0.21
Avail Cap(c_a), veh/h	277	1629	1384	237	1677	1426	216	963	823	305	1152	979
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	14.2	8.9	7.7	13.9	9.0	0.0	14.6	12.2	12.7	14.0	11.5	11.8
Incr Delay (d2), s/veh	4.6	0.3	0.0	3.0	0.4	0.0	9.1	0.1	1.2	2.9	0.0	0.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.6	0.1	0.5	2.4	0.0	0.2	0.1	0.6	0.4	0.1	0.3
LnGrp Delay(d),s/veh	18.8	9.2	7.8	16.9	9.4	0.0	23.7	12.3	13.9	16.9	11.6	12.0
LnGrp LOS	B	A	A	B	A		C	B	B	B	B	B
Approach Vol, veh/h		278			382			100			92	
Approach Delay, s/veh		10.2			10.4			15.0			14.1	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.9	12.8	5.1	6.8	5.4	12.3	4.4	7.6
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	5.0	27.0	5.0	17.0	4.0	28.0	4.0	18.0
Max Q Clear Time (g_c+I1), s	2.6	7.1	2.7	3.5	2.8	5.4	2.2	2.7
Green Ext Time (p_c), s	0.0	1.7	0.0	0.0	0.0	1.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	11.3
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	45	50	1164	20	15	793
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3147		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3147		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	51	56	1308	22	17	891
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	51	10	1329	0	17	891
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	45.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	45.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.35
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2178		67	1077
v/s Ratio Prot	c0.03	0.01	c0.42		c0.01	c0.29
v/s Ratio Perm						
v/c Ratio	0.25	0.04	0.61		0.25	0.83
Uniform Delay, d1	50.8	43.5	10.7		59.0	38.9
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	3.0	0.2	0.9		8.9	7.3
Delay (s)	53.8	43.7	3.7		67.9	46.3
Level of Service	D	D	A		E	D
Approach Delay (s)	48.5		3.7			46.7
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	22.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.61		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	42.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.9

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	30	10	10	65	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	33	11	11	71	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	43	0	130	38
Stage 1	-	-	-	-	38	-
Stage 2	-	-	-	-	92	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1566	-	864	1034
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	932	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1566	-	858	1034
Mov Cap-2 Maneuver	-	-	-	-	858	-
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	925	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	938	-	-	1566	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection	
Int Delay, s/veh	1.8

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	536	10	35	590	10	85
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	0	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	89	89
Heavy Vehicles, %	5	5	8	8	58	58
Mvmt Flow	583	11	38	641	11	96

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	593	0	1305	588
Stage 1	-	-	-	-	588	-
Stage 2	-	-	-	-	717	-
Critical Hdwy	-	-	4.18	-	6.98	6.78
Critical Hdwy Stg 1	-	-	-	-	5.98	-
Critical Hdwy Stg 2	-	-	-	-	5.98	-
Follow-up Hdwy	-	-	2.272	-	4.022	3.822
Pot Cap-1 Maneuver	-	-	954	-	135	418
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	395	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	954	-	130	418
Mov Cap-2 Maneuver	-	-	-	-	130	-
Stage 1	-	-	-	-	460	-
Stage 2	-	-	-	-	379	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.5	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	339	954	-	-	-
HCM Lane V/C Ratio	0.315	0.04	-	-	-
HCM Control Delay (s)	20.4	8.9	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1.3	0.1	-	-	-



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	137	329	155	485	348	190	181	610	490	80	590	96
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1845	1532	1759	1696	1712	1863	1881	1863	1743	1792	1873	1900
Adj Flow Rate, veh/h	152	366	0	539	387	211	201	678	544	89	656	107
Adj No. of Lanes	1	2	1	2	1	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	3	24	8	12	11	2	1	2	9	6	1	1
Cap, veh/h	182	472	242	594	519	480	233	1186	497	121	846	138
Arrive On Green	0.10	0.16	0.00	0.25	0.30	0.30	0.13	0.34	0.34	0.07	0.28	0.28
Sat Flow, veh/h	1757	2911	1495	2423	1712	1583	1792	3539	1482	1707	3066	499
Grp Volume(v), veh/h	152	366	0	539	387	211	201	678	544	89	380	383
Grp Sat Flow(s),veh/h/ln	1757	1456	1495	1212	1712	1583	1792	1770	1482	1707	1780	1785
Q Serve(g_s), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Cycle Q Clear(g_c), s	9.1	12.9	0.0	23.1	21.8	11.5	11.8	16.8	35.8	5.5	21.0	21.1
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.28
Lane Grp Cap(c), veh/h	182	472	242	594	519	480	233	1186	497	121	491	493
V/C Ratio(X)	0.83	0.78	0.00	0.91	0.75	0.44	0.86	0.57	1.10	0.74	0.77	0.78
Avail Cap(c_a), veh/h	263	517	266	703	544	504	285	1186	497	239	549	551
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	47.0	42.9	0.0	39.2	33.5	29.9	45.6	29.2	35.5	48.7	35.6	35.7
Incr Delay (d2), s/veh	14.1	7.3	0.0	14.1	5.8	0.9	19.9	0.7	68.9	8.4	6.5	6.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.1	5.7	0.0	8.9	11.0	5.1	7.1	8.3	24.1	2.9	11.2	11.3
LnGrp Delay(d),s/veh	61.1	50.3	0.0	53.3	39.3	30.8	65.5	30.0	104.5	57.1	42.1	42.2
LnGrp LOS	E	D		D	D	C	E	C	F	E	D	D
Approach Vol, veh/h		518			1137			1423			852	
Approach Delay, s/veh		53.4			44.4			63.5			43.7	
Approach LOS		D			D			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.9	34.5	16.1	37.4	12.6	40.8	31.2	22.3
Change Period (Y+Rc), s	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Max Green Setting (Gmax), s	17.0	33.0	16.0	34.0	15.0	35.0	31.0	19.0
Max Q Clear Time (g_c+I1), s	13.8	23.1	11.1	23.8	7.5	37.8	25.1	14.9
Green Ext Time (p_c), s	0.2	6.4	0.1	5.0	0.1	0.0	1.1	2.4

Intersection Summary	
HCM 2010 Ctrl Delay	52.3
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations												
Volume (veh/h)	40	135	90	60	60	224	119	411	35	20	470	115
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1827	1827	1827	1863	1863	1863	1792	1792	1792	1792	1792	1900
Adj Flow Rate, veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	4	4	4	2	2	2	6	6	6	6	6	6
Cap, veh/h	212	223	190	120	126	107	169	838	712	36	699	0
Arrive On Green	0.12	0.12	0.12	0.07	0.07	0.00	0.10	0.47	0.47	0.02	0.39	0.00
Sat Flow, veh/h	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Grp Volume(v), veh/h	44	150	100	67	67	0	132	457	39	22	522	0
Grp Sat Flow(s),veh/h/ln	1740	1827	1553	1774	1863	1583	1707	1792	1524	1707	1792	0
Q Serve(g_s), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Cycle Q Clear(g_c), s	1.1	3.9	3.0	1.8	1.7	0.0	3.8	9.1	0.7	0.6	12.5	0.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	212	223	190	120	126	107	169	838	712	36	699	0
V/C Ratio(X)	0.21	0.67	0.53	0.56	0.53	0.00	0.78	0.55	0.05	0.61	0.75	0.00
Avail Cap(c_a), veh/h	280	294	250	249	262	223	343	1260	1071	137	1044	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	19.7	20.9	20.5	22.5	22.4	0.0	21.9	9.5	7.2	24.2	13.1	0.0
Incr Delay (d2), s/veh	0.5	3.8	2.3	4.0	3.4	0.0	7.7	0.6	0.0	15.6	1.6	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.6	2.2	1.4	1.0	1.0	0.0	2.1	4.6	0.3	0.4	6.4	0.0
LnGrp Delay(d),s/veh	20.2	24.7	22.8	26.5	25.9	0.0	29.6	10.0	7.3	39.8	14.7	0.0
LnGrp LOS	C	C	C	C	C		C	B	A	D	B	
Approach Vol, veh/h		294			134			628			544	
Approach Delay, s/veh		23.3			26.2			14.0			15.7	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	8.9	23.4		10.1	5.0	27.3		7.4
Change Period (Y+Rc), s	4.0	4.0		4.0	4.0	4.0		4.0
Max Green Setting (Gmax), s	10.0	29.0		8.0	4.0	35.0		7.0
Max Q Clear Time (g_c+I1), s	5.8	14.5		5.9	2.6	11.1		3.8
Green Ext Time (p_c), s	0.1	4.9		0.3	0.0	6.0		0.1

Intersection Summary	
HCM 2010 Ctrl Delay	17.3
HCM 2010 LOS	B



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	230	1064	10	25	768	45	20	10	30	90	10	160
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0		4.0	4.0		4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	1.00	0.95		1.00	0.95		1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	1.00		1.00	0.99		1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00		0.95	1.00		0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	1752	3148		1456	3076		1289	1900	1252	1556	1267	1553
Flt Permitted	0.95	1.00		0.95	1.00		0.75	1.00	1.00	0.75	1.00	1.00
Satd. Flow (perm)	1752	3148		1456	3076		1018	1900	1252	1229	1267	1553
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	247	1144	11	27	826	48	22	11	32	97	11	172
RTOR Reduction (vph)	0	1	0	0	3	0	0	0	25	0	0	76
Lane Group Flow (vph)	247	1154	0	27	871	0	22	11	7	97	11	96
Heavy Vehicles (%)	3%	14%	67%	24%	17%	6%	40%	0%	29%	16%	50%	4%
Turn Type	Prot	NA		Prot	NA		Perm	NA	Perm	Perm	NA	pm+ov
Protected Phases	5	2		1 3	3 6			4			4	5
Permitted Phases							4		4	4		4
Actuated Green, G (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Effective Green, g (s)	25.0	63.0		24.0	66.0		27.0	27.0	27.0	27.0	27.0	52.0
Actuated g/C Ratio	0.19	0.48		0.18	0.51		0.21	0.21	0.21	0.21	0.21	0.40
Clearance Time (s)	4.0	4.0					4.0	4.0	4.0	4.0	4.0	4.0
Lane Grp Cap (vph)	336	1525		268	1561		211	394	260	255	263	668
v/s Ratio Prot	c0.14	c0.37		0.02	c0.28			0.01			0.01	0.03
v/s Ratio Perm							0.02		0.01	c0.08		0.03
v/c Ratio	0.74	0.76		0.10	0.56		0.10	0.03	0.03	0.38	0.04	0.14
Uniform Delay, d1	49.4	27.3		44.0	22.0		41.7	41.0	41.0	44.3	41.2	24.8
Progression Factor	1.00	1.00		0.94	0.00		1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	13.4	3.6		0.4	0.8		1.0	0.1	0.2	4.3	0.3	0.5
Delay (s)	62.8	30.8		41.8	0.9		42.7	41.2	41.2	48.6	41.5	25.3
Level of Service	E	C		D	A		D	D	D	D	D	C
Approach Delay (s)		36.5			2.1			41.7			34.0	
Approach LOS		D			A			D			C	

Intersection Summary			
HCM 2000 Control Delay	24.6	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.66		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	57.1%	ICU Level of Service	B
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.3

Movement	SET	SER	NWL	NWT	NEL	NER
Vol, veh/h	546	15	5	580	25	50
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	210	80	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	89	89	89	89	89	89
Heavy Vehicles, %	4	4	3	3	0	0
Mvmt Flow	613	17	6	652	28	56

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	613	0	1276	613
Stage 1	-	-	-	-	613	-
Stage 2	-	-	-	-	663	-
Critical Hdwy	-	-	4.13	-	6.4	6.2
Critical Hdwy Stg 1	-	-	-	-	5.4	-
Critical Hdwy Stg 2	-	-	-	-	5.4	-
Follow-up Hdwy	-	-	2.227	-	3.5	3.3
Pot Cap-1 Maneuver	-	-	961	-	186	496
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	516	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	961	-	185	496
Mov Cap-2 Maneuver	-	-	-	-	185	-
Stage 1	-	-	-	-	544	-
Stage 2	-	-	-	-	513	-

Approach	SE	NW	NE
HCM Control Delay, s	0	0.1	20.4
HCM LOS			C

Minor Lane/Major Mvmt	NELn1	NWL	NWT	SET	SER
Capacity (veh/h)	318	961	-	-	-
HCM Lane V/C Ratio	0.265	0.006	-	-	-
HCM Control Delay (s)	20.4	8.8	-	-	-
HCM Lane LOS	C	A	-	-	-
HCM 95th %tile Q(veh)	1	0	-	-	-

Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	30	230	12	49	325	125	13	10	75	40	10	40
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1727	1727	1727	1845	1845	1845	1681	1681	1681	1900	1900	1900
Adj Flow Rate, veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Adj No. of Lanes	1	1	1	1	1	1	1	1	1	1	1	1
Peak Hour Factor	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Percent Heavy Veh, %	10	10	10	3	3	3	13	13	13	0	0	0
Cap, veh/h	50	486	413	80	546	464	22	161	142	70	230	195
Arrive On Green	0.03	0.28	0.28	0.05	0.30	0.00	0.01	0.10	0.10	0.04	0.12	0.12
Sat Flow, veh/h	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Grp Volume(v), veh/h	31	235	12	50	332	0	13	10	77	41	10	41
Grp Sat Flow(s),veh/h/ln	1645	1727	1468	1757	1845	1568	1601	1681	1429	1810	1900	1615
Q Serve(g_s), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Cycle Q Clear(g_c), s	0.6	3.4	0.2	0.8	4.6	0.0	0.2	0.2	1.5	0.7	0.1	0.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	50	486	413	80	546	464	22	161	142	70	230	195
V/C Ratio(X)	0.62	0.48	0.03	0.63	0.61	0.00	0.59	0.06	0.54	0.59	0.04	0.21
Avail Cap(c_a), veh/h	277	1629	1384	237	1677	1426	216	963	823	305	1152	979
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	14.2	8.9	7.7	13.9	9.0	0.0	14.6	12.2	12.7	14.0	11.5	11.8
Incr Delay (d2), s/veh	4.6	0.3	0.0	3.0	0.4	0.0	9.1	0.1	1.2	2.9	0.0	0.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.6	0.1	0.5	2.4	0.0	0.2	0.1	0.6	0.4	0.1	0.3
LnGrp Delay(d),s/veh	18.8	9.2	7.8	16.9	9.4	0.0	23.7	12.3	13.9	16.9	11.6	12.0
LnGrp LOS	B	A	A	B	A		C	B	B	B	B	B
Approach Vol, veh/h		278			382			100			92	
Approach Delay, s/veh		10.2			10.4			15.0			14.1	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	4.9	12.8	5.1	6.8	5.4	12.3	4.4	7.6
Change Period (Y+Rc), s	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Max Green Setting (Gmax), s	5.0	27.0	5.0	17.0	4.0	28.0	4.0	18.0
Max Q Clear Time (g_c+I1), s	2.6	7.1	2.7	3.5	2.8	5.4	2.2	2.7
Green Ext Time (p_c), s	0.0	1.7	0.0	0.0	0.0	1.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	11.3
HCM 2010 LOS	B



Movement	NWL	NWR	NET	NER	SWL	SWT
Lane Configurations						
Volume (vph)	45	50	1164	20	15	793
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0		4.0	4.0
Lane Util. Factor	1.00	1.00	0.95		1.00	0.95
Frt	1.00	0.85	1.00		1.00	1.00
Flt Protected	0.95	1.00	1.00		0.95	1.00
Satd. Flow (prot)	1543	1553	3147		1253	3112
Flt Permitted	0.95	1.00	1.00		0.95	1.00
Satd. Flow (perm)	1543	1553	3147		1253	3112
Peak-hour factor, PHF	0.89	0.89	0.89	0.89	0.89	0.89
Adj. Flow (vph)	51	56	1308	22	17	891
RTOR Reduction (vph)	0	46	1	0	0	0
Lane Group Flow (vph)	51	10	1329	0	17	891
Heavy Vehicles (%)	17%	4%	14%	39%	44%	16%
Turn Type	Prot	pt+ov	NA		Prot	NA
Protected Phases	3	1 3	2 4		1	6
Permitted Phases						
Actuated Green, G (s)	17.0	24.0	90.0		7.0	45.0
Effective Green, g (s)	17.0	24.0	90.0		7.0	45.0
Actuated g/C Ratio	0.13	0.18	0.69		0.05	0.35
Clearance Time (s)	4.0				4.0	4.0
Lane Grp Cap (vph)	201	286	2178		67	1077
v/s Ratio Prot	c0.03	0.01	c0.42		c0.01	c0.29
v/s Ratio Perm						
v/c Ratio	0.25	0.04	0.61		0.25	0.83
Uniform Delay, d1	50.8	43.5	10.7		59.0	38.9
Progression Factor	1.00	1.00	0.26		1.00	1.00
Incremental Delay, d2	3.0	0.2	0.9		8.9	7.3
Delay (s)	53.8	43.7	3.7		67.9	46.3
Level of Service	D	D	A		E	D
Approach Delay (s)	48.5		3.7			46.7
Approach LOS	D		A			D

Intersection Summary			
HCM 2000 Control Delay	22.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.61		
Actuated Cycle Length (s)	130.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	42.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection	
Int Delay, s/veh	1.9

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	30	10	10	65	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	33	11	11	71	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	43	0	130	38
Stage 1	-	-	-	-	38	-
Stage 2	-	-	-	-	92	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1566	-	864	1034
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	932	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1566	-	858	1034
Mov Cap-2 Maneuver	-	-	-	-	858	-
Stage 1	-	-	-	-	984	-
Stage 2	-	-	-	-	925	-

Approach	EB	WB	NE
HCM Control Delay, s	0	1	8.9
HCM LOS			A

Minor Lane/Major Mvmt	NELn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	938	-	-	1566	-
HCM Lane V/C Ratio	0.023	-	-	0.007	-
HCM Control Delay (s)	8.9	-	-	7.3	0
HCM Lane LOS	A	-	-	A	A
HCM 95th %tile Q(veh)	0.1	-	-	0	-

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	5	111	619	175
Average Queue (ft)	0	10	41	66
95th Queue (ft)	5	85	285	137
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)			0	
Queuing Penalty (veh)			1	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	214	223	235	14	257	409	642	100	262	281	360	250
Average Queue (ft)	100	102	102	0	132	158	300	67	133	133	148	116
95th Queue (ft)	177	183	192	14	229	299	567	127	217	225	260	214
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	5	3			4	9	47	8	1	1	14	7
Queuing Penalty (veh)	16	11			8	16	74	23	5	4	117	47

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	178	243	256
Average Queue (ft)	67	142	156
95th Queue (ft)	145	235	252
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	2	2
Queuing Penalty (veh)	0	5	7
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	0	6	
Queuing Penalty (veh)	0	4	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	141	249	250	333	343
Average Queue (ft)	9	16	17	24	25
95th Queue (ft)	67	115	119	151	158
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		2	2		
Queuing Penalty (veh)		7	9		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	L	TR	L	TR
Maximum Queue (ft)	115	118	73	8	63	19
Average Queue (ft)	49	46	25	0	15	1
95th Queue (ft)	90	89	58	5	46	9
Link Distance (ft)	233	852		702		3756
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)			175		165	
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	162	308	184
Average Queue (ft)	6	17	8
95th Queue (ft)	58	128	70
Link Distance (ft)	464	3711	404
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	132	587	123
Average Queue (ft)	6	42	12
95th Queue (ft)	54	282	70
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			4
Queuing Penalty (veh)			20
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	40	61	40	70	59	13	80	177	61	176	475
Average Queue (ft)	13	29	9	17	10	0	22	57	15	18	166
95th Queue (ft)	30	52	27	46	36	8	60	124	46	85	350
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	15	38	10								
Queuing Penalty (veh)	11	28	8								
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				0	0			11	2		7
Queuing Penalty (veh)				0	0			11	6		1

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	176	225	82	202	208	137	103
Average Queue (ft)	81	102	21	63	72	58	39
95th Queue (ft)	156	181	61	149	161	109	84
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)			105				130
Storage Blk Time (%)			0	1		0	0
Queuing Penalty (veh)			1	0		0	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	275	565	604	94	58	37	73	53	77	170	88	116
Average Queue (ft)	143	265	286	21	7	3	14	11	22	56	13	41
95th Queue (ft)	263	453	476	67	34	21	49	39	61	121	56	89
Link Distance (ft)		843	843		235	235		684			404	
Upstream Blk Time (%)		0	0									
Queuing Penalty (veh)		0	0									
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	11	23					2	1	1	1	0	
Queuing Penalty (veh)	46	33					1	0	0	1	0	

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	315	376	381	527	534
Average Queue (ft)	138	26	27	48	47
95th Queue (ft)	309	181	183	262	262
Link Distance (ft)	2590	370	370	3950	3950
Upstream Blk Time (%)		2	3		
Queuing Penalty (veh)		11	14		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	SW
Directions Served	L	LR
Maximum Queue (ft)	44	46
Average Queue (ft)	9	17
95th Queue (ft)	32	45
Link Distance (ft)		100
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)	195	
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 25: Douglas Street & Alder Street

Movement	NW	NE
Directions Served	LT	LR
Maximum Queue (ft)	3	57
Average Queue (ft)	0	29
95th Queue (ft)	3	54
Link Distance (ft)	681	100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB	NW
Directions Served	T	T	T	T	T	T
Maximum Queue (ft)	84	169	109	22	56	50
Average Queue (ft)	9	27	9	1	3	2
95th Queue (ft)	48	102	54	10	25	22
Link Distance (ft)		1709	1709	7	7	1681
Upstream Blk Time (%)				4	5	
Queuing Penalty (veh)				2	2	
Storage Bay Dist (ft)	140					
Storage Blk Time (%)		2				
Queuing Penalty (veh)		1				

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	84	88	9
Average Queue (ft)	15	11	0
95th Queue (ft)	79	51	6
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)			1
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	NW	NE
Directions Served	L	LR
Maximum Queue (ft)	26	26
Average Queue (ft)	2	20
95th Queue (ft)	14	33
Link Distance (ft)		10
Upstream Blk Time (%)		9
Queuing Penalty (veh)		5
Storage Bay Dist (ft)	80	
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	34
Average Queue (ft)	13
95th Queue (ft)	39
Link Distance (ft)	26
Upstream Blk Time (%)	1
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	30	87	76	66	112	48
Average Queue (ft)	2	24	27	18	48	5
95th Queue (ft)	15	64	66	53	85	27
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	53
Average Queue (ft)	28
95th Queue (ft)	50
Link Distance (ft)	26
Upstream Blk Time (%)	4
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	202	243	101	213	209	88	128
Average Queue (ft)	81	103	26	62	66	24	54
95th Queue (ft)	162	200	73	155	157	61	101
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)				0	0		
Queuing Penalty (veh)				0	0		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	1			0
Queuing Penalty (veh)			1	0			0

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	224	245	142	274	301	138	261
Average Queue (ft)	138	160	50	102	128	47	118
95th Queue (ft)	235	252	109	228	263	101	209
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	2	4		0	0		
Queuing Penalty (veh)	11	20		0	1		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			1	2			
Queuing Penalty (veh)			2	1			

Intersection: 48: Industrial Way

Movement	EB	WB	NB	SB
Directions Served	T	T	R	R
Maximum Queue (ft)	1	3	104	69
Average Queue (ft)	0	0	41	16
95th Queue (ft)	1	3	81	52
Link Distance (ft)	1239	420	236	90
Upstream Blk Time (%)				0
Queuing Penalty (veh)				0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	55	77	40	36	106	38	39	53	61	39	48
Average Queue (ft)	15	15	3	6	26	8	7	9	23	8	19
95th Queue (ft)	41	48	18	24	71	31	30	36	51	33	45
Link Distance (ft)		1112			2438	3	3	3		2218	
Upstream Blk Time (%)						2	1	1			
Queuing Penalty (veh)						0	0	0			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)		0			0						
Queuing Penalty (veh)		0			0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	267	23	84	46	68
Average Queue (ft)	19	1	6	3	10
95th Queue (ft)	130	14	38	22	43
Link Distance (ft)	5785		2353		3
Upstream Blk Time (%)					11
Queuing Penalty (veh)					3
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		2	7	6	
Queuing Penalty (veh)		0	1	1	

Intersection: 55: Industrial Way

Movement	NB	SB
Directions Served	R	R
Maximum Queue (ft)	72	49
Average Queue (ft)	24	20
95th Queue (ft)	58	48
Link Distance (ft)	99	87
Upstream Blk Time (%)	0	
Queuing Penalty (veh)	0	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	114	117	241	242	166	387	388
Average Queue (ft)	31	33	41	49	25	225	227
95th Queue (ft)	82	82	125	134	96	363	363
Link Distance (ft)		2709	235	235		370	370
Upstream Blk Time (%)			1	1		2	2
Queuing Penalty (veh)			5	6		7	8
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)	0					8	
Queuing Penalty (veh)	0					1	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	144	160	7	6	94
Average Queue (ft)	14	20	0	0	33
95th Queue (ft)	76	92	8	9	75
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)					0
Queuing Penalty (veh)					0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE
Directions Served	LR	L
Maximum Queue (ft)	64	39
Average Queue (ft)	24	8
95th Queue (ft)	54	29
Link Distance (ft)	1001	
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		150
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	7	15	23	55
Average Queue (ft)	0	1	1	2
95th Queue (ft)	5	13	13	26
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	649	612	64	62
Average Queue (ft)	295	280	4	5
95th Queue (ft)	632	615	30	36
Link Distance (ft)	2166	1051	476	313
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: Dike Road & Frontage Road

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	20	45
Average Queue (ft)	1	15
95th Queue (ft)	9	43
Link Distance (ft)	200	313
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 629

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	6	58	566	181
Average Queue (ft)	0	12	39	65
95th Queue (ft)	6	40	279	137
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)			0	
Queuing Penalty (veh)			0	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	232	290	286	41	264	639	976	100	276	322	381	246
Average Queue (ft)	121	125	122	1	140	201	499	68	144	148	155	128
95th Queue (ft)	206	231	221	30	238	452	951	129	250	261	269	229
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	10	5			6	11	58	8	3	1	16	8
Queuing Penalty (veh)	48	24			11	21	89	26	18	6	136	54

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	160	254	256
Average Queue (ft)	64	149	167
95th Queue (ft)	129	241	264
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	2	3
Queuing Penalty (veh)	0	5	8
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	0	6	
Queuing Penalty (veh)	1	5	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	169	243	260	349	358
Average Queue (ft)	10	16	17	23	26
95th Queue (ft)	95	114	122	151	163
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		2	2		
Queuing Penalty (veh)		6	9		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	L	TR	L	T	TR
Maximum Queue (ft)	101	126	79	10	52	12	26
Average Queue (ft)	47	49	24	0	15	0	2
95th Queue (ft)	82	98	58	5	42	8	14
Link Distance (ft)	233	852		702		3455	3455
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)			175		165		
Storage Blk Time (%)							
Queuing Penalty (veh)							

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	165	350	162
Average Queue (ft)	6	20	10
95th Queue (ft)	60	147	77
Link Distance (ft)	464	4046	404
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	152	675	122
Average Queue (ft)	8	48	12
95th Queue (ft)	70	325	70
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			3
Queuing Penalty (veh)			19
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	32	61	42	68	54	2	137	199	62	193	552
Average Queue (ft)	12	32	12	18	9	0	46	74	13	24	217
95th Queue (ft)	28	55	31	47	35	2	107	155	46	105	437
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	17	50	14								
Queuing Penalty (veh)	13	37	10								
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				0	0			14	1		13
Queuing Penalty (veh)				0	0			23	5		3

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	210	236	80	207	217	132	99
Average Queue (ft)	85	106	21	67	75	60	39
95th Queue (ft)	167	195	61	157	172	108	80
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)			105				130
Storage Blk Time (%)			0	1		1	0
Queuing Penalty (veh)			0	0		0	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	274	674	698	94	62	45	74	56	83	166	108	152
Average Queue (ft)	154	288	305	20	7	3	17	11	24	61	19	48
95th Queue (ft)	281	521	536	66	35	23	57	41	66	132	73	107
Link Distance (ft)		843	843		237	237		684			404	
Upstream Blk Time (%)		0	0									
Queuing Penalty (veh)		0	0									
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	12	23					2	0	3	1	0	
Queuing Penalty (veh)	58	33					1	0	1	1	0	

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	326	378	378	525	513
Average Queue (ft)	139	29	29	48	50
95th Queue (ft)	309	186	186	260	262
Link Distance (ft)	2590	370	370	4783	4783
Upstream Blk Time (%)		3	4		
Queuing Penalty (veh)		18	18		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	SW
Directions Served	L	LR
Maximum Queue (ft)	40	39
Average Queue (ft)	7	18
95th Queue (ft)	29	46
Link Distance (ft)		100
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)	195	
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 25: Douglas Street & Alder Street

Movement	NW	NE
Directions Served	LT	LR
Maximum Queue (ft)	10	52
Average Queue (ft)	0	28
95th Queue (ft)	6	52
Link Distance (ft)	681	100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB	NW
Directions Served	T	T	T	T	T	T
Maximum Queue (ft)	102	228	91	24	34	56
Average Queue (ft)	12	52	8	1	2	3
95th Queue (ft)	71	179	41	10	15	26
Link Distance (ft)		1919	1919	7	7	1681
Upstream Blk Time (%)				4	4	
Queuing Penalty (veh)				2	2	
Storage Bay Dist (ft)	140					
Storage Blk Time (%)	0	7				
Queuing Penalty (veh)	0	5				

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	121	79	15
Average Queue (ft)	20	13	1
95th Queue (ft)	117	49	8
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)			1
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	SE	NW	NE
Directions Served	R	L	LR
Maximum Queue (ft)	2	29	24
Average Queue (ft)	0	2	19
95th Queue (ft)	3	13	32
Link Distance (ft)			10
Upstream Blk Time (%)			12
Queuing Penalty (veh)			8
Storage Bay Dist (ft)	210	80	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	34
Average Queue (ft)	13
95th Queue (ft)	39
Link Distance (ft)	26
Upstream Blk Time (%)	2
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	29	95	89	78	102	45
Average Queue (ft)	2	33	31	17	47	6
95th Queue (ft)	15	80	74	53	82	27
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	46
Average Queue (ft)	25
95th Queue (ft)	49
Link Distance (ft)	26
Upstream Blk Time (%)	5
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	255	274	114	240	232	72	119
Average Queue (ft)	91	112	27	72	81	24	56
95th Queue (ft)	190	216	76	176	184	58	100
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)				0	0		
Queuing Penalty (veh)				0	0		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	1			0
Queuing Penalty (veh)			0	0			0

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	231	247	176	282	301	130	257
Average Queue (ft)	147	166	59	115	139	47	117
95th Queue (ft)	244	259	133	246	271	101	209
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	3	5		0	0		
Queuing Penalty (veh)	15	24		1	1		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			1	3			
Queuing Penalty (veh)			2	2			

Intersection: 48: Industrial Way

Movement	NB	SB
Directions Served	R	R
Maximum Queue (ft)	92	61
Average Queue (ft)	41	15
95th Queue (ft)	76	46
Link Distance (ft)	236	90
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	68	103	30	100	114	42	38	79	65	40	50
Average Queue (ft)	16	26	3	30	33	8	5	26	26	7	19
95th Queue (ft)	46	73	16	71	87	33	25	69	56	30	46
Link Distance (ft)		1112			2438	3	3	3		2218	
Upstream Blk Time (%)						3	2	12			
Queuing Penalty (veh)						2	1	10			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)	0	0		0	0						
Queuing Penalty (veh)	0	0		1	0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	282	61	1171	80	60
Average Queue (ft)	18	3	606	46	10
95th Queue (ft)	133	26	1724	81	42
Link Distance (ft)	5784		1608		3
Upstream Blk Time (%)			26		13
Queuing Penalty (veh)			0		9
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		2	12	58	
Queuing Penalty (veh)		3	21	97	

Intersection: 55: Industrial Way

Movement	NB	SB
Directions Served	R	R
Maximum Queue (ft)	83	53
Average Queue (ft)	24	17
95th Queue (ft)	60	46
Link Distance (ft)	99	87
Upstream Blk Time (%)	0	
Queuing Penalty (veh)	0	
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	98	110	238	243	221	388	388
Average Queue (ft)	34	31	49	60	28	234	237
95th Queue (ft)	81	79	145	152	110	388	391
Link Distance (ft)		2710	237	237		370	370
Upstream Blk Time (%)			2	2		2	2
Queuing Penalty (veh)			8	11		8	8
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)		0				9	
Queuing Penalty (veh)		0				1	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	156	178	12	20	102
Average Queue (ft)	21	29	0	1	35
95th Queue (ft)	92	114	7	15	80
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)					0
Queuing Penalty (veh)					0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE	NW
Directions Served	LR	L	TR
Maximum Queue (ft)	58	35	4
Average Queue (ft)	24	6	0
95th Queue (ft)	54	26	3
Link Distance (ft)	1001		2678
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)		150	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	21	17	77	76
Average Queue (ft)	1	1	5	4
95th Queue (ft)	20	20	49	38
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	576	644	69	74
Average Queue (ft)	253	271	5	6
95th Queue (ft)	571	636	41	40
Link Distance (ft)	2166	1051	476	313
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: Dike Road & Frontage Road

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	7	58
Average Queue (ft)	0	16
95th Queue (ft)	5	47
Link Distance (ft)	200	313
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 950

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	6	86	723	282
Average Queue (ft)	0	12	62	86
95th Queue (ft)	4	66	350	238
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)			1	1
Queuing Penalty (veh)			2	0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	232	407	309	116	269	1248	1259	100	348	534	2304	250
Average Queue (ft)	127	129	112	6	143	466	646	69	142	204	402	141
95th Queue (ft)	229	296	239	61	267	1246	1396	130	265	421	1423	269
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)						4	12				2	
Queuing Penalty (veh)						14	46				0	
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	16	5	0		7	11	52	11	2	10	26	13
Queuing Penalty (veh)	68	21	0		12	19	81	34	13	63	211	84

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	222	265	259
Average Queue (ft)	73	152	162
95th Queue (ft)	179	276	284
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	8	9
Queuing Penalty (veh)	0	21	27
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	2	14	
Queuing Penalty (veh)	4	10	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	126	245	248	703	705
Average Queue (ft)	9	33	33	131	137
95th Queue (ft)	59	167	170	522	530
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		10	10	4	4
Queuing Penalty (veh)		38	39	11	11
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	L	T	TR	L	T	TR
Maximum Queue (ft)	112	118	87	4	20	100	321	327
Average Queue (ft)	49	49	24	0	1	16	23	26
95th Queue (ft)	94	91	62	4	10	62	167	174
Link Distance (ft)	233	852		702	702		3455	3455
Upstream Blk Time (%)								
Queuing Penalty (veh)								
Storage Bay Dist (ft)			175			165		
Storage Blk Time (%)							2	
Queuing Penalty (veh)							1	

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	112	857	309
Average Queue (ft)	4	111	45
95th Queue (ft)	41	528	219
Link Distance (ft)	464	4046	404
Upstream Blk Time (%)			1
Queuing Penalty (veh)			2
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	94	1630	118
Average Queue (ft)	4	191	18
95th Queue (ft)	41	977	86
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			11
Queuing Penalty (veh)			57
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	34	58	52	58	123	6	226	380	49	214	380
Average Queue (ft)	11	29	11	16	20	0	56	83	15	29	173
95th Queue (ft)	30	56	35	43	79	4	170	289	46	116	337
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	16	48	12					0			
Queuing Penalty (veh)	12	35	9					0			
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				0	3		1	12	6	0	9
Queuing Penalty (veh)				0	2		3	20	31	0	2

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	236	258	106	221	239	144	98
Average Queue (ft)	84	105	22	70	77	60	39
95th Queue (ft)	181	207	70	172	179	118	80
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)		0					
Queuing Penalty (veh)		0					
Storage Bay Dist (ft)			105				130
Storage Blk Time (%)			0	2		1	0
Queuing Penalty (veh)			1	0		0	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	274	863	859	90	54	34	73	115	103	197	427	387
Average Queue (ft)	155	414	427	18	8	3	16	17	29	61	30	57
95th Queue (ft)	304	839	840	59	38	20	55	80	81	144	167	175
Link Distance (ft)		843	843		237	237		684			404	
Upstream Blk Time (%)		9	10								1	0
Queuing Penalty (veh)		48	50								2	0
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	15	34					2	1	8	2		2
Queuing Penalty (veh)	69	48					1	0	2	3		1

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	284	380	380	1471	1471
Average Queue (ft)	113	71	72	275	277
95th Queue (ft)	261	307	310	1039	1046
Link Distance (ft)	2590	370	370	4783	4783
Upstream Blk Time (%)		12	13		
Queuing Penalty (veh)		62	63		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	NW	SW
Directions Served	L	TR	LR
Maximum Queue (ft)	41	3	42
Average Queue (ft)	8	0	14
95th Queue (ft)	31	3	43
Link Distance (ft)		2660	100
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)	195		
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 25: Douglas Street & Alder Street

Movement	NW	NE
Directions Served	LT	LR
Maximum Queue (ft)	7	47
Average Queue (ft)	0	27
95th Queue (ft)	5	52
Link Distance (ft)	681	100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB	NW
Directions Served	T	T	T	T	T	T
Maximum Queue (ft)	190	575	329	28	40	72
Average Queue (ft)	34	151	40	3	4	3
95th Queue (ft)	141	492	196	15	22	37
Link Distance (ft)		1919	1919	7	7	1681
Upstream Blk Time (%)				13	13	
Queuing Penalty (veh)				6	6	
Storage Bay Dist (ft)	140					
Storage Blk Time (%)		27				
Queuing Penalty (veh)		19				

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	56	196	20
Average Queue (ft)	3	28	1
95th Queue (ft)	28	114	10
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)			4
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	SE	NW	NE
Directions Served	R	L	LR
Maximum Queue (ft)	12	27	24
Average Queue (ft)	1	2	18
95th Queue (ft)	9	13	33
Link Distance (ft)			10
Upstream Blk Time (%)			10
Queuing Penalty (veh)			6
Storage Bay Dist (ft)	210	80	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	SE	NE
Directions Served	T	R
Maximum Queue (ft)	12	36
Average Queue (ft)	0	13
95th Queue (ft)	11	40
Link Distance (ft)	1480	26
Upstream Blk Time (%)		2
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	23	98	90	67	97	50
Average Queue (ft)	2	34	27	19	43	5
95th Queue (ft)	14	82	68	54	75	27
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)		0				
Queuing Penalty (veh)		0				

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	47
Average Queue (ft)	26
95th Queue (ft)	49
Link Distance (ft)	26
Upstream Blk Time (%)	5
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	516	521	113	280	266	187	175
Average Queue (ft)	127	144	28	69	76	33	60
95th Queue (ft)	337	355	78	185	192	113	122
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)		0		0	0		
Queuing Penalty (veh)		0		0	0		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	1		1	1
Queuing Penalty (veh)			1	0		1	0

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	233	248	232	303	306	113	521
Average Queue (ft)	164	180	55	108	123	46	160
95th Queue (ft)	256	264	136	260	281	98	362
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	12	14		0	1		
Queuing Penalty (veh)	57	66		2	3		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			0	3			
Queuing Penalty (veh)			1	2			

Intersection: 48: Industrial Way

Movement	WB	WB	NB	SB
Directions Served	T	T	R	R
Maximum Queue (ft)	357	355	101	84
Average Queue (ft)	60	65	43	24
95th Queue (ft)	272	282	81	66
Link Distance (ft)	420	420	236	90
Upstream Blk Time (%)	1	1		4
Queuing Penalty (veh)	3	5		0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	58	182	111	70	143	36	36	74	68	70	49
Average Queue (ft)	16	31	12	15	33	5	4	15	25	16	20
95th Queue (ft)	42	128	62	51	96	26	23	55	57	55	45
Link Distance (ft)		1112			2438	3	3	3		2218	
Upstream Blk Time (%)						2	1	7			
Queuing Penalty (veh)						1	1	5			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)		0	0		0						
Queuing Penalty (veh)		0	0		0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	233	44	1629	75	66
Average Queue (ft)	13	3	1119	39	11
95th Queue (ft)	97	25	2184	75	40
Link Distance (ft)	5784		1608		3
Upstream Blk Time (%)			48		32
Queuing Penalty (veh)			0		10
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		4	14	79	
Queuing Penalty (veh)		5	19	110	

Intersection: 55: Industrial Way

Movement	NB	SB
Directions Served	R	R
Maximum Queue (ft)	74	55
Average Queue (ft)	22	19
95th Queue (ft)	57	48
Link Distance (ft)	99	87
Upstream Blk Time (%)	0	0
Queuing Penalty (veh)	0	0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	116	180	246	245	212	391	389
Average Queue (ft)	37	48	81	87	29	212	212
95th Queue (ft)	91	127	216	218	115	411	409
Link Distance (ft)		2710	237	237		370	370
Upstream Blk Time (%)			12	12		7	7
Queuing Penalty (veh)			59	60		20	20
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)		2				12	
Queuing Penalty (veh)		1				2	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	309	320	44	56	129
Average Queue (ft)	65	75	2	2	41
95th Queue (ft)	238	252	29	30	97
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)	5	5		0	2
Queuing Penalty (veh)	21	23		0	0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE
Directions Served	LR	L
Maximum Queue (ft)	61	35
Average Queue (ft)	25	6
95th Queue (ft)	54	26
Link Distance (ft)	1001	
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		150
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	299	308	150	157
Average Queue (ft)	51	53	7	10
95th Queue (ft)	225	233	63	75
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)	7	7		
Queuing Penalty (veh)	38	41		
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	570	591	89	77
Average Queue (ft)	271	261	8	7
95th Queue (ft)	576	578	50	44
Link Distance (ft)	2166	1051	476	313
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: Dike Road & Frontage Road

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	3	57
Average Queue (ft)	0	16
95th Queue (ft)	3	45
Link Distance (ft)	200	313
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 1969

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	5	52	506	199
Average Queue (ft)	0	12	35	73
95th Queue (ft)	5	40	245	152
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)			0	
Queuing Penalty (veh)			0	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	230	332	316	137	269	757	976	100	294	408	504	250
Average Queue (ft)	120	158	152	7	192	279	526	76	148	189	213	181
95th Queue (ft)	223	322	298	65	298	602	949	132	261	322	380	290
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)						0	0					
Queuing Penalty (veh)						0	0					
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	14	11	0		15	22	56	11	3	3	24	17
Queuing Penalty (veh)	65	48	0		37	54	106	37	28	23	238	134

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	231	266	264
Average Queue (ft)	88	195	203
95th Queue (ft)	186	287	293
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	6	8
Queuing Penalty (veh)	0	22	29
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	1	18	
Queuing Penalty (veh)	2	15	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	177	248	246	416	422
Average Queue (ft)	10	17	17	42	46
95th Queue (ft)	75	118	118	209	217
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		2	2		
Queuing Penalty (veh)		10	11		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	NB	SB	SB
Directions Served	LTR	LTR	L	T	TR	L	TR
Maximum Queue (ft)	189	140	98	2	22	56	14
Average Queue (ft)	73	57	30	0	1	17	1
95th Queue (ft)	143	108	67	2	10	48	9
Link Distance (ft)	233	852		702	702		5262
Upstream Blk Time (%)	0						
Queuing Penalty (veh)	0						
Storage Bay Dist (ft)			175			165	
Storage Blk Time (%)							
Queuing Penalty (veh)							

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	180	403	262
Average Queue (ft)	7	22	12
95th Queue (ft)	63	161	100
Link Distance (ft)	464	3850	404
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	156	597	121
Average Queue (ft)	8	43	11
95th Queue (ft)	68	289	67
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			4
Queuing Penalty (veh)			20
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	L	T	R	L	TR
Maximum Queue (ft)	33	74	48	74	63	119	215	59	177	492
Average Queue (ft)	12	36	13	23	13	36	72	16	20	213
95th Queue (ft)	29	62	35	57	43	90	158	49	90	407
Link Distance (ft)	7	7	7		1347		1220			1630
Upstream Blk Time (%)	17	55	14							
Queuing Penalty (veh)	15	49	13							
Storage Bay Dist (ft)				90		210		25	160	
Storage Blk Time (%)				0	0		14	2		13
Queuing Penalty (veh)				0	0		18	10		3

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	274	302	124	261	265	172	107
Average Queue (ft)	116	134	29	91	97	67	47
95th Queue (ft)	219	240	84	207	213	130	92
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)		0		0	0		
Queuing Penalty (veh)		0		0	0		
Storage Bay Dist (ft)			105				130
Storage Blk Time (%)			1	3		1	0
Queuing Penalty (veh)			3	1		1	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	275	816	832	86	71	74	98	73	98	209	169	169
Average Queue (ft)	224	394	400	21	10	6	27	13	26	84	17	61
95th Queue (ft)	332	690	691	61	42	37	78	46	72	168	85	128
Link Distance (ft)		843	843		234	234		684			404	
Upstream Blk Time (%)		1	1									
Queuing Penalty (veh)		6	7									
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	36	27					5	2	3	2		0
Queuing Penalty (veh)	187	63					2	1	1	4		0

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	301	379	380	678	677
Average Queue (ft)	137	28	29	100	102
95th Queue (ft)	295	185	187	433	434
Link Distance (ft)	2590	371	371	5564	5564
Upstream Blk Time (%)		3	4		
Queuing Penalty (veh)		19	22		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	NW	SW
Directions Served	L	TR	LR
Maximum Queue (ft)	60	3	70
Average Queue (ft)	17	0	31
95th Queue (ft)	49	3	60
Link Distance (ft)		2660	100
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)	195		
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 25: Douglas Street & Alder Street

Movement	NW	NE
Directions Served	LT	LR
Maximum Queue (ft)	23	63
Average Queue (ft)	1	33
95th Queue (ft)	10	56
Link Distance (ft)	681	100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB	NW
Directions Served	T	T	T	T	T	T
Maximum Queue (ft)	150	313	153	27	49	95
Average Queue (ft)	20	75	14	1	2	5
95th Queue (ft)	99	241	80	11	21	45
Link Distance (ft)		1764	1764	7	7	1681
Upstream Blk Time (%)				4	4	
Queuing Penalty (veh)				2	2	
Storage Bay Dist (ft)	140					
Storage Blk Time (%)		11				
Queuing Penalty (veh)		10				

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	100	101	13
Average Queue (ft)	15	17	1
95th Queue (ft)	81	66	7
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)			1
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	NW	NE
Directions Served	L	LR
Maximum Queue (ft)	27	24
Average Queue (ft)	3	20
95th Queue (ft)	17	32
Link Distance (ft)		10
Upstream Blk Time (%)		13
Queuing Penalty (veh)		10
Storage Bay Dist (ft)	80	
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	36
Average Queue (ft)	14
95th Queue (ft)	40
Link Distance (ft)	26
Upstream Blk Time (%)	2
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	32	117	106	83	129	46
Average Queue (ft)	3	40	38	29	60	5
95th Queue (ft)	18	91	81	68	104	27
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	42
Average Queue (ft)	28
95th Queue (ft)	48
Link Distance (ft)	26
Upstream Blk Time (%)	6
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	303	379	140	308	303	91	152
Average Queue (ft)	123	143	34	112	118	31	71
95th Queue (ft)	242	289	91	247	253	70	125
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)		0		0	0		
Queuing Penalty (veh)		0		1	1		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	2		0	0
Queuing Penalty (veh)			1	1		0	0

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	237	249	244	315	310	142	324
Average Queue (ft)	183	196	68	147	161	59	164
95th Queue (ft)	261	264	153	306	316	119	283
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	9	11		1	1		
Queuing Penalty (veh)	53	65		4	6		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			1	5			
Queuing Penalty (veh)			6	3			

Intersection: 48: Industrial Way

Movement	EB	WB	WB	NB
Directions Served	T	T	T	R
Maximum Queue (ft)	13	3	8	123
Average Queue (ft)	0	0	0	47
95th Queue (ft)	8	3	8	94
Link Distance (ft)	1239	420	420	236
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	58	92	19	30	119	36	47	50	66	46	61
Average Queue (ft)	18	18	1	6	33	10	8	9	27	10	22
95th Queue (ft)	45	58	10	24	87	34	33	35	54	36	50
Link Distance (ft)		2365			2438	3	3	3		2218	
Upstream Blk Time (%)						2	2	1			
Queuing Penalty (veh)						0	0	0			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)		0			0						
Queuing Penalty (veh)		0			0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	245	38	56	47	58
Average Queue (ft)	17	2	4	3	7
95th Queue (ft)	124	17	31	22	35
Link Distance (ft)	5784		1935		3
Upstream Blk Time (%)					9
Queuing Penalty (veh)					3
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		3	5	4	
Queuing Penalty (veh)		1	1	1	

Intersection: 55: Industrial Way

Movement	EB	WB	WB	NB
Directions Served	T	T	T	R
Maximum Queue (ft)	1	3	9	68
Average Queue (ft)	0	0	0	24
95th Queue (ft)	1	3	9	59
Link Distance (ft)	379	746	746	99
Upstream Blk Time (%)				0
Queuing Penalty (veh)				0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	147	109	242	244	236	399	407
Average Queue (ft)	43	33	59	70	34	296	299
95th Queue (ft)	105	79	149	161	148	424	429
Link Distance (ft)		2713	234	234		371	371
Upstream Blk Time (%)			2	2		9	9
Queuing Penalty (veh)			10	13		33	34
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)	0	0			0	20	
Queuing Penalty (veh)	0	0			0	3	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	268	286	73	72	117
Average Queue (ft)	69	79	3	5	45
95th Queue (ft)	205	223	34	39	96
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)	0	0	0		1
Queuing Penalty (veh)	1	2	0		0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE	NW
Directions Served	LR	L	TR
Maximum Queue (ft)	69	44	7
Average Queue (ft)	24	10	0
95th Queue (ft)	55	35	4
Link Distance (ft)	1001		2678
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)		150	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	174	180	159	161
Average Queue (ft)	12	13	16	17
95th Queue (ft)	94	100	85	89
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)	0	0		
Queuing Penalty (veh)	1	2		
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	593	546	63	52
Average Queue (ft)	227	235	4	4
95th Queue (ft)	541	540	31	33
Link Distance (ft)	2167	1051	566	463
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: Dike Road & Frontage Road

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	16	50
Average Queue (ft)	1	16
95th Queue (ft)	8	44
Link Distance (ft)	201	463
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 1574

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	20	211	612	479
Average Queue (ft)	1	24	72	127
95th Queue (ft)	14	128	367	361
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)	0		0	5
Queuing Penalty (veh)	0		0	0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	240	528	516	324	270	1278	1277	100	381	534	2499	250
Average Queue (ft)	135	181	174	24	188	626	839	74	188	290	613	197
95th Queue (ft)	253	403	387	177	325	1435	1536	131	365	490	1877	327
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)						8	18				8	
Queuing Penalty (veh)						39	87				0	
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	18	18	2		18	23	56	18	11	18	38	25
Queuing Penalty (veh)	87	81	7		43	57	107	62	82	142	367	197

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	236	268	270
Average Queue (ft)	93	196	201
95th Queue (ft)	218	331	334
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	21	23
Queuing Penalty (veh)	0	79	87
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	1	32	
Queuing Penalty (veh)	4	25	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	132	243	243	716	725
Average Queue (ft)	10	41	41	276	282
95th Queue (ft)	61	189	189	778	784
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		12	12	10	12
Queuing Penalty (veh)		54	53	39	43
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	L	T	TR	L	T	TR
Maximum Queue (ft)	240	348	119	8	18	266	764	792
Average Queue (ft)	120	103	36	0	1	29	94	99
95th Queue (ft)	250	333	88	8	11	130	448	463
Link Distance (ft)	233	852		702	702		4781	4781
Upstream Blk Time (%)	15	0						
Queuing Penalty (veh)	0	0						
Storage Bay Dist (ft)			175			165		
Storage Blk Time (%)			0				9	
Queuing Penalty (veh)			1				4	

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	142	1319	321
Average Queue (ft)	6	176	60
95th Queue (ft)	52	813	259
Link Distance (ft)	464	3887	404
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	114	2154	121
Average Queue (ft)	5	267	19
95th Queue (ft)	45	1298	90
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			13
Queuing Penalty (veh)			75
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	50	78	51	147	207	6	263	902	58	199	627
Average Queue (ft)	13	32	15	30	37	0	65	186	21	31	264
95th Queue (ft)	35	65	40	90	139	6	192	653	54	117	737
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	20	54	18					1			1
Queuing Penalty (veh)	18	48	16					7			6
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				1	9		1	18	10	0	17
Queuing Penalty (veh)				0	5		5	28	51	0	3

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	274	334	152	335	350	179	140
Average Queue (ft)	117	140	32	119	122	68	50
95th Queue (ft)	235	268	102	296	307	141	108
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)				2	2	0	
Queuing Penalty (veh)				8	9	0	
Storage Bay Dist (ft)			105				130
Storage Blk Time (%)			0	9		2	0
Queuing Penalty (veh)			1	2		1	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	275	861	868	111	67	54	108	216	136	223	402	352
Average Queue (ft)	216	605	613	25	9	6	25	30	39	93	30	75
95th Queue (ft)	369	992	999	77	40	29	74	142	96	203	172	203
Link Distance (ft)		843	843		237	237		684			404	
Upstream Blk Time (%)		14	15								1	0
Queuing Penalty (veh)		89	94								2	0
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	40	42		0			5	3	15	8	0	1
Queuing Penalty (veh)	213	96		0			2	2	4	13	0	1

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	326	374	373	2059	2076
Average Queue (ft)	137	77	78	570	580
95th Queue (ft)	314	324	327	1673	1694
Link Distance (ft)	2590	370	370	5086	5086
Upstream Blk Time (%)		15	16		
Queuing Penalty (veh)		90	95		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	SE	NW	SW
Directions Served	L	T	TR	LR
Maximum Queue (ft)	55	6	122	74
Average Queue (ft)	15	0	20	30
95th Queue (ft)	44	6	232	66
Link Distance (ft)		466	2660	100
Upstream Blk Time (%)				1
Queuing Penalty (veh)				1
Storage Bay Dist (ft)	195			
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 25: Douglas Street & Alder Street

Movement	SE	NW	NE
Directions Served	TR	LT	LR
Maximum Queue (ft)	10	23	62
Average Queue (ft)	1	1	33
95th Queue (ft)	15	11	56
Link Distance (ft)	419	681	100
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB	NW
Directions Served	T	T	T	T	T	T
Maximum Queue (ft)	190	744	482	24	59	89
Average Queue (ft)	54	226	69	3	7	4
95th Queue (ft)	176	671	299	14	36	38
Link Distance (ft)		1752	1752	7	7	1681
Upstream Blk Time (%)				16	16	
Queuing Penalty (veh)				9	9	
Storage Bay Dist (ft)	140					
Storage Blk Time (%)	1	35				
Queuing Penalty (veh)	1	30				

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	88	256	24
Average Queue (ft)	10	47	2
95th Queue (ft)	52	171	13
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)		0	7
Queuing Penalty (veh)		0	1
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	R	L	T	LR
Maximum Queue (ft)	14	38	47	31
Average Queue (ft)	1	3	15	18
95th Queue (ft)	11	26	148	35
Link Distance (ft)			466	10
Upstream Blk Time (%)			1	18
Queuing Penalty (veh)			4	14
Storage Bay Dist (ft)	210	80		
Storage Blk Time (%)			3	
Queuing Penalty (veh)			0	

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	SE	NE
Directions Served	T	R
Maximum Queue (ft)	192	35
Average Queue (ft)	15	12
95th Queue (ft)	176	38
Link Distance (ft)	1480	26
Upstream Blk Time (%)		2
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)	1	
Queuing Penalty (veh)	0	

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	29	138	109	87	131	60
Average Queue (ft)	3	46	41	26	62	5
95th Queue (ft)	16	101	86	66	108	29
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)		0				
Queuing Penalty (veh)		0				

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	45
Average Queue (ft)	28
95th Queue (ft)	50
Link Distance (ft)	26
Upstream Blk Time (%)	6
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	752	754	161	289	296	496	272
Average Queue (ft)	279	292	40	107	109	96	102
95th Queue (ft)	669	679	111	244	251	345	208
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)	7	8		0	0		
Queuing Penalty (veh)	34	38		1	1		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	3		4	10
Queuing Penalty (veh)			1	1		5	4

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	248	255	250	318	317	413	916
Average Queue (ft)	207	211	87	156	169	81	314
95th Queue (ft)	257	257	200	334	346	303	751
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	28	31		1	2	1	2
Queuing Penalty (veh)	161	175		6	9	0	0
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			6	6			
Queuing Penalty (veh)			25	4			

Intersection: 48: Industrial Way

Movement	WB	WB	NB
Directions Served	T	T	R
Maximum Queue (ft)	409	404	122
Average Queue (ft)	110	115	46
95th Queue (ft)	393	392	91
Link Distance (ft)	420	420	236
Upstream Blk Time (%)	4	4	
Queuing Penalty (veh)	17	18	
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	68	167	104	264	306	40	35	80	69	68	54
Average Queue (ft)	21	38	19	84	70	8	6	19	28	15	23
95th Queue (ft)	53	105	72	222	209	30	28	57	57	52	50
Link Distance (ft)		2250			2438	3	3	3		2218	
Upstream Blk Time (%)						3	2	6			
Queuing Penalty (veh)						1	1	2			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)	0	0		22	0						
Queuing Penalty (veh)	0	0		72	0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	235	44	1092	76	68
Average Queue (ft)	15	3	443	31	14
95th Queue (ft)	105	21	1377	72	45
Link Distance (ft)	5783		2106		3
Upstream Blk Time (%)			4		37
Queuing Penalty (veh)			0		26
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		5	4	57	
Queuing Penalty (veh)		3	3	37	

Intersection: 55: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	T	R
Maximum Queue (ft)	308	322	120	116	82
Average Queue (ft)	37	41	10	10	25
95th Queue (ft)	209	220	93	95	64
Link Distance (ft)	379	379	746	746	99
Upstream Blk Time (%)	2	3			0
Queuing Penalty (veh)	9	14			0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	198	331	245	246	245	401	402
Average Queue (ft)	55	70	102	112	31	287	285
95th Queue (ft)	140	237	231	235	115	513	512
Link Distance (ft)		2716	237	237		370	370
Upstream Blk Time (%)			11	14		19	20
Queuing Penalty (veh)			65	83		74	77
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)	0	8				31	
Queuing Penalty (veh)	0	4				4	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	320	331	85	86	153
Average Queue (ft)	172	181	5	6	70
95th Queue (ft)	365	376	46	53	146
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)	11	14	0	0	21
Queuing Penalty (veh)	60	76	0	0	0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE	NW
Directions Served	LR	L	TR
Maximum Queue (ft)	50	51	6
Average Queue (ft)	24	11	0
95th Queue (ft)	50	36	4
Link Distance (ft)	1001		2678
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)		150	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	303	306	197	190
Average Queue (ft)	85	90	24	29
95th Queue (ft)	289	298	111	120
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)	10	11		
Queuing Penalty (veh)	69	73		
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	523	634	100	77
Average Queue (ft)	226	271	9	6
95th Queue (ft)	500	621	58	39
Link Distance (ft)	2167	1051	566	462
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: 432 Ramps

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	15	58
Average Queue (ft)	1	16
95th Queue (ft)	8	45
Link Distance (ft)	287	462
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 4053

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	38	80	571	209
Average Queue (ft)	2	15	44	76
95th Queue (ft)	21	51	281	161
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)	0		0	
Queuing Penalty (veh)	0		1	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	239	427	403	215	270	1081	1208	100	384	534	1860	250
Average Queue (ft)	128	170	166	11	197	459	777	75	176	237	358	188
95th Queue (ft)	243	341	329	106	314	1049	1334	132	322	438	1084	297
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)						1	4				0	
Queuing Penalty (veh)						4	18				0	
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	14	15	1		18	24	60	13	7	8	29	20
Queuing Penalty (veh)	69	68	2		44	59	115	43	61	65	283	160

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	221	270	270
Average Queue (ft)	86	196	205
95th Queue (ft)	192	303	311
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	11	14
Queuing Penalty (veh)	0	42	53
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	0	23	
Queuing Penalty (veh)	1	19	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	112	241	247	673	669
Average Queue (ft)	14	26	27	106	112
95th Queue (ft)	64	145	149	430	437
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		5	6	1	1
Queuing Penalty (veh)		24	25	3	3
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	L	T	TR	L	T	TR
Maximum Queue (ft)	198	146	91	3	9	65	105	112
Average Queue (ft)	73	55	31	0	0	18	6	8
95th Queue (ft)	154	111	69	3	5	49	65	74
Link Distance (ft)	233	852		702	702		5311	5311
Upstream Blk Time (%)	1							
Queuing Penalty (veh)	0							
Storage Bay Dist (ft)			175			165		
Storage Blk Time (%)							0	
Queuing Penalty (veh)							0	

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	60	766	390
Average Queue (ft)	2	73	48
95th Queue (ft)	24	411	253
Link Distance (ft)	464	3771	404
Upstream Blk Time (%)			3
Queuing Penalty (veh)			9
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	146	1145	122
Average Queue (ft)	53	86	12
95th Queue (ft)	182	535	72
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			7
Queuing Penalty (veh)			38
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	44	64	46	88	130	14	316	765	58	214	448
Average Queue (ft)	14	33	15	27	25	0	61	153	19	26	231
95th Queue (ft)	32	59	38	70	89	9	185	531	52	104	413
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	22	56	19					0			
Queuing Penalty (veh)	19	49	17					2			
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				1	4		1	16	8		16
Queuing Penalty (veh)				0	2		3	25	43		3

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	302	315	99	315	298	154	150
Average Queue (ft)	111	132	30	90	93	64	49
95th Queue (ft)	228	249	78	219	223	121	108
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)		0		0	0		
Queuing Penalty (veh)		0		0	0		
Storage Bay Dist (ft)			105			130	
Storage Blk Time (%)			0	3		1	1
Queuing Penalty (veh)			2	1		1	1

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	275	853	862	105	78	60	99	114	112	209	207	318
Average Queue (ft)	226	438	447	24	10	6	26	14	32	86	20	71
95th Queue (ft)	331	761	774	72	48	30	76	71	86	176	113	174
Link Distance (ft)		843	843		239	239		684			404	
Upstream Blk Time (%)		4	4								0	0
Queuing Penalty (veh)		23	27								0	0
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	35	32			0		5	1	6	3		0
Queuing Penalty (veh)	183	74			0		2	0	2	4		0

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	295	375	378	1157	1158
Average Queue (ft)	142	44	50	194	198
95th Queue (ft)	302	239	254	750	761
Link Distance (ft)	2590	368	368	5707	5707
Upstream Blk Time (%)		6	7		
Queuing Penalty (veh)		36	40		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	SW
Directions Served	L	LR
Maximum Queue (ft)	60	81
Average Queue (ft)	15	32
95th Queue (ft)	44	63
Link Distance (ft)		100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)	195	
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 25: Douglas Street & Alder Street

Movement	SE	NW	NE
Directions Served	TR	LT	LR
Maximum Queue (ft)	3	22	68
Average Queue (ft)	0	1	34
95th Queue (ft)	3	13	58
Link Distance (ft)	419	681	100
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	190	649	414	23	44
Average Queue (ft)	44	181	59	2	5
95th Queue (ft)	160	558	286	12	25
Link Distance (ft)		1817	1817	7	7
Upstream Blk Time (%)				12	13
Queuing Penalty (veh)				7	7
Storage Bay Dist (ft)	140				
Storage Blk Time (%)	0	30			
Queuing Penalty (veh)	0	25			

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	156	190	21
Average Queue (ft)	45	30	1
95th Queue (ft)	161	116	10
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)		0	5
Queuing Penalty (veh)		0	1
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	SE	NW	NE
Directions Served	R	L	LR
Maximum Queue (ft)	17	34	31
Average Queue (ft)	1	2	20
95th Queue (ft)	12	16	34
Link Distance (ft)			10
Upstream Blk Time (%)			17
Queuing Penalty (veh)			13
Storage Bay Dist (ft)	210	80	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	SE	NW	NE
Directions Served	T	TR	R
Maximum Queue (ft)	52	2	35
Average Queue (ft)	4	0	12
95th Queue (ft)	69	2	37
Link Distance (ft)	1480	1220	26
Upstream Blk Time (%)			2
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)	0		
Queuing Penalty (veh)	0		

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	31	128	113	88	136	43
Average Queue (ft)	3	46	39	27	61	4
95th Queue (ft)	18	102	85	68	109	24
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)		0				
Queuing Penalty (veh)		0				

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	48
Average Queue (ft)	30
95th Queue (ft)	49
Link Distance (ft)	26
Upstream Blk Time (%)	6
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	330	355	158	299	308	131	159
Average Queue (ft)	135	152	37	110	116	34	75
95th Queue (ft)	272	295	105	247	258	89	131
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)				0	0		
Queuing Penalty (veh)				1	1		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	2		0	1
Queuing Penalty (veh)			0	1		0	0

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	243	252	224	303	312	162	334
Average Queue (ft)	191	202	73	150	164	60	158
95th Queue (ft)	268	268	164	308	327	123	272
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	13	16		1	1		
Queuing Penalty (veh)	74	93		4	6		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			2	6			
Queuing Penalty (veh)			10	4			

Intersection: 48: Industrial Way

Movement	EB	WB	WB	NB
Directions Served	T	T	T	R
Maximum Queue (ft)	19	179	179	136
Average Queue (ft)	1	17	23	47
95th Queue (ft)	13	126	144	95
Link Distance (ft)	1239	420	420	236
Upstream Blk Time (%)		0	0	
Queuing Penalty (veh)		0	0	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	R	L	T	R	L	T	R
Maximum Queue (ft)	94	236	99	278	583	6	42	41	72	78	81	62
Average Queue (ft)	22	46	15	80	83	0	8	5	21	30	18	23
95th Queue (ft)	61	142	63	217	287	6	32	27	58	64	58	53
Link Distance (ft)		2300			2438	2438	3	3	3		2218	
Upstream Blk Time (%)							3	2	6			
Queuing Penalty (veh)							1	1	2			
Storage Bay Dist (ft)	115		225	155						150		200
Storage Blk Time (%)	0	0		18	0						0	
Queuing Penalty (veh)	0	0		60	0						0	

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NE	NE	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	46	842	69	62
Average Queue (ft)	3	321	27	13
95th Queue (ft)	20	1170	68	42
Link Distance (ft)		2045		3
Upstream Blk Time (%)		5		37
Queuing Penalty (veh)		0		26
Storage Bay Dist (ft)	35		25	
Storage Blk Time (%)	5	21	43	
Queuing Penalty (veh)	3	14	28	

Intersection: 55: Industrial Way

Movement	WB	WB	NB
Directions Served	T	T	R
Maximum Queue (ft)	20	9	78
Average Queue (ft)	1	0	23
95th Queue (ft)	16	7	61
Link Distance (ft)	746	746	99
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	132	148	252	250	204	398	398
Average Queue (ft)	41	37	79	90	27	278	282
95th Queue (ft)	97	102	195	203	117	468	470
Link Distance (ft)		2712	239	239		368	368
Upstream Blk Time (%)			6	7	0	10	11
Queuing Penalty (veh)			34	38	0	41	45
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)	0	1				22	
Queuing Penalty (veh)	0	0				3	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	294	303	83	114	138
Average Queue (ft)	90	105	4	6	49
95th Queue (ft)	251	272	39	50	112
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)	1	1	0	0	5
Queuing Penalty (veh)	4	7	0	0	0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE
Directions Served	LR	L
Maximum Queue (ft)	64	38
Average Queue (ft)	25	8
95th Queue (ft)	54	30
Link Distance (ft)	1001	
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		150
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	306	308	151	158
Average Queue (ft)	32	32	13	19
95th Queue (ft)	181	184	78	92
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)	2	2		
Queuing Penalty (veh)	11	15		
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	596	598	65	75
Average Queue (ft)	249	253	6	7
95th Queue (ft)	578	580	40	48
Link Distance (ft)	2167	1051	566	462
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 73: Dike Road & Frontage Road

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	17	43
Average Queue (ft)	1	14
95th Queue (ft)	8	40
Link Distance (ft)	305	462
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Network Summary

Network wide Queuing Penalty: 2355

Intersection: 1: Weyerhaeuser & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	TR	L	T	LR
Maximum Queue (ft)	3	105	675	414
Average Queue (ft)	0	17	95	113
95th Queue (ft)	3	77	437	292
Link Distance (ft)	116	745	745	484
Upstream Blk Time (%)			0	0
Queuing Penalty (veh)			1	0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 2: Oregon Way & Industrial Way

Movement	EB	EB	EB	EB	WB	WB	WB	WB	NB	NB	NB	NB
Directions Served	L	T	T	R	L	L	T	R	L	T	T	R
Maximum Queue (ft)	240	455	423	327	270	1234	1263	100	384	535	2341	250
Average Queue (ft)	148	191	175	22	192	737	1029	74	187	284	555	202
95th Queue (ft)	265	400	360	150	318	1500	1521	131	353	505	1649	317
Link Distance (ft)		745				1239	1239				2473	
Upstream Blk Time (%)						9	18				3	
Queuing Penalty (veh)						43	91				0	
Storage Bay Dist (ft)	140		400	400	160			50	235	235		120
Storage Blk Time (%)	23	16	1	0	18	24	59	19	9	15	35	25
Queuing Penalty (veh)	113	73	3	0	43	58	112	68	68	120	343	199

Intersection: 2: Oregon Way & Industrial Way

Movement	SB	SB	SB
Directions Served	L	T	TR
Maximum Queue (ft)	235	272	267
Average Queue (ft)	94	203	206
95th Queue (ft)	214	330	328
Link Distance (ft)		236	236
Upstream Blk Time (%)	0	25	26
Queuing Penalty (veh)	0	96	102
Storage Bay Dist (ft)	170		
Storage Blk Time (%)	2	35	
Queuing Penalty (veh)	7	29	

Intersection: 4: Oregon Way & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	79	245	253	714	723
Average Queue (ft)	23	45	47	251	260
95th Queue (ft)	64	193	199	681	694
Link Distance (ft)	4581	236	236	702	702
Upstream Blk Time (%)		11	11	2	3
Queuing Penalty (veh)		52	55	9	11
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 5: Oregon Way & Alabama Street

Movement	EB	WB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	L	TR	L	T	TR
Maximum Queue (ft)	187	150	107	2	67	168	184
Average Queue (ft)	79	61	31	0	15	11	15
95th Queue (ft)	162	119	73	2	47	78	91
Link Distance (ft)	233	852		702		5912	5912
Upstream Blk Time (%)	1						
Queuing Penalty (veh)	0						
Storage Bay Dist (ft)			175		165		
Storage Blk Time (%)			0			0	
Queuing Penalty (veh)			0			0	

Intersection: 9: California Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	62	873	410
Average Queue (ft)	3	116	71
95th Queue (ft)	27	515	300
Link Distance (ft)	464	3940	404
Upstream Blk Time (%)			3
Queuing Penalty (veh)			9
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Industrial Way & Spur Line

Movement	WB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	109	1211	129
Average Queue (ft)	45	181	20
95th Queue (ft)	154	810	94
Link Distance (ft)	993	2678	116
Upstream Blk Time (%)			13
Queuing Penalty (veh)			80
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 12: Industrial Way & Washington Way

Movement	EB	EB	EB	WB	WB	WB	SE	SE	SE	NW	NW
Directions Served	L	T	R	L	T	R	L	T	R	L	TR
Maximum Queue (ft)	50	62	61	152	276	21	380	1095	58	198	481
Average Queue (ft)	12	29	14	32	53	1	84	273	22	36	207
95th Queue (ft)	34	61	41	99	192	19	273	886	55	127	402
Link Distance (ft)	7	7	7		1347	1347		1220			1630
Upstream Blk Time (%)	21	52	18					2			
Queuing Penalty (veh)	18	45	16					14			
Storage Bay Dist (ft)				90			210		25	160	
Storage Blk Time (%)				0	15		0	17	19	1	13
Queuing Penalty (veh)				0	9		0	26	103	5	2

Intersection: 16: Columbia Ave & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	292	324	159	326	314	156	116
Average Queue (ft)	109	134	36	129	136	66	47
95th Queue (ft)	228	260	118	338	340	125	93
Link Distance (ft)	420	420		379	379	398	
Upstream Blk Time (%)				5	5		
Queuing Penalty (veh)				21	22		
Storage Bay Dist (ft)			105			130	
Storage Blk Time (%)			0	12		1	0
Queuing Penalty (veh)			2	3		1	0

Intersection: 20: California Way & Industrial Way

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	R	L	T	R
Maximum Queue (ft)	275	862	866	100	64	50	102	123	110	215	400	397
Average Queue (ft)	233	568	575	25	7	5	27	21	36	87	31	93
95th Queue (ft)	354	941	947	73	33	26	79	80	87	184	174	255
Link Distance (ft)		843	843		233	233		684			404	
Upstream Blk Time (%)		10	11								1	0
Queuing Penalty (veh)		66	71								2	0
Storage Bay Dist (ft)	150			150			60		60	165		300
Storage Blk Time (%)	41	42		0			4	1	11	3		2
Queuing Penalty (veh)	219	96		0			2	1	3	6		2

Intersection: 22: 3rd Avenue & Spur Line

Movement	WB	NB	NB	SB	SB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	272	386	380	1347	1338
Average Queue (ft)	113	85	88	402	408
95th Queue (ft)	272	341	345	1082	1097
Link Distance (ft)	2590	371	371	6184	6184
Upstream Blk Time (%)		15	16		
Queuing Penalty (veh)		87	96		
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 24: Industrial Way & Douglas Street

Movement	SE	NW	SW
Directions Served	L	TR	LR
Maximum Queue (ft)	64	5	76
Average Queue (ft)	14	0	31
95th Queue (ft)	45	4	63
Link Distance (ft)		2660	100
Upstream Blk Time (%)			0
Queuing Penalty (veh)			0
Storage Bay Dist (ft)	195		
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 25: Douglas Street & Alder Street

Movement	NW	NE
Directions Served	LT	LR
Maximum Queue (ft)	24	71
Average Queue (ft)	1	34
95th Queue (ft)	14	58
Link Distance (ft)	681	100
Upstream Blk Time (%)		0
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 29: Spur Line & Washington Way

Movement	EB	EB	EB	WB	WB
Directions Served	T	T	T	T	T
Maximum Queue (ft)	190	664	484	29	50
Average Queue (ft)	78	303	106	4	9
95th Queue (ft)	213	699	373	18	34
Link Distance (ft)		1850	1850	7	7
Upstream Blk Time (%)				25	25
Queuing Penalty (veh)				15	15
Storage Bay Dist (ft)	140				
Storage Blk Time (%)	1	56			
Queuing Penalty (veh)	1	50			

Intersection: 31: Weyerhaeuser Access & Spur Line

Movement	NW	NE	SW
Directions Served	T	T	T
Maximum Queue (ft)	99	239	29
Average Queue (ft)	32	54	4
95th Queue (ft)	102	180	17
Link Distance (ft)	5597	313	10
Upstream Blk Time (%)		1	11
Queuing Penalty (veh)		0	2
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 33: Weyerhaeuser Access & Industrial Way

Movement	SE	NW	NW	NE
Directions Served	R	L	T	LR
Maximum Queue (ft)	35	31	13	24
Average Queue (ft)	3	3	0	18
95th Queue (ft)	20	19	13	33
Link Distance (ft)			466	10
Upstream Blk Time (%)				16
Queuing Penalty (veh)				12
Storage Bay Dist (ft)	210	80		
Storage Blk Time (%)		0	0	
Queuing Penalty (veh)		2	0	

Intersection: 37: Weyerhaeuser Access 2 & Industrial Way

Movement	SE	NE
Directions Served	T	R
Maximum Queue (ft)	380	38
Average Queue (ft)	22	13
95th Queue (ft)	179	39
Link Distance (ft)	1480	26
Upstream Blk Time (%)		4
Queuing Penalty (veh)		0
Storage Bay Dist (ft)		
Storage Blk Time (%)	3	
Queuing Penalty (veh)	0	

Intersection: 39: Industrial Way & Prudential Blvd

Movement	SE	SE	NW	NW	SW	SW
Directions Served	L	T	T	T	L	R
Maximum Queue (ft)	26	135	108	76	137	46
Average Queue (ft)	2	42	38	25	60	6
95th Queue (ft)	16	101	85	63	107	28
Link Distance (ft)		2438	513	513	1261	1261
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)	170					
Storage Blk Time (%)		0				
Queuing Penalty (veh)		0				

Intersection: 41: Hoehne Avenue & Industrial Way

Movement	NE
Directions Served	R
Maximum Queue (ft)	54
Average Queue (ft)	29
95th Queue (ft)	52
Link Distance (ft)	26
Upstream Blk Time (%)	6
Queuing Penalty (veh)	0
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 45: International Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	437	468	123	289	302	188	180
Average Queue (ft)	173	186	31	108	113	42	76
95th Queue (ft)	366	387	85	244	254	132	144
Link Distance (ft)	746	746		304	304	973	
Upstream Blk Time (%)				0	0		
Queuing Penalty (veh)				1	1		
Storage Bay Dist (ft)			150				150
Storage Blk Time (%)			0	3		1	1
Queuing Penalty (veh)			0	1		2	1

Intersection: 47: Fiber Way & Industrial Way

Movement	EB	EB	WB	WB	WB	NB	NB
Directions Served	T	TR	L	T	T	L	R
Maximum Queue (ft)	240	247	231	308	319	137	459
Average Queue (ft)	195	205	78	146	160	57	195
95th Queue (ft)	265	267	173	315	331	112	376
Link Distance (ft)	208	208		295	295	975	975
Upstream Blk Time (%)	18	22		1	1		
Queuing Penalty (veh)	109	131		4	7		
Storage Bay Dist (ft)			150				
Storage Blk Time (%)			2	6			
Queuing Penalty (veh)			12	4			

Intersection: 48: Industrial Way

Movement	EB	WB	WB	NB
Directions Served	T	T	T	R
Maximum Queue (ft)	8	302	308	109
Average Queue (ft)	0	115	125	44
95th Queue (ft)	6	405	415	84
Link Distance (ft)	1239	420	420	236
Upstream Blk Time (%)		5	5	
Queuing Penalty (veh)		24	25	
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 49: 38th Avenue & Industrial Way

Movement	SE	SE	SE	NW	NW	NE	NE	NE	SW	SW	SW
Directions Served	L	T	R	L	T	L	T	R	L	T	R
Maximum Queue (ft)	84	343	129	280	569	48	47	72	75	99	64
Average Queue (ft)	22	68	26	109	113	7	6	17	29	26	23
95th Queue (ft)	59	290	93	263	386	30	30	54	63	76	54
Link Distance (ft)		2266			2438	3	3	3		2218	
Upstream Blk Time (%)						3	2	6			
Queuing Penalty (veh)						1	1	2			
Storage Bay Dist (ft)	115		225	155					150		200
Storage Blk Time (%)		2		28	1						
Queuing Penalty (veh)		1		91	0						

Intersection: 50: Aluminum Access 1/38th Avenue & Spur Line

Movement	NW	NE	NE	NE	SW
Directions Served	T	T	T	T	T
Maximum Queue (ft)	32	74	1110	75	62
Average Queue (ft)	2	6	433	38	17
95th Queue (ft)	20	37	1146	77	48
Link Distance (ft)	5784		1907		3
Upstream Blk Time (%)			1		53
Queuing Penalty (veh)			0		37
Storage Bay Dist (ft)		35		25	
Storage Blk Time (%)		7	20	67	
Queuing Penalty (veh)		5	13	43	

Intersection: 55: Industrial Way

Movement	WB	WB	NB
Directions Served	T	T	R
Maximum Queue (ft)	138	138	91
Average Queue (ft)	44	47	24
95th Queue (ft)	282	297	62
Link Distance (ft)	746	746	99
Upstream Blk Time (%)	0	0	0
Queuing Penalty (veh)	1	2	0
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 56: Industrial Way & 3rd Avenue

Movement	NW	NW	NE	NE	SW	SW	SW
Directions Served	L	R	T	TR	L	T	T
Maximum Queue (ft)	142	177	246	248	242	413	402
Average Queue (ft)	43	41	106	116	28	287	288
95th Queue (ft)	100	114	237	241	123	501	500
Link Distance (ft)		2712	233	233		371	371
Upstream Blk Time (%)			13	14		21	21
Queuing Penalty (veh)			75	79		87	90
Storage Bay Dist (ft)	175				250		
Storage Blk Time (%)		1				30	
Queuing Penalty (veh)		1				5	

Intersection: 59: Industrial Way

Movement	EB	EB	WB	WB	NB
Directions Served	T	T	T	TR	R
Maximum Queue (ft)	317	325	79	108	148
Average Queue (ft)	129	140	4	6	64
95th Queue (ft)	320	335	38	49	137
Link Distance (ft)	304	304	208	208	118
Upstream Blk Time (%)	3	5			15
Queuing Penalty (veh)	17	28			0
Storage Bay Dist (ft)					
Storage Blk Time (%)					
Queuing Penalty (veh)					

Intersection: 61: Industrial Way

Movement	SB	SE	NW
Directions Served	LR	L	TR
Maximum Queue (ft)	60	44	3
Average Queue (ft)	24	8	0
95th Queue (ft)	52	31	3
Link Distance (ft)	1001		2678
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)		150	
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 64: Industrial Way

Movement	EB	EB	WB	WB
Directions Served	T	TR	T	T
Maximum Queue (ft)	316	305	171	243
Average Queue (ft)	69	72	13	20
95th Queue (ft)	261	269	80	131
Link Distance (ft)	295	295	843	843
Upstream Blk Time (%)	5	6		0
Queuing Penalty (veh)	33	43		0
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 67: 432 Ramps

Movement	WB	NE
Directions Served	LT	LR
Maximum Queue (ft)	19	51
Average Queue (ft)	1	14
95th Queue (ft)	11	41
Link Distance (ft)	301	462
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 69: Dike Road & Spur Line

Movement	SE	NW	NE	SW
Directions Served	T	T	T	T
Maximum Queue (ft)	420	416	101	88
Average Queue (ft)	137	164	13	13
95th Queue (ft)	369	406	61	64
Link Distance (ft)	2167	1051	566	462
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 3797



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	2	0	0	3	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	2	0	0	3	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	2	0	0	3	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1638.0			1638.0						154.0	
Effective Green, g (s)		1638.0			1638.0						154.0	
Actuated g/C Ratio		0.91			0.91						0.09	
Clearance Time (s)												
Lane Grp Cap (vph)		1695			1695						162	
v/s Ratio Prot		0.00			c0.00						c0.03	
v/s Ratio Perm												
v/c Ratio		0.00			0.00						0.31	
Uniform Delay, d1		7.3			7.3						773.0	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.0			0.0						4.9	
Delay (s)		7.3			7.3						777.9	
Level of Service		A			A						F	
Approach Delay (s)		7.3			7.3			0.0			777.9	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	707.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	48	0	0	72	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1638.0			1638.0						154.0	
Effective Green, g (s)		1638.0			1638.0						154.0	
Actuated g/C Ratio		0.91			0.91						0.09	
Clearance Time (s)												
Lane Grp Cap (vph)		1695			1695						162	
v/s Ratio Prot		0.03			c0.04						c0.03	
v/s Ratio Perm												
v/c Ratio		0.03			0.05						0.31	
Uniform Delay, d1		7.5			7.6						773.0	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.0			0.1						4.9	
Delay (s)		7.5			7.7						777.9	
Level of Service		A			A						F	
Approach Delay (s)		7.5			7.7			0.0			777.9	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	218.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	13.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	0	0	0	50	0	0	28	0	0	42	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)					2.0			2.0			2.0	
Lane Util. Factor					1.00			1.00			1.00	
Frt					1.00			1.00			1.00	
Flt Protected					1.00			1.00			1.00	
Satd. Flow (prot)					1900			1863			1863	
Flt Permitted					1.00			1.00			1.00	
Satd. Flow (perm)					1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	0	0	0	0	50	0	0	31	0	0	47	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	0	0	0	50	0	0	31	0	0	47	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type					NA			NA			NA	
Protected Phases		2 4			2 4			1 3 5			1 3 5	
Permitted Phases												
Actuated Green, G (s)					135.0			1657.0			1657.0	
Effective Green, g (s)					135.0			1657.0			1657.0	
Actuated g/C Ratio					0.08			0.92			0.92	
Clearance Time (s)												
Lane Grp Cap (vph)					142			1714			1714	
v/s Ratio Prot					c0.03			0.02			c0.03	
v/s Ratio Perm												
v/c Ratio					0.35			0.02			0.03	
Uniform Delay, d1					791.0			5.8			5.8	
Progression Factor					1.00			1.00			1.00	
Incremental Delay, d2					6.7			0.0			0.0	
Delay (s)					797.7			5.8			5.9	
Level of Service					F			A			A	
Approach Delay (s)		0.0			797.7			5.8			5.9	
Approach LOS		A			F			A			A	

Intersection Summary			
HCM 2000 Control Delay	315.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	102	0	0	153	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	113	0	0	170	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	113	0	0	170	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1614.0			1614.0						178.0	
Effective Green, g (s)		1614.0			1614.0						178.0	
Actuated g/C Ratio		0.90			0.90						0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1670			1670						187	
v/s Ratio Prot		0.06			c0.09						c0.03	
v/s Ratio Perm												
v/c Ratio		0.07			0.10						0.27	
Uniform Delay, d1		10.2			10.6						750.6	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.1			0.1						3.5	
Delay (s)		10.3			10.7						754.1	
Level of Service		B			B						F	
Approach Delay (s)		10.3			10.7			0.0			754.1	
Approach LOS		B			B			A			F	

Intersection Summary			
HCM 2000 Control Delay	122.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.12		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	18.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	74	0	0	111	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	82	0	0	123	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	82	0	0	123	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1614.0			1614.0						178.0	
Effective Green, g (s)		1614.0			1614.0						178.0	
Actuated g/C Ratio		0.90			0.90						0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1670			1670						187	
v/s Ratio Prot		0.04			c0.07						c0.03	
v/s Ratio Perm												
v/c Ratio		0.05			0.07						0.27	
Uniform Delay, d1		10.1			10.3						750.6	
Progression Factor		1.00			1.00						0.00	
Incremental Delay, d2		0.1			0.1						3.4	
Delay (s)		10.1			10.4						4.8	
Level of Service		B			B						A	
Approach Delay (s)		10.1			10.4			0.0			4.8	
Approach LOS		B			B			A			A	

Intersection Summary			
HCM 2000 Control Delay	9.2	HCM 2000 Level of Service	A
HCM 2000 Volume to Capacity ratio	0.09		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	15.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	48	0	0	72	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1657.0			1657.0						135.0	
Effective Green, g (s)		1657.0			1657.0						135.0	
Actuated g/C Ratio		0.92			0.92						0.08	
Clearance Time (s)												
Lane Grp Cap (vph)		1714			1714						142	
v/s Ratio Prot		0.03			c0.04						c0.03	
v/s Ratio Perm												
v/c Ratio		0.03			0.05						0.35	
Uniform Delay, d1		5.8			5.9						791.0	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.0			0.1						6.7	
Delay (s)		5.9			6.0						797.7	
Level of Service		A			A						F	
Approach Delay (s)		5.9			6.0			0.0			797.7	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	222.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	13.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	88	0	0	177	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1776			1759						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1776			1759						1900	
Peak-hour factor, PHF	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	104	0	0	208	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	104	0	0	208	0	0	0	0	0	50	0
Heavy Vehicles (%)	7%	7%	7%	8%	8%	8%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1657.0			1657.0						135.0	
Effective Green, g (s)		1657.0			1657.0						135.0	
Actuated g/C Ratio		0.92			0.92						0.08	
Clearance Time (s)												
Lane Grp Cap (vph)		1634			1619						142	
v/s Ratio Prot		0.06			c0.12						c0.03	
v/s Ratio Perm												
v/c Ratio		0.06			0.13						0.35	
Uniform Delay, d1		6.0			6.4						791.0	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.1			0.2						6.7	
Delay (s)		6.1			6.6						797.7	
Level of Service		A			A						F	
Approach Delay (s)		6.1			6.6			0.0			797.7	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	115.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.15		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	19.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	124	0	0	76	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1881			1900						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1881			1900						1900	
Peak-hour factor, PHF	0.86	0.86	0.86	0.86	0.86	0.86	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	144	0	0	88	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	144	0	0	88	0	0	0	0	0	50	0
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1657.0			1657.0						135.0	
Effective Green, g (s)		1657.0			1657.0						135.0	
Actuated g/C Ratio		0.92			0.92						0.08	
Clearance Time (s)												
Lane Grp Cap (vph)		1731			1749						142	
v/s Ratio Prot		c0.08			0.05						c0.03	
v/s Ratio Perm												
v/c Ratio		0.08			0.05						0.35	
Uniform Delay, d1		6.2			6.0						791.0	
Progression Factor		1.00			1.00						0.86	
Incremental Delay, d2		0.1			0.1						6.4	
Delay (s)		6.2			6.0						687.0	
Level of Service		A			A						F	
Approach Delay (s)		6.2			6.0			0.0			687.0	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	126.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.10		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	16.5%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	62	0	0	93	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	69	0	0	103	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	69	0	0	103	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5			1 3 5			2 4			2 4	
Permitted Phases												
Actuated Green, G (s)		1657.0			1657.0						135.0	
Effective Green, g (s)		1657.0			1657.0						135.0	
Actuated g/C Ratio		0.92			0.92						0.08	
Clearance Time (s)												
Lane Grp Cap (vph)		1714			1714						142	
v/s Ratio Prot		0.04			c0.06						c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.06						0.35	
Uniform Delay, d1		5.9			6.0						791.0	
Progression Factor		1.00			1.00						0.29	
Incremental Delay, d2		0.0			0.1						6.4	
Delay (s)		5.9			6.1						236.5	
Level of Service		A			A						F	
Approach Delay (s)		5.9			6.1			0.0			236.5	
Approach LOS		A			A			A			F	

Intersection Summary			
HCM 2000 Control Delay	57.9	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	0.08		
Actuated Cycle Length (s)	1800.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	14.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	2	0	0	3	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	2	0	0	3	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	2	0	0	3	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1713.0			1713.0						112.0	
Effective Green, g (s)		1713.0			1713.0						112.0	
Actuated g/C Ratio		0.86			0.86						0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1595			1595						106	
v/s Ratio Prot		0.00			c0.00						c0.03	
v/s Ratio Perm												
v/c Ratio		0.00			0.00						0.47	
Uniform Delay, d1		20.6			20.6						915.3	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.0			0.0						14.3	
Delay (s)		20.6			20.6						929.6	
Level of Service		C			C						F	
Approach Delay (s)		20.6			20.6			0.0			929.6	
Approach LOS		C			C			A			F	

Intersection Summary			
HCM 2000 Control Delay	847.0	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.03		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	48	0	0	72	0	0	0	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0						2.0	
Lane Util. Factor		1.00			1.00						1.00	
Frt		1.00			1.00						1.00	
Flt Protected		1.00			1.00						1.00	
Satd. Flow (prot)		1863			1863						1900	
Flt Permitted		1.00			1.00						1.00	
Satd. Flow (perm)		1863			1863						1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	53	0	0	80	0	0	0	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA						NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1713.0			1713.0						112.0	
Effective Green, g (s)		1713.0			1713.0						112.0	
Actuated g/C Ratio		0.86			0.86						0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1595			1595						106	
v/s Ratio Prot		0.03			c0.04						c0.03	
v/s Ratio Perm												
v/c Ratio		0.03			0.05						0.47	
Uniform Delay, d1		21.2			21.5						915.3	
Progression Factor		1.00			1.00						1.00	
Incremental Delay, d2		0.0			0.1						14.3	
Delay (s)		21.2			21.6						929.6	
Level of Service		C			C						F	
Approach Delay (s)		21.2			21.6			0.0			929.6	
Approach LOS		C			C			A			F	

Intersection Summary			
HCM 2000 Control Delay	269.6	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.07		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	50	0	0	50	0	0	28	0	0	42	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1900			1900			1863			1863	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1900			1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	0	50	0	0	50	0	0	31	0	0	47	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	50	0	0	50	0	0	31	0	0	47	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type		NA			NA			NA			NA	
Protected Phases		4 6			2			1 3 5 7			1 3 5 7	
Permitted Phases												
Actuated Green, G (s)		143.0			98.0			1747.0			1747.0	
Effective Green, g (s)		143.0			98.0			1747.0			1747.0	
Actuated g/C Ratio		0.07			0.05			0.87			0.87	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)		135			93			1627			1627	
v/s Ratio Prot		c0.03			c0.03			0.02			c0.03	
v/s Ratio Perm												
v/c Ratio		0.37			0.54			0.02			0.03	
Uniform Delay, d1		885.6			928.9			16.3			16.4	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		7.6			20.5			0.0			0.0	
Delay (s)		893.2			949.4			16.3			16.4	
Level of Service		F			F			B			B	
Approach Delay (s)		893.2			949.4			16.3			16.4	
Approach LOS		F			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	524.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.08		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	102	0	0	153	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	113	0	0	170	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	113	0	0	170	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1665.0			1665.0			190.0			133.0	
Effective Green, g (s)		1665.0			1665.0			190.0			133.0	
Actuated g/C Ratio		0.83			0.83			0.10			0.07	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1550			1550			180			126	
v/s Ratio Prot		0.06			c0.09			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.07			0.11			0.28			0.40	
Uniform Delay, d1		29.9			30.9			841.2			895.0	
Progression Factor		1.00			1.00			0.00			1.00	
Incremental Delay, d2		0.1			0.1			3.7			9.1	
Delay (s)		30.0			31.0			5.0			904.1	
Level of Service		C			C			A			F	
Approach Delay (s)		30.0			31.0			5.0			904.1	
Approach LOS		C			C			A			F	

Intersection Summary			
HCM 2000 Control Delay	141.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.14		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	18.1%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	74	0	0	111	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	82	0	0	123	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	82	0	0	123	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1665.0			1665.0			190.0			133.0	
Effective Green, g (s)		1665.0			1665.0			190.0			133.0	
Actuated g/C Ratio		0.83			0.83			0.10			0.07	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1550			1550			180			126	
v/s Ratio Prot		0.04			c0.07			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.05			0.08			0.28			0.40	
Uniform Delay, d1		29.3			30.0			841.2			895.0	
Progression Factor		1.00			1.00			1.00			0.00	
Incremental Delay, d2		0.1			0.1			3.8			8.5	
Delay (s)		29.4			30.1			845.0			9.5	
Level of Service		C			C			F			A	
Approach Delay (s)		29.4			30.1			845.0			9.5	
Approach LOS		C			C			F			A	

Intersection Summary			
HCM 2000 Control Delay	160.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.12		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	15.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	48	0	0	72	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	53	0	0	80	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	53	0	0	80	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1747.0			1747.0			143.0			98.0	
Effective Green, g (s)		1747.0			1747.0			143.0			98.0	
Actuated g/C Ratio		0.87			0.87			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1627			1627			135			93	
v/s Ratio Prot		0.03			c0.04			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.03			0.05			0.37			0.54	
Uniform Delay, d1		16.5			16.7			885.6			928.9	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.0			0.1			7.6			20.5	
Delay (s)		16.5			16.8			893.2			949.4	
Level of Service		B			B			F			F	
Approach Delay (s)		16.5			16.8			893.2			949.4	
Approach LOS		B			B			F			F	

Intersection Summary			
HCM 2000 Control Delay	404.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.10		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	88	0	0	177	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1776			1759			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1776			1759			1900			1900	
Peak-hour factor, PHF	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	104	0	0	208	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	104	0	0	208	0	0	50	0	0	50	0
Heavy Vehicles (%)	7%	7%	7%	8%	8%	8%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1747.0			1747.0			143.0			98.0	
Effective Green, g (s)		1747.0			1747.0			143.0			98.0	
Actuated g/C Ratio		0.87			0.87			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1551			1536			135			93	
v/s Ratio Prot		0.06			c0.12			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.07			0.14			0.37			0.54	
Uniform Delay, d1		17.0			18.1			885.6			928.9	
Progression Factor		1.00			1.00			0.01			1.00	
Incremental Delay, d2		0.1			0.2			7.2			20.5	
Delay (s)		17.1			18.3			12.6			949.4	
Level of Service		B			B			B			F	
Approach Delay (s)		17.1			18.3			12.6			949.4	
Approach LOS		B			B			B			F	

Intersection Summary			
HCM 2000 Control Delay	130.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.17		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	19.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	124	0	0	76	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1881			1900			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1881			1900			1900			1900	
Peak-hour factor, PHF	0.86	0.86	0.86	0.86	0.86	0.86	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	144	0	0	88	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	144	0	0	88	0	0	50	0	0	50	0
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1747.0			1747.0			143.0			98.0	
Effective Green, g (s)		1747.0			1747.0			143.0			98.0	
Actuated g/C Ratio		0.87			0.87			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1643			1659			135			93	
v/s Ratio Prot		c0.08			0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.09			0.05			0.37			0.54	
Uniform Delay, d1		17.3			16.8			885.6			928.9	
Progression Factor		1.00			1.00			0.02			0.01	
Incremental Delay, d2		0.1			0.1			7.2			17.7	
Delay (s)		17.4			16.8			21.0			28.4	
Level of Service		B			B			C			C	
Approach Delay (s)		17.4			16.8			21.0			28.4	
Approach LOS		B			B			C			C	

Intersection Summary			
HCM 2000 Control Delay	19.5	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	16.5%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	62	0	0	93	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	69	0	0	103	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	69	0	0	103	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1747.0			1747.0			143.0			98.0	
Effective Green, g (s)		1747.0			1747.0			143.0			98.0	
Actuated g/C Ratio		0.87			0.87			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1627			1627			135			93	
v/s Ratio Prot		0.04			c0.06			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.06			0.37			0.54	
Uniform Delay, d1		16.6			16.9			885.6			928.9	
Progression Factor		1.00			1.00			1.00			0.01	
Incremental Delay, d2		0.0			0.1			7.6			17.7	
Delay (s)		16.7			17.0			893.2			28.5	
Level of Service		B			B			F			C	
Approach Delay (s)		16.7			17.0			893.2			28.5	
Approach LOS		B			B			F			C	

Intersection Summary			
HCM 2000 Control Delay	180.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.11		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	14.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	2	0	0	3	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	2	0	0	3	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	2	0	0	3	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1722.0			1722.0			154.0			112.0	
Effective Green, g (s)		1722.0			1722.0			154.0			112.0	
Actuated g/C Ratio		0.86			0.86			0.08			0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1604			1604			146			106	
v/s Ratio Prot		0.00			c0.00			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.00			0.00			0.34			0.47	
Uniform Delay, d1		19.3			19.4			875.0			915.3	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.0			0.0			6.3			14.3	
Delay (s)		19.3			19.4			881.3			929.6	
Level of Service		B			B			F			F	
Approach Delay (s)		19.3			19.4			881.3			929.6	
Approach LOS		B			B			F			F	

Intersection Summary			
HCM 2000 Control Delay	863.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	58	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1722.0			1722.0			154.0			112.0	
Effective Green, g (s)		1722.0			1722.0			154.0			112.0	
Actuated g/C Ratio		0.86			0.86			0.08			0.06	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1604			1604			146			106	
v/s Ratio Prot		0.03			c0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.06			0.34			0.47	
Uniform Delay, d1		20.0			20.4			875.0			915.3	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.0			0.1			6.3			14.3	
Delay (s)		20.1			20.5			881.3			929.6	
Level of Service		C			C			F			F	
Approach Delay (s)		20.1			20.5			881.3			929.6	
Approach LOS		C			C			F			F	

Intersection Summary			
HCM 2000 Control Delay	359.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.11		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	14.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	50	0	0	50	0	0	34	0	0	51	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1900			1900			1863			1863	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1900			1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	0	50	0	0	50	0	0	38	0	0	57	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	50	0	0	50	0	0	38	0	0	57	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type		NA			NA			NA			NA	
Protected Phases		4 6			2			1 3 5 7			1 3 5 7	
Permitted Phases												
Actuated Green, G (s)		135.0			98.0			1755.0			1755.0	
Effective Green, g (s)		135.0			98.0			1755.0			1755.0	
Actuated g/C Ratio		0.07			0.05			0.88			0.88	
Clearance Time (s)					2.0							
Lane Grp Cap (vph)		128			93			1634			1634	
v/s Ratio Prot		c0.03			c0.03			0.02			c0.03	
v/s Ratio Perm												
v/c Ratio		0.39			0.54			0.02			0.03	
Uniform Delay, d1		893.1			928.9			15.3			15.5	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		8.7			20.5			0.0			0.0	
Delay (s)		901.8			949.4			15.3			15.5	
Level of Service		F			F			B			B	
Approach Delay (s)		901.8			949.4			15.3			15.5	
Approach LOS		F			F			B			B	

Intersection Summary			
HCM 2000 Control Delay	482.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.08		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	120	0	0	180	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	133	0	0	200	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	133	0	0	200	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1677.0			1677.0			178.0			133.0	
Effective Green, g (s)		1677.0			1677.0			178.0			133.0	
Actuated g/C Ratio		0.84			0.84			0.09			0.07	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1562			1562			169			126	
v/s Ratio Prot		0.07			c0.11			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.09			0.13			0.30			0.40	
Uniform Delay, d1		28.1			29.2			852.4			895.0	
Progression Factor		1.00			1.00			0.00			1.00	
Incremental Delay, d2		0.1			0.2			4.3			9.1	
Delay (s)		28.2			29.4			6.3			904.1	
Level of Service		C			C			A			F	
Approach Delay (s)		28.2			29.4			6.3			904.1	
Approach LOS		C			C			A			F	

Intersection Summary			
HCM 2000 Control Delay	127.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.16		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	19.5%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	88	0	0	132	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	98	0	0	147	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	98	0	0	147	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1677.0			1677.0			178.0			133.0	
Effective Green, g (s)		1677.0			1677.0			178.0			133.0	
Actuated g/C Ratio		0.84			0.84			0.09			0.07	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1562			1562			169			126	
v/s Ratio Prot		0.05			c0.08			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.06			0.09			0.30			0.40	
Uniform Delay, d1		27.5			28.3			852.4			895.0	
Progression Factor		1.00			1.00			1.00			0.00	
Incremental Delay, d2		0.1			0.1			4.4			8.5	
Delay (s)		27.6			28.4			856.8			9.5	
Level of Service		C			C			F			A	
Approach Delay (s)		27.6			28.4			856.8			9.5	
Approach LOS		C			C			F			A	

Intersection Summary			
HCM 2000 Control Delay	145.5	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	16.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	58	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1755.0			1755.0			135.0			98.0	
Effective Green, g (s)		1755.0			1755.0			135.0			98.0	
Actuated g/C Ratio		0.88			0.88			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1634			1634			128			93	
v/s Ratio Prot		0.03			c0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.06			0.39			0.54	
Uniform Delay, d1		15.5			15.8			893.1			928.9	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.0			0.1			8.7			20.5	
Delay (s)		15.6			15.9			901.8			949.4	
Level of Service		B			B			F			F	
Approach Delay (s)		15.6			15.9			901.8			949.4	
Approach LOS		B			B			F			F	

Intersection Summary			
HCM 2000 Control Delay	364.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.11		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	14.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	103	0	0	207	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1776			1759			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1776			1759			1900			1900	
Peak-hour factor, PHF	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	121	0	0	244	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	121	0	0	244	0	0	50	0	0	50	0
Heavy Vehicles (%)	7%	7%	7%	8%	8%	8%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1755.0			1755.0			135.0			98.0	
Effective Green, g (s)		1755.0			1755.0			135.0			98.0	
Actuated g/C Ratio		0.88			0.88			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1558			1543			128			93	
v/s Ratio Prot		0.07			c0.14			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.08			0.16			0.39			0.54	
Uniform Delay, d1		16.1			17.4			893.1			928.9	
Progression Factor		1.00			1.00			0.01			1.00	
Incremental Delay, d2		0.1			0.2			8.2			20.5	
Delay (s)		16.2			17.6			13.6			949.4	
Level of Service		B			B			B			F	
Approach Delay (s)		16.2			17.6			13.6			949.4	
Approach LOS		B			B			B			F	

Intersection Summary			
HCM 2000 Control Delay	117.0	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.19		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	20.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	148	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1881			1900			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1881			1900			1900			1900	
Peak-hour factor, PHF	0.86	0.86	0.86	0.86	0.86	0.86	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	172	0	0	101	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	172	0	0	101	0	0	50	0	0	50	0
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1755.0			1755.0			135.0			98.0	
Effective Green, g (s)		1755.0			1755.0			135.0			98.0	
Actuated g/C Ratio		0.88			0.88			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1650			1667			128			93	
v/s Ratio Prot		c0.09			0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.10			0.06			0.39			0.54	
Uniform Delay, d1		16.5			15.8			893.1			928.9	
Progression Factor		1.00			1.00			0.02			0.01	
Incremental Delay, d2		0.1			0.1			8.2			17.7	
Delay (s)		16.6			15.9			21.9			28.4	
Level of Service		B			B			C			C	
Approach Delay (s)		16.6			15.9			21.9			28.4	
Approach LOS		B			B			C			C	

Intersection Summary			
HCM 2000 Control Delay	18.7	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.14		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	17.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	72	0	0	108	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	80	0	0	120	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	80	0	0	120	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2	
Permitted Phases												
Actuated Green, G (s)		1755.0			1755.0			135.0			98.0	
Effective Green, g (s)		1755.0			1755.0			135.0			98.0	
Actuated g/C Ratio		0.88			0.88			0.07			0.05	
Clearance Time (s)											2.0	
Lane Grp Cap (vph)		1634			1634			128			93	
v/s Ratio Prot		0.04			c0.06			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.05			0.07			0.39			0.54	
Uniform Delay, d1		15.7			16.0			893.1			928.9	
Progression Factor		1.00			1.00			1.00			0.01	
Incremental Delay, d2		0.1			0.1			8.7			17.7	
Delay (s)		15.7			16.1			901.8			28.5	
Level of Service		B			B			F			C	
Approach Delay (s)		15.7			16.1			901.8			28.5	
Approach LOS		B			B			F			C	

Intersection Summary			
HCM 2000 Control Delay	165.7	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.12		
Actuated Cycle Length (s)	2000.0	Sum of lost time (s)	14.0
Intersection Capacity Utilization	15.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	2	0	0	3	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	2	0	0	3	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	2	0	0	3	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1498.0			1498.0			164.0			224.0	
Effective Green, g (s)		1498.0			1498.0			164.0			224.0	
Actuated g/C Ratio		0.79			0.79			0.09			0.12	
Clearance Time (s)												
Lane Grp Cap (vph)		1468			1468			164			224	
v/s Ratio Prot		0.00			c0.00			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.00			0.00			0.30			0.22	
Uniform Delay, d1		42.6			42.6			814.5			759.2	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.0			0.0			4.7			2.3	
Delay (s)		42.6			42.6			819.3			761.5	
Level of Service		D			D			F			F	
Approach Delay (s)		42.6			42.6			819.3			761.5	
Approach LOS		D			D			F			F	

Intersection Summary			
HCM 2000 Control Delay	754.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.05		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	58	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1498.0			1498.0			164.0			224.0	
Effective Green, g (s)		1498.0			1498.0			164.0			224.0	
Actuated g/C Ratio		0.79			0.79			0.09			0.12	
Clearance Time (s)												
Lane Grp Cap (vph)		1468			1468			164			224	
v/s Ratio Prot		0.03			c0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.07			0.30			0.22	
Uniform Delay, d1		44.0			44.9			814.5			759.2	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.1			0.1			4.7			2.3	
Delay (s)		44.1			45.0			819.3			761.5	
Level of Service		D			D			F			F	
Approach Delay (s)		44.1			45.0			819.3			761.5	
Approach LOS		D			D			F			F	

Intersection Summary			
HCM 2000 Control Delay	330.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.11		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	14.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SET	SER	NWL	NWT	NWR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	50	0	0	50	0	0	34	0	0	51	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1900			1900			1863			1863	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1900			1900			1863			1863	
Peak-hour factor, PHF	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90
Adj. Flow (vph)	0	50	0	0	50	0	0	38	0	0	57	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	50	0	0	50	0	0	38	0	0	57	0
Heavy Vehicles (%)	0%	0%	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Turn Type		NA			NA			NA			NA	
Protected Phases		4 6			2 8			1 3 5 7			1 3 5 7	
Permitted Phases												
Actuated Green, G (s)		144.0			196.0			1546.0			1546.0	
Effective Green, g (s)		144.0			196.0			1546.0			1546.0	
Actuated g/C Ratio		0.08			0.10			0.81			0.81	
Clearance Time (s)												
Lane Grp Cap (vph)		144			196			1515			1515	
v/s Ratio Prot		c0.03			c0.03			0.02			c0.03	
v/s Ratio Perm												
v/c Ratio		0.35			0.26			0.03			0.04	
Uniform Delay, d1		833.4			784.8			33.7			34.0	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		6.5			3.1			0.0			0.0	
Delay (s)		839.9			787.9			33.7			34.1	
Level of Service		F			F			C			C	
Approach Delay (s)		839.9			787.9			33.7			34.1	
Approach LOS		F			F			C			C	

Intersection Summary			
HCM 2000 Control Delay	433.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.08		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	13.3%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	120	0	0	180	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	133	0	0	200	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	133	0	0	200	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1429.0			1429.0			191.0			266.0	
Effective Green, g (s)		1429.0			1429.0			191.0			266.0	
Actuated g/C Ratio		0.75			0.75			0.10			0.14	
Clearance Time (s)												
Lane Grp Cap (vph)		1401			1401			191			266	
v/s Ratio Prot		0.07			c0.11			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.09			0.14			0.26			0.19	
Uniform Delay, d1		62.9			65.4			789.4			721.6	
Progression Factor		1.00			1.00			0.26			1.00	
Incremental Delay, d2		0.1			0.2			3.2			1.6	
Delay (s)		63.0			65.6			210.2			723.2	
Level of Service		E			E			F			F	
Approach Delay (s)		63.0			65.6			210.2			723.2	
Approach LOS		E			E			F			F	

Intersection Summary			
HCM 2000 Control Delay	157.4	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.16		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	19.5%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	88	0	0	132	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	98	0	0	147	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	98	0	0	147	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1429.0			1429.0			191.0			266.0	
Effective Green, g (s)		1429.0			1429.0			191.0			266.0	
Actuated g/C Ratio		0.75			0.75			0.10			0.14	
Clearance Time (s)												
Lane Grp Cap (vph)		1401			1401			191			266	
v/s Ratio Prot		0.05			c0.08			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.07			0.10			0.26			0.19	
Uniform Delay, d1		61.6			63.4			789.4			721.6	
Progression Factor		1.00			1.00			1.00			0.04	
Incremental Delay, d2		0.1			0.2			3.3			1.5	
Delay (s)		61.7			63.5			792.7			31.9	
Level of Service		E			E			F			C	
Approach Delay (s)		61.7			63.5			792.7			31.9	
Approach LOS		E			E			F			C	

Intersection Summary			
HCM 2000 Control Delay	164.1	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.13		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	16.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	58	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	64	0	0	97	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1546.0			1546.0			144.0			196.0	
Effective Green, g (s)		1546.0			1546.0			144.0			196.0	
Actuated g/C Ratio		0.81			0.81			0.08			0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1515			1515			144			196	
v/s Ratio Prot		0.03			c0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.04			0.06			0.35			0.26	
Uniform Delay, d1		34.2			34.8			833.4			784.8	
Progression Factor		1.00			1.00			1.00			1.00	
Incremental Delay, d2		0.1			0.1			6.5			3.1	
Delay (s)		34.2			34.9			839.9			787.9	
Level of Service		C			C			F			F	
Approach Delay (s)		34.2			34.9			839.9			787.9	
Approach LOS		C			C			F			F	

Intersection Summary			
HCM 2000 Control Delay	333.2	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.11		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	14.6%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	103	0	0	207	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1776			1759			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1776			1759			1900			1900	
Peak-hour factor, PHF	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	121	0	0	244	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	121	0	0	244	0	0	50	0	0	50	0
Heavy Vehicles (%)	7%	7%	7%	8%	8%	8%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1544.0			1544.0			144.0			196.0	
Effective Green, g (s)		1544.0			1544.0			144.0			196.0	
Actuated g/C Ratio		0.81			0.81			0.08			0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1443			1429			144			196	
v/s Ratio Prot		0.07			c0.14			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.08			0.17			0.35			0.26	
Uniform Delay, d1		35.8			38.7			833.4			784.8	
Progression Factor		1.00			1.00			0.00			1.00	
Incremental Delay, d2		0.1			0.3			6.2			3.1	
Delay (s)		35.9			39.0			10.0			787.9	
Level of Service		D			D			A			F	
Approach Delay (s)		35.9			39.0			10.0			787.9	
Approach LOS		D			D			A			F	

Intersection Summary			
HCM 2000 Control Delay	115.6	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.19		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	20.9%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	148	0	0	87	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1881			1900			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1881			1900			1900			1900	
Peak-hour factor, PHF	0.86	0.86	0.86	0.86	0.86	0.86	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	172	0	0	101	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	172	0	0	101	0	0	50	0	0	50	0
Heavy Vehicles (%)	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1544.0			1544.0			144.0			196.0	
Effective Green, g (s)		1544.0			1544.0			144.0			196.0	
Actuated g/C Ratio		0.81			0.81			0.08			0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1528			1544			144			196	
v/s Ratio Prot		c0.09			0.05			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.11			0.07			0.35			0.26	
Uniform Delay, d1		36.7			35.2			833.4			784.8	
Progression Factor		1.00			1.00			0.01			0.05	
Incremental Delay, d2		0.1			0.1			6.2			3.1	
Delay (s)		36.9			35.3			14.5			41.1	
Level of Service		D			D			B			D	
Approach Delay (s)		36.9			35.3			14.5			41.1	
Approach LOS		D			D			B			D	

Intersection Summary			
HCM 2000 Control Delay	34.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.14		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	17.8%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↑			↑			↑			↑	
Volume (vph)	0	72	0	0	108	0	0	50	0	0	50	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		2.0			2.0			2.0			2.0	
Lane Util. Factor		1.00			1.00			1.00			1.00	
Frt		1.00			1.00			1.00			1.00	
Flt Protected		1.00			1.00			1.00			1.00	
Satd. Flow (prot)		1863			1863			1900			1900	
Flt Permitted		1.00			1.00			1.00			1.00	
Satd. Flow (perm)		1863			1863			1900			1900	
Peak-hour factor, PHF	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Adj. Flow (vph)	0	80	0	0	120	0	0	50	0	0	50	0
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	80	0	0	120	0	0	50	0	0	50	0
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	0%	0%	0%	0%	0%	0%
Turn Type		NA			NA			NA			NA	
Protected Phases		1 3 5 7			1 3 5 7			4 6			2 8	
Permitted Phases												
Actuated Green, G (s)		1544.0			1544.0			144.0			196.0	
Effective Green, g (s)		1544.0			1544.0			144.0			196.0	
Actuated g/C Ratio		0.81			0.81			0.08			0.10	
Clearance Time (s)												
Lane Grp Cap (vph)		1513			1513			144			196	
v/s Ratio Prot		0.04			c0.06			c0.03			c0.03	
v/s Ratio Perm												
v/c Ratio		0.05			0.08			0.35			0.26	
Uniform Delay, d1		34.8			35.6			833.4			784.8	
Progression Factor		1.00			1.00			1.00			0.62	
Incremental Delay, d2		0.1			0.1			6.5			3.1	
Delay (s)		34.9			35.8			839.9			487.7	
Level of Service		C			D			F			F	
Approach Delay (s)		34.9			35.8			839.9			487.7	
Approach LOS		C			D			F			F	

Intersection Summary			
HCM 2000 Control Delay	244.9	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	0.12		
Actuated Cycle Length (s)	1900.0	Sum of lost time (s)	16.0
Intersection Capacity Utilization	15.7%	ICU Level of Service	A
Analysis Period (min)	15		
c Critical Lane Group			

Intersection: 3: Main Line & Cowlitz St E/Cowitz St E

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	67	85	373
Average Queue (ft)	4	5	172
95th Queue (ft)	26	35	336
Link Distance (ft)	1245	741	1543
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Cowitz St E & Jo Ann Dr

Movement	EB	SB
Directions Served	LT	LR
Maximum Queue (ft)	7	39
Average Queue (ft)	0	11
95th Queue (ft)	5	37
Link Distance (ft)	741	670
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 20: Main Line & Cowlitz Gardens Rd

Movement	SB	SE	NW
Directions Served	T	T	T
Maximum Queue (ft)	364	30	50
Average Queue (ft)	170	2	3
95th Queue (ft)	333	14	21
Link Distance (ft)	1043	550	636
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 26: Main Line & Riverside Dr/Mill St

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	148	208	352
Average Queue (ft)	12	18	160
95th Queue (ft)	68	95	331
Link Distance (ft)	672	687	934
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 28: Main Line & River Rd

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	87	142	2
Average Queue (ft)	6	10	0
95th Queue (ft)	39	60	4
Link Distance (ft)	778	931	1545
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 47: Main Line & Port Rd

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	66	88	405
Average Queue (ft)	3	5	175
95th Queue (ft)	24	37	352
Link Distance (ft)	897	913	1078
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 51: Main Line & Scott Ave

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	61	167	387
Average Queue (ft)	5	14	168
95th Queue (ft)	31	81	343
Link Distance (ft)	594	737	1217
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 52: Pekin Rd & Guild Rd/Scott Ave

Movement	WB	NB
Directions Served	LT	LR
Maximum Queue (ft)	54	71
Average Queue (ft)	4	32
95th Queue (ft)	29	57
Link Distance (ft)	594	781
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 53: Down River Rd/Dow River Rd & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	8	8	80	78
Average Queue (ft)	0	0	38	33
95th Queue (ft)	6	5	64	58
Link Distance (ft)	737	725	1412	1143
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 54: Main Line & Pekin Rd/Davidson Rd

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	115	89	340
Average Queue (ft)	11	7	150
95th Queue (ft)	61	42	381
Link Distance (ft)	1258	684	4527
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 57: Main Line & Whalen Rd

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	73	110	15
Average Queue (ft)	4	9	4
95th Queue (ft)	29	51	16
Link Distance (ft)	1426	1931	4587
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 67: 5th St & Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	6	60	94	47
Average Queue (ft)	0	15	46	20
95th Queue (ft)	5	48	75	49
Link Distance (ft)	684	755	922	939
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 0

Intersection: 3: Main Line & Cowlitz St E/Cowitz St E

Movement	EB	WB	SB
Directions Served	T	T	T
Maximum Queue (ft)	67	87	630
Average Queue (ft)	6	9	282
95th Queue (ft)	33	46	576
Link Distance (ft)	1245	741	1543
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 10: Cowitz St E & Jo Ann Dr

Movement	EB	SB
Directions Served	LT	LR
Maximum Queue (ft)	14	34
Average Queue (ft)	0	11
95th Queue (ft)	7	36
Link Distance (ft)	741	670
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 20: Main Line & Cowlitz Gardens Rd

Movement	NB	SB	SE	NW
Directions Served	T	T	T	T
Maximum Queue (ft)	469	674	33	42
Average Queue (ft)	226	295	2	3
95th Queue (ft)	445	616	15	20
Link Distance (ft)	938	1043	550	636
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 26: Main Line & Riverside Dr/Mill St

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	160	236	62	632
Average Queue (ft)	20	30	10	296
95th Queue (ft)	86	122	51	605
Link Distance (ft)	672	687	1545	934
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 28: Main Line & River Rd

Movement	EB	WB	NB
Directions Served	T	T	T
Maximum Queue (ft)	140	183	549
Average Queue (ft)	17	22	250
95th Queue (ft)	75	99	505
Link Distance (ft)	778	931	926
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 47: Main Line & Port Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	76	87	546	663
Average Queue (ft)	8	10	266	281
95th Queue (ft)	42	48	510	584
Link Distance (ft)	897	913	1390	1078
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 51: Main Line & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	102	190	80	599
Average Queue (ft)	12	23	15	284
95th Queue (ft)	58	105	64	571
Link Distance (ft)	594	737	4527	1217
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 52: Pekin Rd & Guild Rd/Scott Ave

Movement	WB	NB
Directions Served	LT	LR
Maximum Queue (ft)	43	82
Average Queue (ft)	3	35
95th Queue (ft)	21	65
Link Distance (ft)	594	781
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 53: Down River Rd/Dow River Rd & Scott Ave

Movement	EB	NB	SB
Directions Served	LTR	LTR	LTR
Maximum Queue (ft)	13	90	79
Average Queue (ft)	1	38	33
95th Queue (ft)	7	67	61
Link Distance (ft)	737	1412	1143
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 54: Main Line & Pekin Rd/Davidson Rd

Movement	EB	WB	NB
Directions Served	T	T	T
Maximum Queue (ft)	145	92	172
Average Queue (ft)	20	11	47
95th Queue (ft)	86	51	159
Link Distance (ft)	1258	684	4587
Upstream Blk Time (%)			
Queuing Penalty (veh)			
Storage Bay Dist (ft)			
Storage Blk Time (%)			
Queuing Penalty (veh)			

Intersection: 57: Main Line & Whalen Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	73	103	540	4
Average Queue (ft)	8	13	264	0
95th Queue (ft)	40	61	505	3
Link Distance (ft)	1426	1931	976	4587
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 67: 5th St & Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	8	62	83	49
Average Queue (ft)	0	14	44	20
95th Queue (ft)	5	46	70	49
Link Distance (ft)	684	755	922	939
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 0

Intersection: 3: Main Line & Cowlitz St E/Cowitz St E

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	73	126	532	652
Average Queue (ft)	7	16	233	293
95th Queue (ft)	38	73	485	617
Link Distance (ft)	1245	741	1167	1543
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Cowitz St E & Jo Ann Dr

Movement	EB	SB
Directions Served	LT	LR
Maximum Queue (ft)	3	34
Average Queue (ft)	0	12
95th Queue (ft)	4	38
Link Distance (ft)	741	670
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 20: Main Line & Cowlitz Gardens Rd

Movement	NB	SB	SE	NW
Directions Served	T	T	T	T
Maximum Queue (ft)	538	655	40	44
Average Queue (ft)	243	292	4	4
95th Queue (ft)	486	622	22	22
Link Distance (ft)	938	1043	550	636
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 26: Main Line & Riverside Dr/Mill St

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	156	260	40	667
Average Queue (ft)	22	39	9	301
95th Queue (ft)	95	159	45	626
Link Distance (ft)	672	687	1545	934
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 28: Main Line & River Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	141	184	463	2
Average Queue (ft)	18	25	210	0
95th Queue (ft)	80	109	436	3
Link Distance (ft)	778	931	926	1545
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 47: Main Line & Port Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	68	102	538	601
Average Queue (ft)	8	12	249	270
95th Queue (ft)	39	54	508	566
Link Distance (ft)	897	913	1390	1078
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 51: Main Line & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	109	225	75	698
Average Queue (ft)	13	27	18	311
95th Queue (ft)	61	129	68	629
Link Distance (ft)	594	737	4527	1217
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 52: Pekin Rd & Guild Rd/Scott Ave

Movement	WB	NB
Directions Served	LT	LR
Maximum Queue (ft)	63	82
Average Queue (ft)	5	37
95th Queue (ft)	31	66
Link Distance (ft)	594	781
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 53: Down River Rd/Dow River Rd & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	10	13	84	71
Average Queue (ft)	0	0	38	35
95th Queue (ft)	5	6	66	58
Link Distance (ft)	737	725	1412	1143
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 54: Main Line & Pekin Rd/Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	149	105	149	3
Average Queue (ft)	22	13	41	1
95th Queue (ft)	89	59	144	7
Link Distance (ft)	1258	684	4587	4527
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 57: Main Line & Whalen Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	122	142	506	5
Average Queue (ft)	12	17	241	0
95th Queue (ft)	62	79	464	4
Link Distance (ft)	1426	1931	976	4587
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 67: 5th St & Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	6	86	87	35
Average Queue (ft)	0	21	47	18
95th Queue (ft)	5	61	75	45
Link Distance (ft)	684	755	922	939
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 0

Intersection: 3: Main Line & Taylor Crane Road

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	9	6	506	412
Average Queue (ft)	1	0	224	170
95th Queue (ft)	6	4	484	374
Link Distance (ft)	1245	741	1167	1543
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Taylor Crane Road/Cowitz St E & Jo Ann Dr

Movement	EB	SB
Directions Served	LT	LR
Maximum Queue (ft)	21	34
Average Queue (ft)	1	10
95th Queue (ft)	10	35
Link Distance (ft)	741	670
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Zone Summary

Zone wide Queuing Penalty: 0

Intersection: 3: Main Line & Cowlitz St E/Cowitz St E

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	99	129	598	473
Average Queue (ft)	14	20	258	180
95th Queue (ft)	61	82	537	412
Link Distance (ft)	1245	741	1167	1543
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 10: Cowitz St E & Jo Ann Dr

Movement	EB	SB
Directions Served	LT	LR
Maximum Queue (ft)	12	36
Average Queue (ft)	1	12
95th Queue (ft)	8	38
Link Distance (ft)	741	670
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 20: Main Line & Cowlitz Gardens Rd

Movement	NB	SB	SE	NW
Directions Served	T	T	T	T
Maximum Queue (ft)	503	402	48	65
Average Queue (ft)	206	159	4	7
95th Queue (ft)	465	356	25	36
Link Distance (ft)	938	1043	550	636
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 26: Main Line & Riverside Dr/Mill St

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	266	370	308	449
Average Queue (ft)	46	69	50	177
95th Queue (ft)	170	245	217	401
Link Distance (ft)	672	687	1545	934
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 28: Main Line & River Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	165	299	498	17
Average Queue (ft)	27	48	198	4
95th Queue (ft)	103	180	445	19
Link Distance (ft)	778	931	926	1545
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 47: Main Line & Port Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	88	121	547	418
Average Queue (ft)	12	20	218	170
95th Queue (ft)	53	80	474	386
Link Distance (ft)	897	913	1390	1078
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 51: Main Line & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	148	265	92	442
Average Queue (ft)	28	58	8	165
95th Queue (ft)	100	191	44	370
Link Distance (ft)	594	737	4527	1217
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 52: Pekin Rd & Guild Rd/Scott Ave

Movement	WB	NB
Directions Served	LT	LR
Maximum Queue (ft)	60	82
Average Queue (ft)	5	39
95th Queue (ft)	30	67
Link Distance (ft)	594	781
Upstream Blk Time (%)		
Queuing Penalty (veh)		
Storage Bay Dist (ft)		
Storage Blk Time (%)		
Queuing Penalty (veh)		

Intersection: 53: Down River Rd/Dow River Rd & Scott Ave

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	20	9	81	75
Average Queue (ft)	1	0	38	36
95th Queue (ft)	9	5	64	60
Link Distance (ft)	737	725	1412	1143
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 54: Main Line & Pekin Rd/Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	185	112	168	64
Average Queue (ft)	37	19	23	14
95th Queue (ft)	126	72	113	87
Link Distance (ft)	1258	684	4587	4527
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 57: Main Line & Whalen Rd

Movement	EB	WB	NB	SB
Directions Served	T	T	T	T
Maximum Queue (ft)	101	132	585	402
Average Queue (ft)	15	24	278	156
95th Queue (ft)	62	89	571	433
Link Distance (ft)	1426	1931	976	4587
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Intersection: 67: 5th St & Davidson Rd

Movement	EB	WB	NB	SB
Directions Served	LTR	LTR	LTR	LTR
Maximum Queue (ft)	24	90	96	42
Average Queue (ft)	1	21	47	19
95th Queue (ft)	11	63	77	48
Link Distance (ft)	684	755	922	939
Upstream Blk Time (%)				
Queuing Penalty (veh)				
Storage Bay Dist (ft)				
Storage Blk Time (%)				
Queuing Penalty (veh)				

Network Summary

Network wide Queuing Penalty: 0

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETm
CORRIDOR AND CROSSING DATAm
(without phased improvements)m

User:p kchewukp
Dataset:p Initial dataset
Corridor IDp 12p

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namep	2018 No Action - Spurp					
				Passenger	0.0p	
Technology Factors p	0.50p	0.50p	0.50p	*Freight*	2.5p	Uniformp
Signal Synchronization?p	Falsep			*Switch*	0.0p	Uniformp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calculated: 04-Jan-2017 6:10 pmp

	Fatal	Injuryr	PDO	Total
Base	0.001712p	0.022474p	0.078725p	0.102911p
Alternate	0.001712p	0.022474p	0.078725p	0.102911p

CROSSING DATA FOR THE 2018 NO ACTION - SPUR CORRIDORm

Milepost 2.68p Crossing ID 101826Tp Accidents in 5 Yearsp 0p

Description BNSF - 3RD AVEp

Paved? True p Urban? True
GCX Base Typep Gatesp
Safety Sup. Typep onep
GCX Alt Typep Gatesp
Safety Sup. typep onep
o. RR Tracksp 2p

Train Speeds (mph)p

Max Timetablep	8.0p
Passengerp	8.0p
Freightp	8.0p
Switchp	3.0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	4.0p
Dist from hwayp	0.10p	0.1p
AADTp	16,300p	16,300p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	15.0p	15.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00029p	0.00029p
Injuryp	0.00408p	0.00408p
PDOp	0.01623p	0.01623p
Totalp	0.02060p	0.02060p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	2.5p	5.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		280.0p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 2.79p Crossing ID 101821Jp Accidents in 5 Yearsp 0p

Description BNSF - CALIFORNIA WAYp

Paved? True p Urban? True
GCX Base Typep Lightsp
Safety Sup. Typep onep
GCX Alt Typep Lightsp
Safety Sup. typep onep
o. RR Tracksp 1p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	8.0p
Switchp	3.0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	2.0p
Dist from hwayp	0.10p	0.1p
AADTp	3,750p	3,750p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	7.0p	7.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00017p	0.00017p
Injuryp	0.00219p	0.00219p
PDOp	0.00723p	0.00723p
Totalp	0.00959p	0.00959p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Capitalp		106.1p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 3.67p Crossing ID 101805Ap Accidents in 5 Yearsp 0p

Description BNSF - OREGON WAYp

Paved? True p Urban? True
GCX Base Typep Gatesp
Safety Sup. Typep onep
GCX Alt Typep Gatesp
Safety Sup. typep onep
o. RR Tracksp 1p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	10.0p
Switchp	3.0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	4.0p
Dist from hwayp	0.10p	0.1p
AADTp	13,400p	13,400p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	5.0p	5.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00030p	0.00030p
Injuryp	0.00398p	0.00398p
PDOp	0.01313p	0.01313p
Totalp	0.01741p	0.01741p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	2.5p	5.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		280.0p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 3.88p Crossing ID 101806Gp Accidents in 5 Yearsp 0p

Description BNSF - INDUSTRIAL WAYp

Paved? True p Urban? True
GCX Base Typep Lightsp
Safety Sup. Typep onep
GCX Alt Typep Lightsp
Safety Sup. typep onep
o. RR Tracksp 1p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	10.0p
Switchp	3.0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	2.0p
Dist from hwayp	0.10p	0.1p
AADTp	9,600p	9,600p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	15.0p	15.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00023p	0.00023p
Injuryp	0.00300p	0.00300p
PDOp	0.00992p	0.00992p
Totalp	0.01315p	0.01315p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Capitalp		106.1p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 5.05p Crossing ID p Accidents in 5 Yearsp 0p

Description BNSF - WEYERHAUSER NORPACp

Paved? True p Urban? True
GCX Base Typep Passivep
Safety Sup. Typep onep
GCX Alt Typep Passivep
Safety Sup. typep onep
o. RR Tracksp 1p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	10.0p
Switchp	3.0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	2.0p
Dist from hwayp	0.10p	0.1p
AADTp	700p	700p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	5.0p	5.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00021p	0.00021p
Injuryp	0.00280p	0.00280p
PDOp	0.00924p	0.00924p
Totalp	0.01226p	0.01226p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	0.2p	1.8p
Oth. Lcyclep	0.0p	0.0p
Capitalp		74.8p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 6.47p Crossing ID p

Description BNSF - WASHINGTON WAYp

Paved? True p Urban? True
GCX Base Typep Passivep
Safety Sup. Typep onep
GCX Alt Typep Passivep
Safety Sup. typep onep

o. RR Tracksp 2p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	8.0p
Switchp	3.0p

Accidents in 5 Yearsp 0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	4.0p
Dist from hwayp	0.10p	0.1p
AADTp	3,200p	3,200p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	5.0p	5.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00034p	0.00034p
Injuryp	0.00409p	0.00409p
PDOp	0.01528p	0.01528p
Totalp	0.01971p	0.01971p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Capitalp		106.1p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

Milepost 6.49p Crossing ID p

Description BNSF - 38TH AVEp

Paved? True p Urban? True
GCX Base Typep Passivep
Safety Sup. Typep onep
GCX Alt Typep Passivep
Safety Sup. typep onep

o. RR Tracksp 1p

Train Speeds (mph)p

Max Timetablep	10.0p
Passengerp	10.0p
Freightp	5.0p
Switchp	3.0p

Accidents in 5 Yearsp 0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	2.0p
Dist from hwayp	0.10p	0.1p
AADTp	400p	400p
Auto TOD Distp	Uniformp	Uniformp
Percent Trucksp	5.0p	5.0p
Of this, % trailersp	0.0p	0.0p
Truck TOD Distp	Uniformp	Uniformp
Percent Busp	0.0p	0.0p
Bus TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Improvementp 0.0p

Predicted Annual Accidentsp

	Base	Alternate
Fatalp	0.00018p	0.00018p
Injuryp	0.00233p	0.00233p
PDOp	0.00769p	0.00769p
Totalp	0.01019p	0.01019p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	0.2p	1.8p
Oth. Lcyclep	0.0p	0.0p
Capitalp		74.8p
Sup lementary Safetyp		
O&Mp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Capitalp		0.0p

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm
CORRIDOR AND CROSSING DATAm
(without phased improvements)Mm

User:k chewuk
Dataset:k Initial dataset
Corridor IDk 13ak

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namek	2018 No Action - Dikek					
				Passenger	0.0k	
Technology Factors k	0.50k	0.50k	0.50k	*Freight*	7.0k	Uniformk
Signal Synchronization?k	Falsek			*Switch*	0.0k	Uniformk

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calculated: 21-Dec-2016 10:10 pmk

	Fatal	Injuryr	PDO	Total
Base	0.000270k	0.002154k	0.007820k	0.010244k
Alternate	0.000270k	0.002154k	0.007820k	0.010244k

CROSSING DATA FOR THE 2018 NO ACTION - DIKE CORRIDORm

Milepost 13.43k Crossing ID 101791Uk Accidents in 5 Yearsk 0k

Description BNSF - DIKE RDk

Paved? True k Urban? Falsek
GCX Base Typek Lightsk
Safety Sup. Typek onek
GCX Alt Typek Lightsk
Safety Sup. typek onek
o. RR Tracksk 4k

Train Speeds (mph)k

Max Timetablek	10.0k
Passengerk	10.0k
Freightk	10.0k
Switchk	3.0k

Highway Traffic Characteristicsk

	Base	Alternate
H'way Lanesk	2k	2.0k
Dist from hwayk	0.10k	0.1k
AADTk	400k	400k
Auto TOD Distk	Uniformk	Uniformk
Percent Trucksk	12.0k	12.0k
Of this, % trailersk	0.0k	0.0k
Truck TOD Distk	Uniformk	Uniformk
Percent Busk	0.0k	0.0k
Bus TOD Distk	Uniformk	Uniformk

Costs in '000 $ of Hway Improvementk 0.0k

Predicted Annual Accidentsk

	Base	Alternate
Fatalk	0.00027k	0.00027k
Injuryk	0.00215k	0.00215k
PDOk	0.00782k	0.00782k
Totalk	0.01024k	0.01024k

Costs in '000 $k

	Base	Alternate
Grade Crossing Devicesk		
O&M	1.8k	1.8k
Oth. Lcyclek	0.0k	0.0k
Capitalk		74.8k
Supplementary Safetyk		
O&M	0.0k	0.0k
Oth. Lcyclek	0.0k	0.0k
Capitalk		0.0k

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm
CORRIDOR AND CROSSING DATAm
(without phased improvements)Mm

User:p - chewA-p
Dataset:p Initial dataset
Corridor IDp 1.ap

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namep	2018 ConstrAction TrAc-		SuArp			
				Passenger	050p	
Technology Factors p	05 0 p	05 0 p	05 0 p	*Freight*	25p	Uniformp
Signal Synchronization?p	Falsep			*Switch*	050p	Uniformp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

CalcAlated: 04pJanp2016 9:1.pump

	Fatal	Injuryr	PDO	Total
Base	05001872p	050248.p2p	05089919p	0511kk90p
Alternate	05001872p	050248.p2p	05089919p	0511kk90p

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUC- KSPUR CORRIDORm

Mileuost 2598p Crossing ID 101829Tp 3ccidents in .pYearsp 0p

Descriution BNSF pkRD 3VEp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Gatesp
Safety SAu5Tyuep onep
GCX 3lt Tyuep Gatesp
Safety SAu5tyuep onep

No5RR Trac- sp 2p

Train Sueeds (muh)p

Max Timetablep	850p
Passengerp	850p
Freightp	850p
Switchp	k50p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	450p
Dist from hwayp	0510p	051p
33DTp	16,k00p	16,k00p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc- sp	1.p50p	1.p50p
Of this, % trailersp	050p	050p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	050p	050p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 050p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	0500027p	0500027p
InjAryp	050414p	050414p
PDOp	051949p	051949p
Totalp	052088p	052088p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	25p	.p50p
Oth5Lcyclep	050p	050p
Cauitalp		28050p
SAuulementary Safetyp		
O&Mp	050	p050p
Oth5Lcyclep	050p	050p
Cauitalp		050p

Mileuost 2567p Crossing ID 101821Jp 3ccidents in .pYearsp 0p

Descriution BNSF pC3LIFORNI3 W3Yp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Lightsp
Safety SAu5Tyuep onep
GCX 3lt Tyuep Lightsp
Safety SAu5tyuep onep

No5RR Trac- sp 1p

Train Sueeds (muh)p

Max Timetablep	1050p
Passengerp	1050p
Freightp	850p
Switchp	k50p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	250p
Dist from hwayp	0510p	051p
33DTp	k,6.p0p	k,6.p0p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc- sp	650p	650p
Of this, % trailersp	050p	050p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	050p	050p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 050p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	0500016p	0500016p
InjAryp	050217p	050217p
PDOp	050062kp	050062kp
Totalp	0507.p7p	0507.p7p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	158p	25p
Oth5Lcyclep	050p	050p
Cauitalp		1095lp
SAuulementary Safetyp		
O&Mp	050	p050p
Oth5Lcyclep	050p	050p
Cauitalp		050p

Mileuost k596p Crossing ID 10180.p8p 3ccidents in .pYearsp 0p

Descriution BNSF pOREGON W3Yp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Gatesp
Safety SAu5Tyuep onep
GCX 3lt Tyuep Gatesp
Safety SAu5tyuep onep

No5RR Trac-sp 1p

Train Sueeds (muh)p

Max Timetablep	1050p
Passengerp	1050p
Freightp	1050p
Switchp	k50p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	450p
Dist from hwayp	0510p	051p
33DTp	1k,8.p0p	1k,8.p0p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc-sp	.p50p	.p50p
Of this, % trailersp	050p	050p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	050p	050p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 050p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	05000k0p	05000k0p
InjAryp	0500401p	0500401p
PDOp	0501k24p	0501k24p
Totalp	0516.pp	0516.pp

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	25p	.p50p
Oth5Lcyclep	050p	050p
Cauitalp		2805p
SAuulementary Safetyp		
O&Mp	050	p05p
Oth5Lcyclep	050p	050p
Cauitalp		050p

Mileuost k588p Crossing ID 101809Gp 3ccidents in .pYearsp 0p

Descriution BNSF pINDUSTRI3L W3Yp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Lightsp
Safety SAu5Tyuep onep
GCX 3lt Tyuep Lightsp
Safety SAu5tyuep onep

No5RR Trac-sp 1p

Train Sueeds (muh)p

Max Timetablep	1050p
Passengerp	1050p
Freightp	1050p
Switchp	k50p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	250p
Dist from hwayp	0510p	051p
33DTp	11,.p00p	11,.p00p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc-sp	1.p50p	1.p50p
Of this, % trailersp	050p	050p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	050p	050p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 050p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	0500024p	0500024p
InjAryp	0500k18p	0500k18p
PDOp	0510.p1p	0510.p1p
Totalp	0501k7kp	0501k7kp

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	158p	25p
Oth5Lcyclep	050p	050p
Cauitalp		1095lp
SAuulementary Safetyp		
O&Mp	050	p05p
Oth5Lcyclep	050p	050p
Cauitalp		050p

Mileuost .p50.p Crossing ID p 3ccidents in .pYearsp 0p

Descriution BNSF pWEYERH3USER NORP3Cp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Passivep
Safety SAu5Tyuep onep
GCX 3lt Tyuep Passivep
Safety SAu5tyuep onep

No5RR Trac-sp 1p

Train Sueeds (muh)p

Max Timetablep	1050p
Passengerp	1050p
Freightp	1050p
Switchp	k50p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	250p
Dist from hwayp	0510p	051p
33DTp	600p	600p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc-sp	.p50p	.p50p
Of this, % trailersp	050p	050p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	050p	050p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 050p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	0500021p	0500021p
InjAryp	0500280p	0500280p
PDOp	0500724p	0500724p
Totalp	0501229p	0501229p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	052p	158p
Oth5Lcyclep	050p	050p
Cauitalp		6458p
SAuulementary Safetyp		
O&Mp	050	p05p
Oth5Lcyclep	050p	050p
Cauitalp		050p

Mileuost 954.6p Crossing ID p

Descriution BNSF pW3SHINGTON W3Yp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Passivep
Safety SAu5Tyuep onep
GCX 3lt Tyuep Passivep
Safety SAu5tyuep onep

No5RR Trac-sp 2p

Train Sueeds (muh)p

Max Timetablep	105.0p
Passengerp	105.0p
Freightp	85.0p
Switchp	k5.0p

3ccidents in .pYearsp 0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	4p	45.0p
Dist from hwayp	05.10p	05.1p
33DTp	k,200p	k,200p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc-sp	.p5.0p	.p5.0p
Of this, % trailersp	05.0p	05.0p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	05.0p	05.0p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 05.0p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	05000k4p	05000k4p
InjAryp	05.00407p	05.00407p
PDOp	05.01.p28p	05.01.p28p
Totalp	05.01761p	05.01761p

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	15.8p	25p
Oth5Lcyclep	05.0p	05.0p
Cauitalp		1095.1p
SAuulementary Safetyp		
O&Mp	05.0	p05.0p
Oth5Lcyclep	05.0p	05.0p
Cauitalp		05.0p

Mileuost 954.7p Crossing ID p

Descriution BNSF pk8TH 3VEp

Paved? TrAe p Urban? TrAep
GCX Base Tyuep Passivep
Safety SAu5Tyuep onep
GCX 3lt Tyuep Passivep
Safety SAu5tyuep onep

No5RR Trac-sp 1p

Train Sueeds (muh)p

Max Timetablep	105.0p
Passengerp	105.0p
Freightp	.p5.0p
Switchp	k5.0p

3ccidents in .pYearsp 0p

Highway Traffic Characteristicsp

	Base	Alternate
H'way Lanesp	2p	25.0p
Dist from hwayp	05.10p	05.1p
33DTp	k,0.p0p	k,0.p0p
3Ato TOD Distp	Uniformp	Uniformp
Percent TrAc-sp	.p5.0p	.p5.0p
Of this, % trailersp	05.0p	05.0p
TrAc- TOD Distp	Uniformp	Uniformp
Percent BAsp	05.0p	05.0p
BAs TOD Distp	Uniformp	Uniformp

Costs in '000 $ of Hway Imurovementp 05.0p

Predicted 3nnAal 3ccidentsp

	Base	Alternate
Fatalp	05000k4p	05000k4p
InjAryp	05.00444p	05.00444p
PDOp	05.01499p	05.01499p
Totalp	05.0174kp	05.0174kp

Costs in '000 $p

	Base	Alternate
Grade Crossing Devicesp		
O&Mp	05.2p	15.8p
Oth5Lcyclep	05.0p	05.0p
Cauitalp		645.8p
SAuulementary Safetyp		
O&Mp	05.0	p05.0p
Oth5Lcyclep	05.0p	05.0p
Cauitalp		05.0p

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm
CORRIDOR AND CROSSING DATAm
(without phased improvements)Mm

u serU k	- chewA-k
DatasetUk	Initial dataset
Corridor IDk	13ak

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namek	2018 ConstrAction TrAc-		Di- ek			
				Passenger	0.0k	
Technology Factors k	0.50k	0.50k	0.50k	*Freight*	7.0k	u ni6orm k
Signal Synchronization?k	Falsek			*Switch*	0.0k	u ni6orm k

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

CalcAlatedU21kDeck2013 8U20 :kmk

	Fatal	Injuryr	PDO	Total
Base	0.000270k	0.002154k	0.007820k	0.010244k
Alternate	0.000270k	0.002154k	0.007820k	0.010244k

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUC- KDI- E CORRIDORm

pkile:kost 1fk4fk Crossing ID 101791uk Bccidents in 5 Yearsk 0k

Descri:ktion XNSF k DIKE RDk

bk Ped? TrAe k u rM n? Falsek
vkCG Xase Ty:kek Lightsk
Sa6ety SA:k Ty:kek onek
vkCG Blt Ty:kek Lightsk
Sa6ety SA:k ty:kek onek

No. RR Trac- sk 4k

Train S:keeds (m:kh)k

pk x TimetaMek	10.0k
bk ssengerk	10.0k
Freightk	10.0k
Switchk	fk0k

Highway Tra6Bc Characteristicsk

	Base	Alternate
H'way Lanesk	2k	2.0k
Dist 6rom hwayk	0.10k	0.1k
BBDTk	400k	400k
BAto TOD Distk	u ni6orm k	u ni6orm k
b ercent TrAc- sk	12.0k	12.0k
O6this, % trailersk	0.0k	0.0k
TrAc- TOD Distk	u ni6orm k	u ni6orm k
b ercent XAsk	0.0k	0.0k
XAs TOD Distk	u ni6orm k	u ni6orm k

Costs in '000 $ o6Hway Im:kroPementk 0.0k

b redicted BnnAkl Bccidentsk

	Base	Alternate
Fatalk	0.00027k	0.00027k
InjAryk	0.00215k	0.00215k
bDOk	0.00782k	0.00782k
Totalk	0.01024k	0.01024k

Costs in '000 $k

	Base	Alternate
vkrkade Crossing DePicesk		
O&pk	1.8k	1.8k
Oth. Lcyclek	0.0k	0.0k
Ca:kitalk		74.8k
SA:kkementary Sa6etyk		
O&pk	0.0k	0.0k
Oth. Lcyclek	0.0k	0.0k
Ca:kitalk		0.0k

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETm
CORRIDOR AND CROSSING DATAm
(without phased improvements)m

J ser6 p Uchep ALp
Dataset6p Initial dataset
Corridor IDp 18p

Corridor Namep 2018 ConstrAction -pail pSuArp

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
				Passenger	0.0p	
Technology Factors p	0.50p	0.50p	0.50p	*Freight*	7.0p	J niMrmp
Signal Synchronization?p	Falsep			*Switch*	0.0p	J niMrmp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

CalcAlated607pf np2014 w61wump

	Fatal	Injuryr	PDO	Total
Base	0.002284p	0.029050p	0.101579p	0.1k288wp
Alternate	0.002284p	0.029050p	0.101579p	0.1k288wp

CROSSING DATA FOR THE 2018 CONSTRUCTION RAIL - SPUR CORRIDORm

bpileuost 2.w8p Crossing ID 10182wTp

Descriution 3p SF pk-pD RVEp

vaGed? TrAe p	J rPan? TrAep		
XCB 3pse Tyuep	Xatpesp		
SaMty SAu. Tyuep	onep		
XCB RIt Tyuep	Xatpesp		
SaMty SAu. tyuep	onep		
No. -p-p TracUsp	2p		

Train Sueeds (muh)p

bp x TimetaPlep	8.0p
vp ssengerp	8.0p
Freightp	8.0p
S:pitchp	k.0p

Rccidents in 5 Years p 0p

High:p y TraMc Characteristicsp

	Base	Alternate
H':p y Lanesp	7p	7.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	1w,w50p	1w,w50p
RAto TOD Distp	J niMrmp	J niMrmp
vercent TrAcUsp	15.0p	15.0p
OMhis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J niMrmp	J niMrmp
vercent 3Asp	0.0p	0.0p
3As TOD Distp	J niMrmp	J niMrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

vredicted RnnAal Rccidentsp

	Base	Alternate
Fatalp	0.000k5p	0.000k5p
InjAryp	0.00782p	0.00782p
vDO p	0.01920p	0.01920p
Totalp	0.027k4p	0.027k4p

Costs in '000 $p

	Base	Alternate
XrpaGe Crossing DeGcesp		
O&bp	2.5p	5.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		280.0p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost 2.49p Crossing ID 101821f

Descriution 3p SF pCRLIFO-pNIR WRYp

vaGed? TrAe p	J rPan? TrAep		
XCB 3pse Tyuep	Lightsp		
SaMty SAu. Tyuep	onep		
XCB RIt Tyuep	Lightsp		
SaMty SAu. tyuep	onep		
No. -p-p TracUsp	1p		

Train Sueeds (muh)p

bp x TimetaPlep	10.0p
vp ssengerp	8.0p
Freightp	8.0p
S:pitchp	k.0p

Rccidents in 5 Years p 0p

High:p y TraMc Characteristicsp

	Base	Alternate
H':p y Lanesp	2p	2.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	k,450p	k,450p
RAto TOD Distp	J niMrmp	J niMrmp
vercent TrAcUsp	4.0p	4.0p
OMhis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J niMrmp	J niMrmp
vercent 3Asp	0.0p	0.0p
3As TOD Distp	J niMrmp	J niMrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

vredicted RnnAal Rccidentsp

	Base	Alternate
Fatalp	0.00020p	0.00020p
InjAryp	0.00254p	0.00254p
vDO p	0.00879p	0.00879p
Totalp	0.0112wp	0.0112wp

Costs in '000 $p

	Base	Alternate
XrpaGe Crossing DeGcesp		
O&bp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		10w.1p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost k.w4p Crossing ID 101805Rp

Descriution 3p SF pO-pEXON WRYp

vaGed? TrAe p		J rPan? TrAep	
XCB 3pse Tyuep		Xatpesp	
SaMty SAu. Tyuep		onep	
XCB RIt Tyuep		Xatpesp	
SaMty SAu. tyuep		onep	
No. -p-p TracUsp	1p		

Train Sueeds (muh)p	
bp x TimetaPlep	10.0p
vp ssengerp	10.0p
Freightp	10.0p
S:pitchp	k.0p

Rccidents in 5 Yearsp 0p

High:p y TraNit Characteristicsp	Base	Alternate
H':p y Lanesp	7p	7.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	1k,850p	1k,850p
RAto TOD Distp	J nivrmp	J nivrmp
v ercent TrAcUsp	5.0p	5.0p
OMthis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J nivrmp	J nivrmp
v ercent 3 Asp	0.0p	0.0p
3 As TOD Distp	J nivrmp	J nivrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

v redicted RnnAal Rccidentsp	Base	Alternate
Fatalp	0.000k4p	0.000k4p
InjAryp	0.00747p	0.00747p
v DO p	0.01540p	0.01540p
Totalp	0.02082p	0.02082p

Costs in '000 $p	Base	Alternate
Xrade Crossing DeGcesp		
O&bp	2.5p	5.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		280.0p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost k.88p Crossing ID 10180wXp

Descriution 3p SF pINDJ ST-pIRL WRYp

vaGed? TrAe p		J rPan? TrAep	
XCB 3pse Tyuep		Lightsp	
SaMty SAu. Tyuep		onep	
XCB RIt Tyuep		Lightsp	
SaMty SAu. tyuep		onep	
No. -p-p TracUsp	1p		

Train Sueeds (muh)p	
bp x TimetaPlep	10.0p
vp ssengerp	10.0p
Freightp	10.0p
S:pitchp	k.0p

Rccidents in 5 Yearsp 0p

High:p y TraNit Characteristicsp	Base	Alternate
H':p y Lanesp	2p	2.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	10,400p	10,400p
RAto TOD Distp	J nivrmp	J nivrmp
v ercent TrAcUsp	15.0p	15.0p
OMthis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J nivrmp	J nivrmp
v ercent 3 Asp	0.0p	0.0p
3 As TOD Distp	J nivrmp	J nivrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

v redicted RnnAal Rccidentsp	Base	Alternate
Fatalp	0.00028p	0.00028p
InjAryp	0.00kw0p	0.00kw0p
v DO p	0.01190p	0.01190p
Totalp	0.01548p	0.01548p

Costs in '000 $p	Base	Alternate
Xrade Crossing DeGcesp		
O&bp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		10w.1p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost 5.05p Crossing ID p

Descriution 3p SF pWEYE-pHRJ SE-p NO-pv RCp

vaGed? TrAe p		J rPan? TrAep	
XCB 3pse Tyuep		vp ssiGep	
SaMty SAu. Tyuep		onep	
XCB RIt Tyuep		vp ssiGep	
SaMty SAu. tyuep		onep	
No. -p-p TracUsp	1p		

Train Sueeds (muh)p	
bp x TimetaPlep	10.0p
vp ssengerp	10.0p
Freightp	10.0p
S:pitchp	k.0p

Rccidents in 5 Yearsp 0p

High:p y TraNit Characteristicsp	Base	Alternate
H':p y Lanesp	2p	2.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	400p	400p
RAto TOD Distp	J nivrmp	J nivrmp
v ercent TrAcUsp	5.0p	5.0p
OMthis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J nivrmp	J nivrmp
v ercent 3 Asp	0.0p	0.0p
3 As TOD Distp	J nivrmp	J nivrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

v redicted RnnAal Rccidentsp	Base	Alternate
Fatalp	0.00024p	0.00024p
InjAryp	0.00k7wp	0.00k7wp
v DO p	0.0117wp	0.0117wp
Totalp	0.01519p	0.01519p

Costs in '000 $p	Base	Alternate
Xrade Crossing DeGcesp		
O&bp	0.2p	1.8p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		47.8p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost w.74p Crossing ID p

Descriution 3p SF pWRSHINXTON WRYp

vaGed? TrAe p	JrPan? TrAep
XCB 3pse Tyuep	vpssiGep
SaMty SAu. Tyuep	onep
XCB Rlt Tyuep	vpssiGep
SaMty SAu. tyuep	onep
No. -p-p TracUsp	2p

Train Sueeds (muh)p

bp x TimetaPlep	10.0p
vpssengerp	8.0p
Freightp	8.0p
S:pitchp	k.0p

Rccidents in 5 Yearsp 0p

High:p y TraMc Characteristicsp

	Base	Alternate
H':p y Lanesp	7p	7.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	k,200p	k,200p
RAto TOD Distp	J nidrmp	J nidrmp
vercent TrAcUsp	5.0p	5.0p
OMthis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J nidrmp	J nidrmp
vercent 3Asp	0.0p	0.0p
3As TOD Distp	J nidrmp	J nidrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

vredicted RnnAal Rccidentsp

	Base	Alternate
Fatalp	0.0007kp	0.0007kp
InjAryp	0.0079wp	0.0079wp
vDOp	0.01854p	0.01854p
Totalp	0.02k9wp	0.02k9wp

Costs in '000 $p

	Base	Alternate
Xrade Crossing DeGces		
O&bp	1.8p	2.5p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		10w.1p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

bpileuost w.79p Crossing ID p

Descriution 3p SF pk8TH RVEp

vaGed? TrAe p	JrPan? TrAep
XCB 3pse Tyuep	vpssiGep
SaMty SAu. Tyuep	onep
XCB Rlt Tyuep	vpssiGep
SaMty SAu. tyuep	onep
No. -p-p TracUsp	1p

Train Sueeds (muh)p

bp x TimetaPlep	10.0p
vpssengerp	5.0p
Freightp	5.0p
S:pitchp	k.0p

Rccidents in 5 Yearsp 0p

High:p y TraMc Characteristicsp

	Base	Alternate
H':p y Lanesp	2p	2.0p
Dist Mom h:p yp	0.10p	0.1p
RRDTp	2,200p	2,200p
RAto TOD Distp	J nidrmp	J nidrmp
vercent TrAcUsp	5.0p	5.0p
OMthis, % trailersp	0.0p	0.0p
TrAcUTOD Distp	J nidrmp	J nidrmp
vercent 3Asp	0.0p	0.0p
3As TOD Distp	J nidrmp	J nidrmp

Costs in '000 $ oMH:p y ImuroGementp 0.0p

vredicted RnnAal Rccidentsp

	Base	Alternate
Fatalp	0.000k8p	0.000k8p
InjAryp	0.00790p	0.00790p
vDOp	0.01w2kp	0.01w2kp
Totalp	0.02151p	0.02151p

Costs in '000 $p

	Base	Alternate
Xrade Crossing DeGces		
O&bp	0.2p	1.8p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		47.8p
SAuulementary SaMtyp		
O&bp	0.0p	0.0p
Oth. Lcyclep	0.0p	0.0p
Cauitalp		0.0p

FEDERAL RAILROAD ADMINISTRATIONOm

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CORRIDOR AND CROSSING DATAm

(without phased improvements)Mm

User:k 3cheu A3k
Dataset:k Initial dataset
Corridor IDk 1.ak

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namek	2018 ConstrAction -kail k Di3ek					
				Passenger	050k	
Technology Factors k	0570k	0570k	0570k	*Freight*	850k	UniM0rmk
Signal Synchronization?k	Falsek			*Switch*	050k	UniM0rmk

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

CalcAlated: 21kDeck2016 10:p1 fkmk

	Fatal	Injuryr	PDO	Total
Base	05000287k	05002271k	05008184k	05010w21k
Alternate	05000287k	05002271k	05008184k	05010w21k

CROSSING DATA FOR THE 2018 CONSTRUCTION RAIL - DIKE CORRIDORm

bkilefkost 1p54pk Crossing ID 101w.k1Uk Eccidents in 7 jkearsk 0k

Describkion KNSF k DIRO -kDk

v aGed? TrAe k	UrPkn? Falsek		
XCB Kase Tyfkek	Yightsk		
SaMety SAfk5Tyfkek	onek		
XCB Elt Tyfkek	Yightsk		
SaMety SAfk5tyfkek	onek		
No5-k-k Trac3sk	4k		

Train Sfkeeds)mfkh.k

bk (TimetaPlek	1050k
vk ssengerk	1050k
Freightk	1050k
Su itchk	p50k

'kighuk y TraNMc Characteristicsk

	Base	Alternate
' luk y Yknesk	2k	250k
Dist Mom huk yk	0510k	051k
EEDTk	400k	400k
EAto THD Distk	UniM0rmk	UniM0rmk
v ercent TrAc3sk	1250k	1250k
HMthis%9k trailersk	050k	050k
TrAc3 THD Distk	UniM0rmk	UniM0rmk
v ercent KAsk	050k	050k
KAs THD Distk	UniM0rmk	UniM0rmk

Costs in l000 & oMkuk y ImfkroGementk 050k

v redicted EnnAkl Eccidentsk

	Base	Alternate
Fatalk	05000002.k	05000002.k
InSAryk	05000227k	05000227k
v DH k	05000818k	05000818k
Totalk	05010w2k	05010w2k

Costs in l000 &k

	Base	Alternate
Xrkade Crossing DeGcesk		
Hx bk	158k	158k
Hth5Ycyclek	050k	050k
Cafkitalk		w458k
SAfkkementary SaMetyk		
Hx bk	050	k050k
Hth5Ycyclek	050k	050k
Cafkitalk		050k

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm

CORRIDOR AND CROSSING DATAm

(without phased improvements)Mm

J ser6 p pcheA-p
Dataset6p Initial dataset
Corridor IDp 25ap

Corridor Namep 2021 No 8ction A C- rrent Tracp uS. - rp

				Avg. No. Trains Per Day	Train Time-of-Day Distribution
			Passenger	070p	
Technology Factors p	074Op	074Op	074Op	*Freight* 970p	J niformp
Signal Synchronization?p	Falsep			*Switch* 070p	J niformp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calc- lated625uDecu205k 506 4 . pmp

	Fatal	Injuryr	PDO	Total
Base	070022k1p	07021wUJp	07500U90p	075: 2005p
Alternate	070022k1p	07021wUJp	07500U90p	075: 2005p

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - SPUR CORRIDORm

Mile.post 27k1p Crossing ID 50512kTp 8ccidents in 4 Learsp 0p

Descri.ption BNSF u:p8 D 8RVp

Paved? Tr- e p J rban? Tr- ep
GCX Base Ty.pep Gatesp
Safety S- .p7Ty.pep onep
GCX 8lt Ty.pep Gatesp
Safety S- .p7ty.pep onep

No733 Tracpsp 2p

Train S.peeds xm.ph(p

Ma& Timetablep	170p
Passengerp	170p
Freightp	170p
SAitchp	:p0p

OighApy Traffic Characteristicsp

	Base	Alternate
OlAApy 'p nesp	9p	970p
Dist from hApyp	0750p	075p
88DTp	20)000p	20)000p
8- to TED Distp	J niformp	J niformp
Percent Tr- cpsp	5470p	5470p
E f this) ,p trailersp	070p	070p
Tr- cp TED Distp	J niformp	J niformp
Percent B- sp	070p	070p
B- s TED Distp	J niformp	J niformp

Costs in l000 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	07000:pkp	07000:pkp
InY ry p	0700405p	0700405p
PDEp	0705UUUp	0705UUUp
Totalp	07024:pwp	07024:pwp

Costs in l000 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	274p	470p
Eth7'pcyclep	070p	070p
Ca.pitalp		21070p
S- .ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post 27wUp Crossing ID 505125Wp 8ccidents in 4 Learsp 0p

Descri.ption BNSF uC8'plFE3p l8 %8Lp

Paved? Tr- e p J rban? Tr- ep
GCX Base Ty.pep 'pightsp
Safety S- .p7Ty.pep onep
GCX 8lt Ty.pep 'pightsp
Safety S- .p7ty.pep onep

No733 Tracpsp 5p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	170p
Freightp	170p
SAitchp	:p0p

OighApy Traffic Characteristicsp

	Base	Alternate
OlAApy 'p nesp	2p	270p
Dist from hApyp	0750p	075p
88DTp	4)940p	4)940p
8- to TED Distp	J niformp	J niformp
Percent Tr- cpsp	w70p	w70p
E f this) ,p trailersp	070p	070p
Tr- cp TED Distp	J niformp	J niformp
Percent B- sp	070p	070p
B- s TED Distp	J niformp	J niformp

Costs in l000 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	070002:p	070002:p
InY ry p	07002U0p	07002U0p
PDEp	0700Uk5p	0700Uk5p
Totalp	07052w9p	07052w9p

Costs in l000 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	571p	274p
Eth7'pcyclep	070p	070p
Ca.pitalp		50k75p
S- .ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post :p7kwp Crossing ID 5051048p 8ccidents in 4 Learsp 0p

Descri.ption BNSF uE3 VGEpN %8Lp

Paved? Tr-e p J rban? Tr-ep
GCX Base Ty.pep Gatesp
Safety S-.p7Ty.pep onep
GCX 8lt Ty.pep Gatesp
Safety S-.p7ty.pep onep

No733 Tracpsp 5p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	5070p
Freightp	5070p
SAitchp	:p0p

OighApy Traffic Characteristicsp

	Base	Alternate
OHApy 'p nesp	9p	970p
Dist from hApyp	0750p	075p
88DTp	5k)w40p	5k)w40p
8-to TED Distp	J niformp	J niformp
Percent Tr-cpsp	470p	470p
Ef this),p trailersp	070p	070p
Tr-cp TED Distp	J niformp	J niformp
Percent B-sp	070p	070p
B-s TED Distp	J niformp	J niformp

Costs in l900 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	07000:pUp	07000:pUp
InY-ry p	07009Ukp	07009Ukp
PDEp	0705k90p	0705k90p
Totalp	07025w4p	07025w4p

Costs in l900 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	274p	470p
Eth7'pcyclep	070p	070p
Ca.pitalp		21070p
S-.ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post :p711p Crossing ID 50510kGp 8ccidents in 4 Learsp 0p

Descri.ption BNSF uINDJ ST3 I8'p%8Lp

Paved? Tr-e p J rban? Tr-ep
GCX Base Ty.pep 'pightsp
Safety S-.p7Ty.pep onep
GCX 8lt Ty.pep 'pightsp
Safety S-.p7ty.pep onep

No733 Tracpsp 5p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	5070p
Freightp	5070p
SAitchp	:p0p

OighApy Traffic Characteristicsp

	Base	Alternate
OHApy 'p nesp	2p	270p
Dist from hApyp	0750p	075p
88DTp	50)100p	50)100p
8-to TED Distp	J niformp	J niformp
Percent Tr-cpsp	5470p	5470p
Ef this),p trailersp	070p	070p
Tr-cp TED Distp	J niformp	J niformp
Percent B-sp	070p	070p
B-s TED Distp	J niformp	J niformp

Costs in l900 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	0700021p	0700021p
InY-ry p	0700:pk5p	0700:pk5p
PDEp	07055U:p	07055U:p
Totalp	0705412p	0705412p

Costs in l900 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	571p	274p
Eth7'pcyclep	070p	070p
Ca.pitalp		50k75p
S-.ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post 4704p Crossing ID p 8ccidents in 4 Learsp 0p

Descri.ption BNSF u%VLV3 O8J SV3 NE3 P8Cp

Paved? Tr-e p J rban? Tr-ep
GCX Base Ty.pep Passivep
Safety S-.p7Ty.pep onep
GCX 8lt Ty.pep Passivep
Safety S-.p7ty.pep onep

No733 Tracpsp 5p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	5070p
Freightp	5070p
SAitchp	:p0p

OighApy Traffic Characteristicsp

	Base	Alternate
OHApy 'p nesp	2p	270p
Dist from hApyp	0750p	075p
88DTp	U40p	U40p
8-to TED Distp	J niformp	J niformp
Percent Tr-cpsp	470p	470p
Ef this),p trailersp	070p	070p
Tr-cp TED Distp	J niformp	J niformp
Percent B-sp	070p	070p
B-s TED Distp	J niformp	J niformp

Costs in l900 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	07000:p0p	07000:p0p
InY-ry p	0700:pl5p	0700:pl5p
PDEp	0752k5p	0752k5p
Totalp	075kw5p	075kw5p

Costs in l900 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	072p	571p
Eth7'pcyclep	070p	070p
Ca.pitalp		w971p
S-.ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post k79wp Crossing ID p

Descri.ption BNSF u%8SOlpGTEpN %8Lp

Paved? Tr-e p J rban? Tr-ep
GCX Base Ty.pep Passivep
Safety S-.p7Ty.pep onep
GCX 8lt Ty.pep Passivep
Safety S-.p7ty.pep onep

No733 Tracpsp 2p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	170p
Freightp	170p
SAitchp	:p0p

8ccidents in 4 Learsp 0p

OighApy Traffic Characteristicsp

	Base	Alternate
OHApy 'p nesp	9p	970p
Dist from hApyp	0750p	075p
88DTp	:p)100p	:p)100p
8-to TED Distp	J niformp	J niformp
Percent Tr-cpsp	470p	470p
Ef this),p trailersp	070p	070p
Tr-cp TED Distp	J niformp	J niformp
Percent B-sp	070p	070p
B-s TED Distp	J niformp	J niformp

Costs in l900 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	0700094p	0700094p
InY-ryp	0700425p	0700425p
PDEp	0705U9Up	0705U9Up
Totalp	0702459p	0702459p

Costs in l900 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	571p	274p
Eth7'pcyclep	070p	070p
Ca.pitalp		50k75p
S-.ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

Mile.post k79Up Crossing ID p

Descri.ption BNSF u:p1TO 8RVp

Paved? Tr-e p J rban? Tr-ep
GCX Base Ty.pep Passivep
Safety S-.p7Ty.pep onep
GCX 8lt Ty.pep Passivep
Safety S-.p7ty.pep onep

No733 Tracpsp 5p

Train S.peeds xm.ph(p

Ma& Timetablep	5070p
Passengerp	470p
Freightp	470p
SAitchp	:p0p

8ccidents in 4 Learsp 0p

OighApy Traffic Characteristicsp

	Base	Alternate
OHApy 'p nesp	2p	270p
Dist from hApyp	0750p	075p
88DTp	k00p	k00p
8-to TED Distp	J niformp	J niformp
Percent Tr-cpsp	470p	470p
Ef this),p trailersp	070p	070p
Tr-cp TED Distp	J niformp	J niformp
Percent B-sp	070p	070p
B-s TED Distp	J niformp	J niformp

Costs in l900 jpof OApy Im.provementp 070p

Predicted 8nn-pal 8ccidentsp

	Base	Alternate
Fatalp	070002kp	070002kp
InY-ryp	0700::0p	0700::0p
PDEp	0705U5p	0705U5p
Totalp	070599wp	070599wp

Costs in l900 jp

	Base	Alternate
Grade Crossing Devicesp		
E$Mp	072p	571p
Eth7'pcyclep	070p	070p
Ca.pitalp		w971p
S-.ppementary Safetyp		
E$Mp	070	p070p
Eth7'pcyclep	070p	070p
Ca.pitalp		070p

FEDERAL RAILROAD ADMINISTRATIONOm

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CORRIDOR AND CROSSING DATAm
(without phased improvements)m

u serU k	kcheA-k
DatasetUk	Initial dataset
Corridor IDk	22k

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namek	2021 No 8ction A C- rrent Track 3Dikek					
				Passenger	0.0k	
Technology Factors k	0.50k	0.50k	0.50k	*Freight*	7.0k	u nipormk
Signal Synchronization?k	Falsek			*Switch*	0.0k	u nipormk

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calc- latedU243Dec3204:k 40uw7 6mk

	Fatal	Injuryr	PDO	Total
Base	0.000270k	0.00245wk	0.007120k	0.0402wwk
Alternate	0.000270k	0.00245wk	0.007120k	0.0402wwk

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - DIKE CORRIDORm

fkile6ost 4MwM Crossing ID 404794uk 8ccidents in 5 Yearsk 0k

Descri6tion BNSF 3DIKE RDk

Paved? Tr- e k u rban? Falsek
GCX Base Ty6ek Lightsk
Sapety S- 6. Ty6ek onek
GCX 8lt Ty6ek Lightsk
Sapety S- 6. ty6ek onek

o. RR Tracksk wk

Train S6eeds (m6h)k

fk x Timetablek	40.0k
Passengerk	40.0k
Freightk	40.0k
SAitchk	M0k

HighAky Trapic Characteristicsk

	Base	Alternate
H'Aky Lanesk	2k	2.0k
Dist prom hAkyk	0.40k	0.4k
88DTk	w00k	w00k
8- to TOD Distk	u nipormk	u nipormk
Percent Tr- cksk	42.0k	42.0k
Opthis, % trailersk	0.0k	0.0k
Tr- ck TOD Distk	u nipormk	u nipormk
Percent B-lsk	0.0k	0.0k
B- s TOD Distk	u nipormk	u nipormk

Costs in '000 $ opHAky Im6rovementk 0.0k

Predicted 8nn-kal 8ccidentsk

	Base	Alternate
Fatalk	0.00027k	0.00027k
Inj- ryk	0.00245k	0.00245k
PDOk	0.00712k	0.00712k
Totalk	0.0402wk	0.0402wk

Costs in '000 $k

	Base	Alternate
Grade Crossing Devicesk		
O&fk	4.1k	4.1k
Oth. Lcyclek	0.0k	0.0k
Ca6italk		7w.1k
S- 66lementary Sapetyk		
O&fk	0.0k	0.0k
Oth. Lcyclek	0.0k	0.0k
Ca6italk		0.0k

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm
CORRIDOR AND CROSSING DATAm
(without phased improvements)Mm

J ser6 p uche-p up
Dataset6p Initial dataset
Corridor IDp 27ap

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namep	2021 8 n Site Alt - Cprrent Tracu . S5prp					
				Passenger	040p	
Technology Factors p	0490p	0490p	0490p	*Freight*	2040p	J niformp
Signal Synchronization?p	Falsep			*Switch*	040p	J niformp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calcplated62U.Dec.20:pw U892 5mp

	Fatal	Injuryr	PDO	Total
Base	0400kw9Up	0409: wwkp	04 12U2k p	042U1wk2p
Alternate	0400kw9Up	0409: wwkp	04 12U2k p	042U1wk2p

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - SPUR CmRRIDORm

Mile5ost 24w1p Crossing ID :p0:p12wTp Accidents in 9 'pearsp 0p

Descri5tion BNSF . U3 D ARVp

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Gatesp
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Gatesp
Safety Sp54ty5ep onep

No43 3 Tracusp 2p

Train S5eeds &m5hxp

Ma$ Timetablep	140p
Passengerp	140p
Freightp	140p
S-pitchp	U40p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	kp	k40p
Dist from h-p yp	04 0 p	04p
AADTp	20(220p	20(220p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	:p940p	:p940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in 0000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000w,p	04000w,p
Inlpryp	04001:pUp	04001:pUp
PD8p	040U2,pkp	040U2,pkp
Totalp	040k:p99p	040k:p99p

Costs in 0000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpM p	249p	940p
8 th4Hcyclep	040p	040p
Ca5italp		21040p
Sp55lementary Safetyp		
8 jpM p	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost 24 7 p Crossing ID :p0:p12:pWp Accidents in 9 'pearsp 0p

Descri5tion BNSF . CAHIF8 3p IA %A'p

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Hghtsp
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Hghtsp
Safety Sp54ty5ep onep

No43 3 Tracusp :p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	140p
Freightp	140p
S-pitchp	U40p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	240p
Dist from h-p yp	04 0 p	04p
AADTp	9(k90p	9(k90p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	,p40p	,p40p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in 0000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000k2p	04000k2p
Inlpryp	0400kw,p	0400kw,p
PD8p	040:p9w.p	040:p9w.p
Totalp	04020,p0p	04020,p0p

Costs in 0000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpM p	:p4lp	249p
8 th4Hcyclep	040p	040p
Ca5italp		:p0w4p
Sp55lementary Safetyp		
8 jpM p	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost U4wp Crossing ID :p0:pt109Ap

Descri5tion BNSF . 8 3 VG8pN %A'p

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Gatesp
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Gatesp
Safety Sp54ty5ep onep

No43 3 Tracusp :p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	:p040p
Freightp	:p040p
S-pitchp	U40p

Accidents in 9 'pearsp 0p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	kp	k40p
Dist from h-p yp	04 0 p	04p
AADTp	: , (020 p	: , (020 p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	940p	940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in Q000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000,pkp	04000,pkp
Inlpryp	04001U:p	04001U:p
PD8p	0402, , 7 p	0402, , 7 p
Totalp	040Uw1kp	040Uw1kp

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpM p	249p	940p
8 th4Hcyclep	040p	040p
Ca5italp		21040p
Sp55lementary Safetyp		
8 jpM p	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost U4f1p Crossing ID :p0:pt10wGp

Descri5tion BNSF . INDJ ST3 IAH %A'p

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Hghtsp
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Hghtsp
Safety Sp54ty5ep onep

No43 3 Tracusp :p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	:p040p
Freightp	:p040p
S-pitchp	U40p

Accidents in 9 'pearsp 0p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	240p
Dist from h-p yp	04 0 p	04p
AADTp	: : (k90 p	: : (k90 p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	:p940p	:p940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in Q000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	040009:p	040009:p
Inlpryp	04009wwp	04009wwp
PD8p	040:pt17Up	040:pt17Up
Totalp	0402907p	0402907p

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpM p	:p4f1p	249p
8 th4Hcyclep	040p	040p
Ca5italp		:p0w4p
Sp55lementary Safetyp		
8 jpM p	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost 9409p Crossing ID p

Descri5tion BNSF . %V'pV3 EAJ SV3 N8 3 PACp

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Passivep
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Passivep
Safety Sp54ty5ep onep

No43 3 Tracusp :p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	:p040p
Freightp	:p040p
S-pitchp	U40p

Accidents in 9 'pearsp 0p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	240p
Dist from h-p yp	04 0 p	04p
AADTp	790p	790p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	940p	940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in Q000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000wwp	04000wwp
Inlpryp	0400,pU2p	0400,pU2p
PD8p	0402kk1p	0402kk1p
Totalp	040U2kwp	040U2kwp

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpM p	042p	:p4f1p
8 th4Hcyclep	040p	040p
Ca5italp		,pk4f1p
Sp55lementary Safetyp		
8 jpM p	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost w4k,p Crossing ID p

Descri5tion BNSF . %ASEINGT8pN %A'p

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Passivep
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Passivep
Safety Sp54ty5ep onep

No43 3 Tracusp 2p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	140p
Freightp	140p
S-pitchp	U40p

Accidents in 9 'pearsp 0p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	kp	k40p
Dist from h-p yp	04 0 p	04p
AADTp	U(100p	U(100p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	940p	940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in Q000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000070p	04000070p
Inlpryp	04007:p9p	04007:p9p
PD8p	040Ukw.p	040Ukw.p
Totalp	040kkwwp	040kkwwp

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpMp	:p4lp	249p
8 th4Hcyclep	040p	040p
Ca5italp		:p0w4p
Sp55lementary Safetyp		
8 jpMp	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

Mile5ost w4k7p Crossing ID p

Descri5tion BNSF . U1TE ARVp

Paved? Trpe p J rban? Trpep
GCX Base Ty5ep Passivep
Safety Sp54Ty5ep onep
GCX Alt Ty5ep Passivep
Safety Sp54ty5ep onep

No43 3 Tracusp :p

Train S5eeds &m5hxp

Ma$ Timetablep	:p040p
Passengerp	940p
Freightp	940p
S-pitchp	U40p

Accidents in 9 'pearsp 0p

Eigh-p y Traffic Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	240p
Dist from h-p yp	04 0 p	04p
AADTp	:p(w70p	:p(w70p
Apto T8 D Distp	J niformp	J niformp
Percent Trpcusp	940p	940p
8 f this( )p trailersp	040p	040p
Trpcu T8 D Distp	J niformp	J niformp
Percent Bpsp	040p	040p
Bps T8 D Distp	J niformp	J niformp

Costs in Q000 Y of E-p y Im5rovementp 040p

Predicted Annpal Accidentsp

	Base	Alternate
Fatalp	04000,p9p	04000,p9p
Inlpryp	04001k2p	04001k2p
PD8p	04021:pwp	04021:pwp
Totalp	040U,pUkp	040U,pUkp

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpMp	042p	:p4lp
8 th4Hcyclep	040p	040p
Ca5italp		,pk4lp
Sp55lementary Safetyp		
8 jpMp	040	p040p
8 th4Hcyclep	040p	040p
Ca5italp		040p

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETm
CORRIDOR AND CROSSING DATAm
(without phased improvements)m

User:k 3che-k 3k
Dataset:k Initial dataset
Corridor IDk 21k

Corridor Namek 2021 8 n Site Alt -k Ckrrent Trac3 . Di3ek

				Avg. No. Trains Per Day	Train Time-of-Day Distribution
				Passenger	050k	
Technology Factors k	0570k	0570k	0570k	*Freight*	2450k	Uniformk
Signal Synchronization?k	Falsek			*Switch*	050k	Uniformk

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calcklated: 2u. Dec. 20u6 u0:7wpmk

	Fatal	Injuryr	PDO	Total
Base	0500w41k	0504uwuk	050uu7w7k	050u7u2wk
Alternate	0500w41k	0504uwuk	050uu7w7k	050u7u2wk

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - DIKE CmRRIDORm

Milepost u45w4k
Crossing ID u0u%9uUk
Accidents in 7 Learsk 0k

Description BNSF . DIKE RDk

Paved? Trke k Urban? Falsek
GCX Base Typek 'kightsk
Safety Skp5Typek onek
GCX Alt Typek 'kightsk
Safety Skp5typek onek

No5RR Trac3sk wk

Train Speeds xmph(k

Ma& Timetablek	u050k
Passengerk	u050k
Freightk	u050k
S-kitchk	450k

Oigh-k y Traffic Characteristicsk

	Base	Alternate
OH-k y 'k nesk	2k	250k
Dist from h-k yk	05u0k	05uk
AADTk	w00k	w00k
Akto T8 D Distk	Uniformk	Uniformk
Percent Trkc3sk	u250k	u250k
8 f this) ,k trailersk	050k	050k
Trkc3 T8 D Distk	Uniformk	Uniformk
Percent Bksk	050k	050k
Bks T8 D Distk	Uniformk	Uniformk

Costs in l900 jkof O-k y Improvementk 050k

Predicted Annk l Accidentsk

	Base	Alternate
Fatalk	0500wwk	0500wwk
In\kryk	0504uwk	0504uwk
PD8k	050uu77k	050uu77k
Totalk	050u7u2k	050u7u2k

Costs in l900 jk

	Base	Alternate
Grade Crossing Devicesk		
8 $M	u51k	u51k
8 th5'kcyclek	050k	050k
Capitalk		%w51k
Skpplementary Safetyk		
8 $M	050	k050k
8 th5'kcyclek	050k	050k
Capitalk		050k

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETm
CORRIDOR AND CROSSING DATAm
(without phased improvements)m

6serf . che- 4. p
Datasetf Initial dataset
Corridor IDp 90p

Corridor Namep 2021 8n Site Alt -p ulanned Trac. 5S74rp

				Avg. No. Trains Per Day	Train Time-of-Day Distribution
			Passenger	0k0p	
Technology Factors p	0kw0p	0kw0p	0kw0p	*Freight* 20k0p	6 nim0rmp
Signal Synchronization?p	Falsep			*Switch* 0k0p	6 nim0rmp

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calc4latedf 295Dec520J:p 9fwJ 7mp

	Fatal	Injuryr	PDO	Total
Base	0k00U:pw9p	0k0wJ:p Up	0kJ1292Up	0k291: U2p
Alternate	0k00U:pw9p	0k0wJ:p Up	0kJ1292Up	0k291: U2p

CROSSING DATA FOR THE 2028 ON SITE ALT W/ PLANNED TRACK - SPUR CORRIDORm

bpile7ost 2kp1p Crossing ID J0J12:pTp

Descri7tion BNSF 593 D ARVp

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep Gatesp
Sa0ety S47kTy7ep onep
GCX Alt Ty7ep Gatesp
Sa0ety S47kty7ep onep

Nok3 3 Trac. sp 2p

Train S7eeds &m7hxp

bp $ TimetaPlep	1k0p
upssengerp	1k0p
Freightp	Jwk0p
S-pitchp	9k0p

Accidents in w'pearsp 0p

Eigh-p y TraNWc Characteristicsp

	Base	Alternate
EGp y Hpnesp	Up	Uk0p
Dist Nbm h-p yp	0kJ0p	0kJp
AADTp	20(220p	20(220p
A4to T8 D Distp	6 nim0rmp	6 nim0rmp
uercent Tr4c. sp	Jwk0p	Jwk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 nim0rmp	6 nim0rmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 nim0rmp	6 nim0rmp

Costs in G000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000:pp	0k000:pp
Inl4ryp	0k001J9p	0k001J9p
uD8p	0k092,pUp	0k092,pUp
Totalp	0k0UJwwp	0k0UJwwp

Costs in G000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	2kwp	wk0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		210k0p
S477lementary Sa0etyp		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost 2kp%p Crossing ID J0J12J/p

Descri7tion BNSF 5CAHIF8 3p IA WA'p

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep Hghtsp
Sa0ety S47kTy7ep onep
GCX Alt Ty7ep Hghtsp
Sa0ety S47kty7ep onep

Nok3 3 Trac. sp Jp

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	Jwk0p
S-pitchp	9k0p

Accidents in w'pearsp 0p

Eigh-p y TraNWc Characteristicsp

	Base	Alternate
EGp y Hpnesp	2p	2k0p
Dist Nbm h-p yp	0kJ0p	0kJp
AADTp	w(Uw0p	w(Uw0p
A4to T8 D Distp	6 nim0rmp	6 nim0rmp
uercent Tr4c. sp	,pk0p	,pk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 nim0rmp	6 nim0rmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 nim0rmp	6 nim0rmp

Costs in G000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000U2p	0k000U2p
Inl4ryp	0k00U:pp	0k00U:pp
uD8p	0k0Jw:pJp	0k0Jw:pJp
Totalp	0k020,p0p	0k020,p0p

Costs in G000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	Jk1p	2kwp
8 thkHcyclep	0k0p	0k0p
Ca7italp		J0:pkJp
S477lementary Sa0etyp		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost 9kpp Crossing ID J0J10wAp Accidents in w'pearsp 0p

Descri7tion BNSF 583 VG8p WA'p

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep Gatesp
Saf4ty S47kTy7ep onep
GCX Alt Ty7ep Gatesp
Saf4ty S47kty7ep onep

Nok33 Trac. sp Jp

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	20k0p
S-pitchp	9k0p

Eigh-p y TraNWc Characteristicsp

	Base	Alternate
EQp y Hpmesp	Up	Uk0p
Dist Nbm h-p yp	0kJ0p	0kJp
AADTp	J,p(020p	J,p(020p
A4to T8 D Distp	6 niNdrmp	6 niNdrmp
uercent Tr4c. sp	wk0p	wk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 niNdrmp	6 niNdrmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 niNdrmp	6 niNdrmp

Costs in Q000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000,pUp	0k000,pUp
Inl4ryp	0k0019Jp	0k0019Jp
uD8p	0k02, , % p	0k02, , % p
Totalp	0k09:p1Up	0k09:p1Up

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	2kwp	wk0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		210k0p
S477lementary Saf4typ		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost 9k11p Crossing ID J0J10:pGp Accidents in w'pearsp 0p

Descri7tion BNSF 5IND6 ST3 IAH WA'p

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep Hghtsp
Saf4ty S47kTy7ep onep
GCX Alt Ty7ep Hghtsp
Saf4ty S47kty7ep onep

Nok33 Trac. sp Jp

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	20k0p
S-pitchp	9k0p

Eigh-p y TraNWc Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	2k0p
Dist Nbm h-p yp	0kJ0p	0kJp
AADTp	JJ(Uw0p	JJ(Uw0p
A4to T8 D Distp	6 niNdrmp	6 niNdrmp
uercent Tr4c. sp	Jwk0p	Jwk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 niNdrmp	6 niNdrmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 niNdrmp	6 niNdrmp

Costs in Q000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000wJp	0k000wJp
Inl4ryp	0k00w.pp	0k00w.pp
uD8p	0k0J1%9p	0k0J1%9p
Totalp	0k02w0%p	0k02w0%p

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	Jk1p	2kwp
8 thkHcyclep	0k0p	0k0p
Ca7italp		J0:pkJp
S477lementary Saf4typ		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost wk0wp Crossing ID p Accidents in w'pearsp 0p

Descri7tion BNSF 5WV'pV3 EA6 SV3 N83 uACp

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep upssivep
Saf4ty S47kTy7ep onep
GCX Alt Ty7ep upssivep
Saf4ty S47kty7ep onep

Nok33 Trac. sp Jp

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	Jwk0p
S-pitchp	9k0p

Eigh-p y TraNWc Characteristicsp

	Base	Alternate
EQp y Hpmesp	2p	2k0p
Dist Nbm h-p yp	0kJ0p	0kJp
AADTp	%w0p	%w0p
A4to T8 D Distp	6 niNdrmp	6 niNdrmp
uercent Tr4c. sp	wk0p	wk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 niNdrmp	6 niNdrmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 niNdrmp	6 niNdrmp

Costs in Q000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000:pp	0k000:pp
Inl4ryp	0k00,p92p	0k00,p92p
uD8p	0k02UU1p	0k02UU1p
Totalp	0k092U:p	0k092U:p

Costs in Q000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	0k2p	Jk1p
8 thkHcyclep	0k0p	0k0p
Ca7italp		,pUk1p
S477lementary Saf4typ		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost :pkU.p Crossing ID p

Descri7tion BNSF 5WASEINGT8p WA'p

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep upssivep
SaMety S47kTy7ep onep
GCX Alt Ty7ep upssivep
SaMety S47kty7ep onep

Nok3 3 Trac. sp 2p

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	J0k0p
S-pitchp	9k0p

Accidents in w'pearsp 0p

Eigh-p y TraNMc Characteristicsp

	Base	Alternate
EGp y Hpmesp	Up	Uk0p
Dist Mbm h-p yp	0kJ0p	0kJp
AADTp	9(100p	9(100p
A4to T8 D Distp	6 niMdrmp	6 niMdrmp
uercent Tr4c. sp	wk0p	wk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 niMdrmp	6 niMdrmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 niMdrmp	6 niMdrmp

Costs in C000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000%0p	0k000%0p
Inl4ryp	0k00%Jwp	0k00%Jwp
uD8p	0k09U:puJp	0k09U:puJp
Totalp	0k0UUppp	0k0UUppp

Costs in C000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	Jk1p	2kwp
8 thkHcyclep	0k0p	0k0p
Ca7italp		J0:pkJp
S477lementary SaMetyp		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

bpile7ost :pkU%p Crossing ID p

Descri7tion BNSF 591TE ARVp

upved? Tr4e p 6rPpn? Tr4e
GCX Base Ty7ep upssivep
SaMety S47kTy7ep onep
GCX Alt Ty7ep upssivep
SaMety S47kty7ep onep

Nok3 3 Trac. sp Jp

Train S7eeds &m7hxp

bp $ TimetaPlep	J0k0p
upssengerp	J0k0p
Freightp	wk0p
S-pitchp	9k0p

Accidents in w'pearsp 0p

Eigh-p y TraNMc Characteristicsp

	Base	Alternate
EGp y Hpmesp	2p	2k0p
Dist Mbm h-p yp	0kJ0p	0kJp
AADTp	J(:p%0p	J(:p%0p
A4to T8 D Distp	6 niMdrmp	6 niMdrmp
uercent Tr4c. sp	wk0p	wk0p
8 Mhis( )p trailersp	0k0p	0k0p
Tr4c. T8 D Distp	6 niMdrmp	6 niMdrmp
uercent B4sp	0k0p	0k0p
B4s T8 D Distp	6 niMdrmp	6 niMdrmp

Costs in C000 YoME-p y Im7rovementp 0k0p

uredicted Ann4al Accidentsp

	Base	Alternate
Fatalp	0k000,pwp	0k000,pwp
Inl4ryp	0k001U2p	0k001U2p
uD8p	0k021J:p	0k021J:p
Totalp	0k09,p9Up	0k09,p9Up

Costs in C000 Yp

	Base	Alternate
Grade Crossing Devicesp		
8 jpbp p	0k2p	Jk1p
8 thkHcyclep	0k0p	0k0p
Ca7italp		,pUk1p
S477lementary SaMetyp		
8 jpbp p	0k0p	0k0p
8 thkHcyclep	0k0p	0k0p
Ca7italp		0k0p

FEDERAL RAILROAD ADMINISTRATIONOm

GRADEDEC.NETMm

CORRIDOR AND CROSSING DATAm

(without phased improvements)Mm

6serpk . che- : kk
Datasetpk Initial dataset
Corridor IDk 74ak

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Namek	2021 8 n Site Alt -k 3 lkanned Trac. 5Di. ek					
				Passenger	0v0k	
Technology Factors k	0w0k	0w0k	0w0k	*Freight*	27v0k	6 nibormk
Signal Synchronization?k	Falsek			*Switch*	0v0k	6 nibormk

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSOm

Calc:katedp275Dec5204fk 7puu Mmk

	Fatal	Injuryr	PDO	Total
Base	0v000U71k	0v0074U4k	0v044uUuk	0v04u42Uk
Alternate	0v000U71k	0v0074U4k	0v044uUuk	0v04u42Uk

CROSSING DATA FOR THE 2028 ON SITE ALT W/ PLANNED TRACK - DIKE CORRIDORm

P ileMost 47wu7k Crossing ID 4049V46k Accidents in u Yearsk 0k

DescriMion KNSF 5DIER ODk

3 aGed? Tr:ke k 6 rvkn? Falsek
XCB Kase TyMek Lightsk
Sabety S:kMwTyMek onek
XCB Alt TyMek Lightsk
Sabety S:kMwtyMek onek
owOO Trac. sk Uk

Train SMeeds (mMh)k

Pk x Timetavlek	40v0k
3k ssengerk	40v0k
Freightk	40v0k
S-kitchk	7v0k

High-k y Trabbic Characteristicsk

	Base	Alternate
H'-k y Lanesk	2k	2v0k
Dist brom h-k yk	0w40k	0w4k
AADTk	U00k	U00k
A:kto T8 D Distk	6 nibormk	6 nibormk
3 ercent Tr:kc. sk	42v0k	42v0k
8 bthis, % trailersk	0v0k	0v0k
Tr:kc. T8 D Distk	6 nibormk	6 nibormk
3 ercent K:ksk	0v0k	0v0k
K:ks T8 D Distk	6 nibormk	6 nibormk

Costs in '000 $ obH-k y ImMroGementk 0v0k

3redicted Ann:k l Accidentsk

	Base	Alternate
Fatalk	0v000UUk	0v000UUk
Inj:kryk	0v0074Uk	0v0074Uk
3D8k	0v044uuk	0v044uuk
Totalk	0v04u42k	0v04u42k

Costs in '000 $k

	Base	Alternate
Xkade Crossing DeGcesk		
8 &P k	4v1k	4v1k
8 thwLcyclek	0v0k	0v0k
CaMtalk		9Uv1k
S:kMMementary Sabetyk		
8 &P k	0v0	k0v0k
8 thwLcyclek	0v0k	0v0k
CaMtalk		0v0k

FEDERAL RAILROAD ADMINISTRATION8

GRADEDEC.NET0

CORRIDOR AND CROSSING DATA8

(without phased improvements)0

User:0 kchewuk
Dataset:0 Initial dataset0
Corridor ID0 140

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Name0	2018 No Action - Mainline0			*Passenger*	10.0	Uniform0
echnology Factors 0	0.50	0.50	0.50	*Freight*	45.0	Uniform0
Signal Synchronization?0	False0			*Switch*	0.0	Uniform0

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTS8

Calculated: 28-Sep-2015 1:09 pm0

	Fatal8	Injury8	PDO8	Total8
Base	0.0390440	0.0609360	0.1601750	0.2601550
Alternate	0.0390440	0.0609360	0.1601750	0.2601550

CROSSING DATA FOR THE 2018 NO ACTION - MAINLINE CORRIDOR8

Milepost 82.720 Crossing ID 092481X0 Accidents in 5 Years0 0

Description BNSF - TAYLOR CRANE RD0

Paved? False 0 Urban? False
GCX Base Type0 Passive0
Safety Sup. Type0 None0
GCX Alt Type0 Passive0
Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	50.0
Passenger0	50.0
Freight0	50.0
Switch0	21.0

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	50	50
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	5.0	5.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 2390	0.0 2390
Injury0	0.0 4610	0.0 4610
PDO0	0.010320	0.010320
tal0	0.017320	0.017320

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	0.20	0.20
Oth. Lcycle0	0.0	0.0
Capital0		1.60
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Milepost 87.430 Crossing ID 092476B0 Accidents in 5 Years0 0

Description BNSF - COWLITZ AVE0

Paved? True 0 Urban? False
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	50.0
Passenger0	50.0
Freight0	50.0
Switch0	23.70

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	1,20	1,20
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	2.0	2.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 3790	0.0 3790
Injury0	0.0 7320	0.0 7320
PDO0	0.016380	0.016380
tal0	0.027490	0.027490

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 NO ACTION - MAINLINE CORRIDOR8

Milepost 95.560 Crossing ID 092466V0 Accidents in 5 Years0 0

Description BNSF - COWLITZ GARDEN RD0

Paved? True 0 Urban? True
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 30

rain Speeds (mph)0

Max Timetable0	75.0
Passenger0	75.0
Freight0	60.0
Switch0	15.60

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	70	70
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	10.0	10.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 3930	0.0 3930
Injury0	0.0 5390	0.0 5390
PDO0	0.018030	0.018030
tal0	0.027350	0.027350

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Milepost 97.670 Crossing ID 092458D0 Accidents in 5 Years0 0

Description BNSF - MILL STREET0

Paved? True 0 Urban? True
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 30

rain Speeds (mph)0

Max Timetable0	40.0
Passenger0	40.0
Freight0	40.0
Switch0	22.50

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	2,550	2,550
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	5.0	5.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 2910	0.0 2910
Injury0	0.0 7490	0.0 7490
PDO0	0.024980	0.024980
tal0	0.035380	0.035380

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Milepost 97.980 Crossing ID 092457W0 Accidents in 5 Years0 0

Description BNSF - YEW ST.(S RIVER)0

Paved? True 0 Urban? True
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 30

rain Speeds (mph)0

Max Timetable0	40.0
Passenger0	40.0
Freight0	40.0
Switch0	22.50

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	1,850	1,850
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	50.0	50.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 2740	0.0 2740
Injury0	0.0 7050	0.0 7050
PDO0	0.02350	0.02350
tal0	0.033290	0.033290

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 NO ACTION - MAINLINE CORRIDOR8

Milepost 109.60 Crossing ID 092446J0 Accidents in 5 Years0 0

Description BNSF - TOTEFF ROAD0

Paved? True 0 Urban? False
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	79.0
Passenger0	79.0
Freight0	60.0
Switch0	23.70

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	1,20	1,20
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	50.0	50.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 5540	0.0 5540
Injury0	0.0 6620	0.0 6620
PDO0	0.015330	0.015330
tal0	0.027490	0.027490

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Milepost 115.750 Crossing ID 092437K0 Accidents in 5 Years0 0

Description BNSF - SCOTT AVE WEST0

Paved? True 0 Urban? False
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	75.0
Passenger0	75.0
Freight0	60.0
Switch0	23.70

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	2,650	2,650
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	2.0	2.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 6240	0.0 6240
Injury0	0.0 790	0.0 790
PDO0	0.018160	0.018160
tal0	0.03230	0.03230

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Milepost 116.620 Crossing ID 092435W0 Accidents in 5 Years0 0

Description BNSF - DAVIDSON AVE0

Paved? True 0 Urban? False
GCX Base Type0 Gates0
Safety Sup. Type0 None0
GCX Alt Type0 Gates0
Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	75.0
Passenger0	75.0
Freight0	60.0
Switch0	23.70

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	2,0	2,0
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	35.0	35.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 590	0.0 590
Injury0	0.0 7470	0.0 7470
PDO0	0.017170	0.017170
tal0	0.030540	0.030540

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 NO ACTION - MAINLINE CORRIDOR8

Milepost 117.50 Crossing ID 092434P0

Description BNSF - WHALEN RD.0

Paved? True 0 Urban? False0

GCX Base Type0 Gates0

Safety Sup. Type0 None0

GCX Alt Type0 Gates0

Safety Sup. type0 None0

No. RR Tracks0 20

rain Speeds (mph)0

Max Timetable0	75.0
Passenger0	75.0
Freight0	60.0
Switch0	23.70

Accidents in 5 Years0 0

Highway Traffic Characteristics0

	Base	Alternate
H'way Lanes0	20	2.0
Dist from hway0	0.10	0.10
AADT0	1,550	1,550
Auto TOD Dist0	Uniform0	Uniform0
Percent Trucks0	25.0	25.0
Of this, % trailers0	0.0	0.0
ruck TOD Dist0	Uniform0	Uniform0
Percent Bus0	0.0	0.0
Bus TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hway Improvement0 0.0

Predicted Annual Accidents0

	Base	Alternate
Fatal0	0.0 5610	0.0 561
Injury0	0.0 7090	0.0 7090
PDO0	0.01630	0.01630
tal0	0.0290	0.0290

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&M0	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		106.10
Supplementary Safety0		
O&M0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

FEDERAL RAILROAD ADMINISTRATION8

GRADEDEC.NET0

CORRIDOR AND CROSSING DATA8

(u itho- t phased improvements)0

5 ser: 0 Mcheu - M0
Dataset:0 Initial dataset0
Corridor ID0 1f0

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Name0	2018 Constr- ction Tr- cM4U ainline0					
				Passenger	10.0	5 ni3 0m0
echnology Factors 0	0.90	0.90	0.90	*Freight*	69.0	5 ni3 0m0
Signal Synchronization?0	False0			*Switch*	0.0	5 ni3 0m0

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTS8

Calc- lated: 284Sep42019 1:2f pm0

	Fatal8	Injury8	PDO8	Total8
Base	0.07k0660	0.0w k7w0	0.1w01f090	0.2w 1990
Alternate	0.07k0660	0.0w k7w0	0.1w01f090	0.2w 1990

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUCK - MAINLINE CORRID8R8

U ilepost 82.f020 Crossing ID 0k2681X0 Accidents in 9 Years0 0

Description BNSF 4TAYLOR CRANE RD0

Paved? False 0 5 rban? False0
GCX Base Type0 Passive0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Passive0
Sa3 ety S- p. type0 None0
No. RR Tracks0 20

rain Speeds (mph)0

U ax Timetable0	90.0
Passenger0	90.0
Freight0	90.0
Su itch0	21.0

Highu ay Tra3 c Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3 om hu ay0	0.10	0.10
AADT0	90	90
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	9.0	9.0
O3 this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 27k	0.0 27k
Inj- ry0	0.0 6w10	0.0 6w10
PDO0	0.010720	0.010720
tal0	0.01f0720	0.01f0720

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	0.20	0.20
Oth. Lcycle0	0.0	0.0
Capital0		1.w0
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

U ilepost 8f0670 Crossing ID 0k26f0wB0 Accidents in 9 Years0 0

Description BNSF 4COWLITZ AVE0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3 ety S- p. type0 None0
No. RR Tracks0 20

rain Speeds (mph)0

U ax Timetable0	90.0
Passenger0	90.0
Freight0	90.0
Su itch0	27.f0

Highu ay Tra3 c Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3 om hu ay0	0.10	0.10
AADT0	1,20	1,20
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	2.0	2.0
O3 this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 7f0k	0.0 7f0k
Inj- ry0	0.0 f0720	0.0 f0720
PDO0	0.01w780	0.01w780
tal0	0.02f06k	0.02f06k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUCK - MAINLINE CORRID8R8

Uilepost k9.9w0 Crossing ID 0k26wwV0

Description BNSF 4COWLITZ GARDEN RD0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracMs0 70

rain Speeds (mph)0

Uax Timetable0	f09.0
Passenger0	f09.0
Freight0	w0.0
Su itch0	19.w0

Accidents in 9 Years0 0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	f0	f0
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	10.0	10.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 7k70	0.0 7k70
Inj- ry0	0.0 97k	0.0 97k
PDO0	0.018070	0.018070
tal0	0.02f0790	0.02f0790

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Uilepost kf0wf0 Crossing ID 0k2698D0

Description BNSF 4UILL STREET0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracMs0 70

rain Speeds (mph)0

Uax Timetable0	60.0
Passenger0	60.0
Freight0	60.0
Su itch0	22.90

Accidents in 9 Years0 0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	2,990	2,990
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	9.0	9.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2k10	0.0 2k10
Inj- ry0	0.0 f06k	0.0 f06k
PDO0	0.026k80	0.026k80
tal0	0.079780	0.079780

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Uilepost kf0k80 Crossing ID 0k269f0V0

Description BNSF 4YEW ST.(S RIVER)0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracMs0 70

rain Speeds (mph)0

Uax Timetable0	60.0
Passenger0	60.0
Freight0	60.0
Su itch0	22.90

Accidents in 9 Years0 0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	1,890	1,890
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	90.0	90.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2f060	0.0 2f060
Inj- ry0	0.0 f 090	0.0 f 090
PDO0	0.02790	0.02790
tal0	0.0772k	0.0772k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUCK - MAINLINE CORRID8R8

U ilepost 10k.w0 Crossing ID 0k266wJ0 Accidents in 9 Years0 0

Description BNSF 4TOTEFF ROAD0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	f0k.0
Passenger0	f0k.0
Freight0	w0.0
Su itch0	27.f0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	1,20	1,20
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	90.0	90.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 9960	0.0 9960
Inj- ry0	0.0 ww20	0.0 ww20
PDO0	0.019770	0.019770
tal0	0.02f06k	0.02f06k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

U ilepost 119.f090 Crossing ID 0k267f0K0 Accidents in 9 Years0 0

Description BNSF 4SCOTT AVE WEST0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	f09.0
Passenger0	f09.0
Freight0	w0.0
Su itch0	27.f0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	2,w90	2,w90
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	2.0	2.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 w260	0.0 w260
Inj- ry0	0.0 f0k	0.0 f0k
PDO0	0.0181w0	0.0181w0
tal0	0.07270	0.07270

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

U ilepost 11w.w20 Crossing ID 0k2679W0 Accidents in 9 Years0 0

Description BNSF 4DAVIDSON AVE0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	f09.0
Passenger0	f09.0
Freight0	w0.0
Su itch0	27.f0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	2,0	2,0
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	79.0	79.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 9k	0.0 9k
Inj- ry0	0.0 f06f0	0.0 f06f0
PDO0	0.01f01f0	0.01f01f0
tal0	0.070960	0.070960

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2018 CONSTRUCTION TRUCK - MAINLINE CORRID8R8

Uilepost 11f090 Crossing ID 0k2676P0

Description BNSF 4WHALEN RD.0

Paved? Tr- e 0 5rban? False0

GCX Base Type0 Gates0

Sa3ety S- p. Type0 None0

GCX Alt Type0 Gates0

Sa3ety S- p. type0 None0

No. RR TracM$0 20

rain Speeds (mph)0

Uax Timetable0	f09.0
Passenger0	f09.0
Freight0	w0.0
Su itch0	27.f0

Accidents in 9 Years0 0

Highu ay Tra3ic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist 3om hu ay0	0.10	0.10
AADT0	1,990	1,990
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cM$0	29.0	29.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 9w10	0.0 9w10
Inj- ry0	0.0 f 0k	0.0 f 0k
PDO0	0.01w70	0.01w70
tal0	0.02k	0.02k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		10w.10
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

FEDERAL RAILROAD ADMINISTRATION8

GRADEDEC.NET0

CORRIDOR AND CROSSING DATA8

(u itho- t phased improvements)0

User:0 wcheu - w0
Dataset:0 Initial dataset0
Corridor ID0 20

Corridor Name0 2018 Constr- ction Rail M4 ainline0

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
				Passenger	10.0	Uniform0
echnology Factors 0	0.50	0.50	0.50	*Freight*	39.0	Uniform0
Signal Synchronization?0	False0			*Switch*	0.0	Uniform0

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTS8

Calc- lated: 28M9epM2015 1:62 pm0

	Fatal8	Injury8	PDO8	Total8
Base	0.0676270	0.0912520	0.1911280	0.291k 70
Alternate	0.0676270	0.0912520	0.1911280	0.291k 70

CROSSING DATA FOR THE 2018 CONSTRUCTION RAIL - MAINLINE CORRIDOR8

40lepost 82.k20 Crossing ID 072381X0 Accidents in 5 Years0 0

Description BNSF MTAYLOR CRANE RD0

Paved? False 0 Urban? False
GCX Base Type0 Passive0
Safety S- p. Type0 None0
GCX Alt Type0 Passive0
Safety S- p. type0 None0

No. RR Tracws0 20

rain Speeds (mph)0

40ax Timetable0	50.0
Passenger0	50.0
Freight0	50.0
Su itch0	21.0

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	50	50
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	5.0	5.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2310	0.0 2310
Inj- ry0	0.0 3930	0.0 3930
PDO0	0.010310	0.010310
tal0	0.01k390	0.01k390

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	0.20	0.20
Oth. Lcycle0	0.0	0.0
Capital0		1.90
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 8k.360 Crossing ID 0723k9B0 Accidents in 5 Years0 0

Description BNSF MCOWLITZ AVE0

Paved? Tr- e 0 Urban? False
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 20

rain Speeds (mph)0

40ax Timetable0	50.0
Passenger0	50.0
Freight0	50.0
Su itch0	26.k

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	1,20	1,20
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	2.0	2.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 6820	0.0 6820
Inj- ry0	0.0 k690	0.0 k690
PDO0	0.019380	0.019380
tal0	0.02k990	0.02k990

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 75.590 Crossing ID 072399V0

Description BNSF MCOWLITZ GARDEN RD0

Paved? Tr- e 0 Urban? Tr- e0
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 60

rain Speeds (mph)0

40ax Timetable0	k5.0
Passenger0	k5.0
Freight0	90.0
Su itch0	15.90

Accidents in 5 Years0 0

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	k	k
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	10.0	10.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 6790	0.0 6790
Inj- ry0	0.0 5310	0.0 5310
PDO0	0.018130	0.018130
tal0	0.02k510	0.02k510

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 7k.9k Crossing ID 072358D0

Description BNSF M40LL STREET0

Paved? Tr- e 0 Urban? Tr- e0
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 60

rain Speeds (mph)0

40ax Timetable0	30.0
Passenger0	30.0
Freight0	30.0
Su itch0	22.50

Accidents in 5 Years0 0

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	2,550	2,550
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	5.0	5.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2760	0.0 2760
Inj- ry0	0.0 k560	0.0 k560
PDO0	0.025120	0.025120
tal0	0.0655k	0.0655k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 7k.780 Crossing ID 07235kW0

Description BNSF MYEW ST.(S RIVER)0

Paved? Tr- e 0 Urban? Tr- e0
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 60

rain Speeds (mph)0

40ax Timetable0	30.0
Passenger0	30.0
Freight0	30.0
Su itch0	22.50

Accidents in 5 Years0 0

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	1,850	1,850
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	50.0	50.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2k50	0.0 2k50
Inj- ry0	0.0 k080	0.0 k080
PDO0	0.026930	0.026930
tal0	0.0663k	0.0663k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 107.90 Crossing ID 072339J0 Accidents in 5 Years0 0

Description BNSF MTOTEFF ROAD0

Paved? Tr- e 0 Urban? False
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 20

rain Speeds (mph)0

40ax Timetable0	k7.0
Passenger0	k7.0
Freight0	90.0
Su itch0	26.k

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	1,20	1,20
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	50.0	50.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 5580	0.0 5580
Inj- ry0	0.0 9950	0.0 9950
PDO0	0.015320	0.015320
tal0	0.02k990	0.02k990

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 115.k50 Crossing ID 07236kK0 Accidents in 5 Years0 0

Description BNSF MSCOTT AVE WEST0

Paved? Tr- e 0 Urban? False
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 20

rain Speeds (mph)0

40ax Timetable0	k5.0
Passenger0	k5.0
Freight0	90.0
Su itch0	26.k

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	2,950	2,950
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	2.0	2.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 9270	0.0 9270
Inj- ry0	0.0 k730	0.0 k730
PDO0	0.018290	0.018290
tal0	0.062380	0.062380

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 119.920 Crossing ID 072365W0 Accidents in 5 Years0 0

Description BNSF MDAVIDSON AVE0

Paved? Tr- e 0 Urban? False
GCX Base Type0 Gates0
Safety S- p. Type0 None0
GCX Alt Type0 Gates0
Safety S- p. type0 None0

No. RR Tracws0 20

rain Speeds (mph)0

40ax Timetable0	k5.0
Passenger0	k5.0
Freight0	90.0
Su itch0	26.k

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	2,0	2,0
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	65.0	65.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 5750	0.0 5750
Inj- ry0	0.0 k510	0.0 k510
PDO0	0.01k2k	0.01k2k
tal0	0.060k20	0.060k20

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

40lepost 11k.50 Crossing ID 072363P0

Description BNSF MWHALEN RD.0

Paved? Tr- e 0	Urban? False0
GCX Base Type0	Gates0
Safety S- p. Type0	None0
GCX Alt Type0	Gates0
Safety S- p. type0	None0
No. RR Tracws0	20

rain Speeds (mph)0

40ax Timetable0	k5.0
Passenger0	k5.0
Freight0	90.0
Su itch0	26.k

Accidents in 5 Years0 0

Highu ay Traffic Characteristics0

	Base	Alternate
H'u ay Lanes0	20	2.0
Dist from hu ay0	0.10	0.10
AADT0	1,550	1,550
A- to TOD Dist0	Uniform0	Uniform0
Percent Tr- cws0	25.0	25.0
Of this, % trailers0	0.0	0.0
Tr- cwTOD Dist0	Uniform0	Uniform0
Percent B- s0	0.0	0.0
B- s TOD Dist0	Uniform0	Uniform0

Costs in '0 $ of Hu ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 5950	0.0 595
Inj- ry0	0.0 k160	0.0 k160
PDO0	0.01930	0.01930
tal0	0.0271k	0.0271k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&40	2.50	2.50
Oth. Lcycle0	0.0	0.0
Capital0		109.10
S- pplementary Safety0		
O&40	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Name0	2021 No Action 8 C- rrent TracM4 U ainline0					
				Passenger	60.0	5 ni3 0m0
echnology Factors 0	0.90	0.90	0.90	*Freight*	7f .0	5 ni3 0m0
Signal Synchronization?0	False0			*Switch*	0.0	5 ni3 0m0

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSW

Calc- lated: 214Sep42069 f :6u pm0

	FatalW	InjuryW	PDOW	TotalW
Base	0.0kkw7f0	0.07uu6u0	0.61060	0.2w2u160
Alternate	0.0kkw7f0	0.07uu6u0	0.61060	0.2w2u160

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - MAINLINE CORRIDORW

Uilepost 12.u20 Crossing ID 0w2k16X0 Accidents in 9 Years0 0

Description BNSF 4TAYLOR CRANE RD0

Paved? False 0 5 rban? False0
GCX Base Type0 Passive0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Passive0
Sa3 ety S- p. type0 None0
No. RR TracMs0 20

rain Speeds (mph)0

Uax Timetable0	90.0
Passenger0	90.0
Freight0	90.0
S8 itch0	26.0

High8 ay Tra33c Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3om h8 ay0	0.60	0.60
AADT0	90	90
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	9.0	9.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 2uu0	0.0 2uu0
Inj- ry0	0.0 9610	0.0 9610
PDO0	0.066u20	0.066u20
tal0	0.06w770	0.06w770

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	0.20	0.20
Oth. Lcycle0	0.0	0.0
Capital0		6.70
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Uilepost 1u.kf0 Crossing ID 0w2ku7B0 Accidents in 9 Years0 0

Description BNSF 4COWLITZ AVE0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3 ety S- p. type0 None0
No. RR TracMs0 20

rain Speeds (mph)0

Uax Timetable0	90.0
Passenger0	90.0
Freight0	90.0
S8 itch0	2f0u0

High8 ay Tra33c Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3om h8 ay0	0.60	0.60
AADT0	6,k90	6,k90
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	2.0	2.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 kk60	0.0 kk60
Inj- ry0	0.0 1270	0.0 1270
PDO0	0.0617w0	0.0617w0
tal0	0.0f06f070	0.0f06f070

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - MAINLINE CORRIDORW

Uilepost w9.970 Crossing ID 0w2k77V0 Accidents in 9 Years0 0

Description BNSF 4COWLITZ GARDEN RD0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracM0 f0

rain Speeds (mph)0

Uax Timetable0	u9.0
Passenger0	u9.0
Freight0	70.0
S8itch0	69.70

High8ay Tra3ic Characteristics0

	Base	Alternate
H'8ay Lanes0	20	2.0
Dist 3om h8ay0	0.60	0.60
AADT0	190	190
A- to TOD Dist0	5ni30m0	5ni30m0
Percent Tr- cM0	60.0	60.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5ni30m0	5ni30m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5ni30m0	5ni30m0

Costs in '0 $ o3H8ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 k910	0.0 k910
Inj- ry0	0.0 7070	0.0 7070
PDO0	0.02070	0.02070
tal0	0.0f062k	0.0f062k

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Uilepost wu.7u0 Crossing ID 0w2k91D0 Accidents in 9 Years0 0

Description BNSF 4UILL STREET0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracM0 f0

rain Speeds (mph)0

Uax Timetable0	k0.0
Passenger0	k0.0
Freight0	k0.0
S8itch0	22.90

High8ay Tra3ic Characteristics0

	Base	Alternate
H'8ay Lanes0	20	2.0
Dist 3om h8ay0	0.60	0.60
AADT0	2,90	2,90
A- to TOD Dist0	5ni30m0	5ni30m0
Percent Tr- cM0	9.0	9.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5ni30m0	5ni30m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5ni30m0	5ni30m0

Costs in '0 $ o3H8ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 f0220	0.0 f0220
Inj- ry0	0.0 10k	0.0 10k
PDO0	0.02u0k	0.02u0k
tal0	0.0f012w0	0.0f012w0

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

Uilepost wu.w10 Crossing ID 0w2k9uW0 Accidents in 9 Years0 0

Description BNSF 4YEW ST.(S RIVER)0

Paved? Tr- e 0 5rban? Tr- e0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR TracM0 f0

rain Speeds (mph)0

Uax Timetable0	k0.0
Passenger0	k0.0
Freight0	k0.0
S8itch0	22.90

High8ay Tra3ic Characteristics0

	Base	Alternate
H'8ay Lanes0	20	2.0
Dist 3om h8ay0	0.60	0.60
AADT0	2,20	2,20
A- to TOD Dist0	5ni30m0	5ni30m0
Percent Tr- cM0	90.0	90.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5ni30m0	5ni30m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5ni30m0	5ni30m0

Costs in '0 $ o3H8ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 f0690	0.0 f0690
Inj- ry0	0.0 u190	0.0 u190
PDO0	0.027kf0	0.027kf0
tal0	0.0f0uk20	0.0f0uk20

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - MAINLINE CORRIDORW

U ilepost 60w.70 Crossing ID 0w2kk7J0 Accidents in 9 Years0 0

Description BNSF 4TOTEFF ROAD0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3 ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	uw.0
Passenger0	uw.0
Freight0	70.0
S8 itch0	2f0u0

High8 ay Tra3 ic Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3 om h8 ay0	0.60	0.60
AADT0	6,k90	6,k90
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	90.0	90.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 7kk	0.0 7kk
Inj- ry0	0.0 ukf0	0.0 ukf0
PDO0	0.06ukw0	0.06ukw0
tal0	0.0f06f070	0.0f06f070

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

U ilepost 669.u90 Crossing ID 0w2kf0uK0 Accidents in 9 Years0 0

Description BNSF 4SCOTT AVE WEST0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3 ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	u9.0
Passenger0	u9.0
Freight0	70.0
S8 itch0	2f0u0

High8 ay Tra3 ic Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3 om h8 ay0	0.60	0.60
AADT0	f0,600	f0,600
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	2.0	2.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 u690	0.0 u690
Inj- ry0	0.0 1uf0	0.0 1uf0
PDO0	0.020f0w0	0.020f0w0
tal0	0.0f07210	0.0f07210

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

U ilepost 667.720 Crossing ID 0w2kf09W0 Accidents in 9 Years0 0

Description BNSF 4DAVIDSON AVE0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3 ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3 ety S- p. type0 None0

No. RR Trac Ms0 20

rain Speeds (mph)0

U ax Timetable0	u9.0
Passenger0	u9.0
Freight0	70.0
S8 itch0	2f0u0

High8 ay Tra3 ic Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3 om h8 ay0	0.60	0.60
AADT0	2,f090	2,f090
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cMs0	f09.0	f09.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 7uw0	0.0 7uw0
Inj- ry0	0.0 12w0	0.0 12w0
PDO0	0.06wf070	0.06wf070
tal0	0.0f0kk90	0.0f0kk90

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3 ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

CROSSING DATA FOR THE 2028 NO ACTION W CURRENT TRACK - MAINLINE CORRIDORW

U ilepost 66u.90 Crossing ID 0w2kf0kP0

Description BNSF 4WHALEN RD.0

Paved? Tr- e 0 5 rban? False0
GCX Base Type0 Gates0
Sa3ety S- p. Type0 None0
GCX Alt Type0 Gates0
Sa3ety S- p. type0 None0

No. RR Trac M$0 20

rain Speeds (mph)0

U ax Timetable0	u9.0
Passenger0	u9.0
Freight0	70.0
S8 itch0	2f0u0

Accidents in 9 Years0 0

High8 ay Tra3c Characteristics0

	Base	Alternate
H'8 ay Lanes0	20	2.0
Dist 3om h8 ay0	0.60	0.60
AADT0	6,10	6,10
A- to TOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent Tr- cM$0	29.0	29.0
O3this, % trailers0	0.0	0.0
Tr- cMTOD Dist0	5 ni3 0m0	5 ni3 0m0
Percent B- s0	0.0	0.0
B- s TOD Dist0	5 ni3 0m0	5 ni3 0m0

Costs in '0 $ o3H8 ay Improvement0 0.0

Predicted Ann- al Accidents0

	Base	Alternate
Fatal0	0.0 7k90	0.0 7k90
Inj- ry0	0.0 u110	0.0 u110
PDO0	0.061f0w0	0.061f0w0
tal0	0.0f02u20	0.0f02u20

Costs in '0 $0

	Base	Alternate
Grade Crossing Devices0		
O&U0	2.90	2.90
Oth. Lcycle0	0.0	0.0
Capital0		607.60
S- pplementary Sa3ety0		
O&U0	0.0	0.0
Oth. Lcycle0	0.0	0.0
Capital0		0.0

FEDERAL RAILROAD ADMINISTRATIONW

GRADEDEC.NET0

CORRIDOR AND CROSSING DATAW

v- ithoM(hased im(r0) ementsb0

3 serp0 4che-0M40
Datasetp0 Initial dataset0
Corridor ID0 250

					Avg. No. Trains Per Day	Train Time-of-Day Distribution
Corridor Name0	2021 8 n Site Alt - CMrrent Trac4 Uf0ainline0					
				Passenger	70.0	3 ni9 0m0
echnology Factors 0	0.60	0.60	0.60	*Freight*	57.0	3 ni9 0m0
Signal Synchronization?0	False0			*Switch*	0.0	3 ni9 0m0

CORRIDOR SUMMARY OF PREDICTED ANNUAL ACCIDENTSW

CalcMatedp21USe(U2076 : p05 (m0

	FatalW	InjuryW	PDOW	TotalW
Base	0.0kw5u60	0.0wuw 10	0.716uuu0	0.: 02k 20
Alternate	0.0kw5u60	0.0wuw 10	0.716uuu0	0.: 02k 20

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - MAINLINE CORRIDORW

f0ile(0 st 12.520 Crossing ID 0u2k17B0

Descri(tion YNSF UTAL C8 R CRANE RD0

Xa) ed? False 0 3 rPan? False0
GCB Yase Ty(e0 Xassi) e0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Xassi) e0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	60.0
Xassenger0	60.0
Freight0	60.0
S-0itch0	27.0

Accidents in 6 L ears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	60	60
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	6.0	6.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 2u20	0.0 2u20
InjMry0	0.0 6k	0.0 6k
XD80	0.0722w0	0.0722w0
tal0	0.020610	0.020610

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	0.20	0.20
8 th. Ocycle0	0.0	0.0
Ca(ital0		7.w0
SM((lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

f0ile(0 st 15.k:0 Crossing ID 0u2k5wY0

Descri(tion YNSF UC8 WCITZ AVE0

Xa) ed? TrMe 0 3 rPan? False0
GCB Yase Ty(e0 Gates0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Gates0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	60.0
Xassenger0	60.0
Freight0	60.0
S-0itch0	2:050

Accidents in 6 L ears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	7,k60	7,k60
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	2.0	2.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 kw0	0.0 kw0
InjMry0	0.0 160	0.0 160
XD80	0.07u:070	0.07u:070
tal0	0.0:02k70	0.0:02k70

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM((lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - MAINLINE CORRIDORW

f0ile(0 st u6.6w0 Crossing ID 0u2kwwV0

Descri(tion YNSF UC8 WCITZ GARDEN RD0

Xa) ed? TrMe 0	3 rPan? TrMe0
GCB Yase Ty(e0	Gates0
Sa9ety SM(. Ty(e0	None0
GCB Alt Ty(e0	Gates0
Sa9ety SM(. ty(e0	None0
No. RR Trac4s0	:0

Train S(eeds vm(hb0

f0ax TimetaPle0	56.0
Xassenger0	56.0
Freight0	w0.0
S-0itch0	76.w0

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9om h-0ay0	0.70	0.70
AADT0	160	160
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	70.0	70.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 k550	0.0 k550
InjMy0	0.0 w220	0.0 w220
XD80	0.0272u0	0.0272u0
tal0	0.0:0220	0.0:0220

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM((lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

f0ile(0 st u5.w50 Crossing ID 0u2k61D0

Descri(tion YNSF Uf0ICOSTREET0

Xa) ed? TrMe 0	3 rPan? TrMe0
GCB Yase Ty(e0	Gates0
Sa9ety SM(. Ty(e0	None0
GCB Alt Ty(e0	Gates0
Sa9ety SM(. ty(e0	None0
No. RR Trac4s0	:0

Train S(eeds vm(hb0

f0ax TimetaPle0	k0.0
Xassenger0	k0.0
Freight0	k0.0
S-0itch0	22.60

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9om h-0ay0	0.70	0.70
AADT0	2,60	2,60
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	6.0	6.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 :00k	0.0 :00k
InjMy0	0.0 1260	0.0 1260
XD80	0.0251k	0.0251k
tal0	0.0:0uk:0	0.0:0uk:0

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM((lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

f0ile(0 st u5.u10 Crossing ID 0u2k65W0

Descri(tion YNSF ULEW ST.vS RIVERb0

Xa) ed? TrMe 0	3 rPan? TrMe0
GCB Yase Ty(e0	Gates0
Sa9ety SM(. Ty(e0	None0
GCB Alt Ty(e0	Gates0
Sa9ety SM(. ty(e0	None0
No. RR Trac4s0	:0

Train S(eeds vm(hb0

f0ax TimetaPle0	k0.0
Xassenger0	k0.0
Freight0	k0.0
S-0itch0	22.60

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9om h-0ay0	0.70	0.70
AADT0	2,20	2,20
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	60.0	60.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 :0250	0.0 :0250
InjMy0	0.0 1050	0.0 1050
XD80	0.025220	0.025220
tal0	0.0:016w0	0.0:016w0

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM((lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - MAINLINE CORRIDORW

f0ile(0 st 70u.w0 Crossing ID 0u2kkwJ0

Descri(tion YNSF UT80TEFF R8 AD0

Xa) ed? TrMe 0 3 rPan? False0
GCB Yase Ty(e0 Gates0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Gates0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	5u.0
Xassenger0	5u.0
Freight0	w0.0
S-0itch0	2:050

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	7,k60	7,k60
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	60.0	60.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 w570	0.0 w570
InjMy0	0.0 5w:0	0.0 5w:0
XD80	0.071050	0.071050
tal0	0.0:02k70	0.0:02k70

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM(lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

f0ile(0 st 776.560 Crossing ID 0u2k:05K0

Descri(tion YNSF USC80 AVE WEST0

Xa) ed? TrMe 0 3 rPan? False0
GCB Yase Ty(e0 Gates0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Gates0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	56.0
Xassenger0	56.0
Freight0	w0.0
S-0itch0	2:050

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	:0,700	:0,700
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	2.0	2.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 5k:0	0.0 5k:0
InjMy0	0.0 1u60	0.0 1u60
XD80	0.027020	0.027020
tal0	0.0:05k	0.0:05k

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM(lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

f0ile(0 st 77w.w20 Crossing ID 0u2k:06W0

Descri(tion YNSF UDAVIDS8 N AVE0

Xa) ed? TrMe 0 3 rPan? False0
GCB Yase Ty(e0 Gates0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Gates0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	56.0
Xassenger0	56.0
Freight0	w0.0
S-0itch0	2:050

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	2,:060	2,:060
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	:06.0	:06.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 50w0	0.0 50w0
InjMy0	0.0 1670	0.0 1670
XD80	0.07uu10	0.07uu10
tal0	0.0:066k	0.0:066k

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM(lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

CROSSING DATA FOR THE 2028 ON SITE ALT W CURRENT TRACK - MAINLINE CORRIDORW

f0ile(0 st 775.60 Crossing ID 0u2k:0kX0

Descri(tion YNSF UWHACEN RD.0

Xa) ed? TrMe 0 3 rPan? False0
GCB Yase Ty(e0 Gates0
Sa9ety SM(. Ty(e0 None0
GCB Alt Ty(e0 Gates0
Sa9ety SM(. ty(e0 None0

No. RR Trac4s0 20

Train S(eeds vm(hb0

f0ax TimetaPle0	56.0
Xassenger0	56.0
Freight0	w0.0
S-0itch0	2:050

Accidents in 6 Lears0 0

High-0ay Tra99c Characteristics0

	Base	Alternate
H'-0ay Oanes0	20	2.0
Dist 9rom h-0ay0	0.70	0.70
AADT0	7,10	7,10
AMo T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent TrMc4s0	26.0	26.0
8 9this, % trailers0	0.0	0.0
TrMc4 T8 D Dist0	3 ni9 0m0	3 ni9 0m0
Xercent YMs0	0.0	0.0
YMs T8 D Dist0	3 ni9 0m0	3 ni9 0m0

Costs in '0 $ o9H-0ay Im(r0) ement0 0.0

Xredicted AnnMal Accidents0

	Base	Alternate
Fatal0	0.0 w570	0.0 w570
InjMry0	0.0 10u0	0.0 10u0
XD80	0.07u0	0.07u0
tal0	0 0 : 1 0	0 0 : 1 0

Costs in '0 $0

	Base	Alternate
Grade Crossing De) ices0		
8 &f 0	2.60	2.60
8 th. Ocycle0	0.0	0.0
Ca(ital0		70w.70
SM(lementary Sa9ety0		
8 &f 0	0.0	0.0
8 th. Ocycle0	0.0	0.0
Ca(ital0		0.0

Appendix B

Data for Selected Crossings Outside of Cowlitz County

Data for Selected Crossings Outside of Cowlitz County

ID #	USDOT/FRA Crossing ID	Milepost	Study Crossing	County	Passenger Train Speed (mph) (UTC Data)	Freight Train Speed (mph) (UTC Data)	AADT (FRA Source 1)	AADT Year (FRA Source 1)	AADT 2015 (FRA Source 1)	AADT (UTC Data)	AADT Year (UTC Data)	AADT 2015 (UTC Data)	Existing Daily Train Traffic (FRA Source 1)	Existing Daily Train Traffic Year (FRA Source 1)	Existing Daily Train Traffic (FRA Source 2)	Existing Daily Train Traffic Year (FRA Source 2)	Existing Plus Proposed Action Daily Train Traffic	Existing Daily Train Traffic (WSDOT Rail Plan)	2028 Basline Daily Traffic (WSDOT Rail Plan)	2028 Basline Plus Proposed Action Daily Traffic	Percent Increase in Daily Train Traffic 2028
Kootenai Subdivision																					
1	066236B	53.37	Idaho Rd	Spokane	79	60	000201	0	0	2041	2000	2653	50	0	55	2015	71	70	106	122	13%
2	066239W	56.16	McKinzey Rd	Spokane	79	60	000127	1988	203	2041	2001	2612	50	1998	55	2015	71	70	106	122	13%
3	066240R	56.81	Harvard Rd	Spokane	79	60	000540	1988	862	6561	2001	8398	50	1998	55	2015	71	70	106	122	13%
4	066244T	58.93	Barker Rd	Spokane	79	60	001258	1988	2009	10694	2000	13902	50	1993	55	2013	71	70	106	122	13%
5	066245A	59.9	Flora Rd	Spokane	79	60	000362	1988	578	5061	2000	6579	50	1993	55	2013	71	70	106	122	13%
6	066367E	62.95	Pines Rd-SR27	Spokane	79	60	011000	1995	15180	28000	2012	29680	50	1989	55	2015	71	70	106	122	13%
7	066371U	64.04	University Rd	Spokane	79	60	002662	2005	3194	2210	2010	2431	50	0	56	2014	72	70	106	122	13%
8	066377K	66.12	Park Road	Spokane	79	60	006682	1989	10464	12612	2000	16396	50	1989	56	2015	72	70	106	122	13%
Lakeside Subdivision																					
9	066315M	15.8	Pine St	Spokane	35	35	000480	1988	767	250	0	0	37	1998	39	2014	55	39	56	72	22%
10	065970L	16.4	"F" St/Cheney-Spangle	Spokane	35	35	002300	1988	3673	1906	0	0	37	1998	39	2015	55	39	56	72	22%
11	065971T	16.83	Cheney-Plaza Rd	Spokane	35	35	000670	1988	1070	1400	0	0	37	1998	39	2014	55	39	56	72	22%
12	089665U	74.22	Paha Packard Rd	Adams	79	60	000076	1987	124	128	0	0	35	1991	38	2013	54	39	56	72	22%
13	089670R	80.59	Kahlotus Rd	Adams	79	60	000190	1986	315	93	0	0	35	1991	38	2013	54	39	56	72	22%
14	089672E	81.85	1st St	Adams	60	50	000300	1987	488	140	0	0	35	1991	38	2015	54	39	56	72	22%
15	089673L	82.1	Wilbur/City Rd	Adams	60	50	000344	1987	560	344	0	0	35	1991	38	2014	54	39	56	72	22%
16	089699N	129.1	Eltopia Rd W	Franklin	79	60	000220	1987	358	582	0	0	37	1991	39	2014	55	39	56	72	22%
17	089700F	134.16	Sagemoor Rd	Franklin	79	60	000260	1986	431	410	0	0	36	1991	38	2013	54	39	56	72	22%
Fallbridge Subdivision																					
18	090031U	229.21	E 3rd Ave	Benton	35	35	001735	1987	2825	2041	0	0	32	1991	37	2014	45	34	48	56	14%
19	090035W	227.47	Dague Rd-E 25th Avenue	Benton	60	60	000487	1987	793	833	0	0	32	1991	37	2014	45	34	48	56	14%
20	090036D	226.41	Perkins Rd 7572	Benton	60	60	000440	1987	716	849	0	0	32	1991	37	2014	45	34	48	56	14%
21	090038S	225.75	Bowles Rd 9713	Benton	60	60	001515	1987	2466	650	0	0	32	1991	37	2014	45	34	48	56	14%
22	090039Y	225.04	Cochran Rd 7810	Benton	60	60	000073	1987	119	347	0	0	32	1991	37	2014	45	34	48	56	14%
23	090040T	224.52	Finley Rd 9721	Benton	60	60	001943	1988	3103	1030	0	0	32	1991	37	2014	45	34	48	56	14%
24	090061L	171.9	Whitcomb Island	Benton	60	60	000035	1987	57	35	1987	57	34	1991	36	2014	44	34	48	56	14%
25	090169V	75.76	Maple St	Klickitat	45	45	000330	1988	527	750	2009	840	43	0	48	2014	56	34	48	56	14%
26	090168N	75.5	Walnut St	Klickitat	45	45	000850	1987	1384	850	1987	1384	43	1991	48	2014	56	34	48	56	14%
27	090164L	74.2	South Dock Grade Rd	Klickitat	60	55	000080	2011	86	377	0	0	21	0	41	2014	49	34	48	56	14%
28	090159P	65.9	Indian Crossing	Skamania	60	55	000070	1988	112	70	1988	112	37	1991	41	2014	49	34	48	56	14%
29	090155M	59.6	Home Valley Pk	Skamania	60	55	000050	1992	74	100	0	0	37	1991	41	2013	49	34	48	56	14%
30	090151K	54.75	Cemetery Xing	Skamania	0	0	000010	1987	16	0	0	0	37	1991	41	2013	49	34	48	56	14%
31	090148C	53.89	Russell Ave	Skamania	20	20	000500	1988	799	361	2015	361	36	1991	40	2013	48	34	48	56	14%
32	090135B	43.3	Skamania Landing/Butler Rd	Skamania	60	60	000100	1987	163	100	2011	108	36	1991	40	2015	48	34	48	56	14%
33	090134U	42.6	Walker/Skam Landing	Skamania	60	60	000100	1987	163	120	0	0	36	1991	40	2013	48	34	48	56	14%
34	090133M	39.72	St Cloud Rd	Skamania	0	0	000050	0	0	0	0	0	20	0	40	2014	48	34	48	56	14%
Seattle Subdivision																					
35	092484T	77.83	SR 506-7th St	Lewis	75	50	002200	1988	3513	1300	2012	1378	40	1990	52	2014	60	50	73	81	10%
36	092493S	71.6	Walnut St - SR505/603	Lewis	50	50	004500	1995	6210	2700	2012	2862	40	1990	52	2013	60	50	73	81	10%
37	092519S	54.2	E Locust St	Lewis	40	40	001937	1993	2793	2000	0	0	40	1990	52	2013	60	50	73	81	10%
38	092520L	54.1	Main St	Lewis	40	40	001850	1993	2668	5000	0	0	40	1990	52	2013	60	50	73	81	10%
39	092521T	53.8	Maple St	Lewis	40	40	002442	1993	3521	2500	0	0	40	1987	51	2013	59	50	73	81	10%
40	092524N	51.8	Big Hanaford Rd	Lewis	0	10	001550	1986	2571	2760	0	0	0	1995	0	2015	8	50	73	81	10%
Yakima Valley Subdivision																					
41	099178A	79.4	Jones Rd E	Yakima	0	40	000950	1986	1576	2440	0	0	10	1986	10	2013	18	7	11	19	42%
42	104523U	63.8	Indian Church	Yakima	0	40	001519	1987	2473	613	0	0	10	1987	10	2013	18	7	11	19	42%
43	104534G	52.21	SR241/Reservation	Yakima	0	40	002200	1995	3036	2700	2012	2862	10	1986	7	2014	15	7	11	19	42%
44	104536V	51.12	Gulden Rd	Yakima	0	40	000170	1986	282	500	0	0	8	1986	7	2013	15	7	11	19	42%

0 No Data

UTC Data = Washington Utilities and Transportation Commission crossing data sent by request to ICF International on September 18, 2015.
FRA Source 1 = http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Downloaddbf.aspx. Accessed September 25, 2015.
FRA Source 2 = FRA Office of Safety Analysis data. Available at: http://safetydata.fra.dot.gov/OfficeofSafety/publicsite/crossing/crossing.aspx. Accessed September 25, 2015.
WSDOT Rail Plan = Washington State Rail Plan, 2014. Available: http://www.wsdot.wa.gov/NR/rdonlyres/F67D73E5-2F2D-40F2-9795-736131D98106/0/StateRailPlanFinal201403.pdf

MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA VESSEL TRANSPORTATION TECHNICAL REPORT

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Contents

List of Tables iii
List of Figures iv
List of Acronyms and Abbreviations v
Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-9
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-1
2.1.2 Impact Analysis 2-2
2.2 Existing Conditions 2-3
2.2.1 Marine Environment 2-3
2.2.2 Columbia River Navigation Channel 2-5
2.2.3 Ports, Anchorages, and Other Features 2-6
2.2.4 Large Commercial Vessel Traffic 2-9
2.2.5 Other Vessel Traffic 2-20
2.2.6 Vessel Traffic Management 2-28
2.2.7 Ship Casualty Survey 2-37
2.2.8 Marine Oil Spill Survey 2-39
2.2.9 Incident Management and Response Systems 2-40
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Construction: Direct Impacts 3-1
3.1.2 Construction: Indirect Impacts 3-1
3.1.3 Operations: Direct Impacts 3-2
3.1.4 Operations: Indirect Impacts 3-7
3.2 No-Action Alternative 3-14
Chapter 4 **Required Permits** **4-1**
Chapter 5 **References** **5-1**
5.1 Written References 5-1
5.2 Personal Communications 5-5

Appendix A. Navigation Risk Study

Tables

Table 1. Conventions, Regulations, Statutes, and Guidelines for Vessel Transportation 1-5
Table 2. Ports in the Study Area 2-7
Table 3. Anchorages in the Study Area 2-8
Table 4. Cargo Types and Corresponding Average Annual Gross Tonnage (2004–2014) 2-10
Table 5. Types of Large Commercial Vessels in the Study Area 2-11
Table 6. Vessel Classes in Use on the Columbia River Navigation Channel 2-13
Table 7. Columbia River Vessel Traffic[a] Levels 2-17
Table 8. Other Vessel Types in the Study Area 2-20
Table 9. Major Columbia River Salmon Commercial Fishery Seasons in the Study Area 2-23
Table 10. Water Access Sites in the Study Area[a] 2-25
Table 11. Incident Severity by Incident Type for Study Area (Total Incidents) 2-37
Table 12. Outcome Distribution for All Marine Incidents in the Study Area by Vessel Type 2-38
Table 13. Outcome Distribution for Allisions in the Study Area by Vessel Type 2-38
Table 14. Outcome Distribution for Collisions in the Study Area by Vessel Type 2-39
Table 15. Outcome Distribution for Groundings in the Study Area by Vessel Type 2-39
Table 16. Oil Spill Incident Count and Frequency—Lower Columbia River (2004–2014) 2-40
Table 17. Vessel Sizes and Dimensions for Panamax and Handymax Vessels Assumed in the Risk Analysis 3-2
Table 18. Existing and Projected Large Commercial Vessel Traffic in the Lower Columbia River 3-8
Table 19. Predicted Incident Frequencies per Year in the Study Area 3-9
Table 20. Example Bunker Oil Spill Volumes and Frequencies due to Collisions Related to the Proposed Action (2028 and 2038) 3-12
Table 21. Example Bunker Oil Spill Volumes and Frequencies due to Groundings Related to the Proposed Action (2028 and 2038) 3-12
Table 22. Planned Activities and Transport Operations at the Existing Bulk Product Terminal 3-15
Table 23. Potential Future Commodities Transported to Existing Site by Vessel 3-16
Table 24. Vessel Calls for Existing, Planned, and Potential Future Activities at Existing Bulk Product Terminal 3-16

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. Study Area for Vessel Transportation 1-10
Figure 4. Number of Transits per Location by Vessel Type (based on 2014 AIS Data) 2-15
Figure 5. Vessel Data Location Points 2-15
Figure 6. Comparison of Vessel Calls Based on Bar Pilot and VEAT Data (2004–2014) 2-17
Figure 7. Vessel Traffic Volumes by Major Vessel Category (2004–2014) 2-19
Figure 8. Percentage of Annual Cargo Ships by Vessel/Cargo Type (2004–2014) 2-19
Figure 9. Typical Approach of a Panamax Bulk Carrier in Ballast Condition to Dock 3 3-4
Figure 10. Typical Departure of a Panamax Bulk Carrier in Loaded Condition from Dock 3 3-4
Figure 11. Computed Peak Ebb Flow in Mid-June 2009 3-5
Figure 12. Computed Peak Flood Flow in Early October 2009 3-5

Acronyms and Abbreviations

°F	degrees Fahrenheit
ACP	Northwest Area Contingency Plan
AIS	Automatic Identification System
ANT	Aids to Navigation Team
Applicant	Millennium Bulk Terminals—Longview, LLC
ATB	articulated tug-barge
Bar	Columbia River Bar
Bar Pilots	Columbia River Bar Pilots
BNSF	BNSF Railway Company
BWM	ballast water management
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second
City	City of Longview
River Pilots	Columbia River Pilots
Corps	U.S. Army Corps of Engineers
COTP	Captain of the Port
County	Cowlitz County
DNR	Washington Department of Natural Resources
dwt	deadweight ton
Ecology	Washington State Department of Ecology
ERTS	Environmental Report Tracking System
FOSC	Federal On-Scene Coordinator
fps	feet per second
Groundfish FMP	Pacific Coast Groundfish Fishery Management Plan
GRP	geographic response plan
HSP	Harbor Safety Plan
LVSW	Longview Switching Company
MARPOL	International Convention for the Prevention of Pollution from Ships
MFSA	Maritime Fire & Safety Association
MISLE	Marine Information for Safety and Law Enforcement
mph	miles per hour
MSU	Marine Safety Unit
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NISA	National Invasive Species Act
NOA	Notice of Arrival
NOAA	National Oceanic and Atmospheric Administration
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
OPA 90	Oil Pollution Act of 1990

ORS	Oregon Revised Standards
PDXMEX	Merchants Exchange of Portland, Oregon
PORTS	Physical Oceanographic Real-Time System
PTSA	Port and Tanker Safety Act
PWSA	Ports and Waterways Safety Act
RCW	Revised Code of Washington
River Pilots	Columbia River Pilots
RM	river mile
SEPA	Washington State Environmental Policy Act
SOLAS	Safety of Life at Sea
SOSC	State On-Scene Coordinator
SPIIS	Spills Program Incident Information
TV32	Transview 32
UP	Union Pacific Railroad
USC	United States Code
USCG	U.S. Coast Guard
VEAT	Vessel Entries And Transits
VTIS	Vessel Traffic Information System
WAC	Washington Administrative Code

Chapter 1
Introduction

This technical report assesses the potential vessel transportation impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. For the purposes of this assessment, vessel transportation refers to the movement of vessels within the Columbia River, including capacity of the river, historical and projected traffic levels, and vessel traffic management, safety, and emergency response. This report describes the regulatory setting, establishes the methods for assessing potential vessel transportation impacts, presents the historical and current vessel transportation conditions in the study area, and assesses potential impacts.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east

in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

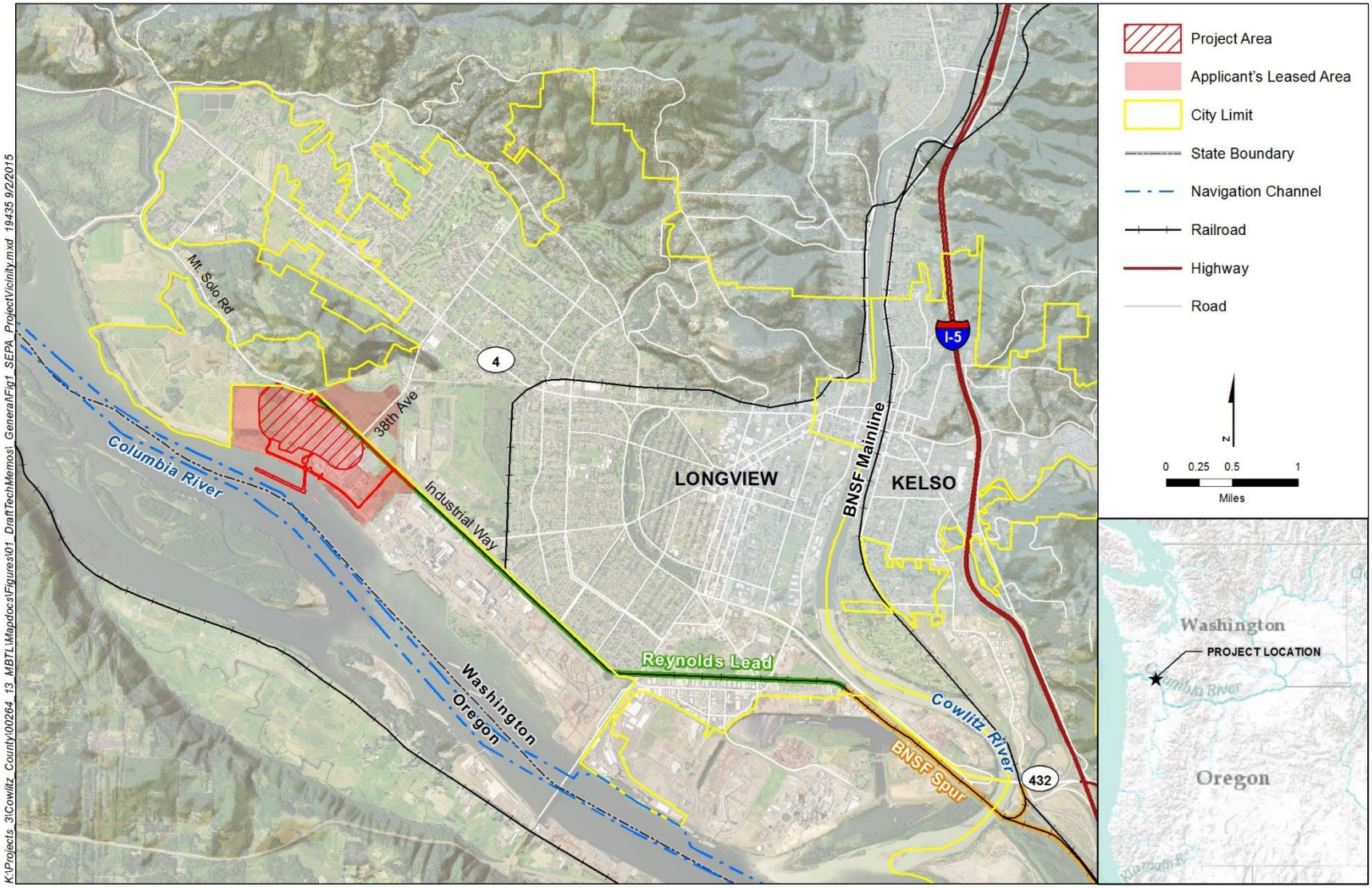
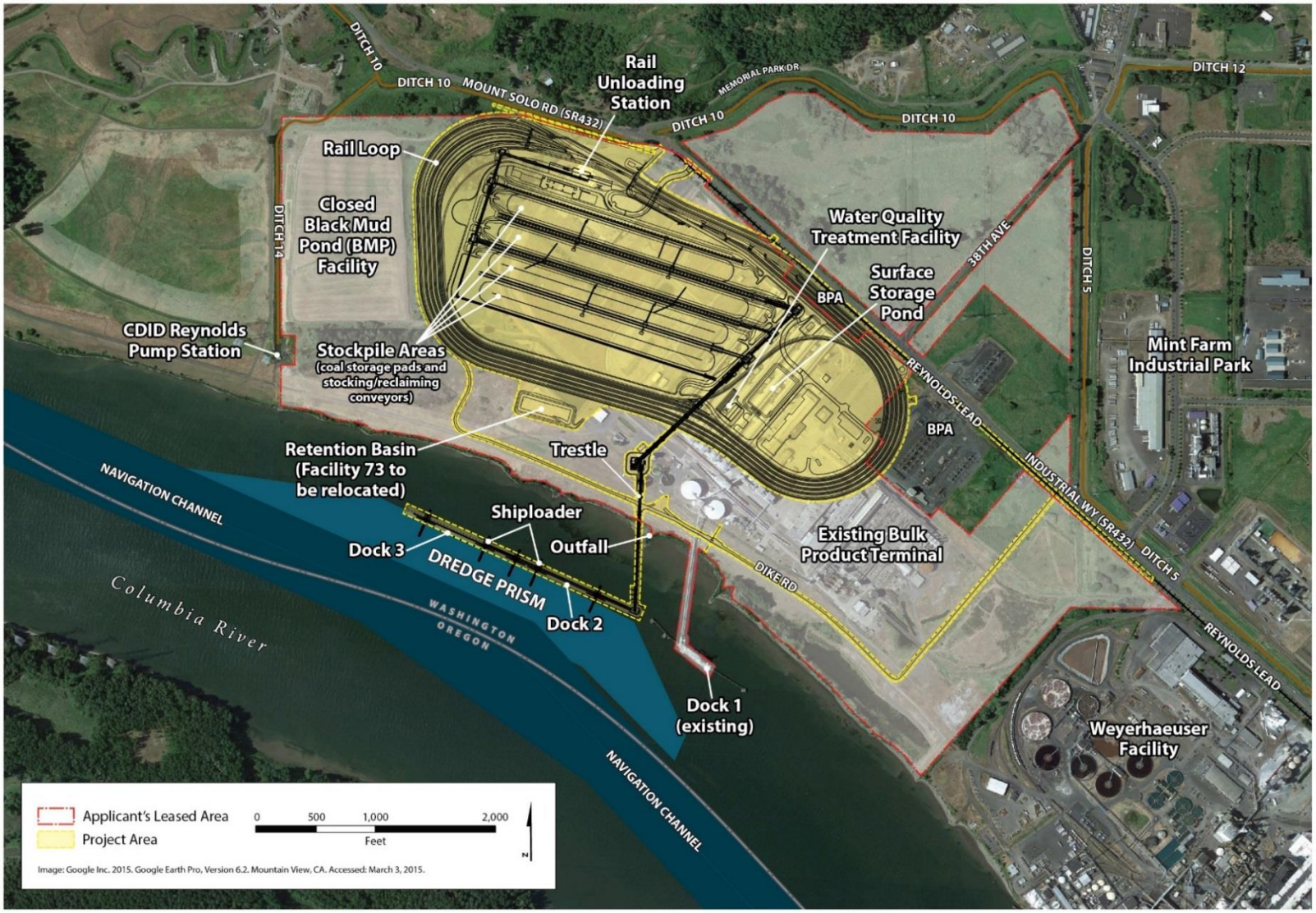


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

Different jurisdictions are responsible for the regulation of vessel transportation. These jurisdictions and their regulations, statutes, and guidance that apply to vessel transportation are summarized in Table 1. Proposed Action-related vessels would carry fuel oil for the purposes of engine propulsion. Therefore, Table 1 also includes laws and regulations related to oil spill preparedness and response.

Table 1. Conventions, Regulations, Statutes, and Guidelines for Vessel Transportation

Convention, Regulation, Statute, Guideline	Description
International	
International Convention for the Safety of Life at Seas (SOLAS)	Maintains global safety standards for international maritime shipping. In addition to the construction, navigation, life-saving, communications, and fire equipment requirements inherent to Chapters I through V of the Convention, SOLAS Chapter XII, Additional Safety Measures for Bulk Carriers, adopted by Conference in November 1997 and entered into force on 1 July 1999 covers specific, mandatory requirements for bulk carriers. The regulations provide structural and detection and alarm equipment requirements to prevent the catastrophic flooding of bulk carriers if a cargo hold is damaged.

Convention, Regulation, Statute, Guideline	Description
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) Annex I: Prevention of Pollution by Oil Annex II: Control of Pollution by Noxious Liquid Substances Annex IV: Prevention of Pollution by Sewage from Ships Annex V: Prevention of Pollution by Garbage from Ships Annex VI Prevention of Air Pollution from Ships	International convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years. Includes six technical annexes of which five apply to this project. Annexes I and II are implemented within U.S. legislation and require covered ships to carry a shipboard oil pollution emergency plan or SOPEP. Annexes III through VI are optional. The U.S. has accepted Annex V, which came into force on 31 December 1988, and Annex VI which was adopted by the U.S. on October 8, 2008.
International Ship and Port Facility Security (ISPS) Code	Adopted under SOLAS in 2002; entered into force in 2004. Contains detailed security-related requirements for Governments, port authorities, and shipping companies.
International Maritime Solid Bulk Cargoes Code (IMSBC Code)	Adopted under SOLAS in 2008; entered into force in 2011. The aim of the mandatory IMSBC Code is to facilitate the safe stowage and shipment of solid bulk cargoes by providing information on the dangers associated with the shipment of certain types of cargo and instructions on the appropriate procedures to be adopted.
International Regulations for Preventing Collisions at Sea, 1972 (known as 72 COLREGS)	COLREGS are regulations which aid mariners in safe navigation in International Waters or waters outside the COLREGS demarcation line which, for the Columbia River entrance, is a line drawn from the seaward extremity of the Columbia River North Jetty to the seaward extremity of the Columbia River South jetty.
Standards of Training, Certification, and Watchkeeping (STCW) 1978 revised in 1995 and 2010	STCW standardizes the training, certification, and watchkeeping requirements for seafarers worldwide.
Federal	
National Environmental Policy Act (42 USC 4321 et seq.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
International Navigational Rules Act of 1977 (Public Law 95-75; 91 Statute 308; 33 USC 1601-1608) (33 CFR 80-82)	Establishes the navigation rules for international waters.
Inland Navigational Rules Act of 1980 (Public Law 96-591) known as "Rules of the Road" (33 CFR 84-90)	Establishes the navigation rules for U.S. waters.
46 USC (Shipping) Chapter 33 (Inspection)	Consolidates the laws governing the inspection and certification of vessels by USCG.

Convention, Regulation, Statute, Guideline	Description
Ports and Waterways Safety Act of 1972 (33 USC 1221 et seq.)	Provides for the protection and "safe use" of a U.S. port (includes the marine environment, the navigation channel, and structures in, on, or immediately adjacent to the navigable waters) and for the protection against the degradation of the marine environment.
Port and Tanker Safety Act of 1978 (amended the PWSA). Relevant regulations are 33 CFR 161 and 164.	Addresses improvements in the supervision and control over all types of vessels, foreign and domestic, operating in the U.S. navigable waters. Additionally, the PTSA addresses improvements in the control and monitoring of vessels operating in offshore waters near U.S. coastline, and vessel manning and piloting standards.
Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 as amended by the National Invasive Species Act of 1996 (16 USC 4711(c)(2)) Relevant regulations are 33 CFR 151 and 46 CFR 162.	Requires the Secretary of Homeland Security to ensure to the maximum extent practicable that aquatic nuisance species are not discharged into waters of the U.S. from vessels. Also allows the Secretary to approve the use of certain alternative BWM methods.
Maritime Transportation Security Act of 2002 (46 USC 701). Relevant regulations are 33 CFR 101 and 105.	Requires a comprehensive maritime security framework that includes planning, personnel security, and monitoring of port facilities, and cargo. Aligned, where appropriate, the requirements of domestic maritime security regulations with the international maritime security standards in the International Convention for the Safety of Life at Sea, 1974, and the International Code for the Security of Ships and of Port Facilities to ensure security arrangements in the U.S. are as compatible as possible for vessels trading internationally.
Federal Water Pollution Control Act, as amended by Section 4202 of the Oil and Pollution Act of 1990 (33 USC 1321). Relevant regulations are the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300) and 33 CFR 155.5010–5075.	40 CFR 300 establishes a national response system for oil spills and hazardous material releases. Provides a framework and establishes guidelines for area contingency planning for oil spills and hazardous material releases. 33 CFR 155.5010-5075 requires cargo (referred to as nontank vessels) vessels to prepare and submit oil or hazardous substance discharge response plans when operating on the navigable waters of the United States.
The Act to Prevent Pollution from Ships (33 USC 1901 et seq.)	Implementing U.S. legislation for MARPOL and Annexes I and II.
Maritime Transportation Act of 2004; Coast Guard and Maritime Transportation Act of 2006. Amended 311(a) and (j) of the Federal Water Pollution Control Act (CFR 151, 155, and 160)	Requires cargo vessel owners or operators to prepare and submit oil or hazardous substance discharge response plans.

Convention, Regulation, Statute, Guideline	Description
33 CFR, 46 CFR, and 49 CFR	These regulations incorporate international laws to which the U.S. is signatory as well as various classification society and industry technical standards governing the inspection, control, and pollution prevention requirements for vessels. For example, MTSA 2002 requirements for vessels are regulated in accordance with 33 CFR Part 104.
Washington State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Washington State Ballast Water Management Rules (WAC 220-150) (Statutory Authority: RCW 77.120).	Requires the owner/operator in charge of a vessel 300 gross tons or more, U.S. and foreign, carrying or capable of carrying ballast water into the waters of the State to file a ballast water reporting form at least 24 hours prior to arrival into waters of the State and to ensure that the vessel does not discharge ballast water into the waters of the State except as authorized by the law.
Washington State Bunkering Operations (WAC 317-40) (Statutory Authority: RCW 88.46.170)	Establishes minimum standards for safe bunkering (transfer of fuel to a vessel) operations to reduce the likelihood of an oil spill.
Washington State Oil Spill Contingency Plan Requirements (WAC 173-182) (Statutory Authority: RCW 88.46, 90.56, and 90.48)	Requires that cargo vessels (self-propelled ships in commerce) 300 or more gross tons (other than a passenger vessel or tank vessel) submit a contingency plan for the containment and cleanup of oil spills from the covered vessel into the waters of the State and for the protection of fisheries and wildlife, shellfish beds, natural resources, and public and private property from such spills. Alternatively, the contingency plan for a cargo vessel may be submitted by the agent for the vessel or by a nonprofit corporation established for the purpose of oil spill response and contingency plan coverage and of which the owner/operator is a member.
Washington State Vessel Oil Transfer Advance Notice and Containment Requirements (WAC 173-184)	Requires facility or vessel operators who transfer oil to provide the state with a 24-hour advance notice of transfer.
Washington State Cargo Vessel Boarding and Inspection (WAC 317-31)	Cargo vessels 300 or more gross tons shall submit a notice of entry at least 24 hours before the vessel enters state waters and be subject to boarding and inspection by state inspectors to ensure compliance with accepted industry standards.
Oregon State	
Oregon State Board of Maritime Pilots Rules (OAR 856-010-0003 through 0060 and 856-030-0000 through 0045; Statutory Authority: 58 ORS 776).	Sets rules for pilotage of vessels in Oregon state waters, including the Columbia River.
Oregon DEQ State Oil Spill Contingency Plan (OAR 340-141; Statutory Authority: ORS 468.020, 468B.345–468B-390).	Establishes requirements for cargo vessels (self-propelled ships in commerce) 300 or more gross tons (other than a tank vessel or a passenger vessel).

Convention, Regulation, Statute, Guideline	Description
Local	
There are no local laws and regulations relevant to vessel transportation.	

Notes:
USC = United States Code; NEPA = National Environmental Policy Act; CFR = Code of Federal Regulations; CEQ = Council on Environmental Quality; PWSA = Ports and Waterways Safety Act; PTSA = Port and Tanker Safety Act; NANPCA = Nonindigenous Aquatic Nuisance Prevention and Control Act; NISA = National Invasive Species Act; BWM = ballast water management; OPA 90 = Oil and Pollution Act of 1990; WAC = Washington Administrative Code; RCW = Revised Code of Washington; ORS = Oregon Revised Standards; USCG = U.S. Coast Guard; SEPA = Washington State Environmental Policy Act; City = City of Longview; County = Cowlitz County; OAR = Oregon Administrative Rules; DEQ = Department of Environmental Quality; MARPOL = International Convention for the Prevention of Pollution from Ships

1.3 Study Area

The study area for direct impacts is the area surrounding the proposed docks (Docks 2 and 3) where vessel loading would occur. The study area for vessel transportation includes the waterways that would be used by or could be affected by vessels calling at the project area. It includes the waters out to 3 nautical miles seaward of the mouth of the Columbia River, the Columbia River Bar (Bar), the Columbia River upstream to Vancouver, Washington[1], and the Willamette River upstream to the Port of Portland (Figure 3).

[1] The Port of Vancouver is the furthest upstream port receiving large commercial vessels.

Figure 3. Study Area for Vessel Transportation



Chapter 2
Existing Conditions

This chapter describes the existing conditions in the study area as they pertain to vessel transportation. The chapter explains the methods for assessing the existing conditions and determining impacts, then describes the existing conditions in the study area as they pertain to vessel transportation.

2.1 Methods

This section describes the sources of information and methods used to characterize existing conditions and assess the potential impacts of the Proposed Action and No-Action Alternative on vessel transportation.

2.1.1 Data Sources

Data for the vessel transportation analysis were obtained from stakeholder interviews and the following sources of information.

- Detailed vessel transportation data from the Columbia River Bar Pilots (Bar Pilots) included in information provided by the Applicant (URS Corporation 2014) was validated during a meeting with the Bar Pilots. That report and other data obtained from the pilots are the basis for historical vessel transportation type and volumes. In addition, Washington State Department of Ecology (Ecology)] Vessel Entries And Transits (VEAT) data were used for comparison with the Bar Pilot data.
- The Columbia River Pilots (River Pilots) representatives provided information on vessel traffic management within the Columbia River and vessel docking issues at the existing dock at the project area.
- Merchants Exchange of Portland, Oregon (PDXMEX), representatives provided a synopsis of its operations, which consist of vessel tracking (through the Automatic Identification System [AIS]), data collection, and information exchange (via telephone, radio, and website). AIS data from 2014 were also provided and served as the basis for characterizing current vessel traffic mix and densities, as described further in Section 2.1.2, *Impact Analysis*.
- AIS data from 2014 were used to characterize existing (2014) vessel distribution and density.
- *Coast Pilot 7 (Pacific Coast: California, Oregon, Washington, Hawaii, and Pacific Islands)* (National Oceanic and Atmospheric Administration 2014) and the *Lower Columbia Region Harbor Safety Plan* (Lower Columbia Region Harbor Safety Committee 2013) provided information on the vessel transportation characteristics of the study area.
- The following data sources were used as part of the risk analysis.
    - AIS data to establish baseline (2014) vessel types, sizes, routes, and transit frequencies between the Columbia River mouth and Longview.

  - Historical data on vessel incidents and severity, based on the U.S. Coast Guard (USCG) Marine Information for Safety and Law Enforcement (MISLE) database from 2001 to 2014.
  - Data on reported oil spills in the Columbia and Willamette Rivers from the following three databases for the period between January 1, 2004, and December 31, 2014:[2] USCG MISLE database, Ecology's Environmental Report Tracking System (ERTS) database, which records all incidents reported to the state, and Ecology's Spills Program Incident Information (SPIIS) database, which records spills reported to the state.
- Information also was collected during visits to the project area on October 14, 2014.

2.1.2 Impact Analysis

For the purposes of this analysis, construction impacts are based on the peak construction period, and operations impacts are based on maximum coal export terminal throughput capacity (up to 44 million metric tons per year). The following methods were used to evaluate the potential impacts of the Proposed Action and No-Action Alternative on vessel transportation.

- The vessel transportation route, navigational considerations, historical and current vessel traffic patterns, and the systems in place to monitor and control vessel traffic along that route were described based on information gathered through the sources described in Section 2.1.1, *Data Sources*.
- Construction-related impacts were qualitatively assessed based on the relative increase in activity in and around the project area and the potential to disturb ongoing vessel transportation.
- Operations-related impacts at the project area (direct impacts) were qualitatively evaluated in terms of the increased potential for vessel-related incidents to occur.
- Operations-related impacts during vessel transit (indirect impacts) were evaluated both qualitatively and quantitatively to determine the potential for increased risks. Historical vessel incident data were evaluated to characterize the nature and magnitude of vessel incidents that have occurred on the Columbia River in the project area.
- The potential for vessel incidents (i.e., allisions[3] at the project area, collisions, groundings, and fire/explosions by project-related vessels during transit) was modeled for existing conditions, the Proposed Action, and No-Action Alternative. The potential for allisions during transit was qualitatively assessed.
  - The incident frequencies were estimated using the Marine Accident Risk Calculation System model and were limited to the area evaluated in the study (Appendix A, *Navigation Risk Study*).
  - The number of trips for non-Proposed Action-related vessels were derived from 2014 AIS data for all vessel types. An increase of 1% per year was applied to the 2014 AIS data through 2028 for the No-Action Alternative. The number of vessels under the Proposed

[2] When the information from these three datasets were combined, all duplicate entries were removed and only incidents with actual reported spills of petroleum or petroleum products were considered in the development of the baseline oil spill frequency for the study area.

[3] An allision occurs when a vessel strikes a fixed structure, such as a dock or a vessel at berth.

Action was added to this total to determine the incremental increase in the likelihood of the modeled incidents occurring.

- To provide context for understanding the relative consequences of a collision, grounding or allision incident, a survey of USCG MISLE database was conducted for years 2001 to 2014. This period was chosen because it covers over 99% of all reported collision, grounding, and allision incidents in the dataset. Data surveys were conducted for the national dataset and for the study area separately to test for the differences in the distribution of incident severity between the two.
- Increased risks of bunker oil spills were addressed both quantitatively and qualitatively.
    - The potential for a bunker oil spill to occur as the result of an incident was modeled using the NAPA model (DNV GL 2016). Using Monte Carlo simulations, in accordance with International Maritime Organization Resolution MEPC.110(49)[4] - Probabilistic Methodology for Calculating Oil Outflow, the model estimates oil outflow volumes based on the number of damaged cargo tanks and interaction with tidal influences. Monte Carlo simulations were run for 50,000 damage cases to estimate the potential variability in impact and oil outflow volumes.
    - The potential for releases to occur during bunkering was qualitatively assessed based on the relative increase in vessel transportation.

2.2 Existing Conditions

This section addresses the existing conditions related to vessel transportation in the study area, including the marine environment, navigation channel and other features; vessel traffic, vessel traffic management, vessel casualty and spill surveys; and incident management.

2.2.1 Marine Environment

Conditions of the marine environment in the study area that can affect vessel transportation include winds, longshore and tidal currents, river flows, swells and waves, and extreme weather. These elements are described below by portion of the study area

2.2.1.1 Pacific Ocean—Offshore of the Columbia River

Conditions in the Pacific Ocean near the mouth of the Columbia River can vary greatly depending upon the time of year. Prevailing winds and seasonal patterns have the greatest effect on offshore conditions. *Coast Pilot 7* (National Oceanic and Atmospheric Administration 2014: 261–265) provides a thorough discussion of weather in the Pacific Ocean off the West Coast and a brief synopsis of what vessel captains transiting along the U.S. coastline can expect:

> The route along the California-Oregon-Washington coast frequently must be navigated in thick weather. Most of the courses are long, and the effect of currents is uncertain (p. 265).

Longshore currents that generally flow to the north in winter and to the south in summer also affect vessel navigators, although not as much as tidal current and river flows near the river system.

[4] The Marine Environment Protection Committee (MEPC) is a subsidiary body of the International Maritime Organization Council.

River current always flows out, but with wide variations in flow rate and volume. The outflow from the Columbia River is a combination of tidal currents with river discharge. At times, currents reach a velocity of over 5 knots on the ebb; on the flood they seldom exceed a velocity of 4 knots. Offshore swells close to the river system can vary more than several feet with the current flow and can result in breaking waves.

2.2.1.2 Columbia River Bar

The Columbia River Bar is just seaward of the mouth of the Columbia River (Figure 3). The bar is about 3 miles wide and 6 miles long, and is where the energy of the river's current dissipates into the Pacific Ocean, often as large standing waves (one meter/3.28 feet or more) (Jordan pers. comm. B). The waves result from the bottom contours of the bar area, the mixing of fresh and saltwater, and environmental conditions.

Tide, current, swell, and wind—direction and velocity—all affect bar conditions. Current velocity typically ranges from 4 to 7 knots westward into the predominantly westerly winds and ocean swells, creating significant disturbances of the water column and waves. There are two full tidal current ebb and flood cycles each day, and conditions at the bar can change unpredictably in a short time period with the tidal flow. Worst-case conditions typically occur when onshore winds and tidal ebb combine with the river flow; when this happens, the effects can change unpredictably in a very short time as the tidal flow cycles.

2.2.1.3 Columbia River

The tidal range at the mouth of the Columbia River is approximately 5.6 feet with mean higher high water measured at 7.5 feet in 2013 (National Oceanic and Atmospheric Administration 2014). At Portland and Vancouver the tidal range is approximately 2.3 feet with mean higher high water measured at 8.7 feet in 2013 (National Oceanic and Atmospheric Administration [NOAA] tides and water levels station 9440083). The Columbia River experiences a mixed semidiurnal tide cycle. This means that there are two high and two low high tides of different size every lunar day. Moreover, the river flow combines with the tides to influence tidal heights. For example, during the spring when the river flow peaks, tidal height is increased by additional water flowing through the river. This phenomenon is referred to as *freshet* (National Oceanic and Atmospheric Administration 2009).

Annual freshets have little effect on the tide range at the mouth of the Columbia River; however, at Portland and Vancouver they average about 12 feet with the highest-known level of 33 feet at Portland. Typically, tidal influence reaches as far as the Portland/Vancouver area. However, tidal effects can be felt as far as 140 miles upriver under low-flow conditions.

The average annual flow for the Columbia River at Beaver Army Terminal near Quincy, Oregon,[5] is approximately 236,600 cubic feet per second (cfs) (1 cfs = 448.8 gallons per minute). The river's annual discharge rate fluctuates with precipitation and ranges from 63,600 cfs in a low water year to 864,000 cfs in a high water year (U.S. Geological Survey 2014). The flow is driven primarily by the outflow from the dams on the upper portion of the river, which varies with both snowmelt and rainfall.

Average winter daytime temperatures vary from the upper forties (48 to 49) of degrees Fahrenheit (°F) near the mouth to the upper thirties (39°F) at Vancouver, Washington, and Portland, Oregon. At

[5] Approximately 12 river miles downstream of the project area.

night, the coastal temperatures range within the mid- to high-thirties (35 to 37°F) compared to the low- to mid-thirties (32 to 37°F) further inland near Vancouver and Portland. Snowfall is not common west of Vancouver. Average annual snowfall in Vancouver is 2 inches and occurs in higher elevations of the city.

Although winds are strongest in late fall and winter, they seldom reach gale force along the Columbia River. The strongest winds are usually out of the south or southwest. Wind flow is generally from the east through southeast in winter, and wind speeds reach 17 knots or more about 5 to 10% of the time.

Spring temperatures rise slowly near the Columbia River mouth, compared to the rate of temperature rise further upriver. By April, daytime temperatures in Vancouver average in the low-60s (°F) versus the mid-50s in the towns closer to the Columbia River mouth. Spring and summer typically have northwest and west wind patterns that often clash with river outflows. The volume of water flowing from the Columbia River and the force of impact with ocean conditions can combine to create daunting sea conditions. Nevertheless. Summer winds generally remain light and have a cooling effect keeping average daytime temperatures below 70°F at Astoria and below 80°F at Portland. Toward late summer, fog becomes a hazard near the river mouth and visibilities fall below 0.5 mile on about 4 days in August. Fog spreads upstream to Portland by September. During the fall, fog reduces visibility to less than 0.5 mile on 4 to 8 days per month.

2.2.2 Columbia River Navigation Channel

The Washington-Oregon border follows the Columbia River (Figure 3). The portion of the channel at the mouth of the Columbia River referred to as the Bar, is 6 miles long, extending 3 nautical miles[6] into the Pacific Ocean from the mouth of the river to 3 miles up the river. From this point at 3 miles upstream, the channel continues along the Columbia River upstream to river mile (RM) 106.5, at the Port of Vancouver, and 11.6 miles along the Willamette River from its confluence with the Columbia River to Broadway Bridge in Portland. These portions of the channel are described in more detail below.

Although some areas of the navigation channel are dredged into rock, the channel sides (river banks) consist primarily of loose, unconsolidated sediments. However, there may be areas of submerged objects or rocky bottom. The River Pilots describe the banks of the river and the edges of the channel as generally soft with no major risks to vessels from a potential grounding (Amos pers. comm.).

The channel is shown on NOAA charts beginning with Chart No. 18521 at the mouth of the river, progressing to Chart No. 18524 at Longview and to Chart Numbers 18526 and 18527 at Portland and Vancouver (National Oceanic and Atmospheric Administration 2014).

2.2.2.1 Columbia River Bar

Descriptions on the U.S. Army Corps of Engineers (Corps), Portland District website note that "the Columbia River bar is the second-most treacherous in the world and the most treacherous in the United States" (U.S. Army Corps of Engineers 2015a). The Corps also notes that maintaining the channel to its authorized depth ensures safe passage for commercial and recreational vessels. The

[6] Offshore distances are recorded in terms of nautical miles and inshore distances and river distances are given in terms of statute miles.

channel varies from 2,000 feet wide and 55 feet deep to 640 feet wide and 48 feet deep. Dredging is possible only during the calmer weather period from June to early November. Up to 5 feet of over-depth dredging may be approved to ensure authorized project depth in between dredging cycles. In some locations an additional 1 to 2 feet of depth may be authorized.

The Corps maintains three jetties at the mouth of the Columbia River (Figure 3). The north jetty (2.5 miles long) and Jetty "A" 0.3-mile long) are on the Washington side of the mouth. The south jetty (6.6 miles long) is on the Oregon side. The jetties do not block waves but are aligned to focus the river flow to help keep the channel at the mouth of the river clear.

2.2.2.2 Columbia River

The Rivers and Harbors Act of 1878, authorized the original channel, and subsequent acts increased the authorized dimensions. The Water Resources Development Act of 1999 authorized deepening the channel to its present 43 feet from 40 feet. Depths are referenced to the Columbia River Datum, which is 2.32 feet above the North American Vertical Datum of 1988 at RM 61.7.

The deepening of the channel was undertaken to "accommodate the current fleet of international bulk cargo and container ships" and was completed in 2010 (U.S. Army Corps of Engineers 2015a). Detailed information is available on the Corps' Portland District website, including the *Columbia River Federal Navigation Channel Operations and Maintenance Dredging and Dredged Material Placement Network Update, River Miles 3 to 106.5, Washington and Oregon* (U.S. Army Corps of Engineers 2014).

The Columbia River navigation channel is maintained to the following dimensions (U.S. Army Corps of Engineers 2015b).

- From the Columbia River entrance at RM 3.0 to Vancouver, at RM 101.4: 43 feet deep and 600 feet wide.
- From RM 101.4 to RM 105.5 at Vancouver: 43 feet deep and 400 feet wide.
- From RM 105.5 to RM 106.5 at Vancouver: 35 feet deep and 500 feet wide.

The navigation channel also includes anchorages and turning basins, discussed below in Section 2.2.3.2, *Anchorages and Turning Basins.*

2.2.2.3 Willamette River

The portion of the navigation channel in the Willamette River is 43 feet deep and runs along the lower 11.6 miles of the Willamette River from its confluence with the Columbia River to the Broadway Bridge in Portland, at Willamette RM 11.6.[7]

2.2.3 Ports, Anchorages, and Other Features

This section describes ports, anchorages, and other physical features along the navigation channel.

[7] Unless specifically referred to as Willamette RM, all references to river mile (RM) in this report apply to the Columbia River.

2.2.3.1 Ports

Table 2 lists the ports in the study area with berthing for large vessels along with their locations and facilities. Figure 3 shows the locations of these ports.

Table 2. Ports in the Study Area

Port	Location	Facilities
Port of Astoria, Oregon	RM 12	Three deep-draft berths; additional berths for small commercial fishing vessels and research vessels; two marinas and a boatyard; two anchorages
Port of St. Helens, Port Westward Industrial Facility, near Clatskanie, OR	RM 53	Port of Westward Industrial Facility. One dock and one deep-water berth
Port of Longview, WA	RM 65	Eight marine terminals containing a total of eight berths
Port of Kalama, WA	RM 75	Seven marine terminals: two grain elevators, one general cargo dock, one barge dock, one liquid bulk facility, one lumber barge berth, and one deep-draft wharf
Port of Portland, OR	RM 100	Four marine terminals containing a total of 18 berths
Port of Vancouver, WA	RM 106.5	Four marine terminals containing a total of 13 berths

Notes:
RM = river mile

2.2.3.2 Anchorages and Turning Basins

This section describes anchorages and turning basins in the study area.

Vessels anchor within the Columbia River system for a variety of reasons, planned (e.g., to take on fuel, to wait for a berth) or unplanned (e.g., mechanical repairs, to wait for better weather conditions). In anticipation of this need, USCG has designated 11 locations for vessels to anchor. Each location has specific characteristics with which vessel masters, crews, and pilots must be familiar. Designated anchorages, as identified by USCG and described in 33 Code of Federal Regulations (CFR) 110.228 (Columbia River, Oregon and Washington), are listed in Table 3 and depicted in Figure 3.

The Corps' regulations establish the operational rules for the anchorages, including a requirement that vessels desiring to anchor must contact the pilot office that manages the anchorage to request a position assignment. The Bar Pilots manage Astoria North and Astoria South anchorages. The River Pilots manage the anchorages upriver from Astoria. The rules also specify that no vessel may occupy a designated anchorage for more than 30 consecutive days without permission from the USCG Captain of the Port (COTP).

The Lower Vancouver and Upper Vancouver anchorages are the only anchorage areas maintained by the Corps as part of the Columbia River navigation channel. The other designated anchorages are at sites identified as naturally deep locations, although shoaling does occur to some extent and dredging is occasionally necessary.

Although the anchorages downstream of the project area (Astoria North and South) can accommodate deep-draft vessels, use by vessels with drafts of more than 28 feet (at the Astoria North Anchorage) are not recommended due to the probability of dragging anchor. However, a deep anchorage position at Astoria North, referred to as The Hole, is normally kept vacant for deep-draft vessels in unusual situations or emergencies or for short-term anchoring (Lower Columbia Region Harbor Safety Committee 2013: 9). The Prescott and Upper Vancouver anchorages have stern mooring buoys that help prevent larger vessels using the anchorage from swinging into the navigation channel while at anchorage.

Table 3. Anchorages in the Study Area

ID[a]	Anchorage Name	River Miles	Range of Depth(s) (feet)	Maximum Vessel Size	Vessel Capacity	Stern Buoy?[b]
A	Astoria North[c]	14–17.8	24–45+	Panamax	6	No
B	Astoria South	15–18.2	20–45+	Handymax	4	No
C	Longview	64–66	29–40+	Handymax	5	No
D	Cottonwood Island	66.7–71.2	19–40+	Handymax	13	No
E	Prescott	72.1–72.5	52–65+	Panamax	1	Yes (1)
F	Kalama	73.2–76.2	26–40+	Panamax	7	No
G	Woodland[d]	83.6–84.3	8–40+	<600 feet LOA	3	No
H	Henrici Bard	91.6–93.9	22–33+	<600 feet LOA	8	No
I	Lower Vancouver	96.2–101.0	Minimum of 50	<600 feet LOA	14	No
J	Kelly Point	101.6–102.0	25–40+	Panamax	1	No
K	Upper Vancouver	102.6–105.2	35–50+	Panamax or larger	7	Yes (2)

Notes:
[a] Identification letter corresponds to letters in Figure 3.
[b] Number in parentheses reflects the number of stern buoys maintained at the anchorage.
[c] This anchorage is generally reserved for large and deeply laden vessels as determined by Columbia River Pilots.
[d] Remote and not currently in use.
Source: Lower Columbia Region Harbor Safety Committee 2013; U.S. Army Corps of Engineers 2015b
LOA = length overall

Four turning basins are in the study area (Figure 3). Turning basins are generally wider areas along a channel dredged to the same depth as the channel, where vessel masters and pilots have maneuvering room to turn vessels for the purposes of pointing the bow of the vessel in the direction of transit.

2.2.3.3 Bridges

Two bridges cross the navigation channel at and downstream of the Longview area: the Lewis and Clark Bridge and Astoria-Megler Bridge.

- Lewis and Clark Bridge crosses the Columbia River between Longview, Washington, and Rainier, Oregon. It has a vertical clearance of 187 feet and a horizontal clearance of 1,120 feet. This bridge is upstream from the project area, and project-related vessels would not pass through this bridge under normal operations.

- Astoria-Megler Bridge crosses the Columbia River between Astoria, Oregon, just inland of the Port of Astoria, and Point Ellice, near Megler, Washington. It has a vertical clearance of 205 feet and a horizontal clearance of 1,070 feet.

2.2.3.4 Ferries

One ferry, the Wahkiakum County, Ferry, crosses the river between Puget Island, Washington, and Westport, Oregon, at RM 37.4 (Figure 3). It is the only ferry crossing downstream of the project area.

2.2.4 Large Commercial Vessel Traffic

This section focuses on commercial vessels—excluding fishing vessels and smaller commercial passenger vessels[8]—calling at ports in the study area. For the purposes of this report, these vessels are referred to as *large commercial vessels*. They are primarily cargo vessels, more than 99% of large commercial vessels,[9] and include ships and barges carrying various cargo (i.e., dry bulk, automobiles, containers, bulk liquids, and other general cargo). These vessels comprise most, if not all, of the deep-draft vessels, which are restricted to movement in the navigation channel, as well as other commercial vessels with shallower drafts that are able to navigate outside of the channel. Commercial fishing vessels and smaller commercial passenger vessels, as well as recreational vessels and service vessels, are discussed in Section 2.2.5, *Other Vessel Traffic*.

The following sections describe types and amounts of cargo transported, vessel types, and traffic volumes for commercial vessels in the study area.

2.2.4.1 Cargo Types and Tonnages

Table 4 presents the types and amounts of cargo transported along the Columbia River. The amounts and percentages in the table reflect average annual gross tonnage for the period 2004 to 2014, based on Bar Pilots data (Jordan pers. comm.). The primary growth areas in recent years have been in the dry bulk and automobile traffic.

[8] Includes passenger car ferry and overnight and daytime vessels.

[9] Cruise ships account for less than 1% of large commercial vessel traffic in the study area. *Historical Traffic Volumes* provides a detailed discussion of vessel traffic by vessel type over a recent 11-year period.

Table 4. Cargo Types and Corresponding Average Annual Gross Tonnage (2004–2014)

Cargo Type	Gross Tonnage	Percentage[a] of Total Cargo Moved
Dry bulk	44,551,063	47.3
Automobiles	20,986,525	22.3
Containers	11,187,455	11.9
General cargo	7,447,913	7.9
Bulk liquid	4,127,333	4.4
Other[b]	5,912,903	6.3
Total	**94,213,193**	**100**

Notes:

[a] Percentages refer to gross tonnage to better represent the approximate quantities of various commodities moved along the Columbia River.

[b] Miscellaneous gross tonnage accounting for vessel movements from one berth to another, passenger vessels, tugs, and empty barge movements.

[c] Numbers are rounded up.

Source: Jordan pers. comm. A.

2.2.4.2 Types of Large Commercial Vessels

The types of large commercial vessels in the study area are listed below by four broad categories.

- Cargo ships
  - Tankers carrying bulk liquids
  - Container ships carrying containerized cargo
  - Dry bulk carriers carrying forest products and steel, ore, grain, potash, and other dry bulk cargoes
  - General cargo ships carrying steel, machinery, and other general cargo that is not containerized or bulk.
  - Automobile carriers
- Barges
  - Tank barges (including articulated tug barges [ATBs][10]) carrying bulk liquids
  - Other cargo barges carrying dry bulk, containerized and other cargo
- Passenger cruise ships
- Other[11]

Table 5 presents typical specifications for these vessels and example images.

[10] An articulated tug barge, or ATB, is a tank barge that is propelled and maneuvered by a high-powered tug positioned in a notch in its stern.

[11] Includes bunkers and other vessel types that occur only occasionally (e.g., military, research, and industrial/marine construction vessels).

Table 5. Types of Large Commercial Vessels in the Study Area

Vessel Category	Vessel Types	Typical Vessel Specifications	Example Photos
Cargo ships	Dry bulk cargo ships (bulkers), container ships, general cargo ships, automobile carriers	**Dry bulk, container, and general cargo ships:** DWT: 50,000–80,000, Length: 650–965 feet Beam: 100- 106 feet Draft: 33–39.5 feet	 Bulk cargo ship (bulk carrier)
		Automobile Carriers: DWT: 18,638 Length 650 feet Bean: 105 feet Draft: 27 feet	 Automobile Carrier
		Container ships: DWT: 57,088 Length: 260 feet Beam: 33 feet Draft: 12.5 feet	 Container Ship

Vessel Category	Vessel Types	Typical Vessel Specifications	Example Photos
		Tankers DWT: 65,000–80,000 Length: 965 feet Beam: 106 feet Draft: 41 feet	 Tanker
Barges	Cargo barges including tank barges, dry cargo barges and container barges	Length: 132–286 feet Beam: 40–55 feet Draft: 8–17 feet DWT: N/A (Gross tons: 559–2,700)	 Dry cargo barge
Passenger cruise ships		Length: 560–965 feet Beam: 78–125 feet Draft: 18–29 feet DWT: 2,700–13,290	 Cruise ship

Notes:
DWT = deadweight tons; ATB = articulated tug barge
Photo sources: MarineTraffic.com except for tanker, worldmaritimenews.com; and dry cargo barge, Tidewater.com.

The vessels discussed in this section come in various sizes, as reflected by the ranges (e.g., width, draft) shown in Table 6. Cargo ships are categorized[12] by their capacity and dimensions. The vessel classes that can be accommodated in the study area are listed in Table 6 with their typical dimensions and cargo capacities.

[12] These category names often reflect the canal through which the vessels are designed to travel.

Table 6. Vessel Classes in Use on the Columbia River Navigation Channel

Vessel Class	Deadweight (tons)	Length (feet)	Beam (feet)	Design Draft (feet)
Handymax	10,000–49,999	490–655	75–105	36–39
Panamax	50,000–79,999	965	106	39.5
Post-Panamax[a]	Over 80,000	965 or greater	106 or greater	39.5 or greater

Notes:

[a] The Post-Panamax class, also referred to as New Panamax, is a new vessel class that reflects the expanded Panama Canal dimensions.

Source: INTERCARGO 2015

2.2.4.3 Tug Assistance

Cargo and cruise ships require tugs (generally a minimum of two) to provide assistance during docking and undocking, because these vessels lack adequate maneuverability at slower speeds. These vessels also may rely on tugs in emergencies to assist, escort, and in some cases provide fire suppression. Tug escorts on the Columbia River are generally engaged only in unusual conditions (e.g., electronic equipment issue that would prevent safe navigation or inoperable vessel propulsion system at normal power levels) that can be mitigated by the tug escort. Most likely an unusual condition that requires a tug escort would be in effect for all portions of the transit (from crossing the bar to the final destination).

Tugs are assigned, primarily for docking assistance, based on the minimum bollard pull required for a particular vessel type or operation. Shaver Transportation Company, Foss Maritime, and Olympic Tug and Barge, all based in Portland, provide tugs suitable for assisting large commercial vessels in the study area. Nine of Shaver's 13 study-area tugs would be appropriate to assist vessels calling at the project area (Rich pers. comm.). Six of Foss's study-area tugs (Hendricks pers. comm.) and 13 of Olympic's study-area tugs would be suitable for assisting Panamax and Handymax ships (Bonnin pers. comm.) at the project area.

Tugs also are used to tow and push barges between destinations in the study area for bunkering, fuel transport, and hauling cargo. The following companies provide barge towing in the study area: Bernert Barge Lines, Brusco, and Tidewater.

2.2.4.4 Vessel Speed and Travel Times

The vessels discussed in this section are primarily restricted to the navigation channel where traffic moves in two lanes: one lane inbound and one lane outbound. Vessel speeds generally range between 9 and 15 knots in the study area, with the slower speeds in that range occurring while passing port areas; still slower speeds of between 6 and 9 knots occur while passing through anchorages (Appendix A, *Navigation Risk Study*).

Travel time across the bar, between the offshore Pilot Station and Tongue Point, takes approximately 2 hours in either direction. River transits depend on the study area terminal origination or destination. As an example, the travel time from Tongue Point to Longview is approximately 5 hours inbound (generally vessels in ballast[13]) and about 6 hours outbound

[13] Vessels *in ballast* are not loaded with cargo, but have had their tanks loaded with water to increase vessel stability; these vessels have less of a draft than when loaded.

(generally loaded vessels). Outbound transits generally take longer than inbound transits for two reasons: the majority of outbound vessels are loaded and travel at reduced speeds; outbound transits are scheduled during high-tide conditions to maximize underkeel clearance [14] and, thus, are usually running against the force of a flood (incoming) tide.

2.2.4.5 Existing and Historical Traffic

This section describes existing (2014) vessel activity and distribution in the study area. It also describes the existing and historical traffic volumes over the past 11 years in the context of historical peak volumes prior to this period.

Existing Commercial Vessel Traffic

This section describes the volume and distribution of existing vessel traffic throughout most of the study area,[15] based on 2014 AIS data (Appendix A, *Navigation Risk Study*). Figure 4 depicts activity by vessel type at eight locations (shown in Figure 5) on the lower Columbia River based on 2014 AIS data. The categories shown in Figure 4 that apply to large commercial vessels are Cargo Ships, Passenger (cruise ships and other large commercial passenger vessels), and, Tug/Tug with Barge.[16] As shown in the figure, vessel activity is greatest near the mouth of the Columbia River. Much of this increased activity at these locations (Ilwaco West, Ilwaco East, and Astoria) is related to service and fishing vessel activity, discussed in Section 2.2.5, *Other Vessel Traffic*. Cargo ship activity is consistent between the project area and the mouth of Columbia River.

[14] *Underkeel clearance* is the amount of space between the hull of the vessel and the bottom of the channel.

[15] The 2014 AIS data were analyzed as part of the risk study (Appendix A, *Navigation Risk Study*). The upstream extent of the study area for risk is Longview. Therefore, this discussion does not include vessel activity in the study area upstream of Longview.

[16] Because barges do not have AIS receivers, barge numbers are captured as part of the tug data. The tug numbers include tugs traveling independently and tugs towing or pushing barges. Only the latter are considered large commercial vessels. The number of tug and barge units (cargo barges), including ATBs, entering and exiting the river are best represented by transits recorded for the Ilwaco locations; the increased tug activity in the upstream portions of the study area, especially near Longview and Wauna, likely represents tugs traveling independently to provide docking services and tugs shifting cargo barges between ports.

Figure 4. Number of Transits per Location by Vessel Type (based on 2014 AIS Data)

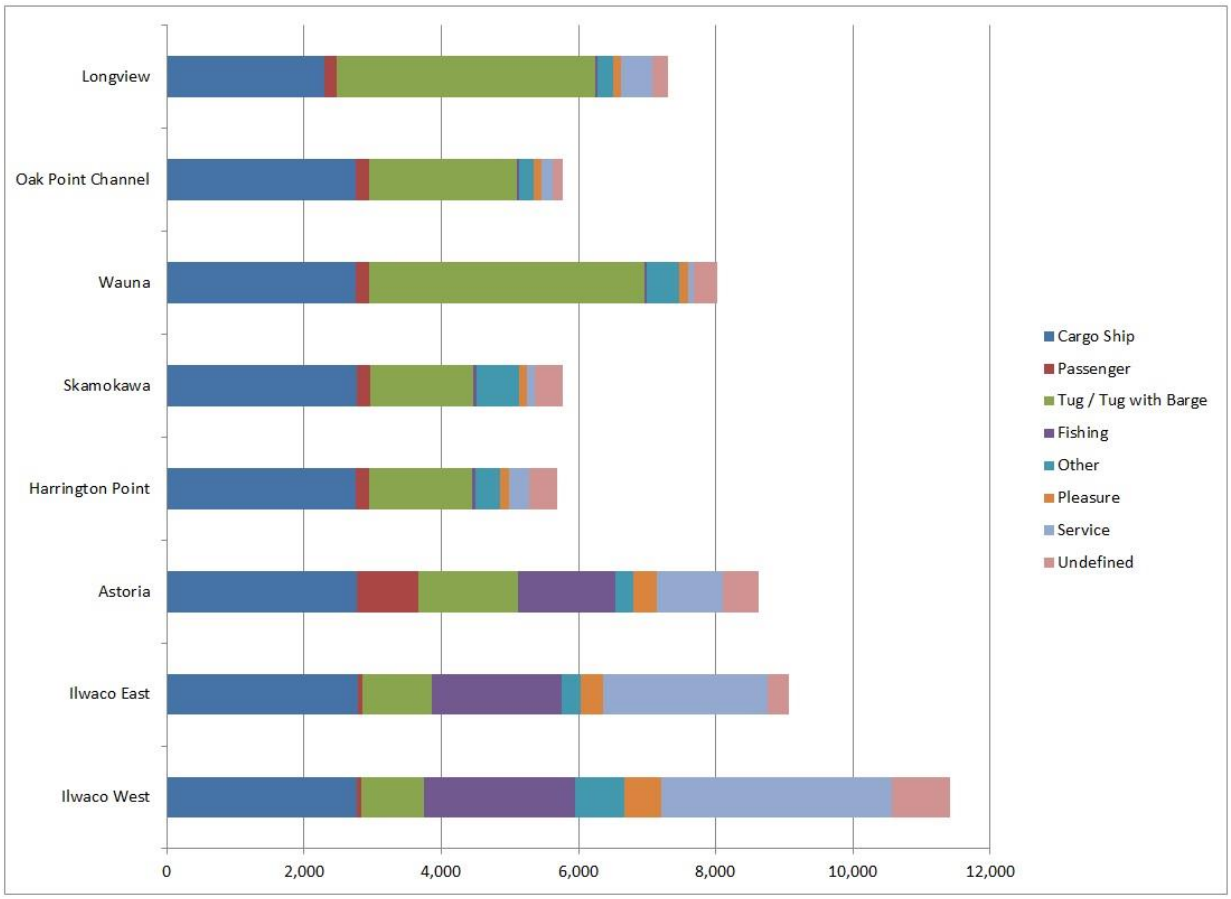
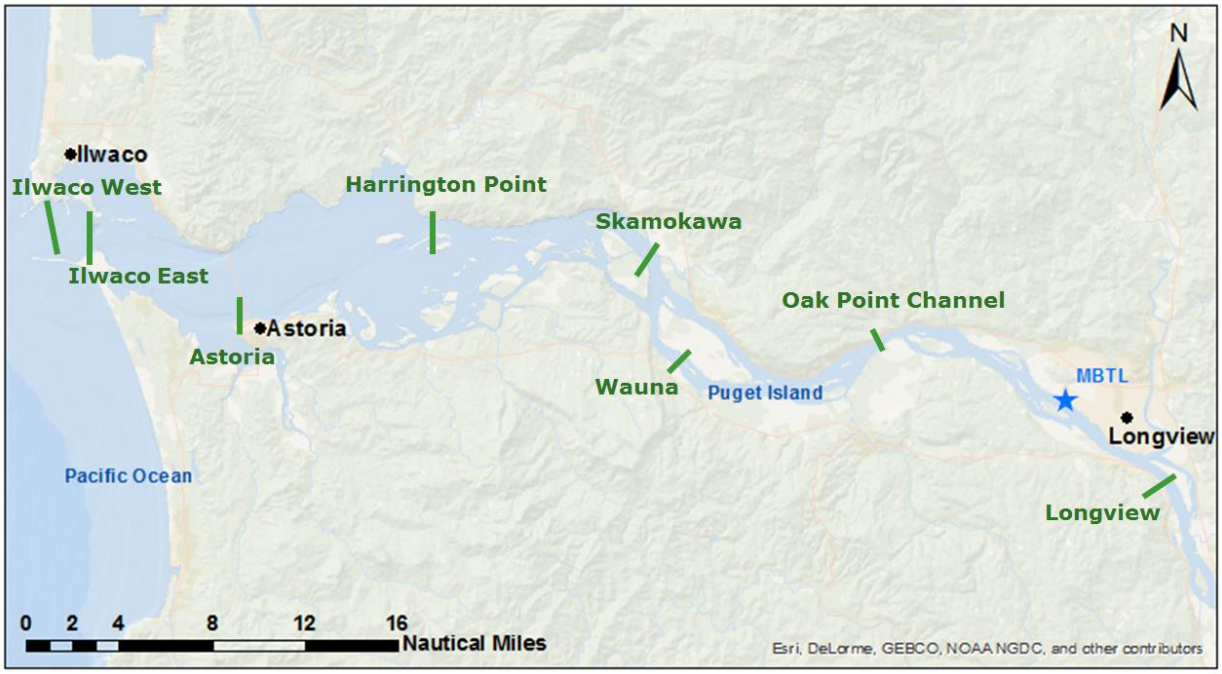


Figure 5. Vessel Data Location Points



Characterizing existing port activity is another way to understand large commercial vessel activity. Types and uses of vessels calling at ports in the study area (Figure 3) are described below.

- Port of Astoria primarily receives cruise ships, loggers and other cargo vessels, and other types of vessels (e.g., USCG, pollution control, commercial fishing, and recreational vessels). The Port reports approximately 230 vessel calls [17] at the Waterfront and Tongue Point berths in 2015 (McGrath pers. comm.).
- Port of St. Helens, Port Westward Industrial Facility receives tankers and tank barges.
- Port of Longview receives cargo ships and barges transporting various types of general and bulk cargo, including steel, lumber, logs, grain, minerals, alumina, fertilizers, pulp, paper, wind energy components, and heavy-lift cargo. The port reported 222 vessel calls in 2015, with a 5-year average of 205 vessel calls per year (Hendriksen pers. comm.).
- Port of Kalama receives cargo ships and barges primarily transporting grain, but also bulk liquid chemicals and general cargo. The port reported 205 vessel calls in 2014 (Port of Kalama 2015).
- Port of Portland receives cargo ships (mostly Handymax and Panamax) and barges, cruise ships, and other vessel types (e.g., other commercial passenger vessels, dredges, pollution control vessels). The cargo vessels transport all types of cargo. The port reported 513 and 352 vessel calls in 2014 and 2015, respectively (Myer pers. comm.).
- Port of Vancouver receives cargo ships (Handymax and Panamax) and barges transporting grain, scrap, steel, automobiles, petroleum products, other dry and liquid bulk cargo, and other products. The port also receives commercial passenger vessels (not cruise ships) and dredges. The port reported 450 vessel calls per year in 2014 and 2015 (Uglum pers. comm.).

Historical Traffic Volumes

This section describes historical commercial vessel traffic volumes in the study area. Table 7 shows annual vessel traffic volumes in the study area over an 11-year period (2004 to 2014), based on VEAT data and Bar Pilots' records. The VEAT numbers reflect vessels entering the Columbia River, which is equivalent to vessel calls. The Bar Pilots record bar crossings, or entries to and exits from the Columbia River, which are equivalent to transits. A call typically results in two transits—an inbound transit and an outbound transit; therefore, the Bar Pilot transits were divided by two for ease of comparison with the VEAT calls in Table 7. As shown in the table, the calls based on Bar Pilots data are slightly higher than those based on VEAT data; this difference reflects that the Bar Pilots record some vessels that are not reported in the VEAT database and vice versa.[18] As shown in Figure 6, despite these relatively minor differences, the two datasets produce very similar traffic volume curves over the 11-year period.

[17] A call represents a visit to a port terminal. A vessel call typically results in two vessel transits: one inbound and one outbound.

[18] The Bar Pilots record several vessel types not recorded in the VEAT data: military vessels, research vessels, industrial/marine construction vessels, and dredges. The VEAT database records some passenger vessels not recorded by the Bar Pilots; while both record cruise ships, the VEAT data also include passenger ferries and inland passenger vessels used for such purposes as day trips and dinner cruises.

Table 7. Columbia River Vessel Traffic[a] Levels

	Calls[b]	
Year	**Bar Pilots Data**	**VEAT Database**
2004	1,777	1,669
2005	1,718	1,654
2006	1,809	1,720
2007	1,929	1,872
2008	1,891	1,806
2009	1,463	1,397
2010	1,683	1,583
2011	1,581	1,466
2012	1,589	1,431
2013	1,724	1,457
2014	1,819	1,662

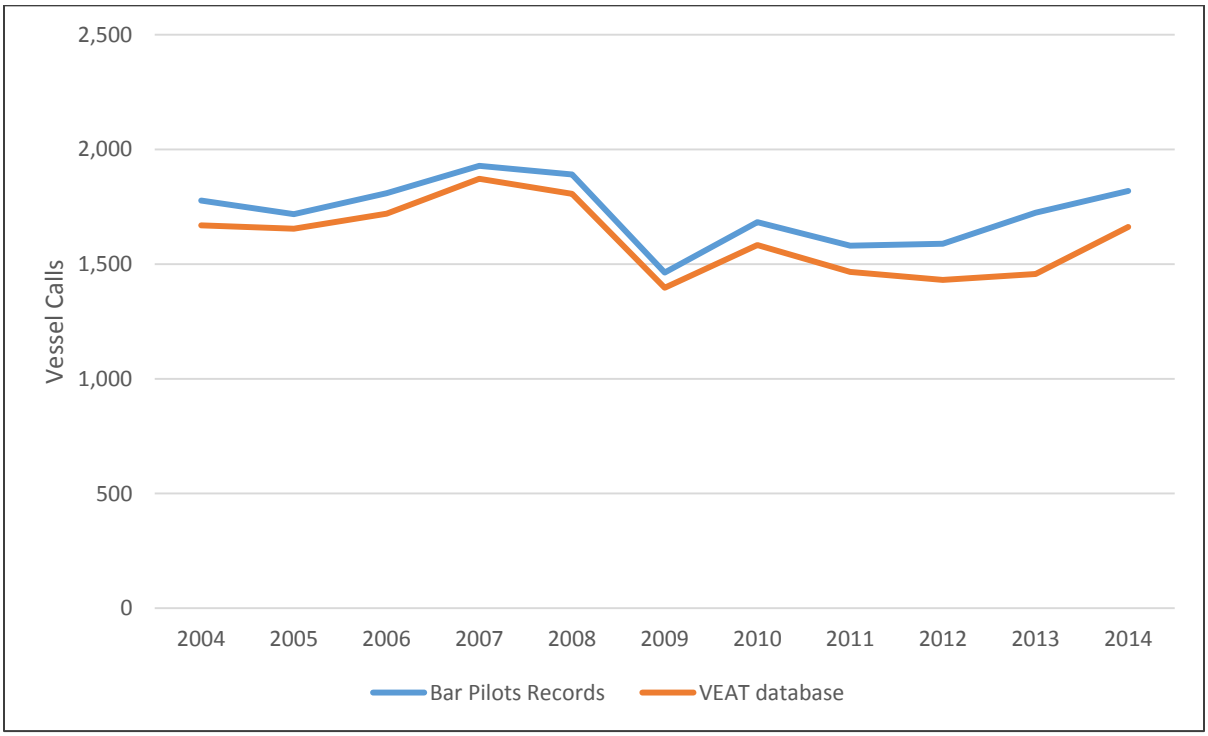
Notes:

[a] Tows consisting of tug and barge traffic, mostly for grain and wood products are not included in the data evaluated. For the most part, that traffic stops upriver from the project area and is not monitored as closely as the deep-draft vessel traffic.

[b] A vessel call represents a vessel's entry to the river or its visit to a port.

Sources: Jordan pers. comm. A; VEAT (Washington State Department of Ecology 2015).

Figure 6. Comparison of Vessel Calls Based on Bar Pilot and VEAT Data (2004–2014)



As shown in Table 7 and Figure 6, traffic volumes were similar in 2004 and 2014, but fluctuated within that period. For comparison, the historical peak vessel traffic year for the Columbia River is 1999 with 2,269 calls based on VEAT data (Washington State Department of Ecology 2014), and 1979 with 2,376 calls, based on the Bar Pilots data (Jordan pers. comm. A). Although vessel traffic volumes have been considerably lower since 2004 compared to these peaks, vessel sizes and total cargo tonnages have increased in recent years.

The overall decrease in vessel traffic levels can be attributed to general economic conditions. The deepening of the Columbia River channel from 40 feet to 43 feet has allowed larger vessels with greater drafts to call at river ports, and vessels that previously had to be light-loaded can now be loaded to deeper drafts. This has resulted in the need for fewer, but larger, vessels with greater drafts to move a given volume of cargo. This is especially the case for the dry bulk cargo vessels that make up a high percentage of the river traffic (Krug pers. comm.; Myer pers. comm.; Amos pers. comm.; Jordan pers. comm. B). The changing nature of vessel design and the likely partial impact on vessel volumes in the study area is illustrative of the multiple factors that can affect vessel traffic volumes over time.

Figure 7 shows annual vessel transits[19] over the past 11 years by the four vessel categories: cargo ships, barges, passenger ships, and other (based on the Bar Pilots data [Jordan pers. comm. A). As shown in the figure, cargo ships[20] (including tankers) constitute the largest percentage of vessel traffic in the study area (around 90% annually on average) over the 11-year period, while barges represent 3 to 10% and cruise ships less than 1%. Approximately 3% consists of a mixture of other vessel types.[21]

This cargo ship traffic can be broken down further into specific vessel types, based on the Bar Pilots records. Figure 8 shows transits of the cargo ship category shown in Figure 7 by cargo ship type. Dry cargo ship transits represent over half (between 50 and 60%) of the cargo ship traffic annually. The remainder (in descending order of magnitude) were automobile carriers, general cargo ships, container ships, and tankers.

[19] These numbers only account for transits across the bar in either direction. They do not include any in-river transits from one terminal or port to another. Moreover, transit lengths vary: one transit may stop at Astoria while another may extend the length of the study area.

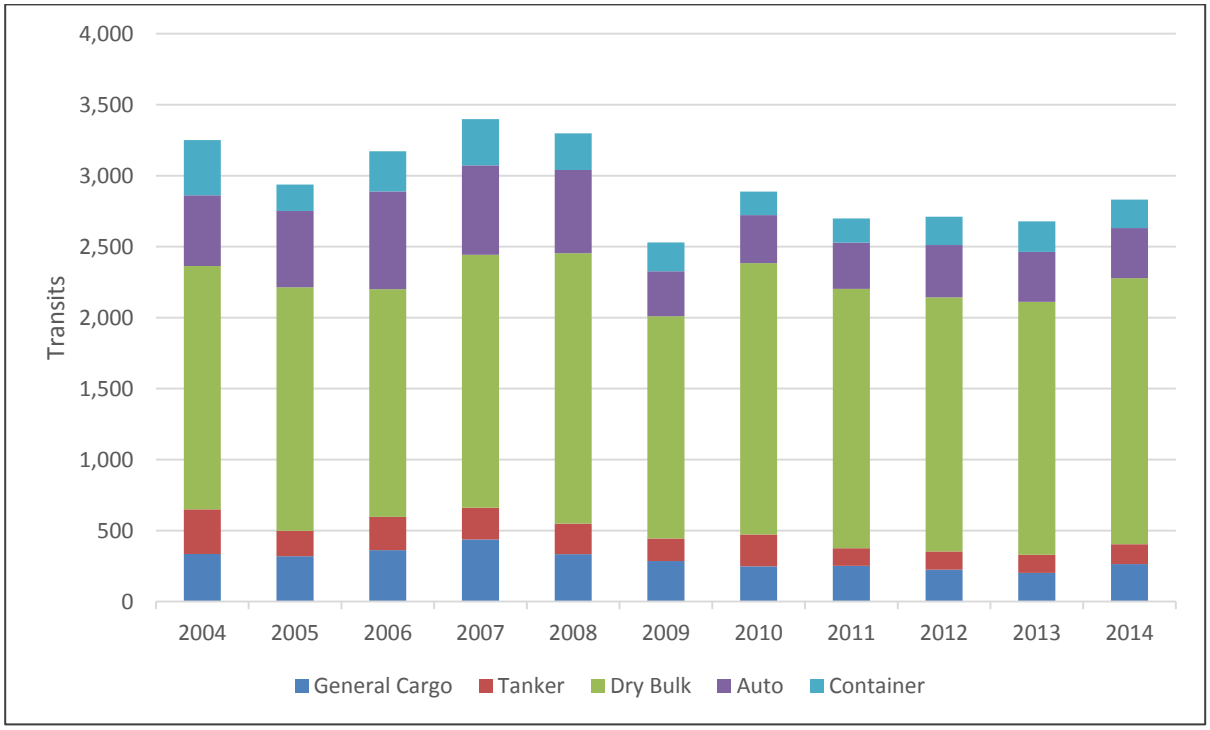
[20] Vessels categorized as *cargo ships* include vessels recorded in Bar Pilot data as general cargo ships, tankers, bulkers, loggers, auto carriers, chippers, and container ships.

[21] Vessels categorized as *other* include vessels recorded in Bar Pilot data as miscellaneous (occasional military vessel, research vessels, industrial/marine construction, dredges), bunkers, shipyard, and shifts.

Figure 7. Vessel Traffic Volumes by Major Vessel Category (2004–2014)



Figure 8. Percentage of Annual Cargo Ships by Vessel/Cargo Type (2004–2014)



2.2.5 Other Vessel Traffic

Other vessels include commercial fishing, recreational, smaller commercial passenger, and service vessels. These vessels are generally much smaller than the vessels discussed in the previous section and have different activity and transit patterns. Most can move about the river without being restricted to the navigation channel. Table 8 presents typical specifications for these vessels and example images.

Table 8. Other Vessel Types in the Study Area

Vessel Type	Typical Specifications	Example Image
Fishing vessels	Length: 20–180 feet Beam: 8–45 feet Draft:: 3–15 feet	 Fishing (gillnetter) vessel
Other commercial passenger vessels: car ferries, inland passenger ships, passenger ferries	**Car ferry:** Length: 109.2 feet Breadth: 47.5 feet Draft: 6 feet **Other commercial passenger vessel:** Gross Tons: < 100 Length: 80–150 feet Beam: 30–40 feet Draft: 6–12 feet	 Car ferry “Oscar B”  River cruise vessel

Vessel Type	Typical Specifications	Example Image
Recreational vessels, including pleasure boats, yachts, sailing vessels	Length: 20–150 feet Beam: 8–40 feet Draft: 3–15 feet	 Pleasure craft
Service vessels Military (USCG), law enforcement, pilot, and Aids to Navigation vessels	U.S. Coast Guard vessels range in length from 22 feet to over 300 feet. **Vessel shown:** Length: 47 feet Beam: 14 feet	 U.S. Coast Guard search and rescue vessel
	Pilot vessel (shown): Length: 72 feet Beam: 20 feet	 Pilot vessel COLUMBIA
	Pollution control vessels: Length: 20–40 feet Beam: 6–20 feet	

Vessel Type	Typical Specifications	Example Image
Tugs	Length: 50–150 feet Beam: 26–35 feet Draft: 9–16 feet	 General tug
Dredge vessels	**Vessel shown:** Length: 200 feet Beam: 58 feet Draft: 16 feet	 Dredge vessel YAQUINA

Notes:
Photo sources: MarineTraffic.com, except fishing (gillnetter) vessel, WDFW Image Gallery; car ferry "Oscar B," Daily Astorian; search and rescue vessel, News Lincoln County.

2.2.5.1 Commercial Fishing

Columbia River

The Columbia River is divided into six commercial fishery management zones; of these, Zones 1 through 3 and a portion of Zone 4 occur in the study area (NOAA Fisheries 2016). The commercial fisheries in these zones are managed by the states of Oregon and Washington.

Zones 1, 2, and 3 support important commercial shad, anchovy, herring, smelt, and salmon fisheries. Commercial fishers deploy gillnets, tangle-nets, or seins depending on species, season, and zone. Anchovies and herring may be taken for commercial purposes at any time in the Columbia River seaward of the Astoria-Megler Bridge (Figure 3). Commercial salmon seasons and authorized fishing gear are shown in Table 9. Shad typically can be taken for commercial purposes from the study area zones during commercial salmon seasons with the same fishing gear authorized for the taking of salmon. The retention of green sturgeon and white sturgeon was prohibited in the Columbia River downstream of Bonneville Dam beginning in 2006 and 2014, respectively.

Table 9. Major Columbia River Salmon Commercial Fishery Seasons in the Study Area

Season[a]	Primary Species	Areas	Authorized Method/Gear
Winter (February–March)	Spring Chinook	Select Area Fisheries[b]	Gillnets and tangle-nets
Spring (April–June)	Spring Chinook	Select Area Fisheries[b] and Columbia River mainstem[c]	Gillnets and tangle-nets
Summer (June–July)[c]	Sockeye and Summer Chinook	Columbia mainstem and Select Area Fisheries[b]	Gillnets
Early Fall (August–mid-September)	Summer and Fall Chinook	Columbia River mainstem and Select Area Fisheries[b]	Gillnets
Late Fall (mid-September–mid-November)	Fall Chinook and Coho	Columbia River mainstem and Select Area Fisheries[b]	Gillnets, tangle nets, and experimental seines

Notes:

[a] Dates and areas subject to stock abundance and management decisions.

[b] Select Area Fisheries include Youngs Bay, Blind Slough/Knappa Slough, Tongue Point/South Channel, and Deep River.

[c] Columbia River mainstem areas include Zones 1 (Columbia River mouth) to 5 (Beacon Rock at RM 142).

Source: Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2015a (winter, spring, and summer) and 2015b (fall fisheries).

Approximately 2,046,747 pounds of shad and salmon (Chinook, coho, pink, and sockeye) were harvested (160,821 landings) on the Columbia River in 2015; the late-fall salmon season accounted for approximately 85% of this total harvest, making the late-fall salmon season the busiest time of year for commercial fishing on the Lower Columbia River (Oregon Department of Fish and Wildlife 2015b).

Coastal, Nearshore, and Ocean Commercial Fishing

Several coastal, nearshore, and offshore open-ocean fisheries, including groundfish, halibut, salmon, albacore, pacific whiting, sardines, and shellfish (primarily Dungeness crab and pink shrimp) are present within or adjacent to the study area. Activities range from harvesting to delivery to shore-based processors, depending on the fishery. The mouth of the Columbia River is the busiest part of the study area for commercial fishing vessel traffic, though numbers of operating vessels fluctuate by season and license by fishery. Fisheries with the greatest likelihood of vessels operating within the study area are discussed below.

Commercial coastal and nearshore fishing in the study area include vessels operating within 3 nautical miles and reporting to the Ports of Astoria, Chinook, and Ilwaco. The U.S. West Coast nearshore groundfish commercial fleet operates in the study area and consists of vessels from 10 to 50 feet long, with an average length of 25 feet (NOAA Fisheries 2016). Fixed gear includes hand-lines, cable gear, fishing poles, and pots (traps). Gear is set to retrieve catch multiple times a day and catch is generally landed on a daily basis.

Regulations for nearshore fisheries are set by both the Pacific Management Council and the states; each state manages its nearshore fleet independently by issuing regulations on the cumulative trip limits of nearshore species in their state waters (NOAA Fisheries 2016). The State of Washington does not allow commercial fishing within its territorial waters (0 to 3 mile from the coastline); therefore, a commercial fixed-gear fleet does not operate in Washington nearshore waters of the

study area (NOAA Fisheries 2016). The nearshore commercial fixed-gear fleet in Oregon typically fishes shallow water and targets cabezon, greenlings, and several species of rockfish (NOAA Fisheries 2016).

The Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP) was implemented in 1982 and has since been amended 20 times by the Pacific Fishery Management Council in response to changes in the fishery, reauthorizations of the Magnuson-Stevens Act, and litigation that invalidated provisions of earlier amendments (Pacific Fishery Management Council 2008). The Groundfish FMP guides the management of groundfish fisheries in federal waters, 3 to 200 nautical miles offshore.

The Pacific Coast Salmon Fishery Management Plan guides the management of salmon fisheries in federal waters. Oregon and Washington's commercial ocean salmon fisheries are hook-and-line troll fisheries. This fishery largely targets Chinook salmon, with minor coho salmon seasons in some years (Oregon Department of Fish and Wildlife 2015c). In odd-numbered years, catches of pink salmon can also be significant off Washington and Oregon coastlines (Pacific Fishery Management Council 2014). This is a limited-entry fishery in both states, meaning that a permit is required to participate actively in the fishery each year.

Commercial fishing for Dungeness crab occurs in the study area along the Washington and Oregon coastlines. The ocean crab season begins December 1 and continues through August 14, with peak harvest occurring during the first 8 weeks of the season. Dungeness crabs are caught using circular steel traps with a length of line and a buoy attached to mark its location. The average commercial Dungeness crab fishing vessel fishes 300 to 500 pots in depths of 30 to 600 feet (Oregon Dungeness Crab Commission 2014).

Oregon and Washington have a limited entry system in-place on the Dungeness crab fishery, with more than 350 vessels in Oregon and 200 vessels in Washington operating the fishery (Oregon Dungeness Crab Commission 2014; Washington Department of Fish and Wildlife 2016a). Vessels range from small wooden trollers to large steel combination vessels. The Columbia River estuary is an important location for commercial Dungeness crab fishing with three main landing locations located in the study area: the Port of Astoria, Port of Ilwaco, and Port of Chinook,

Commercial pink shrimp fishing occurs adjacent to the study area in offshore waters of Oregon and Washington (3 to 200 miles offshore) with processing facilities located at the Port of Ilwaco and the Port of Astoria. A limited entry system for the pink shrimp fishery is in place for Oregon and Washington, with 83 active licenses in Washington.

The pink shrimp season begins April 1 and continues through October 31. Fishing occurs during daylight hours using trawl gear, most commonly utilizing double-rigged, semipelagic, fine-meshed shrimp nets (Washington Department of Fish and Wildlife 2016b). Pink shrimp trawl vessels range in size from 38 to 105 feet long, with an average length of 65 feet.

2.2.5.2 Tribal Fishing

The treaties of 1855 between the United States and individual tribal governments reserved tribal rights to fish, hunt, and gather traditional foods and medicines throughout ceded lands identified in the treaties.

The Columbia River and its tributaries support a variety of tribal resources, including six species of salmon and Pacific lamprey, which have been a reliable and important source of food and trade items to Columbia River. The Columbia River tribes are the Confederated Tribes and Bands of the

Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of Warm Springs, and the Nez Perce Tribe. These four tribes in the Columbia River Basin have reserved rights to anadromous fish in treaties with the United States (Columbia River Inter-Tribal Fish Commission 2016). Zone 6, upstream of the study area from Bonneville Dam to McNary Dam, is managed as an exclusive treaty commercial fishing zone. The Draft Environmental Impact Statement assesses the potential impacts of the Proposed Action on tribal resources.

2.2.5.3 Recreational Fishing and Boating

The Columbia and Willamette Rivers are popular areas for recreational boating (motorized and nonmotorized), fishing, and other recreational activities (Port of Portland 2010). More than 30 water access and boat launch sites along the Columbia and Willamette Rivers in the study area provide public and private river access for recreational boating and fishing (Table 10).

Table 10. Water Access Sites in the Study Area[a]

Boating Facility Name	Owner	Waterbody	County (State)
17th Street Transient Dock	City of Astoria	Columbia River	Clatsop (OR)
Courthouse Docks	City of St. Helens	Columbia River	Columbia (OR)
East Mooring Basin	Port of Astoria	Columbia River	Clatsop (OR)
Hammond Marina	City of Warrenton	Columbia River	Clatsop (OR)
Pier 39	Private	Columbia River	Clatsop (OR)
Rainier City Marina	City of Rainier	Columbia River	Columbia (OR)
Riverfront Park	City of Rainier	Columbia River	Columbia (OR)
Sand Island Marine Park	City of St. Helens	Columbia River	Columbia (OR)
Sand Island Marine Park North	City of St. Helens	Columbia River	Columbia (OR)
Scipio's Goble Landing	Private	Columbia River	Columbia (OR)
St. Helens Marina	Private	Columbia River	Columbia (OR)
West Mooring Basin	Port of Astoria	Columbia River	Clatsop (OR)
Westport Ramp	Clatsop County	Columbia River	Clatsop (OR)
Sportsman Club	WDFW	Columbia River	Cowlitz (WA)
Woodland Bottoms	WDFW	Columbia River	Cowlitz (WA)
Knappton	WDFW	Columbia River	Pacific (WA)
Puget Island	WDFW	Columbia River	Wahkiakum (WA)
Port of Ilwaco Marina	Port of Ilwaco	Columbia River	Pacific (WA)
Port of Chinook	Pacific County	Columbia River	Pacific (WA)
Port of Wahkiakum County No. 1	Wahkiakum County	Columbia River	Wahkiakum (WA)
Port of Wahkiakum County No. 2	Wahkiakum County	Columbia River	Wahkiakum (WA)
Elochoman Slough Marina	Wahkiakum Port District 1	Columbia River	Wahkiakum (WA)
Port of Kalama Marina	Port of Kalama	Columbia River	Cowlitz (WA)
McCuddy's Ridgefield Marina	Private	Columbia River	Cowlitz (WA)
Port of Longview Marinas	Port of Longview	Columbia River	Cowlitz (WA)
Port of Woodland Marina	Port of Woodland	Columbia River	Cowlitz (WA)
Riverplace Marina	Private	Willamette River	Multnomah (OR)
Cathedral Park	City of Portland	Willamette River	Multnomah (OR)

Boating Facility Name	Owner	Waterbody	County (State)
Willamette Park	City of Portland	Willamette River	Multnomah (OR)
Kelley Point Park	City of Portland	Willamette/Columbia Rivers	Multnomah (OR)
Hayden Island Marinas (numerous)	Private and Public	Columbia River	Multnomah (OR)

Notes:

[a] This table does not represent an all-inclusive list of water access points in the study area; additional private, municipal, county, and state facilities may be operational in the study area.

Sources: State of Oregon 2016; Washington Public Ports Association 2016; Washington Department of Fish and Wildlife 2016c; Port of Portland 2010

WDFW = Washington Department of Fish and Wildlife; WA = Washington; OR = Oregon

The Columbia River is the most boated waterbody in the State of Oregon with 524,091 boat use days, followed by the Willamette River with 281,176 boat use days. Hayden Island—which is located on the Columbia River, between Vancouver, Washington, and Portland, Oregon—serves as a key location for recreational boaters traveling to different sections of the Columbia and Willamette Rivers. Marinas in the vicinity report that recreational boating is highest during summer months and that 100% of 3,600 boat slips on Hayden Island are leased between April and October (Port of Portland 2010). The Columbia River Water Trail is a designated area for canoes and kayaks that travels through the study area to the mouth of the river.

The Columbia and Willamette Rivers support numerous aquatic species including salmon, steelhead, small mouth bass, shad, and sturgeon fisheries. Greenling, rockfish, lingcod, and perch are caught from the jetties, and flounder are common on sandy flats. Recreational fishing seasons vary by target species, but fishing occurs year-round for many species. Recreational catch-and-release fishing for green and white sturgeon is currently allowed year-round (Oregon Department of Fish and Wildlife 2015c). Warm-water game fish species season is also year-round in the study area (Oregon Department of Fish and Wildlife 2015c). The spring Chinook and steelhead fishery for the Columbia River is open from January to March depending on fishery management decisions, and Chinook and coho salmon fishing season runs from August to December.

The spring Chinook fishery in the Hayden Island area of the Columbia River is extremely popular and fishing participation rates have increased over recent years. During the spring Chinook season, between 135,000 and 145,000 angler days are documented on this section of the Columbia River between March 1 and June 1 (Port of Portland 2010). Also, the area between the mouth of the river and Tongue Point, which includes Youngs Bay, is a popular area for recreational fishing year-round (Oregon Department of Fish and Wildlife 2016:25). This area is popular, especially during the fall Chinook and coho salmon season, which generally peaks in the last 2 weeks of August (Washington Department of Fish and Wildlife 2016d).

Dungeness crabs are caught in the estuary and in nearshore and offshore areas beyond the mouth of the river, and razor clams are harvested along the ocean beaches north and south of the mouth of the river.

2.2.5.4 Commercial Passenger Vessels (Non-Cruise Ships)

Commercial passenger (noncruise ship) vessels transit from one port to another within the Columbia River; they include a range of vessels up to 100 gross tons carrying from six to over 150 passengers. Examples of these vessels include the Portland Spirit and Columbia Gorge Sternwheeler,

which provide dinner cruises and day trips, respectively, and the Waikiakum County ferry, the only ferry on the Lower Columbia River, which shuttles passengers and up to 12 cars at a time between Puget Island, Washington, and Westport, Oregon.

2.2.5.5 Service Vessels

Service vessels, including USCG, law enforcement, pilot, spill response, tugs, and dredges operate throughout the study area and could be found anywhere on the lower Columbia River at any time. The vessel types and activities are summarized below.

U.S. Coast Guard Vessels

USCG vessels in the study area are stationed primarily at the Port of Astoria, Cape Disappointment, and Portland, Oregon. These vessels are used for search and rescue, maritime law enforcement, boating safety, Aids to Navigation, and homeland security. The area of responsibility for the Coast Guard Aids to Navigation Team (ANT) in Astoria, Oregon, includes the Columbia River up to Portland, Oregon. The ANT stations two medium endurance cutters (USCG Cutter ALERT and USCG Cutter STEADFAST), which operate offshore and near the mouth of the Columbia River providing search and rescue, and illegal drug and immigrant interdictions. The ANT also stations the USCGC Fir, which is a seagoing buoy tender that maintains 150 aids to navigation along the Washington and Oregon coasts, as well as the Columbia River.

USCG Station Cape Disappointment is situated at the mouth of the Columbia River at Ilwaco, Washington, and is the largest search and rescue station on the Northwest Coast. The station has five search and rescue boats, including the 52-foot moto lifeboat Triumph II, two 47-foot motor lifeboats, and two 29-foot second-generation Defender-class response boats. These vessels operate primarily offshore and within the Bar.

Operational responsibilities of the USCG Marine Safety Unit (MSU) in Portland include ship inspections, commercial fishing vessel safety, investigations, waterway management, shoreline facility inspections, and aids to navigation. MSU Portland is homeport to the 100-foot inland buoy tender (USCG Bluebell) responsible for serving aids to navigation throughout the Columbia River and nearby waterways.

Each of the USCG stations described above also has access to a mixture of response and trailerable boats and skiffs.

Local Law Enforcement Vessels

In addition to the USCG law enforcement vessels, Oregon State Police and Washington State Police also operated law enforcement vessels on the Columbia River to coordinate the enforcement of commercial fishery and sport angling regulations and for special investigations. County governments along the Columbia River also staff full-time deputies assigned to patrol the waters of the Columbia River and conduct boat inspections. These local law enforcement vessels can be found operating within their respective jurisdictions of the Columbia River and its adjacent waterways.

Pilot Vessels

Pilot vessels are used to transport Bar Pilots and River Pilots to large vessels for pilotage duties described above in *Large Commercial Vessels, Vessel Traffic Management*. The Bar Pilots use one of

two pilot boats, the Astoria or the Columbia, both 72-feet long, for offshore transfers.[22] For transfers within the Columbia River, the River Pilots and the Bar Pilots use the Connor Foss, a 63-foot-by-17-foot aluminum vessel designed specifically for pilot transfers. The Bar Pilots make approximately 3,600 vessel crossings of the bar each year with vessels ranging from 100-foot tugs to 1,100-foot cargo ships. River Pilots pilot vessels upriver from Astoria including along 13 miles of the Willamette River from its confluence with the Columbia River to the seawall in downtown Portland (Columbia River Pilots 2014).

Spill Response Vessels

Three marine spill response vessels are prestaged in the study area at the Port of Astoria. These vessels belong to Marine Spill Response Corporation – Northwest, which is a cooperative that member companies rely on for oil spill response equipment and support.

Tugs

Tugs operating in the study area include those towing or pushing barges from or to destinations beyond the study area and those from tug companies located along the Columbia River. The latter tug companies provide cargo barge movement services between ports along the river; move bunkers (fuel oil barges) to vessels requiring fuel; and provide docking, escort, and other assistance, as described above under *Large Commercial Vessel Traffic, Tug Assistance*. Figure 4 shows tug traffic levels (with and without barges) at eight cross sections in the study area. Tug activity is much higher in the upstream portions of the study area, especially near Longview and Wauna. This activity likely represents tugs transits to and from terminals to provide docking services and tugs shifting cargo barges between ports.

Dredges

Dredging vessels are used to maintain the navigation channel by removing excess sand, silt, and mud that naturally settles to the bottom and on the sides of the channel over time. Maintenance dredging or channel improvement projects, whereby channel dimensions are altered to accommodate larger sizes and/or more loaded commercial vessels, are accomplished by the Corps. In the past, the Corps has used mechanical dredges in the Columbia River (U.S. Army Corps of Engineers 2003:6-6). These types of dredges remove material by scooping it from the bottom and then placing it into a waiting barge or directly into the disposal area, depending upon the location of the dredging. Dredging operations are always advertised to mariners transiting in the Columbia River and are conducted in such a manner as to generally not impede vessel traffic.

2.2.6 Vessel Traffic Management

Management of vessel traffic in the study area is primarily a real-time activity between the Bar Pilots and River Pilots, the vessel master, and the PDXMEX. Deep-draft vessel traffic moves along the navigation channel in a two-way pattern: one lane inbound and one lane outbound. This simplistic layout constitutes the foundation of the traffic management system.

[22] Embarking and disembarking of Columbia River Bar Pilots offshore can be by boat or helicopter. It is the individual pilot's choice whether to use the boat or helicopter for transfers offshore, with the helicopter being used about 70% of the time (Jordan pers. comm. B).

Oversight and active participation in the vessel traffic management process involves coordination of all stakeholders in the Lower Columbia Region Harbor Safety Committee comprising representatives from the following.

- USCG
- The Corps
- Ecology
- Oregon Department of Environmental Quality (ODEQ)
- River Pilots
- Bar Pilots
- Shipping agents
- Terminal operators
- Vessel operators (tug and barge companies)
- Associations (such as PDXMEX, the Columbia River Yachting Association, and the Maritime Fire & Safety Association [MFSA])
- Port and vessel services (such as Clean Rivers Cooperative)

The Lower Columbia Region Harbor Safety Committee is an open forum that allows for the discussion of the membership's vital interests in assuring safe navigation and maritime practices to protect the public, mariners, the environment, and property. The committee meets approximately every 2 months to review old and new information on the agenda and to hear reports from the active committees (bridges, harbor safety plan, navigation, outreach, and executive steering). The committee publishes and maintains a *Lower Columbia Region Harbor Safety Plan* (last edition published January 2013) which provides users of the Columbia River guidelines to the aids to navigation, anchorages, bunkering, dam lockage, incident management and other navigation practices.

2.2.6.1 Pretransit Planning and Scheduling

Large commercial vessels are required to provide an advance Notice of Arrival (NOA) to USCG at least 96 hours before arrival at the bar in most cases, or upon departure from the last port of call for shorter voyages. This information is provided electronically and shared almost instantaneously with the PDXMEX and the Bar and River Pilots.[23]

Upon receipt of the NOA a coordination process is initiated between the pilots and the shipping agent representing the vessel interests. The Bar Pilots and River Pilots work closely with each other and PDXMEX[24] during the pretransit scheduling. The pilots use information provided in the NOA, as well as weather conditions, pilot availability, tidal and river conditions, and anchorage and berth availability to determine scheduling. Federal (USCG, U.S. Immigration and Customs Enforcement)

[23] In addition to serving as an arrival notification the NOA includes vital information about the vessel, voyage information (specifics about the last five ports visited, name and telephone number of a 24-hour point of contact, etc.), cargo information, information about each crewmember and other people onboard, operational condition of equipment, and documentation specifics.

[24] An information and communication center for ports and stakeholders along the Columbia River.

and state agencies (Ecology, ODEQ) will schedule visits to the vessel once it is docked as required for vessel and crew documentation and cargo checks.

For inbound vessels, tracking and coordination begins when the vessel is approximately 2 to 3 hours away from the pilot boarding station (Jordan pers. comm. B). Traffic management for vessels crossing the bar is the responsibility of the Bar Pilots. Decisions on vessel movements are made by the Bar Pilots alone although other considerations by or affecting the Columbia River Pilots could result in delaying a vessel's transit. Bar Pilots typically start their transits approximately 2 hours before high tide.

The Bar Pilots coordinate closely with the USCG on navigation conditions and safety. While only the USCG COTP can close the bar to vessel traffic, the Bar Pilots can suspend traffic movements when the overall circumstances dictate. In assessing navigation conditions, the pilots use these decision criteria. (Jordan pers. comm.)

- Is it safe for the vessel to cross? Factors considered include the expected underkeel clearance, the vessel's maneuverability and horsepower rating, and other aspects of the vessel's condition.
- Can the pilot get on or off the vessel safely?
- Once the pilot is on board, can the pilot boat or helicopter return to base safely?

Some of the factors that could influence a decision are swell and sea height, swell period, current flow direction, wind speed and direction, coastal jet winds in certain circumstances, and timing relative to storm conditions. Low river flow combined with ebb current creates the worst conditions. Movements of larger ships with deeper drafts are influenced more by the tide and current conditions than smaller vessels with a commensurate effect on vessel speed.

The Bar Pilots give the River Pilots a "window of opportunity" for getting an outbound vessel over the bar (Amos pers. comm.). The River Pilots then develop their transit plans to match that window. Transit planning for draft-constrained vessels varies with river flows. For example, during the low-water season, pilots can only count on having sufficient water under keel during one of the daily high tides. Outbound transit plans are developed at least 8 hours and as much as 24 hours in advance. Vessels may be permitted to sail with the maximum freshwater draft of 43 feet if the river level, tide, and conditions permit (Columbia River Pilots 2016).

The decision to sail outbound is more critical than the decision to bring a vessel in. For outbound traffic, once the vessel starts downriver there is no place to stop or turn around unless the vessel is in extremis and requests to anchor; inbound vessels can stop before approaching the bar (Jordan pers. comm. B). Nevertheless, there is a point at which a vessel approaching the bar from sea or from the river is fully committed to the crossing. This is why the pre-transit planning is key to safe passage across the bar in either direction. As discussed in Section 2.2.4.3, *Tug Assistance,* tug escorts for vessel transits in the study area are rare (Rich pers. comm.).

The Bar Pilot–River Pilot exchange location is at Tongue Point near Astoria with the vessel underway. Vessel size is a significant factor in transit planning. The River Pilots typically place just one pilot on each vessel, but in some circumstances, including vessels with a beam greater than 140 feet, two pilots are assigned.

2.2.6.2 Methods for Managing River Traffic

Marine pilots are highly trained mariners who are experts in vessel navigation and the characteristics of a particular waterway. They are responsible for safely maneuvering vessels on the Columbia River. Their expertise is supported by the vessel master's knowledge of their own vessel and how it maneuvers; the use of electronic navigation tools and information provided by those tools; tug assistance, if required; and the existence of inland rules of the road, regulations, and coordination principles specific to the Columbia River.

Pilotage

The Bar Pilots board inbound vessels outside the bar, at a predetermined site suitable for safe boarding, and are responsible for piloting the vessel to Tongue Point, near Astoria. At Tongue Point, the Bar Pilot disembarks and the River Pilot boards. The River Pilot guides the vessel to the terminal until it is safely moored. For departing vessels, the process is reversed.

Upon boarding, each pilot will conduct an initial safety briefing with the vessel's master, exchanging information prior to assuming pilotage duties (Master-Pilot Exchange). This information typically includes the following.

- Any vessel deficiencies
- Drafts fore and aft
- Air draft corrected for trim.
- Location of navigation equipment
- Type of propulsion
- Propeller type and rotation
- Engine notice requirements
- Thruster status/horsepower, if equipped
- Maneuvering speeds of vessel
- Known errors in the gyrocompass
- Any deficiencies or unusual characteristics of the navigation or ship control systems

The Master/Pilot Exchange will also confirm the following.

- The Captain is immediately available at all times.
- An officer fluent in English is to be on the bridge at all times.
- The helm is manned with a qualified helmsman.
- A proper lookout is posted and direct communications are available.
- Anchors stations are sufficiently manned, ready for immediate and controlled release.
- The intended Passage Plan including:
    - Anticipated traffic.
    - Anticipated tides, currents, and weather.

- Speed restrictions.
- Minimum underkeel/airdraft clearances.
- Berthing/unberthing plan.

If, at any time during the transit, it becomes necessary to anchor a commercial vessel for an unexpected reason the USCG COTP will be contacted (contact could be by the vessel master, the shipping agent, or the pilot) to be informed about the specific reason for anchoring. The USCG COTP will direct the anchoring of the vessel upon consultation with the individual master and pilot, the circumstances, and the weather. The Lower Columbia Region Harbor Safety Plan Anchorage Guidelines provide details about the anchorages and raises awareness about potential hazards (local weather patterns, vessel traffic, recreational river usage, etc.) that could affect the decision where to anchor a vessel and how to maintain the vessel safely at anchorage.

The River Pilots work with the tug companies providing tug-assist services in the study area to ensure that appropriate tugs are available upon request. As discussed in Section 2.2.4.3, *Tug Assistance*, tugs are assigned primarily for docking assistance, based on the minimum bollard pull required for a particular vessel type or operation. Pilots requesting tug support also consider other tug features such as type of propulsion, deck machinery, or number of propellers. Section 2.2.4.3 provides information on companies providing tug services in the study area.

Pilotage Tools

Pilots use a variety of tools to manage traffic on the river and rely mostly on Transview 32 (TV32) Vessel Traffic Information System (VTIS) software, LOADMAX software, and back-up AIS towers.

Bar Pilots and River Pilots carry Portable Pilot Units that they use along with installed navigation equipment on vessels to monitor real-time vessel traffic and data on current weather and tidal conditions. To prevent potential groundings of vessels, they also run underkeel clearance programs that have been customized for each class of vessel; the pilots picked the most critical vessel types for the modeling (Jordan pers. comm. B). Input includes the Corps bottom survey data for the navigation channel and vessel maneuvering information, including squat.[25] Other data are received from tide gages and wave buoys located strategically near the bar and mouth of the river.

There are four NOAA data buoys in the area located as much as 287 nautical miles offshore that provide wave forecasts for periods from 1 to 19 hours before the waves reach the mouth of the river. There are also a number of wave buoys managed by the Scripps Institute; the latter measure waves differently than the NOAA data buoys. They generally show greater wave heights than the NOAA data buoys (as much as twice the height), and the Bar Pilots consider them a better indicator of actual conditions. The Bar Pilots generally consider suspending movement when the buoys show significant wave heights of 20 feet. Data are also received from the NOAA Northwest River Forecast Center.

The computer program includes a Columbia River Estuary Operational Forecast System model, which uses the input data to determine current velocity and estimates ship motion in response to

[25] The squat effect is the hydrodynamic phenomenon by which a vessel moving quickly through shallow water creates an area of lowered pressure that causes the ship to be closer to the seabed than would otherwise be expected.

environmental conditions. It collects real time data from monitoring stations on the waterway and provides forecast guidance for water levels, currents, water temperature, and salinity.

The computer program shows the expected underkeel clearance from the bar to Tongue Point at Astoria, which is where the Bar Pilots and River Pilots exchange duties. The Bar Pilots use the output to forecast the conditions that the vessel will encounter. The vessel's installed AIS system provides continuous information on the vessel's speed over the ground, speed through the water, and position in the channel. The pilot can compare that information to the forecast underkeel conditions. Bar Pilots prefer that the clearance be equal to 2 feet plus the expected squat (Jordan pers. comm. B). If the results show that underkeel clearance will be insufficient for a particular transit, then the pilot can adjust start time or transit speed to ensure that there is adequate clearance at each critical point along the route.

Pilot dispatchers and individual pilots continuously monitor waterway traffic and communications, especially AIS data and TV32 data. Pilots can observe and compare predicted conditions and real-time data at any point in the transit, and historically, those predicted and actual conditions match very closely. The pilot dispatchers also monitor anchorage status and availability. The tug company dispatch offices also have AIS- and communications-monitoring capabilities; however, individual tugs do not.

While operating, every pilot has access to Corps survey data that include channel depths, the 43-foot contour, and cross sections, along with NOAA Physical Oceanographic Real-Time System (PORTS[26]) and LOADMAX data, as well as the vessel's own navigation system information displays. Using this information, pilots can predict vessel meeting points and display those locations when two ships are as much as 70 miles apart. The pilots can then adjust vessel speeds to ensure that the meetings take place in suitable locations and avoid the few places on the river where meeting situations must be avoided (Jordan pers. comm.). The River Pilots also monitor shoaling developments and assess how those might affect transit plans.

The River Pilots note that the well-defined edges of the channel create a bank effect for virtually the entire transit that aids navigation and helps keep vessels away from the sides of the channel (Amos pers. comm.).

Washington and Oregon have separate vessel-tracking requirements that they obtain through a shared Columbia River Plan with PDXMEX. Membership in PDXMEX is a requirement for all commercial vessels of more than 300 gross tons and all vessels carrying oil. Individual vessels may also enroll for spill and incident response services through MFSA.

Merchants Exchange of Portland, Oregon

PDXMEX serves as an information and communication center for all of the ports and various stakeholders along Columbia River. By way of a subscription service, PDXMEX provides a monitoring system that allows users to locate vessels on the Columbia and Willamette Rivers. PDMEX also operates a dispatch center that assists in vessel traffic management by coordinating with the River Pilots and Bar Pilots dispatch centers to ensure proper vessel traffic management. PDXMEX is also a central point of contact for vessel agents, who provide necessary shore-side services for vessels.

[26] PORTS measures surface current speeds, water depth, wind direction, and wind speed. Data are transmitted and displayed on the TV32 interface every 6 minutes.

Transview 32

TV32 is real-time, vessel traffic information and management system software that portrays vessel movements and interactions on the river, along with water depth, current flow information, and updated bathymetry charts. It combines the following systems to provide extremely high spatial resolution accuracy: AIS[27], ENC and ECDIS, NOAA nautical charts, NOAA PORTS, and differential global positioning system. TV32 allows pilots to determine vessel meeting points to facilitate informed decision making regarding navigation, anchorage, and traffic coordination.

TV32 is considered a VTIS. In a VTIS, vessel location, course, and speed data are made available directly to vessels operating in the area so that navigation decisions can be made and agreed upon between the pilots. For the most part, this is a "pull" type of system in that the user (pilots) must deliberately access information in order to have situational awareness. For comparison, the Vessel Traffic Service in Puget Sound is managed within a Vessel Traffic Center that is manned by continuously receiving and disseminating navigation safety information to those vessels asking for or requiring it via VHF-FM communications.

LOADMAX

LOADMAX is a system made up of seven computer-connected PORTS gages along the Columbia River, from RM 17 at Astoria, Oregon, to RM 106.5 at Vancouver, Washington. These gages measure water level in real time and are tied into a system that produces daily email forecasts of river stage and velocity at 1-hour intervals, with a forecast horizon of 10 days. Pilots routinely use these data to time river transits. Pilots operating draft-constrained vessels transiting the Columbia River have to adjust the time of their transit to allow for 2 feet of underkeel clearance on the river (Columbia River Pilots 2016).

AIS and Aids to Navigation

The River Pilots have specifically credited AIS towers and virtual aids as important to their navigation. Pilots have two relay towers that allow them to see the entire length of the route and monitor traffic using the waterway. It is a requirement of the International Convention for the Safety of Life at Sea (SOLAS). SOLAS requires that AIS transmitters are active onboard all vessels of more than 300 gross tons, a requirement that River Pilots actively enforce.

Aids to navigation allow vessels to identify and locate other vessels and increase situational awareness of hazards and route features not otherwise physically marked (or would require extra time and resources to mark).

USCG is responsible for maintaining the aids to navigation systems on the Columbia River. The aids include a series of fixed and floating aids, which are visual, aural, electronic or any combination of all three. Visual aids include buoys, beacons, day marks, and lights. In the navigation system in place on the Columbia River entering from seaward, red buoys and marks are kept to starboard, and green buoys and marks are kept to port. Preferred channel markers, buoys, and markers with alternating red and green stripes may also be employed to identify junctions and obstructions and indicate the preferred route to avoid obstruction.

[27] AIS is required on large commercial vessels, vessels over 65 feet, and passenger vessels (33 CFR 64.01 and 164.46). AIS technology ensures that basic identification and movement information for these vessels is available to government agencies, cooperative public/private associations, port managers, and pilots with the most basic computer equipment and an internet (or wireless) connection.

Aural aids (sound-producing devices) include bells, whistles, and fog signals. Bells and whistles are typically buoy-mounted and activated by wave action. Fog signals are shore-based, mounted on buoys or mounted on offshore structures.

Nautical charts depict the location and characteristics of aids to navigation, both fixed and floating. The abbreviations used to describe the aids are specified by the International Hydrography Organization.

Inland Rules and Other Applicable Regulations

The navigation of commercial vessels worldwide is subject to a set of international rules formalized in the Convention on the International Regulations for Preventing Collisions at Sea, 1972, effective July 15, 1977. The rules (commonly called 72 COLREGS) are part of the convention, and vessels that enter the study area, foreign and domestic, must adhere to the rules where applicable.[28] The rules are applicable on waters outside of established navigational lines of demarcation. These COLREGS Demarcation Lines delineate the waters upon which mariners must comply with the Inland and International Rules. The Demarcation Lines for U.S. ports are listed in 33 CFR 80. The Demarcation Line at the Columbia River entrance (between Oregon and Washington states) is a line drawn from the seaward extremity of the Columbia River North Jetty to the seaward extremity of the Columbia River South Jetty.

In 1980, Congress passed the Inland Navigational Rules Act. This legislation set out Rules 1 through 38 constituting the Inland Rules (Rules of the Road) which mariners follow upon passing across the Demarcation Line inland into the Columbia River. The International and Inland Rules are, for the most part, very similar in both content and format.[29]

USCG is responsible for establishing and enforcing the Rules of the Road, which are defined and described in 33 CFR E – Inland Navigation Rules. The primary objective of the Rules of the Road is to facilitate safe maritime travel. All vessels, both recreational and commercial, in the study area are required to understand and comply with the Rules of the Road.

Cooperative Coordination

Cooperative coordination between the Bar Pilots and River Pilots, primarily used in meeting situations on specific portions of the route, is a unique local practice that is an effective method of collision avoidance. As a standard practice, River Pilots avoid meeting situations in the following areas of the river.

- Miller Sands (RMs 22 through 25)
- Skamokawa/Abernathy (RMs 28 through 34)
- Bugby Hole(RMs 39 through 40)
- Bunker Hill (RMs 55.5 through 56.5).
- Longview Bridge (RMs 65 through 67)

[28] Congress adopted the 72 COLREGS as the International Navigational Rules Act of 1977 and other countries signatory to the International Convention similarly adopted the rules.

[29] Annex V to the Inland Rules, Pilot Rules, are for obvious reasons unique to the inland waters of the United States.

In general, the Bar Pilots and River Pilots avoid overtaking situations where one vessel passes another from behind. The Bar Pilots do not engage in cooperative coordination at specific locations on the Columbia River navigation channel; rather, they coordinate with each other to ensure that deep-draft vessels do not pass each other on the bar.

2.2.6.3 Limitations and Restrictions for Vessel Traffic

Commercial vessel traffic on the Columbia River may be affected by weather patterns, river and tidal conditions, and other (smaller) vessel traffic.

Environmental Conditions

Weather along the Columbia River consists of a series of microclimates that have the potential to cause operational issues. Environmental restrictions can result from fog, high winds, and tidal currents.

When coastal fog restricts visibility on the Bar and its approaches, the vessel's master and pilot (if employed) should assess all variables and determine whether it is safe for a vessel to enter the river. In some cases, it may be safer to wait offshore until visibility improves. In situations of restricted visibility, a vessel that is underway on the Columbia River may proceed along its intended passage with caution. Vessels intending to dock in restricted visibility should be able to see the intended wharf for the entire length of the vessel. However, the vessel's master and pilot may assess all variables and determine that the best course of action is to proceed to the dock. Vessels at dock or anchored in a safe anchorage should not commence movement if visibility is less than 0.5 mile unless the master and pilot assess all variables and determine that the vessel can proceed safely.

In all cases, the vessel's master and pilot should evaluate the current and forecasted weather and the impact on vessel movement, and if necessary, delay movement, call for additional tugs, or take other appropriate measures to ensure safe operations. Masters and pilots should consult the Coast Pilot and other sources of local knowledge when transiting high risk areas, and be prepared for strong tides, currents, and weather conditions.

2.2.6.4 Recreational and Fishing Vessels

The USCG is the primary federal maritime law enforcement agency on the Columbia River. Oregon State Police and Oregon county law enforcement (Clatsop County Sheriff Marine Patrol) also patrol on the Columbia River (Oregon.gov 2016). Vessels in these state and local law enforcement units are used to regulate recreational and fishing vessel traffic on the river in accordance with state and local laws.

USCG boards commercial fishing vessels at sea to ensure compliance with safety equipment requirements required by the Commercial Fishing Industry Vessel Safety Act of 1988. The USCG auxiliary conducts dockside inspections of commercial fishing vessels to supplement the at-sea boardings and educate anglers on safety equipment and training requirements. USCG vessels participate with state and local law enforcement in joint operations on a periodic basis to manage vessel traffic and maintain boater safety (U.S. Coast Guard 2014a). For example, during August and September each year, the Coast Guard Auxiliary, in conjunction with USCG Station Cape Disappointment, Clatsop County Sheriff's Office, and Oregon State Police, engage in a Recreational Boating Safety surge operation to educate and inform boaters participating in Columbia River recreational salmon season. USCG also hosts Operation Make Way, a yearly joint recreational boater

education and enforcement campaign, to educate recreational boat users about the need to give way and stay clear of large commercial vessels operating within the Columbia and Willamette navigation channels. The program aligns with the states' and counties' recreational boating safety missions.

2.2.7 Ship Casualty Survey

The information presented in this section is based on data from the USCG (2014) MISLE database (2001 through 2014) (Appendix A, *Navigation Risk Study*). The data are collected for 26 vessel incident types and are not predictive of cargo vessel casualties. Three primary incident types—collision, allision, and a combination of grounding/set adrift—are representative of the navigational incidents that could occur and compare best to the results of the incident modeling (Table 11).

The database notes the severity of each incident and describes vessel damage. Table 11 presents the outcome distribution in three categories—total loss,[30] damaged, and undamaged—for marine incidents that took place between the Columbia River mouth and the Port of Portland.

The results of the data surveys are very similar to those from nationwide incidents in that approximately two-thirds of incidents resulted in no damage, one-third in some damage, and slightly less than 3% in total loss.

Table 11. Incident Severity by Incident Type for Study Area (Total Incidents)

Damage Status	Total Loss (% of Total)	Damaged (% of Total)	Undamaged (% of Total)	Total
Allision	3 (5%)	24 (43%)	29 (52%)	56
Collision	1 (5%)	9 (47%)	9 (47%)	19
Grounding /Adrift	1 (1%)	16 (21%)	59 (78%)	76
Total[a]	**5 (3%)**	**49 (32%)**	**97 (64%)**	**151**

Notes:
[a] Total may not sum due to rounding.
Source: Appendix A, *Navigation Risk Study*

Groundings were the most common type of incident, followed by allisions, then collisions. Although collisions represented less than 13% of total incidents during the survey period, they resulted in the highest severity outcomes, followed closely by allisions; groundings resulted in significantly less severe outcomes (78% of grounding resulted in no vessel damage).

Table 12 presents the distribution of incident severity in the study area for all incidents by vessel type. The table shows that the higher severity events more typically involved smaller craft (e.g., fishing or recreational vessels).

[30] For the purposes of this analysis, *actual total loss*, *total constructive loss: salvaged*, and *total constructive loss: unsalvaged* were combined into a single *total loss* category.

Table 12. Outcome Distribution for All Marine Incidents in the Study Area by Vessel Type

Vessel Type	Total Loss (%)	Damaged (%)	Undamaged (%)	Total (%)
General Dry Cargo	0	1	3	4
Bulk Carrier	0	2	16	18
Ro-Ro Cargo	0	1	1	2
Tank	0	0	2	2
Barge	0	2	7	9
Military	0	1	0	1
Passenger	1	8	7	15
Recreational	1	3	0	3
Fishing	2	5	13	21
Towing	0	7	13	20
Miscellaneous	0	1	0	1
Unspecified	0	1	3	4
Total[a]	**3**	**32**	**64**	**100**

Notes:
[a] Total may not sum due to rounding.
Source: Appendix A, *Navigation Risk Study*

Tables 13 through 15 present the distribution of incident severity by vessel type and by incident type for the study area. These tables show that collisions appear to result in the highest severity outcomes, with 5% resulting in a vessel loss and 47% resulting in damage to the vessel(s) involved in the incident. Allisions have the second highest severity outcomes with 5% vessel loss and 43% damage. Groundings result in only 1% vessel loss and 21% vessel damage.

Table 13. Outcome Distribution for Allisions in the Study Area by Vessel Type

Vessel Type	Total Loss (%)	Damaged (%)	Undamaged (%)	Total (%)
General Dry Cargo	0	4	0	4
Bulk Carrier	0	4	5	9
Ro-Ro Cargo	0	2	0	2
Barge	0	2	14	16
Passenger	0	13	4	16
Towing	0	11	23	34
Recreational	0	2	0	2
Fishing	5	2	4	11
Miscellaneous	0	2	0	2
Unspecified	0	4	2	5
Total[a]	**5**	**43**	**52**	**100**

Notes:
[a] Total may not sum due to rounding.
Source: Appendix A, *Navigation Risk Study*

Table 14. Outcome Distribution for Collisions in the Study Area by Vessel Type

Vessel Type	Total Loss (%)	Damaged (%)	Undamaged (%)	Total (%)
Tank	0	0	5	5
Barge	0	0	11	11
Military	0	5	0	5
Passenger	0	5	5	11
Towing	0	5	11	16
Recreational	5	16	0	21
Fishing	0	11	11	21
Miscellaneous	0	5	0	5
Unspecified	0	0	5	5
Total[a]	**5**	**47**	**47**	**100**

Notes:
[a] Total may not sum due to rounding.
Source: Appendix A, *Navigation Risk Study*

Table 15. Outcome Distribution for Groundings in the Study Area by Vessel Type

Vessel Type	Total Loss (%)	Damaged (%)	Undamaged (%)	Total (%)
General Dry Cargo	0	0	5	5
Bulk Carrier	0	1	28	29
Ro-Ro Cargo	0	0	3	3
Tank	0	0	3	3
Barge	0	3	1	4
Passenger	1	5	9	16
Fishing	0	7	21	28
Towing	0	5	5	11
Unspecified	0	0	3	3
Total[a]	**1**	**21**	**78**	**100**

Notes:
[a] Total may not sum due to rounding.
Source: Appendix A, *Navigation Risk Study*

2.2.8 Marine Oil Spill Survey

Vessel-related oil spills that occurred in the study area from 2004 through 2014 are presented in Table 16 by spill volume and incident type, based on MISLE, SPIIS, and ERTS data. Spill volumes per incident ranged from 0.1 gallon to 1,603 gallons. An average 15.6 oil spills per year occurred during the study period; of these, 84% had a volume of less than 10 gallons. As reflected in Table 16, most of the spills were not related to a vessel incident. Spills greater than 100 gallons occurred at a frequency of 0.4 per year or once every 2.2 years. The average size of these spills was approximately 630 gallons.

Table 16. Oil Spill Incident Count and Frequency—Lower Columbia River (2004–2014)

Incident Type	Oil Spill Incident Count by Spill Volume					Oil Spills per Year
	< 1 gal	1–10 gal	10–100 gal	> 100 gal	Total gal	
Allision	1	-	-	-	1	0.1
Capsize	1	-	-	-	1	0.1
Environmental Damage	123	57	28	6	214	15.3
Grounding	-	-	1	-	1	0.1
Sinking	-	2	-	-	2	0.1
Total	**125**	**59**	**29**	**6**	**219**	**15.6**
Spills per Year	**8.9**	**4.2**	**2.1**	**0.4**	**15.6**	

Notes:
gal = gallons

The vessel-related spill survey was largely confined to the specified period of 2004 through 2014, to develop a baseline representative of existing risk. Additionally, this period provided the best overlap in data available from the three datasets. Larger-scale incidents involving the release of oil have occurred in previous years; however, these events predate legislation targeted at and largely successful in reducing the likelihood of oil spills from vessels or diminishing the impact of a spill should it occur, namely, the enforcement in U.S. waters of the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Oil Pollution Act of 1990. The latter brought about more stringent planning and spill prevention activities than the previous U.S. legislation (the Federal Water Pollution Control Act as amended by the Clean Water Act) and improved preparedness and response capability (public and private), and established a double hull requirement for tank vessels.

2.2.9 Incident Management and Response Systems

The National Contingency Plan (NCP) codified in 40 CFR 300 establishes Federal On-Scene Coordinators (FOSCs) for oil spills and hazardous material releases within the inland zone and coastal environments. The NCP is the foundation document for state, regional, and local planning documents governing pollution response; it provides organizational focus for the related emergencies that can lead to oil spills, such as vessel groundings, collisions, allisions, and fires. [31] Under the NCP, the FOSC is designated as either USCG or U.S. Environmental Protection Agency, depending on the location of the spill. The project vessel route and site are located within the USCG FOSC and COTP zones (Sector Columbia River and MSU Portland hold these authorities). Ecology is the designated state on-the-scene coordinator for spill response (Revised Code of Washington 90.56.020). The Washington Emergency Management Division is the designated State On-Scene Coordinator (SOSC) for natural disasters. The Washington State Patrol or state fire marshal is the designated SOSC for fires. The Washington State Emergency Response system is designed to provide coordinated state agency response, in cooperation with federal agencies for effective clean-up of oil or hazardous substance spills. Within Oregon State, DEQ is the lead agency for oil or hazardous material spills. The Oregon Office of Emergency Management coordinates support from other state agencies, when required, and the Office of the State (Oregon) Fire Marshal provides hazardous

[31] Washington and Oregon legislative and regulatory requirements for state oil spill contingency plans applicable to vessels calling under the Proposed Action are listed in Table 1.

materials/fire incident response coordination and support from unaffected state jurisdictions when a situation exceeds local response capabilities.

The Northwest Area Contingency Plan (ACP) is the regional planning framework for oil and hazardous substance spill response in Washington, Idaho, and Oregon. Representatives from the federal and state agencies listed here and local governments plan for spill response emergencies together and come together to implement the ACP when an incident occurs. The plan includes but is not limited to the following elements.

- A description of the area covered by the plan, including the areas of special economic or environmental importance that might be damaged by a spill.
- Roles and responsibilities of an owner or operator and of federal, state, and local agencies in spill response and in mitigating or preventing a substantial threat of a discharge.
- A link to an online list of equipment available to respond to oil spills.
- Site-specific geographic response plan (GRP).

GRPs are part of the ACP. Each plan is written for a specific area, including the Lower Columbia River, and includes tactical response strategies tailored to a particular shore or waterway at risk of injury from oil. GRPs have two main objectives: to identify sensitive resources at risk of injury from oil spills and to direct response actions related to sensitive resource protection during the initial hours of a response. Strategies in the plan are deployed by a part of the response organization as soon as potential impacts (generally with real-time weather data and oil spill trajectories) are evaluated even while other parts of the response organization may still be addressing immediate concern of controlling and containing the source of a spill.

In addition to the ACP and the GRP governing spill response within the Lower Columbia River the Lower Columbia Region Harbor Safety Committee[32] meets on a regular basis to discuss waterway issues in the river, including emergency procedures in case of a vessel incident. The standards, guidelines, and protocols agreed upon by members of the committee are promulgated and maintained within the Harbor Safety Plan (HSP). The HSP complements existing regulations by advising mariners of unique conditions and requirements associated with transiting the Lower Columbia River. The HSP includes incident management guidelines, emergency communications, notification requirements in case of an oil spill, steps to take in case of a vessel grounding, vessel collision, bridge allision, and mechanical or equipment failures.

These government and agency plans all help coordinate response efforts by the responsible party (the spiller, in this case the vessel owner/operator) and federal and state agencies.

Since the proposed coal export terminal would not transfer oil to project-related vessels in bulk, the Proposed Action would not be required to submit a federal facility response plan for oil spills. The coal export terminal would likely be a designated waterfront facility under 33 CFR 126.13, which means that the coal export terminal would be designated for handling, storing, loading, and discharging a hazardous material whose transport is subject to the Dangerous Cargoes Regulations contained in 49 CFR 170–179.

[32] The Lower Columbia Region Harbor Safety Committee comprises public and private stakeholders with vital interest in assuring safe navigation and maritime practices on the Columbia River.

Under SOLAS, coal is defined as dangerous goods in solid form when in bulk. Consequently, this designation requires that the Applicant meet certain conditions at the project area (applicable USCG regulations are contained in 33 CFR 126.15) including the following.

- Fire extinguishing equipment (automatic sprinklers, hydrants, hose connections, and firefighting water supplies) must be available and maintained in adequate quantities and locations.
- The location of fire appliances such as fire hydrants, standpipes, hose stations, fire extinguishers, and fire alarm boxes must be conspicuously marked and readily accessible (according to National Fire Protection Association).
- Warning signs must be posted.
- If coal is transferred between sunset and sunrise then the Applicant must install outdoor lighting that adequately illuminates the transfer work area.
- Access restrictions whenever the cargo is transferred or stored at the terminal.
- Security measures must be in place to deter and detect unlawful entrance; to detect and report fire hazards, fires, and releases of dangerous cargo and hazardous materials.

The security measures described above could be guards or "equivalent controls" such as alarm systems, closed-circuit television cameras and monitors, or a combination of both. In case of an emergency the situation must be reported to USCG personnel as soon as they are discovered. Since the facility is not a covered facility under Washington State law for oil spill contingency planning, the Applicant is not required to have an oil spill response plan under state law.

Vessel owners/operators of the project-related vessels would be required to prepare and submit oil spill response plans under federal requirements (33 CFR 155.5010-155.5075) and state requirements (Washington Administrative Code 173-182 and Oregon State Administrative Rules 340-141) to ensure that resources, including equipment, are in place for a spill of the vessel's fuel oil and of any oil carried as secondary cargo. The Non-tank Vessel Response Plans would include notification procedures, shipboard spill mitigation procedures, shore-based response activities, a list of contacts, and training and exercise procedures.

The vessel owner/operator would be required to have available through contract or other approved means an oil spill removal organization and a spill management team. It is customary for owners/operators of vessels to contract with cooperative organizations that specialize in oil spill response and personnel that maintain, train, and exercise the equipment. MFSA generally serves this role in the Columbia River and has access to oil spill response equipment on the river system (through a sharing agreement with Clean Rivers Cooperative).[33]

The MFSA vessel response plan is an umbrella plan for enrolled vessels entering the Columbia River. MFSA recently updated the Master Oil Spill Contingency Plan for Covered Vessels and submitted it to Ecology for approval. Ecology has approved the update.

[33] Working with federal granting agencies and local jurisdictions, Astoria Fire Department/Port of Astoria, Clark County Fire & Rescue, Scappoose Rural Fire District and Vancouver Fire Department achieved funding to acquire new Quick Response Vessels in 2014. The Quick Response Vessels provide enhanced response capabilities between Vancouver and Astoria.

2.2.9.1 Oil Spill Incident Response

This section describes the incident response system in place on the Columbia River, as spelled out in the MFSA response plan.

USCG is the FOSC for oil and hazardous materials spills on the Lower Columbia River. Ecology and ODEQ are the SOSCs for spills and impacts on state waters. These agencies and the responsible party (as represented by the MFSA for a covered vessel) represent the Unified Command. The Unified Command coordinates responses, mitigation, and cleanup efforts for spills on the Lower Columbia River to protect public health and safety, response personnel, and the environment (Maritime Fire & Safety Association 2013).

For vessels covered under MFSA, these general steps are followed when a bunker spill occurs.

1. Ignition is shut down, personnel are warned, containment is initiated, and vessel is secured.
2. Vessel representative initiates MFSA and federal and state response plans by notifying the Merchants Exchange, USCG, and state emergency management offices.
3. Vessel representative designates MFSA as Incident Commander representing company interests.
4. MFSA representative assesses situation, makes necessary notifications for response resources, and participates in Unified Command.
5. MFSA returns control to the vessel representative for completion of clean-up, damage assessment, decontamination, disposal, and demobilization.

The contract between the vessel owner/operator and the MFSA and the incident specifics determine when steps three and five take place.

2.2.9.2 Shipboard Fire Incident Response

Under the Federal Fire Prevention and Control Act of 1974, fire prevention remains a local and state responsibility (Northwest Area Committee 2015). The local fire jurisdiction is the first responder to a shipboard fire. If the incident is beyond the local jurisdiction's capacity, mutual aid resources[34] are requested through the MFSA Fire Protection Agencies Advisory Council. The council's mutual aid network extends to 13 fire agencies along the Lower Columbia and Willamette Rivers. If local and mutual aid resources are exhausted, the local fire chief requests assistance from the state emergency management office. With appropriate approvals, the state fire chief (Oregon) or state fire marshal mobilization coordinator (Washington) takes control over the response (Office of State Fire Marshal 2015; Washington State Patrol 2015).

The USCG COTP will act as the FOSC if there is a shipboard fire outside a fire agency's jurisdiction but within the Sector Columbia River COTP zone, or if a vessel fire is treated as a search-and-rescue case (Northwest Area Committee 2015).

2.2.9.3 Collision and Grounding Incident Response

For collision and grounding incidents, the vessel must immediately secure all necessary watertight closures in accordance with the ship's emergency procedures and contact the USCG COTP, Ecology, and ODEQ. The USCG COTP may establish a communications schedule and request the vessel to

[34] Local and state firefighting organizations enter into reciprocal agreements to provide mutual aid when resources are overwhelmed.

update its situation periodically. If the waterway is blocked or needs to be closed, a safety marine information broadcast will be issued, including providing information of the incident, including location, vessel type and cargo, incident description, and other details.

In response to a collision, USCG response personnel and state investigators may respond to the scene for initial assessment and on-scene communications and supervision and may form a Unified Command. The Unified Command will instruct the responsible parties on standard procedures for separating vessels, if joined, and moving them to an available dock, anchorage, or directly to a shipyard for repairs. The USCG COTP will work with the vessel and Unified Command to initiate pollution response measures as necessary. In most cases, a surveyor will be required to inspect damage and verify repairs.

In response to a grounding, the objective is to refloat the vessel and minimize damage to the vessel and environment. Upon grounding, the responsible party must contact the USCG COTP to provide vessel and incident information and a safety marine information broadcast is issued. The responsible party must submit a salvage plan to the USCG COTP or Unified Command for approval prior to attempting to refloat. If calculations determine that the vessel cannot be refloated at the recorded draft just prior to grounding the lightering[35] of vessel cargo and/or fuel may take place to lighten the vessel. This transfer of coal or fuel would be completed only after all other options were evaluated for refloating the vessel and the salvage and lightering plan is approved by the USCG.[36] Most likely, approval of the salvage and lightering plan will include a requirement that the responsible party activate the vessel response plan to mitigate any pollution threat prior to refloating. The type of bottom (mud, sand, gravel, rock) and the speed of the vessel (underway, maneuvering with tugs, dragged anchor in high winds) prior to grounding will most often determine the severity of the incident and the precautions to be taken until the vessel refloats. In most cases, a surveyor is required either on scene or to inspect damage and verify repairs.

[35] Lightering is the process of transferring cargo between vessels of different sizes, usually between a barge and a bulker or oil tanker.

[36] Depending on the severity of the grounding (determined by length of time the vessel is grounded, whether or not the navigation channel is blocked, and if lightering must take place to refloat) a Unified Command may be formed. In this case the Unified Command would review and approve the salvage and lightering plan.

Chapter 3
Impacts

This chapter describes the impacts related to vessel transportation that would result from construction and operation of the Proposed Action or the ongoing conditions under the No-Action Alternative.

3.1 Proposed Action

Potential impacts related to vessel transportation from the Proposed Action are described below. The Proposed Action would load 70 vessels a month or 840 vessels a year. This equates to 1,680 vessel transits in the Columbia River. Proposed Action-related cargo vessels would be required by federal and state law to meet vessel standards and plan requirements. These include structural, fire-fighting and personnel requirements as well as oil spill contingency and response plans as previously described

3.1.1 Construction: Direct Impacts

Construction of the Proposed Action would result in the following direct impacts.

In-water dock construction (pile-driving, dredging, and general construction of above water elements) would occur over a 6-month to 1-year period (Grette Associates, LLC 2014:12). For this work, barges would be located near the proposed docks (Docks 2 and 3). The barges would be positioned outside of the navigation channel to not impede vessels traveling within the channel. The barges would also be placed outside of the area used by vessels accessing Dock 1, so they would not affect these activities. Additional information on dredging and pile driving is included in the SEPA Water Quality Technical Report (ICF 2017a).

3.1.2 Construction: Indirect Impacts

Construction of the Proposed Action would result in the following indirect impacts.

If supplies and equipment for construction are delivered to or removed from the project area by barge, there would be a temporary increase in barge activity in the study area.

The Applicant has identified three construction-material-delivery scenarios: delivery by truck, rail, or barge. If material is delivered by barge, it is assumed that approximately 1,130 barge trips would be required over the construction period. Approximately two-thirds of the barge trips would occur during the peak construction year, assumed to be 2018. Approximately 750 barge trips in the study area would be required during the peak construction year to deliver construction materials. Because the project area does not have an existing barge dock, the material would be off-loaded at an existing dock elsewhere on the Columbia River and transported to the project area by truck.

Barges are shallower in draft and could transit the Columbia River navigation channel during periods of low water to avoid interfering with larger vessel traffic. Coordination would take place with the River Pilots prior to and during transit. Moreover, the construction barges would be

transiting a portion of the navigation channel during construction near the project area and not the entire study area. Therefore, impacts on vessel traffic in the study area as a result of construction-related barge traffic would be low because barge traffic would avoid interfere with larger vessels and would only traverse a portion of the Lower Columbia River.

3.1.3 Operations: Direct Impacts

Operation of the Proposed Action would result in the following direct impacts. The Proposed Action would load 70 vessels a month or 840 vessels a year. This equates to 1,680 vessel transits in the Columbia River.

The Proposed Action would add two docks (Docks 2 and 3) and eventually have the capacity to export 44 million metric tons of coal by vessel. Loading coal onto vessels for export is the only activity proposed for the new docks. Vessel loading would be performed using an electric-powered, single-traveling shiploader. One shiploader would be installed on each new dock. Each shiploader would have an average capacity of 6,500 metric tons per hour. At maximum throughput, an average of 70 vessels per month (an average of over two per day) would be loaded at the new docks. The berths for the new docks are expected to be occupied by Proposed Action-related vessels 365 days per year.

River Pilots would pilot the incoming and outgoing vessels (from Astoria inland and vice versa) and direct docking and undocking maneuvers. At least two tugs would be used to assist with docking and undocking maneuvers for each arriving and departing project-related vessel (Gill pers. comm.). Therefore, at least two tugs would be active near the docks four times per day on average. The pilot determines the appropriate size and horsepower of the tugs depending on a number of factors such as the size of the vessel, weather conditions, and currents at the time of maneuvers (Gill pers. comm.).

Docks 2 and 3 would be designed to accommodate dry bulk cargo ships up to 830 feet long and 130 feet wide, which would accommodate standard Panamax vessels and the somewhat smaller Handymax vessels. The berths at Docks 2 and 3 would have a depth of 43 feet, which is the depth at which the Columbia River navigation channel is maintained (U.S. Army Corps of Engineers 2015b).

The expected fleet mix is 80% Panamax and 20% Handymax vessels. Table 17 contains the size and dimensions of these types of vessels assumed for the risk analysis (Appendix A, *Navigation Risk Study*).

Table 17. Vessel Sizes and Dimensions for Panamax and Handymax Vessels Assumed in the Risk Analysis

Vessel Class[a]	Deadweight Tons	Length Overall (feet)	Beam (feet)	Draft (feet)
Handymax	46,101	600	106	36.1
Panamax	68,541	738	106	43.6

Notes:
[a] These specifications chosen to represent the size and dimensions for Panamax and Handymax class vessels are representative of an "average-sized" Panamax class vessel and an "average-sized" Handymax class vessel.
Source: Appendix A, *Navigation Risk Study*

Operational impacts related to the Proposed Action are based on the following assumptions:

- The River Pilots anticipate turning the ships in the project area in loaded condition—in preparation for departure, as opposed to turning downstream upon arrival (Gill pers. comm.).[37] Thus, inbound ships would approach Docks 2 and 3 in ballast (headed upstream), maneuver out of the navigation channel toward the dock, and align parallel to the dock, docking with the assistance of tugs. Figure 9 depicts typical maneuvering of a ship approaching the downstream berth, Dock 3, with a Panamax ship already at Dock 2.
- Pilots estimate that operations at the project area (Docks 2 and 3) would require the two assisting tugs to have bollard pull ratings of at least 30 tons operating ahead and at least 22.5 tons operating astern. Those tugs would be in the 3,000 to 4,000 horsepower range (Gill pers. comm.). Pilots would determine tug assistance needs.
- The River Pilots anticipate that they would turn vessels off the dock, as opposed to using the turning basin upstream of the project area (Gill pers. comm.). If river conditions were not suitable or the vessel was too long, however, they would use the turning basin. A typical departure of a loaded vessel (Figure 10) with the assistance of the tugs, would involve moving the bow out into the channel, while keeping the stern near the dock to give the pilot accurate positioning of the vessel during the turn, and allowing the current to rotate the bow until the vessel points downriver and can begin moving downriver. The width of the channel at this point is approximately 1,200 feet, which provides a turning area approximately 1.6 times the length of the vessel.
- Currently, maneuvering a vessel to the existing berth (Dock 1) upstream of the proposed docks can be challenging (Amos pers. comm.). The outflow from the bank at that dock creates the need for more tugs, vessel power, and time to dock safely. Pilots expect that conditions for Docks 2 and 3 would require similar operations as at Dock 1 (Gill pers. comm.). Pilots would be aware of this issue and would consider it during planning and operations.

[37] Currents in the river at the project area are typically directed downriver or ebbing due to the river flow overriding the tidal currents. It is expected to be more efficient and safer to dock the ship heading into the current using the forward power of the engines which is stronger than the vessel's backing power. When the loaded vessel leaves the dock with the bow pointing upstream, the currents assist the vessel turning in the channel by pushing the bow around and downstream. Pilots are responsible for vessel movements and would determine the appropriate actions for vessel arrivals and departures.

Figure 9. Typical Approach of a Panamax Bulk Carrier in Ballast Condition to Dock 3

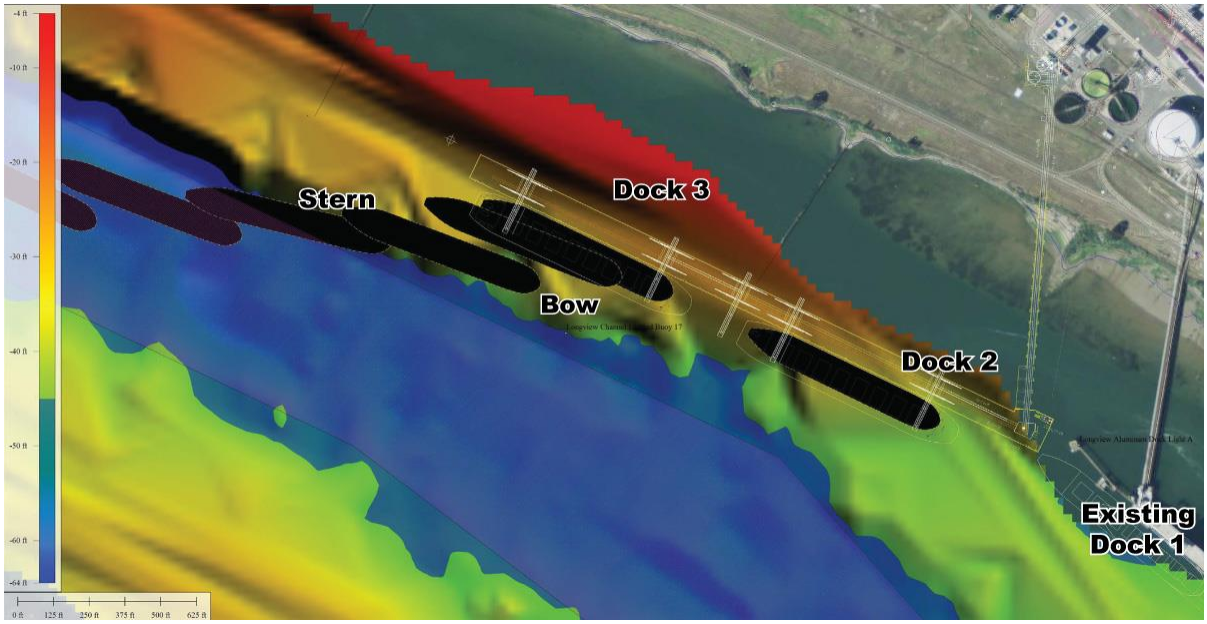


Figure 10. Typical Departure of a Panamax Bulk Carrier in Loaded Condition from Dock 3

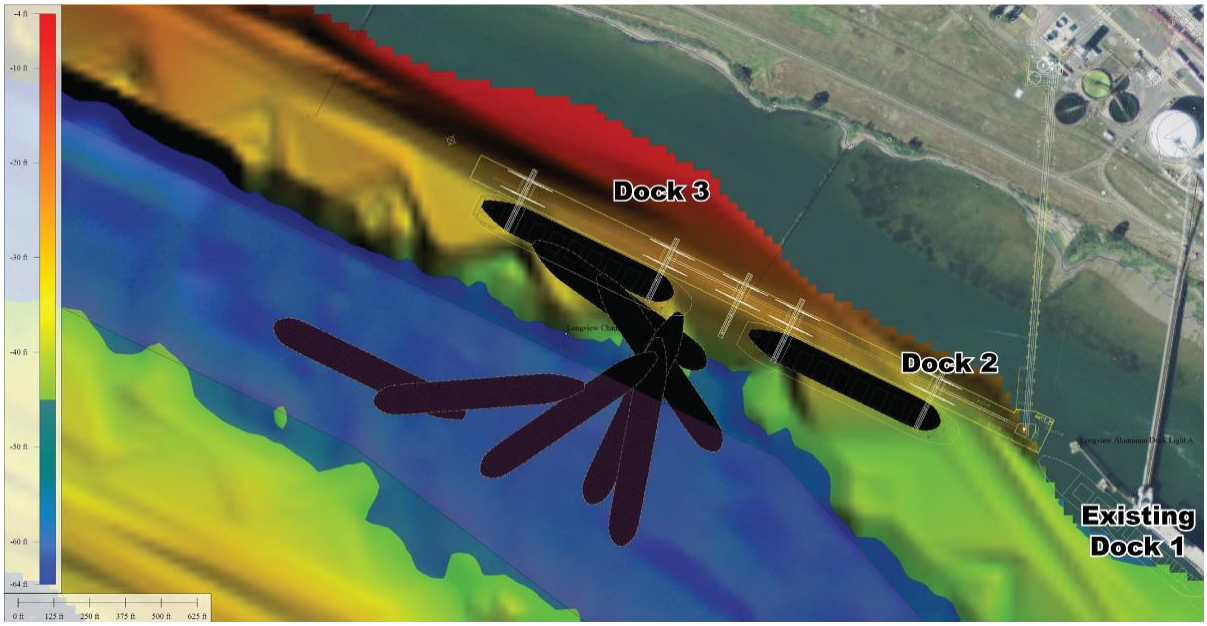
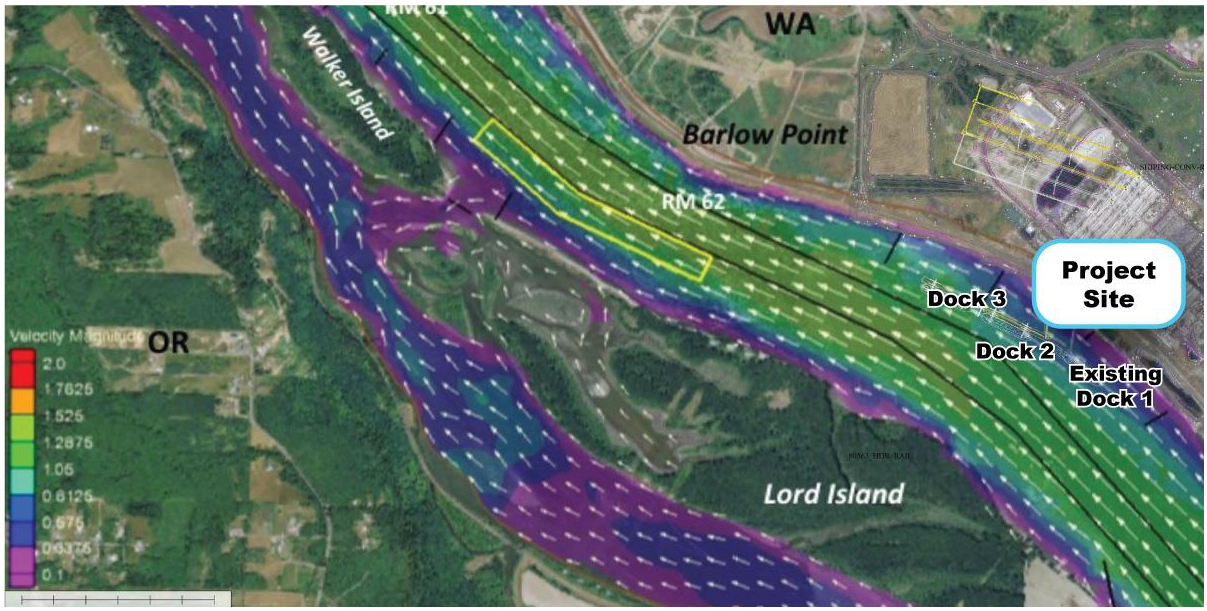


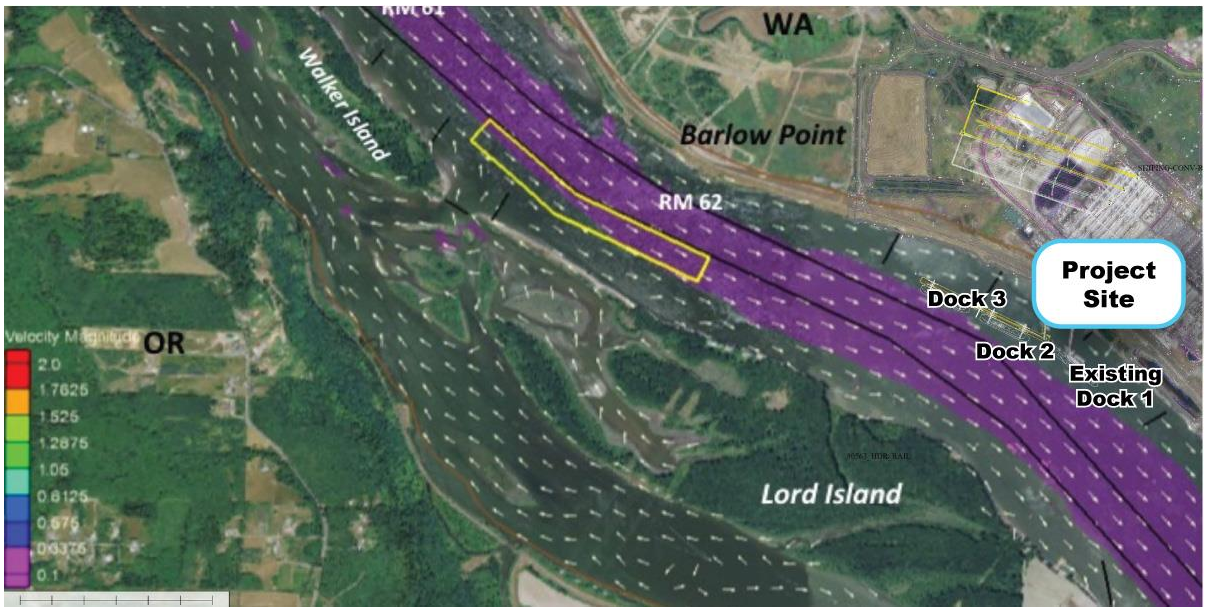
Figure 11 shows the computed current vector plot of the peak ebb period in mid-June 2009. This figure shows that the currents are relatively parallel to both the existing and proposed berths except at the upriver end of Dock 2 where the currents have a component that would push the ship onto the dock and could make moving off the dock more difficult. The magnitude of the current at Dock 1 is approximately 0.7 to 0.8 feet per second (fps), while at the down-river berth, Dock 3, the velocity magnitude would be approximately 1.5 to 1.8 fps.

Figure 11. Computed Peak Ebb Flow in Mid-June 2009



A plot of the flood currents during a low river discharge period is shown in Figure 12. The velocity vectors are aligned with all three berths with this flow, and the magnitudes of the velocities are very low, below 0.1 fps.

Figure 12. Computed Peak Flood Flow in Early October 2009



These vector plots of depth-averaged velocities do not provide any evidence showing why the pilots would have difficulty moving a ship onto the existing berth. However, the computational grid of these plots indicates that the data resolution in the area of the docks is low, and it is questionable as to whether the dikes along the shoreline near the docks are included in the computational grid.

These dikes could have a significant impact on the velocities along the shoreline that could cause eddies to form, as well as redirection of the currents away from the shoreline.

Should an incident occur during operations, it would most likely be attributable to increased risk of a vessel fire at the dock, an increased risk of an oil spill while at the dock, or an increased risk of a vessel allision while at the dock. Each of these situations is discussed below.

Increased Risk of a Vessel Fire While at Dock

Coal, in any form, is a combustible material, making it susceptible to a variety of ignition scenarios. Coal fires during transfer and loading operations are typically caused by one of two sources of ignition: the coal itself (self-ignition) or the conveyor belt used in the transport of coal (e.g., over-heating due to damaged bearings, roller, belt slip). Safety requirements prohibit open flames near coal-loading operations.

A fire in the vessel's machinery spaces or accommodation areas is a potential emergency scenario. Vessel design standards, fire equipment requirements, and crew training are in place to prevent or to facilitate rapid response to a vessel emergency while at the dock. All of these standards and requirements are implemented in accordance with SOLAS in foreign and domestic cargo vessels (and codified in U.S. regulations) and enforced by USCG. Therefore, an onboard emergency is unlikely to affect resources other than the vessel itself.

A bulk carrier such as the project-related vessels would have the following fire prevention and response features.

- Structural fire protection, including certain bulkheads constructed to prevent the passage of flame and smoke for one hour. Other bulkheads must be constructed of incombustible materials. Current regulations require that risk of fire hazards be eliminated as much as possible in other construction features of the vessel (46 CFR 92).
- Structural insulation around compartments containing the emergency source of power (such as the ship's service generators). Other approved materials capable of preventing an excessive temperature rise in the space may also be used to eliminate the spread of a fire that originates in this type of compartment (46 CFR 92).
- Fire pumps, hydrants, hoses, and nozzles for the purposes of onboard firefighting. In additional certain spaces must have approved hand portable fire extinguishers and semiportable fire extinguishing systems (46 CFR 95).
- Officers and crewmembers with a basic level of training that includes fire prevention and firefighting (U.S. Coast Guard 2014b).

Within the hold of a vessel, coal can be susceptible to ignition due primarily to self-heating and/or the creation and subsequent ignition of certain gases, including methane and hydrogen. Fire-detection systems including carbon monoxide detection and infrared scanning would be in place to monitor and minimize the potential for onboard coal fires. Additionally, manual scanning by workers would enhance built-in mechanical detection systems. Automated fire suppression systems that are activated in the early stages of fire development are critical to reducing the potential for flame spread. These typically include water sprinklers combined with a fire-extinguishing agent such as wetting agents or foam. Therefore, an onboard emergency is unlikely to affect resources other than the vessel itself.

Increased Risk of an Oil Spill While at Dock

An oil spill at the dock would most likely occur during bunkering (i.e., a ship receiving fuel while at the dock). The Applicant has committed to not allowing vessel bunkering at Docks 2 and 3; therefore, there would be no risk of an oil spill at docks associated with oil transfers under the Proposed Action. Oil spill risks that might occur during transit are addressed under Section 3.1.4, *Operations: Indirect Impacts*.

Increased Risk of a Vessel Allision at the Dock

An allision occurs when a vessel strikes a fixed structure, such as a project-related vessel striking the proposed docks at the project area or another vessel striking a project-related vessel at berth.

Pilots sometimes experience difficulties getting a ship to the berth at Dock 1, which is just upstream of the proposed Docks 2 and 3. The reason for this cannot be determined from the examination of current vectors provided by the Corps, making it difficult to link the maneuvering challenges at Dock 1 with potential maneuvering challenges due to currents and river flow at the proposed docks. A vessel allision with the dock is a potential outcome when there are strong currents near the dock during vessel maneuvers. An allision may also occur if there were a loss of steering or loss of propulsion during transit or maneuvering at the dock. Despite the uncertainty associated with vessel maneuvers at the dock, the likelihood of a vessel allision is lessened due to the presence of tug power while docking and undocking.

Risk of allision could also involve another vessel striking a project-related vessel while the vessel was at berth. All large commercial vessel traffic bound for Longview or ports further upriver, including the Port of Portland and Port of Vancouver, pass the project area. Based on incident modeling (Appendix A, *Navigation Risk Study*), the likelihood of an allision under the Proposed Action is once in 39 years (2028) and once in 25 years (2038). However, as noted in Section 2.2.7, *Ship Casualty Survey*, most allisions do not result in substantial consequences, such as a total vessel loss. Between 2001 and 2014, 5% of allisions resulted in substantial consequences, such as total vessel loss, and all of these events involved fishing vessels only.[38]

3.1.4 Operations: Indirect Impacts

Operations of the Proposed Action would result in the following indirect impacts.

As noted above, all large commercial vessel traffic bound for ports further upriver pass the project area. Transiting project-related vessels could affect or be affected by other vessel movements in the study area. Moreover, increased vessel traffic could result in changes in wake patterns, increased propeller wake, increased underwater noise, and vessel emissions that could affect environmental resources. These impacts are addressed in the SEPA Water Quality Technical Report (ICF 2017a), SEPA Noise and Vibration Technical Report (ICF and Wilson Ihrig 2017), and SEPA Air Quality Technical Report (ICF 2017b). Impacts on the vessel transportation system and related environmental resources along the Columbia River navigation channel due to vessel operations are considered to be indirect impacts under SEPA.

[38] The data also show that between 2001 and 2014, 4% of the allisions resulting in some damage were bulk carrier allisions.

As discussed in in Appendix A, *Navigation Risk Study*, vessel traffic for existing conditions (2014) was based on AIS data. Table 18 compares large commercial vessel traffic under existing conditions (based on 2014 AIS data), the No-Action Alternative (2028), and with the Proposed Action (2028). Vessel traffic unrelated to the Proposed Action was projected using a 1% growth rate and is included for 2028, the year of full build-out.

Table 18. Existing and Projected Large Commercial Vessel Traffic in the Lower Columbia River

Condition	Vessel Transits per Year
Existing Conditions (2014)	3,862
No-Action Alternative (2028)	4,440
Proposed Action (2028)	6,120

Notes:
Source: Based on 2014 AIS data for Cargo/Carrier, Tanker, Tug, and Passenger vessel types; a projected growth rate of 1% was applied to the 2014 transits to obtain the 2028 vessel transits under the no-action alternative; and proposed vessel transits (1,680) were added to the no-action transits to obtain transits with the Proposed Action.

For the purposes of incident modeling, the baseline traffic year of 2014 was selected to represent relatively recent traffic conditions on the river. The VTIS in operation in the study area and other risk-reduction factors were considered in the analysis of the potential for increased risks during vessel transit as discussed in Appendix A, *Navigation Risk Study*.

The vessel incidents evaluated in the modeling include allision, collision, grounding (powered or drift), and fire/explosion, (Section 2.2.7, *Ship Casualty Survey*). Incident modeling considered the interaction between project-related vessels and other large commercial vessels using the channel, as well as smaller vessels (e.g., recreational boats or commercial fishing vessels) not limited to the channel. The potential increases in these risks are discussed below.

Increased Risk of a Vessel Allision (with a Fixed Object) during Transit

For vessels outbound from the project area, no fixed structures or waterfront facilities are close to the edge of the navigation channel until the Port Westward dock at RM 53 (Figure 3) and after that a small barge terminal dock at RM 36. Thereafter, there are no facilities or structures until reaching the Port of Astoria, and those are well clear of the channel. The Astoria-Megler Bridge is the next structure encountered, and once past that, the remaining structures are the jetties at the entrance of the river.[39] Due to the minimal impediments to vessel traffic within the navigation channel, the likelihood of a project-related vessel alliding with a fixed structure while in transit is low and was not quantitatively evaluated in the risk assessment (Appendix A, *Navigation Risk Study*). As shown in Table 11, 56 vessel allisions occurred in the study area from 2001 to 2014 (compared to an average of more than 3,000 large commercial vessel transits annual during this time). Of these, just over half (52%) resulted in no damage. Of the remaining incidents, 43% resulted in some level of damage and 5% resulted in total loss[40]. Therefore,

[39] Since they are piloted, large commercial vessels have an advantage over fishing and recreational vessels as pilots are specifically trained to keep a large commercial vessel from alliding with a known object in the navigation route, including a bridge. Approximately 30 years ago, there was an allision at the Astoria-Megler Bridge that involved a piloted vessel. Since this incident, Bar Pilots have implemented risk-reduction measures to reduce the probability of allisions at the bridge: they avoid meeting other piloted vessels at the bridge, observe weather and river current conditions, and review weather forecasts before transiting under the bridge (Appendix A, *Navigation Risk Study*).

[40] All total losses resulting from allision were to fishing vessels.

although there would be an increase in risks compared to existing conditions, the overall risk of a project-related vessel resulting in an allision to or from the project area would be low.

Increased Risk of Other Incidents during Transit

While a collision may seem to be a more likely incident scenario in the two-lane channel, the vessel casualty data (Table 11) and incident modeling results (Table 19) show that groundings, specifically powered groundings, are more likely under all traffic scenarios.

As presented in Table 19, the Proposed Action would result in an increased potential for incidents compared to both existing condition (2014) and the No-Action Alternative (2028). The predicted increase in incidents is primarily because of the increase in the number of vessels transiting the Lower Columbia River. It should be noted that the consequences of a modeled incident can vary greatly from no damage to total loss and that the increase in likelihood alone is not representative of the magnitude of the potential consequences. In other words, not all of these incidents are likely to result in notable damages. For example, of the 151 reported incidents that occurred in the study area from 2001 through 2014 (Table 11), over half (64%) resulted in no damage, 32% resulted in damage, and 3% resulted in total loss.

Additionally, it is important to note the incident frequencies predicted for existing conditions are from a single year (2014); while this year accounts for higher vessel traffic compared to more recent years, it does not account for the wide variation in vessel traffic that has occurred prior to the recession or the historical highs for traffic on the Columbia River. Further, because the Proposed Action would ramp up over time, it is important to note that comparing the addition of 840 vessels to the existing condition is a conservative approach. Therefore, it is important to also consider how the No-Action Alternative would compare to the existing condition and how the Proposed Action would compare to the No-Action Alternative. As shown in Table 19, a relative increase in the likelihood of all incident types would occur over time unrelated to the Proposed Action.

Table 19. Predicted Incident Frequencies per Year in the Study Area

Scenario	Predicted Collision Incident Frequency	Predicted Powered Grounding Incident Frequency	Predicted Drift Grounding Incident Frequency	Predicted Fire/Explosion Incident Frequency	Total Incident Frequency
Existing Condition (2014)	1.94	11.8	2.8	0.0032	16.6
No Action (2028)	2.53	13.6	3.3	0.0037	19.4
Proposed Action (2028)	3.06	15.2	3.9	0.0043	22.2

Notes:
Source: Appendix A, *Navigation Risk Study*

Collisions. As noted in Section 2.2.6.2, *Methods for Managing River Traffic*, the River Pilots and Bar Pilots generally avoid overtaking situations where one vessel passes another from behind. Thus, the most likely collision scenario is an inbound vessel meeting an outbound vessel. The River Pilots have identified specific points on the river where conditions are not suitable for vessels to pass each other, and they carefully manage transits to avoid two vessels meeting in

those locations. Instead, they manage the vessel transits so if they do need to pass each other, it is done in a safe area. Avoidance of these areas was taken into consideration in the calculation of incident frequencies (i.e., estimating the likelihood of a collision due to the Proposed Action) in the incident modeling.

The most likely collision scenarios are bow-to-bow and side-to-side contact involving two large commercial vessels transiting the navigation channel. Bow-to-side is a possibility, but the channel width and the sizes of the vessels would likely make it more of a glancing impact rather than a straight on "T" impact.

Bow-to-bow contact is generally viewed as the easiest type to avoid because the target area is small and either vessel can act independently to avoid it. Also, a vessel's bow is its strongest structural point and bow-to-bow collisions would not be expected to result in cargo hold damage or fuel oil release. In addition, the hydrodynamic interaction between ships meeting causes the bows to be pushed away from each other as they approach.

Side-to-side or a glancing bow-to-side collision could result in damage to the hull, but the likelihood of catastrophic damage is relatively low. For dry cargo vessels—including bulk carriers—it is unlikely that any coal cargo would be released into the water in the event of an angle of impact less than 22.5 degrees (Appendix A, *Navigation Risk Study*). For tank vessels—including ATBs carrying oil in bulk—the risk of an oil spill cannot be ruled out; however, modern tank vessel design standards, including double hull construction of tankers, significantly reduce that potential.

As noted in Section 2.2.5, *Other Vessel Traffic*, the Columbia and Willamette Rivers provide important fisheries for commercial, tribal, and recreational purposes. Although these smaller vessels are not restricted to the navigation channel, they do often cross the river to access various locations within the study area. Particularly during periods of high fishing activity, there would be an increased chance for a vessel collision to occur. However, in general, because these smaller vessels are not restricted to the channel and must by law yield to oncoming large commercial vessels, the potential for a collision between a smaller vessel and a project-related vessel would be low. Although it is not possible to predict the types of vessels that might be involved in a future incident, the incident modeling does show a very small increase in the potential for collisions involving fishing vessels (0.05 incident per year) and recreational vessels (0.01 incident per year).

Groundings. The River Pilots noted that there are few areas where waterway conditions create a substantial chance for a grounding to occur. Awareness of river conditions and timing vessel transits with tidal heights and currents allows the River Pilots to avoid hazardous conditions conducive to grounding. They also note that the nature of the river channel is such that there is a bank cushion effect that helps to keep vessels away from the channel edges.[41] (Amos pers. comm.) The vessel drafts assumed in the analysis and presented in Table 17 are representative of fully loaded vessels; the actual draft of any given transiting vessel would depend on the amount of cargo or ballast water onboard. Actual draft information is provided to pilots prior to transiting the Columbia River. As described in Section 2.2.6, *Vessel Traffic Management*, pilots make the final decisions for vessel movements and determine if the planned operation can be successfully completed. The Columbia River Pilots' Vessel Movement Guidelines (Columbia

[41] When the ship is near the bank, the water is forced between the narrowing gap between the ship's bow and the bank. This water tends to create a "cushion" that pushes the ship away from the bank.

River Pilots 2016) state, "vessels may be permitted to sail with the maximum freshwater draft of 43 feet if the river level, tide, and conditions permit." As stated in Section 2.2.6, *Vessel Traffic Management*, pilots operating draft-constrained vessels in the study area have to adjust the time of their transit to allow for at least 2 feet of underkeel clearance on the river plus expected squat to reduce the risk of groundings.

Fires, Explosions, and Other Emergencies. Equipment failure affecting power or steering while the vessel is underway could lead to loss of control of a vessel. A fire in the vessel's machinery spaces or accommodation areas is also a potential emergency scenario. For any of these situations the vessel master would do what is necessary to protect the safety of his crew first, and avoid damage to the vessel second. A prudent action would be to remove the vessel from the navigation channel to a safe haven, i.e., a location where appropriate actions can be taken by the vessel crew without compounding the emergency by involving another vessel or structure.

Safe haven opportunities on the river are minimal. Marine terminals at the port areas and designated anchorages are the only places where vessels can stop to manage an emergency. Two anchorages at Astoria can accommodate five deep-draft vessels, at most, depending on their sizes. There are no other anchorage areas until reaching Longview (past the project area). Once a loaded vessel gets underway inbound to or outbound from the Longview area, it is committed to completing the planned transit.[42]

Nothing prevents a vessel's master from anchoring anywhere in the river under emergency conditions; however, there is no way to predict how successful such an action might be in stopping the vessel. Anchoring effectiveness is dependent on factors such as the nature and condition of the waterway bottom, water depth, and vessel speed at the time of the anchoring. Risks include the potential for the anchor to damage the vessel if the water is not sufficiently deep. The vessel's location in or near the channel could also hamper or endanger other vessels depending on their locations at the time. Dropping an anchor or anchors in an attempt to stop a vessel would be done only if other control measures failed. Opportunities for these emergency measures would be discussed as part of the pretransit planning between the master and the pilot.

In an emergency, a vessel could anchor in the channel at some locations; however, that presents significant risks for the vessel with respect to the narrow channel and most likely would block virtually all other traffic. The likelihood of a vessel emergency causing a collision is low. Safe haven limitations (described above) mean that vessel transit would not begin until everyone involved is satisfied that the vessel is fully capable of completing the transit.

Although a vessel emergency increases the likelihood of indirect impacts on the Columbia River navigation channel, the likelihood of such an emergency occurring is minimal. As shown in Table 19, the likelihood of fires/explosions is substantially lower than any other type of incident considered in the risk assessment. If such an emergency were to occur, the presence of a qualified vessel master and the pilot, in addition to crew training, vessel design, and equipment would help minimize the harmful impact on human safety and the environment.

[42] A number of potential sites for additional anchorages are being discussed by the waterway stakeholders; however, they are generally shallow water sites. Reportedly, the discussions include the possibility of the Corps maintaining those areas as part of the federal channel project. Provision of additional stern buoys is also being considered.

Increased Risk of an Oil Spill during Transit or at Anchorages

An oil spill involving diesel or heavy fuel oil could occur as the result of an incident during transit or during bunkering transfers at locations other than the proposed docks. If an incident occurred that resulted in an impact, there is a possibility that a fuel tank could be damaged and fuel spilled. Oil spills could also occur during bunkering at anchorages within the study area. In general, the risks of spills would increase under the Proposed Action due to an increase in the number of vessels calling at the project area and the resultant increase to overall vessel traffic in the study area. To provide additional information about the relative likelihood of various sized oil spills, the risk assessment also quantitatively evaluated the incremental increase in risks of a spill (in the event of a collision or grounding) due to the Proposed Action.

Tables 20 and 21 present the likelihood (in terms of return periods[43]) of representative spill sizes that could occur as the result of the modeled increased risk of collisions or groundings, respectively.

Table 20. Example Bunker Oil Spill Volumes and Frequencies due to Collisions Related to the Proposed Action (2028 and 2038)

Return Period (years)[a]		
2028	**2038**	**Oil Spill Volume (gallons)**
341	224	20,900 or less
581	381	59,300 or less
676	444	107,400 or less
3,748	2,461	166,500 or less

Notes:
[a] Frequency of collisions in 2038 is higher compared to 2028 due to an increase in the overall vessel traffic in the study area.
Source: Appendix A, *Navigation Risk Study*

Table 21. Example Bunker Oil Spill Volumes and Frequencies due to Groundings Related to the Proposed Action (2028 and 2038)

Return Period (years)[a]	Oil Spill Volume (gallons)
140	5,700 or less
182	10,700 or less
403	39,700 or less
4,299	45,800 or less

Notes:
[a] Grounding frequencies do not vary from 2028 to 2038 since the number of project vessels remains at 840 in both years.
Source: Appendix A, *Navigation Risk Study*

As shown in the tables, the likelihood of bunker oil spills from a vessel incident is relatively low with the most likely scenarios occurring in the range of once every 244 years for collisions (2038 traffic levels) and once every 140 years for groundings (2028 or 2038 traffic levels). As noted in Section 2.2.8, *Marine Oil Spill Survey*, spills that have historically occurred in the study

[43] Estimated period of time between occurrences of an event.

area are much smaller than the quantities indicated in Tables 20 and 21 and have ranged from 0.1 gallon to 1,603 gallons.[44] The average number of oil spills within this same timeframe (2004 through 2014) is 15.6 spills per year with 84% having a volume of less than 10 gallons. Spills of more than 100 gallons have occurred at a frequency of 0.4 per year or once every 2.2 years. The average size of these relatively larger spills is approximately 630 gallons.

The reason that the potential spill sizes modeled for the Proposed Action are larger is because the spill scenarios presented above are associated with large-scale vessel incidents: collisions or groundings. For such an incident to result in a release of bunker oil, the energy involved in the initial incident must be great enough to puncture the vessel's tanks. Increases in the types of oil spills of a scale more similar to those that have occurred over the last 10 years would also be expected under the Proposed Action to be somewhat commensurate with the relative increase in vessel traffic. Expansion of the casualty survey to a longer (beyond 11 years) timeframe, would include more unlikely events of a larger scale more in line with those addressed by the incident modeling.

An amendment to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex that went into force in 2007, included a new Annex I Regulation, 12A, on oil fuel tank protection. That regulation applies to any ship that has an aggregate oil fuel capacity of 785 cubic yards—3,774 barrels (158,508 gallons) of oil equivalent—or more and was contracted for on or after August 1, 2007; or had a keel laying date on or after February 1, 2008; or was delivered on or after August 1, 2010. The regulation limits an individual fuel tank to a maximum capacity limit of 3,270 cubic yards—15,725 barrels (660,450 gallons) —and includes requirements for the protected location of the fuel tanks and performance standards for accidental oil fuel outflow. It requires consideration of general safety aspects, including maintenance and inspection needs, when approving the vessel's design and construction. These improvements are intended to reduce the extent of releases in the event of a vessel incident.

Increased vessel traffic associated with the Proposed Action also has the potential to result in an increased risk of oil spills during bunkering activities. Causes of oil spills during bunkering transfers include overflow of the tank, parting the hose due to mooring fault, operator error in connecting the hose, failure of the hose or pipework, and failure of bunker tanks (HSE 2012). Experience from insurance claims (Gard 2002) is that most bunker spills result from an overflow of the bunker tank due to carelessness or negligence, either on the part of those supplying the bunkers, or those on board the vessel receiving them.

The main safeguards against the occurrence of bunker spills are use of bunkering best practices, including attentive tank-level monitoring and valve alignment, use of bunkering procedures and checklists, and supervision of the bunkering operation by a qualified person.[45] Standard/ABS (2012) lists the main features of such procedures.

The consequences of a spill of heavy fuel oil into the marine environment are, in general, considered more severe than for other fuels, although this may depend on the sensitivity of the

[44] The data presented in Section 2.2.8, *Marine Oil Spill Survey*, include all reported vessel-related spills from 2004 to 2014, not just those caused by vessel incidents such as groundings and collisions.

[45] *Bunkering Best Practices: A Reference Manual for Safe Bunkering Operations in Washington State* (Washington State Department of Ecology 2014) and Bunkering Guidelines in *Lower Columbia Region Harbor Safety Plan* (January 2013). These references provide extensive guidelines related to winds, sea states, mooring equipment, tug availability, and regulatory requirements to provide for safe, spill-free bunkering operations.

local environment to acute toxicity (DNV GL 2011). Undoubtedly, spills of heavy fuel oil will be more persistent, taking longer to weather naturally and being more difficult to clean-up. The average clean-up costs per metric ton of oil spilled have been estimated as more than 7 times higher for heavy fuel oil than for diesel (Etkin 2000).

There were nine oil spills during refueling of large cargo vessels in the study area from 2004 to 2014. Spills of oil cargoes are better documented than spills from bunkering. Therefore, previous risk analyses have assumed the frequency of spills during bunkering is the same as during transfer of liquid cargoes: 1.8×10^{-4} (one spill every 5,555 years) per bunkering operation for spills exceeding 1 metric ton (7.3 barrels or 308 gallons). The frequency of smaller spills is likely to be much greater. This implies that the annual likelihood depends on the number of bunkering operations. If the vessel bunkers 10 times per year, the likelihood of a spill of 1 metric ton or more would be 1.8×10^{-3} per year, or approximately 1 chance in 500 per year. Although it is not possible to predict the number of vessels that may bunker or where they would bunker, the risks of a spill during transfer would increase slightly due to the increase in vessel trips under the Proposed Action.

Increased Vessel Activity

Increased vessel traffic associated with the Proposed Action would also have the potential to result in other impacts from increased activity, vessel wake, propeller wash, underwater noise and vibration, and vessel emissions. The potential impacts on cultural resources, water quality, surface water and floodplains, vegetation, fish, and wildlife are addressed in the SEPA Water Quality Technical Report (ICF 2017a), SEPA Surface Water and Floodplains Technical Report (ICF 2017c), SEPA Vegetation Technical Report (ICF 2017d), SEPA Fish Technical Report (ICF 2017e), and SEPA Wildlife Technical Report (ICF 2017f), respectively. The magnitude of these vessel-related impacts would depend on a variety of interrelated factors, including but not limited to, the distance of the channel from the shoreline, depth of the intervening riverbed, placement and size of dredged materials, the presence of particularly sensitive species, the speed and size of the vessels, the prevailing river and tidal currents, and otherwise natural-occurring wave action. Many of these factors are regulated by the federal government, including dredging activities, the placement of dredged spoils, and vessel traffic management within the study area. In general, the increase in deep-draft vessels associated with the Proposed Action would result in the increased potential for vessel-related impacts to occur.

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal, including Docks 2 and 3. Dock 1 would continue to be used for bulk cargo, primarily alumina, and could also be used for general cargo. The largest vessels currently calling at this facility are in the Handymax class, typically in the 35,000 deadweight tons range; however, the dock might be modified to accept somewhat larger Panamax-class vessels. The project area could be developed for other industrial uses, including an expanded bulk product terminal. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcined petroleum coke, coal tar pitch, and cement. No new docks would be built under the No-Action Alternative.

Table 22 describes the extent of these planned activities. When compared to the existing operations, this represents an additional 8 vessel calls (16 transits) per year.

Table 22. Planned Activities and Transport Operations at the Existing Bulk Product Terminal

Commodity	Vessel Class	Facility Activity	Vessel Activity (includes existing operations)
Alumina	Handymax	Vessels deliver alumina to Dock 1. Alumina is stored on site and then shipped to Chelan County by train.	8 ships/year
Other Commodities	Not provided	Other commodities that are assumed to be delivered by vessel, stored, and shipped via truck and train to various locations.	6 ships/year

Notes:
[a] See typical dimensions of a Handymax-class vessel in Table 6.
Source: URS Corporation 2014.

3.2.1.1 Potential Future Marine Terminal Activities

In addition to current and planned activities, the Applicant is considering the receipt and shipment of any products permitted by the terms of the Washington State Department of Natural Resources (DNR) lease,[46] including calcine pet coke, coal tar pitch, cement, fly ash, and sand (Table 23). Before the existing bulk product terminal could expand to accept additional products, it would need to obtain the necessary permit modifications or approvals. The following are estimates of the amount and method for transporting each of these commodities.

- Calcine pet coke would be imported by ship from Asia, unloaded from ships using a vacuum unloader, and stored in an existing on-site building. Approximately 600,000 tons of calcine pet coke per year could be imported.
- Coal tar pitch would arrive by ship via super-sacks, and unloaded from either vessel mounted unloading gear or new equipment. Approximately 200,000 tons of coal tar pitch per year could be imported.
- Cement would arrive by ship and be distributed either by rail or truck.
- Fly ash would come in by rail and depart by truck, or come in by truck and depart by rail.
- Sand or gravel would likely come in by rail and depart by truck, or come in by truck and depart by rail.

[46] Northwest Alloys holds a 30-year aquatic lease (20-B09222) with DNR allowing the use of DNR property for three ship docks. The lease expires on January 2, 2038. Per the DNR Lease Exhibit B Plan of Development, Operations and Maintenance Docks:

- The existing dock can be used for off-loading alumina ore from ships for transfer to railcar or trucks, off-loading cement for transfer to railcars and trucks, and off-loading any product that can be moved by vacuum including any type powder or granulated product.
- Two new fixed docks can be used for products not compatible with the existing system on Dock 1. The products would include coal, silica sand, dry fertilizer, potash, coke, cement clinker and other general bulk cargo.

Table 23. Potential Future Commodities Transported to Existing Site by Vessel

Commodity	Vessel Class	Facility Activity	Vessel Activity (includes existing operations)
Calcine pet coke Coal tar pitch Cement Fly ash Sand or gravel	Not provided	Ships deliver cargo over Dock 1; the cargo is temporarily stored and then shipped out by ground transport	10 to 12 additional ships/year

Notes:
Source: URS Corporation 2014.

3.2.1.2 Total Vessel Traffic

If all planned and potential activities are implemented, combined with existing storage and transport operations at the existing site, the vessel calls listed in Table 24 are anticipated by year 2020.

Table 24. Vessel Calls for Existing, Planned, and Potential Future Activities at Existing Bulk Product Terminal

Commodity	Vessel Class	Facility Activity	Vessel Activity (includes existing operations)
Existing, Planned, and Potential Future	Not provided	Ships deliver cargo over Dock 1; the cargo is temporarily stored and then shipped out by ground transport	26 vessels/year

Notes:
Source: URS Corporation 2014.

The No-Action Alternative would result in 26 vessel calls (54 transits) per year, an increase of 20 vessel calls (40 transits) over existing operations. In addition, vessel traffic in the study area in general would continue to increase over time with further industrial development along the river. As assumed for the incident modeling, large commercial vessel traffic would reach approximately 2,200 vessel calls (4,400 transits) per year by 2028. Therefore, there would be an increase in the number of incidents likely to occur compared to existing conditions unrelated to the Proposed Action.

Management of vessel traffic on the Lower Columbia River will be an ongoing concern for federal (USCG and Corps) and state (Ecology and ODEQ) agencies, local coastal jurisdictions, the Bar Pilots and River Pilots, maritime associations (such as PDXMEX and MFSA), and private interests. With or without the Proposed Action, vessel traffic volume is expected to be variable along the Lower Columbia River due to economic and market fluctuations, changes in port infrastructure, and vessel design modifications. The Columbia River VTIS and the Lower Columbia Region Harbor Safety Committee are both part of a system that adapts the processes currently in place in the Columbia

River to changes in the nature and the volume of vessel traffic.[47] These systems would continue to operate under the No-Action Alternative and help reduce the impacts related to the anticipated increases in vessel traffic in the Lower Columbia River.

[47] The Lower Columbia Region Harbor Safety Committee consists of federal, state, and local government representatives, port employees, vessel and facility operators, vessel agents, spill response cooperatives, and any other stakeholders that meet on a regular basis to exchange information, plan for contingencies, and review current operating procedures in light of any recent incidents. The *Lower Columbia Region Harbor Safety Plan* includes regularly revised guidelines on current traffic management practices and procedures for port users and is available via the Harbor Safety Committee's website (http://www.lcrhsc.org/).

Chapter 4
Required Permits

The Proposed Action would not require permits or approvals related to vessel transportation.

Chapter 5
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Appendix A

Navigation Risk Study

DNV·GL

MILLENNIUM BULK TERMINALS LONGVIEW (MBTL) PROJECT

Navigation Risk Study

ICF Jones & Stokes, Inc.

Report No.: PP141993-2, Rev. 1
Document No.: PP141993-2
Date: January 19, 2016



Project name:	Millennium Bulk Terminals Longview (MBTL) Project	DNV GL Oil & Gas
Report title:	Navigation Risk Study	Risk Advisory Services
Customer:	ICF Jones & Stokes, Inc., 630 K. Street, Suite 400, Sacramento, CA 95814	1400 Ravello Drive Katy, TX
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Date of issue:	January 19, 2016	USA
Project No.:	PP141993	Tel: +1 281 396 1000
Organization unit:	Environmental & Navigational Risk	[Company Reg No]
Report No.:	PP141993-2, Rev. 1	
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Applicable contract(s) governing the provision of this Report:

Objective:

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Keywords:
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Table of contents

1 EXECUTIVE SUMMARY 1
1.1 Incremental Contribution to Marine Incidents 2
1.2 Incremental Contribution to Oil Spill Risk 3

2 INTRODUCTION 5
2.1 Stated Objectives 5
2.2 Study Area 6

3 DESCRIPTION OF VESSEL TRAFFIC 7
3.1 Project Vessel Specifications and Number of Transits 7
3.2 Use of AIS 2014 Data 9
3.3 Vessel Type Categories 13
3.4 Vessel Traffic Cross Sections 21
3.5 Vessel Traffic Density by Vessel Type 23
3.6 Vessel Traffic by Vessel Transit Speed 33

4 MARINE INCIDENT AND OIL SPILL DATA SURVEYS 44
4.1 Review of Incident Severity in U.S. Waters 45
4.2 Review of Incident Severity in the Lower Columbia River 46
4.3 Review of Oil Spill Data from the Lower Columbia River 49

5 MODELING APPROACH 52
5.1 Inputs and Assumptions 52
5.2 DNV GL Methodologies 66

6 INCREMENTAL IMPACT OF PROJECT VESSELS ON RIVER NAVIGATION 75
6.1 Estimated Navigation Incident Frequencies 75
6.2 Incremental Contribution due to the Proposed Project 84

7 ESTIMATED BUNKER SPILL RISK OF PROJECT VESSELS AT FULL BUILD OUT 88
7.1 Estimated Bunker Spill Frequencies 89
7.2 Estimated Conditional Probabilities of Spill Volumes 92

8 CONCLUSIONS 97
8.1 Incremental Contribution to Marine Incidents 97
8.2 Incremental Contribution to Oil Spill Risk 98

9 REFERENCES 100

1 EXECUTIVE SUMMARY

DNV GL was hired as subcontractor to ICF International who was tasked by Cowlitz County, the Washington State Department of Ecology, and the U.S. Army Corps of Engineers to estimate the impact of the proposed Millennium Bulk Terminals—Longview project—a coal export terminal in Cowlitz County, Washington, along the Columbia River—on navigational safety, marine incident and oil spill risk in the Lower Columbia River. There would be 840 vessel calls to the terminal per year with 80% being Panamax class bulk carriers and 20% being Handymax class bulk carriers.

The study addresses impacts incrementally over a 24-year period (Base Case in 2014, Project Impact in 2028 and Cumulative Impact in 2038) in order to understand the contribution of the proposed project to future navigation safety. The study area for this study includes the waterways that would be used by or could be affected by vessels calling at the project sites. It includes the waters out to 3 nautical miles seaward of the mouth of the Columbia River, the Columbia River Bar, and the Columbia River upstream to Vancouver, Washington.

DNV GL's proprietary model, Marine Accident Risk Calculation (MARCS) was used to estimate navigation incident frequencies and bunker spill frequencies of project vessels and other vessel traffic; and the Naval Architecture Package (NAPA) was used to estimate the conditional probabilities of bunker oil spill volumes for project vessels. A survey of marine incident data was also performed in order to establish a severity distribution for marine incident outcomes. Finally, further data analysis was performed to measure the incremental impact of the proposed project on navigational safety.

MARCS combines processed AIS data for vessel traffic (e.g., vessel types, sizes, routes, and transit frequencies), the marine environment (e.g., location of shallow water, visibility data, and wind data) and operational aspects of shipping (e.g., pilotage, escort tugs) to predict the frequency of incidents at sea, including:

- Collision
- Allision
- Drift grounding
- Powered grounding
- Fire / Explosion

Collisions generally occur in the navigable part of the channel where the traffic is most dense. Drift and powered groundings occur near the shoreline or in shallow waters.

Preliminary MARCS and NAPA results were presented in a stakeholder workshop with DNV GL, ICF International, Washington State Department of Ecology (Ecology), Cowlitz County, U.S. Environmental Protection Agency (EPA), U.S. Coast Guard (USCG), and the U.S. Army Corp of Engineers Sector Columbia River (USACE) on November 9, 2015.

1.1 Incremental Contribution to Marine Incidents

The total incremental incident frequency due to proposed project in 2028 is 1.5 incidents per year which equates to an 8% increase over the no-action scenario in 2028. Of these 1.6 incidents, 0.8 are powered groundings, 0.34 are drift groundings, 0.38 are collisions and 0.03 are allisions.

The total incremental incident frequency due to proposed project in 2038 is 1.6 incidents per year which equates to a 6% increase over the no-action scenario in 2038. Of these 1.7 incidents, 0.8 are powered groundings, 0.34 are drift groundings, 0.47 are collisions and 0.04 are allisions.

In order to provide context around the consequences of a collision, grounding or allision incident, a survey of USCG Marine Information for Safety and Law Enforcement (MISLE) database was conducted for years 2001 to 2014. For the purposes of this study, the various categories used to describe incident severity for each reported incident were aggregated into “Total Loss”, “Damage” and “No Damage”. The data coverage period of 2001 to 2014 was chosen, as it covers over 99% of all reported collision, grounding, and allision incidents in the dataset. Data surveys were conducted for the national dataset and for the study area separately in order to test for differences in the distribution of incident severity between the two. Survey findings show that for a given incident type, the severity distributions were very similar for national incident data compared to Lower Columbia River incident data.

Using the results of the data survey, we can therefore comment on the likely severity of the incremental contribution of marine incidents contributed by the project.

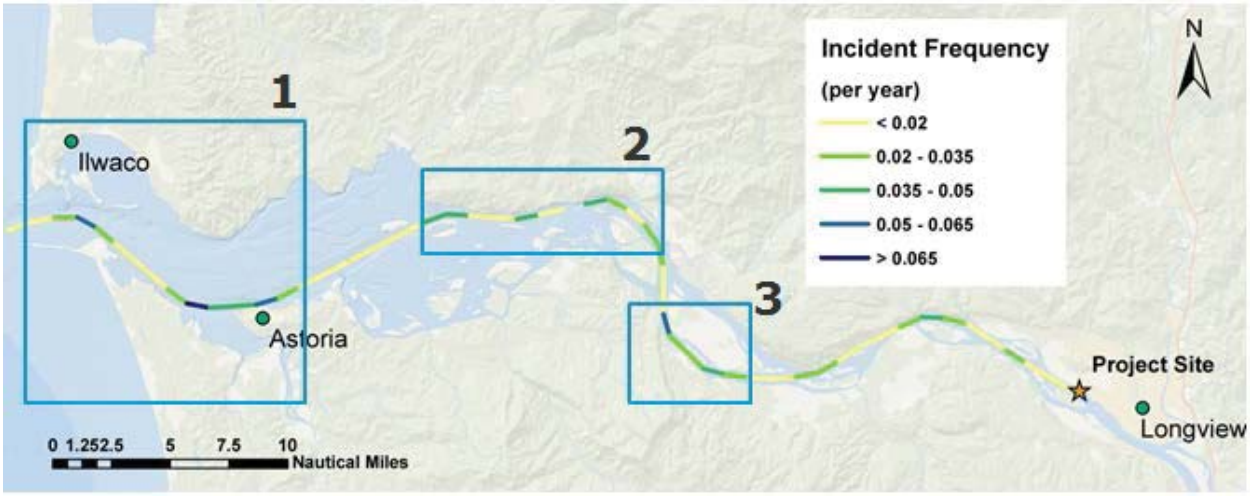
- Based on a survey of historical incident severity, 1-2% of the grounding events contributed by the project are likely to result in a total loss of the vessel, 21-24% are likely to result in damage to vessel and 74-78% are likely to result in no reported damage. Note: None of the total loss events reported due to grounding involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a grounding event were passenger vessels.
- Based on a survey of historical incident severity, 3-5% of the collision events contributed by the project are likely to result in a total loss of one or more vessels, 47-53% are likely to result in damage to one more vessels and 44-47% are likely to result in no reported damage.
  Note: None of the total loss events reported due to collision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a collision event were recreational vessels.
- Based on a survey of historical incident severity, 1-5% of the allision events surveyed resulted in a total loss of the vessel, 43-45% resulted in vessel damage and 52-54% resulted in no reported damage.
  Note: None of the total loss events reported due to allision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in an allision event were fishing vessels.

Assuming the distributions described above, the project would contribute to an incident resulting in the total loss of a vessel roughly once every 30 years, incidents resulting in reportable damage once every 2 years and approximately 1 incident per year resulting in no damage.

The incremental contribution appears to decrease from 2028 (8%) to 2038 (6%) because non-project vessel traffic continues to increase over this ten-year time period while the number of project vessels remains constant at 840 per year. Therefore the relative contribution in 2038 is lower because project vessels make up a smaller portion of overall vessel traffic.

Figure 1-1 below presents marine incident frequencies for project vessels in 2028 and 2038 along the proposed route. Notes explaining primary drivers are provided.

Figure 1-1 Incident Frequency – 2028 & 2038 With-Project



1) River Mile (RM) 2-14: Primary Driver of increased incident frequency is Powered Grounding but this area also contributes the highest collision frequencies of the study area.
2) RM 22-33 & 3) RM 36-40: Primary Driver of increased incident frequency is Powered Grounding. No variation was found in grounding frequency between 2028 and 2038 as number of project vessels remains constant.

1.2 Incremental Contribution to Oil Spill Risk

Less than 1% of the collision, grounding and allision incidents involving project vessels are expected to result in a bunker oil spill. As a result, the frequency of a bunker spill of any size due to a marine incident involving a project vessel is estimated to be 1.02×10^{-2} in 2028 and 1.17×10^{-2} in 2038. This equates to roughly one spill (of any size) every 98 years in 2028 and one spill (of any size) every 85 years in 2038. Based on a survey of oil spill data from 2004 to 2014, the Lower Columbia River has experienced a spill of greater than 100 gallons approximately once every 2.2 years. Therefore, the proposed project would increase the frequency of a spill greater than 100 gallons by approximately 2 to 3% to approximately once in every 2.15 years.

In the event that a collision or grounding event resulted in a bunker oil spill, the smallest estimated bunker oil spill volume from a project vessel would be roughly 20 m^3 for grounding and 80 m^3 for collisions (5,700 and 20,900 gallons, respectively). The frequency of various bunker oil spill sizes is provided in Table 1-1 for grounding scenarios. Since the number of project vessels does not change between 2028 and 2038, frequencies are the same in both years. The frequency of various bunker oil spill sizes is provided in Table 1-2 and Table 1-3 for collision scenarios. Since the number of non-project vessels increases between 2028 and 2038, collision frequencies vary across those years. It is important to note that this study did not assess the risk of small spills due to activities such as bunkering, damage to the environment and other causes unrelated to navigational incidents.

Table 1-1 Example Bunker Oil Spill Volumes & Frequencies due to Grounding (2028/2038)

Return Period (Years)	Spill Volume (gal)
140	5,700 or less
182	10,700 or less
403	39,700 or less
4,299	45,800 or less

Table 1-2 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2028)

Return Period (Years)	Spill Volume (gal)
341	20,900 or less
581	59,300 or less
676	107,400 or less
3,748	166,500 or less

Table 1-3 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2038)

Return Period (Years)	Spill Volume (gal)
224	20,900 or less
381	59,300 or less
444	107,400 or less
2,461	166,500 or less

2 INTRODUCTION

Millennium Bulk Terminals—Longview, LLC (Applicant) proposes to construct and operate a coal export terminal in Longview, WA along the Lower Columbia River. The terminal would receive coal via rail shipment, then load and transport the coal by ocean-going ships via the Columbia River and Pacific Ocean. There would be 840 vessel calls to the terminal per annum; 80% of vessels calling the terminal would be Panamax class bulk carriers and 20% would be Handymax class bulk carriers.

DNV GL was tasked to estimate the impact of the proposed project and associated increases in vessel calls on navigation safety on the Columbia River. DNV GL's study estimates the impact of the proposed project to other vessel traffic from the precautionary zone in the Pacific Ocean to the proposed terminal facility. The study addresses impacts incrementally over a 24-year period (Base Case in 2014, Project Impact in 2028 and Cumulative Impact in 2038) to understand future trends in navigation safety. DNV GL's findings will supplement the environmental impact statement (EIS) for the proposed project, and is expected to address public concerns regarding navigation safety.

2.1 Stated Objectives

The primary objective of this study is to quantify the incremental risk in 2028 and 2038 posed by project vessels to other vessel traffic on the river in terms of the increased likelihood of any incident. The secondary objective was to provide additional information about the potential consequences of these incidents, more specifically, qualification of the magnitude or severity of potential outcomes using 1. Comparisons to historical data and 2. Modeling likelihood for different bunker oil release volumes. To achieve these objectives the following four questions are addressed:

1. Could there be an incident?
2. If so, how severe would the incident be?
3. Could the incident result in a release of bunker oil?
4. If so, how much bunker oil would be released?

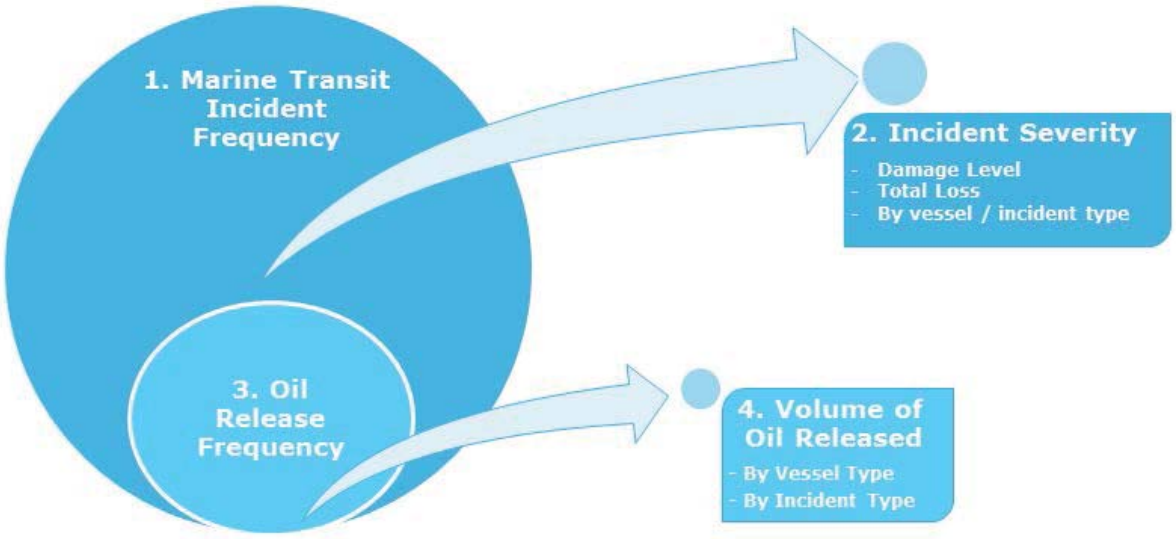


Figure 2-1 Navigational Risk Study Objectives

To achieve these goals, the following modeling outputs were obtained from this navigational risk study:

1. The incremental difference of navigation incident frequencies of project and non-project vessels in traffic conditions with and without proposed project are estimated for years 2028 and 2038.
2. A distribution of incident severity is developed based on a survey of historical marine incident data.
3. Bunker spill frequencies contributed by project vessels at full build-out in 2028 and 2038.
4. Conditional probabilities of bunker spill volumes contributed by project vessels at full build-out in 2028 and 2038.

2.2 Study Area

The study area for this study includes the waterways that would be used by or could be affected by vessels calling at the project sites. It includes the waters out to 3 nautical miles seaward of the mouth of the Columbia River, the Columbia River Bar, and the Columbia River upstream to Vancouver, Washington.

3 DESCRIPTION OF VESSEL TRAFFIC

This section describes the AIS data and assumptions related to vessels and vessel traffic that are applied in the study.

3.1 Project Vessel Specifications and Number of Transits

Two design vessels have been chosen to represent an average sized Panamax class vessel and an average sized Handymax class vessel.

The design vessels chosen to represent the Panamax class and the Handymax class are the MP Panamax 6 and the Advance II, respectively. The vessels' specifications are outlined in Table 3-1(Ref. /1/, /2/)

Table 3-1 Vessels' Specifications (Ref. /1/)

	MP Panamax 6	Advance II
Deadweight Tonnage (DWT)	68,541 tons	46,101 tons
Gross Tonnage (GT)	36,097 tons	30,032 tons
Length Overall (LOA)	225.0 meters	183.0 meters
Length Between Perpendiculars (LBP)	216.0 meters	173.9 meters
Breadth (B)	32.2 meters	32.3 meters
Draught (D)	13.3 meters	11.0 meters

It is expected that the proposed project would result in 672 Panamax vessels per year and 168 Handymax vessels per year in 2028 and 2038, for a total of 840 MBTL vessel calls a year.

Results will be presented as total incident frequencies for all project vessel calls and will not differentiate between Handymax and Panamax vessels.

3.1.1 Bunker Oil Capacity

For the purposes of estimating potential bunker spill volumes, bunker oil capacity and bunker tank locations from a typical Panamax class vessel are assumed.

Figure 3-1 shows the locations of the bunker oil / heavy fuel oil (HFO) tanks for a typical Panamax class vessel (shown in red at the stern of the vessel). Based on a review of DNV GL-classed Panamax-class carriers, the typical Bunker Oil capacity for these vessels is assumed to between 2400 and 2500 m^3.



Figure 3-1 Bunker Oil / HFO tank locations for typical Panamax class carrier

3.2 Use of AIS 2014 Data

The MARCS model (described in detail in Section 4) for this study requires Automatic Identification System (AIS) data for the area around the terminal and shipping routes. Tracks are created from the AIS data points and are used to establish vessel traffic patterns and densities within the study area.

Figure 3-2 presents the general methodology used to treat the AIS dataset. Once the data for a full calendar year is received, it is then plotted geospatially in a geographic information system (GIS). The dataset was plotted as individual points for each data entry in the study area. From the plotted dataset, the vessel density, speed and traffic patterns are determined for analysis and use in the MARCS model.

To determine the traffic density, the AIS dataset was translated into the number of AIS points per grid cell (0.005 x 0.005 decimal degrees), which is interpreted as vessel density. The vessel density was not used as input into the MARCS model, but as a method of understanding vessel behavior in the study area. A vessel density 'heat' map was created for the overall traffic and each defined vessel category used in MARCS.

Speed profiles were created to determine the vessel category speeds to be used as an input to the MARCS model. The timestamp in the AIS data for a single vessel is used to determine the speed of the vessel when travelling between two given AIS data entries. An average speed for each vessel category at a given location is applied in MARCS. A map of the varying speeds along the route was created for each vessel category.

The entries of each vessel in the AIS dataset are linked throughout the study area based on the location and time stamp to create vessel tracks. The tracks present the general traffic patterns and route in the study area. To input the information into the MARCS model, it is necessary to consolidate the vessel tracks into the main traffic routes for the study area. The vessel frequency for each vessel type travelling along (co-flow and counter flow traffic) the defined main traffic route is inputted into the model. A vessel track frequency is included in the count of a given route if it is within a 27° degree angle of the defined main traffic route. The vast majority of vessel tracks are captured on one of the defined main routes. This method allows for the large amount of AIS dataset to be accurately and efficiently utilized in the MARCS model.

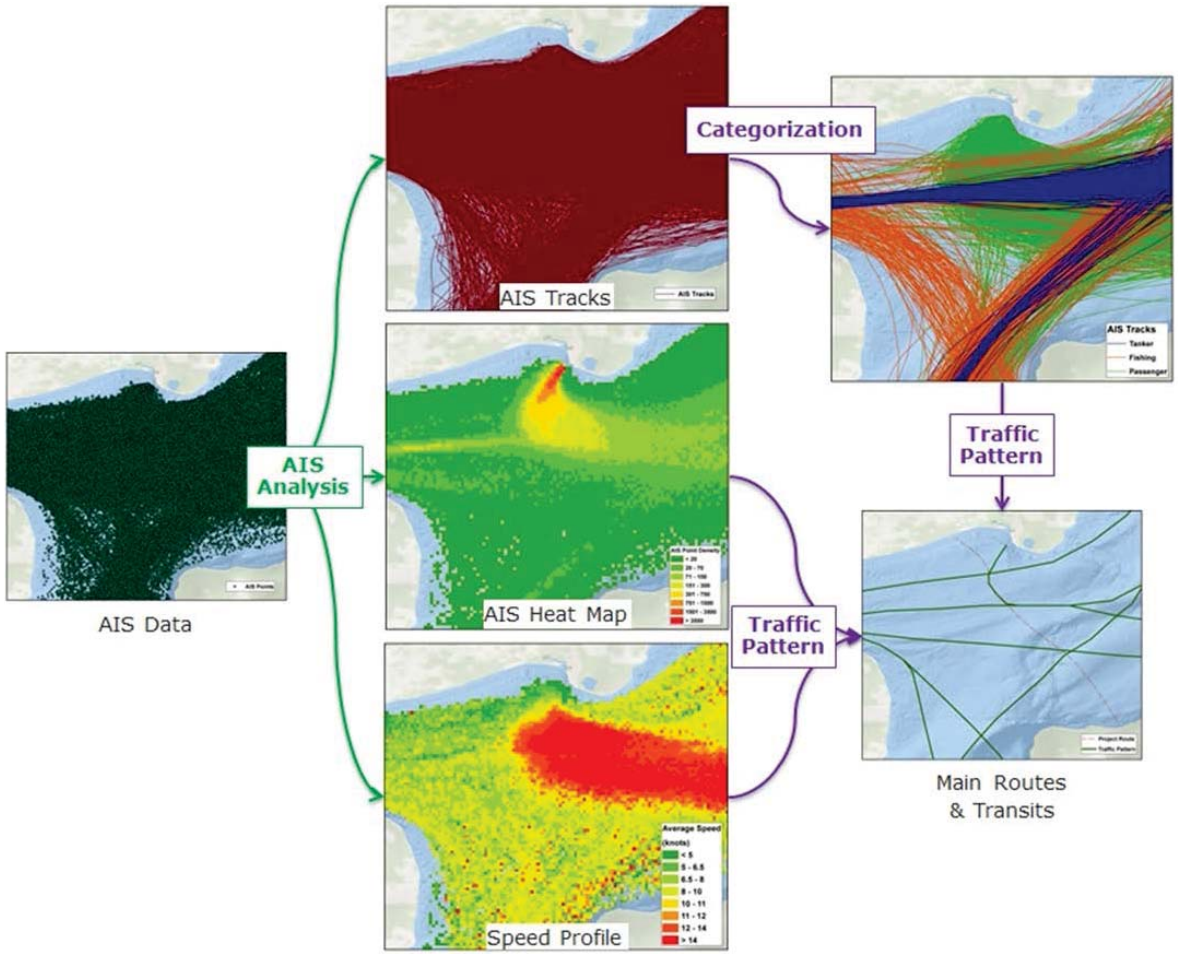


Figure 3-2 AIS Data Treatment Methodology

The AIS dataset, presented in Figure 3-3, was obtained from Merchants Exchange in Portland, OR. The period of coverage for the AIS data is from '2014-01-1 00:00' to '2014-12-31 23:59' (Ref. /3/).

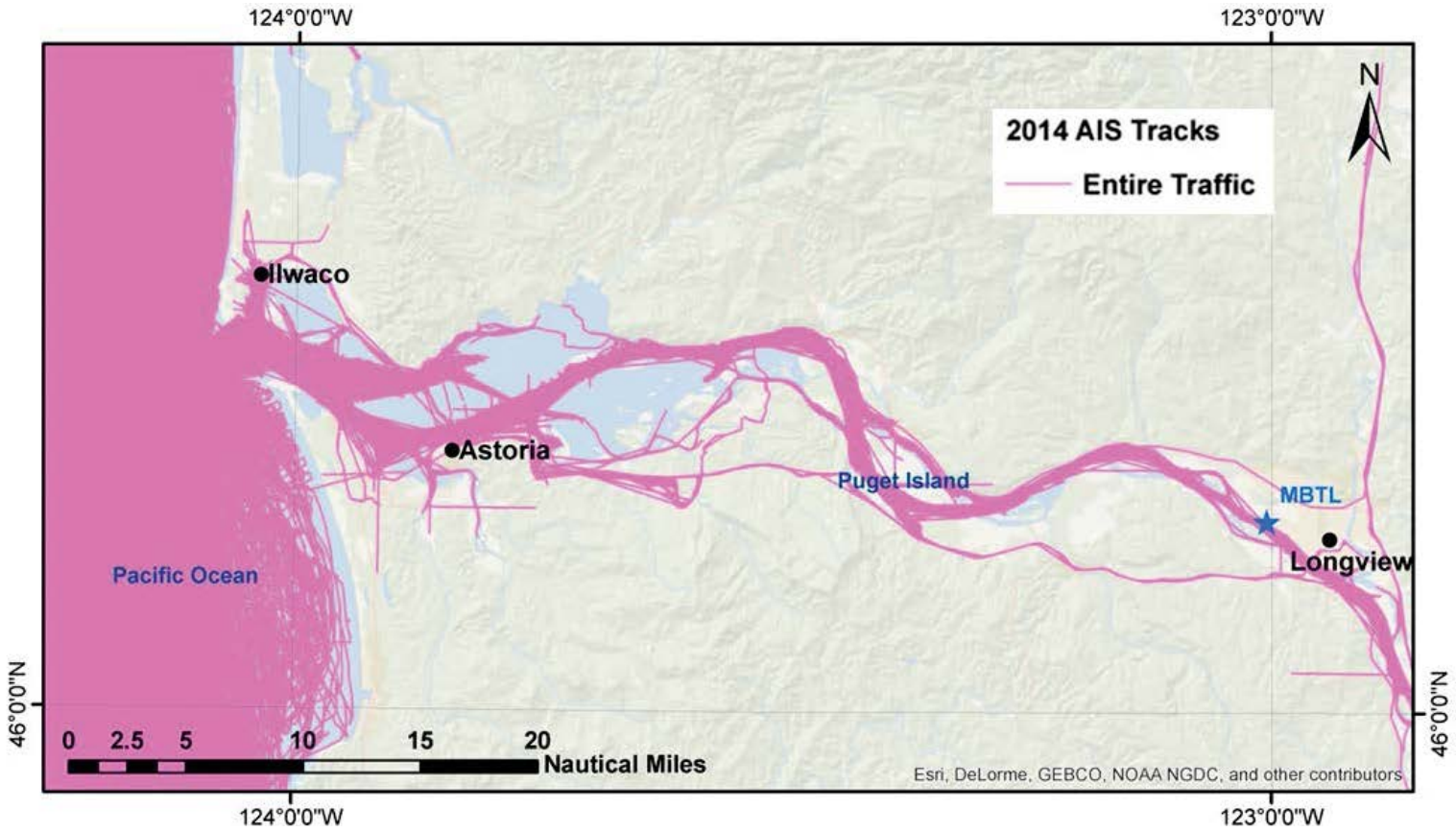


Figure 3-3 2014 AIS Tracks for All Transits

Figure 3-4 provides a close-up of the project vessel route and AIS tracks near the proposed terminal location.

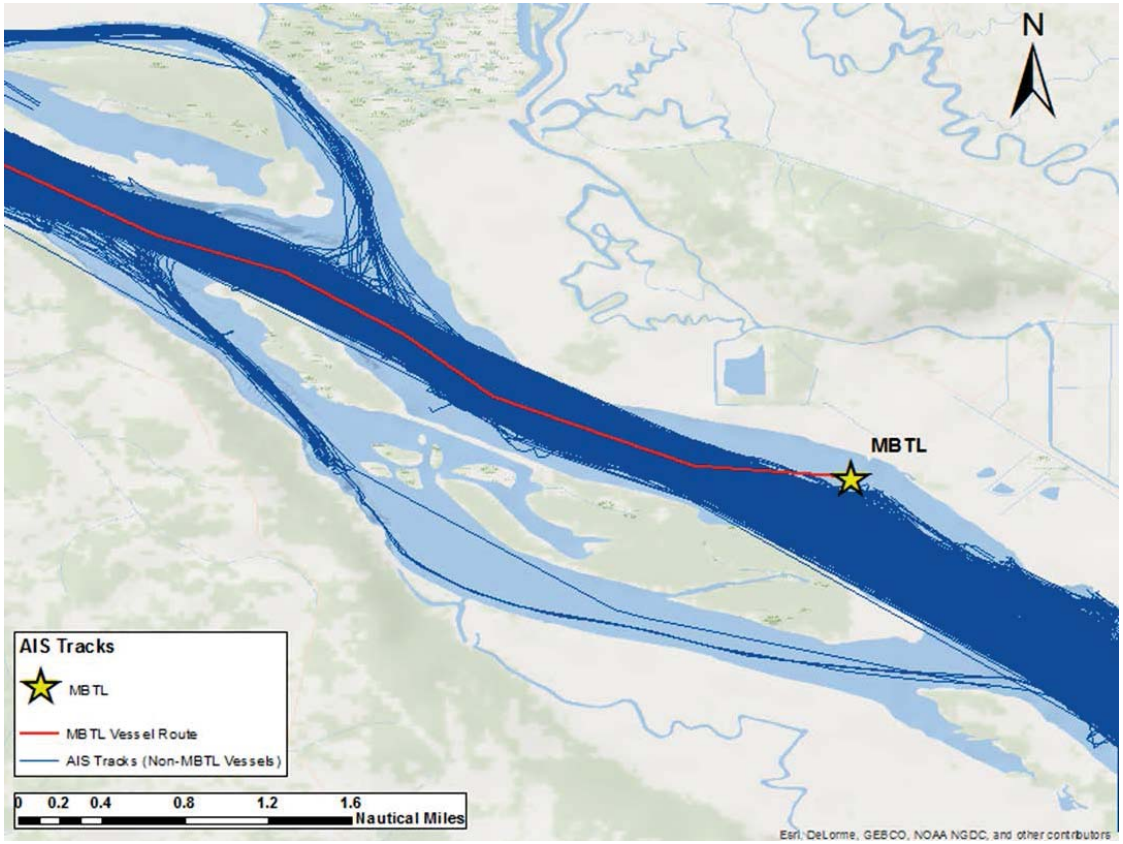


Figure 3-4 AIS Tracks near Project Location

3.3 Vessel Type Categories

The vessel categories are used to group AIS descriptors together in categories. Each category of vessels has a common specified average speed, average size (DWT, LOA, and B) and set of risk reductions that are applied to each vessel. The average speed and size of vessel categories are derived from the AIS data.

3.3.1 Vessel Type Descriptions

The marine traffic risk assessment used AIS data to characterize vessel traffic. Vessel categories used in the navigational risk model included:

- Cargo/Carrier
- Passenger
- Service
- Tug
- Fishing
- Pleasure
- Tanker
- Other
- Undefined

Table 3-2 provides a summary description of the typical vessel types operating on the Columbia River that correspond to the AIS vessel types used in the marine traffic risk assessment. A description of the information found in each column of Table 3-2 is summarized below.

- Vessel Category: Grouping of vessel types from the AIS Data. These are grouped by commonalities in function/service as well as vessel dimensions.
- AIS Vessel Types: Vessel categories extracted directly from AIS data which are then grouped into the “Vessel Category” field.
- Service Description: Functions and operations typical to each vessel category.
- Vessel Specifications: typical vessel dimensions including length, beam, draft and Dead Weight Tonnage (DWT)
- Image: Photograph of a typical vessel from each category.

Table 3-2 Typical Vessel Types Operating on the Columbia River

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Cargo/ Carrier	Bulk carriers, container ships, general cargo ships, automobile carriers, timber carriers	Cargo/carrier vessels include a wide range of vessels commonly seen on the Columbia River carrying forest products; steel, ore, grain, potash, and other dry bulk cargoes; general cargo; containerships; and automobiles.	Bulk Carriers (may include bulk, timber, general cargo): DWT: 50,000 - 80,000, Length: 650 - 965 ft Beam: 100- 106 ft Draft: 33 - 39.5 ft Car Carriers: DWT: 18,638 Length 650 ft Beam: 105 ft Draft: 27 ft	 Example of a Bulk Carrier  Example of Car Carrier[1]

[1] Marine Traffic. *Photos of PASSERO (MMSI: 236111887)*. Available at: http://www.marinetraffic.com/en/photos/of/ships/shipid:204314/shipname:PASSERO/#forward

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
			Container ships: DWT: 57,088 Length: 260 ft Beam: 33 ft Draft: 12.5	 Example of Containership[2]
Tanker	LPG tankers, oil tankers, chemical tankers	Carriage of bulk liquid or gas petroleum, hydrocarbon or chemical products	DWT: 65,000 – 80,000 Length: 965 ft Beam: 106 ft Draft: 41 ft	 Example of an oil tanker

[2] Marine Traffic. *Photos of HORIZON SPIRIT (MMSI: 366629000)*. Available at: http://www.marinetraffic.com/en/photos/of/ships/shipid:426112/shipname:HORIZON%20SPIRIT/mmsi:366629000

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Tug	General tugs, towing vessels, , towing long and wide	All tugs are included in this category, regardless of their service or configuration of tow (e.g., towing, pushing, ATB). This category also includes barges attached to tugs.	Tugs: Length: 50 ft – 150 ft Beam: 26 ft – 35 ft Draft: 9 ft – 16 ft	 Example of a general tug[3]
Fishing	Trawlers, all commercial and recreational fishing vessels	This category includes all commercial and fishing vessels.	Length: 100 – 180 ft Beam: 25 – 45 ft Draft:: 9 – 15 ft	 Example of a fishing vessel[4]

[3] Marine Traffic. *Photos of STACY T (MMSI: 367516730).* Available at: http://www.marinetraffic.com/en/photos/of/ships/shipid:448629/#forward

[4] Vessel Finder. *JOYCE MARIE – Fishing Vessel.* Available at : https://www.vesselfinder.com/vessels/ship-photo/0-367406690-99eacfaa3613eade55f4610e76c36c78/1

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Service	Military, law enforcement, search and rescue vessels, pilot vessels, pollution control vessels	U.S. Coast Guard vessels are captured in AIS as either Military, Law Enforcement, or SAR vessels.	Coast Guard vessels range in length from 22 ft to over 300 ft.	 Example of U.S. Coast Guard Search and Rescue vessel
		Pilot vessels are vessels whose specific function is the transport of pilots to/from vessels subject to pilotage.	Length: 72 ft Beam: 20 ft	 Pilot Vessel COLUMBIA[5]
		Pollution control vessels inlcude vessels specifically designated for pollution response.	Length: 20 ft - 40 ft Beam: 6 ft – 20 ft	

[5] Marine Traffic. *COLUMBIA*. Available at: http://www.marinetraffic.com/en/ais/details/ships/shipid:441374/mmsi:367331730/vessel:COLUMBIA

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Passenger	Ro-Ro/Passenger ships (i.e., car ferries), inland passenger ships, passenger ferries	The Oscar B (Waikiakum County ferry) is the only car ferry on the Lower Columbia River. Passenger vessels include cruise ships, passenger ferries, small passenger vessels (SPV) (as defined in 46 U.S.C. §2101) used for such purposes as day trips and dinner cruises..	Ro-Ro Passenger Vessel: Length: 109.2 ft Breadth: 47.5 ft Draft: 6 ft Inland Passenger Ship: GT: < 100 Length: 80-150 ft Beam: 30-40 ft Draft: 6-12 ft	 Example of a Ferry (Ro-Ro Passenger Vessel)[6]  Example of an SPV, American Empress[7]

[6] Churchill, D. *Astoria Day Trips, Bridges and Ferries.* Available at: https://astoriadaytrips.wordpress.com/bridge-and-ferry/

[7] FleetMon. *Photo of AMERICAN EMPRESS*. Available at: https://www.fleetmon.com/vessels/american-empress_9263538_15186/photos/1221103/

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Pleasure	Pleasure crafts, yachts, sailing vessels	Wide range	Length: 20 ft – 150 ft Beam: 8 ft – 40 ft Draft: 3 ft – 15 ft	 Example of a pleasure craft[8]
Other	Dredgers, Cable Layers, Offshore Supply Vessels, Replenishment Vessels, Heavy Lift Vessels	Wide range.	Length: 150 - 800 ft Beam: 30 - 180 ft Draft: 13 – 30 ft	 Dredge vessel YAQUINA[9]

[8] Marine Traffic. *Photos of GEORGE EMERGY (MMSI: 367465340)*. Available at: http://www.marinetraffic.com/en/photos/of/ships/shipid:446392/#forward

[9] Marine Traffic. *YAQUINA*. Available at: http://www.marinetraffic.com/en/ais/details/ships/shipid:430981/mmsi:366971000/vessel:YAQUINA

Vessel Category	AIS Vessel Types	Service Description	Typical Vessel Specifications	Image
Undefined	Vessels where vessel type is missing from AIS data	Sometimes vessel operators fail to enter the proper Vessel Type in AIS. This results in the receipt of an AIS signal, but the signal does not include sufficient data to provide identifying characteristics about the vessel.	N/A	N/A

3.4 Vessel Traffic Cross Sections

Cross sections were placed at various locations to perform an analysis of the type of traffic transiting the Columbia River. At each cross section, the number of vessels that passed through the defined section was taken to be a transit.

Cross sections are areas where “slices” of 2014 AIS vessel traffic data were extracted to retrieve information on vessel traffic density. More specifically, cross sections were used to identify where vessels transit, classify vessel traffic trends and patterns, and understand the composition of vessel types over the study area. Findings from cross sections are then used to understand how traffic trends, patterns and composition can affect quantitative model results generated in MARCS, DNV GL’s proprietary navigation risk model (see Section 4).

Figure 3-5 presents the locations of the defined cross sections.

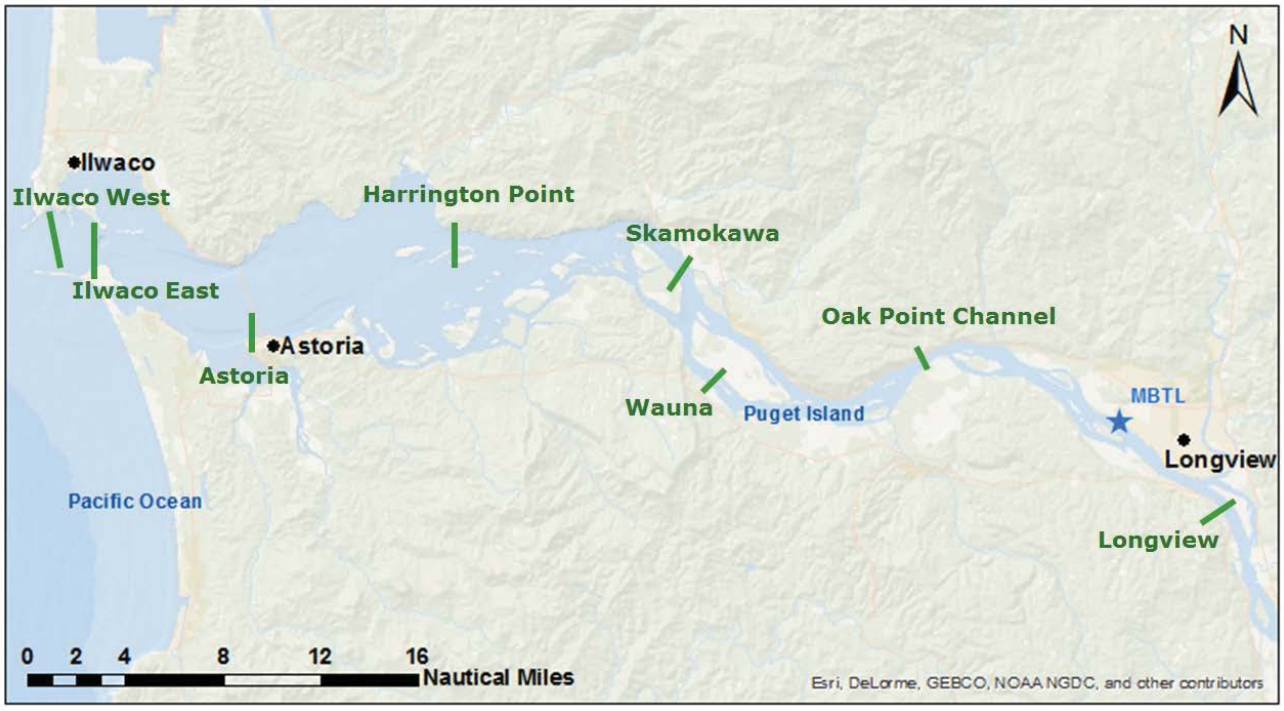


Figure 3-5 Cross Sections for Traffic Analysis

Figure 3-6 presents the distribution of vessel types that transit through each cross section.

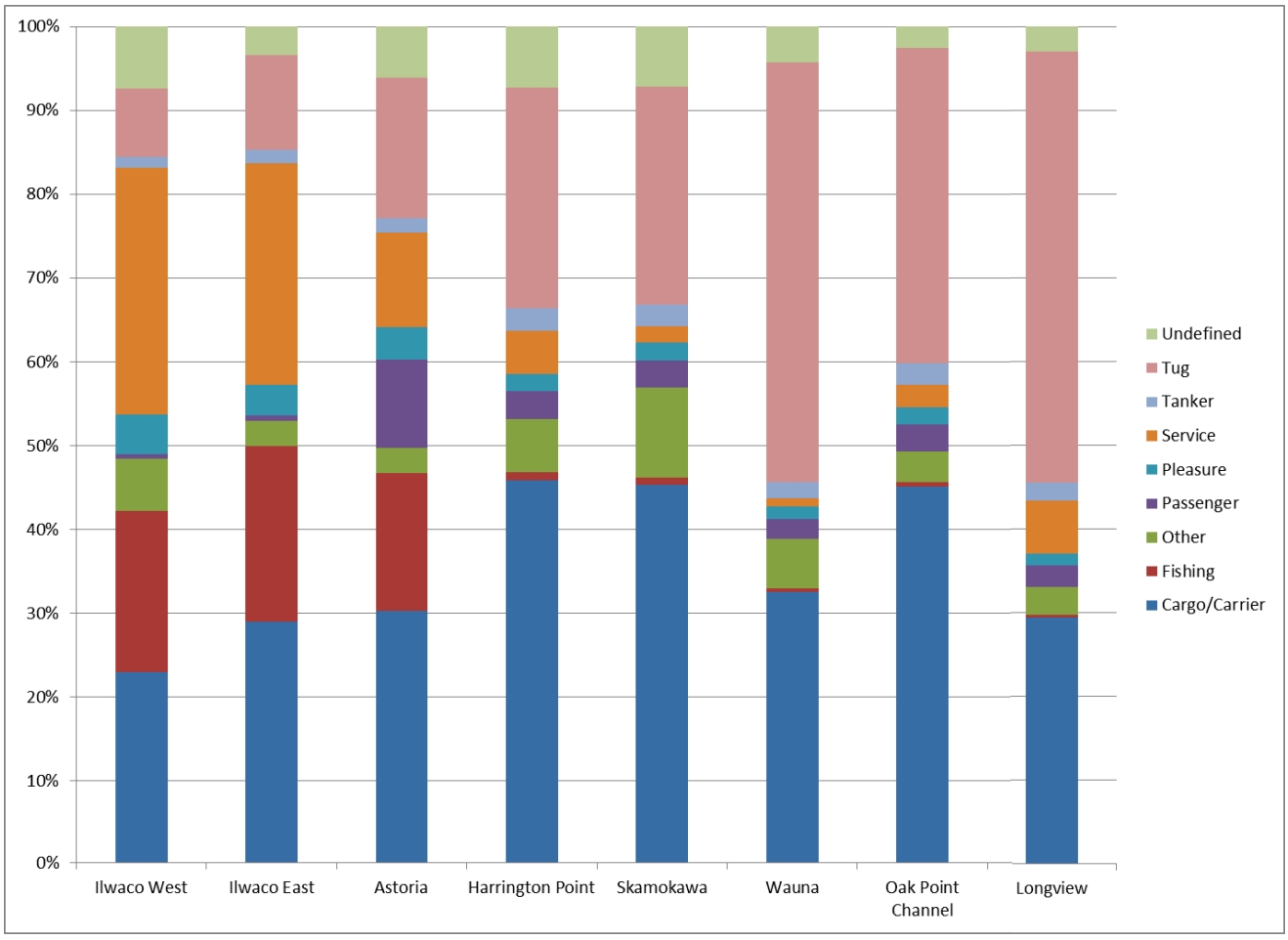


Figure 3-6 Vessel Type Distribution at Cross Sections (2014 AIS Data)

Figure 3-6 presents the number of transits through the defined cross sections, combined with the number of transits contributed by each vessel type. It can be seen that more vessels passed through the cross sections at the mouth of the Columbia River.

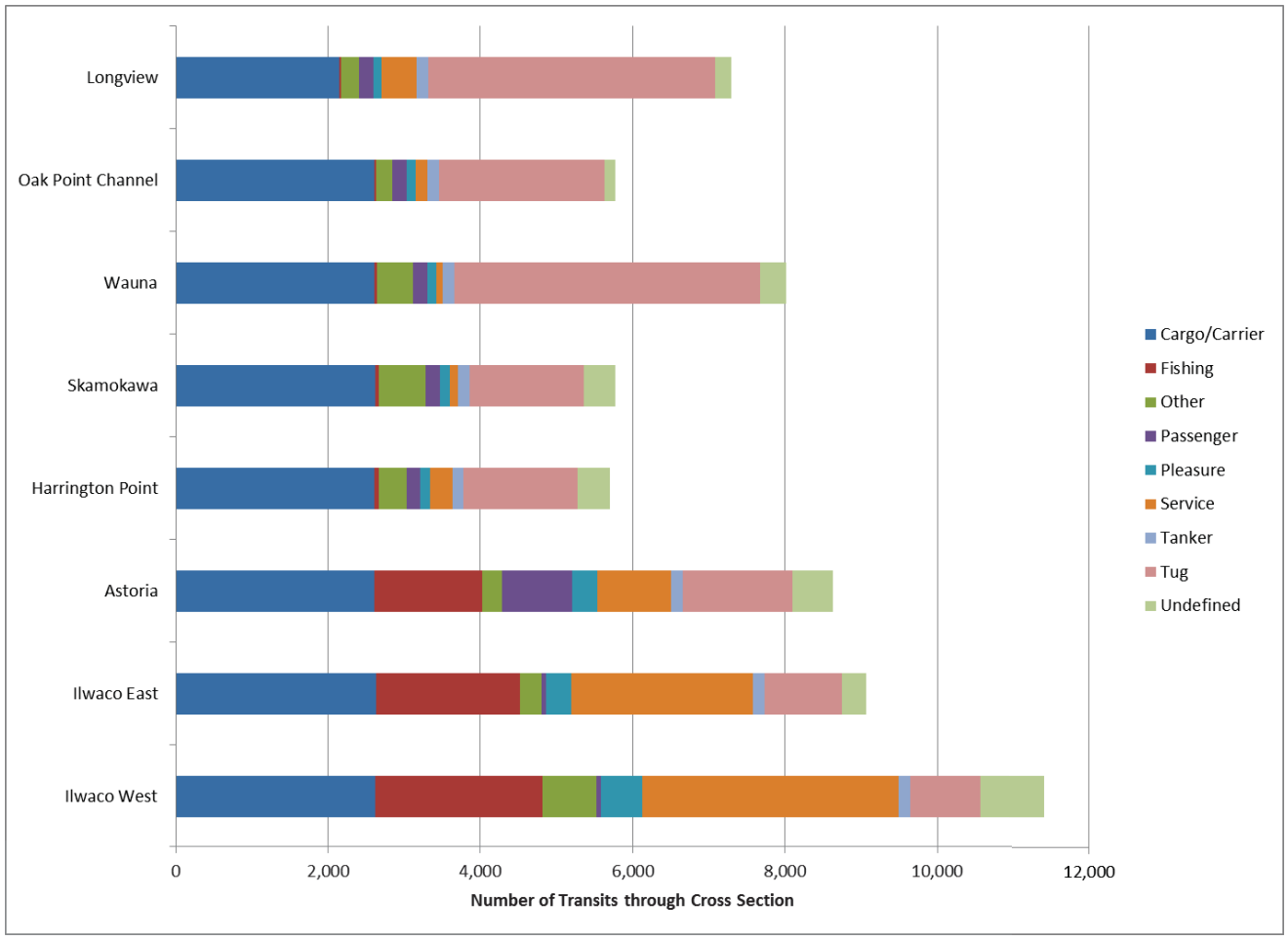


Figure 3-7 Number of Transits per Cross Section by Vessel Type (2014 AIS Data)

3.5 Vessel Traffic Density by Vessel Type

AIS data was used to map the traffic density in the study area. The AIS dataset was translated into the number of AIS points per grid cell (0.005 x 0.005 decimal degrees), which was interpreted as vessel density.

Figure 3-7 to Figure 3-16 present the density of each ship type as a 'heat map' with yellow representing the least dense areas and dark blue represent the densest areas.

It is noteworthy that areas of slower speeds, such as direction changes in the channel, are shown as higher density areas on the heat maps. This is assumed to occur because when vessels travel at a slower speed, they are transmitting more AIS data while in that area than if they were travelling at higher speeds. The figure shows that areas of relatively greater density begin to occur around the Columbia River bar and persist in the navigable channel past Longview.

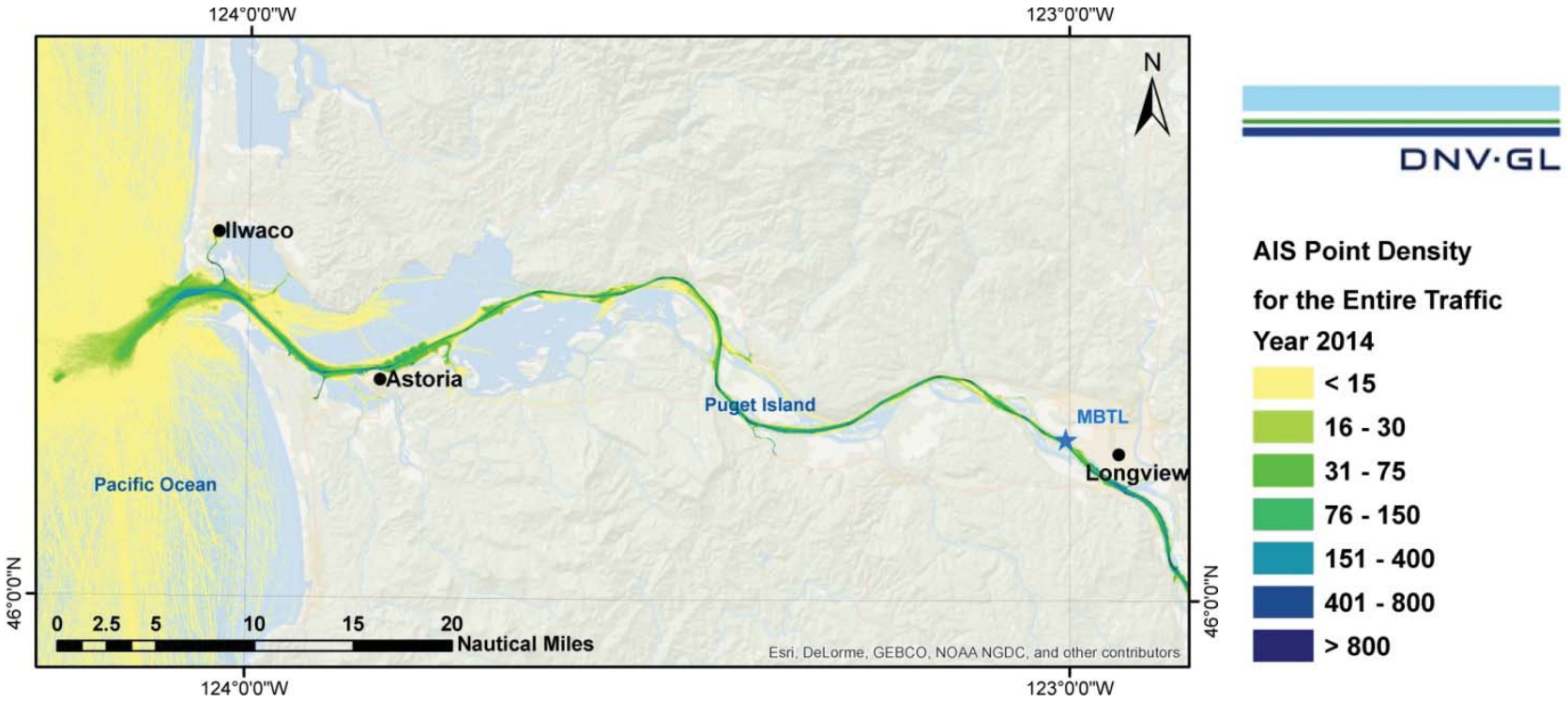


Figure 3-8 2014 AIS Density Profile for All Vessels Transits

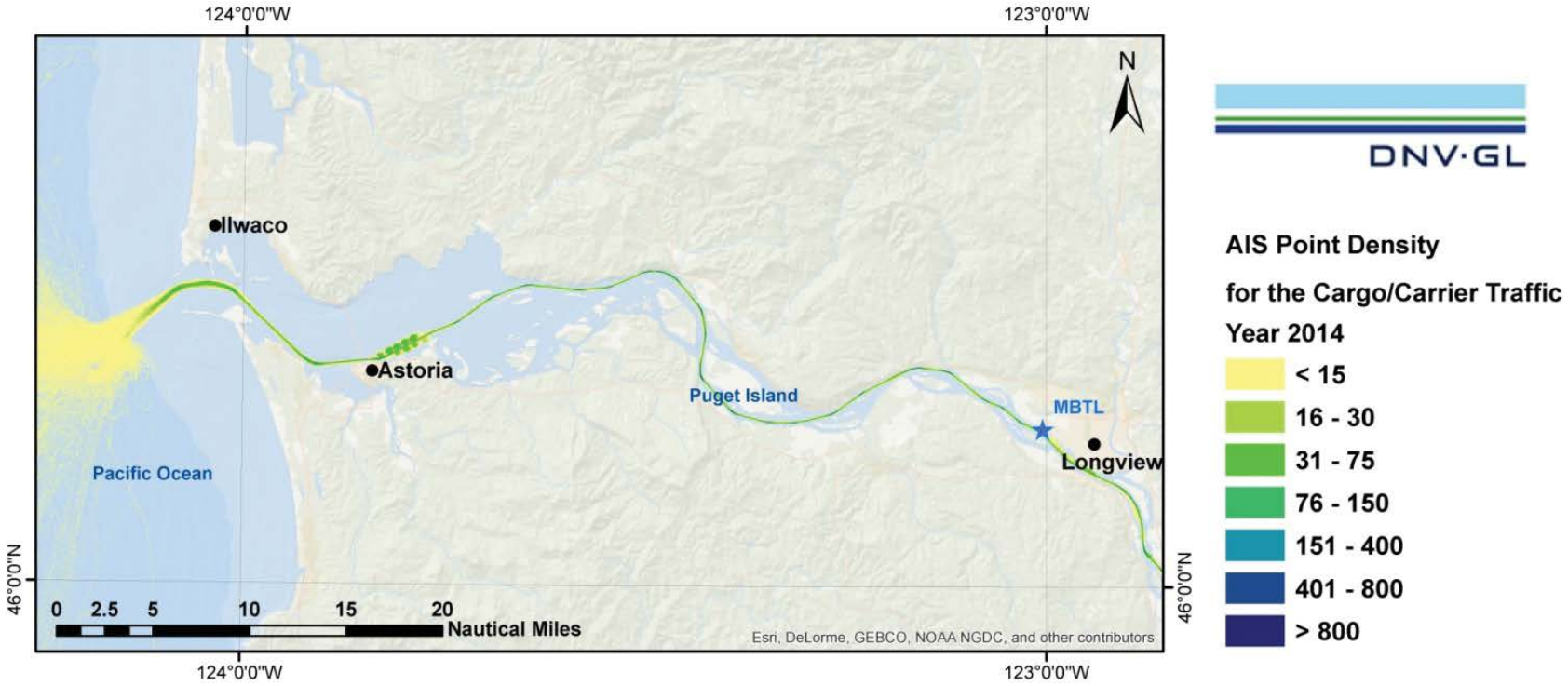


Figure 3-9 2014 AIS Density Profile for Cargo/Carrier Transits

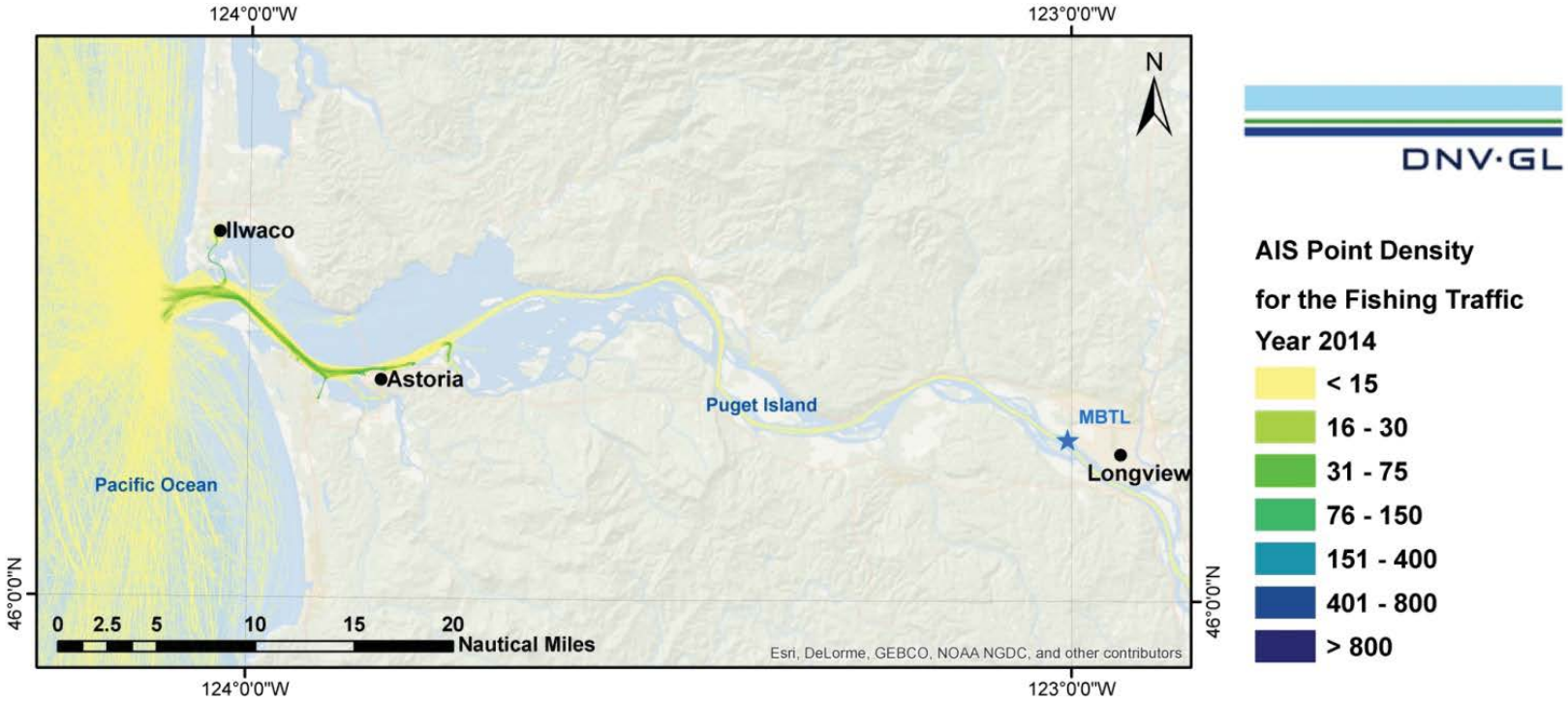


Figure 3-10 2014 AIS Density Profile for Fishing Transits

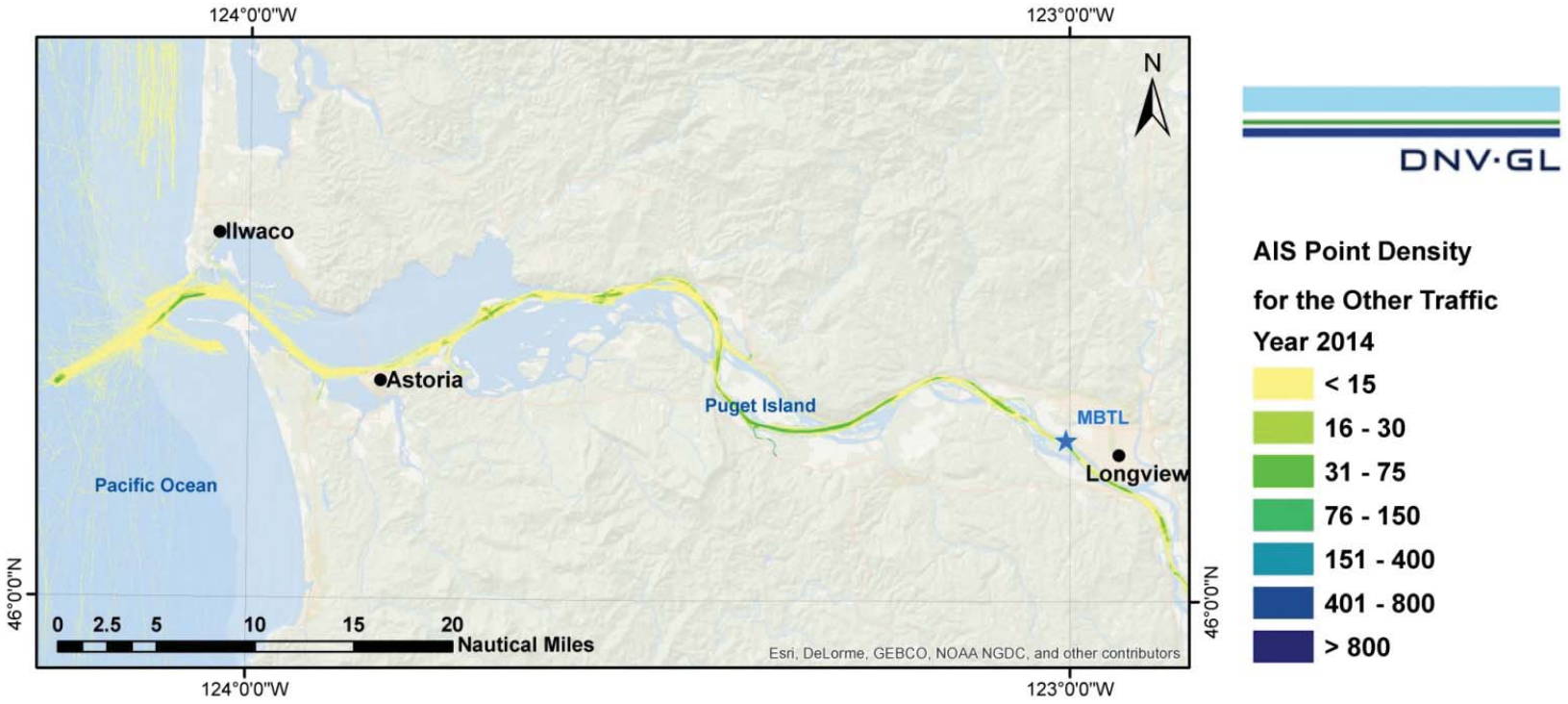


Figure 3-11 2014 AIS Density Profile for Other Transits

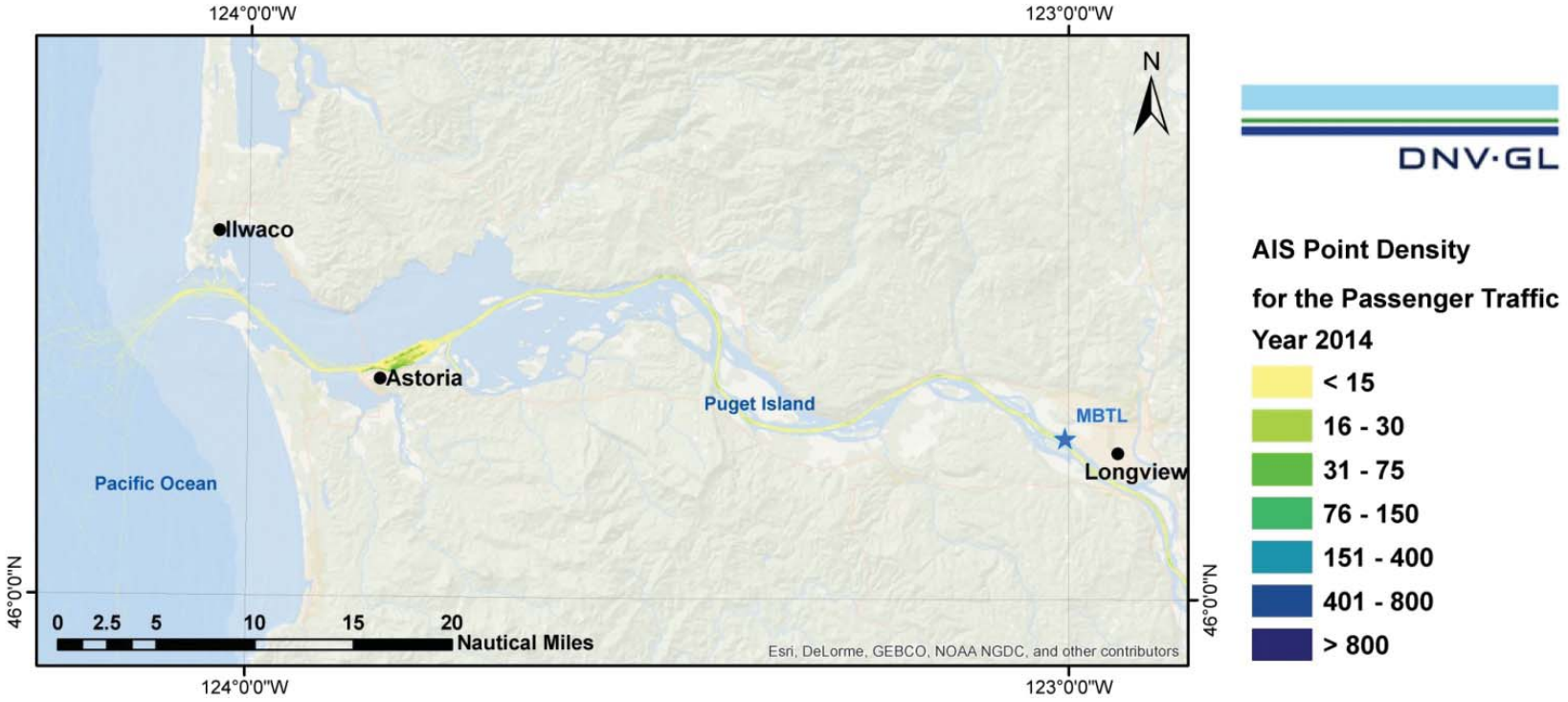


Figure 3-12 2014 AIS Density Profile for Passenger Transits

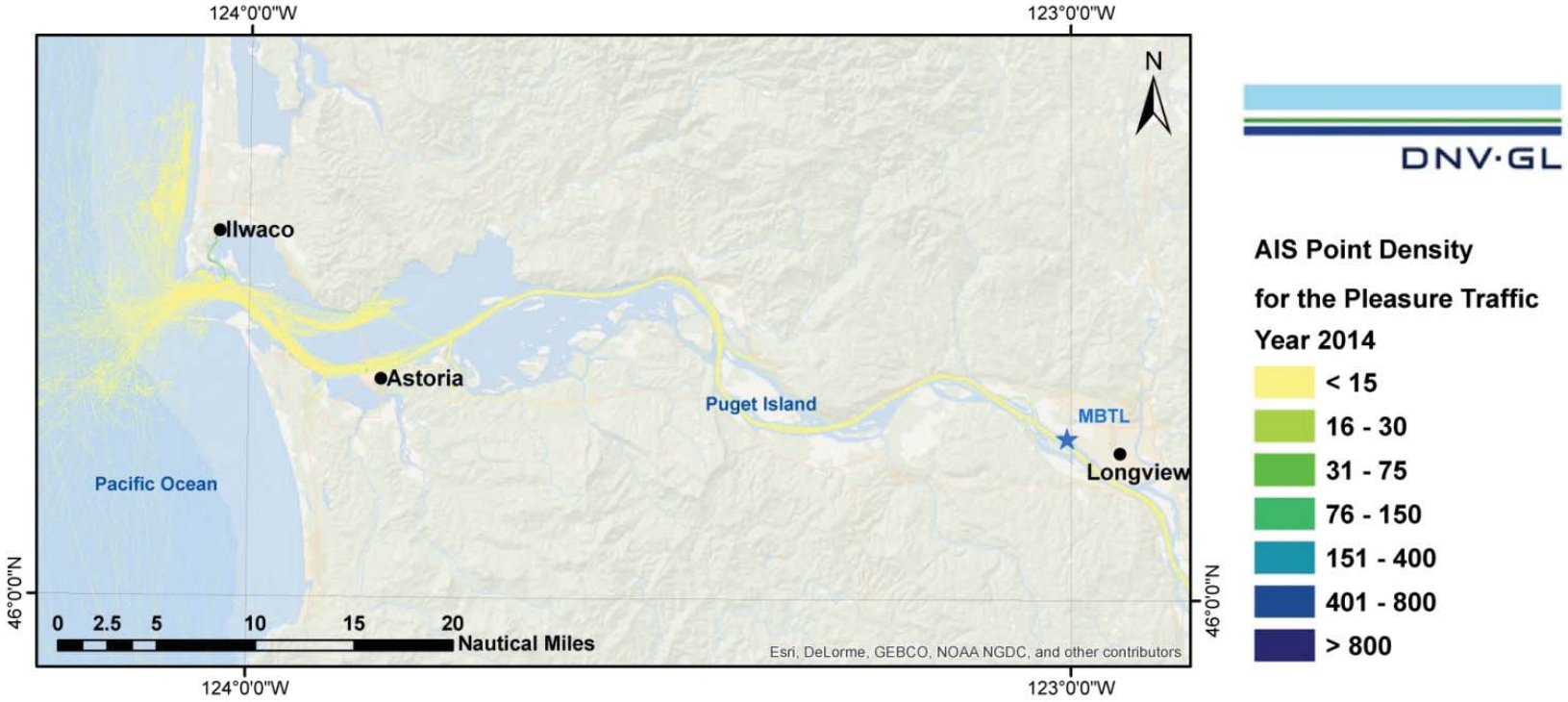


Figure 3-13 2014 AIS Density Profile for Pleasure Transits

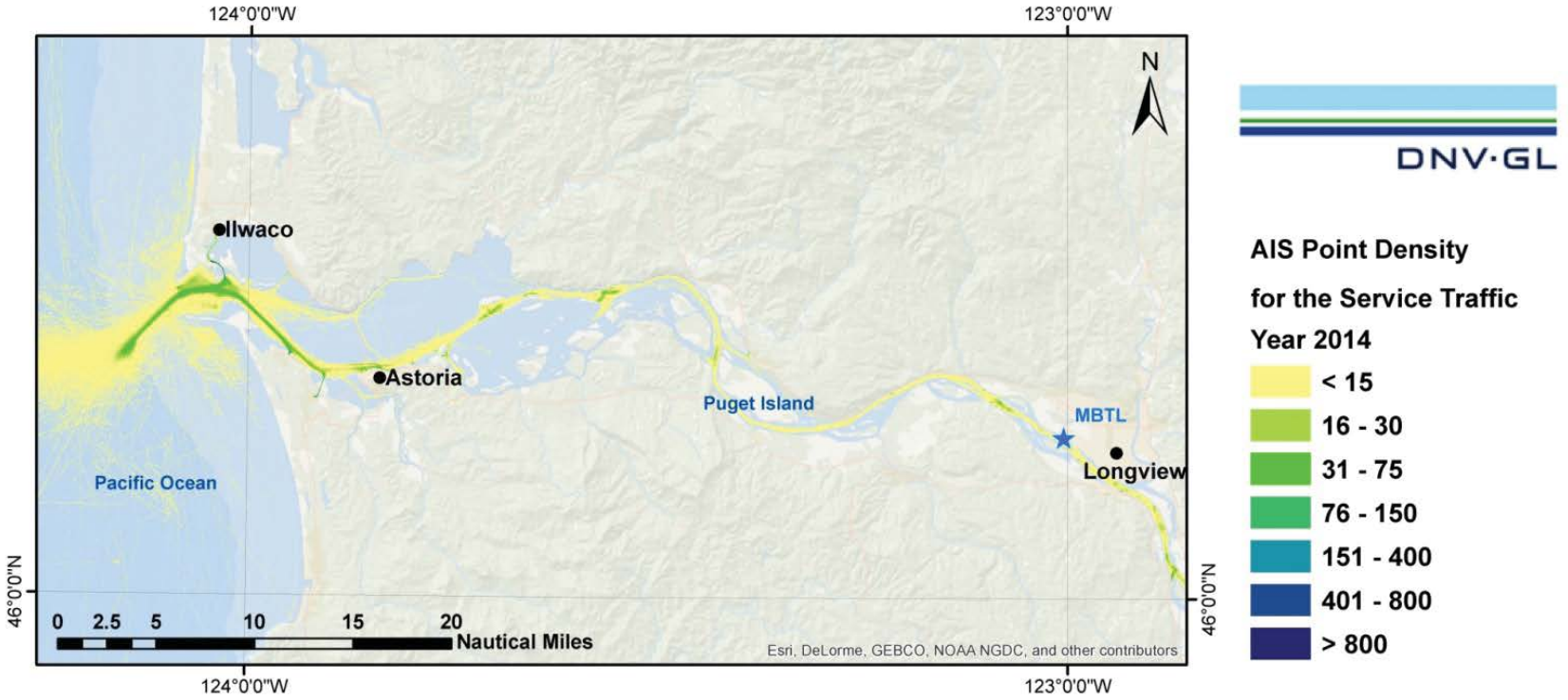


Figure 3-14 2014 AIS Density Profile for Service Transits

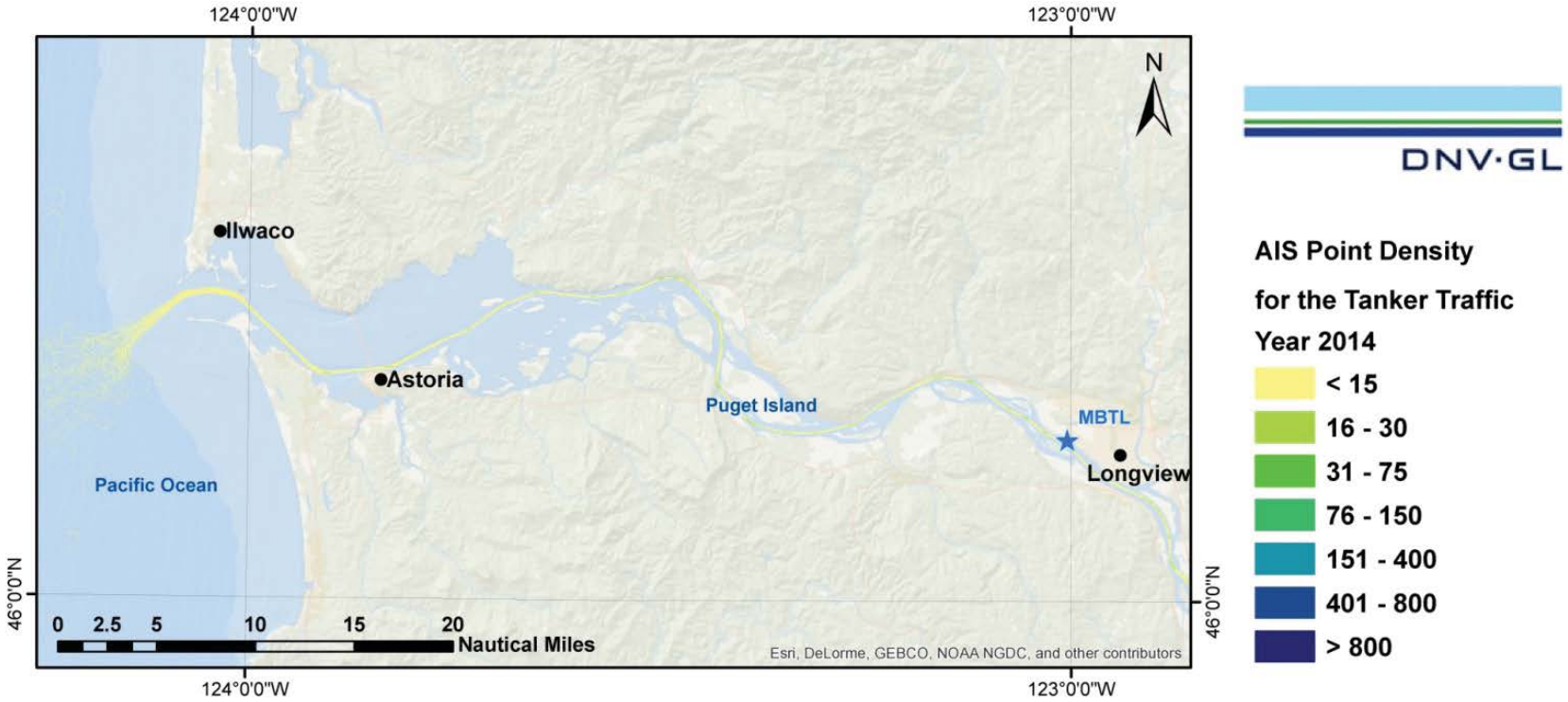


Figure 3-15 2014 AIS Density Profile for Tanker Transits

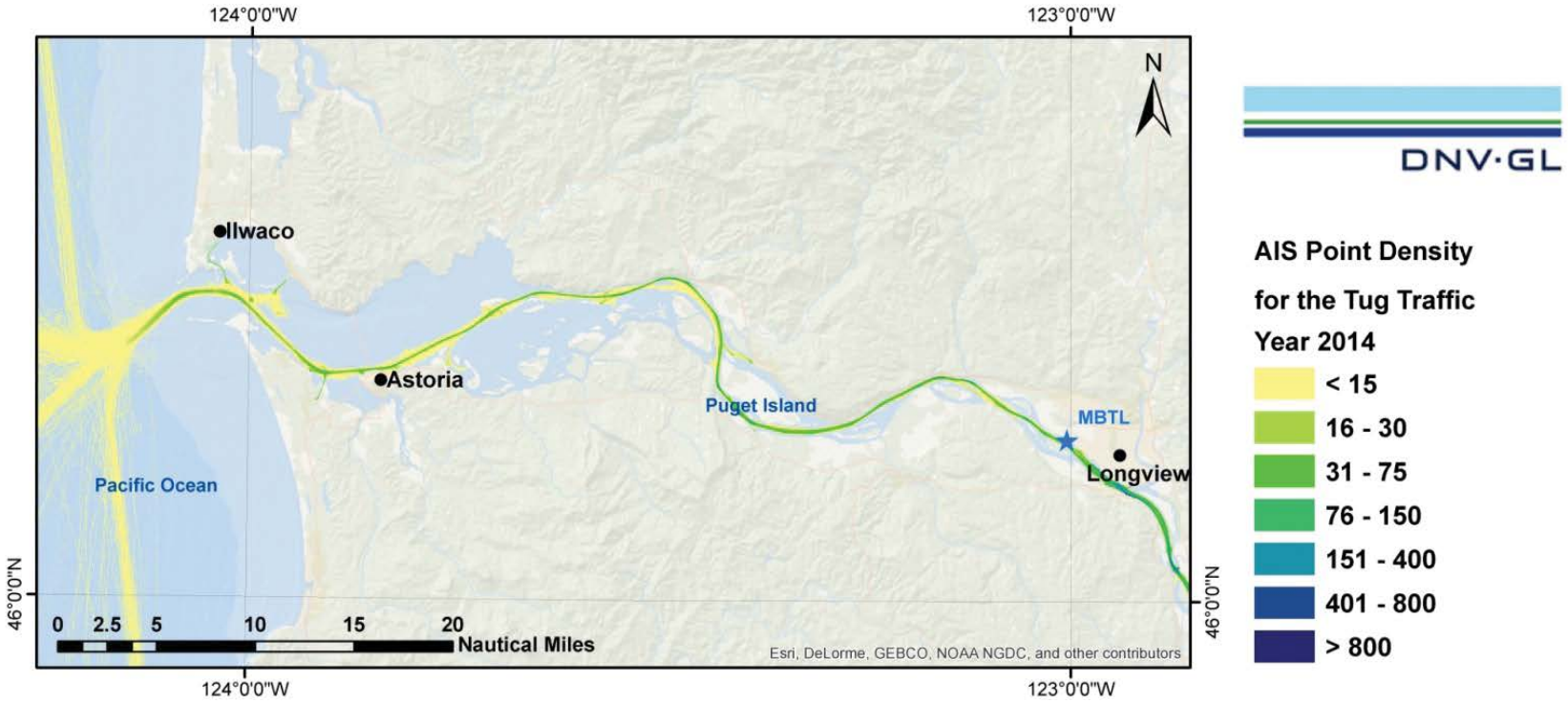


Figure 3-16 2014 AIS Density Profile for Tug Transits

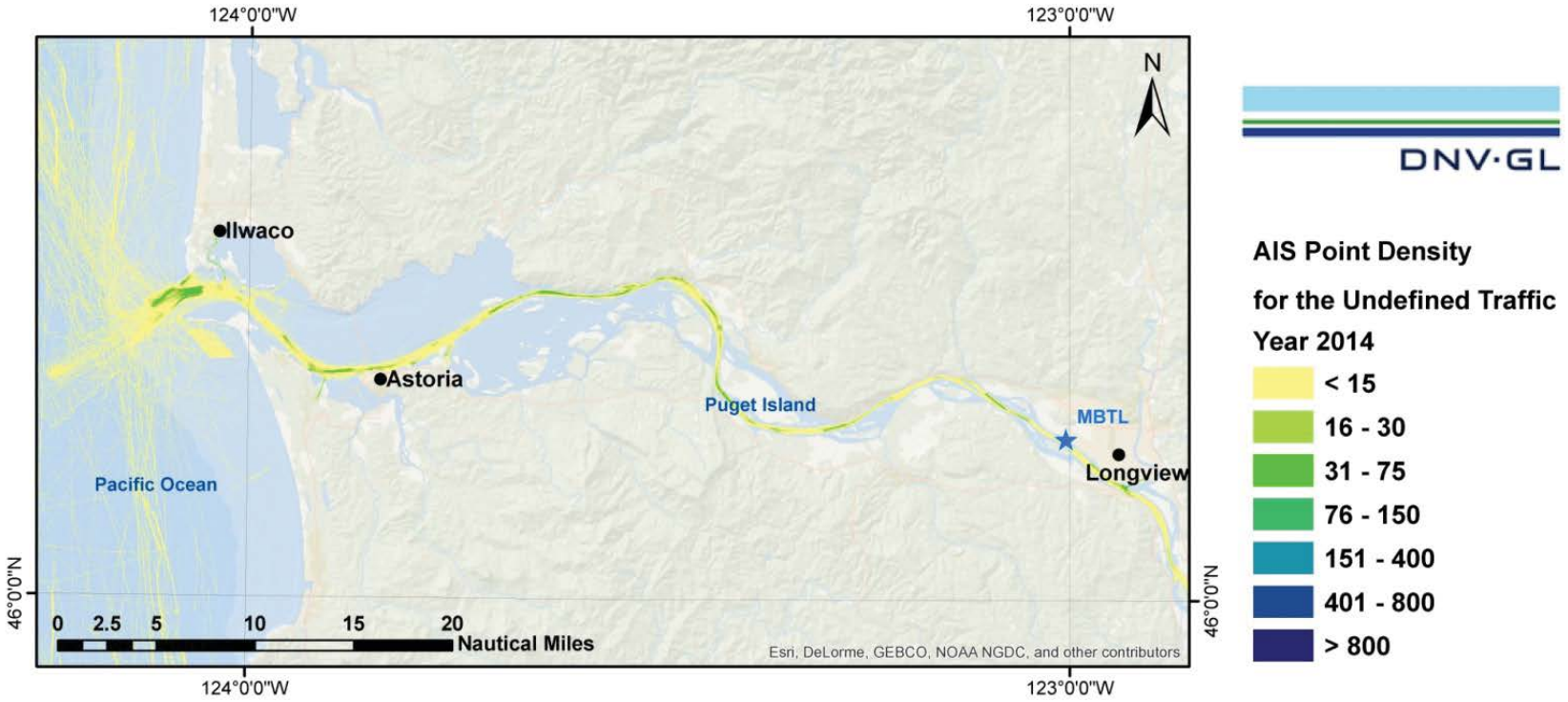


Figure 3-17 2014 AIS Density Profile for Undefined Transits

3.6 Vessel Traffic by Vessel Transit Speed

Figure 3-17 to Figure 3-26 present the average speeds determined from the time stamps in the AIS dataset. The figures show that the vessels along the project vessel route generally transit at a speed between 6 and 12 knots. The estimated average speeds for each vessel type (based on the AIS data) are presented in Table 3-3.

Table 3-3 Average Speed by Vessel Types

Vessel Category	Speed (knots)
Cargo/Carrier	12
Fishing	9
Other / Undefined	9
Passenger	10
Pleasure	9
Service	15
Tanker	12
Tug	8

Figure 3-18 presents the speed profile for all vessel transits.

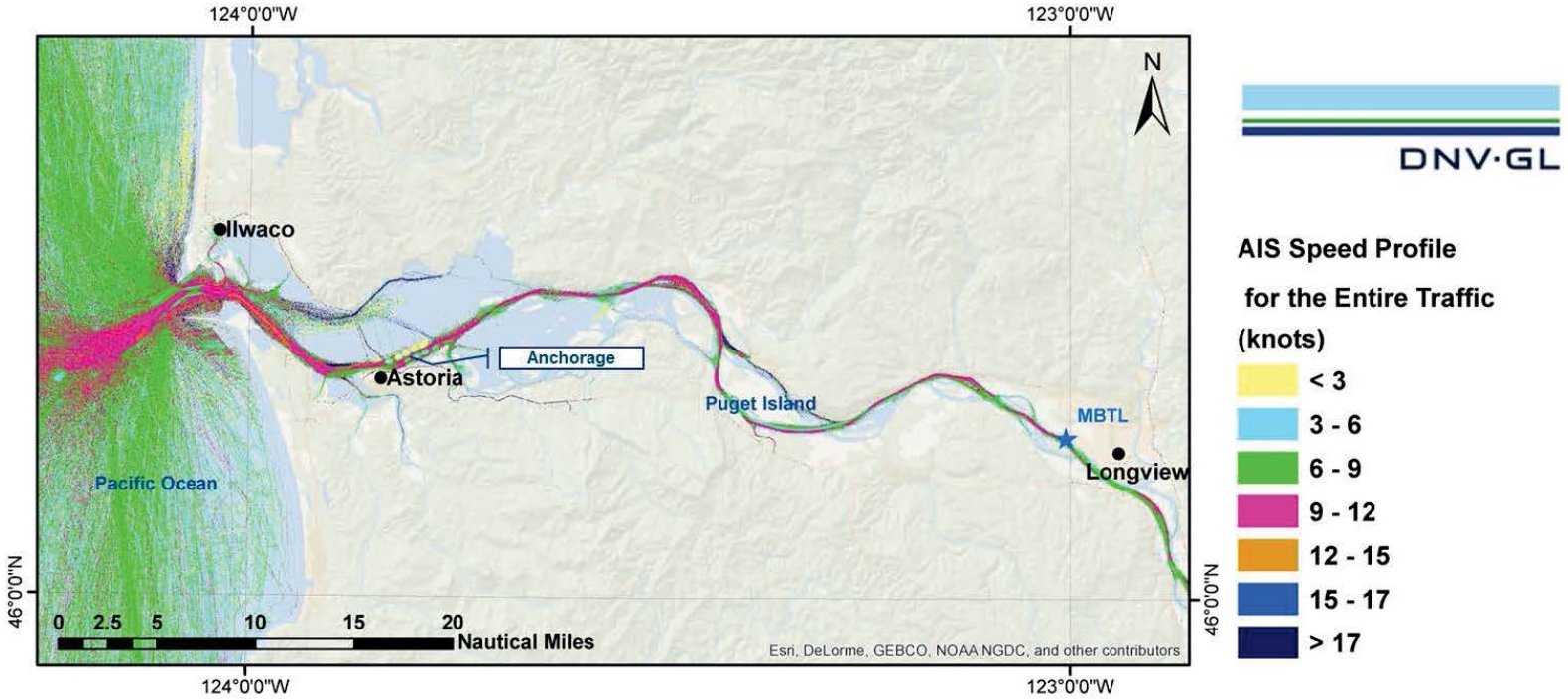


Figure 3-18 2014 AIS Speed Profile for All Vessels Transits

The speed profile of cargo/carrier vessels, Figure 3-19, shows a consistent speed distribution between 9 knots and 15 knots along the navigable channel. Slower speeds due to anchorage areas are present near Astoria.

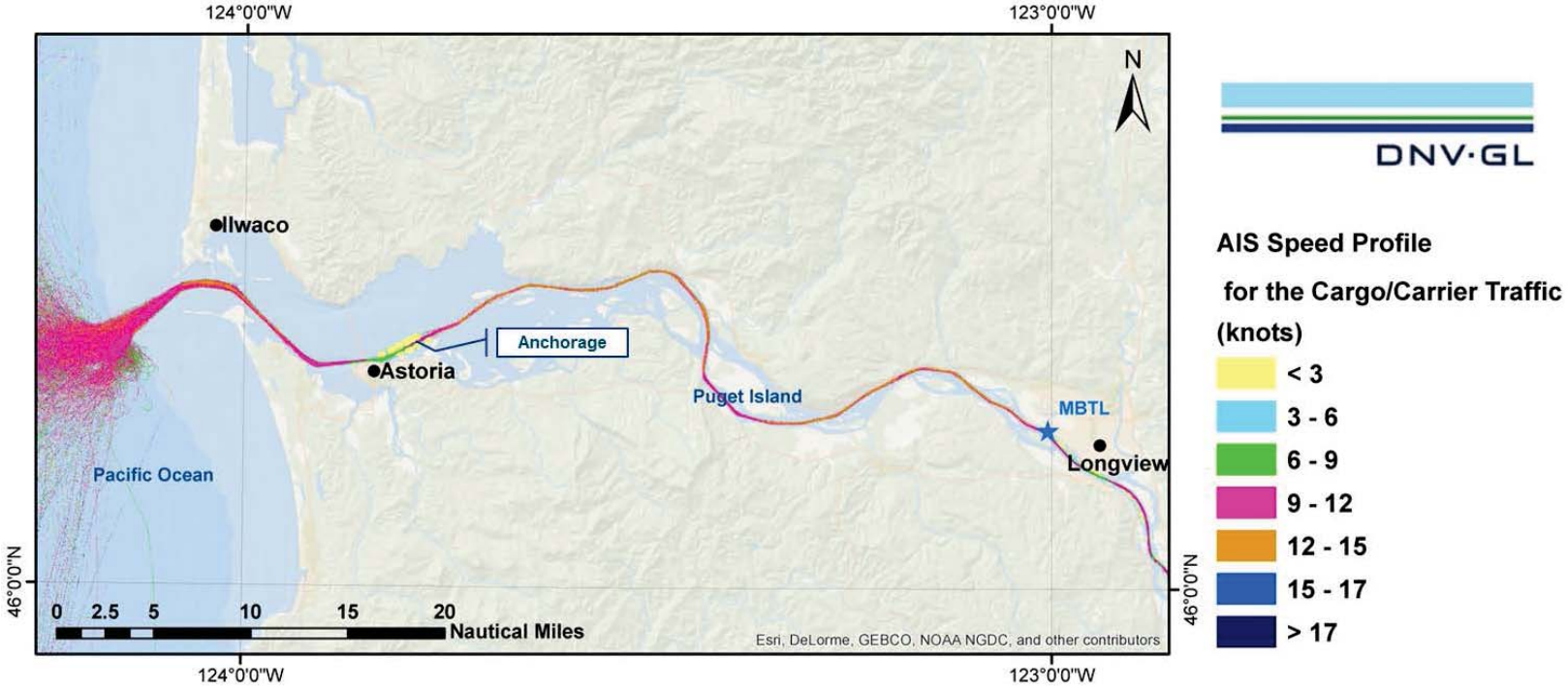


Figure 3-19 AIS Speed Profile for Cargo/Carrier Transits

The speed profile of fishing vessels, Figure 3-20, shows a speed distribution between 6 knots and 12 knots along the navigable channel.

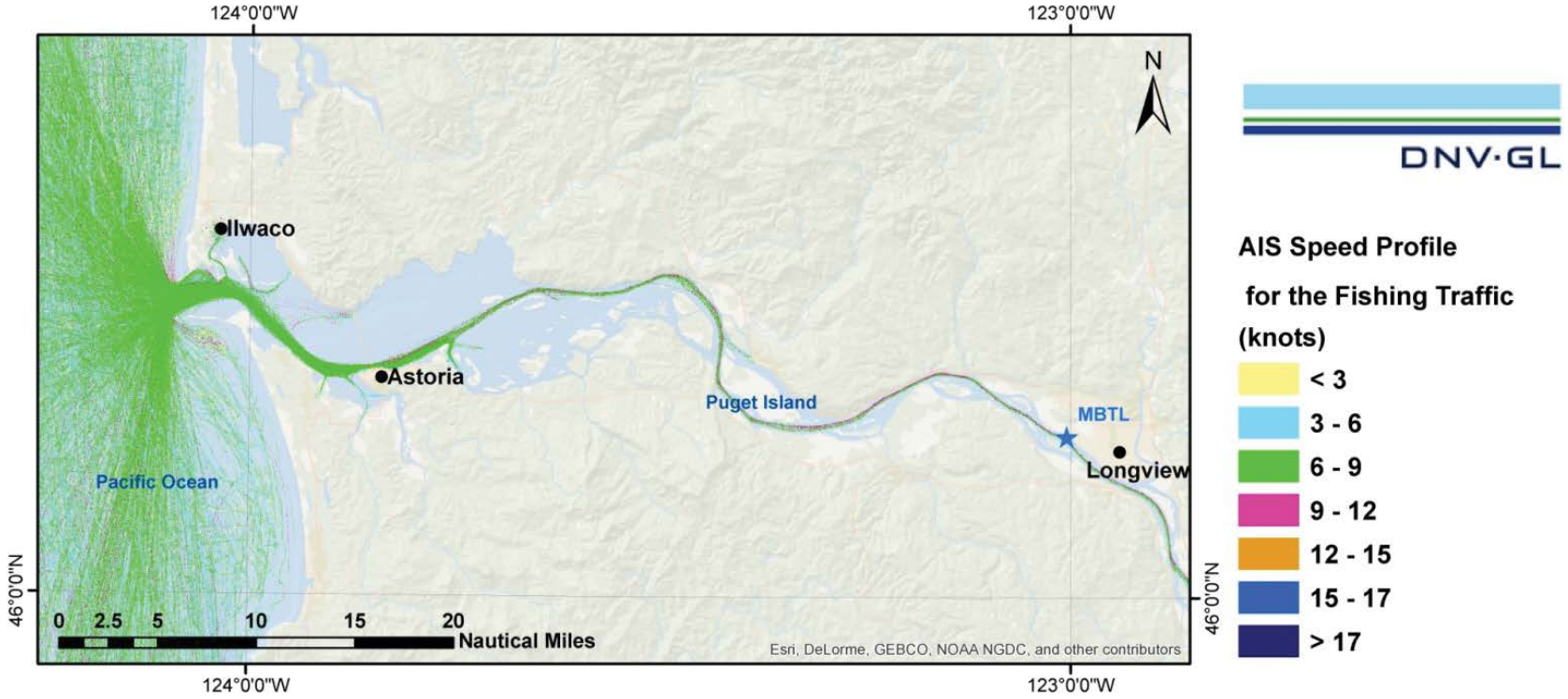


Figure 3-20 AIS Speed Profile for Fishing Transits

The speed profile of other vessels, Figure 3-21, shows many variations in speed along the waterway. The areas of highest speed are on the northeast side of Tenasillahe Island and Puget Island, where the AIS data shows other vessels reach speeds of over 17 knots.

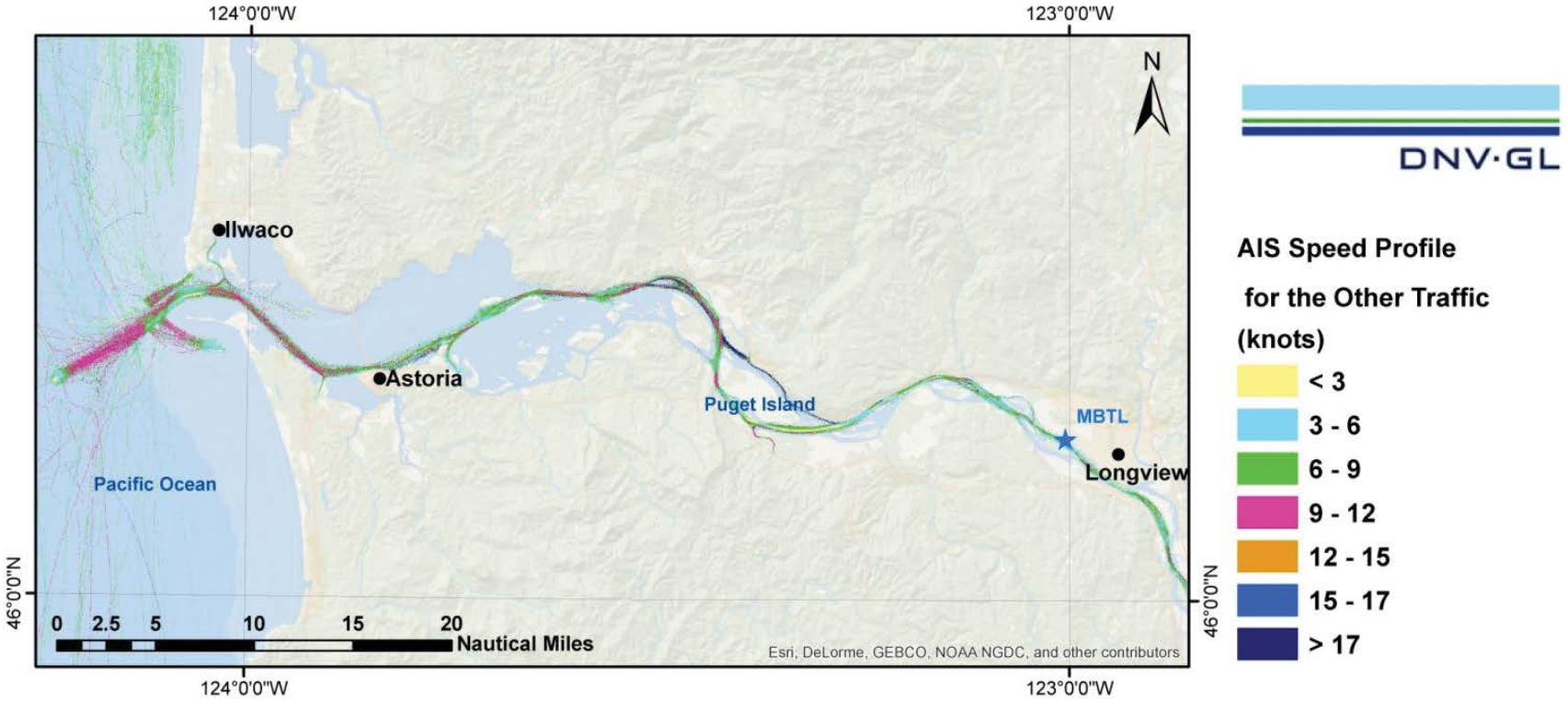


Figure 3-21 AIS Speed Profile for Other Transits

The speed profile of passenger vessels, Figure 3-22, shows a consistent speed distribution between 9 knots and 12 knots along the navigable channel. Areas of reduced speed, between 6 and 9 knots, are present near Astoria.

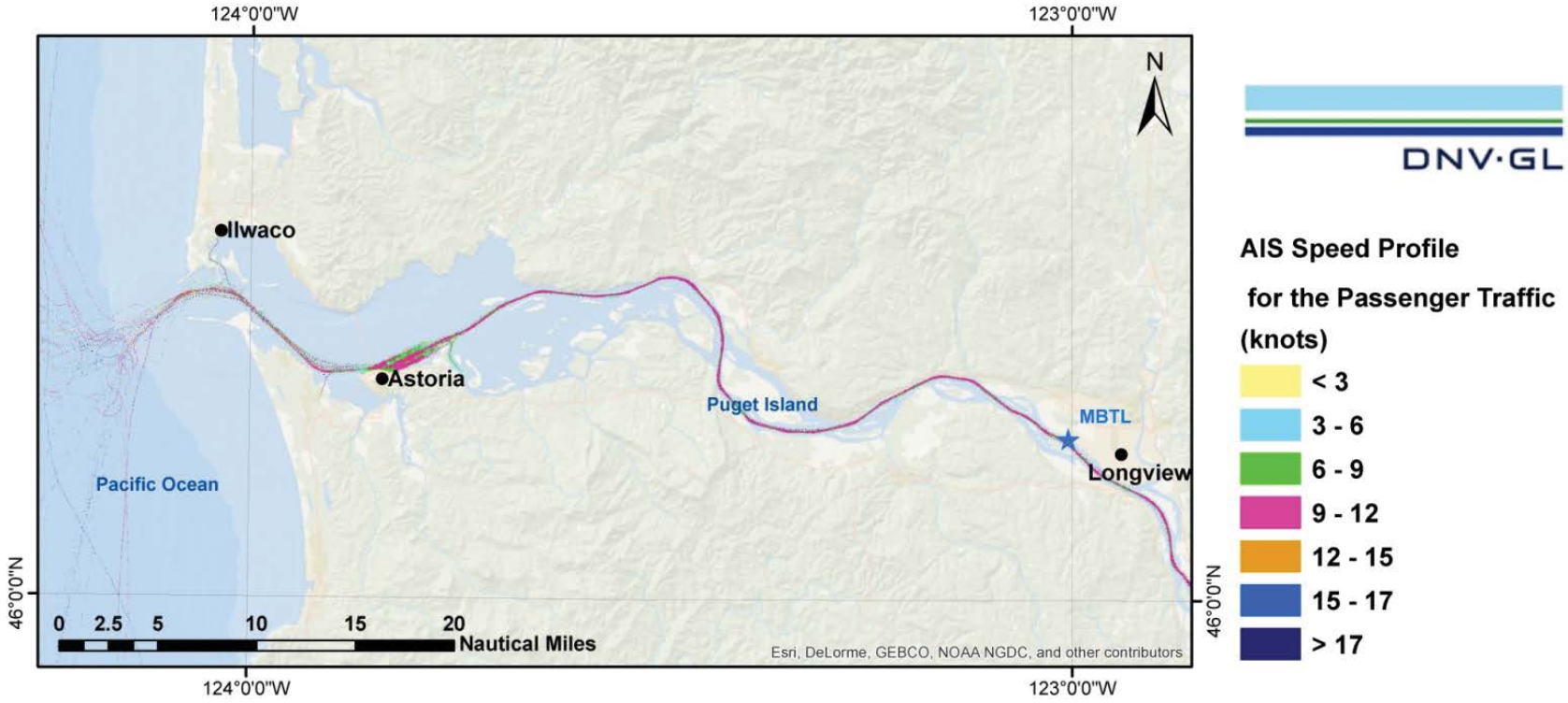


Figure 3-22 AIS Speed Profile for Passenger Transits

Figure 3-23 presents the speed profile for pleasure vessels. Pleasure vessels typically travel at approximately 9 knots, with slower speeds near Astoria.

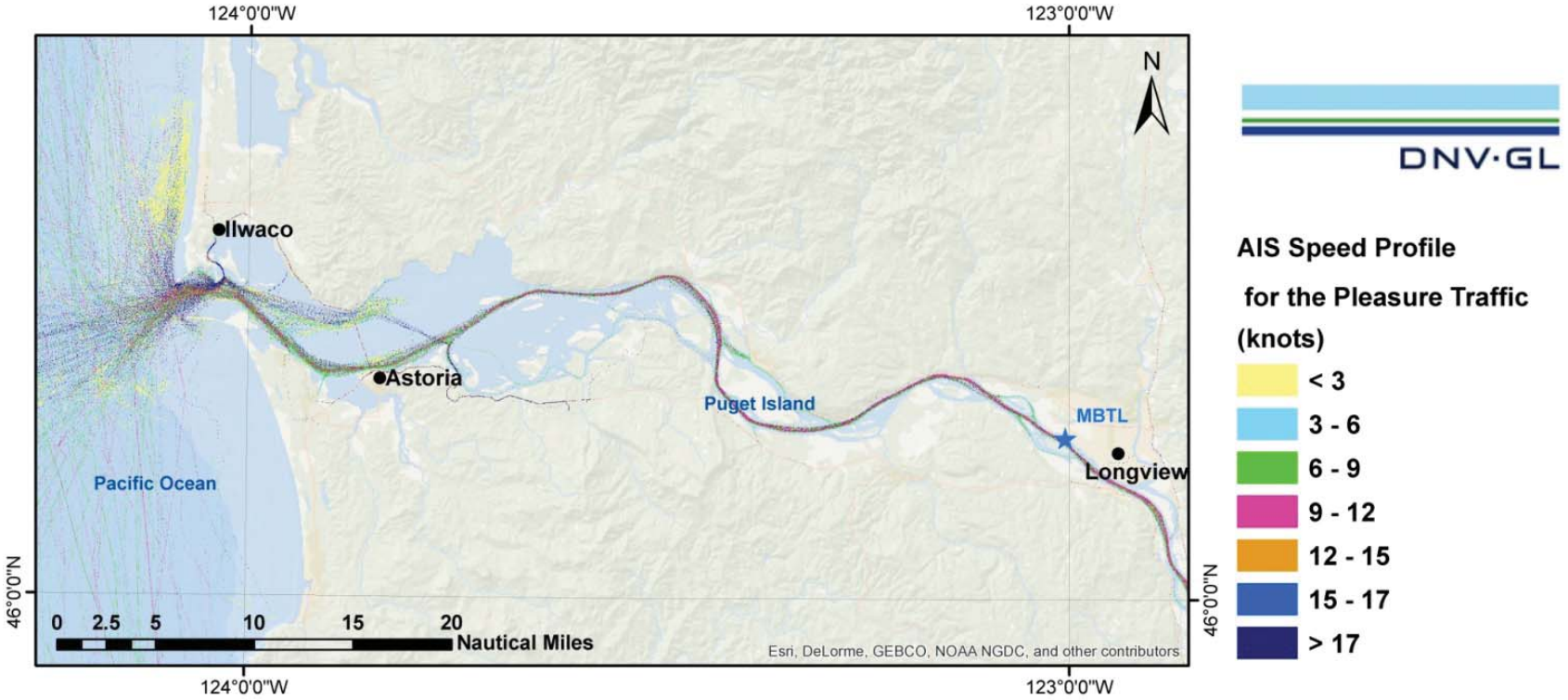


Figure 3-23 AIS Speed Profile for Pleasure Transits

Figure 3-24 presents the speed profile for service vessels. Service vessels travel at approximately 15 knots. Areas of speeds between 6 and 9 knots are present along the route.

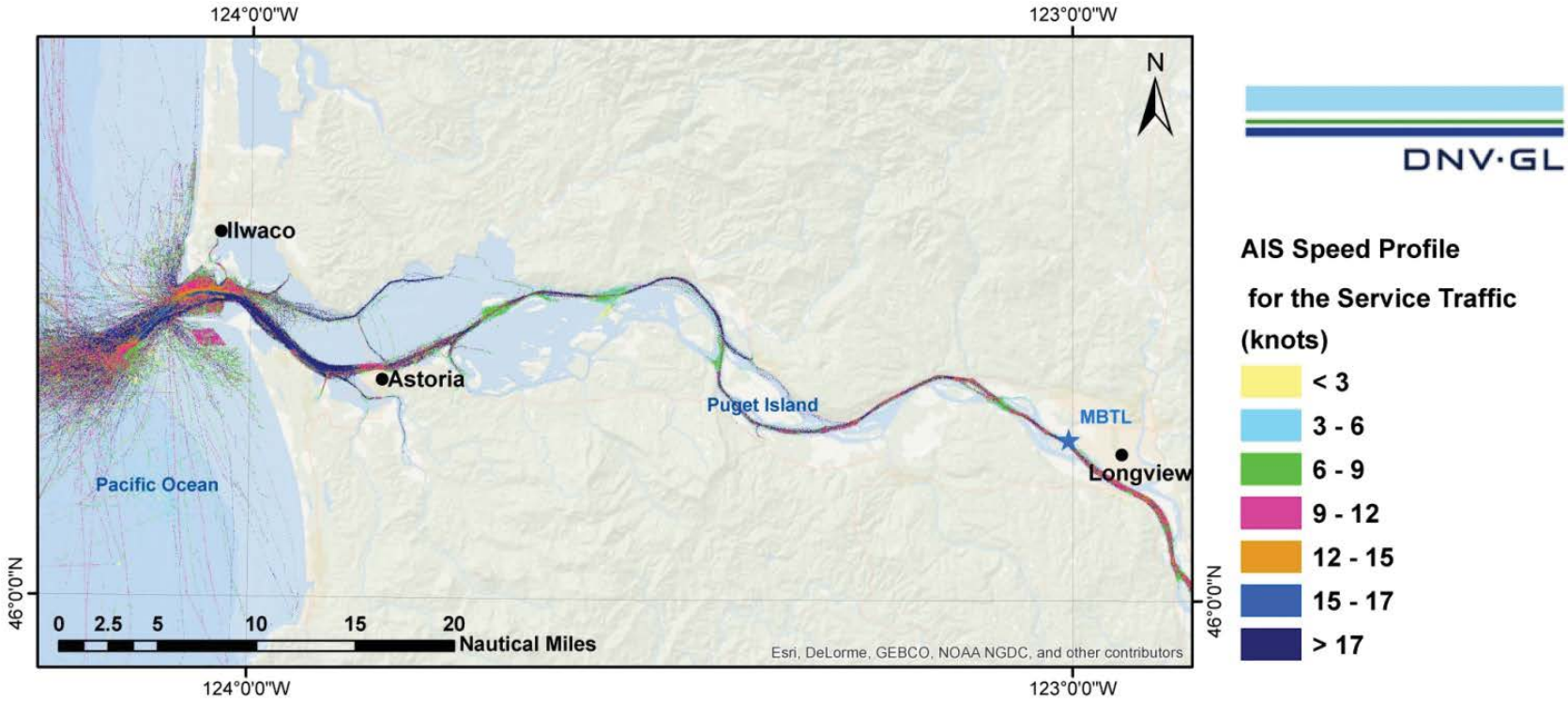


Figure 3-24 AIS Speed Profile for Service Transits

Figure 3-25 presents the speed profile for tankers. The profile shows that tankers travel at a generally uniform speed between 9 and 12 knots.

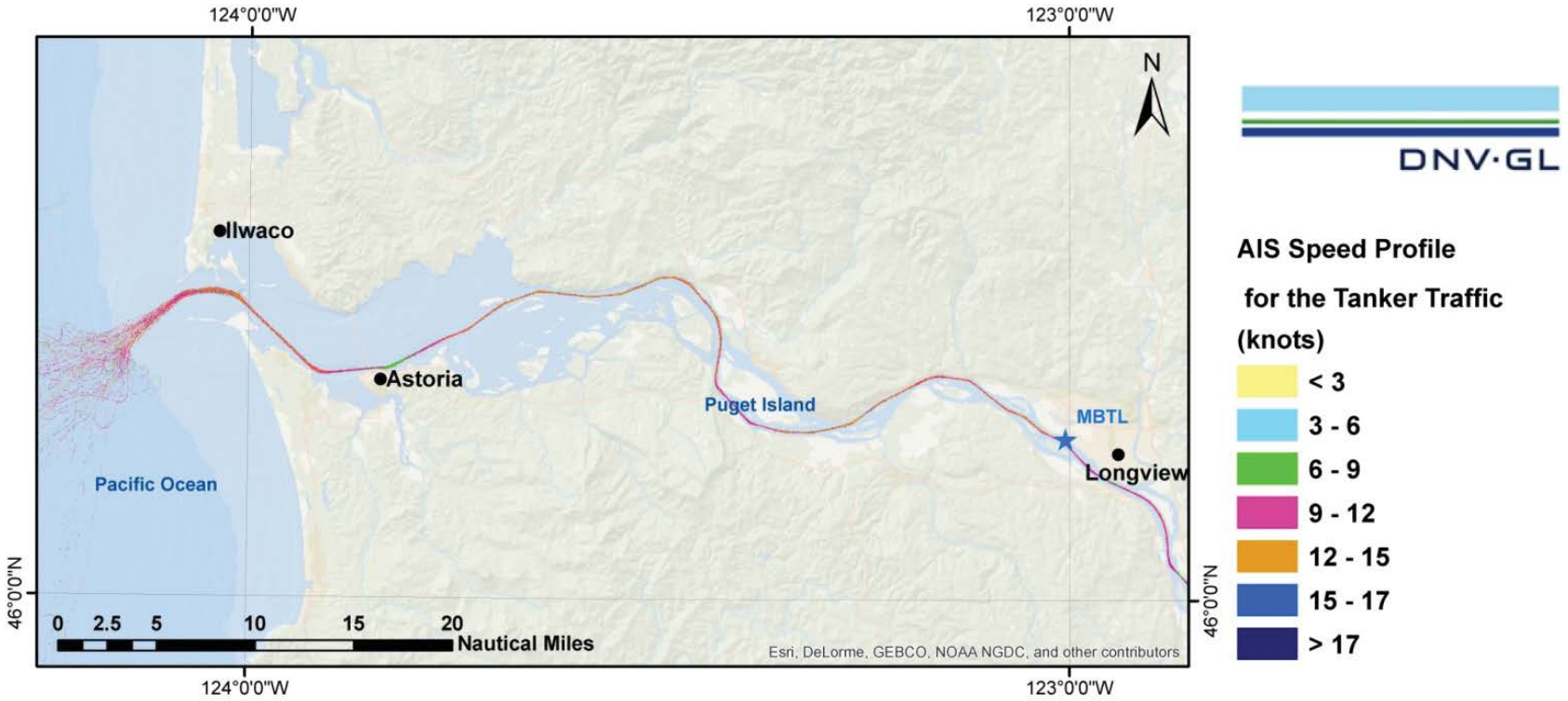


Figure 3-25 AIS Speed Profile for Tanker Transits

Figure 3-26 presents the speed profile for tug transits. Tugs typically travel between 6 and 9 knots, with some areas along the route reaching speeds between 9 and 12 knots.

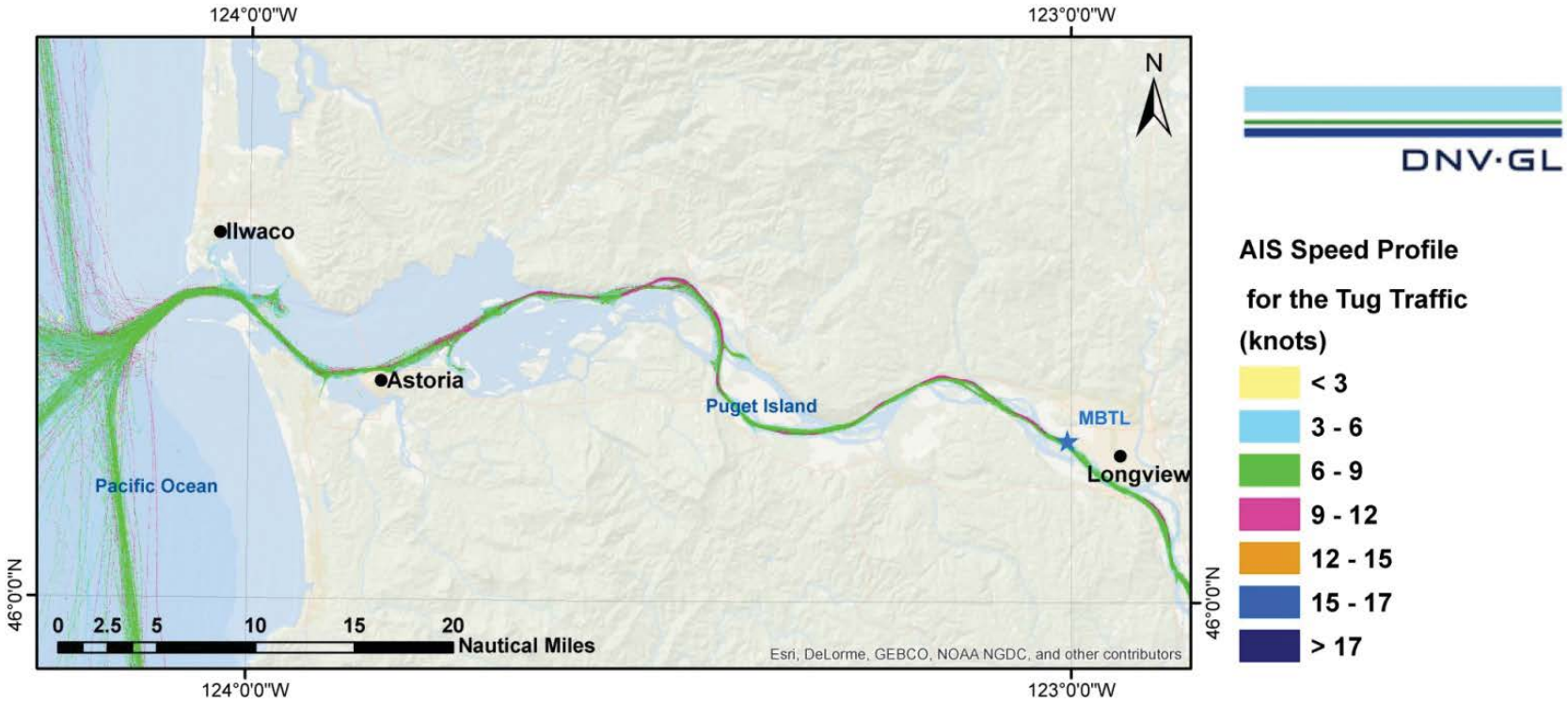


Figure 3-26 AIS Speed Profile for Tug Transits

Figure 3-27 presents the traffic profile for undefined vessels. Typically undefined vessels travel between 9 and 12 knots. However, due to the nature of the "undefined" vessel category, this is much variation in speed.

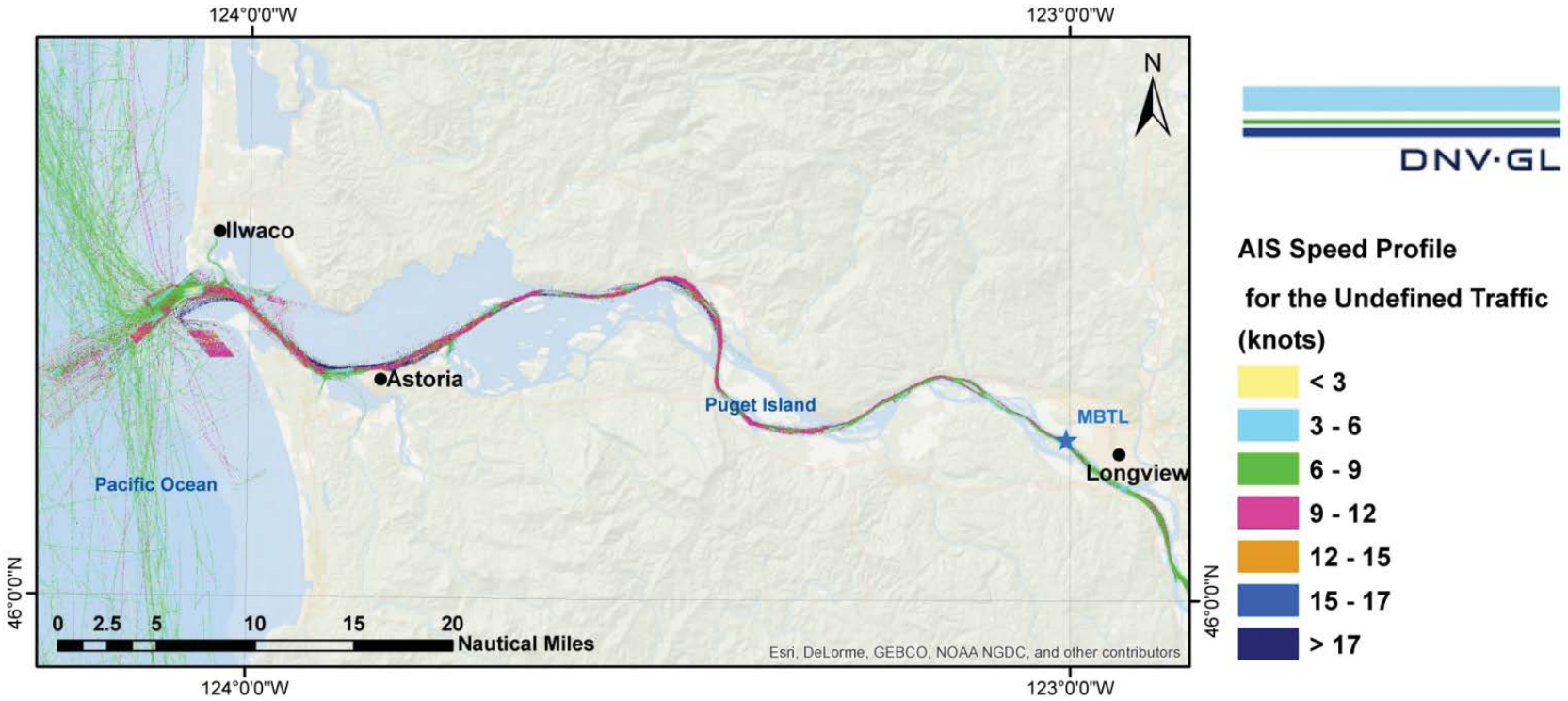


Figure 3-27 AIS Speed Profile for Undefined Transits

4 MARINE INCIDENT AND OIL SPILL DATA SURVEYS

This section presents the results of a survey describing typical damage outcome or severity of marine incidents as well as frequency and severity of reported oil spills in the study area. This survey also provides a coarse review of severity from marine incidents in U.S. waters. The purpose of these data surveys is to provide a basis for evaluating the incremental risk from the proposed project, as estimated in this study.

Figure 4-1 and Figure 4-2 describe the data processing and categorization that were applied for the two objectives listed in Section 2.1.

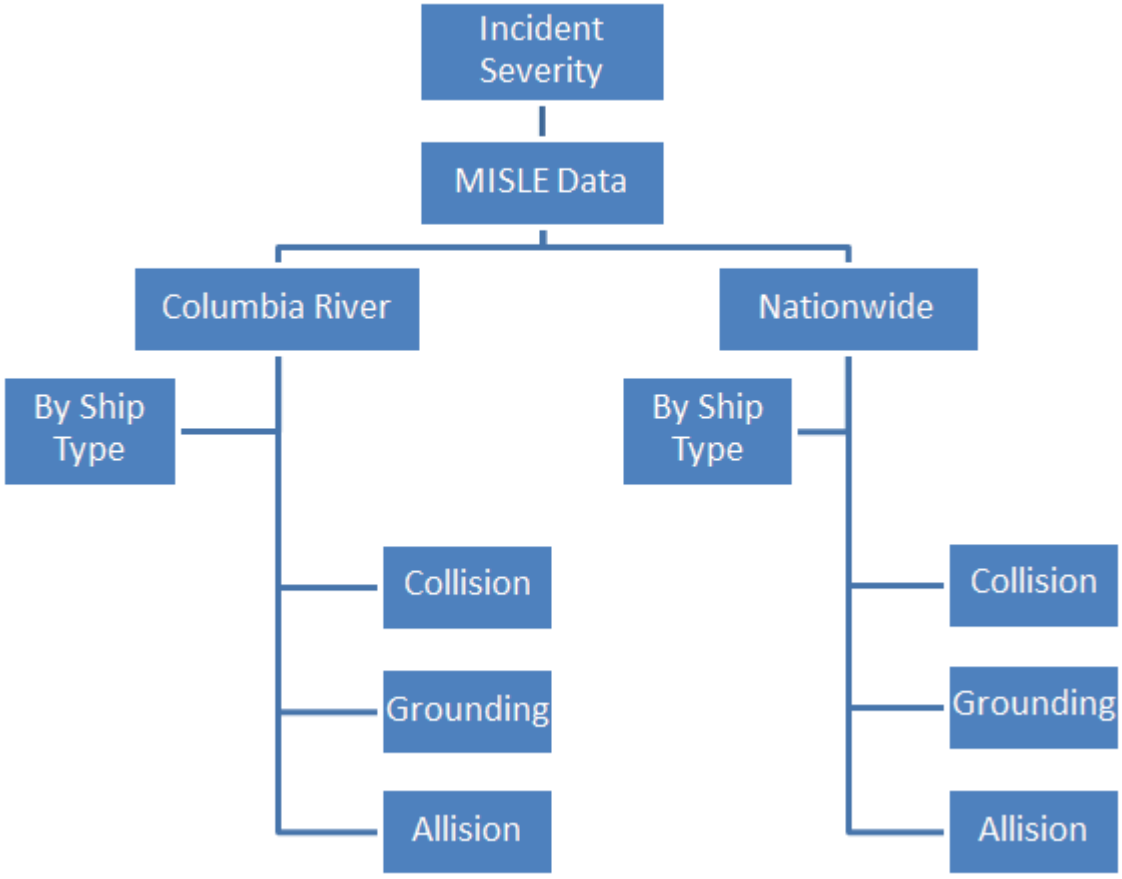


Figure 4-1 Incident Severity Data Survey Methodology

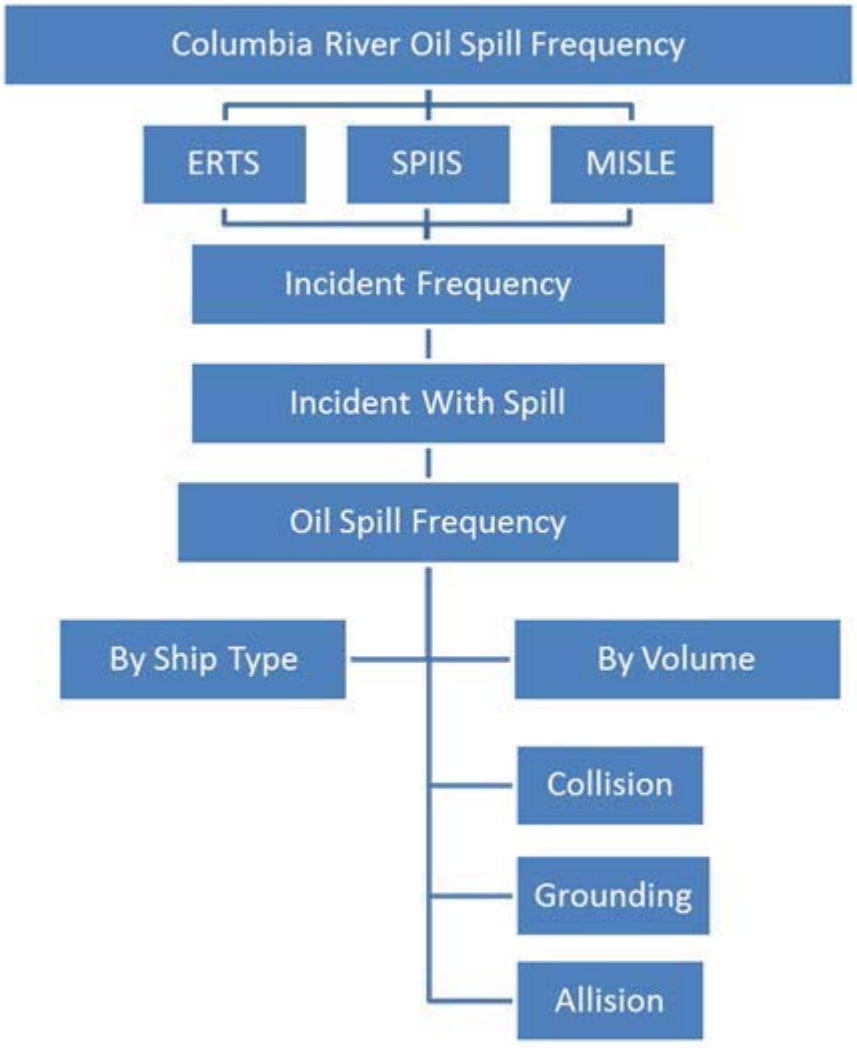


Figure 4-2 Oil Spill Frequency Data Survey Methodology

4.1 Review of Incident Severity in U.S. Waters

The information presented in this section is based on data obtained from the U.S. Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database and covers all available data from 2001 through 2014 (Ref. /4/). This period was chosen as it covers over 99% of all collision, grounding, and allision incidents reported in the dataset. The remaining 1% of data are sparsely distributed 1900 to 2000. The data are presented for the vessel types reported in the MISLE database, which are comparable to those identified in the AIS data, and are not predictive of bulk carrier casualties.

The "Accident Type" field includes 26 different entry categories. Of these, only incident types *collision*, *allision*, and a combination of *grounding / set adrift* were analyzed because the objective of this data survey

is to provide context around the consequences of the incidents evaluated in this navigational risk study which are limited to collisions, powered and drift groundings, and allisions.

The severity of a marine incident is captured in the "Damage Status" field of the MISLE data, which describes damage to the vessel(s) implicated in the incident and includes five different categories. For the purposes of this analysis, the categories *Actual Total Loss*, *Total Constructive Loss: Salvaged*, and *Total Constructive Loss: Unsalvaged* were combined into a single category called "Total Loss". The other two categories are *Damaged* and *Undamaged*.

Table 4-1 and Table 4-2 present the severity distribution for the three incident types discussed above.

Table 4-1 Incident Severity by Incident Type for U.S. Waters – Incident Count (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Allision	149	4,525	5,479	10,153
Collision	114	2,092	1,727	3,933
Grounding / Adrift	364	3,929	12,162	16,455
TOTAL	**627**	**10,546**	**19,368**	**30541**

Table 4-2 Incident Severity by Incident Type for U.S. Waters - % of incidents (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Allision	1%	45%	54%	100%
Collision	3%	53%	44%	100%
Grounding / Adrift	2%	24%	74%	100%
TOTAL	**2%**	**35%**	**63%**	**100%**

4.2 Review of Incident Severity in the Lower Columbia River

The same approach was applied to data covering incidents within the study area. Table 4-3 and Table 4-4 present the outcome distribution for marine incidents that took place between the Columbia River mouth and the Port of Portland.

The results of this data survey are very similar to those from nation-wide incidents in that approximately two-thirds of incidents result in no damage, one-third in some damage to the vessel(s) involved and slightly less than 3% result in a vessel total loss.

Table 4-3 Incident Severity by Incident Type for Study Area – Incident Count (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Allision	3	24	29	56
Collision	1	9	9	19
Grounding /Adrift	1	16	59	76
TOTAL	**5**	**49**	**97**	**151**

Table 4-4 Incident Severity by Incident Type for Study Area - % of incidents (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total*
Allision	5%	43%	52%	100%
Collision	5%	47%	47%	100%
Grounding /Adrift	1%	21%	78%	100%
TOTAL	**3%**	**32%**	**64%**	**100%**

*Note: Sum of percentages do not always add up to 100% due to rounding.

This data was further parsed to show incident severity by incident type and vessel type. All vessel types presented found in the AIS data and described in Section 3.3 are covered in the USCG MISLE database.

Table 4-5 presents the distribution of incident severity for all incident types by vessel type for the study area. Table 4-6 to Table 4-8 present the distribution of incident severity by incident type and vessel type for the study area. These tables show that collisions appear to result in the highest severity outcomes, with 5% resulting in a vessel loss and 47% resulting in damage to the vessel(s) involved in the incident. Allisions have the second highest severity outcomes with 5% vessel loss and 43% damage. Groundings result in only 1% vessel loss and 21% vessel damage .

It is worth noting that none of the total loss outcomes reported in the data were due to grounding, collision or allision incidents involved carriers or vessels of similar size. The only vessel categories reported as a total loss in any of these incident types were passenger vessels, fishing vessels and recreational vessels.

Table 4-5 Outcome Distribution for All Marine Incidents - Study Area Only (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Barge	0%	2%	7%	9%
Bulk Carrier	0%	2%	16%	18%
Fishing Vessel	2%	5%	13%	21%
General Dry Cargo Ship	0%	1%	3%	4%
Miscellaneous Vessel	0%	1%	0%	1%
Passenger Ship	1%	8%	7%	15%
Recreational	1%	3%	0%	3%
Ro-Ro Cargo Ship	0%	1%	1%	2%
Tank Ship	0%	0%	2%	2%
Towing Vessel	0%	7%	13%	20%
UNSPECIFIED	0%	1%	3%	4%
Warship	0%	1%	0%	1%
TOTAL	**3%**	**32%**	**64%**	**100%**

Table 4-6 Outcome Distribution for Allisions - Study Area Only (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Barge	0%	2%	14%	16%
Bulk Carrier	0%	4%	5%	9%
Fishing Vessel	5%	2%	4%	11%
General Dry Cargo Ship	0%	4%	0%	4%
Miscellaneous Vessel	0%	2%	0%	2%
Passenger Ship	0%	13%	4%	16%
Recreational	0%	2%	0%	2%
Ro-Ro Cargo Ship	0%	2%	0%	2%
Towing Vessel	0%	11%	23%	34%
UNSPECIFIED	0%	4%	2%	5%
TOTAL	**5%**	**43%**	**52%**	**100%**

Table 4-7 Outcome Distribution for Collisions - Study Area Only (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Barge	0%	0%	11%	11%
Fishing Vessel	0%	11%	11%	21%
Miscellaneous Vessel	0%	5%	0%	5%
Passenger Ship	0%	5%	5%	11%
Recreational	5%	16%	0%	21%
Tank Ship	0%	0%	5%	5%
Towing Vessel	0%	5%	11%	16%
UNSPECIFIED	0%	0%	5%	5%
Warship	0%	5%	0%	5%
TOTAL	**5%**	**47%**	**47%**	**100%**

Table 4-8 Outcome Distribution for Groundings - Study Area Only (USCG MISLE data 2001-2014)

Damage Status	Total Loss	Damaged	Undamaged	Total
Barge	0%	3%	1%	4%
Bulk Carrier	0%	1%	28%	29%
Fishing Vessel	0%	7%	21%	28%
General Dry Cargo Ship	0%	0%	5%	5%
Passenger Ship	1%	5%	9%	16%
Ro-Ro Cargo Ship	0%	0%	3%	3%
Tank Ship	0%	0%	3%	3%
Towing Vessel	0%	5%	5%	11%
UNSPECIFIED	0%	0%	3%	3%
TOTAL	**1%**	**21%**	**78%**	**100%**

4.3 Review of Oil Spill Data from the Lower Columbia River

In order to properly assess the potential bunker oil spill risk contributed by the project in 2028 and 2038, a survey of historical oil spill data from the Lower Columbia River was performed. The purpose of this data survey is to establish the baseline risk of any hydrocarbon spill for the study area, and is not limited to spills of bunker oil. Additionally, all vessel and incident types included in the data are considered. Estimates of the oil spill risk contributed by the project can then be compared to this baseline in order to quantify the increase in risk contributed by the project in 2028 and 2038.

Data on all reported oil spills, including bunker oil spills, were reviewed from the following three databases for the period between January 1, 2004 and December 31, 2014. All three datasets overlap during this eleven year time period therefore providing the most complete data coverage of oil spill risk available for the study area.

- USCG MISLE Data: described in Section 4.1.
- SPIIS Data from Washington State Department of Ecology: The Spills Program Incident Information System (SPIIS) tracks Spill Program incidents and actions. The data only include vessels that are "covered" by state requirements for planning, preparedness, and liability in case of any vessel emergency that results in the discharge or substantial threat of discharge of oil into state waters. A "covered" vessel is a commercial vessel of 300 or more gross tons and can be a tank vessel, cargo vessel, or passenger vessel.
- The Washington State's Environmental Report Tracking System (ERTS) database collects data on all incidents reported to the state as required by law (RCW 88.46.100 for "covered" vessels; and RCW 90.56.280 duty of anyone with knowledge of a discharge into the waters of the state to notify Coast Guard and State Division of Emergency Management) that could result in the discharge or substantial threat of discharge oil into state waters.

When combining these three datasets, all duplicative entries were removed and only incidents with actual reported spills of petroleum or petroleum products were considered. All vessel categories and incident types are considered in the data survey as the objective of this survey is to establish the baseline oil spill frequency for the study area.

Table 4-9 and Figure 4-3 present oil spill incident counts and spill frequencies by spill volume and incident type. Spill volumes per incident range from 0.1 to 1,603 gallons. The average oil spill frequency for the study area is 15.6 spills per year with 84% of these spills having a volume of less than 10 gallons. Spills of more than 100 gallons have occurred at a frequency of 0.4 per year or once every 2.2 years. The average size of these larger spills is approximately 630 gallons with the largest being a 1600 gallon spill from a barge in 2011.

Other datasets with sparser coverage of the oil spills on the Columbia River do exist and include records of some larger spills including a 4,600 gallon bunker oil spill from a chemical tanker in 2003. These datasets are not included in this survey as their sparseness makes spill frequency estimates unreliable but they do provide data points on the historical size of oil spills on the Lower Columbia River including several spills larger than 1600 gallons.

Table 4-9 Oil Spill Incident Count and Frequency - Lower Columbia River (2004-2014)

Incident Type	Oil Spill Incident Count by Spill Volume					*Oil Spills /year*
	< 1 gal	1 - 10 gal	10 - 100 gal	> 100 gal	Total	
Allision	1	-	-	-	**1**	***0.1***
Capsize	1	-	-	-	**1**	***0.1***
Damage to the Environment	123	57	28	6	**214**	***15.3***
Grounding	-	-	1	-	**1**	***0.1***
Sinking	-	2	-	-	**2**	***0.1***
Total	**125**	**59**	**29**	**6**	**219**	***15.6***
Spills /year	***8.9***	***4.2***	***2.1***	***0.4***	***15.6***	

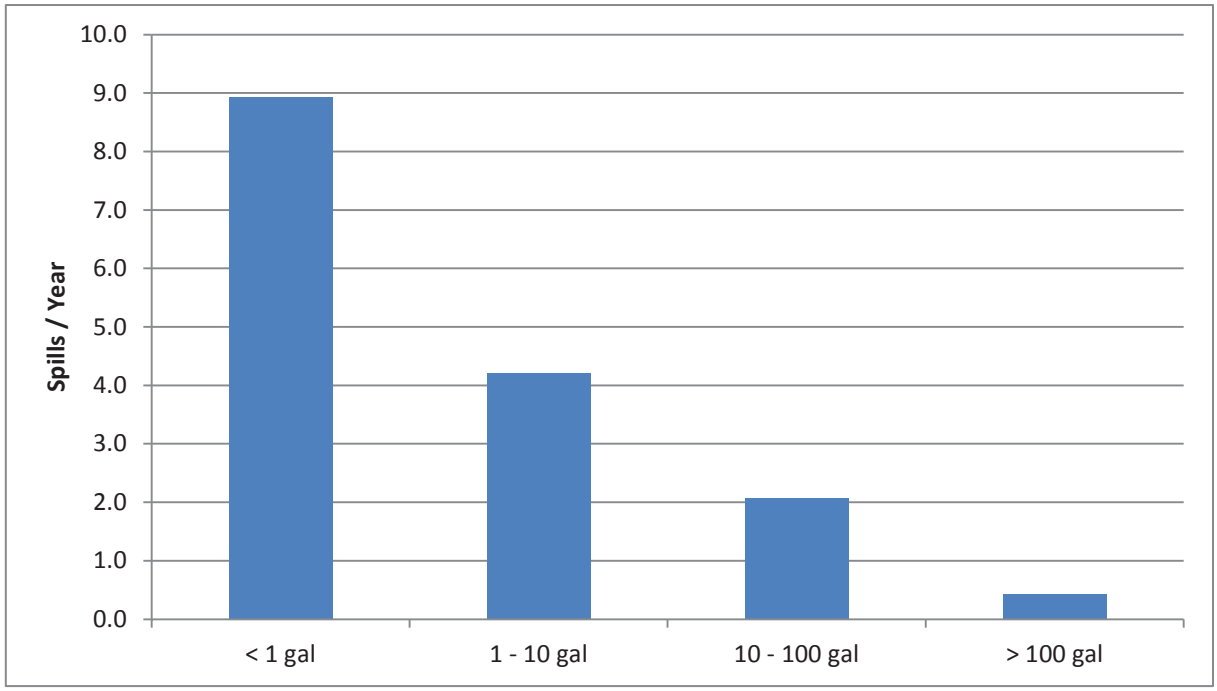


Figure 4-3 Oil Spill Frequency by Volume (Lower Columbia River 2004-2014)

5 MODELING APPROACH

Figure 5-1 presents general approach to DNV GL's navigation study. Inputs and assumptions were applied to two models. DNV GL's proprietary model, Marine Accident Risk Calculation (MARCS) and the allision calculation were used to estimate navigation incident frequencies; further data analysis was performed to measure the incremental impact of the proposed project. MARCS and the oil spill methodology was used to estimate bunker spill frequencies of project and non-project vessels; the Naval Architecture Package (NAPA) was then used to estimate the conditional probabilities of bunker oil spill volumes for project vessels. Further data analysis was performed to measure the incremental impact of the proposed project.

Preliminary MARCS and NAPA results were presented in a stakeholder workshop with DNV GL, ICF International, Washington State Department of Ecology (Ecology), Cowlitz County, U.S. Environmental Protection Agency (EPA), U.S. Coast Guard (USCG), and the U.S. Army Corp of Engineers Sector Columbia River (USACE) on November 9, 2015. Study conclusions are based on the incremental impact of the proposed project in 2028 and 2038, and the conditional probability of bunker oil spill volumes.

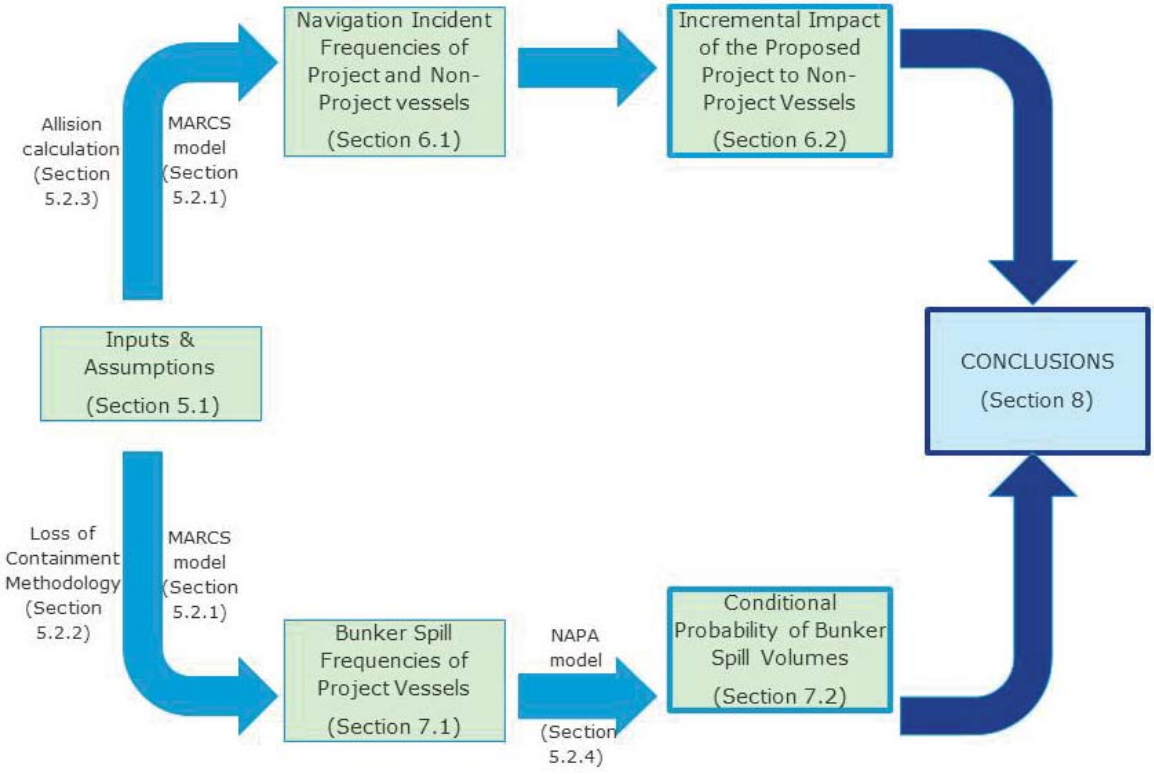


Figure 5-1 General Approach to DNV GL's Navigation Study

5.1 Inputs and Assumptions

5.1.1 Case Definitions

DNV GL has modelled five cases to present a full picture of the risks on the Columbia River due to the proposed project. The cases are defined in Table 5-1.

Table 5-1 Case Definitions

Scenario	1. Existing Conditions 2014	2. No Action 2028	3. Proposed Project 2028	4. No Action 2038	5. Proposed Project 2038
Non-project vessels	2014 AIS data	AIS (including projected growth rate to 2028)	AIS (including projected growth rate to 2028)	AIS (including projected growth rate to 2038) + additional traffic from future projects	AIS (including projected growth rate to 2038) + additional traffic from future projects
Project vessels	6 calls / year (1 ship type)*	26 calls / year (3 ship types)*	840 calls / year (2 ship types)	26 calls / year (3 ship types)*	840 calls / year (2 ship types)

*Will not be studied separately from non-project vessels

The projected growth rate will be further discussed in Section 5.1.3.

5.1.2 Route

The geographic extent of the work is from 0.5 nautical mile (NM) upriver of the proposed terminal to the mouth of the Columbia River at the boundary of the Territorial Sea. The route is presented in Figure 5-2.

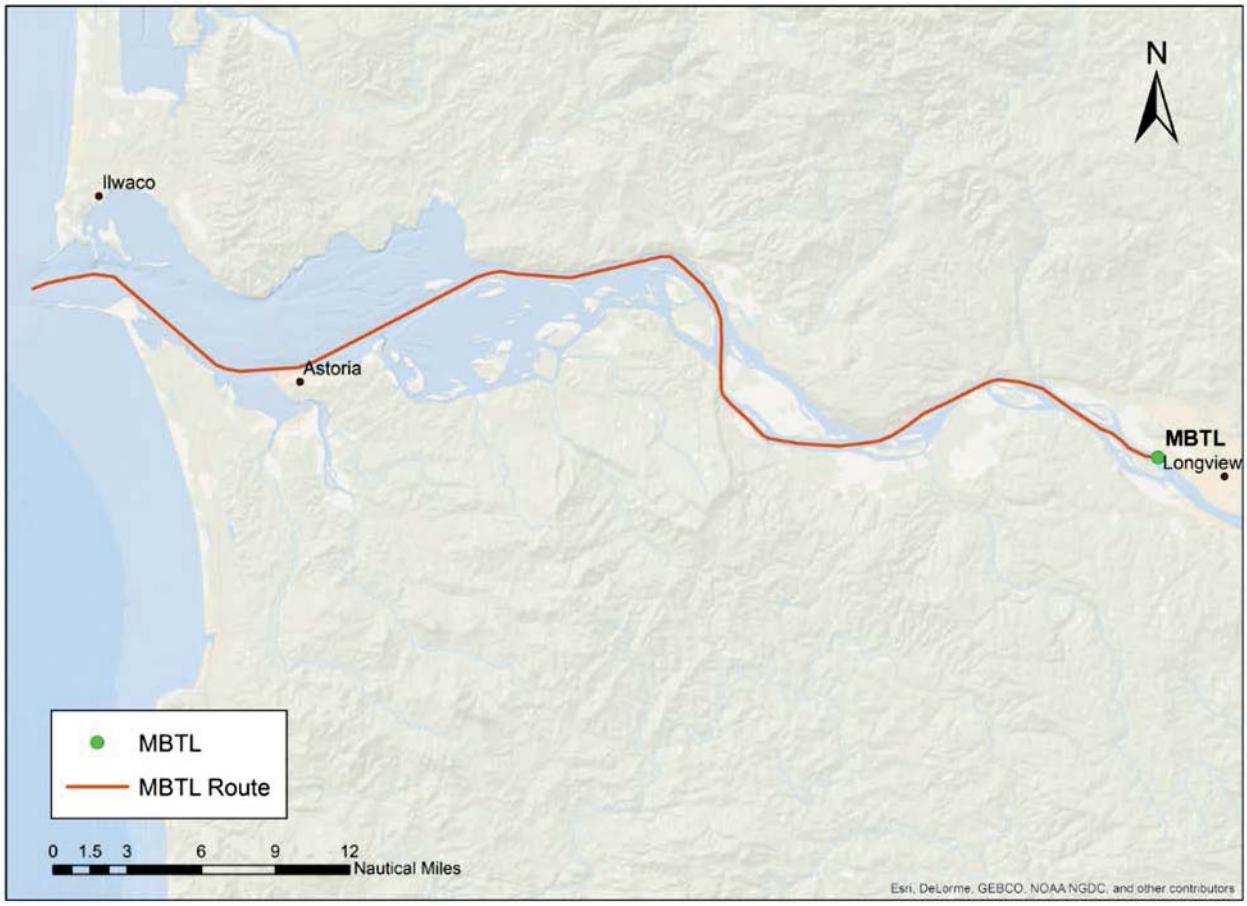


Figure 5-2 Project Vessel Inbound and Outbound Route

5.1.3 Traffic Increase and Potential Projects

An increase of 1% per year was applied to the 2014 baseline traffic data for all vessel categories; with the exceptions of project vessels which will remain constant from 2028 on (Ref. /5/).

Projected increases in vessel traffic from reasonably foreseeable future projects were also included in the analysis. These projects were identified through research and conversations with various stakeholders in the study area. The number of vessels expected to be added to river traffic was added to specified areas after the 1% per year increase has been applied. Vessel traffic from potential future projects are shown in

Table 5-2 and Figure 5-3 below – this additional vessel traffic is applied in case 4 and case 5 only (2038 with and without the project).

Table 5-2 Vessel Traffic from Potential Future Projects

Project	Location	Vessels per Year *	Anticipated Vessel Type and Cargo
Columbia Pacific Bio-Refinery	Port Westward – Clatskanie, OR	108	Tanker – Crude Oil
Columbia River Carbonates	Woodland, WA	24	Cargo – Calcium Carbonate Stone
Coyote Island Terminal Project	Port of Morrow – Broardman, OR	133	Cargo - Coal
Kalama Manufacturing and Marine Export facility	Port of Kalama-Cowlitz County, WA	54	Carrier - Methanol
LPG Facility – Pembina Pipeline Corp.	Port of Portland	30	Carrier - Propane
Northwest Innovation Works, LLC	Port Westward in Clatskanie, OR	54	Carrier - Methanol
Oregon LNG	Warrenton, OR	125	Carrier - LNG
Riverside Refinery	Port of Longview, WA	24	Tanker – Crude Oil
Vancouver Energy Project	Port of Vancouver, WA	290	Tanker - Crude Oil
Vancouver Transportation Logistic Improvement	Port of Vancouver, WA	18	Tanker – Crude Oil
Washington Energy Storage and Transfer	Port of Longview, WA	54	Carrier - LPG

*Included in 2038 MARCS models, no-project and with-project scenarios.

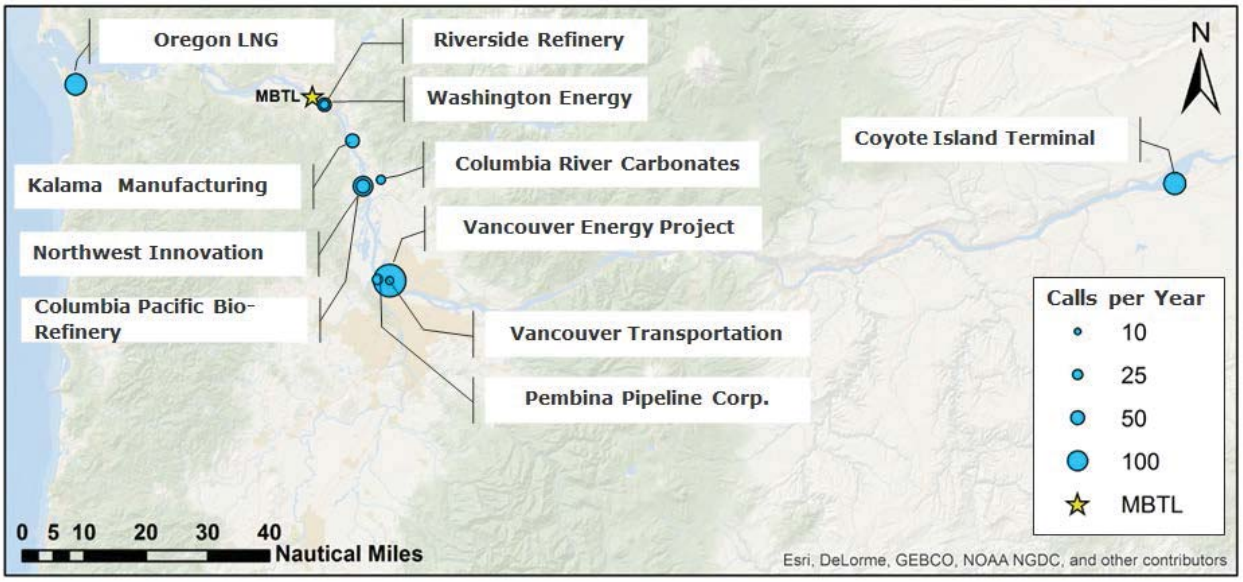


Figure 5-3 Terminal Locations and Annual Call Frequency for Potential Future Projects

5.1.4 Environmental Data

The MARCS model utilized met-ocean data that include wind speed, wind direction, and visibility statistics for the study area. To ensure high levels of accuracy, these data should cover areas in close proximity to the shipping route that project vessels will use at the approach to and from the terminal. The categories of data that would be implemented are as follows:

- Visibility data
- Wind data
- Sea-state data

The stations from which data were obtained are presented in Figure 5-4.

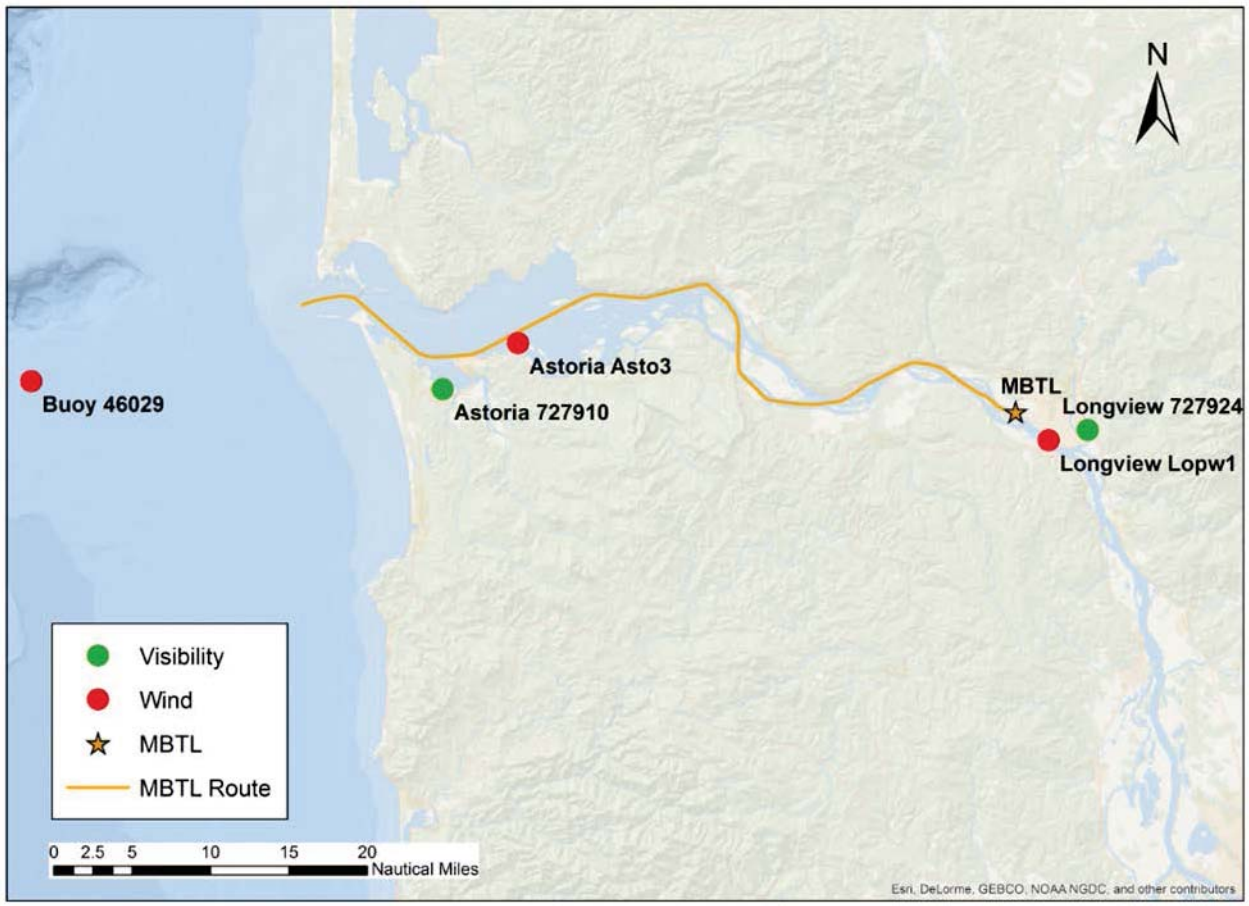


Figure 5-4 Weather Data Station Locations

Each station has a particular area of coverage that must be assigned in the MARCS model. The coverage areas for each station are presented in Figure 5-5.

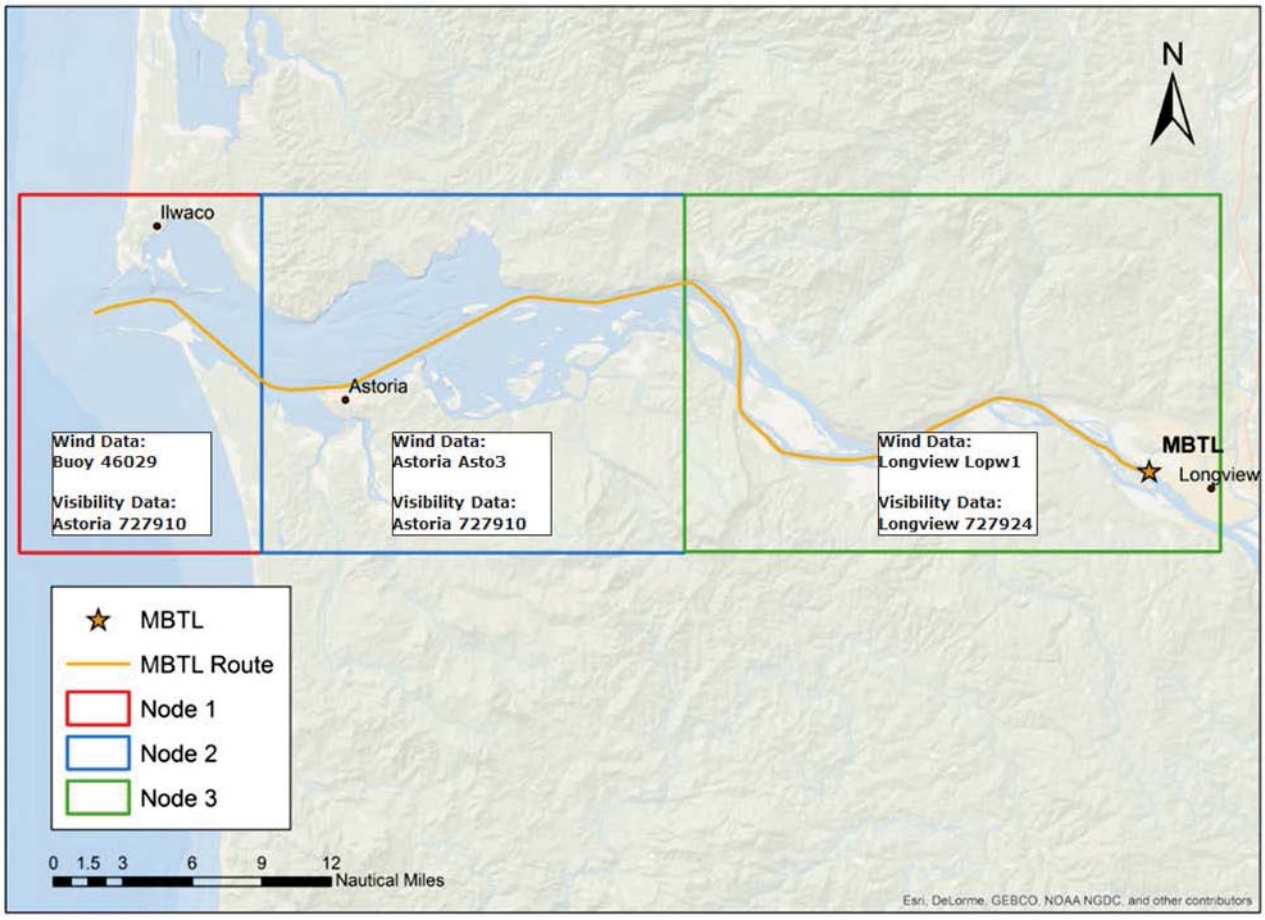


Figure 5-5 Areas of Coverage for Weather Stations

5.1.4.1 Wind Data

The wind data provide magnitude and corresponding probabilities for all relevant scenarios which were input into MARCS as factors that affect grounding frequencies. The wind data were divided into four speed categories (0-20, 20-30, 30-45, 45+ knots).

The probability of occurrence for the wind speed categories applied in MARCS is presented in Table 5-3.

Table 5-3 Wind Speeds Applied in MARCS (probability of occurrence) (Ref. /6/, /7/, /8/, /9/)

Weather Station	0-20 knots	20-30 knots	30-45 knots	>45 knots
Buoy 46029	0.88	0.11	0.01	0.00
Astoria	0.99	0.00	0.00	0.00
Longview	1.00	0.00	0.00	0.00

Due to lack of available sea state data, sea-state is taken as a function of wind speed.

5.1.4.2 Visibility Data

The probability of occurrence for good and poor visibility applied in MARCS is presented in Table 5-4.

Table 5-4 Visibility Data Applied in MARCS (probability of occurrence) (Ref. /7/,/8/,/9/)

Weather Station	Good (>2 nm)	Poor (<2 nm)
Astoria	0.87	0.13
Longview	0.98	0.02

Good visibility is defined as visibility greater than 2 nm; poor visibility is defined as visibility less than 2 nm.

5.1.5 Existing & Assumed Risk Reduction Measures

Risk reduction options are applied to vessels transiting the study area based on vessel type and location. The risk reductions applied in the modeling per vessel category are shown in Table 5-5.

Table 5-5 Risk Reduction Options Applied by Vessel Category

	Project Vessels	Tankers / Cargo Carriers	Tug	All Other Vessels
TV32	Yes	Yes	Yes	No
Pilotage	Yes	Yes	Yes	No
Portable Pilotage Unit	Yes	Yes	Yes	No
Digital Global Positioning Satellite	Yes	Yes	No	No
Conventional Aids to Navigation	Yes	Yes	Yes	Yes
Electronic Chart Display and Information System	Yes	Yes	No	No
Port State Control	Yes	Yes	No	No
Under Keel Clearance Management	Yes	Yes	No	No

The subsequent sections detail the effects of the above risk reduction options.

5.1.5.1 Transview32

TV32 is a real time, vessel traffic information and management system that provides a real-time portrayal of vessel movements and interactions on the river along with water depth, current flow information and updated bathymetry charts. It combines four different systems that provided 2-centimeter spatial resolution accuracy (Ref. /10/):

- AIS
- ENC and ECDIS

- NOAA Nautical Charts
- NOAA Physical Oceanographic Real-Time System (PORTS)
- DGPS

PORTS creates a layered architecture of ocean technologies (i.e., three acoustic sensors, with a back-up pressure sensor for freezing conditions) to measure surface current speeds, water depth, and wind direction and speed. The resolution of all acoustic and pressure sensors is 1 mm and the sample interval is every six minutes. Data are transmitted and displayed on the TV32 interface every six minutes.

TV32 may enhance Bar and River Pilot's performance by:

- Providing redundancy against ship navigational equipment failure or incorrect calibration.
- Providing improved accuracy compared to the ship's own equipment.
- Providing fine spatial and time resolutions
- Providing a layered architecture of technology systems for increased situational awareness.
- Allowing Pilots to accurately determine vessel meeting points to facilitate informed decision making regarding navigation, anchorage, and traffic coordination.

TV32 is considered a Vessel Traffic Information System (VTIS). The risk reduction factor of TV32, as its own unique navigation tool, was not quantified.

Risk reduction factors for a Vessel Traffic Service (VTS) have been quantified by DNV GL. The USCG operates Vessel Traffic Centers (VTC) which provide a VTS in 12 ports in the U.S. One of the differences between a VTS and a VTIS is that in a VTS, vessel location, speed and course data are consolidated in a centralized location, such as a control room (typically staffed by USCG personnel who, when necessary, are authorized by the local Captain of the Port to provide direction to vessel masters) and relevant information is disseminated from the control room to ships in the area. In a VTIS, vessel location, course, and speed data are made available directly to vessels operating in the area so that navigation decisions can be agreed upon between the pilots. As such, TV32 is regarded to be an efficient form of data dissemination given the nature of vessel traffic management on the Columbia River where navigation decisions are made by Columbia River Bar Pilots and Columbia River Pilots.

Table 5-6 summarizes a selection of relevant studies addressing the reduction in collision and grounding frequencies based on implementation of a VTS.

Table 5-6 Summary of Studies that Quantify the Effects of VTS

Study	Information
COST-301: Shore-based Marine Navigation Aid Systems (Ref. /11/)	Estimated radar-based VTS would provide a 40% risk reduction for collisions and groundings
Ship Collision with Bridges (Ref. /12/)	Found a 50% to 67% risk reduction
The Estimation of Collision Risk for Marin Traffic in UK Waters (Ref. /13/)	Indicated that the effects of VTS were most prominent in thick fog Example: In the case of crossing encounters with 99% clear and 1% thick fog, a 57% reduction was found
Safety of Shipping in Coastal Waters Summary Report (Ref. /14/)	Quoted data from the Western Sheldt estuary that indicated a 40% risk reduction for collisions and a 20% risk reduction for powered groundings
Summary Report on Evaluating VTS and Pilotage as Risk Reduction Measures (Ref. /15/)	Reports various studies in the Baltic area obtaining a 55% to 80% risk reduction

The progressive adoption of VTS may contribute to an overall decrease in global incident frequencies of collisions and groundings, as the studies indicate. This collectively resulted in a 43% risk reduction for groundings and 30% risk reduction for collisions.

TV32 does not have USCG 24/7 oversight as a VTS does, although for the purposes of this study, DNV GL finds it appropriate to give TV32 the same level of risk reduction as VTS.

5.1.5.2 Pilotage

Pilotage would be compulsory for all project vessels. The presence of Bar and River Pilots was accounted for in MARCS for project vessels, as well as on cargo/carriers, tankers, and tugs . Pilotage was included as a risk control measure, decreasing the frequency of collision and powered grounding.

When representing the effects of Pilotage, or any risk reduction option, in MARCS, the model parameters are modified according to Performance Shaping Factors (PSFs). A performance shaping factor is a factor that accounts for a risk reduction and is defined as:

$$PSF = \frac{Probability\ of\ model\ parameter\ without\ risk\ reduction\ option}{Probability\ of\ model\ parameter\ with\ risk\ reduction\ option}$$

Previous worldwide research listed in Table 5-7 quantified the effects of Pilotage. PSFs for Pilotage were used to account for an estimated 26% reduction of incident frequency for collision, and a 51% reduction of incident frequency for powered grounding.

Table 5-7 Summary of Studies that Quantify the Effects of Pilotage

Study	Information
Ship Collision with Bridges (Ref. /12/)	Indicates that a Pilot on board reduced incident frequency by 83%
Risk Assessment of Pollution from Oil and Chemical Spills in Australian Ports and Waters (Ref. /16/)	49% risk reduction for compulsory Pilotage for majority of ships
Assessment of the Risk of Pollution from Marine Oil Spills in Australian Ports and Waters (Ref. /16/)	Updated 1999 DNV study recently as a 50% risk reduction for “non-compulsory Pilotage”
Summary Report on Evaluating Pilotage as Risk Reduction Measures (Ref. /15/)	Reports various studies using risk reduction factors in the range of 50%-97% reduction. Note: No data in this report is used in this study to support specific risk reduction factors.

5.1.5.3 Portable Pilotage Unit

The Portable Pilotage Unit (PPU) is a portable GPS unit, which gives Pilots their own source of accurate heading and positioning data, displayed on an electronic chart. It can be seen as a support tool to enhance the pilot's navigational performance. PPUs' benefits include:

- Familiarity to Pilots.
- Provides additional redundancy against ship navigation equipment failure or incorrect calibration.
- Provides onboard VTIS to a Pilot in real time.

Combined with pilotage, it is judged that PPU was modelled to improve the pilot's human error performance with respect to powered grounding by 10%. The effects of collisions are assumed to be negligible in comparison.

5.1.5.4 Differential Global Positioning Systems

Differential Global Positioning Systems (DGPS) signals allow a receiver to calculate its position based on signals received from triangulation of GPS satellites, thereby enhancing GPS.

The advantages of DGPS over conventional aids to navigation (AtoN) are that:

- It provides a very accurate and continuously updated calculation of the ship's position in all weather conditions.
- It requires less time than conventional navigation and hence reduces bridge workload (i.e., by plotting on a conventional chart).

Although DGPS is widely believed to make a major contribution to the safety of navigation, there are no known studies that provide a comparison between incident rates of vessels equipped with DGPS versus vessels with conventional (non-GPS) navigation. Figure 5-6 shows the global historical trend in the frequency of groundings in the world-wide fleet, most of which are powered groundings. The frequency of total losses has declined at an average rate of approximately 5.5% per year. However, when serious casualties and non-serious incidents are included, the frequency appears to increase from 2002 to 2007. The causes were not entirely clear, but the effect was that the global historical trend does not show any clear decline that could be apportioned into its various causes, including aids to navigation, changes in operating procedures and safety management.

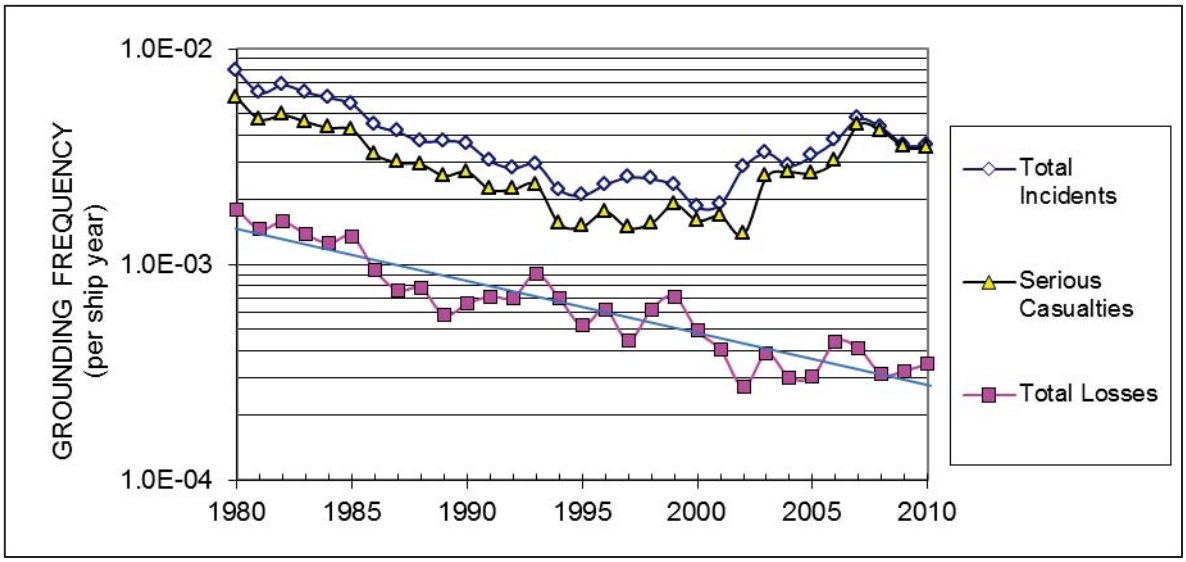


Figure 5-6 Global Grounding Frequency Trends, 1980-2010

The best available data concerning causes of grounding incidents studied Norwegian registered ships over 1,600 Gross register tonnage (GRT) during 1970 to 1978. It described the main causal areas as shown in Table 5-8.

Table 5-8 Causal Factors in Groundings, 1970-78 (Ref. /17/)

Causal Factor		Contribution	
External conditions		**39.9%**	
	Channel and shallow water		18.9%
	Reduced visibility		12.6%
	Fault/deficiency of lights, marks etc.		6.4%
	Other external conditions		2.0%
Technical failure		**8.8%**	
	Fault in the ship's technical systems		5.7%
	Other technical failures		3.1%
Inadequate navigational factors		**18.9%**	
	Bridge manning/organization		8.4%
	Error/deficiency in charts/publications		8.1%
	Other navigational factors		2.4%
Navigational error		**22.9%**	
	Navigation and maneuvering factors		11.7%
	Misinterpretation of lights/marks		8.4%
	Other navigational error		2.8%
Non-compliance		**8.1%**	
	Inadequate coverage of the watch		5.7%
	Other non-compliance		2.4%
Other ship		**1.4%**	**1.4%**
Total		**100.0%**	**100.0%**

Errors in conventional navigation, which might be prevented by GPS, were represented by "misinterpretation of lights/marks", and amounted to 8.4% of incidents. GPS would not necessarily prevent all such errors, and indeed may have some negative impacts that would not be visible in data from this period. However, GPS might have indirect benefits on all navigational errors. Therefore a reduction in groundings of 8.4% is justified by this data as all project vessels will be equipped with GPS.

5.1.5.5 Conventional Aids to Navigation

Conventional aids to navigation are key enablers for spatial awareness, leading to safe navigation. Aids on the Columbia River comprise a group of interacting external reference devices intended to collectively provide sufficient and timely information with which to safely navigate (Ref. /18/). The aids include a series of fixed and floating aids, which are visual, aural, electronic or any combination of all three.

There is no obvious baseline (i.e. risk without AtoN) that could be used for comparison. However, it is possible to consider the benefits of improvements in conventional AtoN.

Data shown in Table 5-8 were used to indicate the effects of conventional AtoN in reducing powered grounding. Using conventional AtoN decreases the number of incidents related to deficiency or fault of lights and markings by 6.4%. Therefore, a reduction in groundings by 6.4% can be justified by these data.

5.1.5.6 Electronic Navigation Charts on ECDIS

An Electronic Chart Display and Information System (ECDIS) is an electronic navigation aid that can be used instead of paper charts and publications to plan and display a ship's route and plot, and monitor its position throughout a voyage.

ECDIS's benefits include:

- It provides a continuous display of a vessel's position in relation to land, charted objects, aids to navigation and possible unseen hazards.
- It provides an improved representation of the vessel's position, compared to paper charts.
- It reduces the workload due to position plotting.
- It can be located where convenient on the bridge, so as to enable the watch-keeper to maintain a good lookout, instead of needing a screened chart table.
- It allows charts to be updated in a more efficient way by inserting a CD into the ECDIS computer, instead of manually annotating paper charts.
- It allows route planning and continuous monitoring.
- It provides improved functionality, such as:
    - Location polygons can be defined and alarms set if the ship exits defined safe areas.
    - AIS data can be displayed.
    - Radar targets can be superimposed on the ECDIS.

The potential risk reduction achieved by implementation of ECDIS was evaluated in previous research. A Formal Safety Assessment (FSA) was submitted to IMO Marine Safety Committee in 2006 in connection with a proposal for ECDIS carriage requirements. The assessment concluded that ECDIS reduced grounding risk by approximately 36%. This was due to a combination of more time available on the bridge for situational awareness, more efficient plotting of the ship's position and more efficient updating routines. A subsequent study (Ref. /19/) that took account of 11 different routes and a mix of ship types found reductions in grounding risk between 11% and 38% due to variations in ECDIS coverage. Where ECDIS coverage was 100% the reduction in grounding risk was 38%.

A 38% reduction in powered grounding was applied because the Columbia River was considered to have 100% ECDIS coverage.

While ECDIS provides a continuous display of a vessel's position in relation to land, charted objects and AtoN, it does not display another vessel's position. Seeing another vessel's location is necessary to reduce the risk of collision. Therefore, no reduction was applied for collision.

5.1.5.7 Port State Control

Port State Control (PSC) is the inspection of ships in national ports to verify that the condition of the ship and its equipment complies with the requirements of international regulations and that the ship is also manned and operated in compliance with these rules. In this report, the term PSC was also used to include other general shipping industry initiatives with similar goals, such as: classification society rules; enhanced surveys; vessel design standards; and bunker fuel oil quality testing.

Knapp et. al., (Ref. /20/) estimated the survival gains for different ship types in the years 2003 to 2007 based on individual ship loss experience and PSC inspections in Australia and the USA. PSC inspections were associated with ship survival gains of 0.1% to 0.5% on base risk rates of 1-3%. Combining the data for four cargo ship types over five years, the average gain was 12% of the risk of total loss. The average benefit may be smaller because not all ships are inspected. On the other hand, the benefit may be increased through the targeting of inspections of high-risk ships, and the possibility that any ship may be inspected and detained if not compliant. Overall, this analysis was considered to provide the best estimate of the benefit of PSC.

The effect of PSC was represented by:

- Applying a PSF of 0.88 for all the technical failure rates in the risk model. This directly affects the frequency of drift grounding, fire / explosion and foundering. It also has a very minor impact on collision and powered grounding (which are dominated by human error and human incapacitation).
- Applying a human error and human incapacitation PSF of 0.88 in the collision and powered grounding incident models. This represents the emphasis placed on International Safety Management (ISM) regulations by PSC inspections and should help ensure reductions in the likelihood of excessively fatigued navigating officers.

5.1.5.8 Underkeel Clearance Management

Underkeel clearance (UKC) is managed by the Pilots and vessel masters and is required by a ship's Safety Management System (SMS). Vessels calling at the Project terminal depart a dock or enter the river only when they can make the transit of the entire river with a minimum 2 feet of underkeel clearance and 10 feet across the bar. UKC management takes into account tide, weather, and vessel characteristics to ensure the underkeel clearance standard is maintained. The availability of water level sensor data via PORTS is a key component of the UKC management system on the Columbia River.

The main benefit of UKC management system is that it ensures adequate clearance between a vessel's keel and the river bottom to avoid grounding by providing improved information to navigators on underkeel clearance.

For an individual transit of a deep-draft vessel, an UKC management system is expected to make a significant reduction in grounding probability. Since UKC management is required on the river and at the port, a 10% reduction in powered grounding probability is reasonable.

5.2 DNV GL Methodologies

This section provides an overview of the methodologies applied in this study. First a description of the method for modeling marine incident frequencies is provided (Section 5.2.1), followed by the method for estimating whether each incident leads to a bunker oil spill (Section 5.2.2 and 5.2.3) and finally the method for estimating the spill volume given a bunker oil spill event has occurred (Section 5.2.4).

5.2.1 MARCS Model

The frequency of marine incidents involving project vessels was estimated using MARCS software. MARCS was developed by DNV GL to support its navigational risk consultancy services.

MARCS combines data for vessel traffic (e.g., vessel types, sizes, routes, and transit frequencies), the marine environment (e.g., location of shallow water, visibility data, and wind data) and operational aspects of shipping (e.g., pilotage, escort tugs) to predict the frequency of incidents at sea, such as:

- Collision
- Drift grounding
- Powered grounding
- Fire / Explosion

Collisions generally occur in the navigable part of the channel where the traffic is most dense. Drift and powered groundings occur near the shoreline or in shallow waters.

Incident frequencies were estimated using MARCS for the proposed route.

5.2.1.1 The Collision Model

The collision model calculates the frequency of serious inter-ship powered collisions at a given geographical location in two stages. The model first estimates the frequency of encounters (critical situations for collision - when two vessels pass within 0.5 nautical miles of each other) from the traffic image data using a pair-wise summation technique, assuming no collision avoidance actions are taken. This enables the calculation of either total encounter frequencies, or encounter frequencies involving specific vessel types.

The model then applies a probability of a collision for each encounter, obtained from fault tree analysis, to give the collision frequency. The collision probability value depends on a number of factors including, for example, visibility or the presence of a Pilot.

Figure 5-7 shows a graphical representation of the way in which the collision model operates.

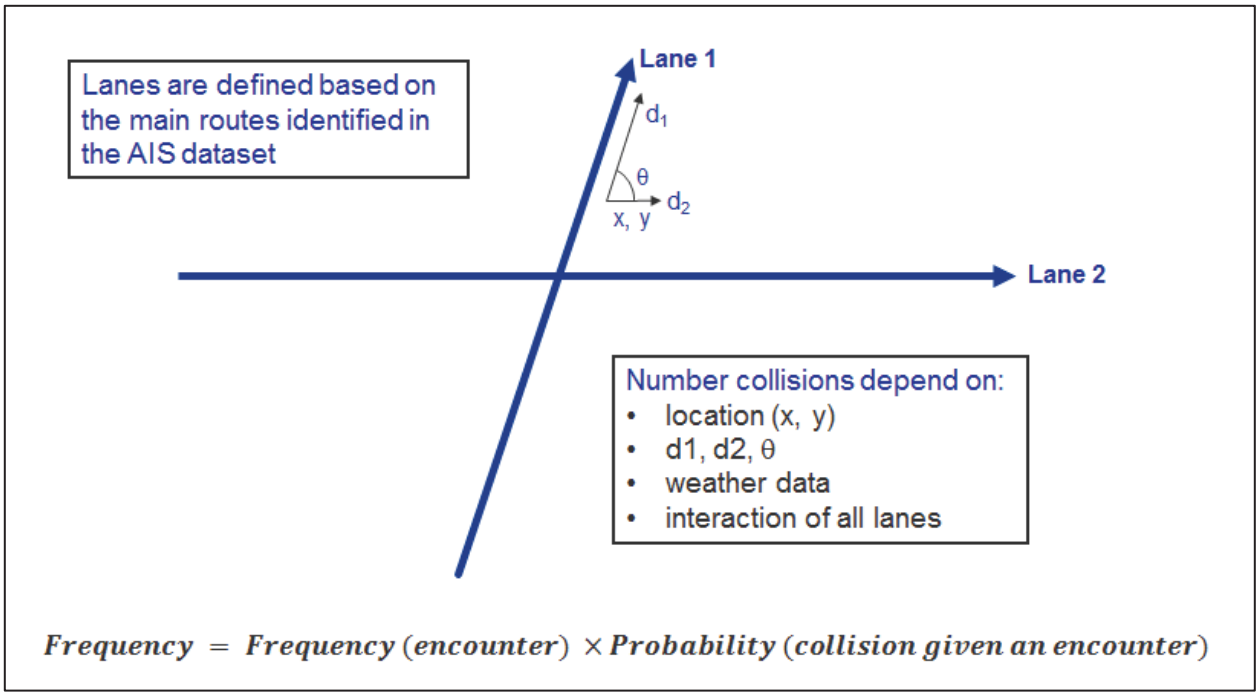


Figure 5-7 Graphical Representation of the Collision Model

In Figure 5-7, d_1 refers to the density of traffic associated with Lane 1 at the location (x, y). The frequency of encounters at location (x, y) through the interaction of Lanes 1 and 2 is proportional to the product of d_1, d_2 and the relative velocity between the lane densities.

5.2.1.2 The Powered Grounding Model

The powered grounding frequency model calculates the frequency of serious powered grounding incidents in two stages. The model first calculates the frequency of critical situations (sometimes called 'dangerous courses' for powered grounding incidents). Two types of critical situations are defined as illustrated in Figure 5-8. The first critical situation arises when a course change point (waypoint) is located such that failure to make the course change would result in grounding within 20 minutes navigation from the planned course change point if the course change is not made successfully. The second critical situation results when a grounding location is within 20 minutes navigation of the course centerline. In this case, crew inattention combined with wind, current or other factors could result in a powered grounding.

The frequency of serious powered groundings is calculated as the frequency of critical situations multiplied by the probability of failure to avoid grounding.

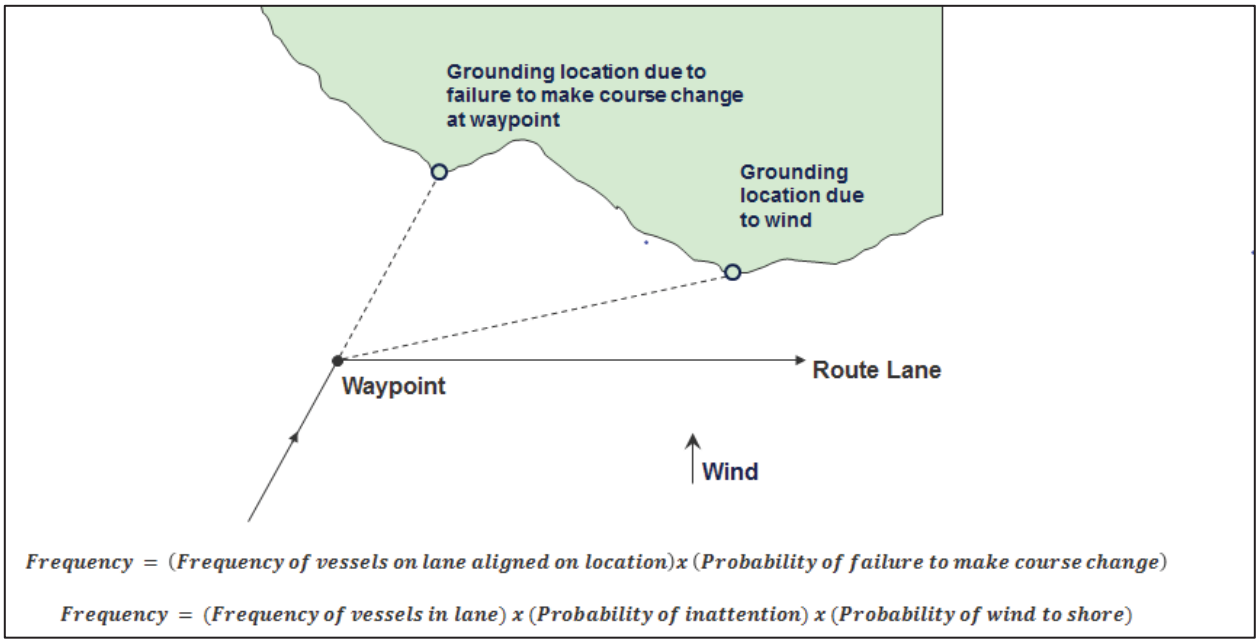


Figure 5-8 Graphical Representation of the Powered Grounding Model

The powered grounding probabilities are derived from the fault tree analysis of powered grounding. The powered grounding fault tree contains two main branches:

- Powered grounding through failure to make a course change whilst on a dangerous course. A dangerous course is defined as one that would ground the vessel within 20 minutes if the course change were not made.
- Powered grounding caused by crew inattention and wind or current from the side when the ship lane runs parallel to a shore within 20 minutes sailing.

Both these branches are illustrated in Figure 5-8. The powered grounding frequency model takes into account internal and external vigilance, visibility and the presence of navigational tools (e.g., radar) in deducing failure parameters.

5.2.1.3 The Drift Grounding Model

The drift grounding frequency model consists of two main elements: first, the ship traffic image is combined with the ship breakdown frequency factor to generate the location and frequency of vessel breakdowns; second, the recovery of control of drifting ships can be regained by one of three mechanisms:

- Repair
- Emergency tow vessel assistance
- Anchoring

Those drifting ships that are not saved by one of these three mechanisms (and do not drift out into the open sea) contribute to the serious drift grounding incident frequency results.

The number and size distribution of ships which start to drift is determined from the ship breakdown frequency, the annual number of transits along the lane and the size distribution of vessels using the lane.

The proportion of drifting vessels that are saved (fail to ground) is determined from the vessel recovery models. The drift grounding frequency model is illustrated in Figure 5-9.

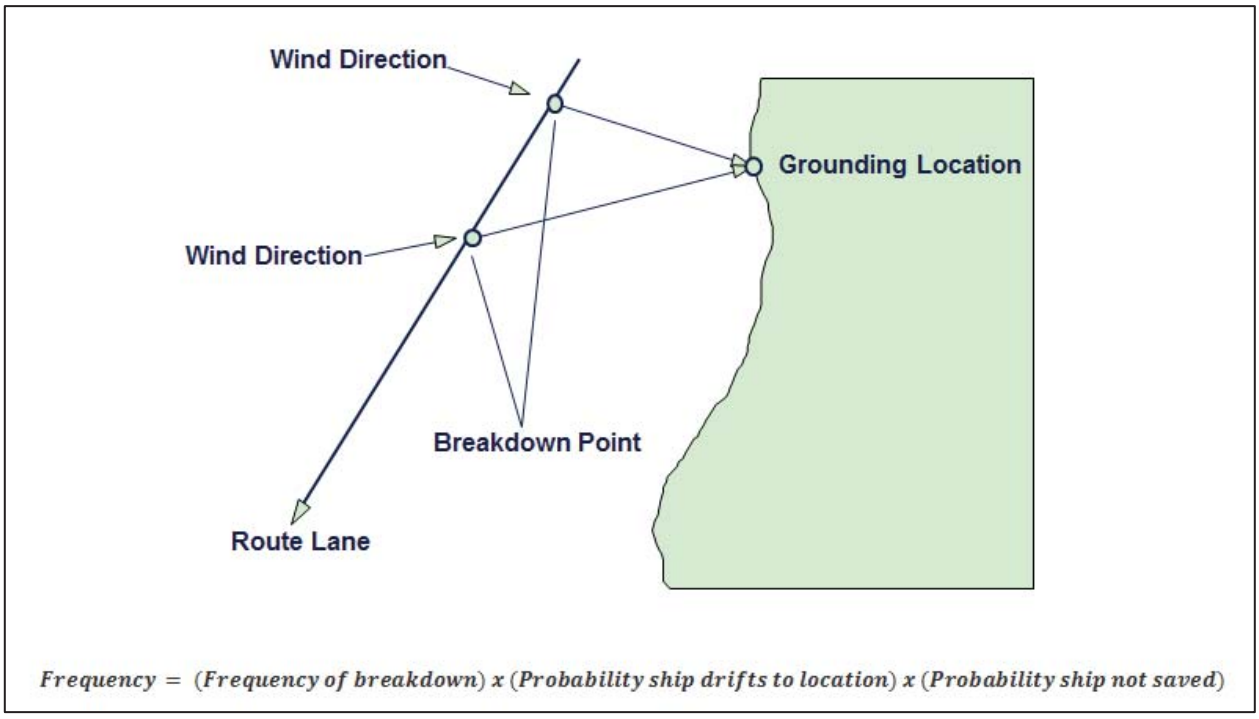


Figure 5-9 Graphical Representation of the Drift Grounding Model

Implicit in Figure 5-9 is the importance of the time taken for the ship to drift aground. When this time is lengthy (because the distance to the shore is large and / or because the drift velocity is small) then the probability that the ship will recover control before grounding (via repair or tug assistance) will be increased.

5.2.1.4 The Fire and Explosion Model

The fire / explosion accident frequency model applies the accident frequency parameters derived from accident data or fault tree analysis with calculations of the ship exposure time to obtain the serious accident frequency. The total ship exposure time (number of vessel hours) in any area can be calculated from the traffic image parameters (locations of lanes, frequencies of movements and vessel speeds). The fire / explosion serious accident frequency is then obtained by multiplying these vessel exposure times by the appropriate fire / explosion frequency factor (accidents per vessel-hour). It should be noted that fire / explosion frequency factors are assumed to be independent of environmental conditions outside the vessel.

5.2.2 Oil Spill Frequency Methodology

Incident frequency results from MARCS are used as input to determine the oil spill frequency. This section describes the methodology used to determine which incidents from MARCS results in an oil spill.

5.2.2.1 Collision

In calculating the conditional release probability for collision incidents, the amount of energy required to breach the bunker tank, referred to as the energy threshold. The energy threshold was taken as 13 MJ, which corresponds with the minimum distance from the bunker tank to the outer hull (1m) as specified by MARPOL requirements (Ref. /21/). The correlation between the indentation depth and the energy absorbed is presented in the Figure 5-10. The graph is based on a DNV GL finite element analysis of vessel collisions.

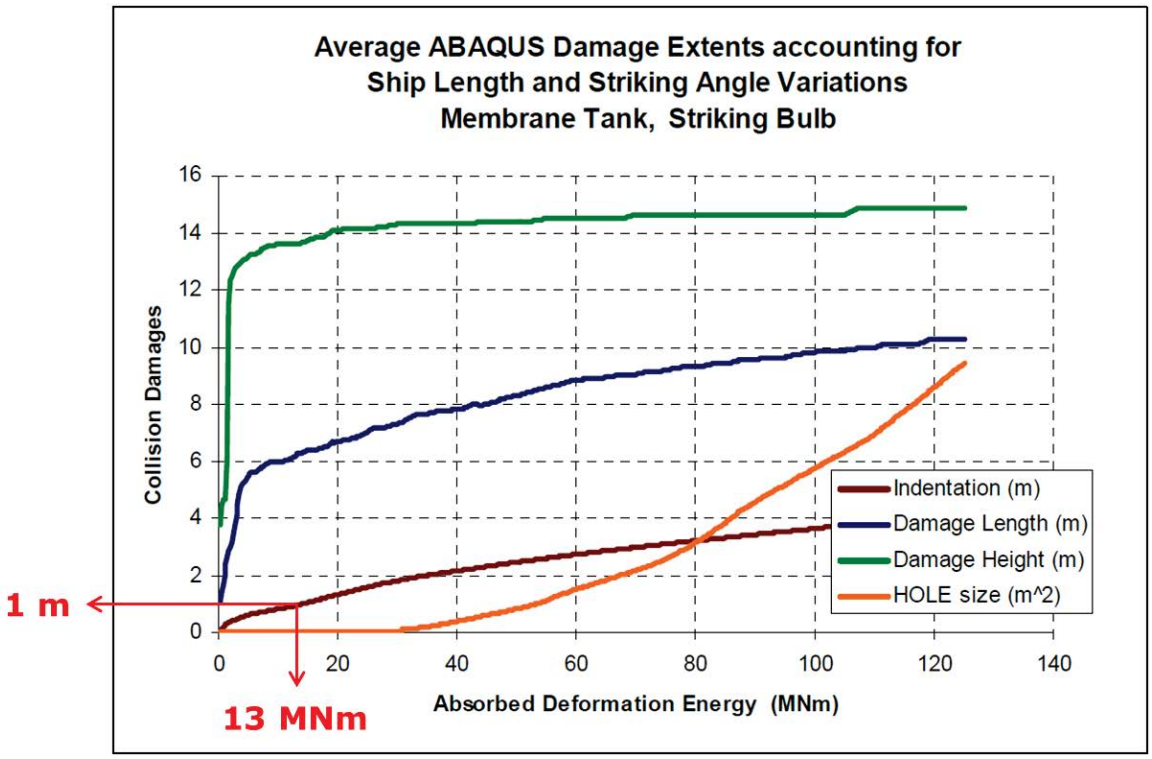


Figure 5-10 Relationship between Indentation Depth and Absorbed Energy

In estimating collision energy, information about vessels' masses and relative velocities is used to estimate the amount of energy involved in the collision, and therefore in the deformation, of the project vessel that could cause a loss of bunker oil to the environment.

The equation for assessing the estimated frequency of a bunker oil release is as follows:

$$F_{Bunker\ Oil\ Release} = F_{Collision} \times P_{E_{abs}>E_{crit}} \times P_{Geometric}$$

Where,

$F_{Collision} = Annual\ collision\ frequency$

$P_{E_{abs}>E_{crit}} = The\ probability\ that\ the\ energy\ absobed\ by\ the\ MBTL\ vessel\ exceeds\ the\ energy\ threshold$

$P_{Geometric} = Geometric\ probability\ of\ striking\ the\ vessel\ at\ a\ location\ of\ bunker\ tank$

As part of applying the theoretical methods to postulated events, several key assumptions are made:

1. 25% of the available impact energy is used towards deformation of the striking vessel. The remainder of the energy is assumed to deform the project vessel.
2. Angles of impact less than 22.5° or greater than 157.5° do not breach a cargo tank. These glancing impacts do not have a sufficiently steep angle to penetrate a project vessel.
3. A release of bunker oil is only credible if a project vessel is struck at a location with a bunker oil tank behind it.

Figure 5-11 provides an overview of the collision oil spill methodology.

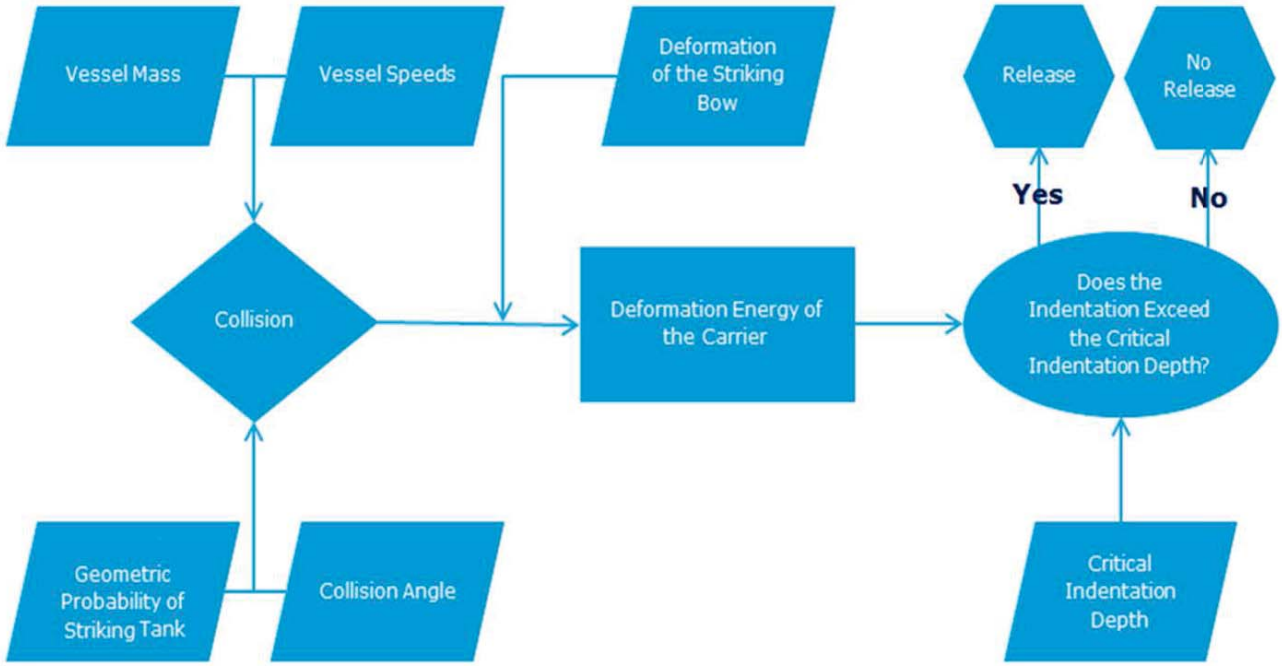


Figure 5-11 Collision Oil spill Methodology

5.2.2.2 Grounding

In order to estimate the probability of oil spill due to drift and powered grounding incidents, historical data are used in combination with route specific characteristics to estimate the potential for a release of bunker fuel. This approach utilizes a best fit cumulative distribution function to determine the probability that the indentation depth, caused by a grounding incident, exceeds the depth required to puncture the bunker oil tank. Based on MARPOL requirements (Ref. /21/), the distance between the outer hull and the bunker tank is assumed to be 1.6 m.

Based on impact data from the European Union-funded HARDER (Harmonisation of Rules and Design Rationale) studies and participation in the GOALDS (goal-based damage stability) project, DNV GL has developed an empirical formulation to estimate the probability of oil spill due to grounding. Vessels with

lengths between perpendiculars greater than 100 m were included in the assessment. A narrower filter on the dataset was not possible without reducing the number of observations to an insignificant sample size.

The results of this analysis were done using a probability distribution estimation tool that showed that the best fit cumulative distribution function of the indentation depth was the Fréchet distribution. By definition, the Fréchet distribution gives the probability that the actual value will be less than the value (I_d) supplied to it. However, in this portion of the assessment we are interested in when the grounding might cause a bunker oil spill. Therefore, to get the probability that the indentation depth exceeds 2 m we subtract the Fréchet distribution from 1 as shown in the below equation and let $I_d = 1.6$.

$$F(I_d) = 1 - \exp\left(-\left(\frac{\beta}{I_d - \gamma}\right)^{\alpha}\right)$$

Where

$\alpha\ (shape\ parameter) = 2.629$
$\beta\ (scale\ parameter) = 1.9368$
$\gamma\ (location\ parameter) = 0$

5.2.3 Allision Calculation

The annual allision frequency is estimated as the likelihood that a non-project vessel will strike a project vessel at berth. The method was developed based on guidelines for vessel collision and bridges from the American Association of State Highway and Transportation Officials (AASHTO). Project vessel characteristics (such as ultimate resistance of the tanker), waterway characteristics, geometry, and marine traffic characteristics were compared to standard acceptance criteria to estimate the extent of damage to a project vessel.

The annual failure rate caused by vessel collisions, A_F, can be expressed as:

$$A_F = N \times P_A \times P_C \times P_G$$

Where:

$N =$ Number of vessels and type that transit the waterway.

$P_A =$ Probability of vessel aberrancy (to stray away from normal navigation channel).

$P_C =$ Probability that the study vessel's bunker tank will be punctured given that a passing vessel struck the study vessel.

$P_G =$ Geometric Probability associated with striking vessel type and the study vessel.

5.2.3.1 Probability of Aberrancy, P_A

The probability of aberrancy is a measure of the risk of a vessel losing control as a result of pilot error, adverse environmental conditions, or mechanical failure. The evaluation of accident statistics indicates that human error (causing 60% to 85% of the aberrancy cases) and environmental conditions are the primary causes of accidents. To evaluate probability of aberrancy, DNV GL accounted for the following factors: the geometry of the navigation channel and the location of project vessels in the channel; the current direction and speed; vessel traffic density; and cross currents.

The equation is:

$$P_A = BR\,(R_B)\,(R_C)\,(R_{XC})\,(R_D)$$

Where:

BR = aberrancy base rate (0.6×10^{-4} for vessel or 1.2×10^{-4} for barges);

R_B = correction factor for Sample Vessel location. $R_B = (1 + \frac{\theta}{90^\circ})$

R_c = correction factor for current acting parallel to vessel path. $R_C = (1 + \frac{V_C}{10})$, with V_C specific to the proposed project.

R_{xc} = correction factor for crosscurrents acting perpendicular to vessel transit path. $R_{XC} = (1 + V_{XC})$, with V_{XC} specific to the proposed project.

R_D = correction factor for vessel traffic density depending on the frequency of vessels.

The specific risk controls that are accounted for in this portion of the analysis are:

- Electronic Chart Display & Information System.
- Pilotage.
- Vessel Traffic Information Service (TV32).

5.2.3.2 Probability of Bunker Tank Puncture, P_C

P_C must be interpreted as if a vessel has become aberrant and struck a project vessel at berth. In order to determine the potential to breach a bunker tank, it is necessary to calculate the available impact energy from the striking vessel. The available energy in the proximity of a project vessel is therefore assessed based on the speed and mass of the ships passing the berth.

The ship movements are defined by average speed and deadweight tonnage for each ship type. From these inputs, the maximum impact energy is estimated. The ratio of ultimate lateral resistance to the vessel impact force is also calculated to estimate the probability of sufficient energy to breach the hull and bunker tank of a project vessel.

5.2.3.3 Geometric Probability of Striking, P_G

In order to estimate geometric probability of striking, the assumption must be made that the striking vessel already strayed away from the navigation channel. Once a vessel has become aberrant, it is then necessary to estimate the probability that the vessel will strike a project vessel. To do this, geometric considerations are necessary.

The geometric probability is based on a number of parameters including the geometry of the waterway, location of the dock, sailing path of vessel, location, heading and velocity of vessel, environmental conditions, width, length, and shape of vessel, and vessel draft.

The lateral position of a vessel in the waterway follows a normal distribution with a mean value centered on the required path line (center line of navigation route). The standard deviation of this lateral position distribution is equal to the overall length of vessel designated as LOA. The use of a standard deviation equal

to length of the vessel was justified based on accident data to reflect the influence of the size of the colliding vessel.

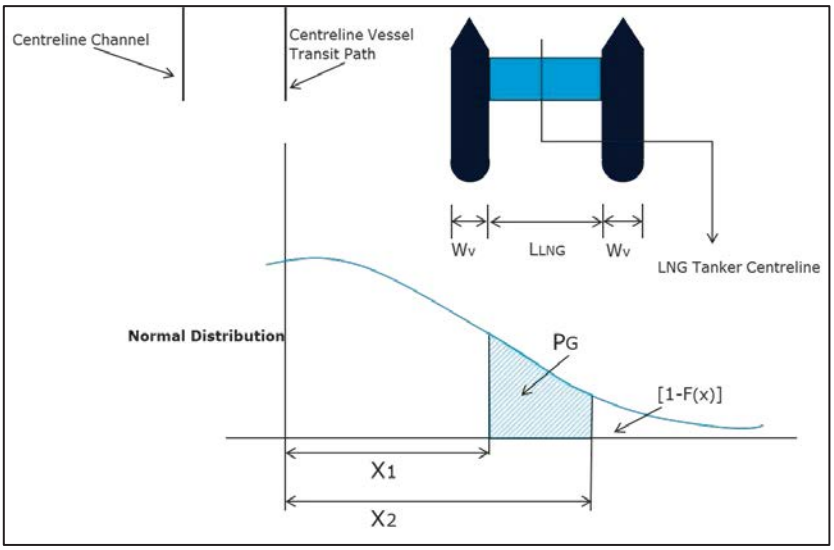


Figure 5-12 Model for Geometric Probability of Vessel Collision with the Sample Vessel

5.2.3.4 Omitting Analysis on Astoria-Megler Bridge

The decision to omit the allision analysis on the Astoria-Megler Bridge was based on feedback from Columbia Bar and River Pilots.

There was an allision at the Astoria-Megler Bridge that involved a piloted vessel approximately 30 years ago. Since this incident, Bar Pilots have implemented risk reduction measures to reduce the probability of allisions at the bridge; they avoid meeting other piloted vessels at the bridge, observe weather and river current conditions, and review weather forecasts before transiting under the bridge.

Given the very low historical frequency of allision at the Astoria-Megler Bridge and the assessment by the Bar and River Pilots that the bridge does not present an allision risk for piloted vessels, this structure has been omitted from the allision analysis.

5.2.4 NAPA Model

A commercial naval architecture package called NAPA is used to estimate the probability of oil outflow from project vessels. Using Monte Carlo simulations, in accordance with IMO Resolution MEPC.110(49) - Probabilistic Methodology for Calculating Oil Outflow, the model estimates oil outflow volumes based on the number of damaged cargo tanks and interaction with tidal influences. Monte Carlo simulations were run for 50,000 damage cases to estimate the potential variability in impact and in oil outflow volumes.

6 INCREMENTAL IMPACT OF PROJECT VESSELS ON RIVER NAVIGATION

6.1 Estimated Navigation Incident Frequencies

For each of the five cases presented in Section 5.1.1, incident frequencies for project vessel transits were estimated. These incident frequencies were estimated using the MARCS model and are limited to the study area. For this analysis, a marine incident was defined as an unintentional event (not a near miss), which may or may not result in a spill event. Incident frequencies were calculated for the following events:

- Collision
- Powered grounding
- Drift grounding
- Fire / Explosion
- Allision at Berth

6.1.1 2014 Existing Traffic

Table 6-1 provides estimated incident frequencies by vessel type for existing conditions (2014).

Table 6-1 Incident Frequency by Vessel Type for Non-Project Vessels (2014)

	Cargo / Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Total Incident Frequency
Collision	3.96E-01	3.41E-01	3.77E-01	8.53E-02	8.34E-02	3.24E-01	2.29E-02	3.09E-01	1.94E+00
Fire / Explosion	1.02E-03	2.79E-04	4.32E-04	9.21E-05	9.12E-05	1.96E-04	5.85E-05	9.88E-04	3.15E-03
Powered Grounding	2.20E+00	1.70E+00	2.69E+00	6.77E-01	5.25E-01	1.81E+00	1.27E-01	2.07E+00	1.18E+01
Drift Grounding	9.13E-01	2.39E-01	3.85E-01	8.32E-02	8.04E-02	1.68E-01	5.26E-02	9.01E-01	2.82E+00
Total Incident Frequency	3.51E+00	2.28E+00	3.46E+00	8.46E-01	6.89E-01	2.30E+00	2.02E-01	3.29E+00	1.66E+01

6.1.2 2028 No-Action Traffic

Table 6-2 provides estimated incident frequencies by vessel type for 2028 without project vessels.

Table 6-2 Incident Frequency by Vessel Type for Non-Project Vessels (2028 No Action)

	Cargo/ Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Total Incident Frequency
Collision	4.81E-01	4.53E-01	5.01E-01	1.13E-01	1.11E-01	4.29E-01	2.75E-02	4.10E-01	2.53E+00
Fire / Explosion	1.19E-03	3.21E-04	4.97E-04	1.06E-04	1.05E-04	2.26E-04	6.73E-05	1.14E-03	3.65E-03
Powered Grounding	2.56E+00	1.95E+00	3.10E+00	7.79E-01	6.03E-01	2.08E+00	1.46E-01	2.38E+00	1.36E+01
Drift Grounding	1.07E+00	2.74E-01	4.42E-01	9.56E-02	9.24E-02	1.94E-01	6.05E-02	1.04E+00	3.27E+00
Total Incident Frequency	4.11E+00	2.68E+00	4.04E+00	9.88E-01	8.07E-01	2.70E+00	2.34E-01	3.83E+00	1.94E+01

6.1.3 2028 With-Project Traffic

Table 6-3 provides estimated incident frequencies by vessel type for non-project vessels under 2028 with-project conditions.

Table 6-3 Incident Frequency by Vessel Type for Non-Project Vessels (2028 With-Project)

	Cargo/ Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Total Incident Frequency
Collision	5.16E-01	4.91E-01	5.54E-01	1.25E-01	1.22E-01	4.63E-01	2.99E-02	4.56E-01	2.91E+00
Fire / Explosion	1.17E-03	3.21E-04	4.97E-04	1.06E-04	1.05E-04	2.26E-04	6.73E-05	1.14E-03	4.01E-03
Powered Grounding	2.52E+00	1.95E+00	3.10E+00	7.79E-01	6.03E-01	2.08E+00	1.46E-01	2.38E+00	1.44E+01
Drift Grounding	1.05E+00	2.74E-01	4.42E-01	9.56E-02	9.24E-02	1.94E-01	6.05E-02	1.04E+00	3.59E+00
Total Incident Frequency	4.09E+00	2.72E+00	4.10E+00	1.00E+00	8.18E-01	2.74E+00	2.37E-01	3.88E+00	2.09E+01

Table 6-4 provides estimated incident frequencies for project vessels in 2028.

Table 6-4 Incident Frequency by Vessel Type for Project Vessels (2028 With-Project)

	Project vessel (inbound)	Project vessel (outbound)	Total Incident Frequency
Collision	7.63E-02	7.49E-02	1.51E-01
Fire/Explosion	1.90E-04	1.90E-04	3.80E-04
Powered Ground	3.98E-01	4.10E-01	8.07E-01
Drift Ground	1.71E-01	1.71E-01	3.42E-01
Allision at Berth	N/A	N/A	2.56E-02
Total Incident Frequency	6.46E-01	6.57E-01	1.33E+00

Figure 6-1 to Figure 6-3 present the incident results for collision, powered grounding and drift grounding for project vessels in 2028, respectively. It is noteworthy that the results for grounding of project vessels in 2028 are the same as the results for grounding of project vessels in 2038 because the number of project vessels is the same in both cases. Additionally, the reader should note that Figure 6-1 to Figure 6-3 have **different legend categories** and thus, need to be interpreted separately.

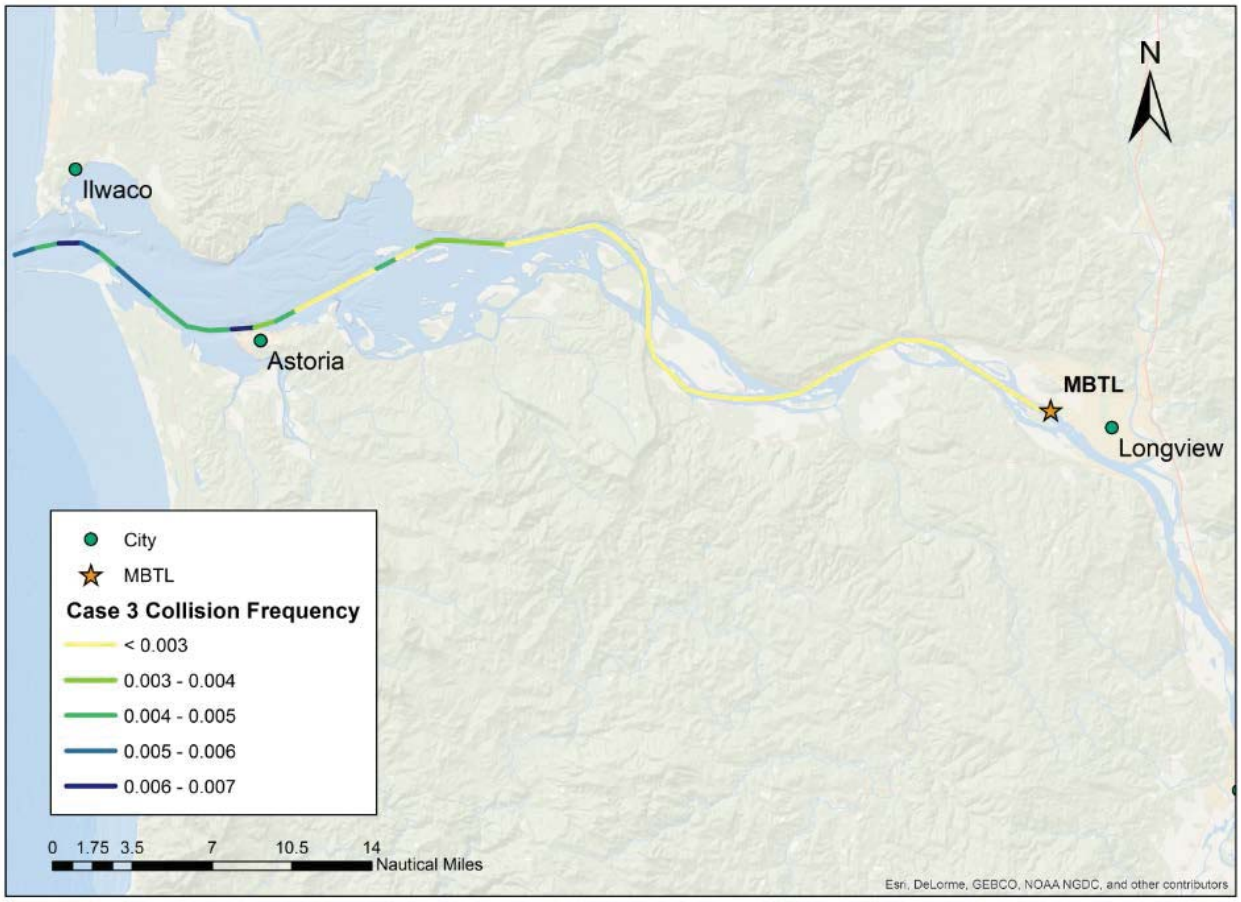


Figure 6-1 2028 Project Vessel Collision Incident Frequency Results

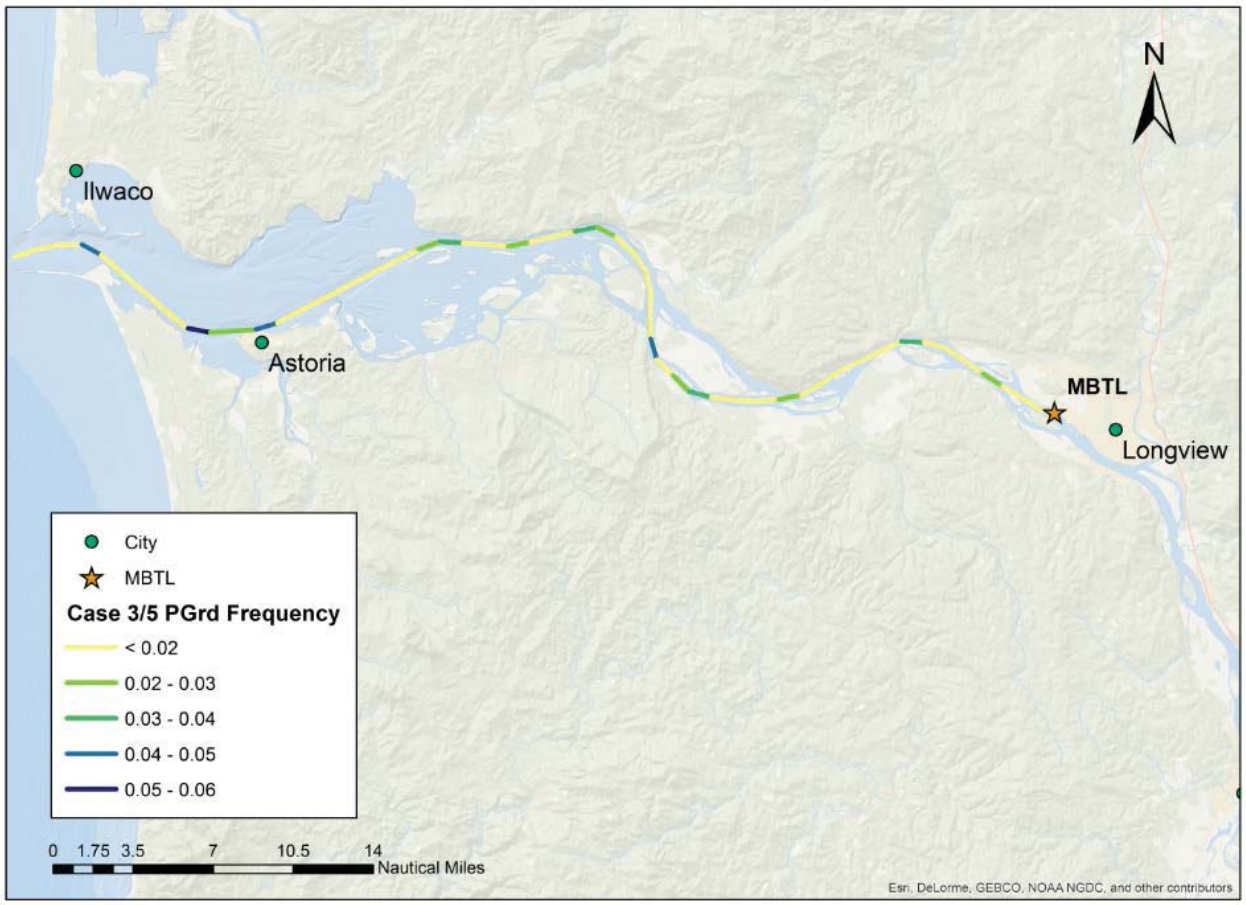


Figure 6-2 2028 Project Vessel Powered Grounding Incident Frequency Results

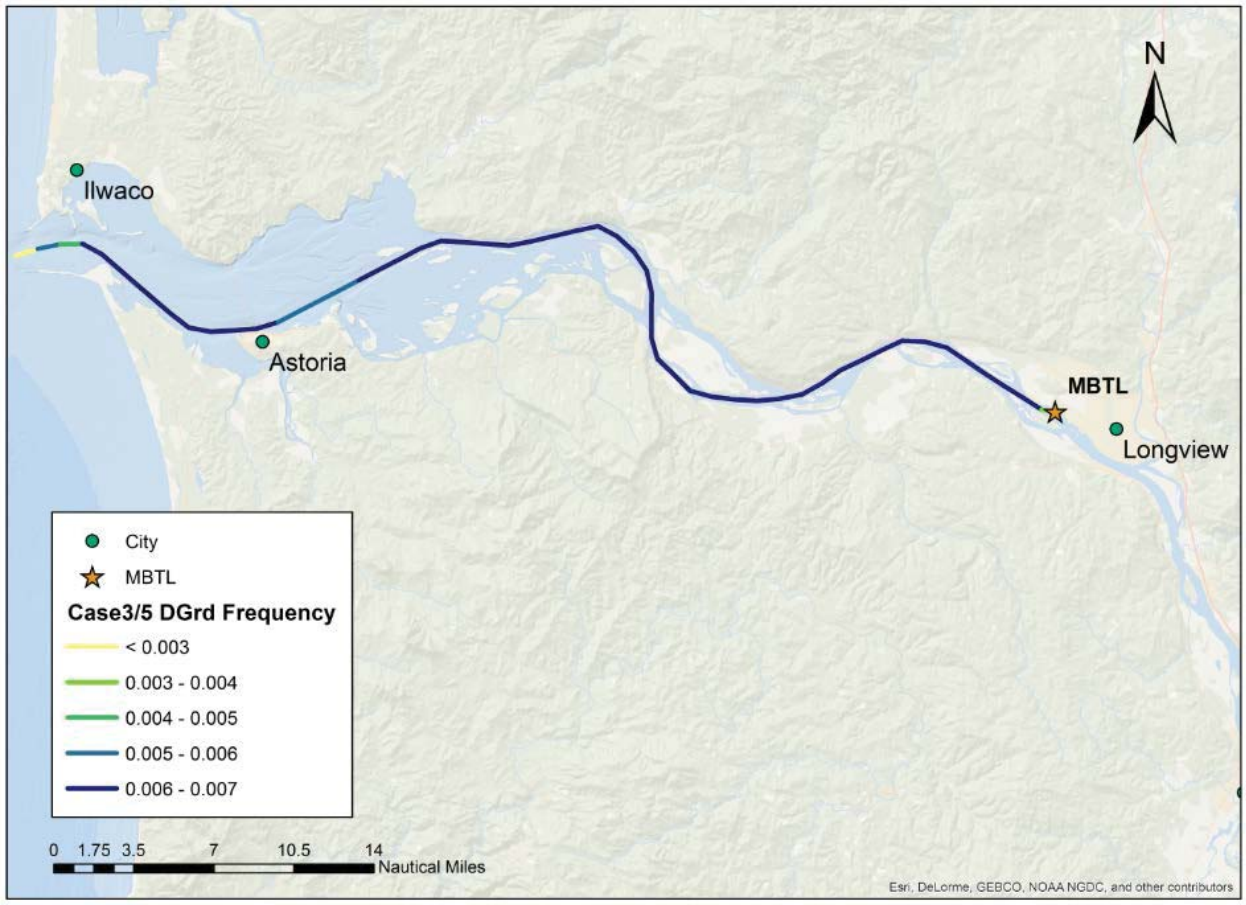


Figure 6-3 2028 Project Vessel Drift Grounding Incident Frequency Results

6.1.4 2038 No-Action Traffic

Table 6-5 provides estimated incident frequencies by vessel type for 2038 without project vessels.

Table 6-5 Incident Frequency by Vessel Type for Non-Project Vessels (2038 No Action)

	Cargo / Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Total Incident Frequency
Collision	1.02E+00	6.45E-01	7.29E-01	1.62E-01	1.60E-01	6.03E-01	3.87E-02	5.97E-01	3.95E+00
Fire / Explosion	2.00E-03	3.54E-04	5.49E-04	1.17E-04	1.16E-04	2.49E-04	7.43E-05	1.26E-03	4.72E-03
Powered Grounding	4.33E+00	2.16E+00	3.42E+00	8.60E-01	6.67E-01	2.30E+00	1.61E-01	2.63E+00	1.65E+01
Drift Grounding	1.80E+00	3.03E-01	4.88E-01	1.06E-01	1.02E-01	2.14E-01	6.68E-02	1.14E+00	4.22E+00
Total Incident Frequency	7.16E+00	3.11E+00	4.64E+00	1.13E+00	9.29E-01	3.12E+00	2.67E-01	4.37E+00	2.47E+01

6.1.5 2038 With-Project Traffic

Table 6-6 provides estimated incident frequencies by vessel type for 2038 non-project vessels under with-project conditions.

Table 6-6 Incident Frequency by Vessel Type for Non-Project Vessels (2038 With-Project)

	Cargo/ Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Total Incident Frequency
Collision	1.08E+00	6.87E-01	7.88E-01	1.75E-01	1.72E-01	6.40E-01	4.13E-02	6.48E-01	4.42E+00
Fire / Explosion	1.99E-03	3.54E-04	5.49E-04	1.17E-04	1.16E-04	2.49E-04	7.43E-05	1.26E-03	5.09E-03
Powered Grounding	4.29E+00	2.16E+00	3.42E+00	8.60E-01	6.67E-01	2.30E+00	1.61E-01	2.63E+00	1.73E+01
Drift Grounding	1.78E+00	3.03E-01	4.88E-01	1.06E-01	1.02E-01	2.14E-01	6.68E-02	1.14E+00	4.54E+00
Total Incident Frequency	7.16E+00	3.15E+00	4.70E+00	1.14E+00	9.41E-01	3.15E+00	2.69E-01	4.42E+00	2.63E+01

Table 6-7 provides estimated incident frequencies for project vessels in 2038.

Table 6-7 Incident Frequency by Vessel Type for Project Vessels (2038 With-Project)

	Project vessel (inbound)	Project vessel (outbound)	Total Incident Frequency
Collision	9.64E-02	9.49E-02	1.91E-01
Fire/Explosion	1.90E-04	1.90E-04	3.80E-04
Powered Ground	3.98E-01	4.10E-01	8.07E-01
Drift Ground	1.71E-01	1.71E-01	3.42E-01
Allision at Berth	N/A	N/A	3.97E-02
Total Incident Frequency	6.66E-01	6.77E-01	1.38E+00

The reader should note Figure 6-4 to Figure 6-6 have **different legend categories** and thus, need to be interpreted separately.

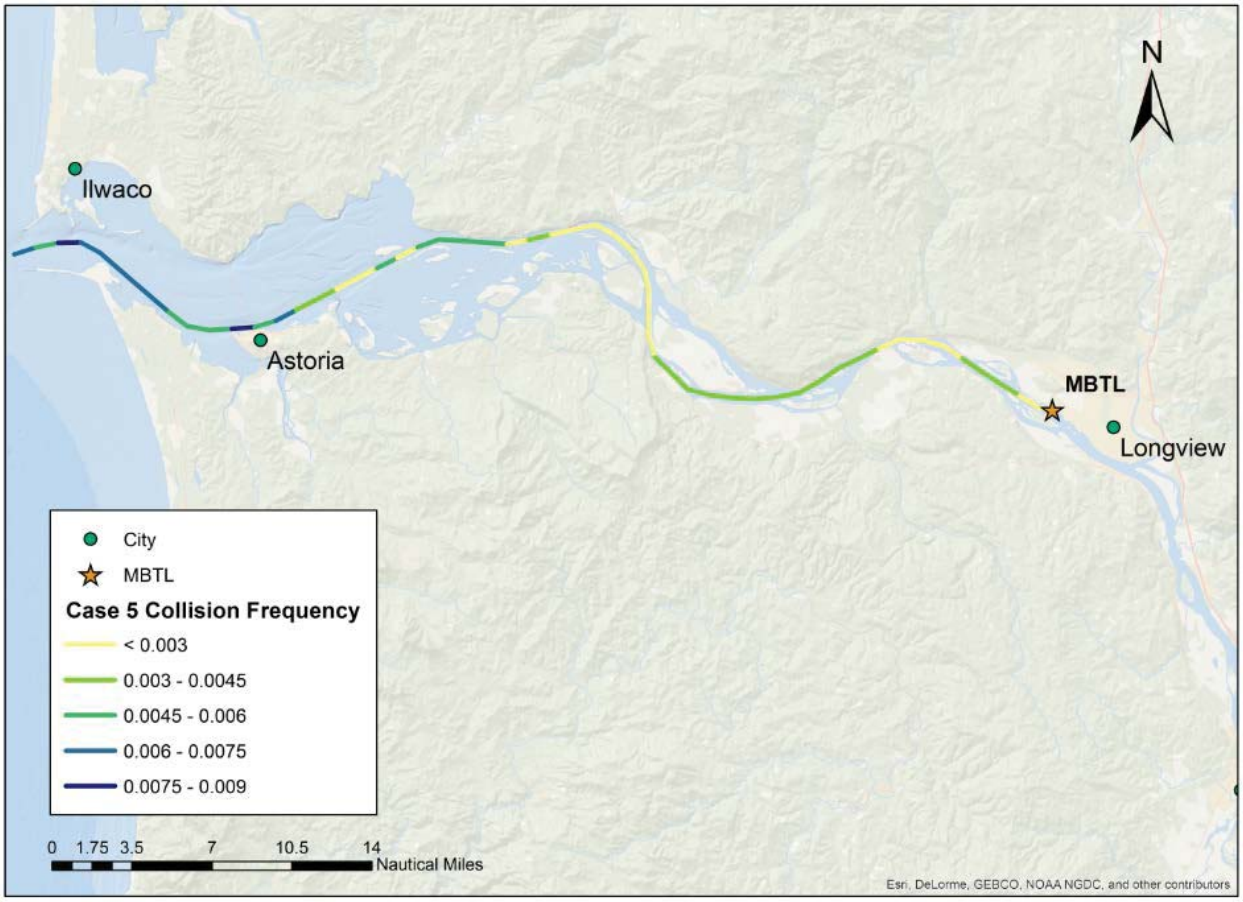


Figure 6-4 2038 Project Vessel Collision Incident Frequency Results

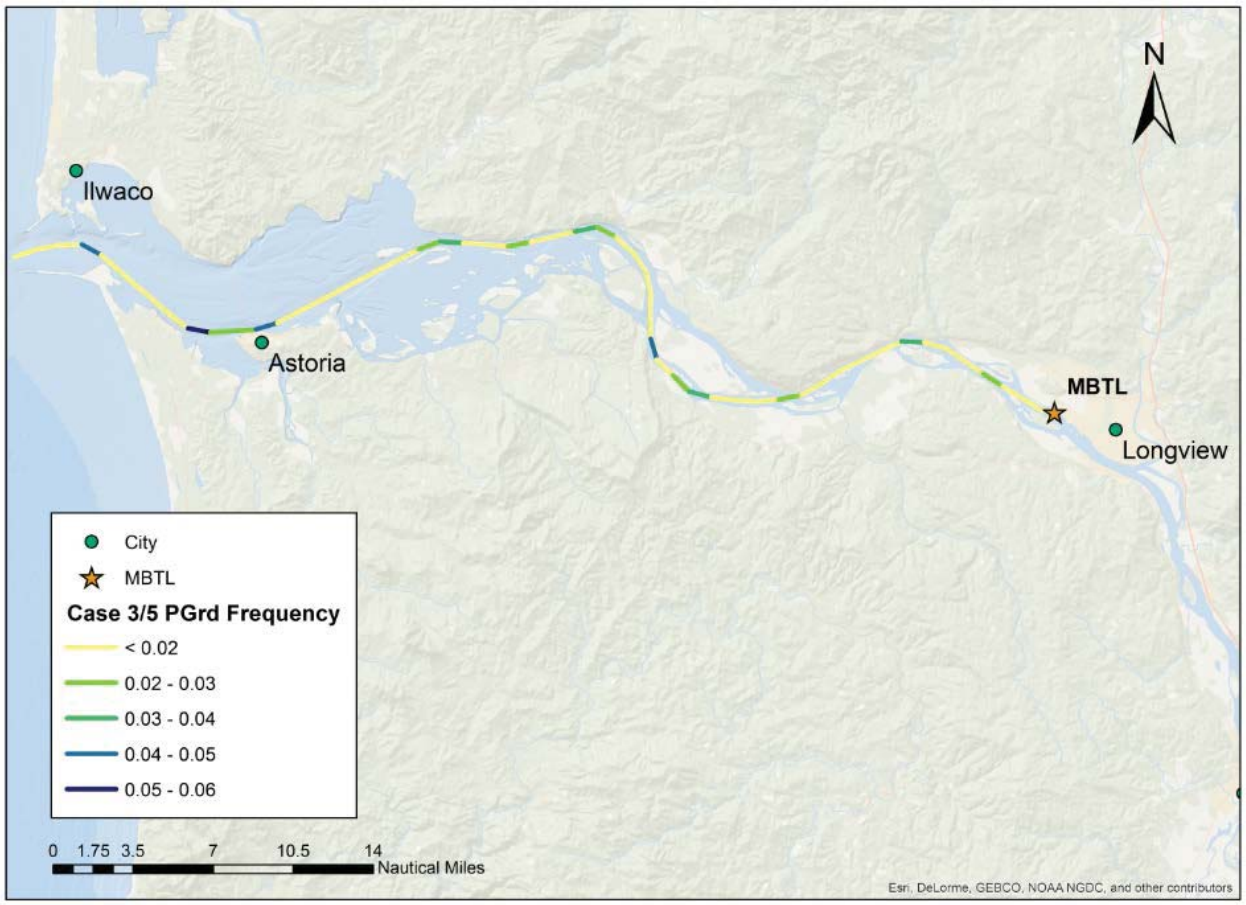


Figure 6-5 2038 Project Vessel Powered Grounding Incident Frequency Results

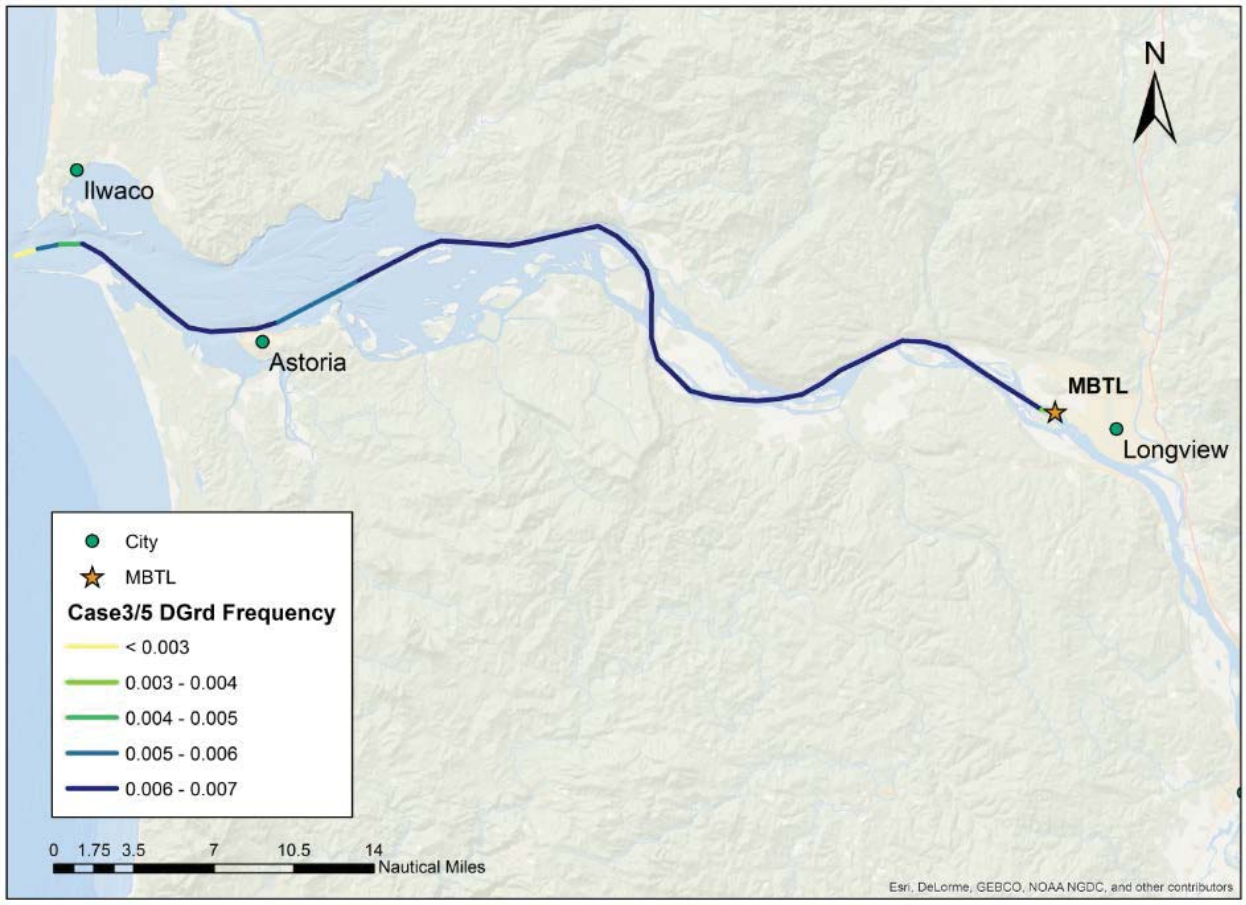


Figure 6-6 2038 Project Vessel Drift Grounding Incident Frequency Results

6.2 Incremental Contribution due to the Proposed Project

Table 6-8 presents the incremental risk that the proposed project contributes to vessel traffic incidents in 2028 and in 2038. These results are presented both in terms of annual frequency for each incident type as well as the percentage increase contributed by the project.

The total incremental incident frequency due to proposed project in 2028 is 1.5 incidents per year which equates to an 8% increase over the no-action scenario in 2028. Of these 1.6 incidents 0.8 are powered groundings, 0.34 are drift groundings, 0.38 are collisions and 0.03 are allisions.

The total incremental incident frequency due to proposed project in 2038 is 1.6 incidents per year which equates to a 6% increase over the no-action scenario in 2038. Of these 1.7 incidents 0.8 are powered groundings, 0.34 are drift groundings, 0.47 are collisions and 0.04 are allisions.

Using the results of the data survey presented in Section 4.1 and 4.2, we can comment on the likely severity of the incremental contribution of marine incidents contributed by the project.

- Based on a survey of historical incident severity, 1--2% of the grounding events contributed by the project are likely to result in a total loss of the vessel, 21-24% are likely to result in damage to

vessel and 74-78% are likely to result in no reported damage. Note: None of the total loss events reported due to grounding involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a grounding event were passenger vessels.

- Based on a survey of historical incident severity, 3--5% of the collision events contributed by the project are likely to result in a total loss of one or more vessels, 47-53% are likely to result in damage to one more vessels and 44-47% are likely to result in no reported damage.
  Note: None of the total loss events reported due to collision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a collision event were recreational vessels.
- Based on a survey of historical incident severity, 1--5% of the allision events surveyed resulted in a total loss of the vessel, 43-45% resulted in vessel damage and 52-54% resulted in no reported damage.
  Note: None of the total loss events reported due to allision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in an allision event were fishing vessels.

Assuming the distributions described above, the project would contribute fewer than 0.05 incidents with a total loss per year, fewer than 0.5 incidents resulting in reportable damage per year and approximately 1 incident per year resulting in no damage.

The incremental contribution appears to decrease from 2028 (8%) to 2038 (6%) because non-project vessel traffic continues to increase over this 10-year time period while the number of project vessels remains constant at 840 per year. Therefore the relative contribution in 2038 is lower because project vessels make up a smaller portion of overall vessel traffic.

Table 6-8 Incremental Change in Incident Frequency Contributed by Proposed Project

	2028		2038	
	Frequency	% increase	Frequency	% increase
Collision	3.83E-01	15%	4.68E-01	12%
Fire / Explosion	3.80E-04	10%	3.80E-04	8%
Powered Grounding	8.07E-01	6%	8.07E-01	5%
Drift Grounding	3.42E-01	10%	3.42E-01	8%
Allision at Berth	2.56E-02	N/A	3.97E-02	N/A
Total Incident Frequency	1.56E+00	8%	1.66E+00	6%

6.2.1 In 2028 Traffic Conditions

Table 6-9 presents incremental collision frequencies by vessel type for 2028 due to project vessels. This table shows how the total incremental increase in collision incidents is distributed across vessel types.

Table 6-9 Incremental Collision Frequency/Percentage by Vessel Type Contributed by the Proposed Project in 2028

Impacted Vessel	Cargo/ Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Project Vessels	Total
Collision No Action	4.81E-01	4.53E-01	5.01E-01	1.13E-01	1.11E-01	4.29E-01	2.75E-02	4.10E-01	N/A	2.53E+00
Collision With-Project	5.16E-01	4.91E-01	5.54E-01	1.25E-01	1.22E-01	4.63E-01	2.99E-02	4.56E-01	1.51E-01	2.91E+00
Incremental TIF Increase	3.50E-02	3.80E-02	5.30E-02	1.20E-02	1.10E-02	3.40E-02	2.40E-03	4.60E-02	1.51E-01	3.83E-01
Incremental % Increase	7.3%	8.4%	10.6%	10.6%	9.9%	7.9%	8.7%	11.2%	N/A	15%

Figure 6-7 shows how the incremental incident frequency varies by incident type for each river mile segment along the proposed route in 2028.

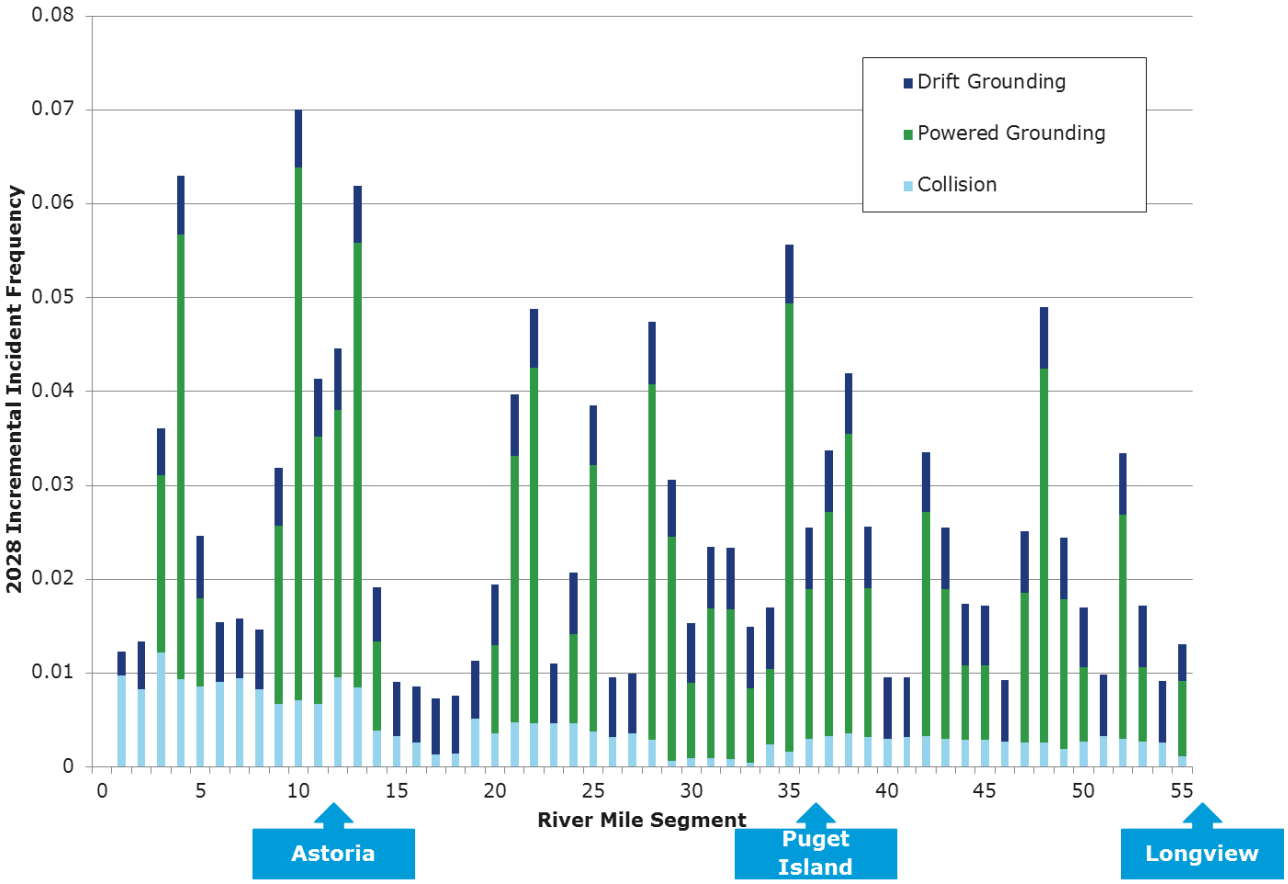


Figure 6-7 Incremental Incident Frequency by Incident Type Contributed by Proposed Project in 2028

6.2.2 In 2038 Traffic Conditions

Table 6-10 presents incremental collision frequencies by vessel type for 2038 due to project vessels. This table shows how the total incremental increase in collision incidents is distributed across vessel types.

Table 6-10 Incremental Collision Frequency / Percentage by Vessel Type Contributed by Proposed Project in 2038

Impacted Vessel	Cargo / Carrier	Fishing	Other / Undefined	Passenger	Pleasure	Service	Tanker	Tug	Project Vessels	Total
Collision No Action	1.02E+00	6.45E-01	7.29E-01	1.62E-01	1.60E-01	6.03E-01	3.87E-02	5.97E-01	N/A	3.95E+00
Collision With-Project	1.08E+00	6.87E-01	7.88E-01	1.75E-01	1.72E-01	6.40E-01	4.13E-02	6.48E-01	1.91E-01	4.42E+00
Incremental TIF Increase	6.00E-02	4.20E-02	5.90E-02	1.30E-02	1.20E-02	3.70E-02	2.60E-03	5.10E-02	1.91E-01	4.68E-01
Incremental % Increase	5.9%	6.5%	8.1%	8.0%	7.5%	6.1%	6.7%	8.5%	N/A	12%

Figure 6-8 shows how the incremental incident frequency varies by incident type for each river mile segment along the proposed route in 2038.

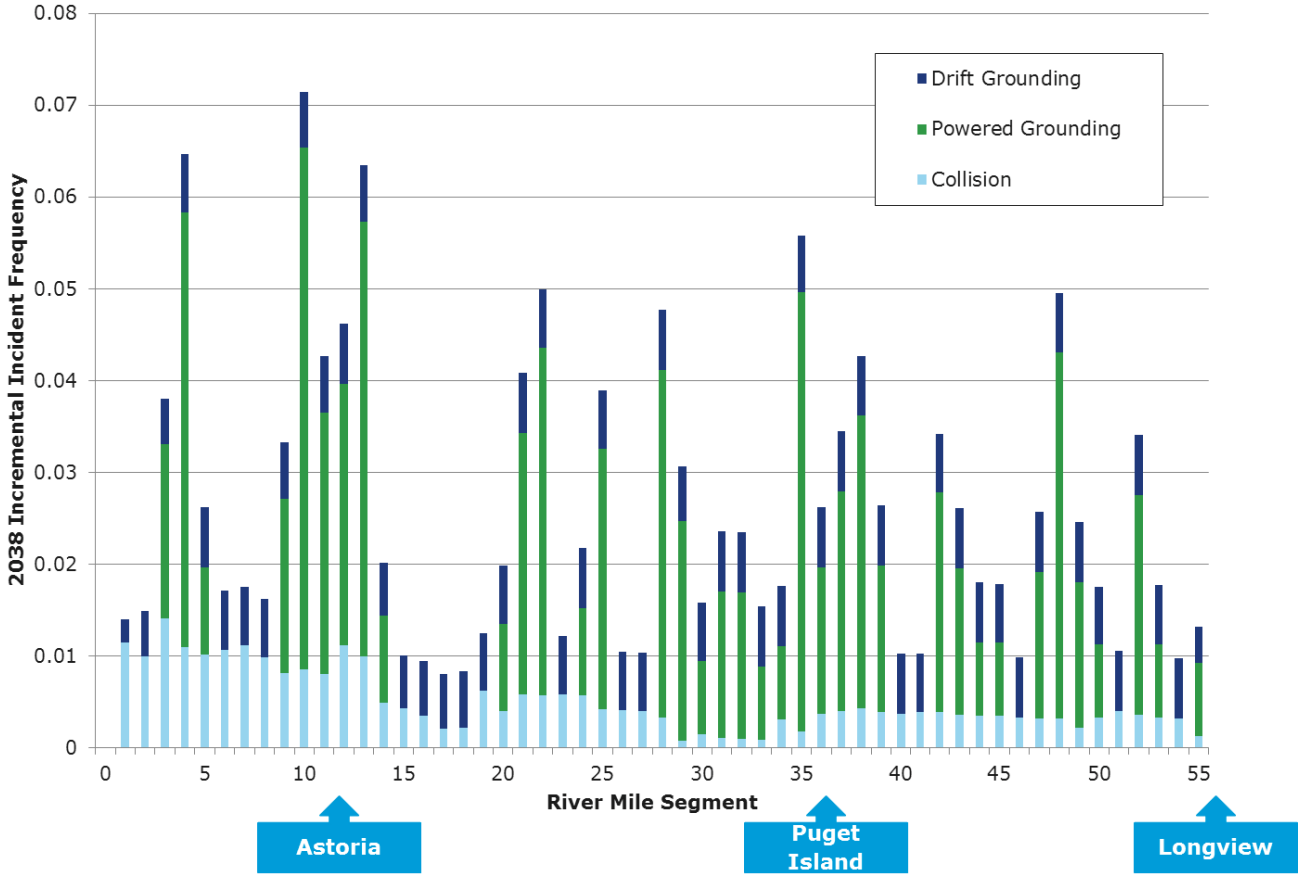


Figure 6-8 Incremental Incident Frequency by Vessel Type Contributed by the Proposed Project in 2038

7 ESTIMATED BUNKER SPILL RISK OF PROJECT VESSELS AT FULL BUILD OUT

The annual bunker spill frequency is calculated for project vessels for collision (grouped with allision at berth for this analysis), powered grounding and drift grounding. To assess the frequency of a release from the bunker tank due to collision the following probabilities are used: the probability that a collision results in sufficient energy to puncture the bunker tank and the geometric probability of striking the location of the bunker tank on the vessel. To assess the frequency of a release from the bunker tank due to drift grounding the following probabilities are used: the probability that the indentation depth exceeds the critical indentation depth required to puncture the bunker tank, the geometric probability of striking the location of the bunker tank on the vessel and the probability that the project vessel grounds on a rocky shoreline. The frequency of a release from the bunker tank due to powered grounding is assumed to be 0.01% of the total incidents. This is applied because a powered grounding that results in a release of bunker fuel is a very unlikely event as the bunker tanks are located in the stern of the vessel while the impact location is almost always near the bow.

7.1 Estimated Bunker Spill Frequencies

As shown below, the estimated bunker spill frequency due to the proposed project is $1.02x10^{-2}$ in 2028 and $1.17\ x10^{-2}$ in 2038. This equates to roughly one spill (of any size) every 98 years in 2028 and one spill every 85 years in 2038. Recall that, based on the survey of oil spill data from 2004 to 2014 (Section 4.3), the Lower Columbia River has experienced a spill greater than 100 gallons approximately once every 2.2 years.

7.1.1 In 2028 Traffic Conditions

Table 7-1 provides estimated bunker oil spill frequencies (of any size) by incident type for project vessels in 2028.

Table 7-1 2028 Bunker Oil Spill Frequency from Project Vessels

	Project Vessel (inbound)	Project Vessel (outbound)	Total Incident Frequency
Collision	1.54E-04	1.54E-04	3.09E-04
Powered Ground	3.98E-05	4.10E-05	8.07E-05
Drift Ground	3.56E-03	3.57E-03	7.13E-03
Allision at Berth	N/A	N/A	2.65E-03
Total Incident Frequency	3.75E-03	3.77E-03	1.02E-02

Figure 7-1 shows how the bunker oil spill frequency varies across each river mile segment along the proposed route in 2028.

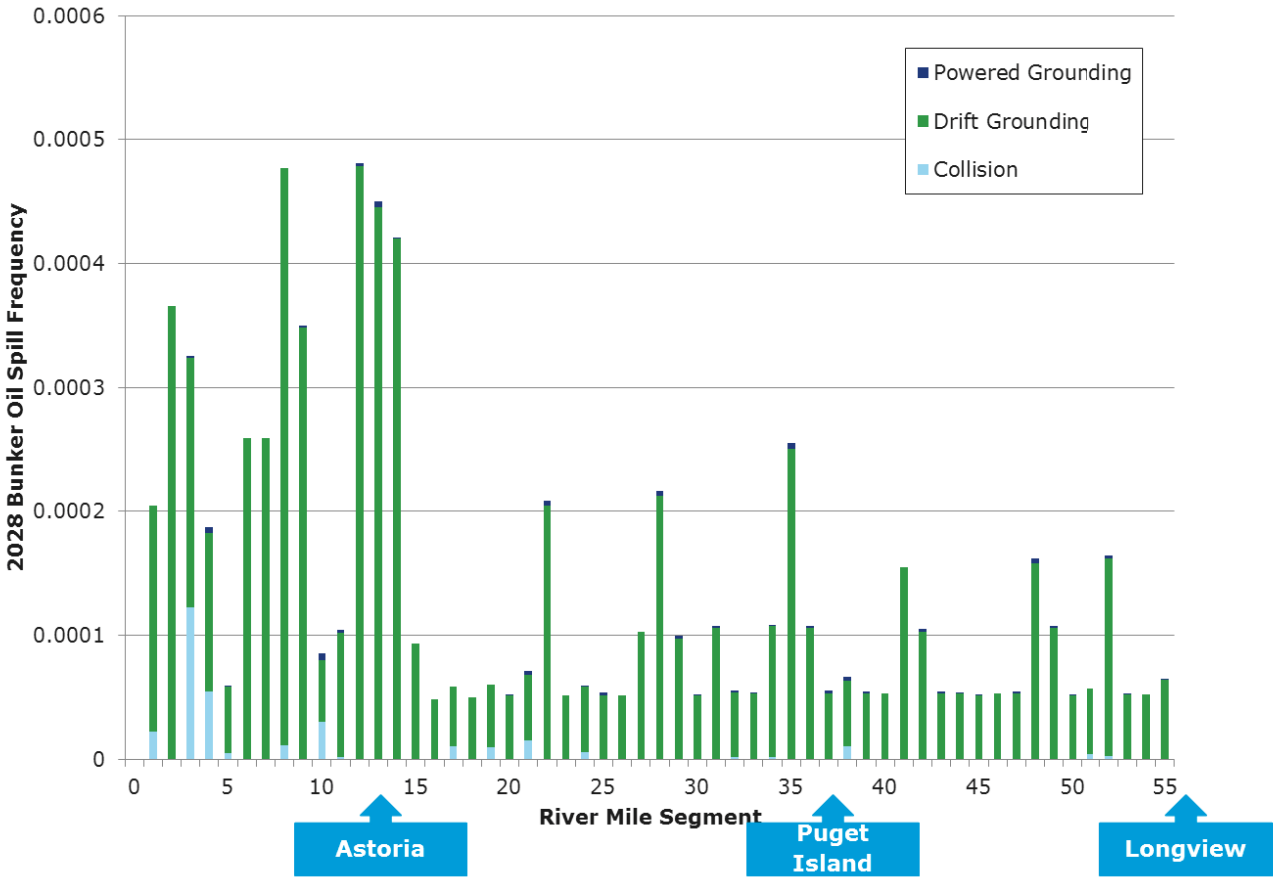


Figure 7-1 2028 Annual Incremental Bunker Oil Spill Frequency

Table 7-2 provides the percentage of incidents that result in a bunker oil spill (of any size) for project vessels in 2028.

Table 7-2 Percentage of Incidents Leading to Bunker Oil Spill (2028)

	Project Vessel (inbound)	Project Vessel (outbound)	Total Incident Frequency
Collision	0.20%	0.21%	0.21%
Powered Ground	0.01%	0.01%	0.01%
Drift Ground	2.08%	2.09%	2.08%
Allision at Berth	N/A	N/A	10.4%
Total Incident Frequency	0.58%	0.57%	0.77%

7.1.2 In 2038 Traffic Conditions

Table 7-3 provides estimated bunker oil spill frequencies by incident type for project vessels in 2038.

Table 7-3 2038 Bunker Spill Frequency from Project Vessels

	Project Vessel (inbound)	Project Vessel (outbound)	Total Incident Frequency
Collision	1.73E-04	1.73E-04	3.47E-04
Powered Ground	3.98E-05	4.10E-05	8.07E-05
Drift Ground	3.56E-03	3.57E-03	7.13E-03
Allision at Berth	N/A	N/A	4.16E-03
Total Incident Frequency	3.77E-03	3.78E-03	1.17E-02

Figure 7-2 shows how the bunker oil spill frequency varies across each river mile segment along the proposed route in 2038.

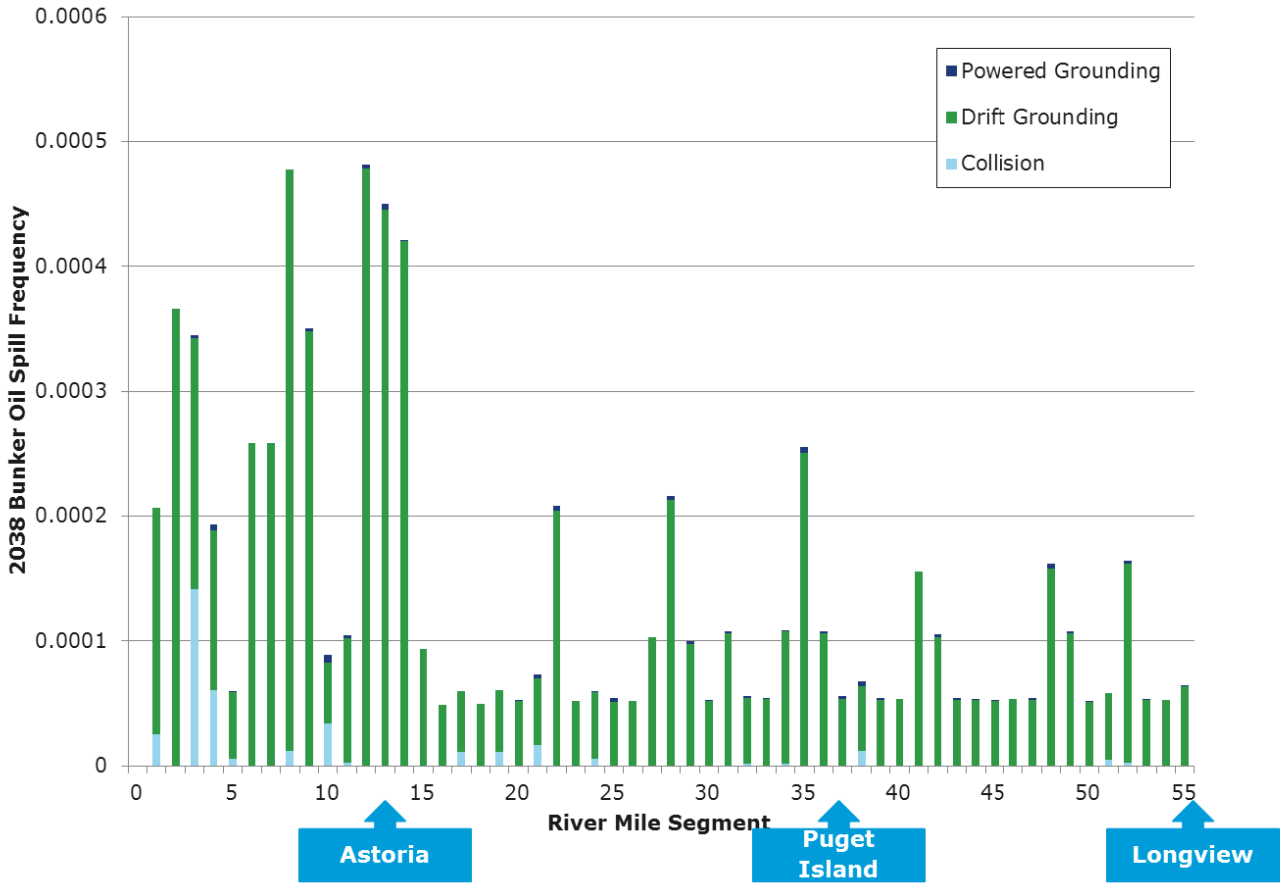


Figure 7-2 2038 Annual Incremental Bunker Oil Spill Frequency

Table 7-4 provides the percentage of incidents that result in a bunker oil spill (of any size) for project vessels in 2038.

Table 7-4 Percentage of Incidents Leading to Bunker Oil Spill (2038)

	Project Vessel (inbound)	Project Vessel (outbound)	Total Incident Frequency
Collision	0.18%	0.18%	0.18%
Powered Ground	0.01%	0.01%	0.01%
Drift Ground	2.08%	2.09%	2.08%
Allision at Berth	N/A	N/A	10.47%
Total Incident Frequency	0.57%	0.56%	0.85%

7.2 Estimated Conditional Probabilities of Spill Volumes

This section presents conditional spill volume probabilities of bunker oil from a project vessel, which was assessed using the Naval Architecture Package (NAPA) model.

These results are presented as curves showing the conditional probability of the volume of bunker oil that would be released given that a bunker oil tank has been breached and oil is flowing out of the tank(s). Figure 7-3 presents these results in gallons for a representative Panamax vessel assuming bunker tanks are 100% full.

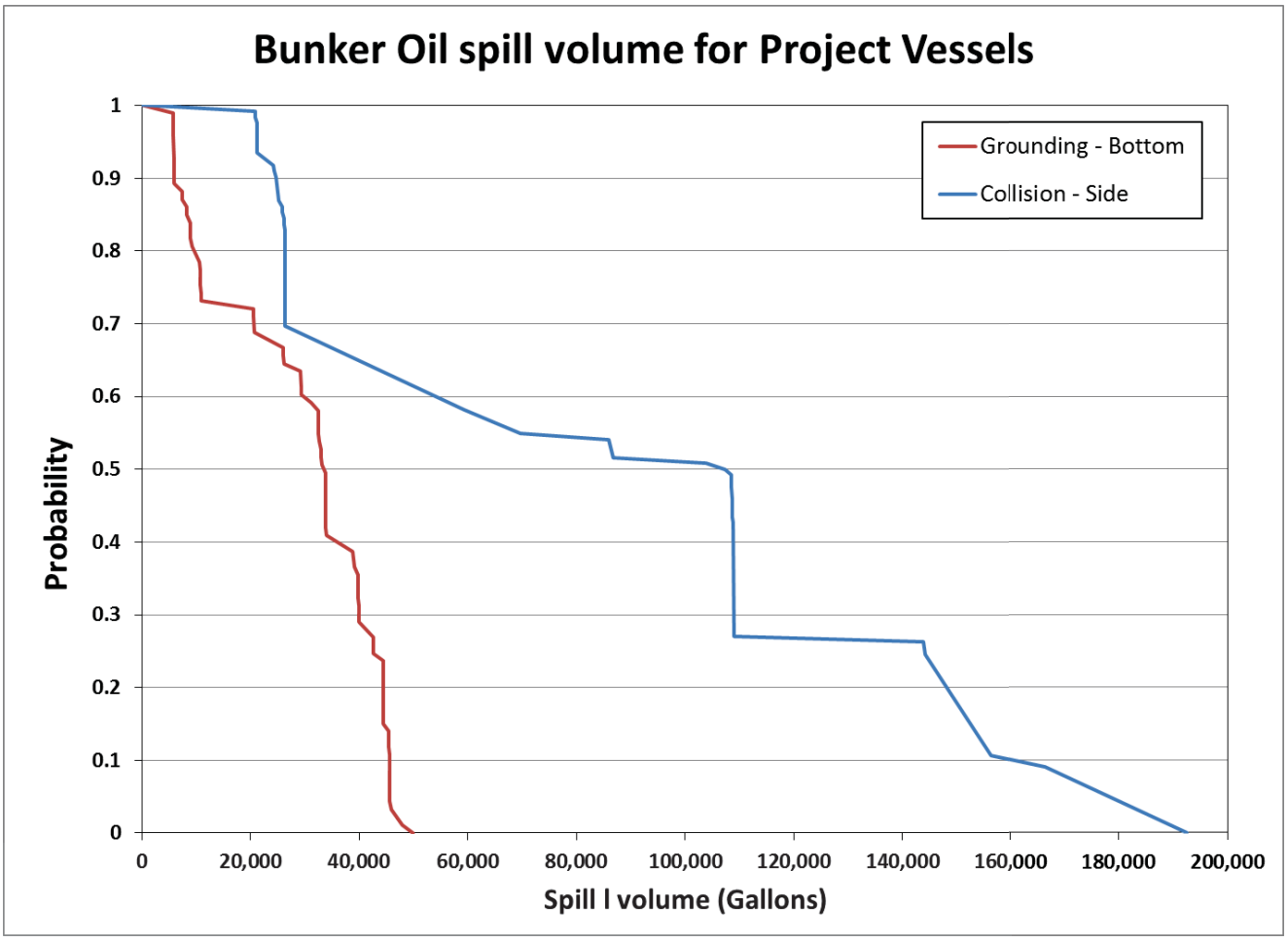


Figure 7-3 NAPA Results - Bunker Oil Spill (gallons)

As shown in Figure 7-3, if a collision or grounding event resulted in a bunker oil spill, the smallest estimated spill volume would be roughly 20 m^3 for a grounding and 80 m^3 for a collision. This equates to 5,700 and 20,900 gallons of bunker oil (respectively).

These volumes can then be paired with the Bunker Oil Spill Frequencies provided in Section 7.1 for a more complete picture of bunker oil spill risk. The frequency of bunker oil spill volumes is provided in Figure 7-4 and Figure 7-5 below for grounding and collision events, respectively. Note that grounding frequencies do not vary from 2028 to 2038 since the number of project vessels remains at 840 in both years. Frequency of collision incidents is higher in 2038 compared to 2028 due to an increase in the overall vessel traffic in the study area.

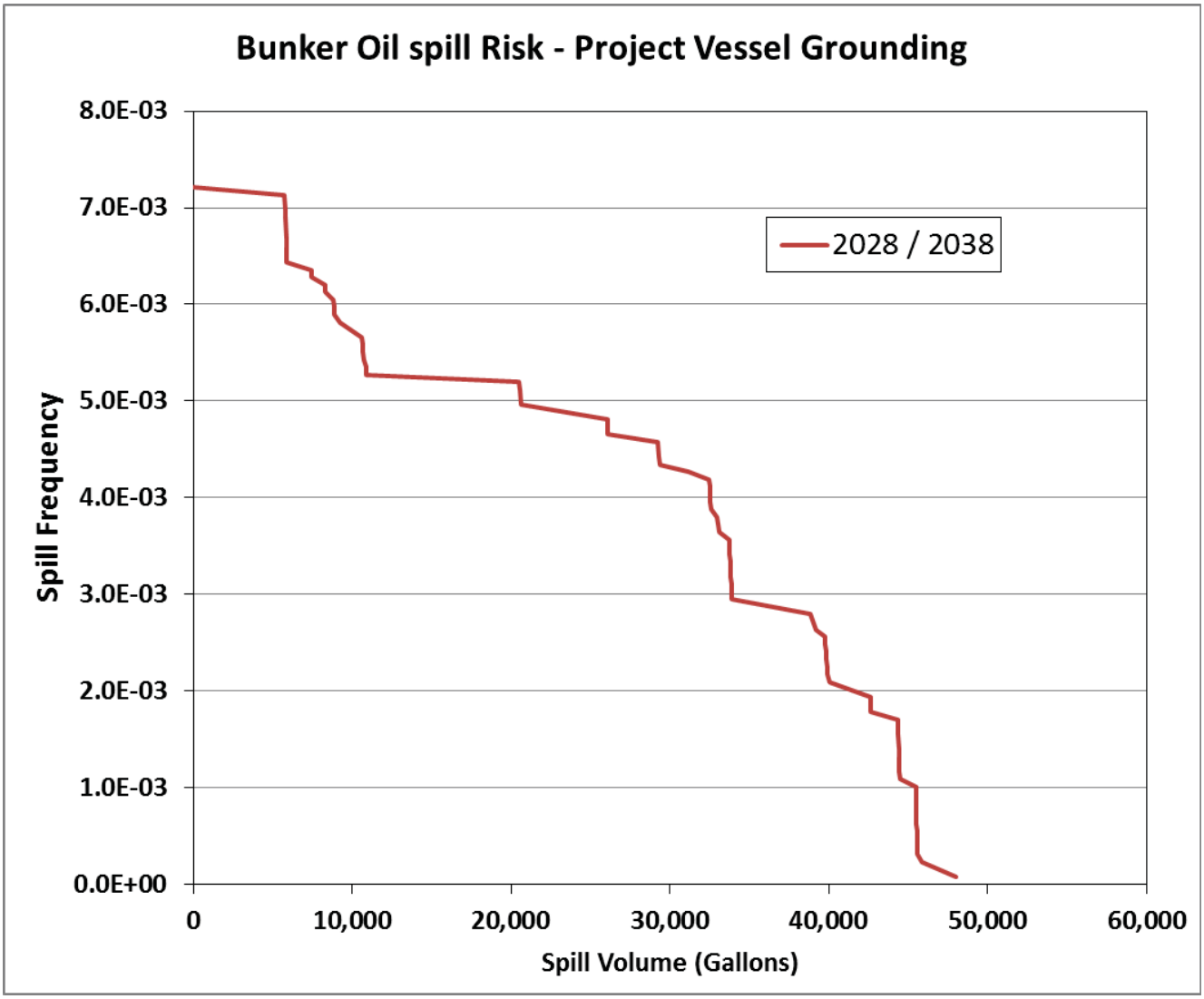


Figure 7-4 Frequency vs volume of Bunker Oil Spill due to Grounding of Project Vessel

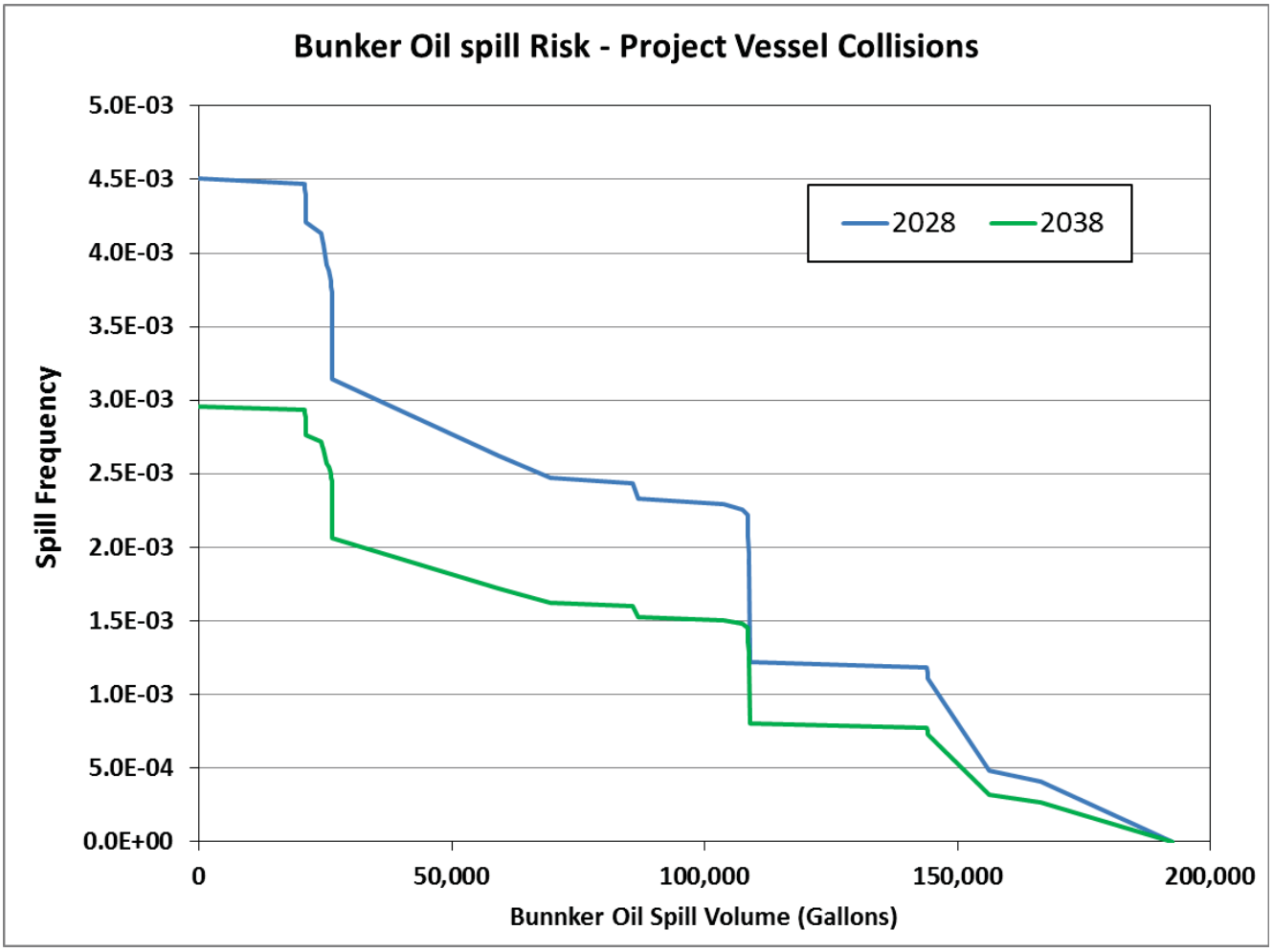


Figure 7-5 Frequency vs volume of Bunker Oil Spill due to Collision involving Project Vessel

Examples of frequency- spill size pairs are provided in Table 7-5 to Table 7-7. It is important to note that this study did not assess the risk of small spills due to activities such as bunkering, damage to the environment and other causes unrelated to navigational incidents.

Table 7-5 Example Bunker Oil Spill Volumes & Frequencies due to Grounding (2028/2038)

Return Period (Years)	Spill Volume (gal)
140	5,700 or less
182	10,700 or less
403	39,700 or less
4,299	45,800 or less

Table 7-6 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2028)

Return Period (Years)	Spill Volume (gal)
341	20,900 or less
581	59,300 or less
676	107,400 or less
3,748	166,500 or less

Table 7-7 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2038)

Return Period (Years)	Spill Volume (gal)
224	20,900 or less
381	59,300 or less
444	107,400 or less
2,461	166,500 or less

8 CONCLUSIONS

8.1 Incremental Contribution to Marine Incidents

The total incremental incident frequency due to proposed project in 2028 is 1.5 incidents per year which equates to an 8% increase over the no-action scenario in 2028. Of these 1.6 incidents 0.8 are powered groundings, 0.34 are drift groundings, 0.38 are collisions and 0.03 are allisions.

The total incremental incident frequency due to proposed project in 2038 is 1.6 incidents per year which equates to a 6% increase over the no-action scenario in 2038. Of these 1.7 incidents 0.8 are powered groundings, 0.34 are drift groundings, 0.47 are collisions and 0.04 are allisions.

In order to provide context around the consequences of a collision, grounding or allision incident, a survey of USCG Marine Information for Safety and Law Enforcement (MISLE) database was conducted for years 2001 to 2014. For the purposes of this study, the various categories used to describe incident severity for each reported incident were aggregated into “Total Loss”, “Damage” and “No Damage”. The data coverage period of 2001 to 2014 was chosen as it covers over 99% of all reported collision, grounding, and allision incidents in the dataset. Data surveys were conducted for the national dataset and for the study area separately in order to test for differences in the distribution of incident severity between the two. Our findings show that for a given incident type, the severity distributions were very similar for national incident data compared to Lower Columbia River incident data.

Using the results of the data survey, we can therefore comment on the likely severity of the incremental contribution of marine incidents contributed by the project.

- Based on a survey of historical incident severity, 1--2% of the grounding events contributed by the project are likely to result in a total loss of the vessel, 21-24% are likely to result in damage to vessel and 74-78% are likely to result in no reported damage. Note: None of the total loss events reported due to grounding involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a grounding event were passenger vessels.
- Based on a survey of historical incident severity, 3--5% of the collision events contributed by the project are likely to result in a total loss of one or more vessels, 47-53% are likely to result in damage to one more vessels and 44-47% are likely to result in no reported damage.
  Note: None of the total loss events reported due to collision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in a collision event were recreational vessels.
- Based on a survey of historical incident severity, 1--5% of the allision events surveyed resulted in a total loss of the vessel, 43-45% resulted in vessel damage and 52-54% resulted in no reported damage.
  Note: None of the total loss events reported due to allision involved carriers or vessels of similar size. The only vessel categories reported as a total loss in an allision event were fishing vessels.

Assuming the distributions described above, the project would contribute fewer than 0.05 incidents with a total loss per year, fewer than 0.5 incidents resulting in reportable damage per year and approximately 1 incident per year resulting in no damage.

The incremental contribution appears to decrease from 2028 (8%) to 2038 (6%) because non-project vessel traffic continues to increase over this ten-year time period while the number of project vessels remains

constant at 840 per year. Therefore the relative contribution in 2038 is lower because project vessels make up a smaller portion of overall vessel traffic.

8.2 Incremental Contribution to Oil Spill Risk

Less than 1% of the collision, grounding and allision incidents involving project vessels are expected to result in a bunker oil spill. As a result, the frequency of a bunker spill of any size due to a marine incident involving a project vessel is estimated to be 1.02×10^{-2} in 2028 and 1.17×10^{-2} in 2038. This equates to roughly one spill (of any size) every 98 years in 2028 and one spill (of any size) every 85 years in 2038. Based on a survey of oil spill data from 2004 to 2014, the Lower Columbia River has experienced a spill of greater than 100 gallons approximately once every 2.2 years. Therefore, the proposed project would increase the frequency of a spill greater than 100 gallons by approximately 2 to 3% to approximately once in every 2.15 years.

In the unlikely event that a collision or grounding event resulted in a bunker oil spill, the smallest estimated bunker oil spill volume from a project vessel would be roughly 20 m^3 for grounding and 80 m^3 for collisions (5,700 and 20,900 gallons, respectively). The frequency of various bunker oil spill sizes is provided in Table 8-1 for grounding scenarios. Since the number of project vessels does not change between 2028 and 2038, frequencies are the same in both years. The frequency of various bunker oil spill sizes is provided in Table 8-2 and Table 8-3 for collision scenarios. Since the number of non-project vessels increases between 2028 and 2038, collision frequencies vary across those years. It is important to note that this study did not assess the risk of small spills due to activities such as bunkering, damage to the environment and other causes unrelated to navigational incidents.

Table 8-1 Example Bunker Oil Spill Volumes & Frequencies due to Grounding (2028/2038)

Return Period (Years)	Spill Volume (gal)
140	5,700 or less
182	10,700 or less
403	39,700 or less
4,299	45,800 or less

Table 8-2 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2028)

Return Period (Years)	Spill Volume (gal)
341	20,900 or less
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Table 8-3 Example Bunker Oil Spill Volumes & Frequencies due to Collision (2038)

Return Period (Years)	Spill Volume (gal)
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444	107,400 or less
2,461	166,500 or less

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MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT SEPA NOISE AND VIBRATION TECHNICAL REPORT

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Contents

List of Tables ii
List of Figures iii
List of Photographs iv
List of Acronyms and Abbreviations v

Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-6
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-1
2.1.2 Impact Analysis 2-8
2.2 Existing Conditions 2-28
2.2.1 Proposed Action 2-34
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Construction: Direct Impacts 3-1
3.1.2 Construction: Indirect Impacts 3-1
3.1.3 Operations: Direct Impacts 3-2
3.1.4 Operations: Indirect Impacts 3-4
3.2 No-Action Alternative 3-17
Chapter 4 **Required Permits** **4-1**
Chapter 5 **References** **5-1**

Appendix A Existing Ambient Sound Pressure Level Survey Data
Appendix B Construction Noise Impact Analysis

Tables

Table 1. Regulations, Statutes, and Guidelines for Noise and Vibration 1-5

Table 2. Anticipated Roster of Construction Equipment 2-9

Table 3. Equipment Quantities and Acoustic Centers for Each Phase of Construction 2-10

Table 4. Vibration Source Levels for Construction Equipment 2-11

Table 5. Modeled Point-Type Sound Sources for Operations 2-12

Table 6. Modeled Line-Type Sound Sources for Operations 2-14

Table 7. Estimated Transmission Loss for Fiberglass-Reinforced Plastic Cladding Material 2-17

Table 8. Average Freight Rail Traffic, Consists, and Speed—BNSF Spur to Reynolds Lead 2-18

Table 9. Average Freight Schedule, Consists, and Speed—Reynolds Lead from BNSF Spur to 3rd Avenue and California Way 2-18

Table 10. Average Freight Schedule, Consists, and Speed—Reynolds Lead from Oregon Way and Industrial Way to Project Area 2-19

Table 11. Freight Schedule, Consists, and Speed—Reynolds Lead from Midway between Industrial Way and Weyerhaeuser Entrance to Project Area 2-19

Table 12. Cadna/A® Freight Train Noise Model Input—BNSF Spur to Reynolds Lead 2-21

Table 13. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from BNSF Spur to 3rd Avenue and California Way 2-22

Table 14. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from Oregon Way and Industrial to the Project Area 2-23

Table 15. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from Midway between Industrial Way and Weyerhaeuser Entrance to Project Area 2-24

Table 16. Existing Environmental Noise Sources near the Project Area[a] 2-34

Table 17. Daily Noise Measurements at Sources near the Project Area 2-35

Table 18. Short-Term Noise Measurements at Sources near the Project Area 2-36

Table 19. 2028 Noise Impact Assessment with Proposed Action-Related Rail Traffic 3-9

Table 20. Estimated Number of Noise-Sensitive Receptors with Noise Impacts from Proposed Action-Related Train Traffic 3-12

Table 21. Potential Noise Exposure Levels from Vessel Traffic at Various Perpendicular Distances from the Columbia River Navigational Channel 3-14

Table 22. 2028 Rail Traffic Volumes on BNSF and UP Routes to and from Longview, WA and Potential Increase in Noise Exposure from Proposed Action-Related Trains 3-16

Table 23. Noise Impact Assessment for No-Action Alternative, 2028 Rail Traffic 3-22

Figures

Figure 1. Project Vicinity 1-3

Figure 2. Proposed Action 1-4

Figure 3. Study Area 1-7

Figure 4. Sensitive Receptors in the Study Area 2-2

Figure 5. Ambient Sound Pressure Level Survey Locations 2-3

Figure 6. Noise Impact Criteria 2-25

Figure 7. Existing Rail Noise Contours, BNSF Spur to Reynolds Lead, Including Train Horns 2-30

Figure 8. Existing Rail Noise Contours, Beginning of Reynolds Lead, Including Train Horns 2-31

Figure 9. Existing Rail Noise Contours, Mid-Reynolds Lead, Including Train Horns 2-32

Figure 10. Existing Rail Noise Contours, End of Reynolds Lead, Including Train Horns 2-33

Figure 11. Predicted Continuous Noise Level (Leq) Contours during Operations 3-3

Figure 12. Noise Contours for Proposed Action 2028 Rail Traffic, BNSF Spur to Reynolds Lead, Including Train Horns 3-5

Figure 13. Noise Contours for Proposed Action 2028 Rail Traffic, Beginning of Reynolds Lead, Including Train Horns 3-6

Figure 14. Noise Contours for Proposed Action 2028 Rail Traffic, Mid-Reynolds Lead, Including Train Horns 3-7

Figure 15. Noise Contours for Proposed Action 2028 Rail Traffic, End of Reynolds Lead, Including Train Horns 3-8

Figure 16. Noise Impacts from Proposed Action-Related Rail Traffic 3-11

Figure 17. Washington Rail Network Daily Track Utilization, 2028 with Proposed Action-Related Train Traffic 3-15

Figure 18. Noise Contours for No-Action Alternative 2028 Rail Traffic, BNSF Spur to Reynolds Lead, Including Train Horns 3-18

Figure 19. Noise Contours for No-Action Alternative 2028 Rail Traffic, Beginning of Reynolds Lead, Including Train Horns 3-19

Figure 20. Noise Contours for No-Action Alternative 2028 Rail Traffic, Mid-Reynolds Lead, Including Train Horns 3-20

Figure 21. Noise Contours for No-Action Alternative 2028 Rail Traffic, End of Reynolds Lead, Including Train Horns 3-21

Photographs

Photograph 1 Location N1, 602 California Way, Longview, WA 2-4

Photograph 2 Location N2, 111-15th Avenue, Longview, WA 2-4

Photograph 3 Location N3, 221 Beech Street, Longview, WA 2-5

Photograph 4 Location N4, 875 34th Avenue, Longview, WA (survey equipment not shown) 2-5

Photograph 5 Location N5, 3600 Memorial Park Drive, Longview, WA 2-6

Photograph 6 Location N6, 420 Rutherglen Drive, Longview, WA 2-6

Photograph 7 Location N7, 4723 Mt. Solo Road, Longview, WA 2-7

Photograph 8 Location N8, 1719 Dorothy Avenue, Longview, WA 2-7

Acronyms and Abbreviations

Applicant	Millennium Bulk Terminal—Longview, LLC
ADT	average daily traffic
BNSF	BNSF Railway Company
Cadna/A®	Computer-Aided Noise Abatement Noise Prediction Model
CCC	Cowlitz County Code
CFR	Code of Federal Regulations
CNEL	community noise equivalent
dBA	A-weighted decibels
FRA	Federal Railroad Administration
FRP	fiberglass reinforced plastic
FTA	Federal Transit Administration
HP	horsepower
Hz	Hertz
L_{dn}	day-night average noise level
L_{eq}	equivalent sound level
L_{max}	maximum sound level
L_v	vibration velocity level
LVSW	Longview Switching Company
mph	miles per hour
NEPA	National Environmental Policy Act
RCW	Revised Code of Washington
RMS	root mean square
SEL	sound exposure level
SEPA	Washington State Environmental Policy Act
SPL	sound pressure level
UP	Union Pacific Railroad
USC	United States Code
VdB	vibration velocity level expressed in decibels
WAC	Washington Administrative Code

Chapter 1
Introduction

This technical report assesses the potential noise and vibration impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. This report describes the regulatory setting, establishes the methods for assessing potential noise and vibration impacts, presents the historical and current noise and vibration conditions in the study area, and assesses potential noise and vibration impacts.

This technical analysis is supported by the data and results provided in Appendix A, *Existing Ambient Sound Pressure Level Survey Data*; and Appendix B, *Construction Noise Impact Analysis*.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east

in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

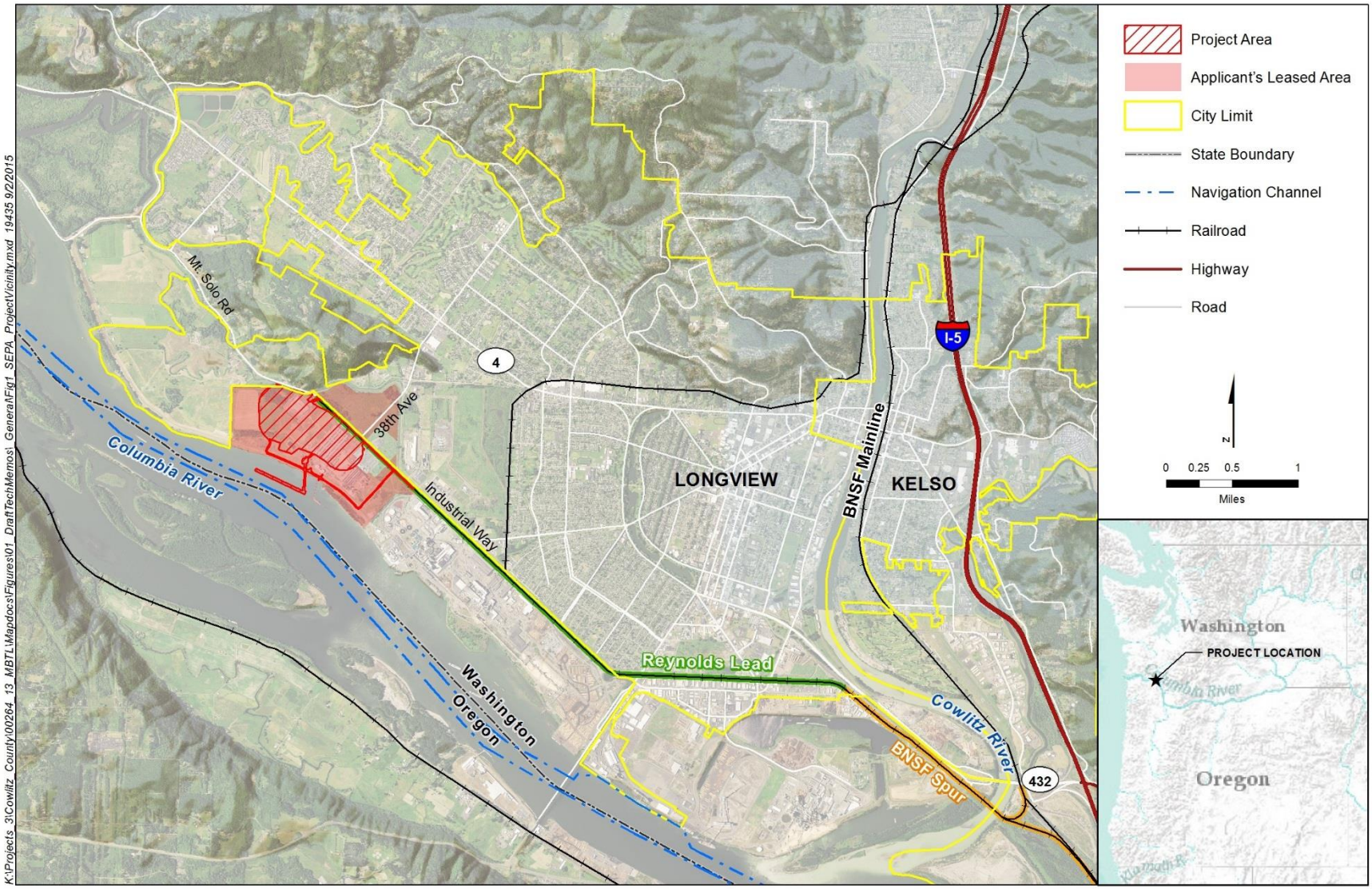
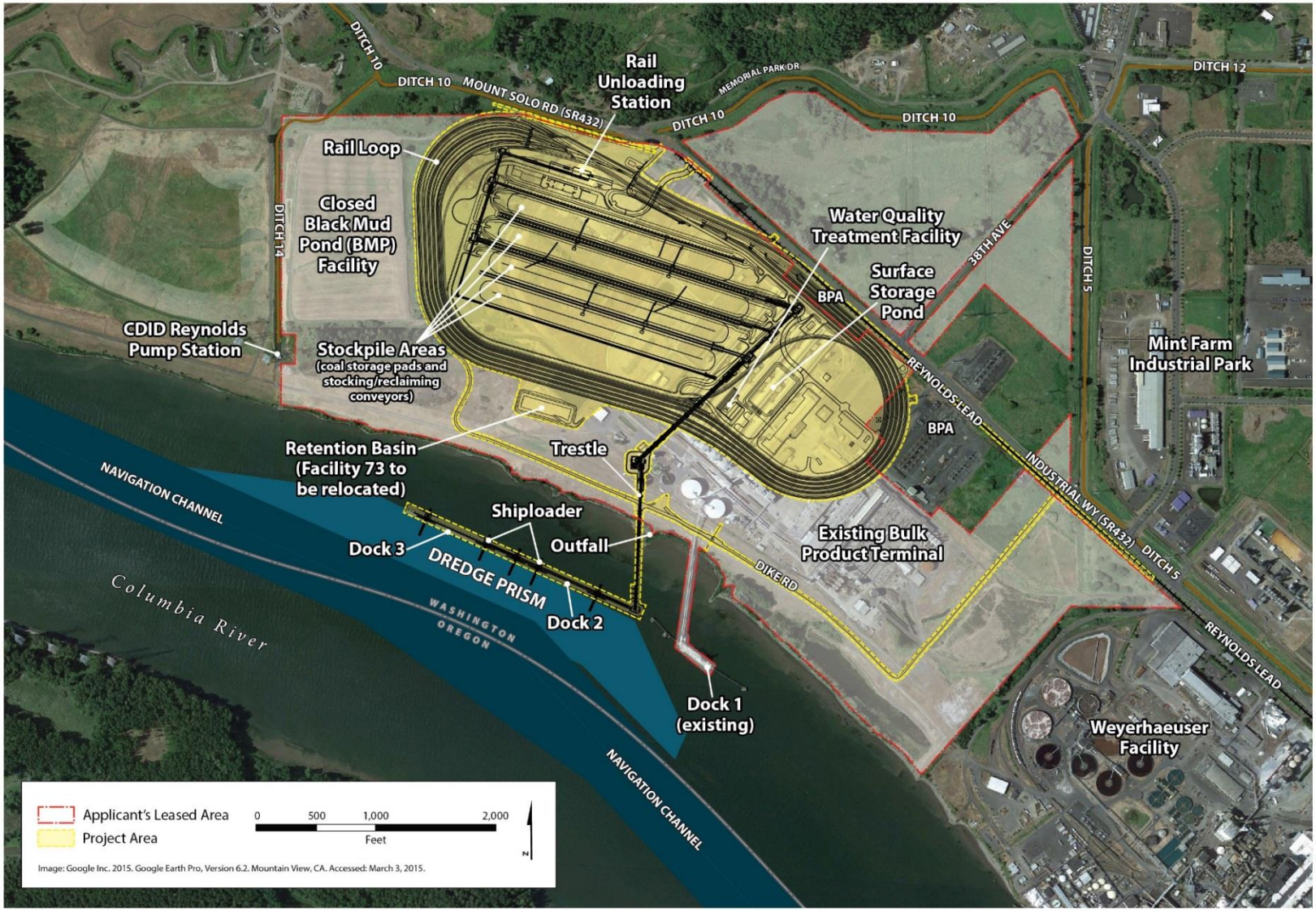


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

The jurisdictional authorities and corresponding regulations, statutes, and guidelines for determining potential impacts related to noise and vibration are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidelines for Noise and Vibration

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Noise Control Act of 1972 (42 USC 4910)	Protects the health and welfare of U.S. citizens from the growing risk of noise pollution, primarily from transportation vehicles, machinery, and other commerce products. Increased coordination between federal researchers and noise control activities; established noise emission standards; and presented noise emission and reduction information to the public.
Federal Transit Administration Transit Noise and Vibration Impact Assessment (FTA-VA-90-1003-06, May 2006)	Provides procedures and guidance for analyzing the level of noise and vibration, assessing the resulting impacts, and determining possible mitigation for most federally funded transit projects.
Federal Transit Administration Transit Noise and Vibration Impact Assessment (FTA-VA-90-1003-06, May 2006)	Provides procedures and guidance for analyzing the level of noise and vibration, assessing the resulting impacts, and determining possible mitigation for most federally funded transit projects.

Regulation, Statute, Guideline	Description
Federal Railroad Administration High-Speed Ground Transportation Noise and Vibration Impact Assessment (October 2012)	Provides guidance and methods for the assessment of potential noise and vibration impacts resulting from proposed high-speed ground transportation projects. (Federal Railroad Administration 2012).
U.S. Environmental Protection Agency Railroad Noise Emission Standards (40 CFR 201)	Establishes final noise emission standards for surface carriers engaged in interstate commerce by railroad. This rulemaking is pursuant to Section 17 of the Noise Control Act of 1972.
FRA Railroad Noise Emission Compliance Regulations (49 CFR 210)	These regulations indicate the minimum compliance regulations necessary to enforce EPA's Railroad Noise Emission Standards.
FRA Final Rule on the Use of Locomotive Horns at Highway-Rail Grade Crossings (49 CFR 222 and 229)	Requires the sounding of locomotive horns at public highway rail grade crossings. Considers the allowance of quiet zones when the increase risk is mitigated with supplementary grade crossing safety measures.
State	
Washington State Environmental Policy Act (197-11 WAC, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Maximum Environmental Noise Levels (WAC 173-60)	Establishes maximum environmental noise levels. However, noise from surface carriers engaged in interstate commerce by railroad is exempt from these regulations.
Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provide for the implementation of SEPA in Cowlitz County.
Cowlitz County Nuisance Noises (CCC 10.25)	Regulates excessive intermittent noise that interfere with the use, value and enjoyment of property and which pose a hazard to the public health, safety and welfare.

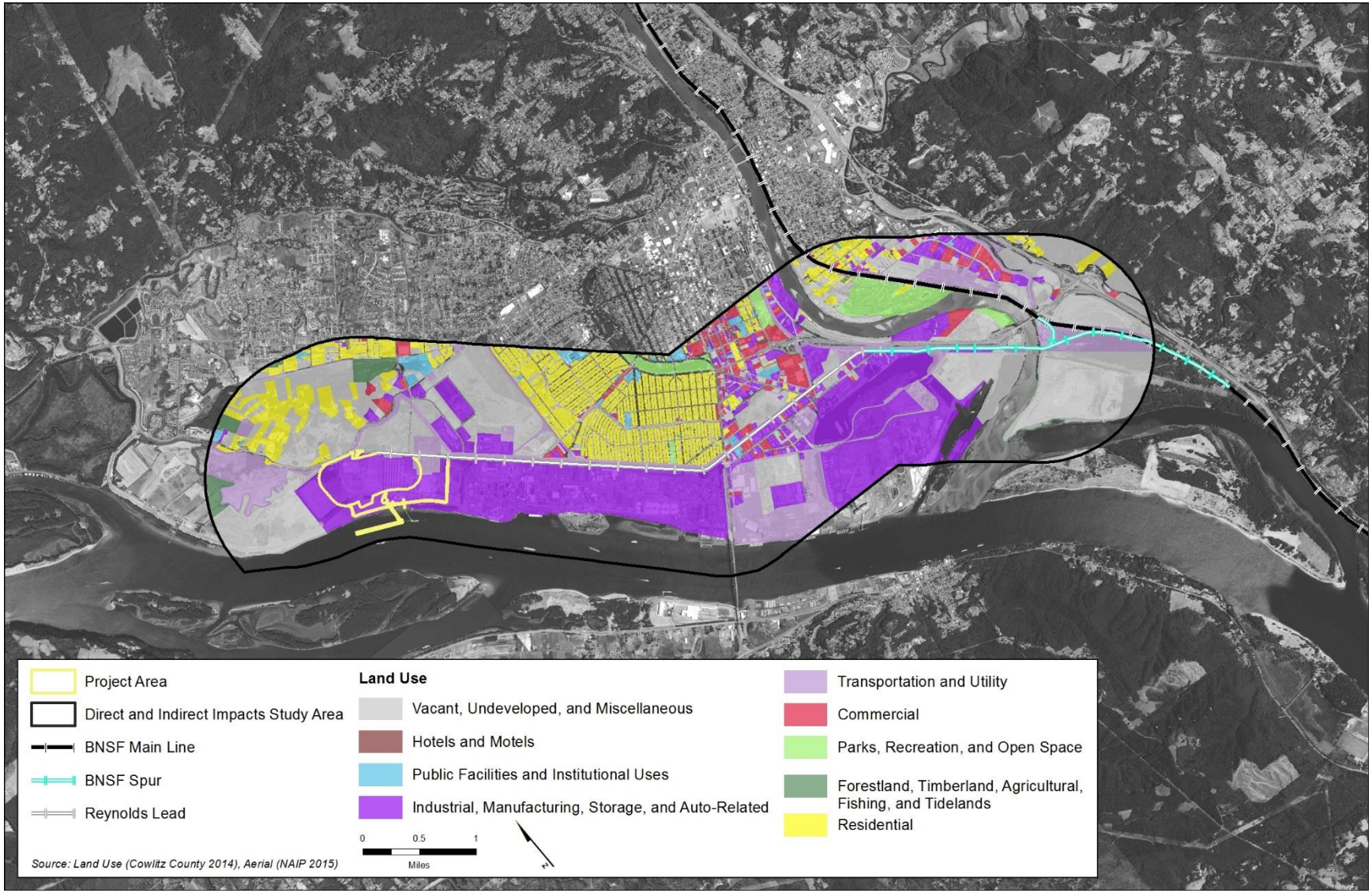
Notes:
USC = United States Code;, NEPA = National Environmental Policy Act;, CFR = Code of Federal Regulations;
FTA = Federal Transit Administration; FRA = Federal Railroad Administration;
RCW = Revised Code of Washington; SEPA = Washington State Environmental Policy Act ; WAC = Washington Administrative Code; CCC = Cowlitz County Code

1.3 Study Area

The study area for noise and vibration direct impacts is within 1 mile of the project area. The study area for noise and vibration indirect impacts is the area within 1 mile (from centerline) of the Reynolds Lead and BNSF Spur. Figure 3 illustrates the combined study area.

An assessment of potential noise and vibration indirect impacts is also included for the rail routes in Washington State for Proposed Action-Related trains and Proposed Action-Related vessel traffic along the Columbia River between the project area and 3 nautical miles offshore.

Figure 3. Study Area



Chapter 2
Existing Conditions

This chapter explains the methods for assessing the existing conditions and determining impacts, and describes the existing conditions in the study area as they pertain to noise and vibration.

2.1 Methods

This section describes the sources of information and methods used to characterize the existing conditions and assess the potential impacts of the Proposed Action and No-Action Alternative on noise and vibration.

2.1.1 Data Sources

The following sources of information were used to evaluate the noise and vibration characteristics of the study area. Citations are provided in the methods discussion where appropriate.

- Information provided by the Applicant, including project design features and a list of typical construction and operation equipment.
- Lists of typical construction and operation equipment provided from reference projects and typical corresponding sound pressure and vibration levels.
- Data on locomotive and train noise levels.
- Existing and future rail traffic estimates for the BNSF Spur and the Reynolds Lead provided by LVSW and the Applicant.
- Reference sound level for rail equipment.
- Ambient noise monitoring data collected during field surveys in the study area.

2.1.1.1 Field Surveys of Ambient Sound Pressure Levels

Field surveys were performed from October 28 through November 10, 2014, and from January 11 through January 16, 2015, to measure existing outdoor ambient sound levels at representative noise-sensitive receptors (ambient noise levels). Noise-sensitive receptors include residential and industrial land uses such as schools and churches (Figure 4). The surveys focused on locations in the study areas where noise-sensitive receptors (mostly residential properties) could be exposed to noise from project activities and where receptors are close to railroad grade crossings. Institutional noise-sensitive receptors, such as schools and churches, were also considered during the selection of the ambient survey locations.

Prior to the field survey, the project team coordinated with the City of Longview and the Cowlitz County Public Utilities District to identify and access representative noise-sensitive receptors where short-term (10-minute) and long-term (24-hour) sound level meters could be set up for sound pressure level (SPL) measurements. The project team also obtained contact information from the Applicant for owners of private property where the Applicant's contractors had previously measured noise. The project team worked directly with the property owners to obtain rights of entry to private property. Selected locations appear in Figure 5.

Figure 4. Sensitive Receptors in the Study Area

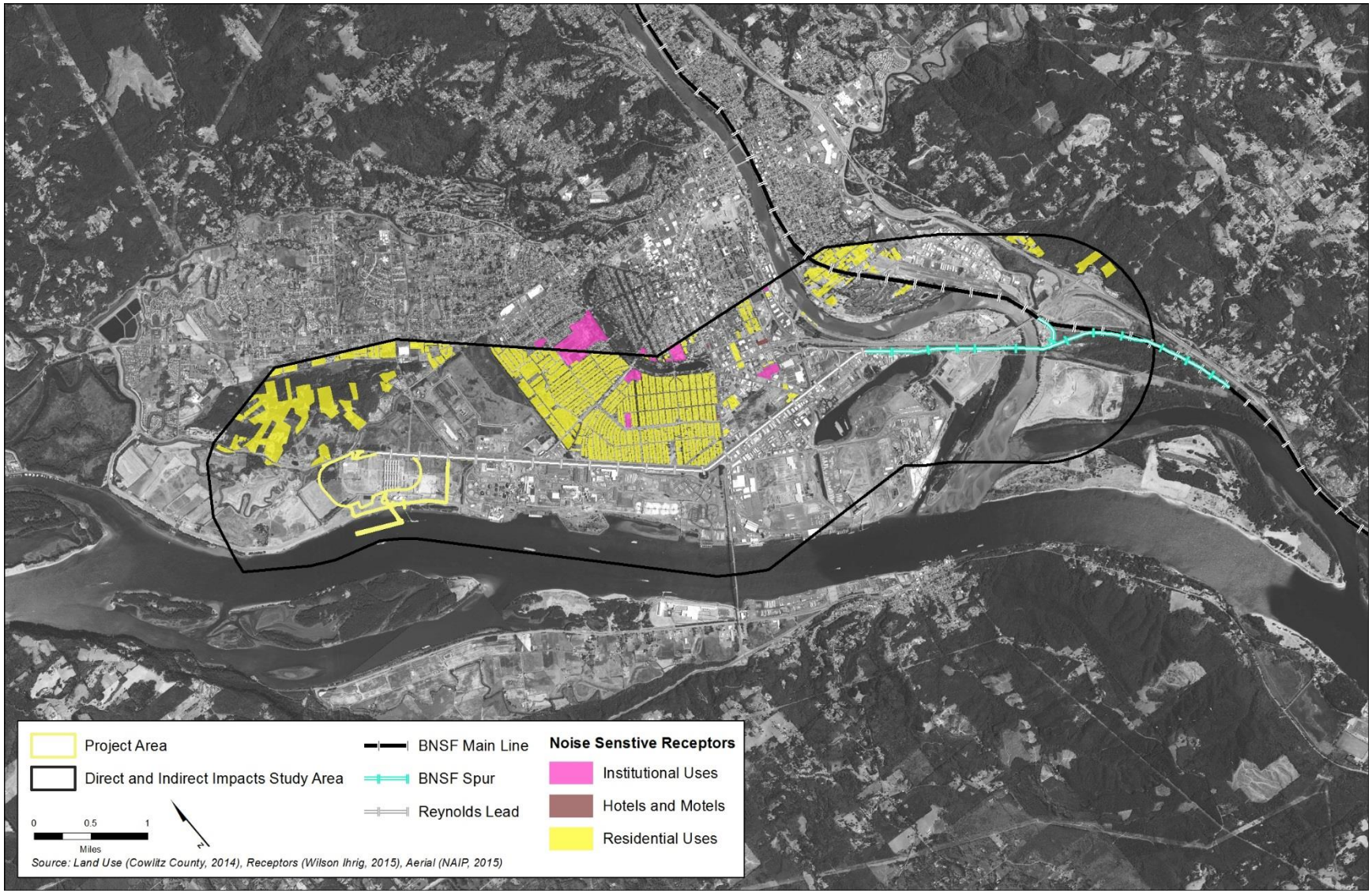
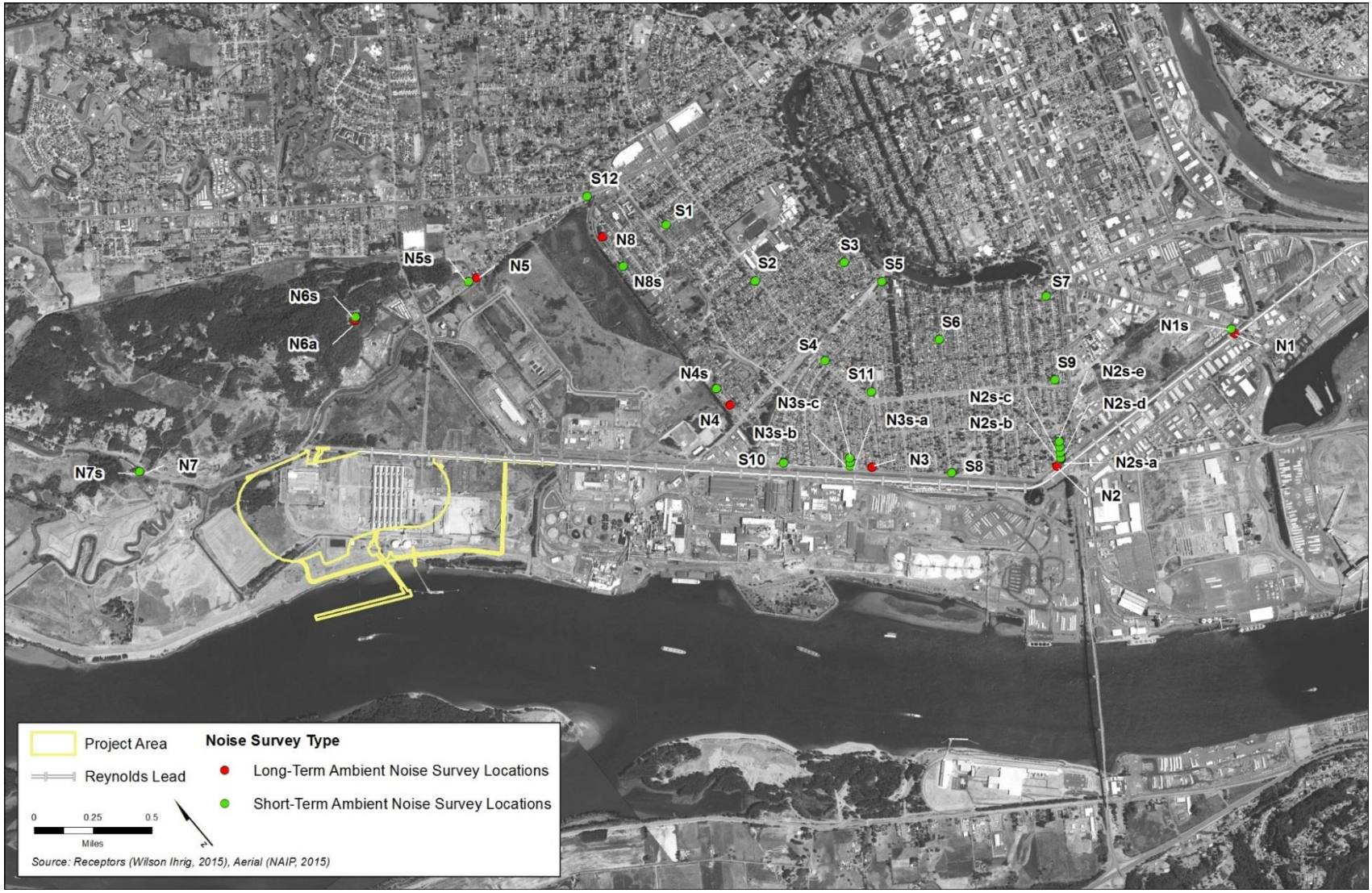


Figure 5. Ambient Sound Pressure Level Survey Locations

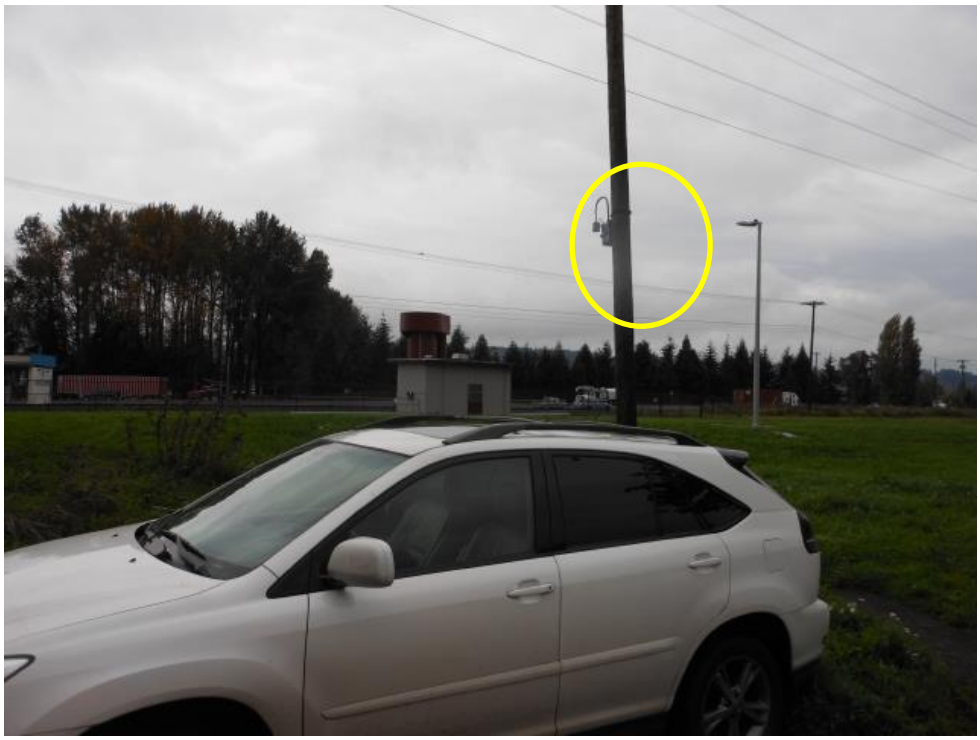


Photographs of the long-term survey locations are provided in Photographs 1 through 7.

Photograph 1. Location N1, 602 California Way, Longview, WA



Photograph 2. Location N2, 111-15th Avenue, Longview, WA



Photograph 3. Location N3, 221 Beech Street, Longview, WA



Photograph 4. Location N4, 875 34th Avenue, Longview, WA (survey equipment not shown)



Photograph 5. Location N5, 3600 Memorial Park Drive, Longview, WA



Photograph 6. Location N6, 420 Rutherglen Drive, Longview, WA



Photograph 7. Location N7, 4723 Mount Solo Road, Longview, WA



Photograph 8. Location N8, 1719 Dorothy Avenue, Longview, WA



Four calibrated, precision, digitally logging sound-level meters were installed on the afternoon of October 27, 2014, then relocated on the evening of November 2, 2014, providing at least 6 full days of data collected at each of eight locations, N1 through N8 (Photographs 1 through 8). All noise monitors included Larson Davis Model 812 logging sound level meters and were mounted on safely accessible wood utility poles or metal light poles with the microphone at a height of approximately 10 feet above the ground surface. The one exception to this installation was location N6, where the monitor was strapped to a patio railing because no poles were available (Photograph 6).

The meters were programmed to store data at 1-hour intervals including statistical levels of L_2, L_8, L_{25}, and $L_{90,}$ where L_n is the SPL that is exceeded n% of the time within the 1-hour interval. The L_2, L_8 and L_{25} metrics were selected to correspond with allowable noise limit exceedance durations of 1.5, 5, and 15 minutes specified in Washington Administrative Code (WAC) 173-60-040. The meters were calibrated with a Brüel & Kjær Type 4230 Sound Level Calibrator prior to each deployment and the calibration was checked at the completion of each measurement period. All calibration checks were within 0.5 decibels of the premeasurement calibration level. The measurements were deemed sufficiently accurate and no data were discarded.

Short-term measurements were conducted during the same period as the long-term survey, typically while deploying, relocating, or recovering the long-term survey equipment. The short-term measurements were conducted using a Brüel & Kjær Type 2230 Precision Integrating Sound Level Meter with the electrical signal from the microphone recorded on a digital recorder for data analysis upon return to the office. The sound level meter and digital recording were calibrated at the start and end of each day the short-term measurements were conducted using the same calibrator used for the long-term survey. For all short-term measurements, the calibration checks were within 0.1 decibel of the initial calibration. The microphone of the short-term equipment was located 5 feet above ground surface and the SPL was measured and recorded for a period of 10 minutes at each short-term survey location, providing the 10-minute equivalent sound level for (L_{eq})[1] at each short-term location.

2.1.2 Impact Analysis

The following methods were used to evaluate the potential impacts of the Proposed Action and No-Action Alternative on noise and vibration. For the purposes of this analysis, construction impacts are based on the peak construction period and operations impacts are based on maximum throughput capacity (up to 44 million metric tons of coal per year), which is assumed to be in 2028.

2.1.2.1 Construction—Project Area

The Applicant has identified three construction scenarios.

- **Truck.** If material is delivered by truck, it is assumed approximately 88,000 truck trips would be required over the construction period. Approximately 56,000 loaded truck trips would be needed during the peak construction year.
- **Rail.** If material is delivered by rail, it is assumed approximately 700 train trips (35,000 loaded rail cars) would be required over the construction period. Approximately two-thirds of the rail trips would occur during the peak construction year.

[1] Equivalent sound level (L_{eq}) is generally referenced to 1 hour unless otherwise indicated.

- **Barge.** If material is delivered by barge, it is assumed approximately 1,130 barge trips would be required over the construction period. Approximately two-thirds of the barge trips would occur during the peak construction year. Because the project area does not have an existing barge dock, the material would be off-loaded at an existing dock elsewhere on the Columbia River.

The methods for analyzing noise and vibration impacts related to construction on the project area are described in this subsection.

Noise

Daytime construction is exempt from Washington State noise limits (WAC 173-60-040) and the Applicant is not proposing nighttime construction. However, to establish a reasonable benchmark for evaluating potential impacts and provide context, construction noise in the project area was evaluated on an average aggregate daytime L_{eq} basis over an 8-hour shift per guidelines established by the Federal Transit Administration (FTA) (2006) and the Federal Railroad Administration (FRA) (2012) (referred to as the FTA/FRA guidance). The 8-hour L_{eq} was estimated at the noise-sensitive receptors in the study area using detailed information about the anticipated roster of construction equipment to be used, based on the construction of a similar terminal project (URS Corporation 2014a) and the assumptions described in this section of this report.

Because a monthly schedule of construction activities was not available, the construction noise analysis conservatively assumed that the maximum amount of equipment would be operating concurrently for three areas of construction activity (Table 2).

- Rail infrastructure and rotary car dumper
- Conveyors, transfer towers, and surge bins
- Shiploader, dock, and trestles

Table 2. Anticipated Roster of Construction Equipment

			Rail Infrastructure & Rotary Car, Dumper		Conveyors, Transfer Towers, & Surge Bins		Shiploader, Dock, & Trestles	
Construction Equipment Type	**Util. Factor[a] (%)**	**L_{max} at 50 feet[b] (dBA)**	**Max. Qty. per Month**	**Months**	**Max. Qty. per Month**	**Months**	**Max. Qty. per Month**	**Months**
Mobile crane[c]	16	83	5	18	5	18	5	18
Elevated work platform	20	85[a]	2	3	4	18	2	12
Water truck[d]	40	88	1	12	1	12	NA	NA
Dump truck	40	88	3	12	1	12	NA	NA
Dozer	40	85	1	5	NA	NA	NA	NA
Excavator[c]	40	85[a]	1	9	2	12	1	3
Roller	20	85	2	9	2	12	1	3
Grader	40	85	2	9	NA	NA	1	3
Compactor	20	82	2	9	2	12	1	3
Track laying machine	50	85	1	6	NA	NA	NA	NA
Drill rig	20	84[a]	1	2	2	6	NA	NA

Impact pile driver	20	101	2	6	2	6	2	6
Loader[c]	40	85	1	12	1	12	1	9
River barge	50	85[e]	NA	NA	NA	NA	2	18
Generator	50	81	2	18	2	18	2	18
Air compressor	40	81	2	18	2	18	2	18
Construction labor (e.g., misc. Pneumatic tools)	50	85[a]	6	18	6	18	6	18

Notes:
[a] Source: Federal Highway Administration 2006
[b] Source: Federal Transit Administration 2006, except where noted
[c] Shared between all three areas of construction activity
[d] Shared between the two areas of land construction
[e] Source: Federal Highway Administration 2006 for "All other equipment >5 HP"
L_{max} = maximum sound level; dBA = A=weighted decibels

For purposes of this analysis, and because the exact locations of these activities (or the involved equipment and processes) are either unknown at this time or could vary during the course of construction, noise was treated as originating from the acoustic center of the geographic locations described in Table 3.

Table 3. Equipment Quantities and Acoustic Centers for Each Phase of Construction

Equipment[a]	Geographic Acoustic Center of Activity
Rail Infrastructure & rotary car dumper with two mobile cranes, no pile driver	Centerline of perimeter track loop closest to receptors
Conveyors, transfer towers, & surge bins with two mobile cranes, one excavator, no water truck, no loader, no pile driver	Midpoint of Stage 1 reclaim travel path
Shiploader, Dock & Trestles w/ 1 mobile crane, no excavator, no loader, no pile driver	Transfer tower TT-08
Pile driver (one)	Closest pile to receptor from rotary car dumper or Stage 1 reclaim travel path

Notes:
[a] Accounting for equipment shared between areas.

The L_{eq} from each piece of equipment, with the exception of the pile driver, was calculated using the following formula from the FTA/FRA guidance.

$$L_{eq}(equip) = E.L. + 10 \log_{10}(U.F.) - 20 \log_{10}(D/50) - 10G \log_{10}(D/50)$$

Where:

- $L_{eq}(equip)$ is the L_{eq} at a receptor resulting from the operation of a single piece of equipment over a specified period.
- E.L. is the noise emission level of the particular piece of equipment at the reference distance of 50 feet, taken from Table 2 for this analysis.
- U.F. is a usage factor that accounts for the fraction of time that the equipment is in use over the specified period, i.e., 8-hours in this analysis and taken from Table 2.
- D is the distance from the receptor to the piece of equipment.

- G is a constant that accounts for topography and ground effects, assumed to equal zero in this analysis for a conservative estimate of the construction noise at the receptors; i.e., ignoring reduction due to topography or ground effects.

Pile driving is often the dominant source of noise complaints during construction. A conservative approach was taken by calculating the maximum sound level (L_{max}) that would result from driving a single pile at the location closest to the noise-sensitive receptor. The L_{max} is unaffected by the number of pile drivers operating at a given time because the impacts are discrete, short duration events that typically do not overlap in time. However, the 8-hour L_{eq}, calculated for all other equipment as described above, was added to the L_{max} calculated for pile-driving noise to get the total construction noise for comparison to the noise criteria.

Vibration

Impact pile driving would be the dominant source of ground vibration during construction. The vibration velocity level (L_v) during pile driving was calculated using the following formula from the FTA/FRA guidance.

$$L_v(D) = L_v(25\text{ ft}) - 30\log_{10}(D/25)$$

Where:

- L_v is the root mean square (RMS) vibration velocity level expressed in decibels (VdB) referenced to 1 micro-inch/second.
- L_v(25 feet) is the reference vibration velocity level for the piece of equipment. In this case, a value of 112 VdB was used, which represents the upper range of vibration level generated by an impact pile driver.
- D is the distance from the receptor to the piece of equipment.

A list of reference vibration velocity levels for typical construction equipment is provided in Table 4.

Table 4. Vibration Source Levels for Construction Equipment

Equipment	Peak Particle Velocity at 25 feet (inches per second)	Approximate L_v[a] at 25 feet
Pile driver (impact)	1.518	112
Vibratory roller	0.210	94
Hoe ram	0.089	87
Large bulldozer	0.089	87
Loaded trucks	0.076	86
Jackhammer	0.035	79
Small bulldozer	0.003	58

Notes:
[a] RMS velocity in decibels (VdB) are 1 micro-inch/second
Source: Federal Railroad Administration 2012
L_v = vibration velocity level;, RMS = root mean square;, VdB = vibration decibel

The FTA/FRA guidance recommends a slightly different formula to assess potential for structural damage due to ground vibration. However, human annoyance occurs at much lower vibration levels

than vibration levels that may cause cosmetic damage to structures so this lower threshold was used to assess impacts.

2.1.2.2 Operations—Project Area

The methods for analyzing noise and vibration impacts related to operations on the project area are described in this subsection.

Noise

The Computer-Aided Noise Abatement (Cadna/A®) Noise Prediction Model (Version 4.4.145) was used to estimate the propagation of sound from aggregate project operations at the project area. Cadna/A® is a Windows-based software program that predicts and assesses noise levels near industrial noise sources using standardized algorithms for noise propagation calculations (International Organization for Standardization 1996). The software can accept sound power levels (in dB re: 1 pico-Watt) in octave-band center frequency resolution to describe the multiple sound propagation sources of the site processes or activity to be modeled. The calculations account for classical sound wave divergence plus attenuation factors resulting from air absorption, basic ground effects, and barriers or shielding. The advantage of using Cadna/A® is that it helps handle the three-dimensional sound propagation complexity of considering realistic intervening natural and human-made topographical barrier effects, including those resulting from terrain features (e.g., Mount Solo) and from structures such as major buildings, storage tanks, and large equipment. The model predicted SPLs at all noise-sensitive receptors in the study area and generated noise contours of equal $L_{eq,}$ 50 A-weighted decibels (dBA) and 60 dBA, for comparison to the Washington State regulatory noise criteria.

A detailed Cadna/A® model for the Proposed Action (URS Corporation 2014b) was reviewed and found to be reasonable. Minor modifications included the addition of calculation points at each of the noise-sensitive receptors. Table 5 and Table 6 list the point-type and line-type sound sources, respectively, that were included in the model, and the assumptions for each source are described following the tables. The Applicant has stated that several of the line-type sources would have corrugated fiberglass-reinforced plastic (FRP) panels as exterior cladding material (Table 7) (URS Corporation 2014b). Atmospheric conditions of no wind and no temperature inversions were assumed for all predictions. (Historical information indicates the likelihood of a temperature inversion in the area is approximately 5% [City of Portland 1955].)

Table 5. Modeled Point-Type Sound Sources for Operations

Noise Source	Sound Power Level (dBA)[a]	Attenuation Applied	Height Above Ground (feet)[b]
Idling Train North1	109	—	6.56
Idling Train North2	109	—	6.56
Idling Train North3	109	—	6.56
Idling Train North4	109	—	6.56
Idling Train North5	109	—	6.56
Idling Train North6	109	—	6.56
Idling Train North7	109	—	6.56
Idling Train South1	109	—	6.56

Noise Source	Sound Power Level (dBA)[a]	Attenuation Applied	Height Above Ground (feet)[b]
Idling Train South2	109	—	6.56
Idling Train South3	109	—	6.56
Idling Train South4	109	—	6.56
Idling Train South5	109	—	6.56
Idling Train South6	109	—	6.56
Idling Train South7	109	—	6.56
Surge Bin 15-SB-01	102.7	—	73.08
Tandem Rotary Dumper	103	—	21.25
Stg1 Conv Drv 01	100.2	—	11.97
Stg1 Conv Drv 03	100.2	—	11.97
Stg1 Conv Drv 05	100.2	—	11.97
Stg1 Conv Drv 09	100.2	—	11.97
Stg1 Conv Drv 10	100.2	—	11.97
Stg1 Conv Drv 06	100.2	—	11.97
Stg1 Conv Drv 13	100.2	—	11.97
Stg1 Conv Drv 15	100.2	—	11.97
Stg1 Conv Drv 17	100.2	—	11.97
Stg1 Trnsf Twr 1	98.8	—	41.26
Stg1 Trnsf Twr 2	98.8	—	36.08
Stg1 Trnsf Twr 3	98.8	—	40.97
Stg1 Trnsf Twr 5	98.8	—	31.75
Stg1 Trnsf Twr 6	98.8	—	31.75
Stg1 Trnsf Twr 7	98.8	—	31.75
Stg1 Trnsf Twr 8	98.8	—	47.69
Stg2 Conv Drv A	100.2	—	11.97
Stg2 Conv Drv B	100.2	—	11.97
Stg2 Conv Drv C	100.2	—	11.97
Stg2 Conv Drv D	100.2	—	11.97
Stg2 Conv Drv E	100.2	—	11.97
Stg2 Trnsf Twr 4	98.8	—	36.08
Stg2 Conv Drv F	100.2	—	11.97
Surge Bin 15-SB-02	102.7	—	73.08
Idling Train North1	109	—	6.56

Notes:
[a] Sound Power Level in dB re: 1 pico-Watt
[b] Site ground elevation 10 feet
Source: URS 2014a
dBA = A-weighted decibels; FRP = fiberglass reinforced plastic

Table 6. Modeled Line-Type Sound Sources for Operations

Noise Source	Sound Power Level (dBA)[a]	Attenuation Applied	Height Above Ground (feet)[b]
Rail track	113.4	—	6.56
Tandem Rotary Dumper to TT01	88.5	FRP	87.53
Stage1 15-SB-02 to TT08	90.7	FRP	99.44
Stage1 Dock Conveyor	108.7	—	58.79
Stage1 Reclaim Conveyor to TT05	112.3	—	71.78
Stage1 Reclaim Conveyor to TT05	112.3	—	71.78
Stage1 Reclaim for 14-CV-09	106.5	—	114.83
Stage1 Reclaim for 14-CV-10	106.5	—	114.83
Stage1 Shiploader for Dock2	106.3	—	85.30
Stage1 Stacker for 13-CV-05	106.5	—	98.43
Stage1 Stacker for 13-CV-06	106.5	—	98.43
Stage1 Stacking Conveyor from TT03	112.3	—	71.78
Stage1 TT01 to TT02	83.8	FRP	80.54
Stage1 TT02 to Stacking	111.5	—	35.17
Stage1 TT02 to TT03	86.6	FRP	89.70
Stage1 TT05 to Surge Bin (15-SB-02)	92.4	FRP	149.28
Stage1 TT06 to TT09d	86.3	FRP	49.28
Stage1 TT09 to Surge Bind	87.3	FRP	149.28
Stage2 15-SB-02 to TT08	90.6	FRP	99.44
Stage2 Dock Conveyor	111.2	—	58.79
Stage2 Reclaim Conveyor to TT07	111.8	—	71.78
Stage2 Reclaim Conveyor to TT07	111.9	—	71.78
Stage2 Reclaim for 14-CV-11	106.5	—	114.83
Stage2 Reclaim for 14-CV-12	106.5	—	114.83
Stage2 Shiploader for Dock3	106.3	—	85.30
Stage2 Stacker for 13-CV-08	106.5	—	85.30
Stage2 Stacking Conveyor from TT04	111.7	—	35.17
Stage2 TT03 to TT04	86.9	FRP	89.70
Stage2 TT07 to 15-SB-02	90.9	FRP	149.28
Stage2 TT07 to TT09d	88.3	FRP	49.28
Stage2 TT09 to Surge Bind	87.2	FRP	149.28

Notes:
[a] Sound Power Level in dB re: 1 pico-Watt
[b] Site ground elevation 10 feet
Source: URS 2014a
dBA = A-weighted decibels; FRP = fiberglass reinforced plastic

Parameters and Assumptions—Operations Equipment

The following notes and assumptions relate to the operations-related equipment of the project area.

- **Transfer towers.** The 98.8 dBA sound power level was derived from estimated octave band center frequency levels (Edison Electric Institute 1984: Table 4.34), adjusted downward by 17

decibels in each octave band so that the overall dBA was comparable to a transfer tower reference point (Heggies 2006). This adjustment reflects the addition of a cladded enclosure, so the FRP attenuation was not applied. The source height is approximately the top of the cladded structure (Edison Electric Institute 1984). While the transfer tower noise levels may include material falling and conveyor belts, they do not include the conveyor drives, which are considered separately.

- **Conveyor belts.** The stacking, reclaim, and dock conveyors are exposed to the outdoors and hence do not receive the benefit of cladding noise reduction as do the other conveyor segments. The 103 dBA sound power level (per 100 meters of length) was recommended for unenclosed low-noise conveyors based on an exchange of confidential information between URS and SLR Consulting (URS Corporation 2014b) regarding sound levels "generally being achieved in practice" at Kooragong Coal Terminal. For enclosed conveyor galleries, the FRP attenuation adjustment was applied.
- **Conveyor drives.** Conveyor drive locations were identified from available Worley-Parsons plan and elevation drawing sets. Consistent with these drawings, all conveyor drives would be located near grade and exposed to the outdoors. They would not be located inside the cladded transfer towers nor do they feature any substantial noise-reducing enclosure or other means of noise reduction. While project design information indicates that conveyor drives would have up to four 400-horsepower (HP) motors (URS Corporation 2014b), predictive model data (Heggies 2006) suggest that the low-noise specification sound power level is 100 dBA for either a 630-kilowatt motor (845 HP) or an 800-kilowatt motor (1,073 HP) and thus does not depend on the total drive power. Hence, all drives in the model for this technical report, ranging from 400 to 1,600 HP, had the same 100 dBA L_{eq} sound power.
- **Tandem rotary dumper.** The tandem rotary dumper sound level is assumed to include motor noise from indexers (positioners) fore and aft of the dumper building. The 103 dBA sound power level was derived from measured level octave band center frequency levels taken at the exteriors of the entry and exit openings of a similar rotary dumper facility (Pittsburgh Testing Laboratory 1982).
- **Startup rapid unloader.** For purposes of this analysis, the startup rapid unloader was assumed similar to the tandem rotary dumper with respect to noise emission.
- **Shiploader.** The shiploaders move bulk materials along the dock conveyors and are point sources of noise. The 106.3 dBA SPL was derived from a reference terminal (Whitt et al. 2007), adjusted so that the overall dBA was comparable to the value shown for the shiploader in a comparable noise impact assessment (Heggies 2006).
- **Stacker/reclaimer.** The stackers and reclaimers move bulk materials along assigned conveyors and are point sources of noise. The stackers and reclaimers do not emit noise from fixed positions but emit variable noise along a length (i.e., the underlying conveyor position). The model provides an average source position and depicts stacker and reclaimer movement or variable positions. The source heights correspond with the highest point of the boom (stacker) or the wheel axle (reclaimer). The 106.5 dBA SPL was derived from estimated octave band center frequency levels (Edison Electric Institute 1984: Table 4.34) so that the overall dBA was comparable to a stacker and reclaimer reference point (Heggies 2006).
- **Surge bin.** The 102.7 dBA sound power level was derived from octave band center frequency levels in a reference noise assessment (Heggies 2010), adjusted so that the overall dBA was

comparable to the value shown for the buffer bin in a comparable noise impact assessment (Heggies 2006).

- **Train loops.** Trains undergoing active railcar unloading through the rotary car dumper would move slowly during the worst-case hour under consideration. Measurement data from a reference report (U.S. Environmental Protection Agency 1974) provides the basis for an assumed octave-band signature for a comparable sample train of four locomotives and 89 loaded cars. For this operations noise model, a value of 77 dBA per meter generates noise for the moving train (undergoing unloading) that is consistent with recommendations (URS Corporation 2014b) and sound power data from another noise impact assessment (Heggies 2006). Because other trains could be idling, the sound exposure level (SEL) was estimated (Federal Transit Administration 2006: Tables 5-5 and 5-6) and the octave-band profile was approximated data from the reference report (U.S. Environmental Protection Agency 1974). Idling trains were modeled as point sources of noise, with a pair of locomotives at the head of the train, and a single locomotive at the tail.

Parameters and Assumptions—Site Features

- **Structures.** The Cadna/A® 3-D model included path-occluding buildings and structures such as the tandem rotary dumper and the administration office and warehouse.
- **Coal storage.** The Cadna/A® model approximates the tall heaps of stored coal as sloped 15-meter-tall embankments having a size and geometry similar to what appears in available 3-D project layout rendering images.
- **Surface acoustical absorption.** On a recognized scale of zero to one, with zero representing a fully acoustically reflective surface and one representing a fully absorptive surface, the ground surface, on average, was considered 0.5. However, the Columbia River area was locally set to zero.
- **Foliage.** Consistent with what is shown on available aerial photography and observations from the ambient sound survey.
- **Temperature and relative humidity.** The Cadna/A® model assumes at least 70% relative humidity and 20 degrees Celsius—standard values in the model configuration. Available weather data for the project area indicates that seasonal average relative humidity ranges from 72 to 80% (Golden Gate Weather Services 2015), and high temperatures range from about 7 to 26 degrees Celsius (Western Regional Climate Center 2015). Hence, the selected relative humidity value is within the annual relative humidity range and would be considered representative; and, the selected temperature value is near the high value of the region's recorded range and would be considered both representative and conservative, because (all else being equal) sound travels farther in an atmosphere with higher temperatures. The relative humidity affects the degree to which sound is absorbed by the atmosphere over large distances and the effect is more pronounced at higher frequencies. At 20 degrees Celsius and at a fixed distance from a noise source, a change in humidity from 70 to 80%, would be expected to produce a reduction in noise level (from a continuous source) of approximately 1 decibel.
- **Cladding noise reduction.** Based on the Applicant's response to a data request, this analysis assumes that the three major types (roof, opaque wall, translucent window) of exterior surface material are corrugated FRP having a surface weight of 8 ounces per square foot. Because actual sound transmission loss data were not included in the material specifications and engineering data nor were such data found after a reasonable online search, an approximation was used for

this analysis. Assuming its thickness and fluted structure was functionally similar to FRP material, the transmission loss data for a corrugated asbestos sheet of 2 pounds per square foot (Bies and Hansen 1996) was reduced by 12 decibel in each octave band to account for the mass law (a reduction of 6 decibel for each halving of material mass). Then, to account for expected differences between laboratory test and actual field conditions, another reduction of 3 decibels was conservatively applied. The resulting octave band center frequency transmission loss data are shown in Table 7.

Table 7. Estimated Transmission Loss for Fiberglass-Reinforced Plastic Cladding Material

Octave Band (Hz)	63	125	250	500	1000	2000	4000	8000
Transmission Loss (decibels)	5	10	15	18	18	23	24	27

Hz = Hertz

Vibration

There would be no substantial sources of ground vibration on site during operations with the possible exception of trains moving on the rail loop. Using generalized ground surface vibration curves (Federal Transit Administration 2006) and correcting for speed (a maximum of 10 miles per hour on the rail loop), vibration impact from train operations is unlikely at distances more than 40 feet from a railroad track for infrequent events (less than 30 passbys per day). The closest vibration-sensitive receptor (a residence) is approximately 275 feet from the outer track of the rail loop. Therefore, no analysis was conducted to estimate vibration generated during project area operations.

2.1.2.3 Operations—Rail Traffic

The methods for analyzing noise and vibration impacts related to rail traffic to and from the project area are described in this subsection.

Noise

Operations-related rail traffic was estimated for four rail segments.

- BNSF Spur to the Reynolds Lead.
- Reynolds Lead from BNSF Spur to 3rd Avenue and California Way.
- Reynolds Lead from 3rd Avenue and California Way to midway between Industrial Way (State Route 432) and the Weyerhaeuser entrance.
- Reynolds Lead from midway between Industrial Way and Weyerhaeuser entrance to the project area.

The assumptions related to estimates of rail traffic are summarized in Tables 8 through 11.

Table 8. Average Freight Rail Traffic, Consists, and Speed—BNSF Spur to Reynolds Lead

	Number of Locomotives per Train	Number of Railcars per Train	Total Train Length (feet)[a]	Daily Average Train Traffic	Daily Total Train Passbys along BNSF Spur in Both Directions	Speed (mph)
Existing Traffic 2015	2.6	78	4,919	3.6	7.1	10
No-Action 2018	2.6	78	4,919	3.6	7.1	10
No-Action 2028[b]	2.6	78	4,919	3.6	7.1	10
Proposed Terminal Operation 2028[b]	4	125	6,844	8	16	10
Proposed Terminal Operation 2028[c]	4	125	6,844	8	16	20

Notes:
[a] Existing and No-Action Alternative locomotive length = 68.7 feet average; railcar length = 60.8 feet average; project locomotive length = 73 feet; project length = 53 feet
[b] Without track improvements
[c] With track improvements
mph = miles per hour

Table 9. Average Freight Schedule, Consists, and Speed—Reynolds Lead from BNSF Spur to 3rd Avenue and California Way

	Number of Locomotives per Train	Number of Railcars per Train	Total Train Length (feet)	Daily Average Trains	Daily Total Train Passbys along Reynolds Lead in Both Directions	Speed (mph)
Existing Traffic 2015	2	20.6	1,459	1.1	2.3	10
No-Action 2018	2	29.6	2,041	1.1	2.3	10
No-Action 2028[b]	2	29.8	2,052	2.0	4.0	10
No Action 2028[c]	2	29.8	2,052	2.0	4.0	20
Proposed Terminal Operation 2028[b]	4	125	6,844	8	16	10
Proposed Terminal Operation 2028[c]	4	125	6,844	8	16	20

Notes:
[a] Existing and No-Action Alternative locomotive length = 68.7 feet average; railcar length = 60.8 feet average; project locomotive length = 73 feet; project length = 53 feet
[b] Without track improvements
[c] With track improvements
mph = miles per hour

Table 10. Average Freight Schedule, Consists, and Speed—Reynolds Lead from Oregon Way and Industrial Way to Project Area

	Number of Locomotives per Train	Number of Railcars per Train	Total Train Length (feet)[a]	Daily Average Trains	Daily Total Train Passbys along Reynolds Lead in Both Directions	Speed (mph)
Existing Traffic 2015	2	20.6	1,441	1.1	2.3	10
No-Action 2018	2	29.6	2,024	1.1	2.3	10
No-Action 2028[e]	2	29.8	2,035	2.0	4.0	10
Proposed Terminal Operation 2028[b]	4	125	6,844	8	16	10
Proposed Terminal Operation 2028[c]	4	125	6,844	8	16	20

Notes:
[a] Existing and No-Action Alternative locomotive length = 68.7 feet average; railcar length = 60.8 feet average; project locomotive length = 73 feet; project length = 53 feet
[b] Without track improvements
[c] With track improvements
mph = miles per hour

Table 11. Freight Schedule, Consists, and Speed—Reynolds Lead from Midway between Industrial Way and Weyerhaeuser Entrance to Project Area

	Number of Locomotives per Train	Number of Railcars per Train	Total Train Length (feet)[a]	Daily Average Trains	Daily Total Train Passbys along Reynolds Lead in Both Directions	Speed (mph)
Existing Traffic 2015	2	20.6	1,441	1.14	2.3	10
No-Action 2018	2	29.6	2,024	1.14	2.3	10
No-Action 2028[b]	2	29.8	2,035	1.995	4.0	10
Proposed Terminal Operation 2028[b]	4	125	6,844	8	16	10
Proposed Terminal Operation 2028[c]	4	125	6,844	8	16	10

Notes:
[a] Existing and No-Action Alternative locomotive length = 68.7 feet average; railcar length = 60.8 feet average; project locomotive length = 73 feet; project length = 53 feet
[b] Without track improvements
[c] With track improvements
mph = miles per hour

For the 2028 Proposed Action and No-Action Alternative analysis, proposed track improvements would include additional track around the yard and a new power switch. These improvements would allow an increase in train speed across some of the crossings from 10 to 20 miles per hour. The analysis also considered without track improvements. For this study, a conservative analysis incorporated the maximum allowable train speed into the noise model for the full length of each segment.

Reference SELs (Federal Railroad Administration 2012) for trains are 97 dBA SEL for freight locomotives (90 feet long) and 100 dBA SEL for freight cars (2,000 feet long). These reference SELs are normalized to 1-second duration at 50 feet for a train traveling 40 miles per hour. These reference SELs represent at-grade ballast and tie track with continuously welded rail conditions, similar to the Reynolds Lead track construction.

There are five public at-grade crossings along the Reynolds Lead and BNSF Spur from the main line to the project area.

- Dike Road
- 3rd Avenue
- California Way
- Oregon Way
- Industrial Way

At Industrial Way, the rail line crosses from the north side to the south side of Industrial Way, approximately 1000 feet west of the crossing at Oregon Way. The crossings at 3rd Avenue and California Way are within approximately 500 feet of each other. In addition to these public crossings, there are three private at-grade crossings.

- Weyerhaeuser entrance west of Douglas Street
- Weyerhaeuser entrance at Washington Way
- 38th Avenue entrance to the Applicant's existing bulk product terminal

The noise model included the FRA provision that horns be sounded not fewer than 15 seconds or more than 20 seconds before the locomotive reaches a crossing. To be conservative, the analysis assumes locomotive horn sounding would begin 20 seconds before the locomotive reaches a crossing (or 600 feet at 20 miles per hour) with a source reference level of 113 dBA SEL, per the FRA guidelines (2012) for assessing train horn noise impacts in the vicinity of grade crossings.

Day-night sound level (L_{dn}) is the A-weighted L_{eq} for a 24-hour period with a 10-decibel penalty applied to noise levels between 10 p.m. and 7 a.m. To calculate the L_{dn} metric, it is necessary to define the number of trains that pass during daytime hours (7 a.m. to 10 p.m.) and nighttime hours (10 p.m. to 7 a.m.). The proposed coal export terminal would operate 24 hours a day and 7 days a week. For the L_{dn} calculations, it was assumed rail traffic would be evenly distributed; therefore, 62.5% of the daily train traffic was assumed to pass in the day and the remaining 37.5% was assumed to pass in the night.

The Cadna/A® model was used to predict noise levels generated by rail traffic along the BNSF Spur and Reynolds Line for existing conditions (2015), the No-Action Alternative in 2018 (No Action 2018), the No-Action Alternative in 2028 (No Action 2028), and operation of the Proposed Action in 2028 (Operations 2028). A summary of the model input is provided in Tables 12 through 15. The noise levels were predicted for trains running without sounding horns at crossings and for trains running with horns sounding at crossings.

Table 12. Cadna/A® Freight Train Noise Model Input—BNSF Spur to Reynolds Lead

		Existing 2015	No Action 2018	No Action 2028[c]	No Action 2028[d]	Terminal Operation 2028[c]	Terminal Operation 2028[d]	Peak Hour, 1 Roundtrip Train
Locomotives	Reference SEL, dBA[a]	97	97	97	97	97	97	97
	Reference length, feet	90	90	90	90	90	90	90
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	10	10	10	10	10	10	10
	Length per unit, feet	69	69	69	69	72	72	72
	Total number of daytime passbys[b]	12	12	12	12	40	40	8
	Total number of nighttime passbys[b]	7	7	7	7	24	24	n/a
Railcars	Reference SEL, dBA[a]	100	100	100	100	100	100	100
	Reference length, feet	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	20	20	20	20	20	20	20
	Length per unit, feet	62	66	66	66	52	52	52
	Total number of daytime passbys[b]	347	347	347	347	1,250	1,250	250
	Total number of nighttime passbys[b]	208	208	208	208	750	750	n/a
Horns	Reference SEL, dBA1	113	113	113	113	113	113	113
	Number of daytime passbys[b]	4	4	4	4	10	10	2
	Number of nighttime passbys[b]	3	3	3	3	6	6	-
	Train speed, mph	10	10	10	20	10	20	20

Notes:
[a] Reference SEL at distance of 50 feet
[b] Daytime: 7 a.m. to 10 p.m., Nighttime: 10 p.m. to 7 a.m.
[c] Without track improvements
[d] With track improvements
SEL = sound exposure level; dBA = A-weighted decibel; mph = miles per hour; K = speed coefficient; n/a = not applicable

Table 13. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from BNSF Spur to 3rd Avenue and California Way

		Existing 2015	No Action 2018	No Action 2028[c]	No Action 2028[d]	Terminal Operation 2028[c]	Terminal Operation 2028[d]	Peak Hour, 1 Roundtrip Train
Locomotives	Reference SEL, dBA[a]	97	97	97	97	97	97	97
	Reference length, feet	90	90	90	90	90	90	90
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	10	10	10	10	10	10	10
	Length per unit, feet	59	59	59	59	72	72	72
	Total number of daytime passbys[b]	3	3	5	5	40	40	8
	Total number of nighttime passbys[b]	2	2	3	3	24	24	n/a
Railcars	Reference SEL, dBA[a]	100	100	100	100	100	100	100
	Reference length, feet	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	20	20	20	20	20	20	20
	Length per unit, feet	66	66	66	66	52	52	52
	Total number of daytime passbys[b]	29	42	74	74	1,250	1,250	250
	Total number of nighttime passbys[b]	18	25	45	45	750	750	n/a
Horns	Reference SEL, dBA1	113	113	113	113	113	113	113
	Number of daytime passbys[b]	1	1	2	2	10	10	2
	Number of nighttime passbys[b]	1	1	1	1	6	6	-
	Train speed, mph	10	10	10	20	10	20	20

Notes:

[a] Reference SEL at distance of 50 feet

[b] Daytime: 7 a.m. to 10 p.m., Nighttime: 10 p.m. to 7 a.m.

[c] Without track improvements

[d] With track improvements

SEL = sound exposure level; dBA = A-weighted decibel; mph = miles per hour; K = speed coefficient; n/a = not applicable

Table 14. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from Oregon Way and Industrial to the Project Area

		Existing 2015	No Action 2018	No Action 2028[c]	No Action 2028[d]	Terminal Operation 2028[c]	Terminal Operation 2028[d]	Peak Hour, 1 Roundtrip Train
Locomotives	Reference SEL, dBA[a]	97	97	97	97	97	97	97
	Reference length, feet	90	90	90	90	90	90	90
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	10	10	10	10	10	10	10
	Length per unit, feet	49	49	49	49	72	72	72
	Total number of daytime passbys[b]	3	3	5	5	40	40	8
	Total number of nighttime passbys[b]	2	2	3	3	24	24	n/a
Railcars	Reference SEL, dBA[a]	100	100	100	100	100	100	100
	Reference length, feet	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	20	20	20	20	20	20	20
	Length per unit, feet	66	66	66	66	52	52	52
	Total number of daytime passbys[b]	29	42	74	74	1,250	1,250	250
	Total number of nighttime passbys[b]	18	25	45	45	750	750	n/a
Horns	Reference SEL, dBA1	113	113	113	113	113	113	113
	Number of daytime passbys[b]	1	1	2	2	10	10	2
	Number of nighttime passbys[b]	1	1	1	1	6	6	-
	Train speed, mph	10	10	10	20	10	20	20

Notes:

[a] Reference SEL at distance of 50 feet

[b] Daytime: 7 a.m. to 10 p.m., Nighttime: 10 p.m. to 7 a.m.

[c] Without track improvements

[d] With track improvements

SEL = sound exposure level; dBA = A-weighted decibel; mph = miles per hour; K = speed coefficient; n/a = not applicable

Table 15. Cadna/A® Freight Train Noise Model Input—Reynolds Lead from Midway between Industrial Way and Weyerhaeuser Entrance to Project Area

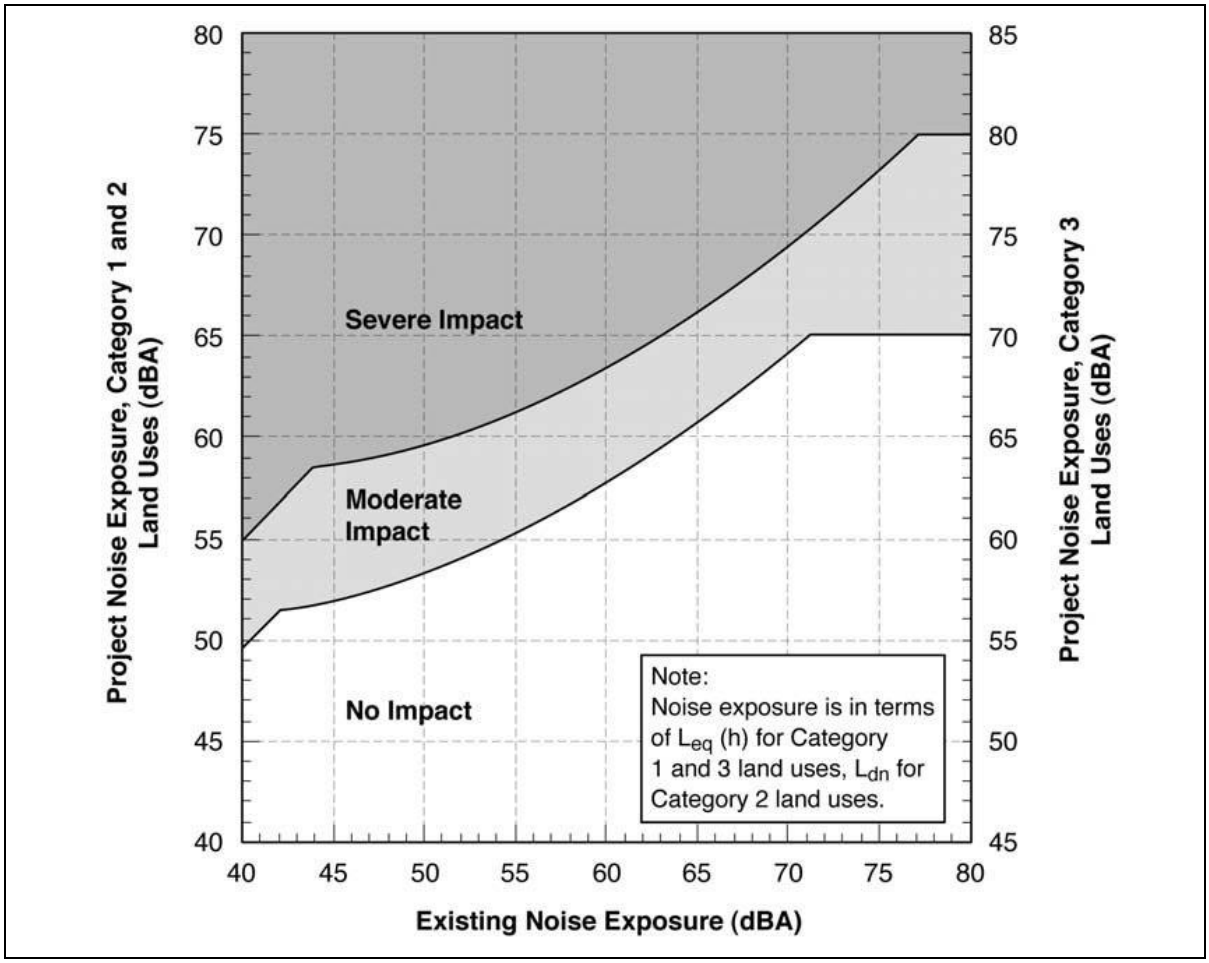
		Existing / Baseline	No Action 2018	No Action 2028[c]	No Action 2028[d]	Terminal Operation 2028[c]	Terminal Operation 2028[d]	Peak Hour, 1 Roundtrip Train
Locomotives	Reference SEL, dBA[a]	97	97	97	97	97	97	97
	Reference length, feet	90	90	90	90	90	90	90
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	10	10	10	10	10	10	10
	Length per unit, feet	49	49	49	49	72	72	72
	Total number of daytime passbys[b]	3	3	5	5	40	40	8
	Total number of nighttime passbys[b]	2	2	3	3	24	24	n/a
Railcars	Reference SEL, dBA[a]	100	100	100	100	100	100	100
	Reference length, feet	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Reference speed, mph	40	40	40	40	40	40	40
	Speed coefficient, K	20	20	20	20	20	20	20
	Length per unit, feet	66	66	66	66	52	52	52
	Total number of daytime passbys[b]	29	42	74	74	1,250	1,250	250
	Total number of nighttime passbys[b]	18	25	45	45	750	750	n/a
Horns	Reference SEL, dBA1	113	113	113	113	113	113	113
	Number of daytime passbys[b]	1	1	2	2	10	10	2
	Number of nighttime passbys[b]	1	1	1	1	6	6	-
	Train speed, mph	10	10	10	10	10	10	10

Notes:
[a] Reference SEL at distance of 50 feet
[b] Daytime: 7 a.m. to 10 p.m., Nighttime: 10 p.m. to 7 a.m.
[c] Without track improvements
[d] With track improvements
SEL = sound exposure level; dBA = A-weighted decibel; mph = miles per hour; K = speed coefficient; n/a not applicable

Railroad noise is exempt from Washington State noise limits. There are no criteria or guidelines for assessing noise impacts specifically from freight trains. However, the guidelines provided for assessing noise impacts from high-speed rail projects (Federal Railroad Administration 2012) and from transit projects (Federal Transit Administration 2006) are appropriate for assessing potential noise impacts from rail traffic for the Proposed Action. Per these guidelines, noise impacts are determined by the increase in ambient noise level (L_{dn} or peak hour L_{eq}, depending on the type of receptor) after the project is completed. The amount of increase that is acceptable depends on the existing ambient noise level.

The FTA/FRA guidance defines two levels of potential impact, *moderate impact* or *severe impact*. The level of impact is determined by the existing level of noise exposure and the change in noise exposure that would result from the Proposed Action using a sliding scale according to the land uses affected. Noise impacts are assessed by comparing the existing outdoor noise exposure with Proposed Action-related outdoor noise levels, as illustrated in Figure 6. The criterion for each degree of impact is based on a sliding scale that is dependent on the existing noise exposure and noise exposure with project-related trains. As the existing level of noise exposure increases, the additional noise exposure causing a moderate or severe impact decreases.

Figure 6. Noise Impact Criteria



Source: Federal Transit Administration 2006.

FTA/FRA guidance noise impact criteria are based on the land-use category of the receiving properties. The FTA/FRA guidance identifies three land-use categories for assessing potential noise impacts.[2]

- **Category 1.** Land where quiet is an essential element of intended purpose, such as outdoor amphitheaters, concert pavilions, and national historic landmarks with significant outdoor use.

[2] Noise exposure values are reported as hourly equivalent sound level ($L_{eq[h]}$) for Category 1 and 3 land uses, and L_{dn} for residential land uses (Category 2).

- **Category 2.** Residences and buildings where people normally sleep, including homes, hospitals, and hotels.
- **Category 3.** Institutional land uses (schools, places of worship, libraries) that are typically available during daytime and evening hours. Other uses in this category can include medical offices, conference rooms, recording studios, concert halls, cemeteries, monuments, museums, historical sites, parks, and recreational facilities.

The analysis considered two types of rail noise.

- *Wayside* noise refers to the combined effect of locomotive noise and car/wheel noise.
- *Horn* noise refers to the sound of locomotive warning horns, which are sounded at public at-grade road/rail crossings. Because horn sounding is intentionally loud to warn motorists of oncoming trains, the horn noise footprint is often larger than the wayside noise footprint.

To determine noise impact for the No-Action Alternative, the L_{dn} predicted for existing trains was decibel subtracted from the measured L_{dn} at each ambient survey location. This provided L_{dn} levels representative of sources other than trains. The L_{dn} predicted for the No-Action Alternative was then added to the result to provide the No-Action Alternative L_{dn} including all sources of noise. Any increases between the No-Action Alternative L_{dn} and the measured L_{dn} (which included noise from the existing trains) were compared to the FTA/FRA guidance to determine impact.

To determine noise impacts for the operation of the Proposed Action in 2028, the calculated L_{dn} for associated train traffic was added to the No Action 2028 L_{dn} calculated at each ambient survey location as described above. Any relative increases between the above summation and the No Action 2028 levels were compared to the FTA/FRA guidance. The above approach accounted for increases, if any, in rail traffic noise not associated with the Proposed Action by 2028.

At locations where potential noise impacts were indicated, additional nearby calculation points were added to the Cadna/A® model to determine the potential extent of the impacts. The model results and online satellite photography were then used to determine the number of potentially affected properties.

For noise-sensitive receptors that have predominantly daytime use only (e.g., churches, schools), noise impacts are determined from the peak hour L_{eq} per the FTA/FRA guidance. The existing L_{eq} was determined at each ambient survey location from the long-term survey data. The ambient survey data and the calculated L_{eq} were used to determine impacts in a similar fashion as for the L_{dn} at residences described above.

Statewide Analysis of Train Noise

Assessment of the potential noise impact from increased train traffic on BNSF and UP routes in Washington State to and from the project area was based on a potential increase in L_{dn}, which was calculated using the following equation.

$$L_{dn}\ \text{increase} = 10 \log \left(\frac{V_{total}}{V_{non\text{-}project}} \right)$$

Where:

- V_{total} is the total volume of train traffic, i.e., the average total number of trains per day, including Proposed Action-related trains and all other trains.

- $V_{non\text{-}project}$ is the number of trains per day that are not related to the Proposed Action.

The above equation is similar to the method used to calculate noise exposure based on train traffic volume per the FTA guidance manual for detailed noise analysis (Federal Transit Administration 2006). The above assumes that the distribution of the number of trains between daytime and nighttime does not change.

Vibration

Using generalized ground surface vibration curves (Federal Transit Administration 2006) and correcting for speed (a maximum 20 miles per hour with proposed track improvements), a vibration impact from Proposed Action-related train operations is unlikely at distances more than 60 feet from a railroad track for infrequent events (fewer than 30 passbys per day). The closest vibration-sensitive receptor (a residence) is approximately 180 feet away from the Reynolds Lead. There are no vibration sensitive receptors along the BNSF Spur. Therefore, no analysis was conducted to estimate vibration generated during rail operations.

2.1.2.4 Operations—Vessel Traffic

The methods for analyzing noise and vibration impacts related to vessel traffic to and from the project area are described in this subsection.

Noise

There are numerous sources of noise from stationary and moving vessels, summarized as follows.

- **Stationary vessels.** Vessels may be considered stationary noise sources while moored at the docks for loading or unloading. The primary sources of airborne noise from large commercial cargo vessels are the ventilation systems for the engine room and cargo hold. Localized noise may also emit from exhaust stacks or ventilation ducts on the sides of a ship. Noise levels produced by a large moored bulk container ship have been measured at about 65 dBA at a distance of 19 meters (62 feet) at both the engine room ventilation fans and the cargo hold fans (Badino et al. 2014). Using the above information as a reference, the L_{eq} at any distance from a stationary vessel was calculated using the following equation.

$$L_{eq_{(\text{stationary vessel})}} = 65 - 20\log\left(\frac{d}{62}\right)$$

Where d is the distance in feet between the receiver and the vessel. The above equation is based on the basic concept of spherical spreading from a point source of noise (i.e., 6 dB reduction per doubling of distance). A similar term is used in the FTA guidance manual for projecting noise during construction (Federal Transit Administration 2006).

- **Vessels under way.** Vessels may be considered slow moving, single sources of noise while under way in the river. For these vessels, the dominant noise source is engine noise transmitted through intake air vents and exhaust stacks. An analysis of noise from vessels under way estimated the L_{dn} from a moving ship, assuming existing self-propelled vessel traffic on the Columbia River with an average of 6.46 ships per day (U.S. Army Corps of Engineers 2011), half during daytime hours and half at night, passing the Port of Longview, Washington. At a perpendicular distance of 400 feet from the moving ship, the L_{dn} was estimated to be 45 dBA, well under the European Union Directive noise limit of 75 dBA at 25 meters for vessels under

way (URS Corporation 2014a). Using the above information as a reference, the L_{dn} at any perpendicular distance from the shipping lane with a specific volume of ship traffic was calculated using the following equation.

$$L_{dn_{\substack{(\text{vessels}\\ \text{under}\\ \text{way})}}} = 45 - 20\log\left(\frac{d}{400}\right) + 10\log\left(\frac{V}{6.46}\right)$$

Where:

- d is the perpendicular distance between the lane of ship traffic and the noise sensitive receiver.
- V is the volume of ship traffic, i.e., average total number of vessels per day.

The second term on the right-hand side of the above equation accounts for spherical spreading from a point source of noise as described for stationary vehicles above. The third term is similar to the method used to calculate noise exposure based on train traffic volume per FTA guidance for detailed noise analysis (Federal Transit Administration 2006).

- **Foghorns.** Vessels may sound their foghorns while under way in heavy fog. One such horn was heard and monitored during a site visit. The foghorn reached a maximum noise level of 60 dBA at the ship's point of closest approach to the measurement location (approximately 1,800 feet). This represents the highest foghorn sound level to which noise-sensitive receptors would be exposed. The L_{max} from foghorns at any perpendicular distance from the shipping lane was calculated using the following equation.

$$L_{max_{(\text{foghorn})}} = 60 - 20\log\left(\frac{d}{1800}\right)$$

Where d is the perpendicular distance in feet between the receiver and the shipping lane. The above equation accounts for spherical spreading from a point source of noise as described for stationary vehicles above.

Vibration

The vessels that would be used are similar to those which are already traveling on the Columbia River. There have been no documented cases of perceptible vibration on shore generated by ship traffic on the river. Therefore, no analysis was conducted to estimate vibration generated during vessel operations.

2.2 Existing Conditions

This section describes the existing noise conditions in the study area.

Figure 3 in Section 1.3, *Study Area*, illustrates the land uses in the study area. Figure 4 in Section 2.1, *Methods*, illustrates the sensitive receptors in the study area, including residential land uses. As shown in Figure 4, the closest noise-sensitive receptors to the project area and Reynolds Lead and BNSF Spur are residential land uses. These land uses are located north of the Reynolds Lead and Industrial Way (SR 432) between Oregon Way and Washington Way (a distance of approximately 1.5 miles along the Reynolds Lead). Residential land uses are also located across Mount Solo Road (SR 432) from the project area. Figures 7 through 10 are plots of the equal L_{dn} estimated for existing rail traffic along the Reynolds Lead and BNSF Spur based on the existing rail

traffic provided in the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017). The following subsections describe existing noise contours for all noise sources including train horns. The existing ambient noise levels formed the baseline against which the effects of the Proposed Action and No-Action Alternative were measured.

Figure 7. Existing Rail Noise Contours, BNSF Spur to Reynolds Lead, Including Train Horns

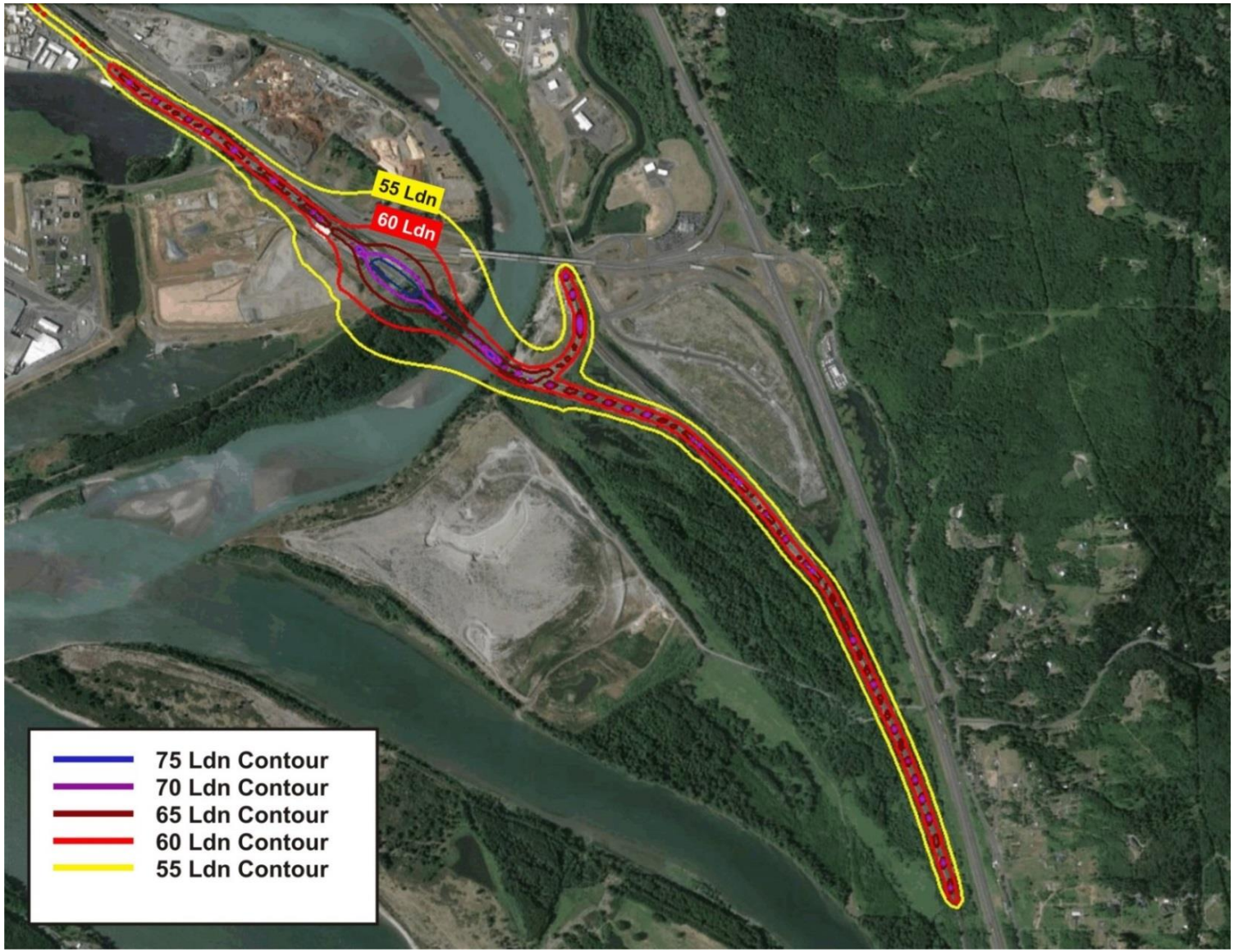


Figure 8. Existing Rail Noise Contours, Beginning of Reynolds Lead, Including Train Horns

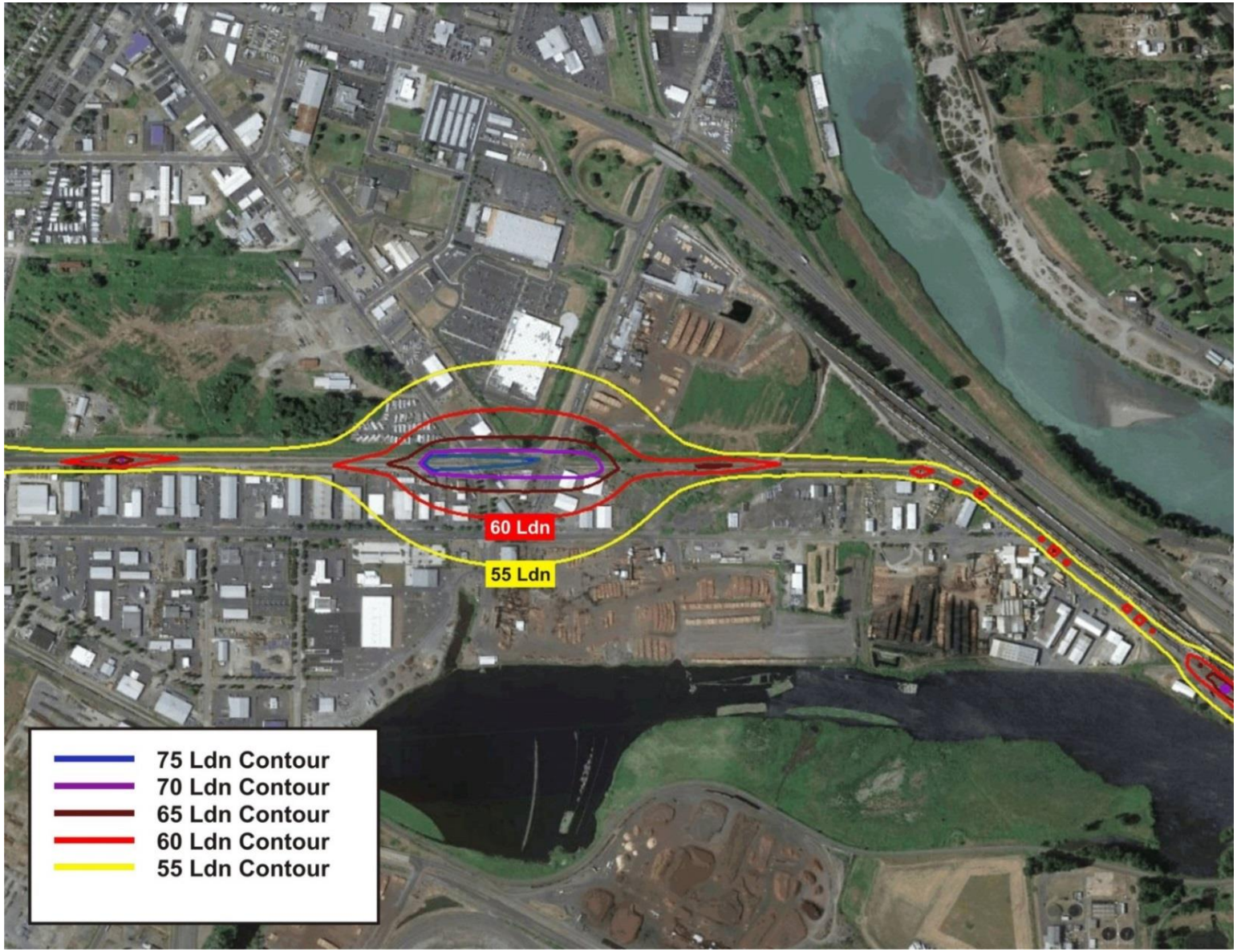
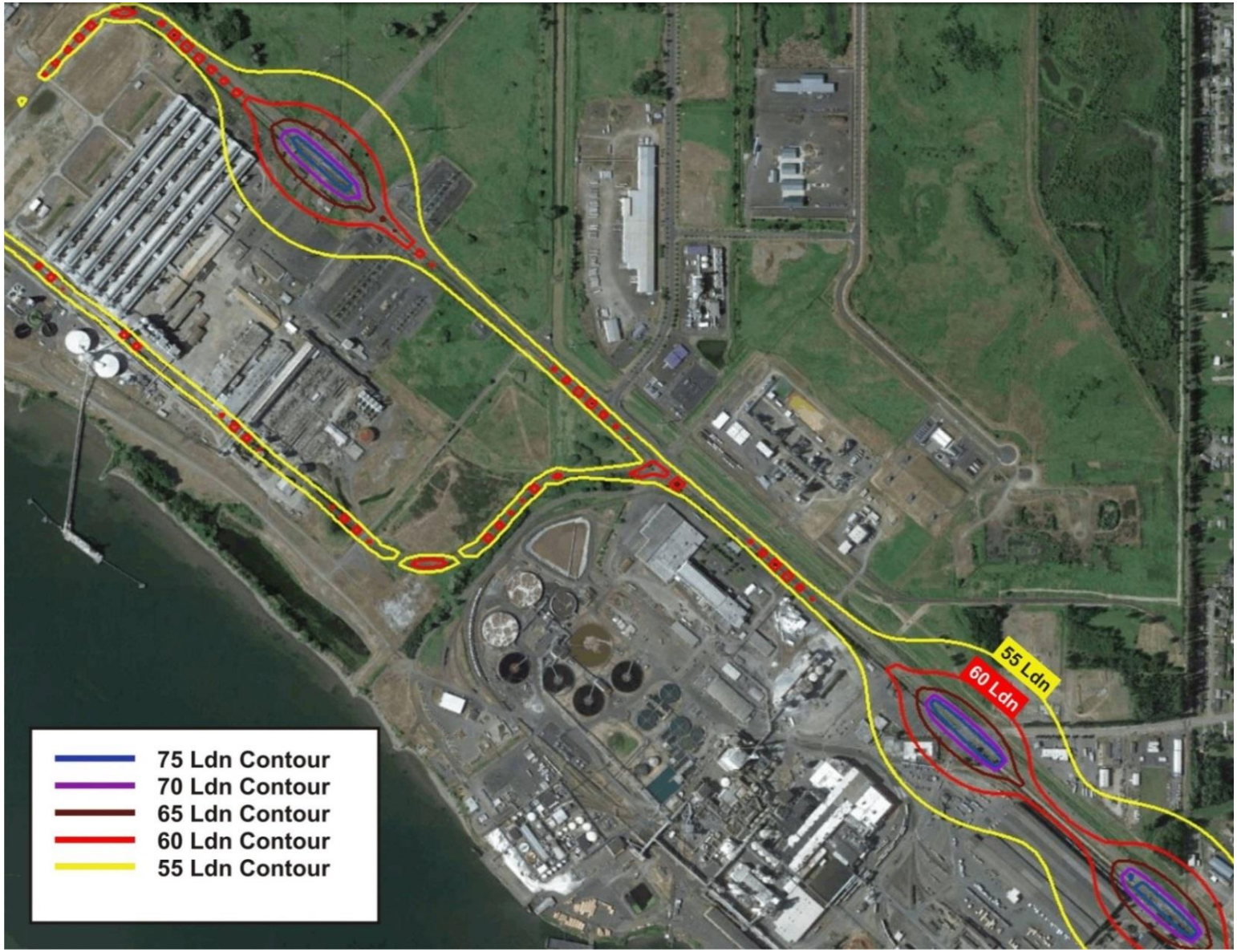


Figure 9. Existing Rail Noise Contours, Mid-Reynolds Lead, Including Train Horns



Figure 10. Existing Rail Noise Contours, End of Reynolds Lead, Including Train Horns



2.2.1 Proposed Action

A summary of primary noise sources at each long-term survey location is included in Table 16.

Table 16. Existing Environmental Noise Sources near the Project Area[a]

Location	Noise Sources
N1: 602 California Way	California Way and Industrial Way traffic Trains on Reynolds Lead Horizon Metals recycling center on California Way
N2: 111 15th Avenue	Industrial Way cars and trucks Trains on Reynolds Lead
N3: 221 Beech Street	Local traffic Industrial Way traffic Weyerhaeuser mill Trains on Reynolds Lead
N4: 875 34th Avenue	Local traffic and residential activity PNW Metal Recycling at Mint Farm
N5: 3600 Memorial Park	Local traffic PNW Metal Recycling at Mint Farm
N6: 420 Rutherglen Drive	Distant industrial at Mint Farm, Weyerhaeuser mill Port of Longview
N7: 4723 Mount Solo Road	Traffic on Mount Solo Road (mostly cars)
N8: 1719 Dorothy Avenue	Local traffic and residential activity PMW Metal Recycling at Mint Farm

Notes:
[a] As observed at long-term ambient noise survey locations.

A summary of daily noise descriptors (L_{dn}, community noise equivalent [CNEL], daytime L_{eq} and nighttime L_{eq}) for each day of measurements at all long-term locations is included in Table 17. The data in Table 17 indicate that the L_{dn} and CNEL values are generally within 1 decibel of each other, which is typical of environmental noise dominated by daytime human activity. The hourly L_{eq} for 6 or 7 days of measurement at locations N1 through N8 are plotted in Appendix A, *Existing Ambient Sound Pressure Level Survey Data*. The hourly statistical SPL for each 24-hour period of measurement and at all eight locations are also plotted in Appendix A.

Table 17. Daily Noise Measurements at Sources near the Project Area

Location	Date	L_{dn} (dBA)	CNEL (dBA)	Daytime L_{eq} (dBA)	Nighttime L_{eq} (dBA)
N1 602 California Way	Tue, Oct 28, 2014	75	75	72	68
	Wed, Oct 29, 2014	76	76	67	70
	Thu, Oct 30, 2014	78	78	68	71
	Fri, Oct 31, 2014	77	77	70	70
	Sat, Nov 1, 2014	72	72	64	66
	Sun, Nov 2, 2014	69	73	67	56
N2 111 15th Avenue	Tue, Nov 4, 2014	77	77	63	71
	Wed, Nov 5, 2014	72	72	60	66
	Thu, Nov 6, 2014	72	73	64	66
	Fri, Nov 7, 2014	67	67	60	61
	Sat, Nov 8, 2014	60	60	60	51
	Sun, Nov 9, 2014	63	63	64	53
	Mon, Nov 10, 2014	74	74	61	68
N3 221 Beech Street at Alder St.	Tue, Nov 4, 2014	72	72	68	65
	Wed, Nov 5, 2014	71	71	68	64
	Thu, Nov 6, 2014	71	71	68	64
	Fri, Nov 7, 2014	70	70	67	63
	Sat, Nov 8, 2014	67	67	64	59
	Sun, Nov 9, 2014	67	67	66	59
	Mon, Nov 10, 2014	70	71	67	63
N4 875 34th Avenue	Tue, Nov 4, 2014	67	67	56	61
	Wed, Nov 5, 2014	60	60	51	54
	Thu, Nov 6, 2014	63	63	58	57
	Fri, Nov 7, 2014	58	58	49	52
	Sat, Nov 8, 2014	60	60	60	51
	Sun, Nov 9, 2014	61	61	60	53
	Mon, Nov 10, 2014	58	58	49	52
N5 3600 Memorial Park Drive	Tue, Oct 28, 2014	71	71	66	64
	Wed, Oct 29, 2014	62	62	59	55
	Thu, Oct 30, 2014	66	66	61	59
	Fri, Oct 31, 2014	70	70	63	64
	Sat, Nov 1, 2014	59	60	57	52
	Sun, Nov 2, 2014	61	62	61	51
N6 420 Rutherglen Drive	Tue, Oct 28, 2014	65	65	55	59
	Wed, Oct 29, 2014	62	62	63	52
	Thu, Oct 30, 2014	62	62	56	55
	Fri, Oct 31, 2014	65	65	56	59
	Sat, Nov 1, 2014	52	52	49	44
	Sun, Nov 2, 2014	56	57	55	48

Location	Date	L_{dn} (dBA)	CNEL (dBA)	Daytime L_{eq} (dBA)	Nighttime L_{eq} (dBA)
N7 4723 Mount Solo Road	Tue, Oct 28, 2014	69	69	65	62
	Wed, Oct 29, 2014	68	68	65	60
	Thu, Oct 30, 2014	68	68	65	60
	Fri, Oct 31, 2014	69	69	65	62
	Sat, Nov 1, 2014	65	65	63	56
	Sun, Nov 2, 2014	63	64	62	55
N8 1719 Dorothy Avenue	Tue, Nov 4, 2014	64	64	56	57
	Wed, Nov 5, 2014	58	58	52	51
	Thu, Nov 6, 2014	63	64	64	53
	Fri, Nov 7, 2014	90[a]	90[a]	93[a]	49
	Sat, Nov 8, 2014	57	57	55	50
	Sun, Nov 9, 2014	88[a]	89[a]	60	81[a]
	Mon, Nov 10, 2014	86[a]	86[a]	53	81[a]

Notes:
[a] Includes anomalous high-level events, likely due to residential activity near microphone or heavy rainfall.
Ldn = day-night sound level; dBA = A-weighted decibels; CNEL = community noise equivalent; L_{eq} = equivalent sound level

A summary of the short-term ambient survey results (10-minute L_{eq}) is provided in Table 18. For the purpose of assessing potential noise impacts due to increased rail traffic associated with the Proposed Action along the Reynolds Lead, L_{dn} levels were estimated at each of the above short-term locations by comparing the 10-minute L_{eq} to the hourly L_{eq} detected at the nearest long-term measurement during the same time of day as the short-term measurement (the hourly L_{eq}s were averaged over the days included in the long-term measurements). The L_{dn} estimated at each short-term location is included in Table 18.

Table 18. Short-Term Noise Measurements at Sources near the Project Area

Location	Address (Longview, WA)	Date	Time	10-minute L_{eq} (dBA)	L_{dn}[a] (dBA)
N1s	605 California	10/27/14	4:28–4:38 p.m.	66	76
N2s-a	111 15th Avenue	11/3/14	3:06–3:16 p.m.	62	76
N2s-b	End of Sidewalk at 15th Ave at Pole	11/3/14	4:18–4:24 p.m.	59	73
N2s-c	125 feet north of N2s-b	11/3/14	4:27–4:34 p.m.	57	71
N2s-d	250 feet north of N2s-b	11/3/14	4:37–4:43 p.m.	56	70
N2s-e	375 feet north of N2s-b	11/3/14	4:46–4:53 p.m.	56	70
N3s-a	Beech Street & Alder Street	11/3/14	5:55–6:05 p.m.	65	71
N3s-b	100 feet north up Beech from N3s-a	11/3/14	7:15–7:24 p.m.	62	68
N3s-c	200 feet north up Beech from N3s-a	11/3/14	7:25–7:31 p.m.	57	63
N4s	875 34th Avenue	12/8/14	11:10–11:20 a.m.	51	63
N5s	3534 Memorial Park Drive	10/27/14	3:25–3:35 p.m.	55	66

Location	Address (Longview, WA)	Date	Time	10-minute L_{eq} (dBA)	L_{dn}[a] (dBA)
N6s	420 Rutherglen Drive	11/3/14	1:40–1:50 p.m.	50	62
N7s	4723 Mount Solo Road	10/27/14	5:11–5:21 p.m.	62	68
N8s	1719 Dorothy Avenue	12/8/14	10:37–10:47 a.m.	52	61
S1	3128 Louisiana Street	12/8/14	10:52–11:02 a.m.	51	71
S2	3011 Hemlock Street	12/8/14	11:35–11:45 a.m.	59	71
S3	2642 Field Street	12/8/14	11:54 a.m.–12:04 p.m.	56	68
S4	30th Ave median & Colorado Street	12/8/14	12:25–12:35 p.m.	61	73
S5	St Rose	12/8/14	3:32–3:42 p.m.	58	70
S6	540 23rd Avenue	12/8/14	12:58–1:08 p.m.	49	55
S7	645 15th Avenue	12/8/14	2:59–3:09 p.m.	63	77
S8	214 23rd Avenue	12/8/14	1:43–1:53 p.m.	61	67
S9	410 15th Avenue	12/8/14	1:19–1:29 p.m.	57	91
S10	Alder Street & Douglas Street	12/8/14	2:05–2:15 p.m.	63	69
S11	427 28th Avenue	12/8/14	12:40–12:50 p.m.	55	61
S12	Olive Way & Ocean Beach Hwy	12/8/14	2:32–2:42 p.m.	68	77

Notes:
[a] Estimated from the data collected at the nearest long-term survey location
L_{eq} = equivalent sound level; L_{dn} = day-night sound level; dBA = A-weighted decibel

Chapter 3
Impacts

This chapter describes the direct and indirect impacts related to noise and vibration that would result from construction and operation of the Proposed Action and the No-Action Alternative.

3.1 Proposed Action

Potential impacts that could occur in the study area as a result of construction and operation of the Proposed Action are described below.

3.1.1 Construction: Direct Impacts

Construction of the Proposed Action would result in the following direct impacts. These impacts would occur during the construction period in 2018.

Emit Noise during Construction

The maximum noise level the closest noise-sensitive receptor (the residence at 104 Bradford Place) during construction is predicted to be 83 dBA, which would occur during pile driving. While not a regulatory noise standard for construction noise, to provide context, this noise level would exceed FTA/FRA noise level criteria of 80 dBA for construction noise when pile activities occur within approximately 1,500 feet of this residence. Projected noise levels during construction are summarized in Appendix B, *Construction Noise Impact Analysis*, Table B-1.

Emit Pile-Driving Vibration during Construction

The maximum predicted vibration levels would occur during pile driving. The maximum predicted vibration velocity level at the closest vibration-sensitive receptor (the residence at 104 Bradford Place) would be 72 VdB during pile driving. While not a regulatory standard for vibration during construction, to provide context, this vibration level would not exceed FTA/FRA criteria for maximum allowable vibration due to construction at residences. Therefore, while construction of the Proposed Action would emit vibration from pile driving, the vibration would be not be substantive enough to have an adverse impact at the nearest residence.

3.1.2 Construction: Indirect Impacts

Construction of the Proposed Action would result in the following indirect impacts.

Emit Noise from Construction-Related Vehicle Traffic

A potential source of noise impacts related to construction would be automobile and truck traffic traveling to and from the project area, mainly on Industrial Way. As discussed in the SEPA Vehicle Transportation Technical Report (ICF and DKS Associates 2017), the average daily traffic (ADT) on Industrial Way approaches 10,000 trucks per day, of which approximately 7%

(or 700 trucks) are heavy trucks with three or more axles. In general, changes in a noise level of less than 3 dBA are not typically noticed by the human ear. A doubling of traffic volume (a 100% increase) would be required to increase the L_{dn} from road traffic by 3 dBA at the noise-sensitive receptors. Approximately 330 truck trips per day would be required for a 6-month period during the first year to support construction. The increase in truck traffic represents an increase of 3.3% in ADT for all vehicles on Industrial Way. The potential for noise impact would be less if truck traffic distributed off Industrial Way to other roadways in the study area. This increase in vehicular traffic would not result in a substantial change to the existing noise level. In addition, it would be temporary (during the peak year of construction) and would occur only during daytime hours. Therefore, no noise or vibration impact related to construction traffic would be anticipated.

Emit Noise from Construction-Related Rail Traffic

The Proposed Action would add approximately 1.3 train trips during the peak construction year if construction materials are delivered by rail. This level of rail activity would not cause noise levels to increase more than 3 L_{dn} (dBA). Proposed Action-related rail traffic would not result in noise impacts that would meet FTA/FRA criteria for a noise impact.

3.1.3 Operations: Direct Impacts

3.1.3.1 Noise

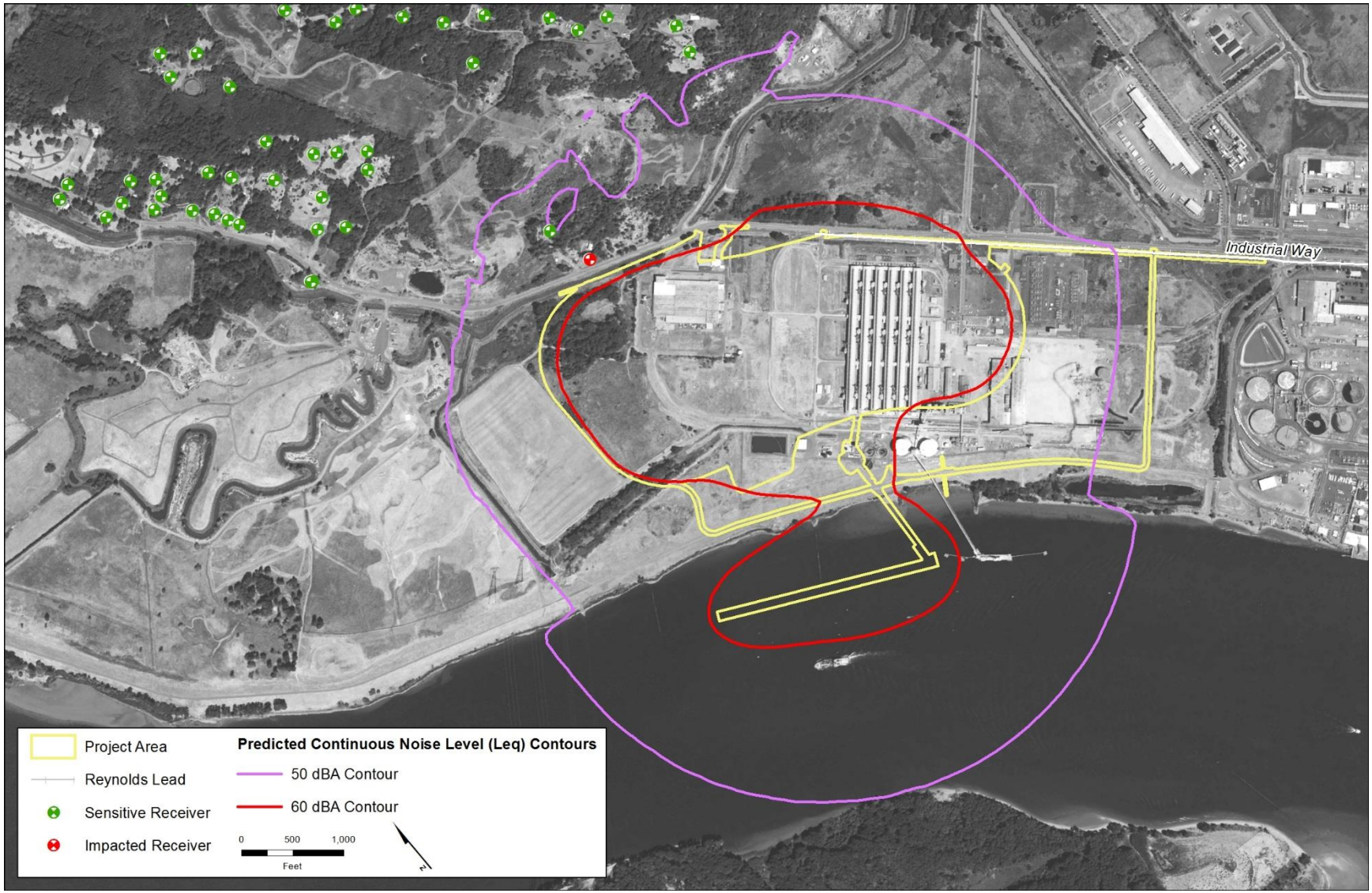
Operation of the Proposed Action would result in the following direct impacts. These impacts are estimated for full-scale operations in 2028.

Exceed Washington Administrative Code Maximum Environmental Noise Levels

Figure 11 indicates the predicted noise contours (L_{eq} of 50 dBA and 60 dBA) for operations at the project area. The analysis indicates noise from operation of the Proposed Action in 2028 would exceed the Washington State noise standard at a single residence (104 Bradford Place). As indicated in Figure 11, this residence is within the 50 dBA L_{eq} contour, which is the applicable Washington State limit for nighttime noise levels in a residential area when the noise is from an industrial source. The predicted L_{eq} at the residence is 55 dBA. This predicted noise level is likely comparable to the current nighttime noise level because the residence has a similar exposure to the Mount Solo Road traffic noise as the N7 noise monitor location. At N7, the nighttime noise levels ranged from 55 dBA on a Sunday night to 62 dBA on weeknights.

Another residence, just north of the Bradford Place residence, would be shielded by the topography of the land (Figure 11). The predicted L_{eq} at the second residence is 50 dBA and would not exceed the Washington State maximum environmental noise level at this location.

Figure 11. Predicted Continuous Noise Level (L_{eq}) Contours during Operations



3.1.3.2 Vibration

No significant sources of ground vibration would occur at the project area during operations and the closest vibration receptor (a residence) is too far away to be affected by vibration from trains on the rail loop. Therefore, no vibration impacts associated with operations at the project area would be anticipated.

3.1.4 Operations: Indirect Impacts

Figures 12 through 15 are plots of the equal L_{dn} noise levels in 2028 with the Proposed Action. All contours include the contribution of noise from train horns. Operation of the Proposed Action would result in the following indirect impacts. These impacts are estimated for full-scale operations in 2028.

Exceed FTA/FRA Guidelines for No Noise Impact

Operation of the Proposed Action would increase rail traffic-related noise along the Reynolds Lead and BNSF Spur. Train engineers are required by FRA rules to begin to sound locomotive horns at least 15 seconds and not more than 20 seconds in advance of public grade crossings.[3] In addition, LVSW operating rules require train engineers to sound locomotive horns at private grade crossings. These noise impacts would occur with or without the incorporation of proposed track improvements that would allow higher train speed through the grade crossings. In either case, train horns sounded near grade crossings would still be required and would be the dominant noise impact.

Noise from surface carriers engaged in interstate commerce by railroad is exempt from Washington state maximum permissible noise level regulations (WAC 173-60-040). As discussed above in Section 2.1.2.3, *Operations—Rail Traffic*, FTA and FRA have defined two levels of potential impact, *moderate impact* or *severe impact*. The level of impact is determined by the existing level of noise exposure and the change in noise exposure that would result from the Proposed Action. As the existing level of noise exposure increases, the additional noise exposure needed to cause a moderate or severe impact decreases. For this analysis, the existing level of noise exposure was determined by the ambient noise study results and the projected No-Action Alternative 2028 noise levels described in Section 2.1.2.4 *Operations—Rail Traffic*.

[3] The FRA horn noise regulations that require locomotive horn sounding at public at-grade crossings also include provisions for establishing quiet zones where horn sounding would not be required if adequate alternative safety measures are provided.

Figure 12. Noise Contours for Proposed Action 2028 Rail Traffic, BNSF Spur to Reynolds Lead, Including Train Horns

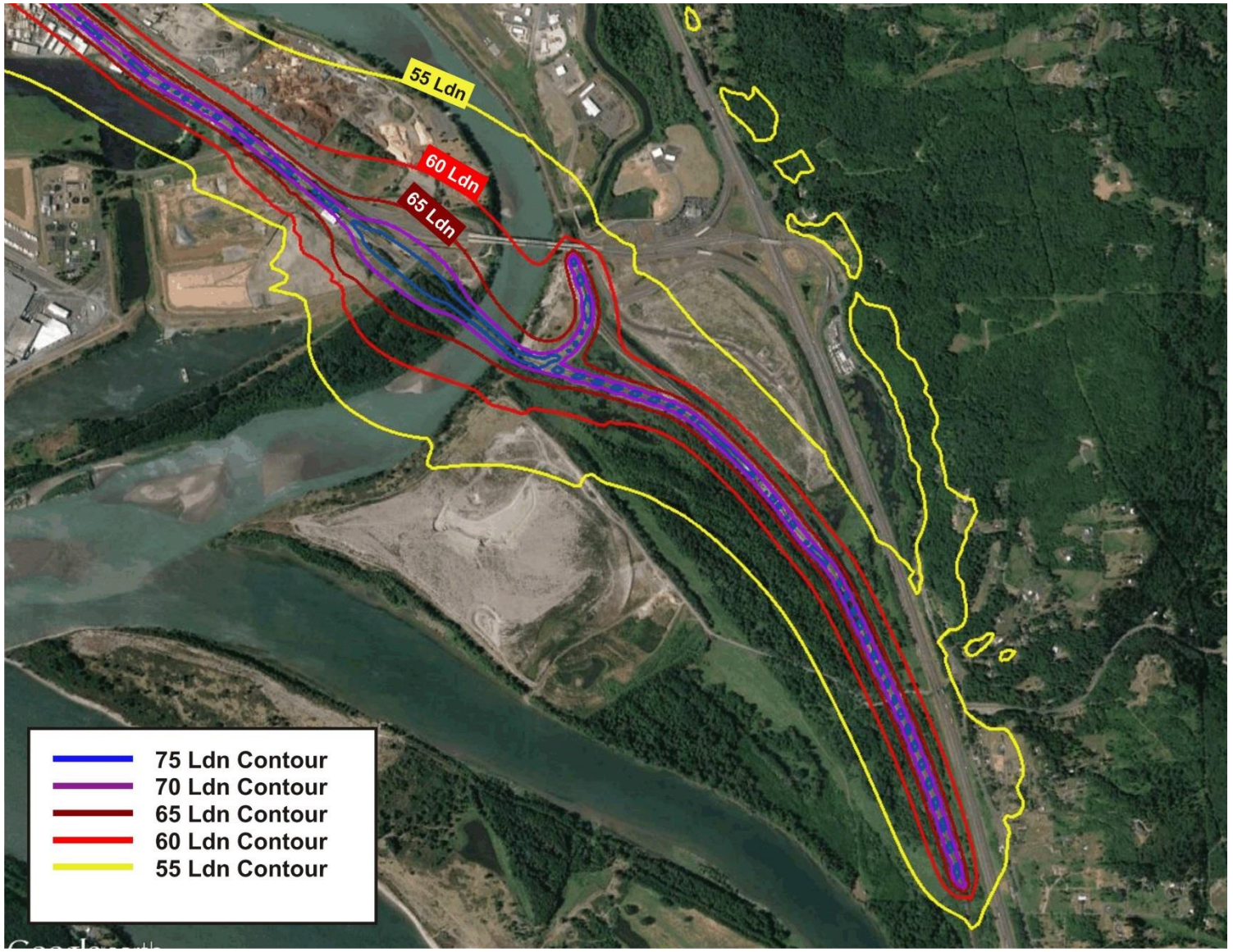


Figure 13. Noise Contours for Proposed Action 2028 Rail Traffic, Beginning of Reynolds Lead, Including Train Horns

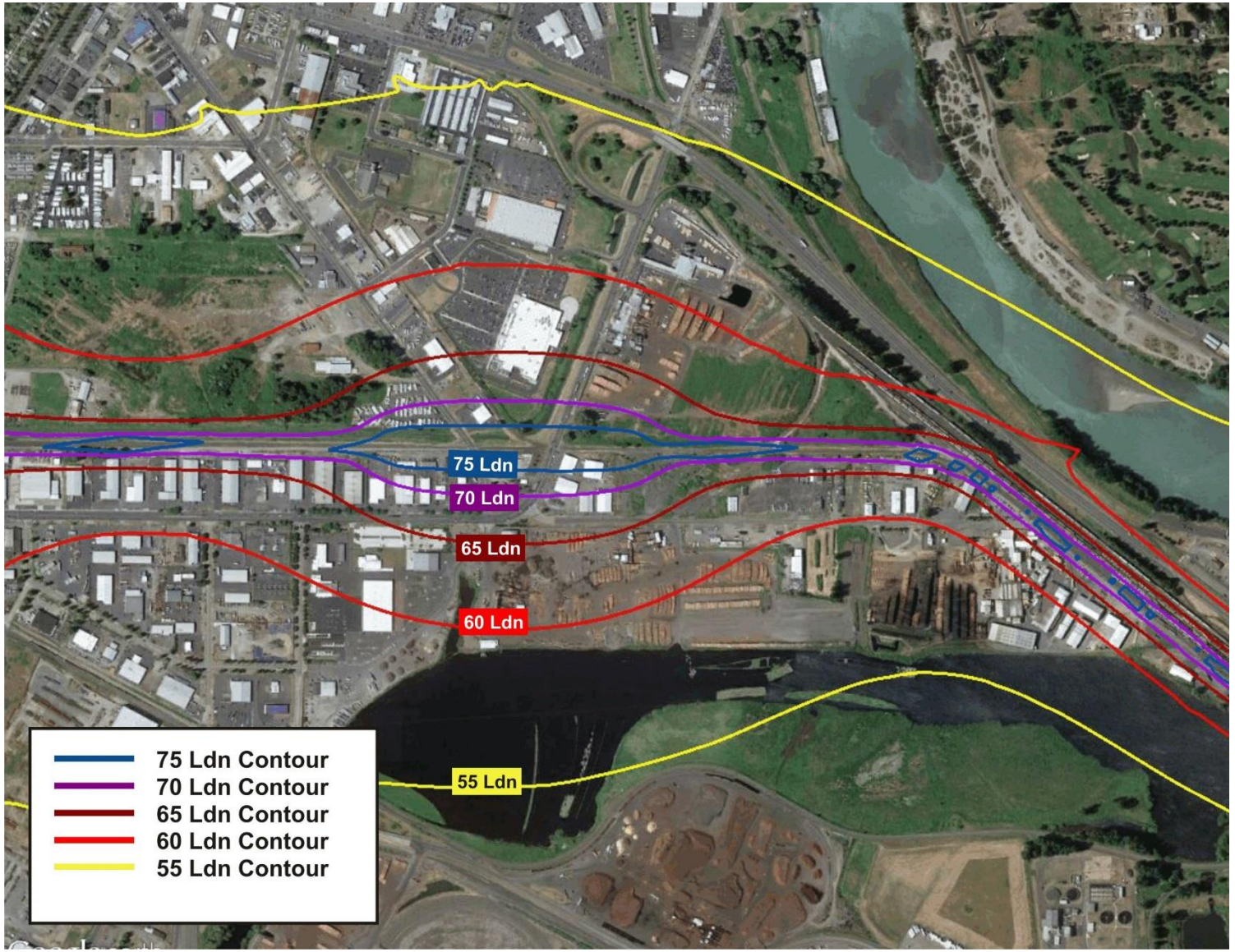


Figure 14. Noise Contours for Proposed Action 2028 Rail Traffic, Mid-Reynolds Lead, Including Train Horns

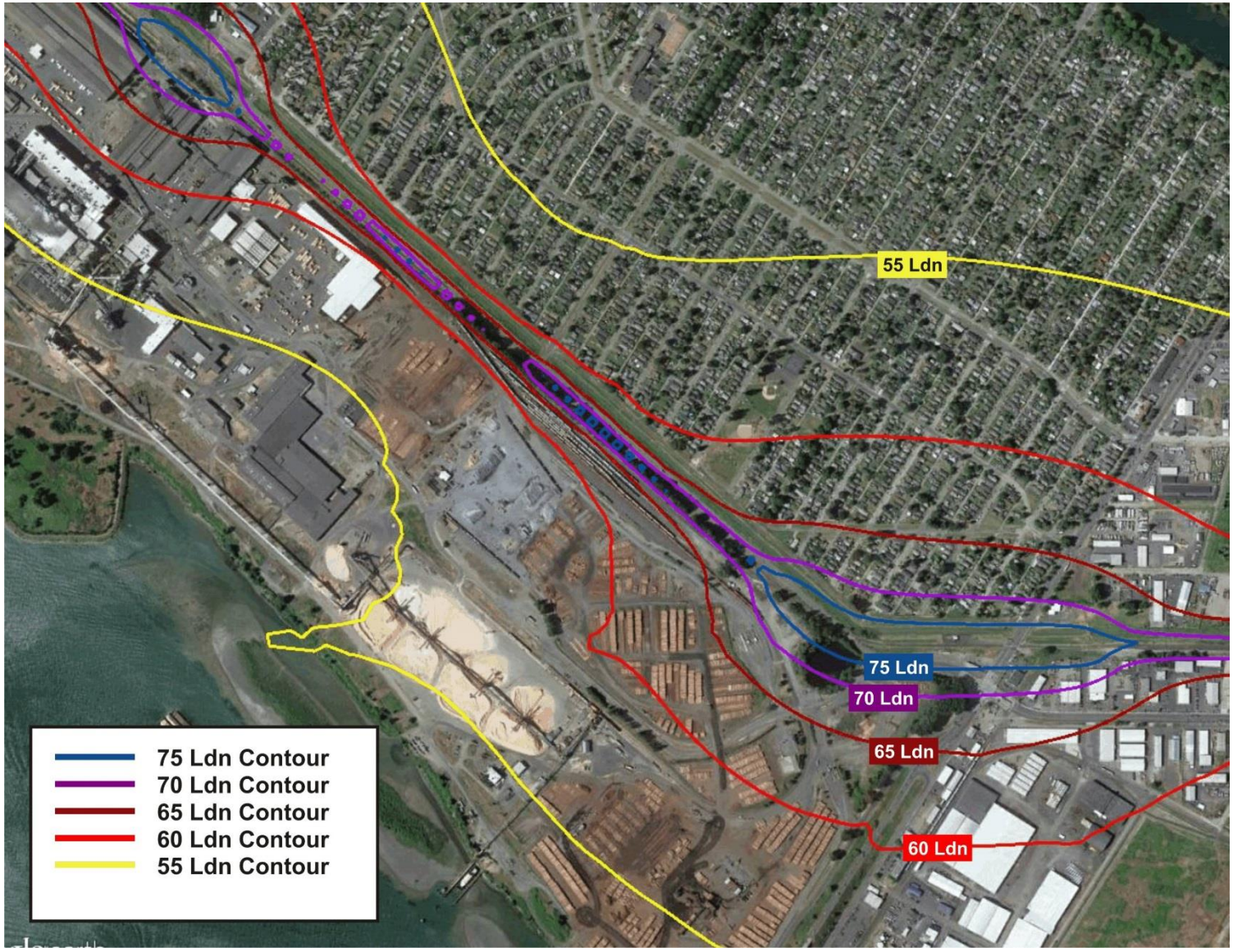


Figure 15. Noise Contours for Proposed Action 2028 Rail Traffic, End of Reynolds Lead, Including Train Horns

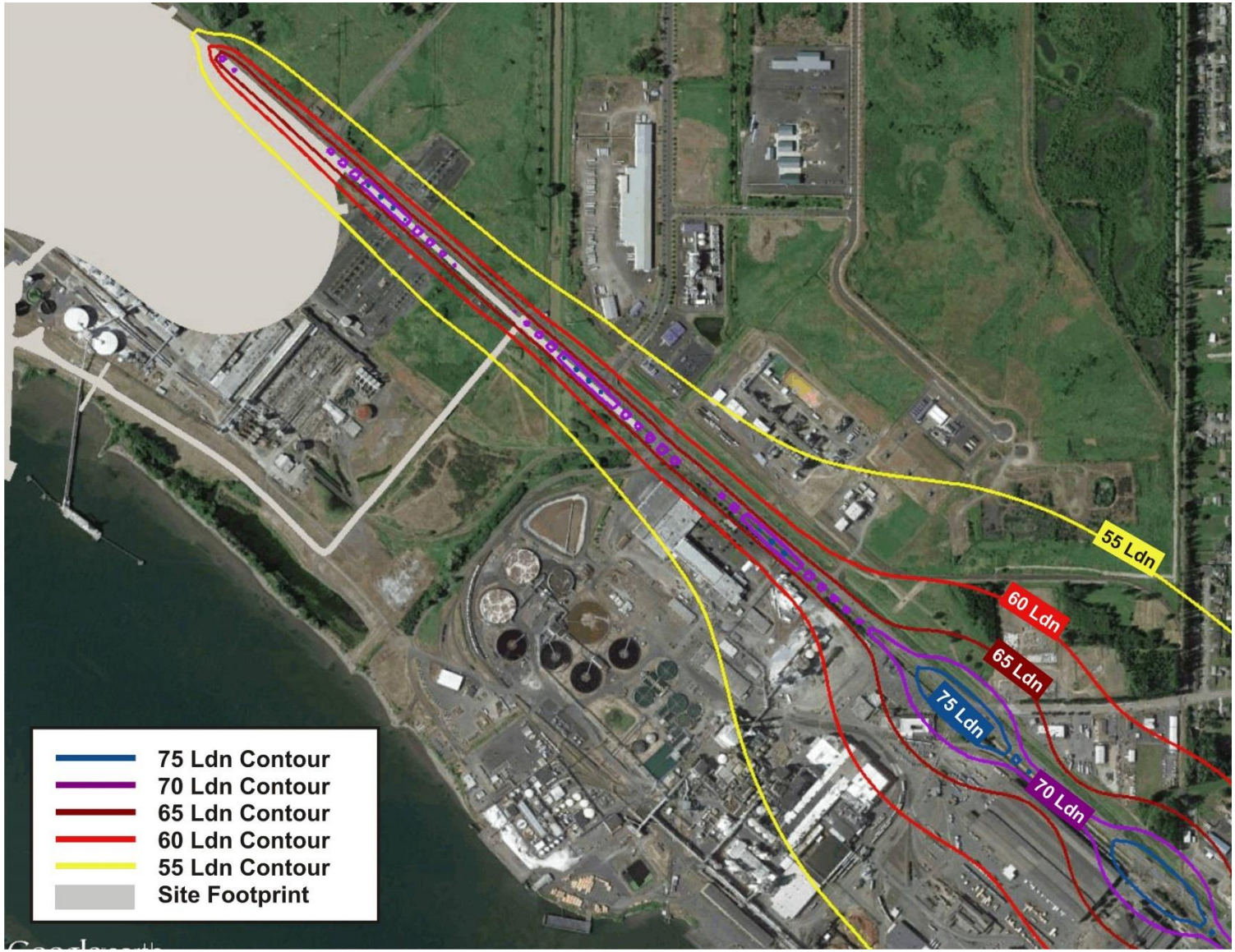


Table 19 lists the results of the noise impact assessment per the guidelines established by the FTA/FRA guidance at each ambient survey location for trains traveling to and from the project area. The table lists the following.

- L_{dn} existing noise exposure (based on the ambient noise study results presented in Chapter 2)
- L_{dn} predicted existing noise exposure
- L_{dn} levels representative of all other sources of noise not related to trains (decibel subtracted)
- L_{dn} predicted for the No-Action Alternative trains alone
- L_{dn} for total noise exposure (Proposed Action-related trains, plus No-Action Alternative trains, plus all other sources of noise not related to trains)
- Net increase in noise exposure
- The thresholds of moderate and severe impact

Impact determination at each survey location per the moderate and severe thresholds established according to FTA/FRA guidance. The net increase is determined relative to the estimated future ambient level (2028 No-Action Alternative trains plus all other sources of noise not related to trains).

Table 19. 2028 Noise Impact Assessment with Proposed Action-Related Rail Traffic

Location	Distance to Track (feet)	Measured Existing Level, L_{dn} (dBA)	Existing Trains, L_{dn} (dBA)	Ambient All Other Sources, L_{dn} (dBA)	No Action Trains, L_{dn} (dBA)	Project Trains, L_{dn} (dBA)	Total Noise, L_{dn} (dBA)	Increase (dBA)	MI Threshold	SI Threshold	Impact Type
N1, 602 California Way	171	76	64	76	65	74	78	2.1	0.3	2.1	**MI**
N1s, 605 California Way	146	76	66	76	66	75	79	2.5	0.3	2.1	**SI**
N2, 111 15th Avenue	212	73	65	72	65	73	76	2.9	0.6	2.4	**SI**
N2s-a, 111 15th Avenue	189	76	65	76	66	74	78	2.0	0.3	2.1	**MI**
N2s-b, 111 15th Avenue	212	73	65	72	65	73	76	2.9	0.6	2.4	**SI**
N2s-c, 139 15th Avenue	313	71	62	70	62	70	74	2.7	1.0	2.6	**SI**
N2s-d, 151 15th Avenue	416	70	60	70	60	69	72	2.3	1.0	2.8	**MI**
N2s-e, 163 15th Avenue	522	70	58	70	58	67	72	1.8	1.0	2.8	**MI**
N3, 221 Beech St at Alder	252	71	48	71	50	59	71	0.2	1.0	2.6	NI
N3s-a, 221-227 Beech St	256	71	49	71	50	59	71	0.3	1.0	2.6	NI
N3s-b, 221-227 Beech St	363	68	48	68	49	58	68	0.4	1.2	3.1	NI
N3s-c, 255 Beech Street	458	63	48	63	49	57	64	1.0	1.6	4.1	NI
N4, 875 34th Avenue	1838	63	46	63	46	54	64	0.5	1.6	4.1	NI
N4s, 875 34th Avenue	1838	63	46	63	46	54	64	0.5	1.6	4.1	NI
N5, 3600 Memorial Park Dr	4018	66	38	66	39	44	66	0.0	1.3	3.4	NI

Location	Distance to Track (feet)	Measured Existing Level, L_{dn} (dBA)	Existing Trains, L_{dn} (dBA)	Ambient All Other Sources, L_{dn} (dBA)	No Action Trains, L_{dn} (dBA)	Project Trains, L_{dn} (dBA)	Total Noise, L_{dn} (dBA)	Increase (dBA)	MI Threshold	SI Threshold	Impact Type
N5s, 3600 Memorial Park Dr	3936	66	38	66	39	44	66	0.0	1.3	3.4	NI
N6, 420 Rutherglen Dr	2933	62	45	62	46	49	62	0.2	1.7	4.4	NI
N6s, 420 Rutherglen Dr	2987	62	45	62	46	49	62	0.2	1.7	4.4	NI
N7, 4723 Mount Solo Road	4490	68	24	68	25	28	68	0.0	1.2	3.1	NI
N7s, 4723 Mount Solo Road	4491	68	24	68	25	28	68	0.0	1.2	3.1	NI
N8, 1719 Dorothy Avenue	4511	61	39	61	39	47	61	0.2	1.9	4.7	NI
N8s, 1715 Dorothy Avenue	4457	61	39	61	39	47	61	0.2	1.9	4.7	NI
S1, 3128 Louisiana Street	5443	71	38	71	38	46	71	0.0	1.0	2.6	NI
S2, 3007 Hemlock Street	4306	71	40	71	40	48	71	0.0	1.0	2.6	NI
S3, 2642 Field Street	4824	68	40	68	40	49	68	0.0	1.2	3.1	NI
S4, 30th Avenue	2595	73	43	73	43	52	73	0.0	0.6	2.4	NI
S5, St Rose de Viterbo	4426	70	40	70	41	49	70	0.0	1.0	2.8	NI
S6, 540 23rd Road	3207	55	43	55	43	52	57	1.8	3.1	7.1	NI
S7, 645 15th Avenue	3281	77	43	77	44	53	77	0.0	0.3	2.1	NI
S8, 23rd Ave/Industrial Way	252	67	50	67	51	61	68	0.9	1.2	3.2	NI
S9, 410 15th Avenue	1669	71	48	71	49	58	71	0.2	1.0	2.6	NI
S10, Alder Street	261	69	59	69	59	67	71	2.1	1.1	2.9	**MI**
S11, 427 28th Avenue	1970	61	44	61	44	53	62	0.6	1.9	4.7	NI
S12, 3297 Ocean Bch Hwy	5988	77	37	77	37	44	77	0.0	0.3	2.1	NI

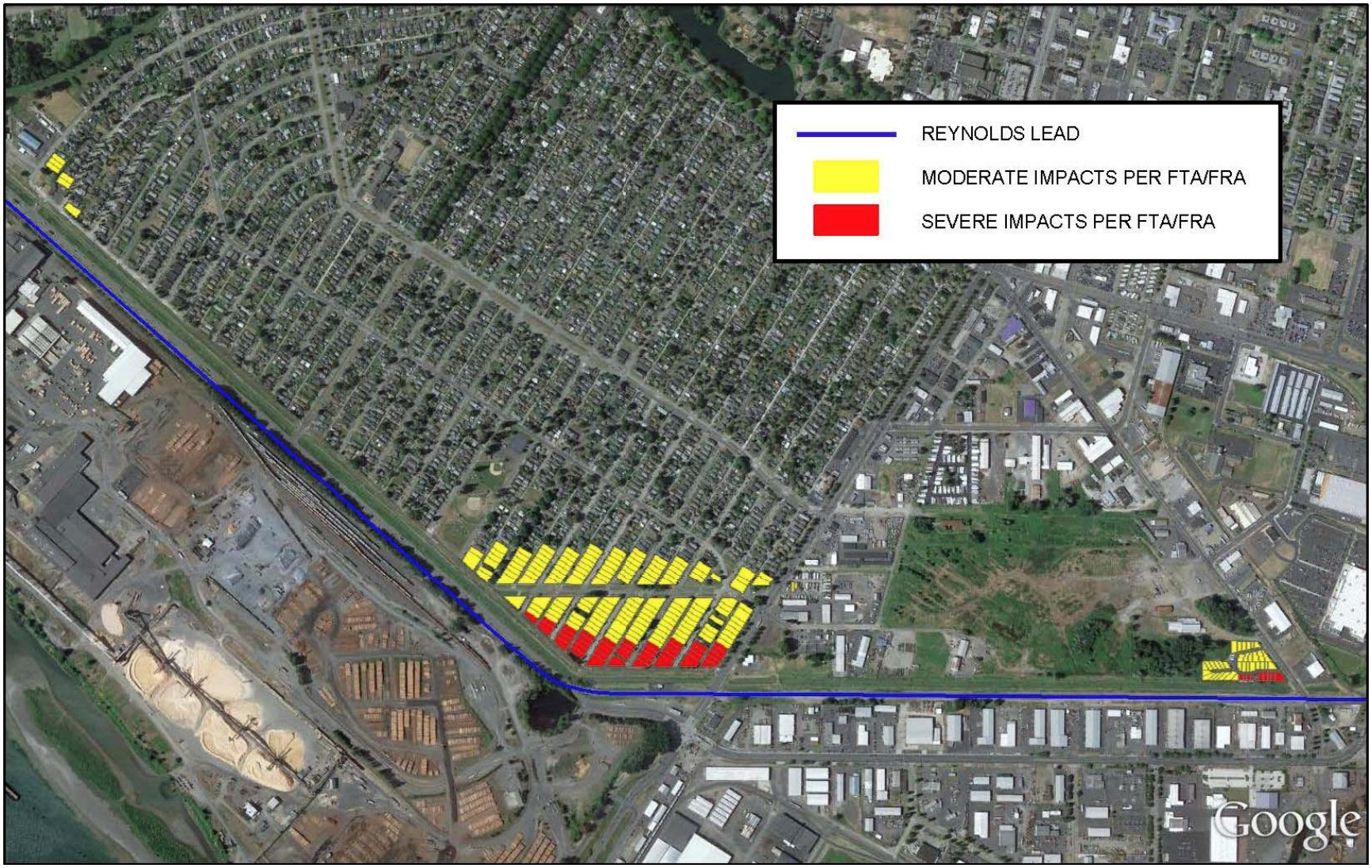
Notes:

[a] Impact determinations of moderate or severe are established per Federal Transit Administration (2006) and Federal Railroad Administration (2012) guidelines

L_{dn} = day-night equivalent; dBA = A-weighted decibel; NI = No Impact; MI = Moderate Impact; SI = Severe Impact

Figure 16 indicates the properties that would be expected to have moderate to severe noise impacts from Proposed Action-related rail traffic. The impacts would be the same with or without the track improvements because the train noise would be dominated by the locomotive horn sounding at the grade crossings. Increased noise from locomotive or car traffic alone (without horn sounding) would not result in noise impacts based on the FTA/FRA guidance. This applies for train speeds of 10 or 20 miles per hour.

Figure 16. Noise Impacts from Proposed Action-Related Rail Traffic



Note: If the Oregon Way/Industrial Way Intersection Project grade-separates the Oregon Way and Industrial Way crossings with the Reynolds Lead, all severe and moderate noise impacts near the Oregon Way and Industrial Way crossings would not occur.

Table 20 summarizes the number of affected noise-sensitive receptors predicted near each grade crossing. Some of the properties that may be affected are multifamily residences. The number of single residential units that could be affected at each multifamily residence was estimated using online satellite and street photography.

Table 20. Estimated Number of Noise-Sensitive Receptors with Noise Impacts from Proposed Action-Related Train Traffic

	Estimated Number of Receptors Impacted	
Reynolds Lead Crossing(s)	**Moderate Impact** [a]	**Severe Impact** [a]
3rd Avenue & California Way	34 single-family residences	10 single-family residences
Oregon Way & Industrial Way [b]	135 single-family residences 18 multi-family residences [c]	34 single-family residences 5 multi-family residences [e]
Private driveway at Weyerhaeuser (near Douglas Street & Washington Way)	4 single-family residences 2 multi-family residences [d]	0
Total Properties	**193**	**49**

Notes:

[a] Per FTA/FRA guidance as described in Section 2.1, *Methods*.

[b] If the Industrial Way/Oregon Way Intersection Project grade-separates the Oregon Way and Industrial Way crossings of the Reynolds Lead by 2028, the moderate and severe noise impacts at the Oregon Way and Industrial Way crossings would not occur because Proposed Action-related trains would not be required to sound horns for public safety at these crossings.

[c] Estimated 52 individual residences affected

[d] Estimated 4 individual residences affected

[e] Estimated 16 individual residences affected

The Industrial Way/Oregon Way Intersection Project led by Cowlitz County Public Works, currently in the preliminary design and NEPA and SEPA environmental compliance phase, is addressing traffic congestion, freight mobility, and safety issues at the Industrial Way/Oregon Way intersection. In January 2017, one of two design options advanced to analysis in the environmental impact statement would grade-separate the Reynolds Lead crossing with Oregon Way and Industrial Way, meaning trains would not be required to sound horns for public safety at the Oregon Way and Industrial Way crossings of the Reynolds Lead. As a result, all projected impacts from Proposed Action–related rail traffic noise near the crossings at Oregon Way and Industrial Way would be eliminated (i.e., those impacts indicated in the center of Figure 16), leaving only the potential impacts projected near the grade crossings at 3rd Avenue and California Way and the driveway near Douglas Street and Washington Way. Therefore, an estimated 40 receptors representing approximately 42 residences would be exposed to a moderate noise impact, and an estimated 10 receptors representing approximately 10 residences would be exposed to a severe noise impact with Proposed Action-related trains traveling on the Reynolds Lead.

Emit Noise and Vibration from Operations-Related Road Traffic

A potential source of noise impacts related to operations would be automobile and truck traffic traveling to and from the project area, mainly on Industrial Way. As discussed in the SEPA Vehicle Transportation Technical Report (ICF and DKS Associates 2017), the annual ADT on Industrial Way is projected be approximately 11,450 without the Proposed Action, and 12,100 with the Proposed Action, representing 5.7% increase in ADT for all vehicles. In general, changes in a noise level of less than 3 dBA are not typically noticed by the human ear. A doubling of traffic volume (i.e., a 100% increase) would be required to increase the L_{dn} from road traffic by 3 dBA at the noise sensitive receptors. The increase in vehicle traffic represents an increase of 5.6% in ADT for all vehicles on Industrial Way. This increase in vehicular traffic would not result in a material significant change in noise levels. Therefore, no noise or vibration impact related to operations traffic would be anticipated.

Emit Noise from Vessel Operations

For ships moored at the project area docks, the noise associated with stationary vessels is estimated to be 29 dBA at the closest noise-sensitive receptors on Mount Solo Road, approximately 3,800 feet away. This accounts only for sound attenuation with distance from the source. The estimated Proposed Action-related ship noise would be comparable to or less than ambient noise levels at this noise-sensitive receptor. Therefore, noise from river vessels associated with the Proposed Action would not cause a noise impact at noise-sensitive receptors.

For vessels under way, ship traffic is expected to be 70 ships per month during full operation in 2028. This corresponds to daily traffic of 4.66 ships per day. The noise-sensitive receptors on Barlow Point Road are all more than 400 feet from the edge of the Columbia River. Online satellite imagery indicates that a typical minimum distance between these receptors and vessels navigating the Columbia River would be about 1,600 feet. The corresponding L_{dn}, corrected to the 1,600-foot distance, would be 32 $L_{dn.}$ Other receptors are at substantially greater distances. The estimated noise exposure from Proposed Action-related ship traffic would be comparable or less than ambient noise levels at the noise sensitive receivers and would, therefore, not result in any noise impacts at the receivers. Table 21 summarizes the potential L_{dn} from Proposed Action 2028 vessel traffic at various perpendicular distances from the Columbia River navigational channel. The estimated noise exposure from Proposed Action-related ship traffic would be comparable to or less than ambient noise levels at noise sensitive receivers and is unlikely to cause noise impacts along the Columbia River.

Table 21. Potential Noise Exposure Levels from Vessel Traffic at Various Perpendicular Distances from the Columbia River Navigational Channel

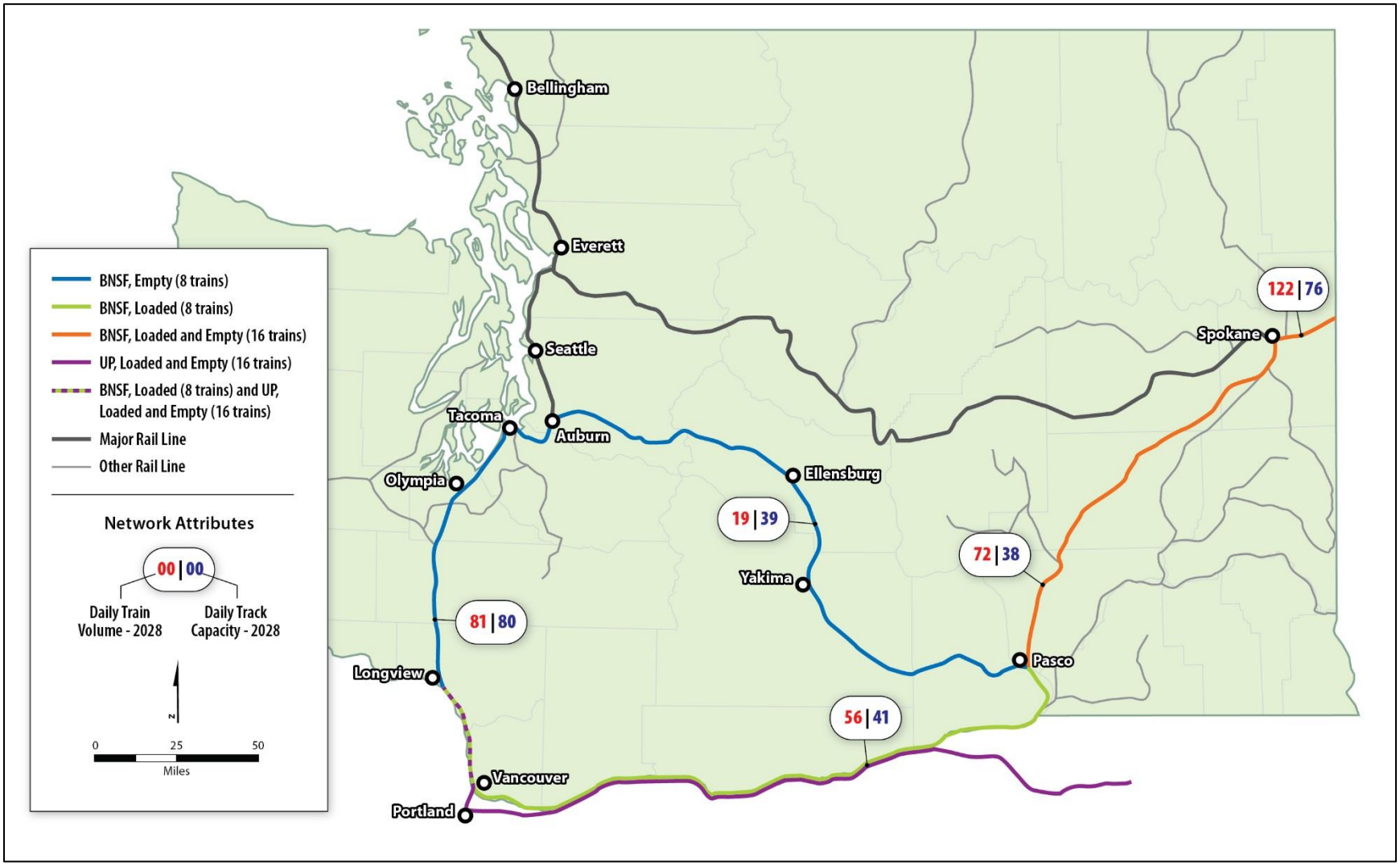
Distance (feet)	L_{dn}
400	44
600	40
800	38
1000	36
1200	34
1400	33
1600	32

With respect to foghorn noise, a foghorn was recorded from Barlow Road. It sounded for approximately 4 seconds every 2 minutes and achieved a maximum noise level of 60 dBA at its point of closest approach to the measurement location (approximately 1,800 feet). These noise levels represent the highest foghorn sound levels to which noise-sensitive receptors on Barlow Point Road are exposed. The levee that runs between the Columbia River and Barlow Point Road interrupts the line of sight between the receptors and vessels under way in the river, and therefore, serves to some extent as a sound barrier. The exception is the noise-sensitive receptor at 274 Barlow Point Road, which sits on top of the dike and has a clear view of the river. The next-closest receptors along Mount Solo Road are at a distance of 4,000 feet or more from the middle of the river. Noise from foghorns is infrequent and is not expected to cause any noise impacts at the noise-sensitive receivers.

Emit Noise from Rail Traffic on Main Line Routes in Washington State

At full operation, the coal export terminal would add 8 loaded and 8 empty trains per day (16 total trains per day) to the rail network in Washington State beyond Longview Junction. As described in the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017), the rail routes to the Longview area would are assumed the same as current BNSF and UP routes. Loaded trains would be expected to travel through Spokane and Pasco along BNSF's Fallbridge Subdivision to Vancouver, Washington. From there, loaded trains would likely move north on BNSF's Seattle Division main line north to Longview Junction. Empty trains would likely move from Longview Junction north on BNSF's Seattle Division main line to Auburn, Washington. From Auburn, trains would likely move east over BNSF's Stampede and Yakima Valley Subdivisions to Pasco, Washington. From Pasco, empty trains would move over the same route as the loaded trains. Figure 17 illustrates the route of loaded and empty coal trains with estimated 2028 daily track volume, including Proposed Action-related trains, and 2028 daily track capacity.

Figure 17. Washington Rail Network Daily Track Utilization, 2028 with Proposed Action-Related Train Traffic



Trains associated with the Proposed Action would travel at similar speeds as existing trains, and locomotives would sound horns consistent with existing practices. Therefore, the wayside and horn noise levels associated with any individual train trips would not change substantially compared to existing conditions. However, because the Proposed Action would result in more rail traffic, average noise levels would increase. Generally, in areas where existing noise levels are low (particularly at night), there is a greater likelihood that increased train traffic at night would result in more noticeable noise, particularly near grade crossings where trains are required to sound horns.

Table 22 provides a summary of existing train volumes, 2028 baseline train volumes, and 2028 train volumes with the Proposed Action. The table also provides a summary of the potential increase in train-related L_{dn} levels from the addition of Proposed Action-related trains relative to baseline conditions.

In general, changes in a noise level of less than 3 dBA are not typically noticed by the human ear. As indicated in Table 22, the potential increase from Proposed Action-related trains is less than 3 dBA on all routes to and from the project area. In most cases, the potential increase is less than 1 dBA, which is within the level of precision for acoustical measurements. Therefore, noise impacts from Proposed Action-related trains on the routes to and from Longview would not be expected.

Table 22. 2028 Rail Traffic Volumes on BNSF and UP Routes to and from Longview, WA and Potential Increase in Noise Exposure from Proposed Action-Related Trains

	Trains per Day			
Route	**Existing**	**Projected Baseline 2028**	**Projected Baseline 2028 with Proposed Action[a]**	**L_{dn} Increase**
Idaho/Washington State Line-Spokane	70	106	122	0.6
Spokane-Pasco	39	56	72	1.1
Pasco-Vancouver	34	48	56	0.7
Vancouver-Longview Junction	50	73	81	0.5
Longview Junction-Auburn	50	73	81	0.5
Auburn-Pasco	7	11	19	2.4

Notes:
[a] Includes No Action volume plus Operations 2028 volume.

There is the potential that all Proposed Action-related trains could travel through the Columbia River Gorge (16 trains per day). The analysis indicated that the increase in noise that would occur between Pasco and Longview Junction would range between 0.9 and 1.2 L_{dn}. Therefore, no adverse noise impacts from Proposed Action-related trains would be expected if all trains traveled via the Columbia River Gorge and Vancouver.

3.2 No-Action Alternative

Under the No Action Alternative, the Applicant would not construct the coal export terminal and noise and vibration impacts related to construction and operation of the coal export terminal would not occur. The Applicant would continue with current and future increased operations in the project area. The project area could be developed for other industrial uses including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement. The No-Action Alternative would require approximately 2 train trips per day on the BNSF Spur and Reynolds Lead.

The potential for changes in noise levels for 2 trains trips per day on the BNSF Spur and Reynolds Lead were analyzed for 2028. This assessment concluded that the net increases relative to the existing noise exposure from 2 train trips per day on the BNSF Spur and Reynolds Lead would not result in adverse noise impacts. No-Action Alternative construction-related and operation-related vehicle traffic volumes would be expected to be less than rail traffic under the Proposed Action, which would not result in an adverse noise impact. Therefore, No-Action Alternative-related construction and operations traffic would not result in an adverse noise impact. The No-Action Alternative would not cause vibration impacts because the closest receptors are too far away to experience significant vibration generated by the trains on the Reynolds Lead and BNSF Spur.

Figures 18 through 21 are plots of the equal L_{dn} noise levels from rail traffic related to the No-Action Alternative in 2028.

Figure 18. Noise Contours for No-Action Alternative 2028 Rail Traffic, BNSF Spur to Reynolds Lead, Including Train Horns

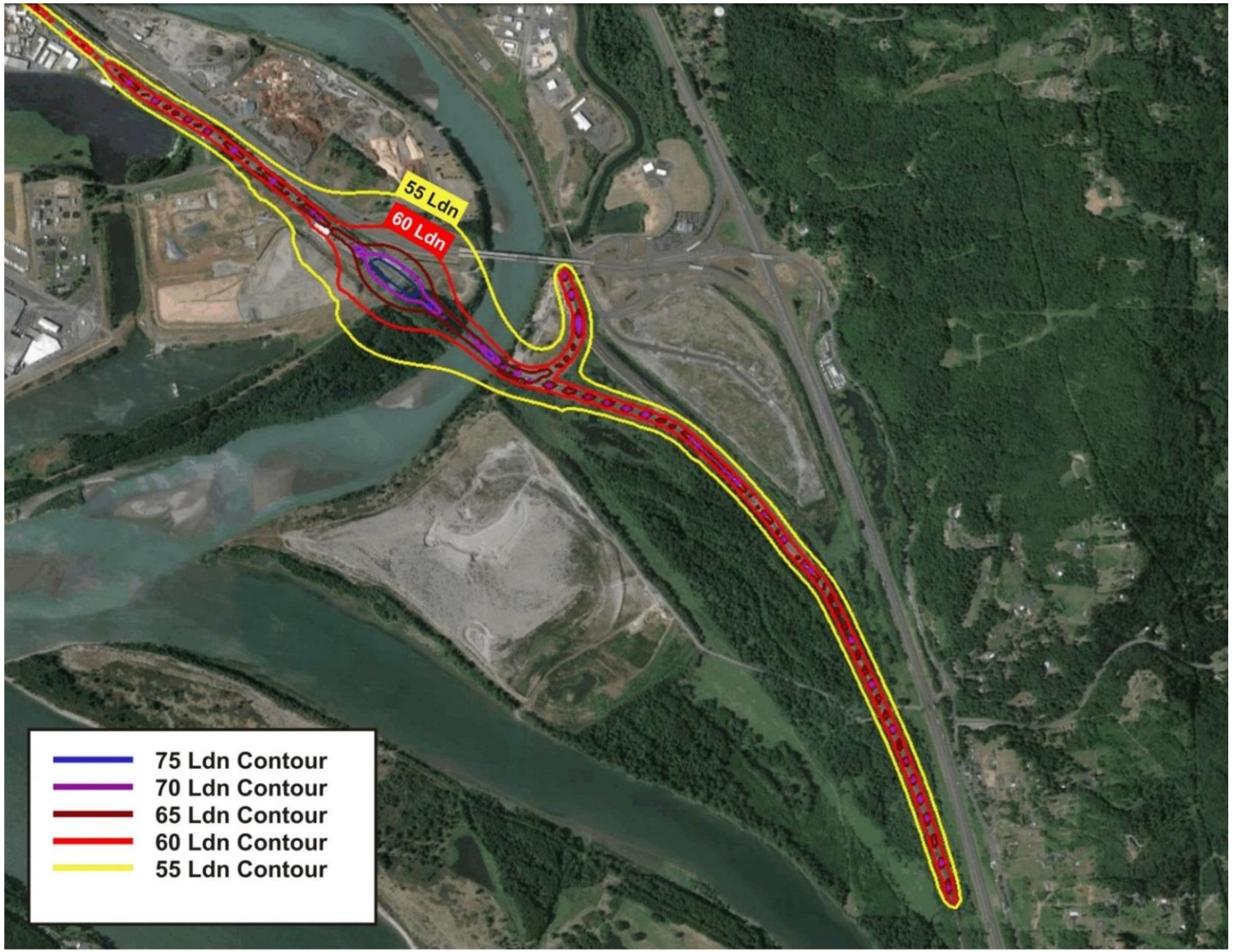


Figure 19. Noise Contours for No-Action Alternative 2028 Rail Traffic, Beginning of Reynolds Lead, Including Train Horns

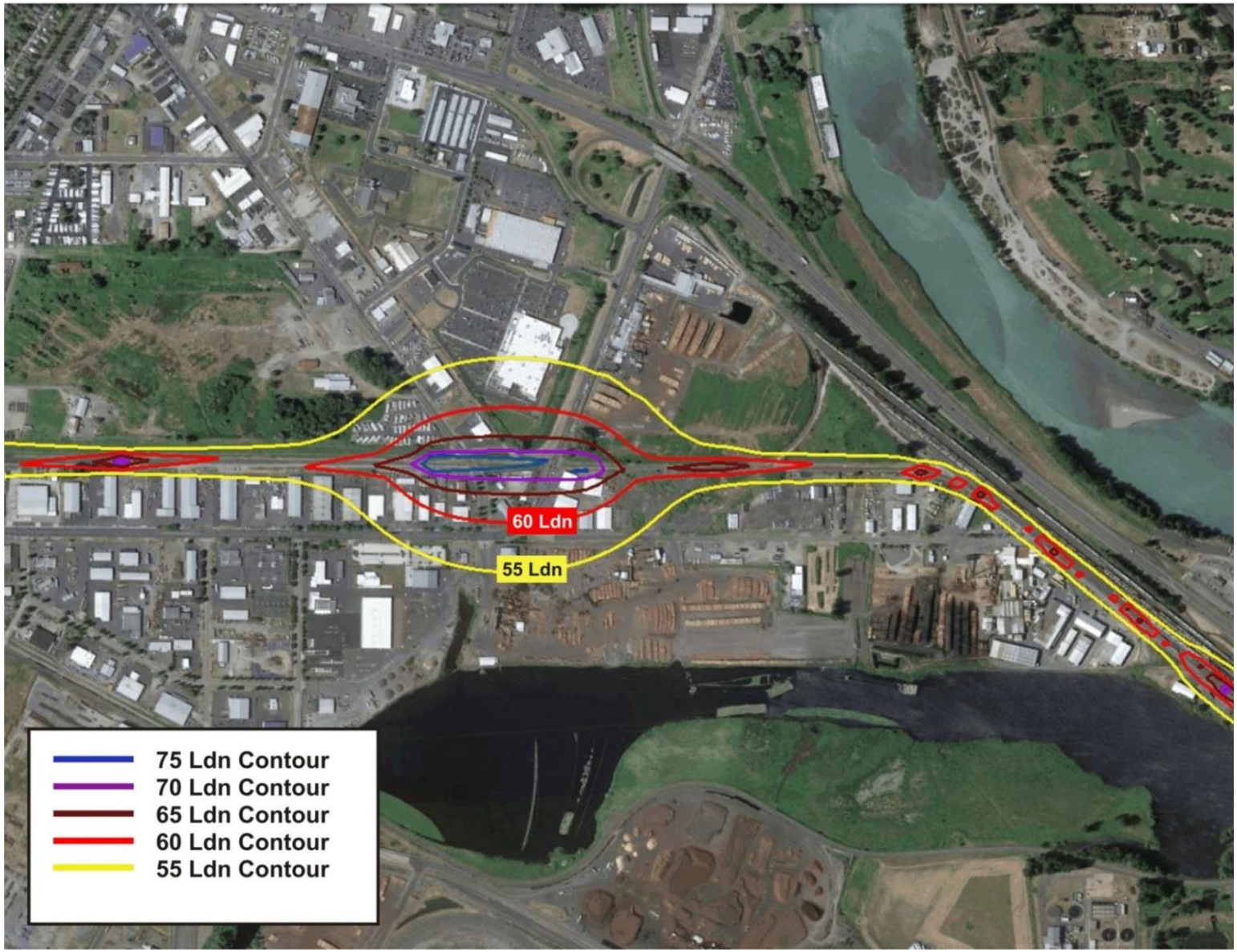


Figure 20. Noise Contours for No-Action Alternative 2028 Rail Traffic, Mid-Reynolds Lead, Including Train Horns



Figure 21. Noise Contours for No-Action Alternative 2028 Rail Traffic, End of Reynolds Lead, Including Train Horns

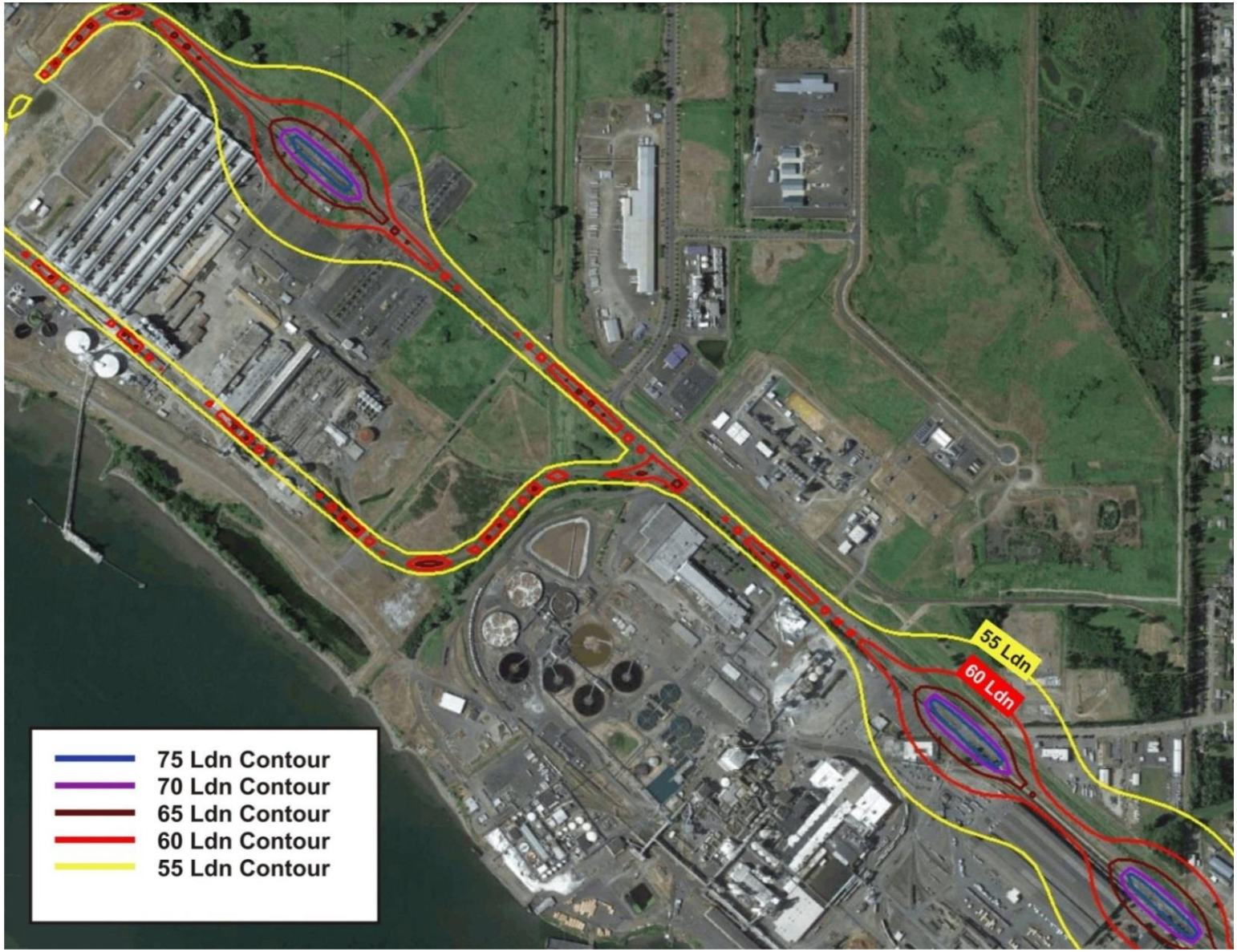


Table 23 lists the results of the noise impact assessment per the guidelines established by the FTA/FRA guidance at each ambient survey location. The table illustrates the net increase relative to the existing noise exposure based on the ambient noise study results.

Table 23. Noise Impact Assessment for No-Action Alternative, 2028 Rail Traffic

Location	Distance to Track (feet)	Measured Existing Level, L_{dn} (dBA)	Existing Trains, L_{dn} (dBA)	Ambient All Other Sources, L_{dn} (dBA)	No Action Trains, L_{dn} (dBA)	Project Trains, L_{dn} (dBA)	Total Noise, L_{dn} (dBA)	Increase (dBA)	MI Threshold[a]	SI Threshold[a]	Impact Type
N1, 602 California Way	171	76	64	76	65	n/a	76	0.0	0.3	2.1	NI
N1s, 605 California Way	146	76	66	76	66	n/a	76	0.0	0.3	2.1	NI
N2, 111 15th Avenue	212	73	65	72	65	n/a	73	0.1	0.6	2.4	NI
N2s-a, 111 15th Avenue	189	76	65	76	66	n/a	76	0.0	0.3	2.1	NI
N2s-b, 111 15th Avenue	212	73	65	72	65	n/a	73	0.1	0.6	2.4	NI
N2s-c, 139 15th Avenue	313	71	62	70	62	n/a	71	0.1	1.0	2.6	NI
N2s-d, 151 15th Avenue	416	70	60	70	60	n/a	70	0.0	1.0	2.8	NI
N2s-e, 163 15th Avenue	522	70	58	70	58	n/a	70	0.0	1.0	2.8	NI
N3, 221 Beech St at Alder	252	71	48	71	50	n/a	71	0.0	1.0	2.6	NI
N3s-a, 221-227 Beech St	256	71	49	71	50	n/a	71	0.0	1.0	2.6	NI
N3s-b, 221-227 Beech St	363	68	48	68	49	n/a	68	0.0	1.2	3.1	NI
N3s-c, 255 Beech Street	458	63	48	63	49	n/a	63	0.0	1.6	4.1	NI
N4, 875 34th Avenue	1838	63	46	63	46	n/a	63	0.0	1.6	4.1	NI
N4s, 875 34th Avenue	1838	63	46	63	46	n/a	63	0.0	1.6	4.1	NI
N5, 3600 Memorial Park Dr	4018	66	38	66	39	n/a	66	0.0	1.3	3.4	NI
N5s, 3600 Memorial Park Dr	3936	66	38	66	39	n/a	66	0.0	1.3	3.4	NI
N6, 420 Rutherglen Dr	2933	62	45	62	46	n/a	62	0.0	1.7	4.4	NI
N6s, 420 Rutherglen Dr	2987	62	45	62	46	n/a	62	0.0	1.7	4.4	NI
N7, 4723 Mount Solo Road	4490	68	24	68	25	n/a	68	0.0	1.2	3.1	NI
N7s, 4723 Mount Solo Road	4491	68	24	68	25	n/a	68	0.0	1.2	3.1	NI
N8, 1719 Dorothy Avenue	4511	61	39	61	39	n/a	61	0.0	1.9	4.7	NI
N8s, 1715 Dorothy Avenue	4457	61	39	61	39	n/a	61	0.0	1.9	4.7	NI
S1, 3128 Louisiana Street	5443	71	38	71	38	n/a	71	0.0	1.0	2.6	NI
S2, 3007 Hemlock Street	4306	71	40	71	40	n/a	71	0.0	1.0	2.6	NI
S3, 2642 Field Street	4824	68	40	68	40	n/a	68	0.0	1.2	3.1	NI

Location	Distance to Track (feet)	Measured Existing Level, L_{dn} (dBA)	Existing Trains, L_{dn} (dBA)	Ambient All Other Sources, L_{dn} (dBA)	No Action Trains, L_{dn} (dBA)	Project Trains, L_{dn} (dBA)	Total Noise, L_{dn} (dBA)	Increase (dBA)	MI Threshold[a]	SI Threshold[a]	Impact Type
S4, 30th Avenue	2595	73	43	73	43	n/a	73	0.0	0.6	2.4	NI
S5, St Rose de Viterbo	4426	70	40	70	41	n/a	70	0.0	1.0	2.8	NI
S6, 540 23rd Road	3207	55	43	55	43	n/a	55	0.0	3.2	7.1	NI
S7, 645 15th Avenue	3281	77	43	77	44	n/a	77	0.0	0.3	2.0	NI
S8, 23rd Ave/Industrial Way	252	67	50	67	51	n/a	67	0.0	1.2	3.2	NI
S9, 410 15th Avenue	1669	71	48	71	49	n/a	71	0.0	1.0	2.6	NI
S10, Alder Street	261	69	59	69	59	n/a	69	0.0	1.1	2.9	NI
S11, 427 28th Avenue	1970	61	44	61	44	n/a	61	0.0	1.9	4.7	NI
S12, 3297 Ocean Bch Hwy	5988	77	37	77	37	n/a	77	0.0	0.3	2.0	NI

Notes:

[a] Impact determinations of moderate or severe are established per Federal Transit Administration (2006) and Federal Railroad Administration (2012) guidelines

L_{dn} = day-night equivalent; dBA = A-weighted decibel; NI = No Impact; MI = Moderate Impact; SI = Severe Impact

Chapter 4
Required Permits

No permits specific to noise or vibration would be required for construction and operation of the Proposed Action.

Chapter 5
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Appendix A

Existing Ambient Sound Pressure Level Survey Data

Appendix A
Existing Ambient Sound Pressure Level Survey Data

Figures A-1 through Figure A-8 provide plots of the hourly equivalent sound level (L_{eq}) for each full day of measurements at eight long-term ambient survey locations (N1 through N8). Figures A-9 through Figure A-60 provide plots of the hourly Statistical sound pressure levels (SPL) for each 24-hour period of measurement at all eight locations (N1 through N8).

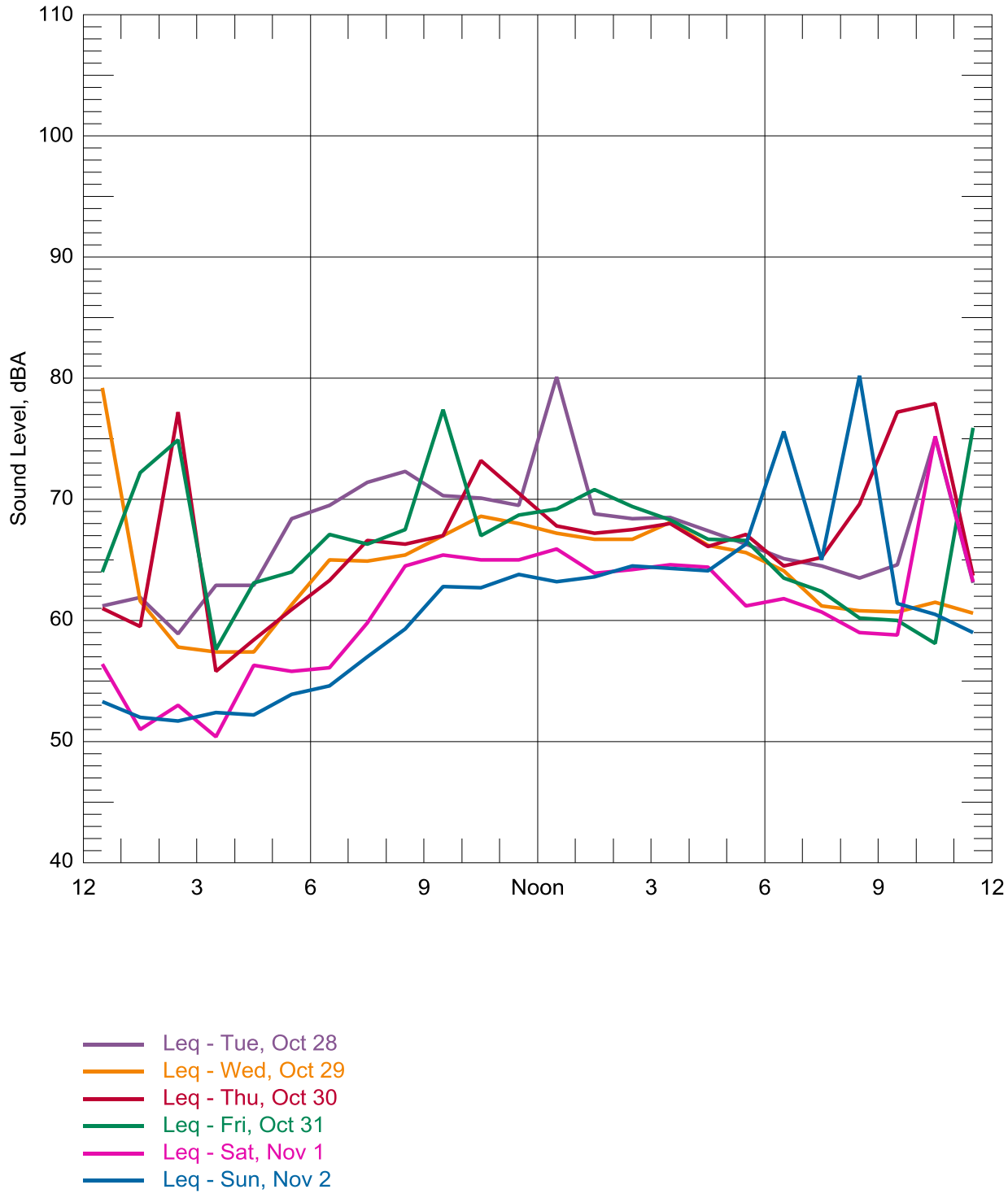

Figure A-1. Location N1, 602 California Way, Longview, WA, hourly L_{eq}

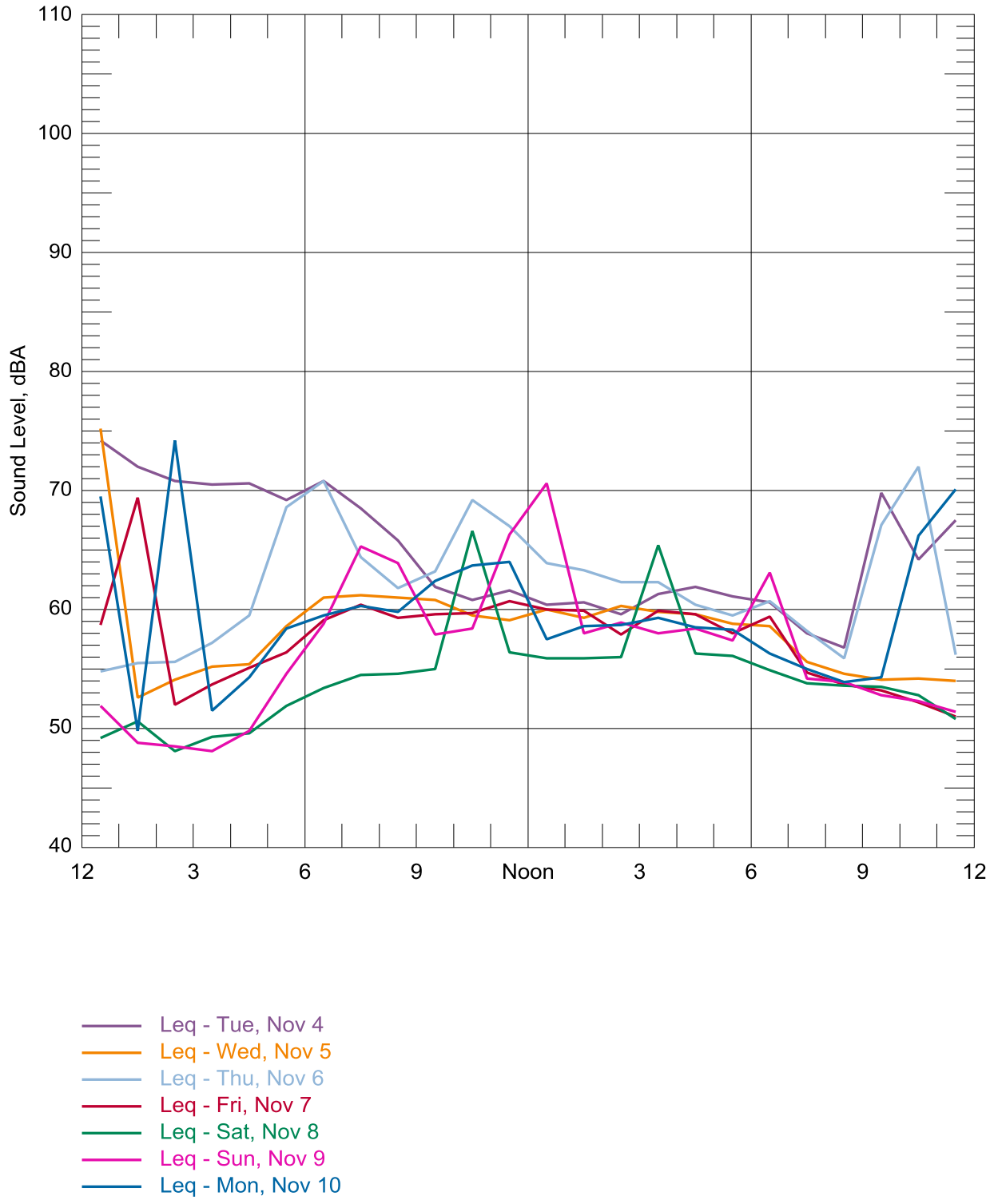

Figure A-2. Location N2, 111-15th Avenue, Longview, WA, hourly L_{eq}

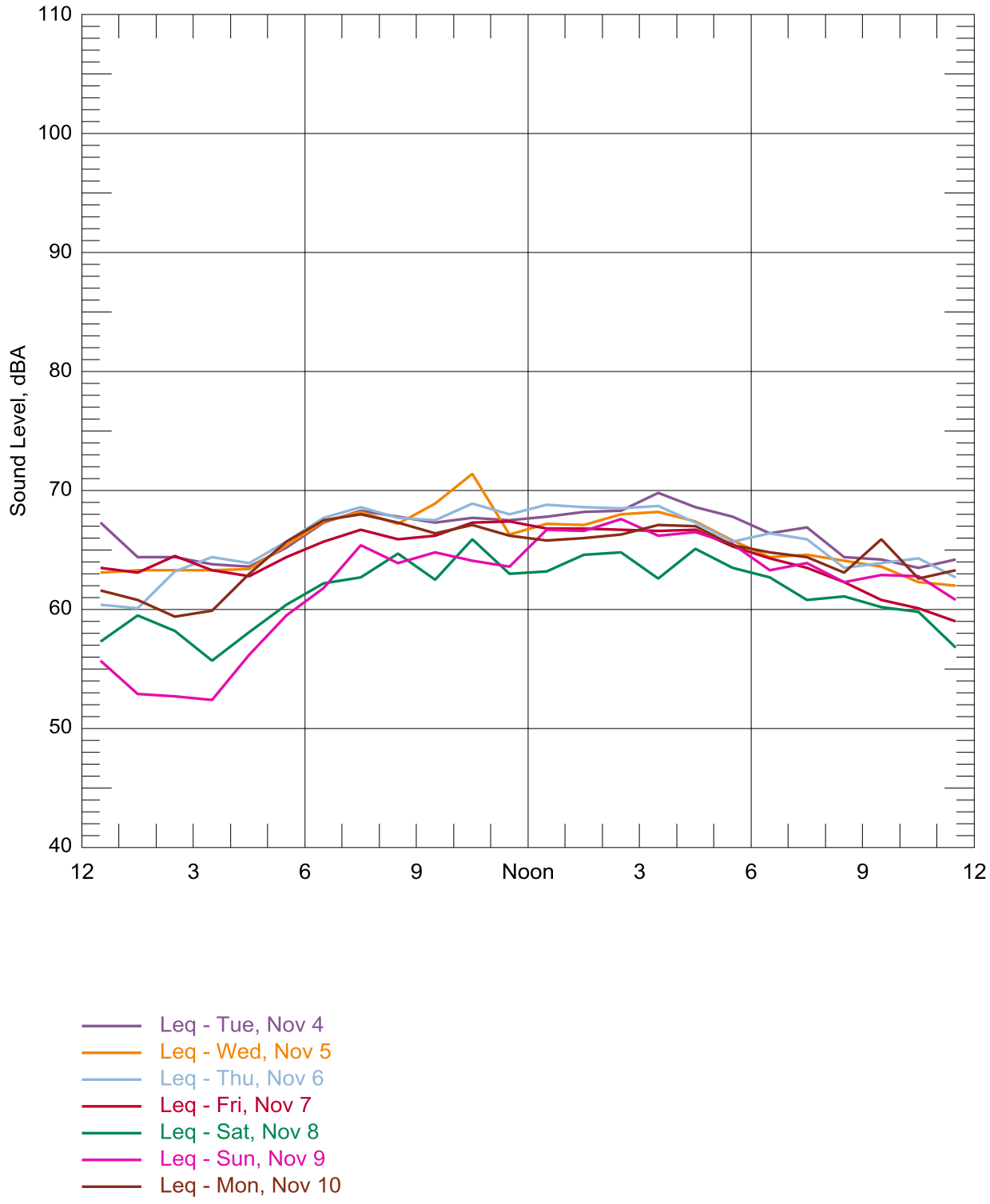

Figure A-3. Location N3, 221 Beech Street, Longview, WA, hourly L_{eq}

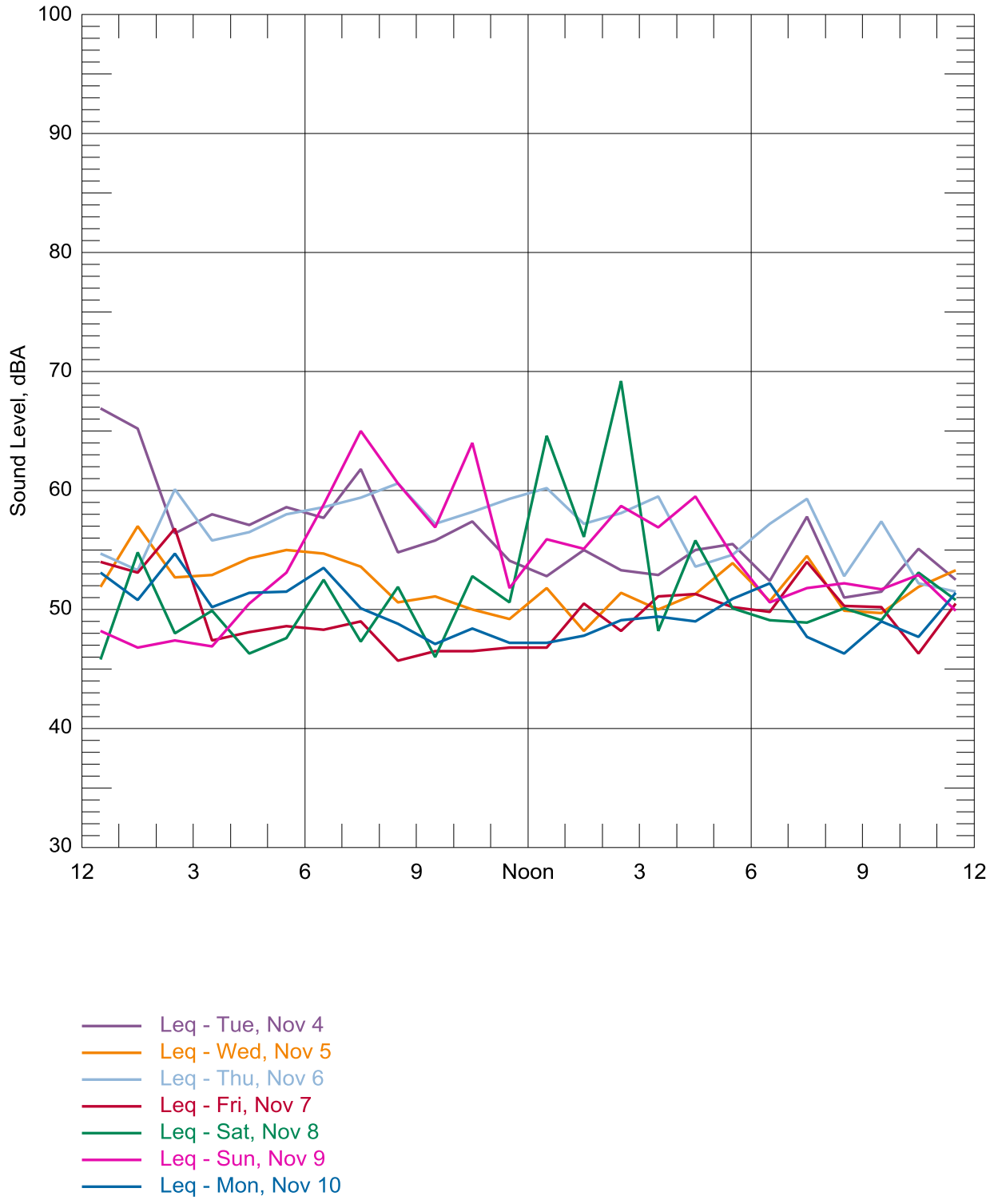

Figure A-4. Location N4, 875-34th Avenue, Longview, WA, hourly L_{eq}

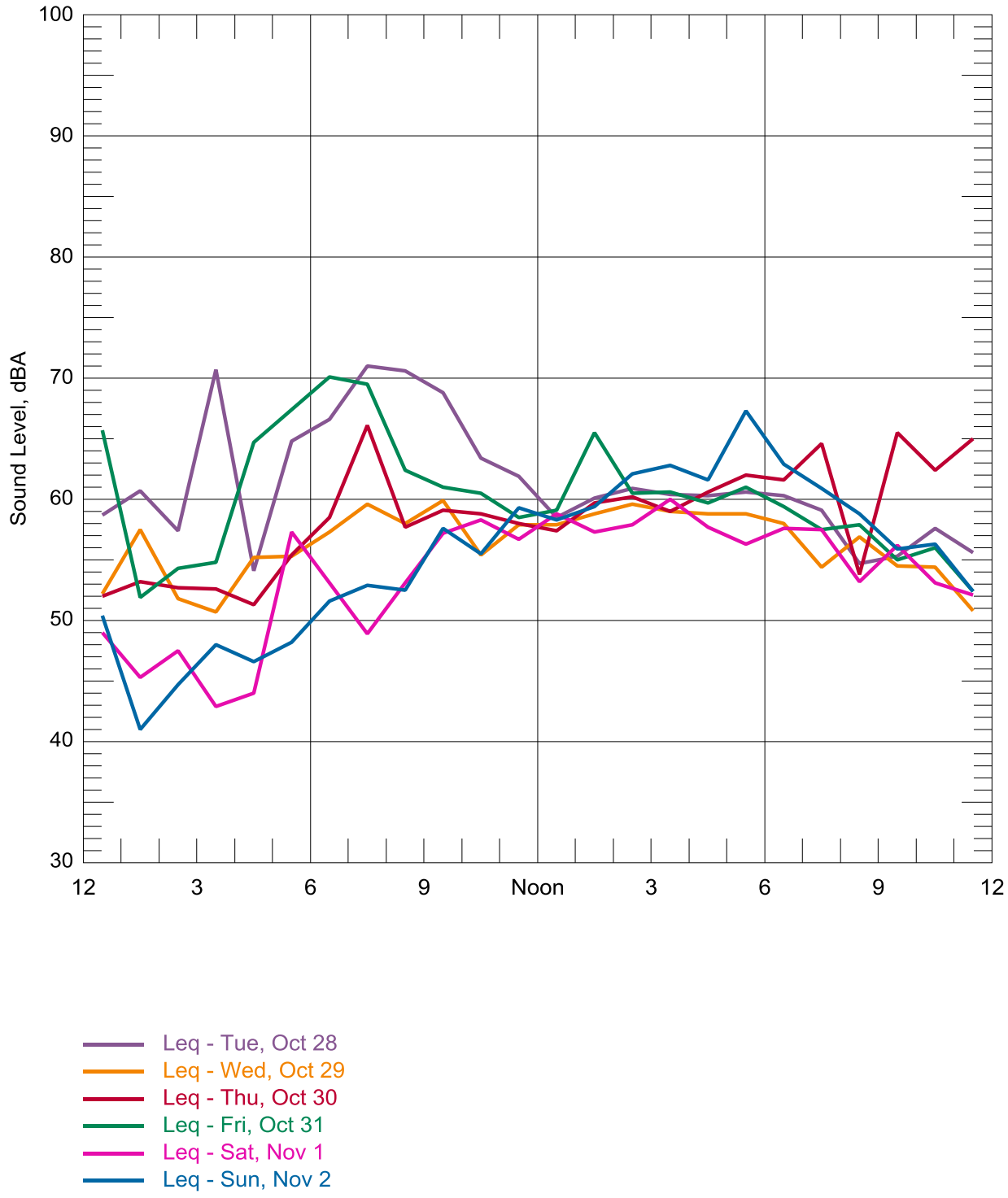

Figure A-5. Location N5, 3600 Memorial Park Drive, Longview, WA, hourly L_{eq}

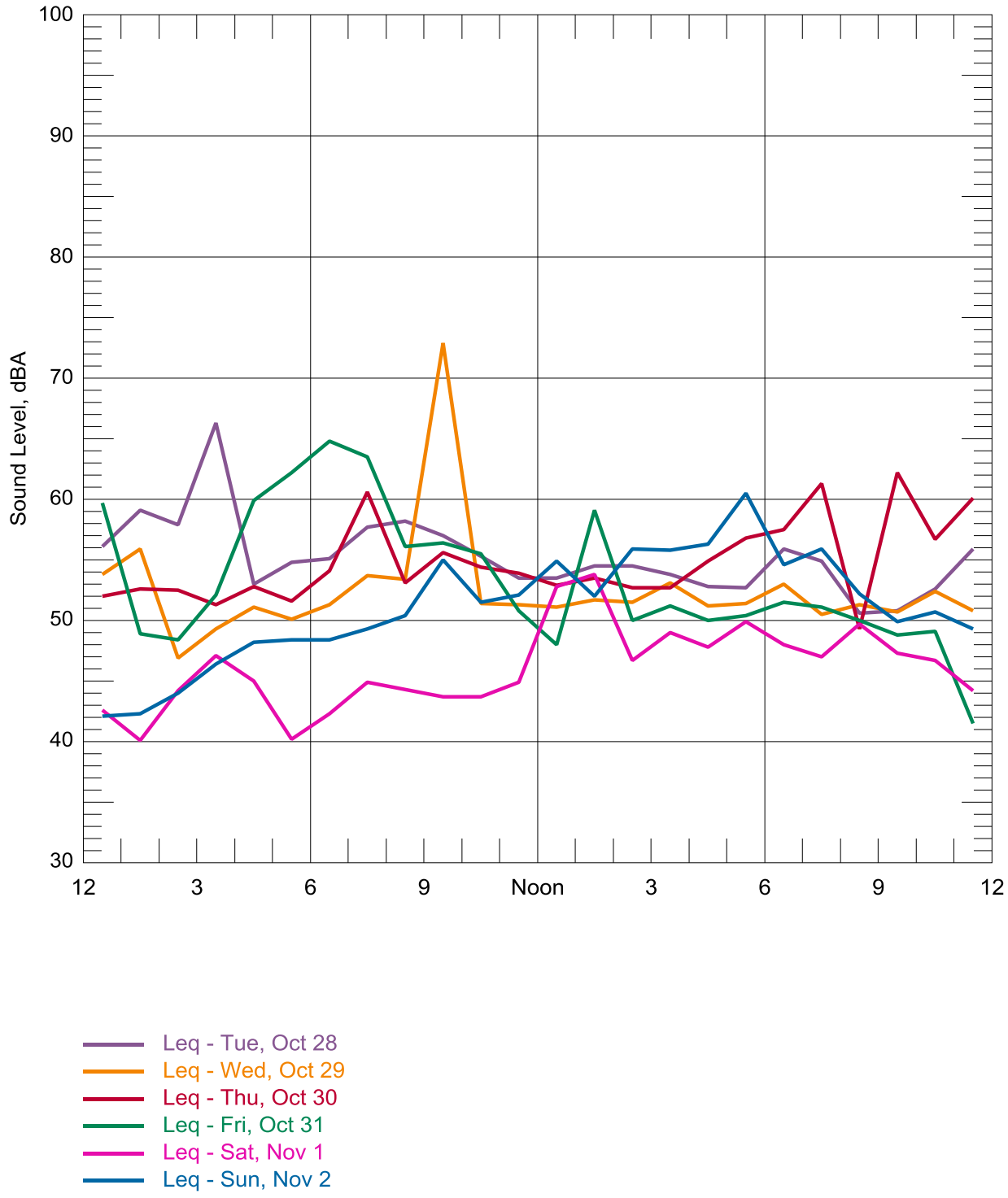

Figure A-6. Location N6, 420 Rutherglen Drive, Longview, WA, hourly L_{eq}

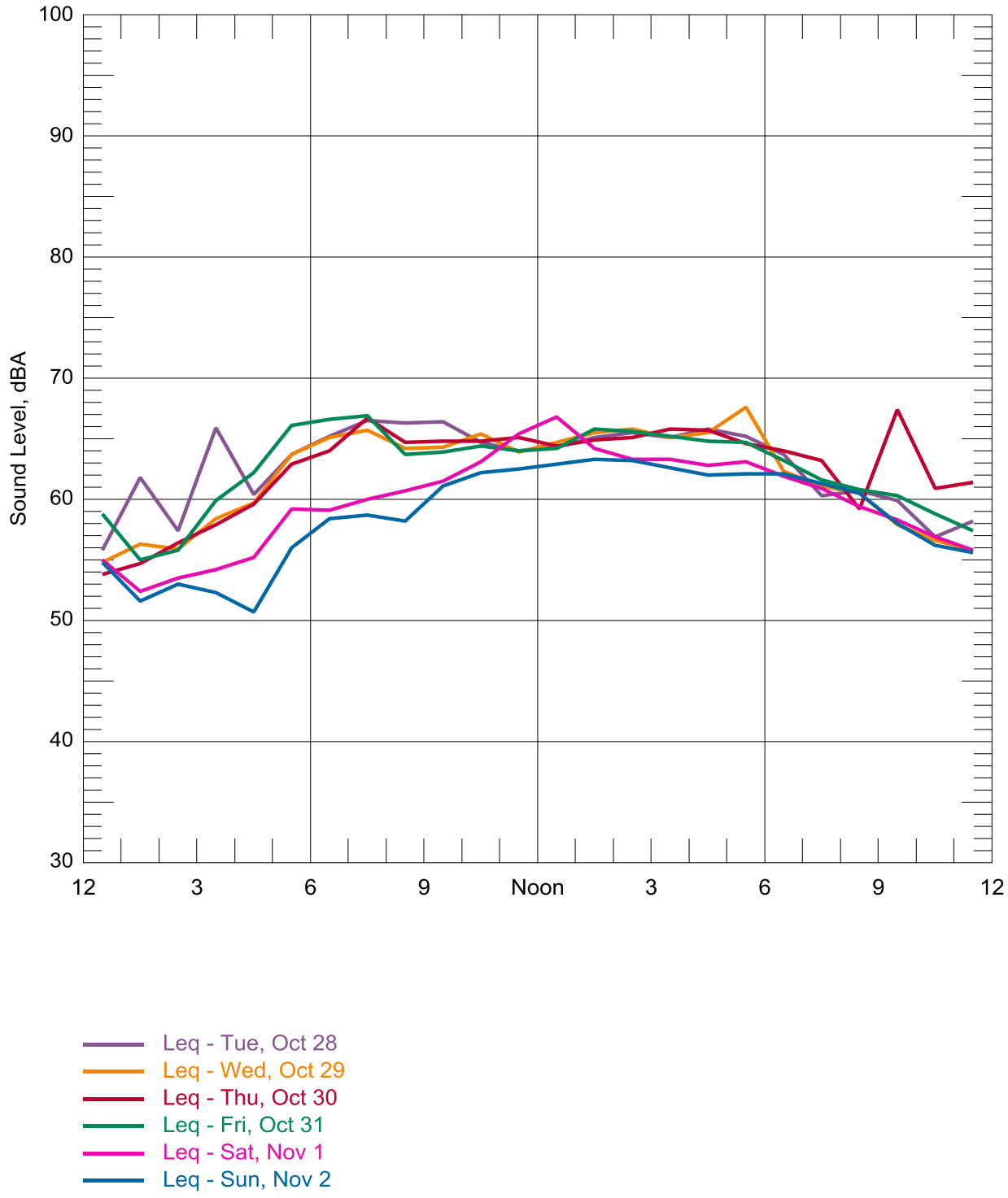

Figure A-7. Location N7, 4723 Mount Solo Road, Longview, WA, hourly L_{eq}

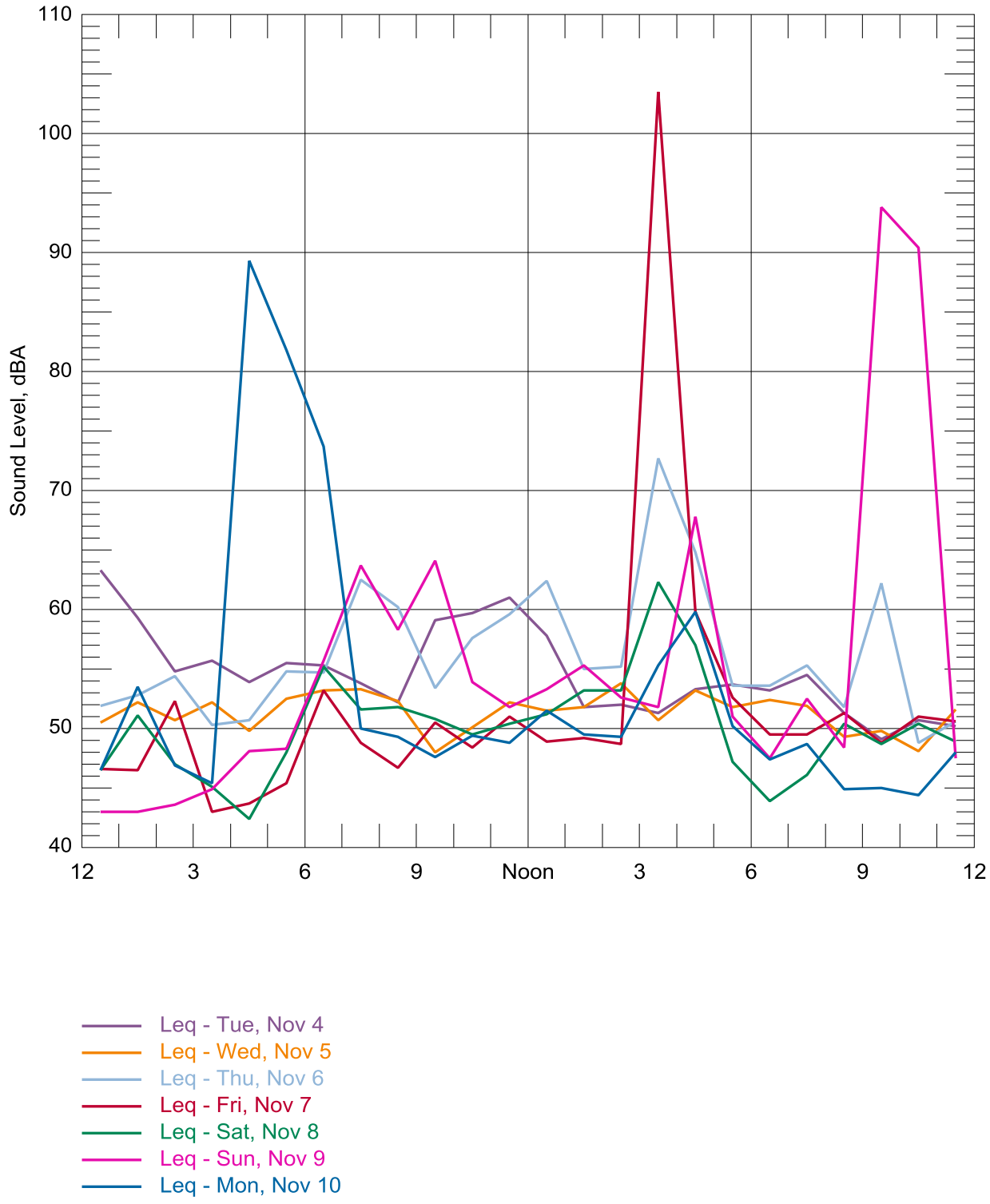

Figure A-8. Location N8, 1719 Dorothy Avenue, Longview, WA, hourly L_{eq}

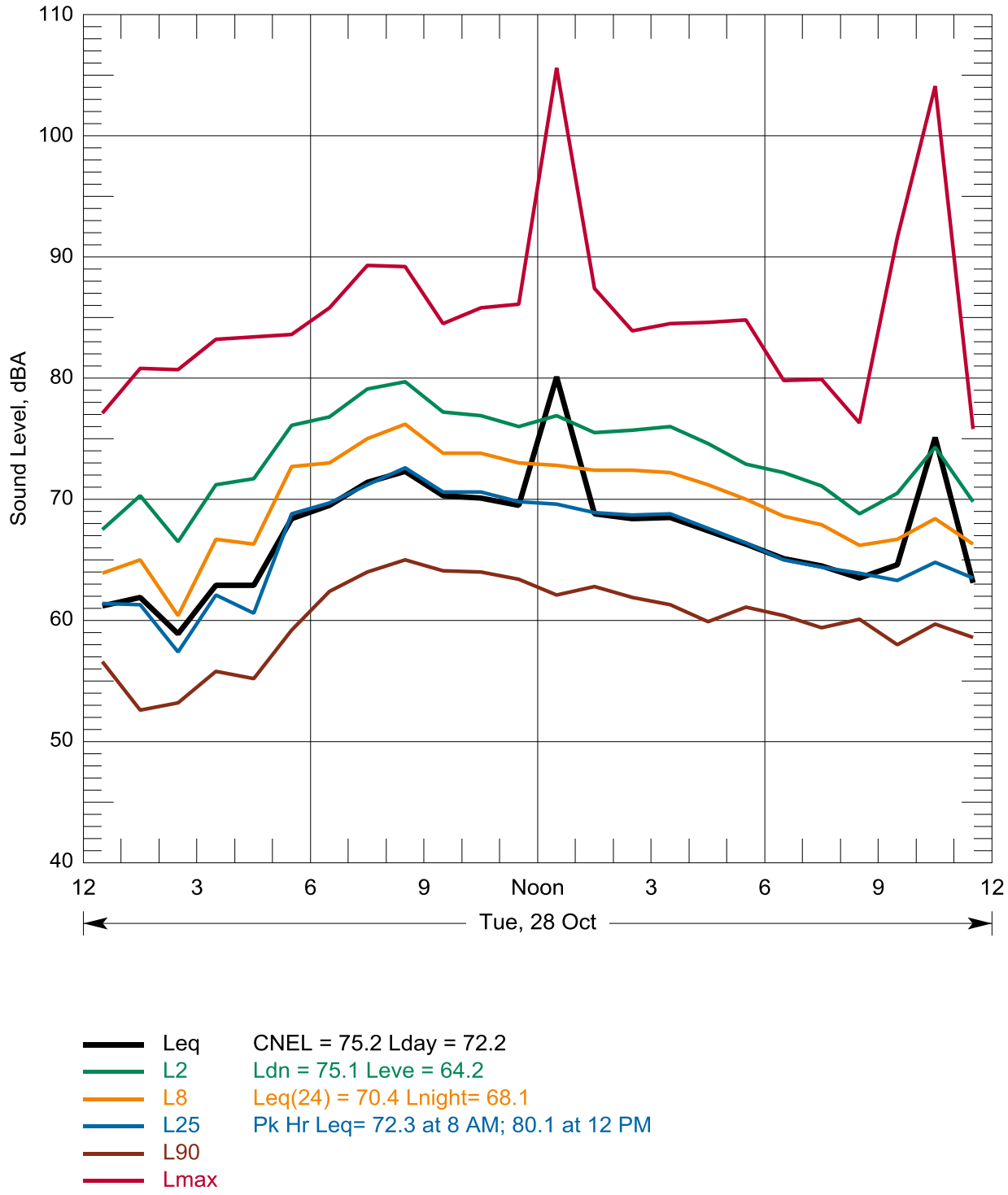

Figure A-9. Hourly Statistical Summary of Noise Levels on Oct 28, 2014 Location N1, 602 California Way, Longview, WA

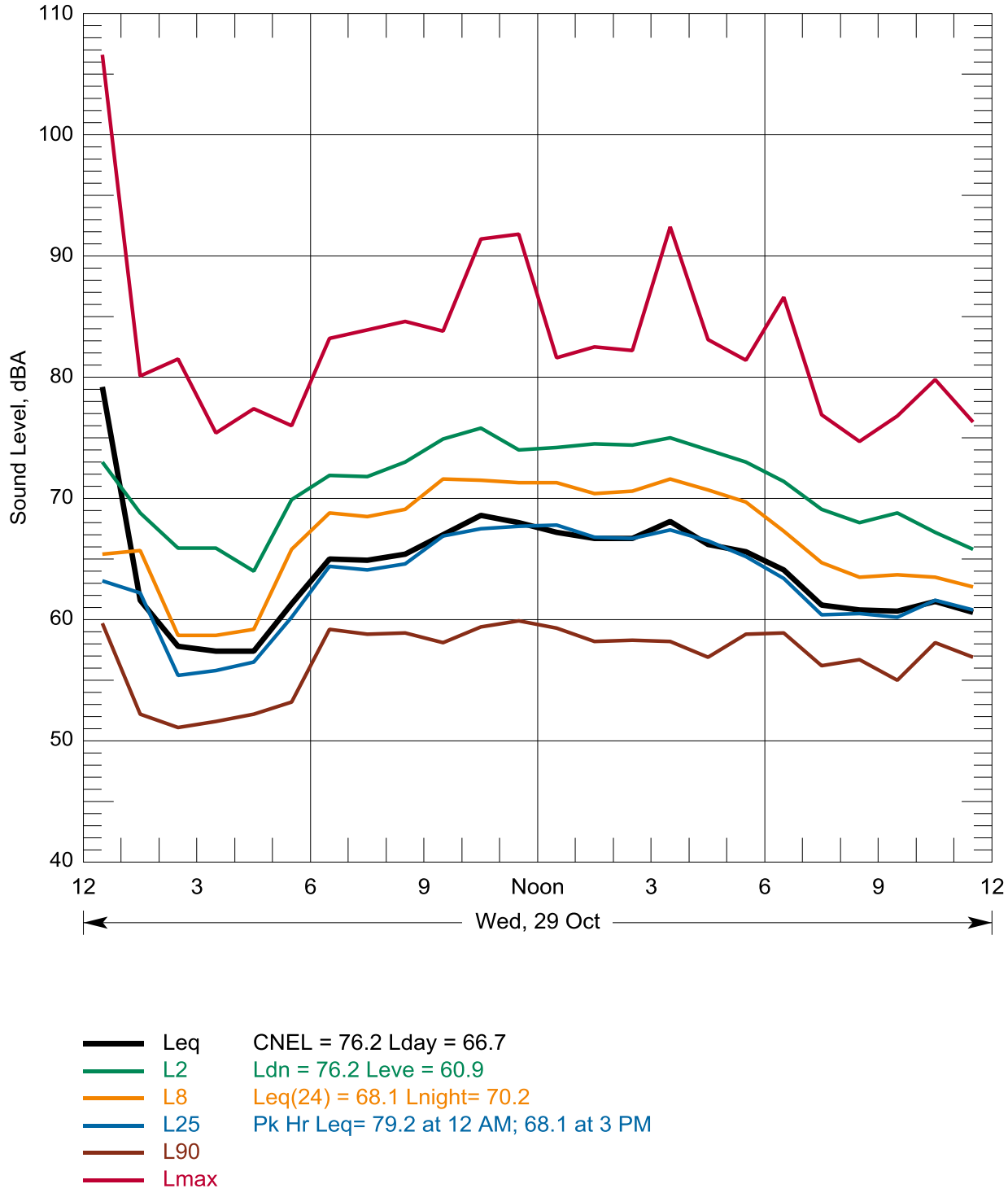

Figure A-10. Hourly Statistical Summary of Noise Levels on Oct 29, 2014 Location N1, 602 California Way, Longview, WA

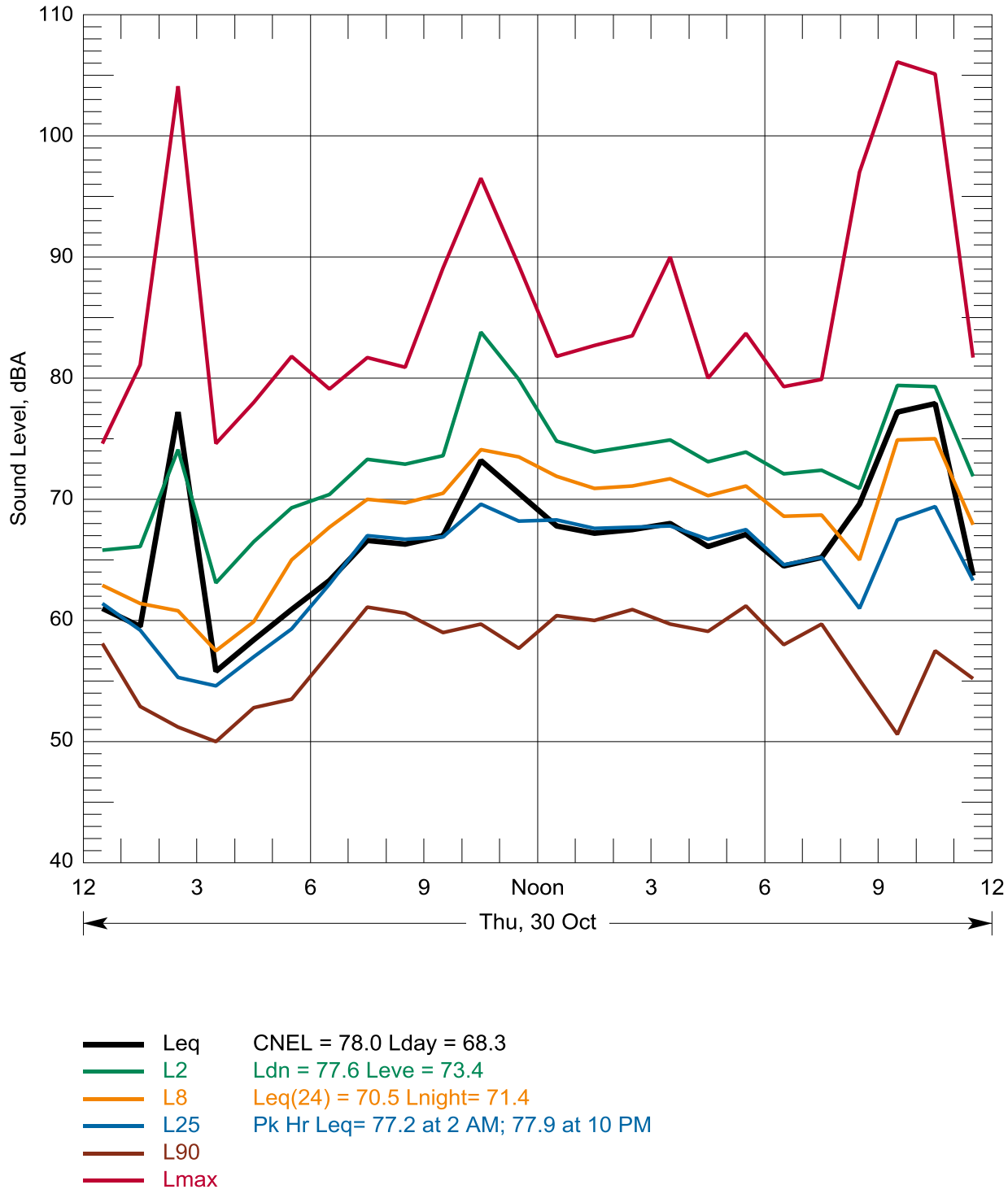

Figure A-11. Hourly Statistical Summary of Noise Levels on Oct 30, 2014 Location N1, 602 California Way, Longview, WA

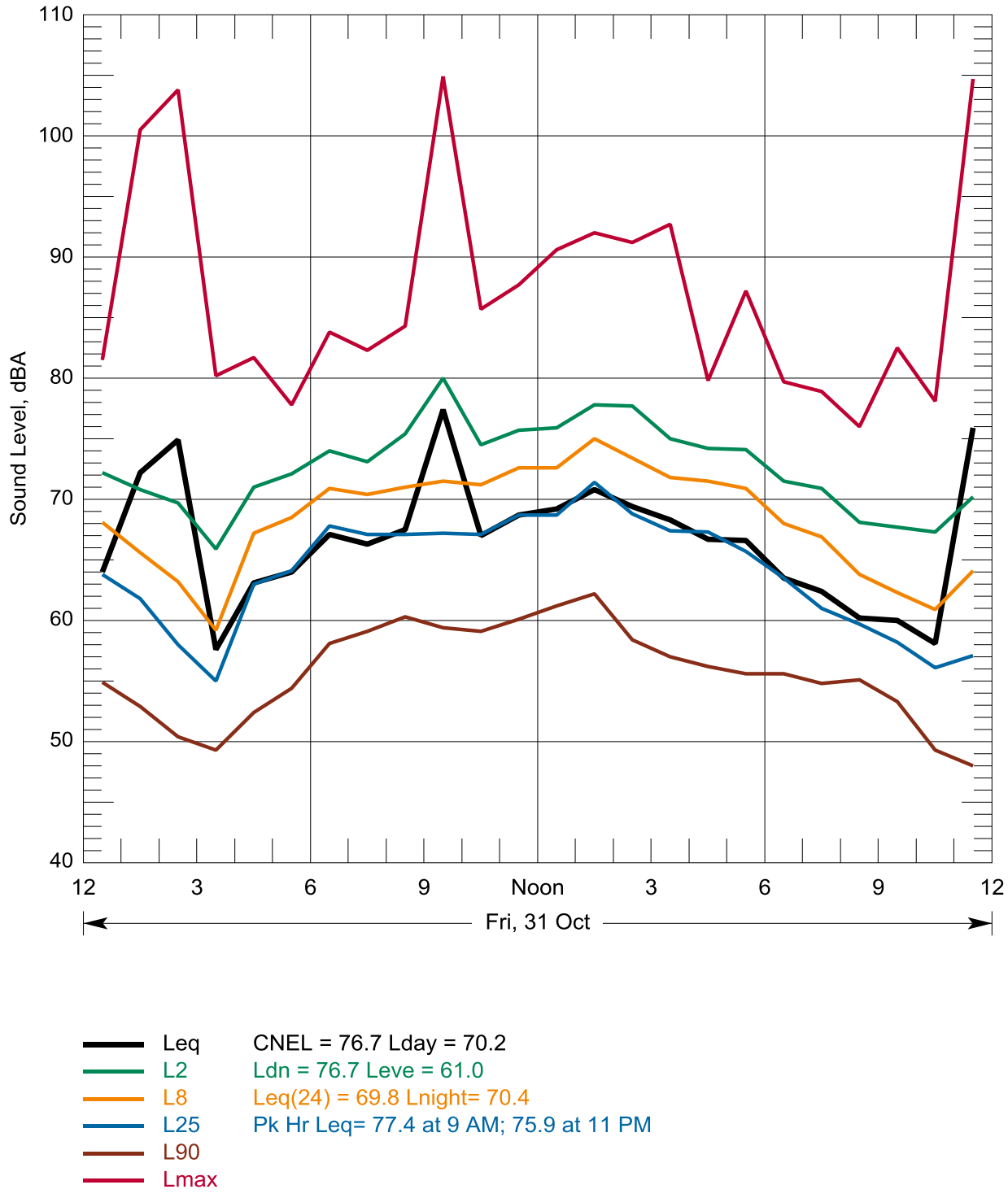

Figure A-12. Hourly Statistical Summary of Noise Levels on Oct 31, 2014 Location N1, 602 California Way, Longview, WA

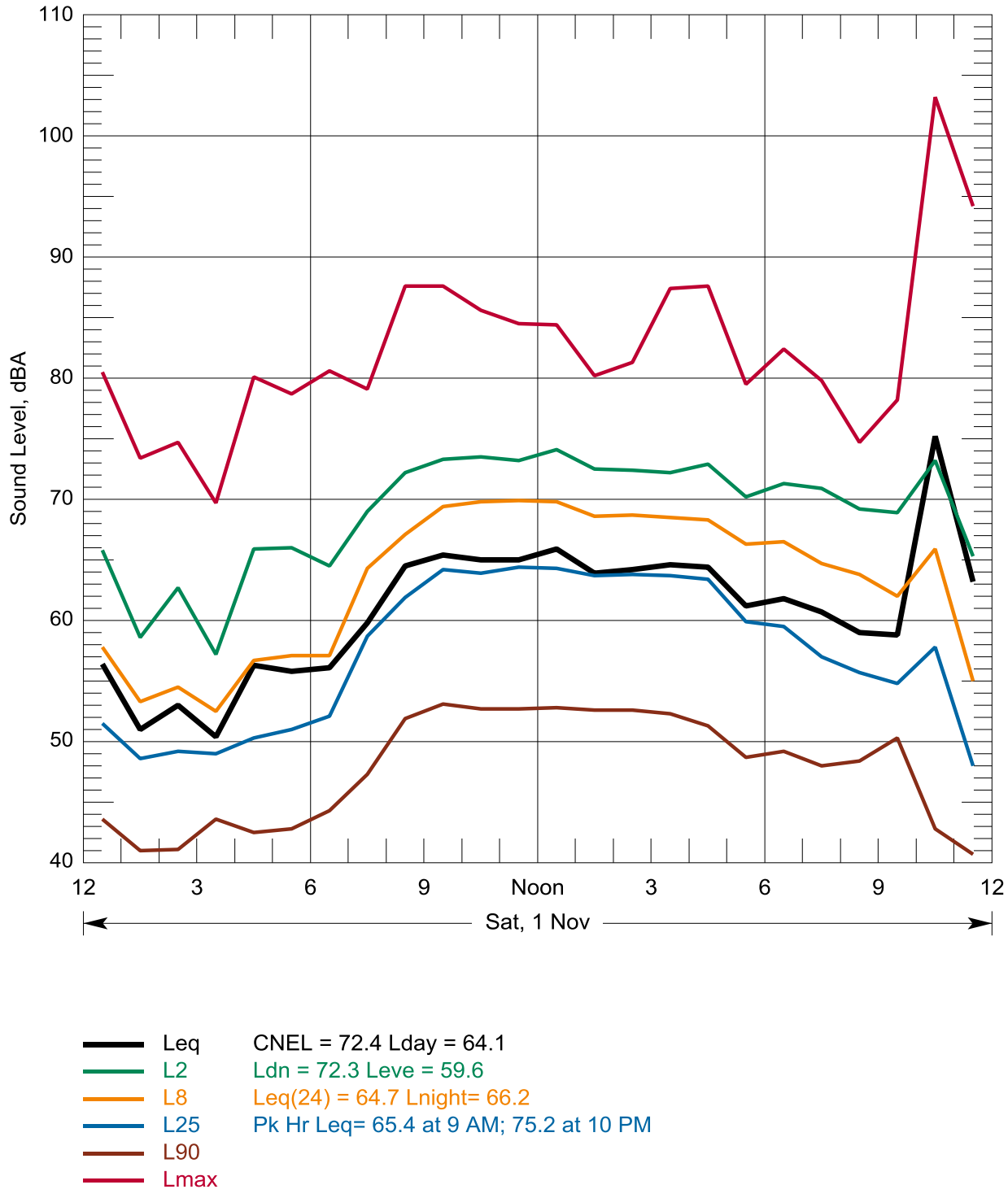

Figure A-13. Hourly Statistical Summary of Noise Levels on Nov 1, 2014 Location N1, 602 California Way, Longview, WA

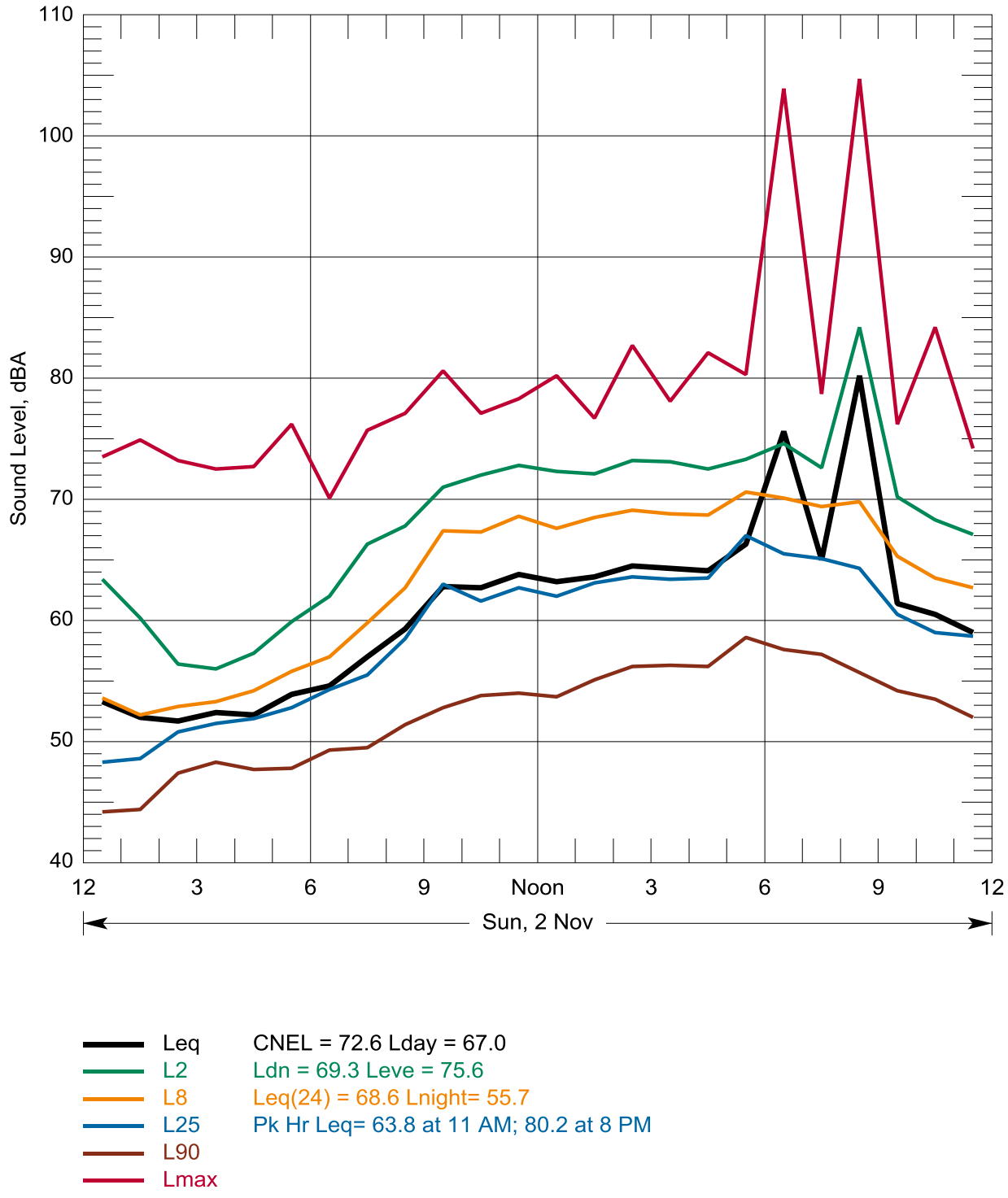

Figure A-14. Hourly Statistical Summary of Noise Levels on Nov 2, 2014 Location N1, 602 California Way, Longview, WA

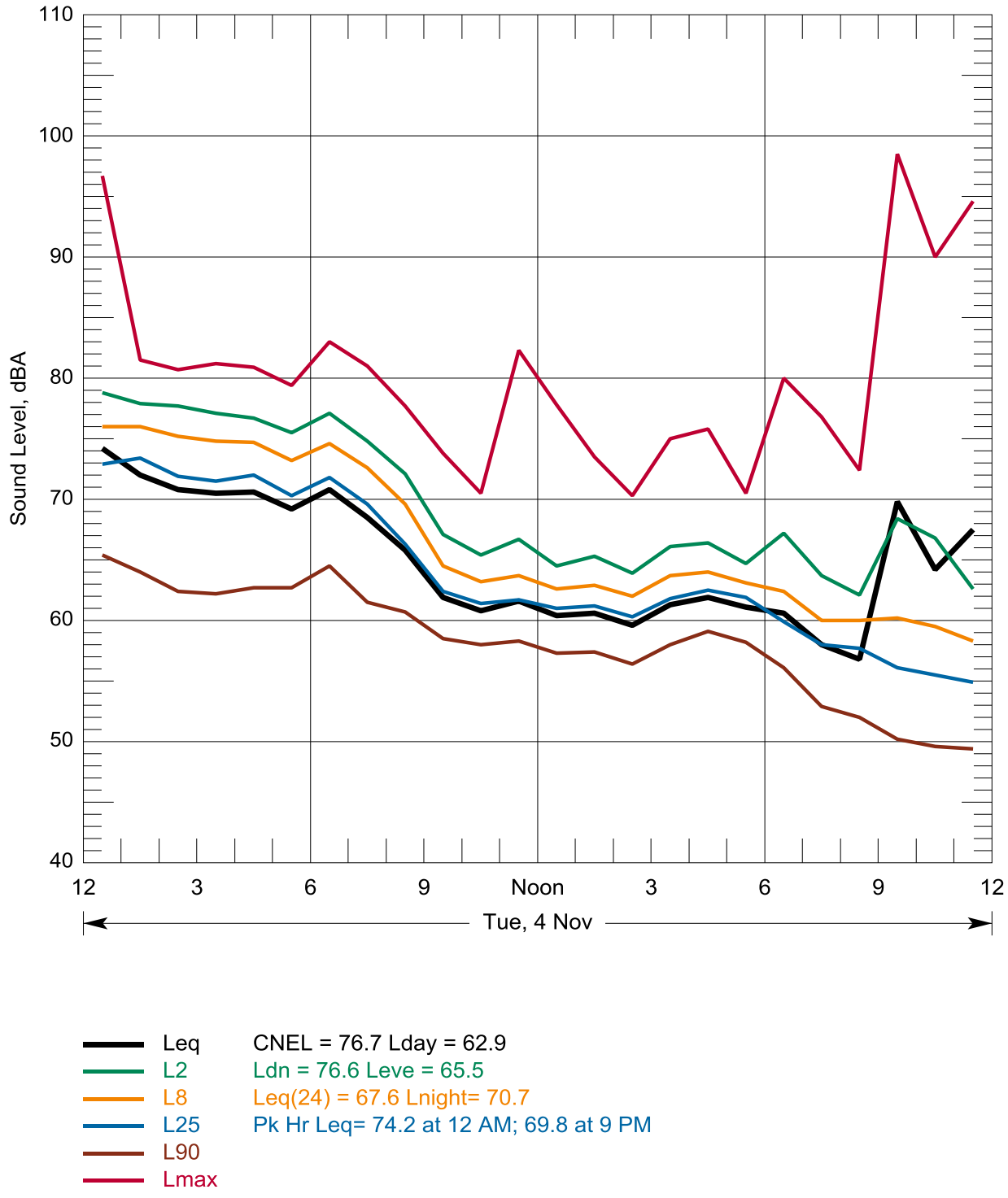

Figure A-15. Hourly Statistical Summary of Noise Levels on Nov 4, 2014 Location N2, 111-15th Avenue, Longview, WA

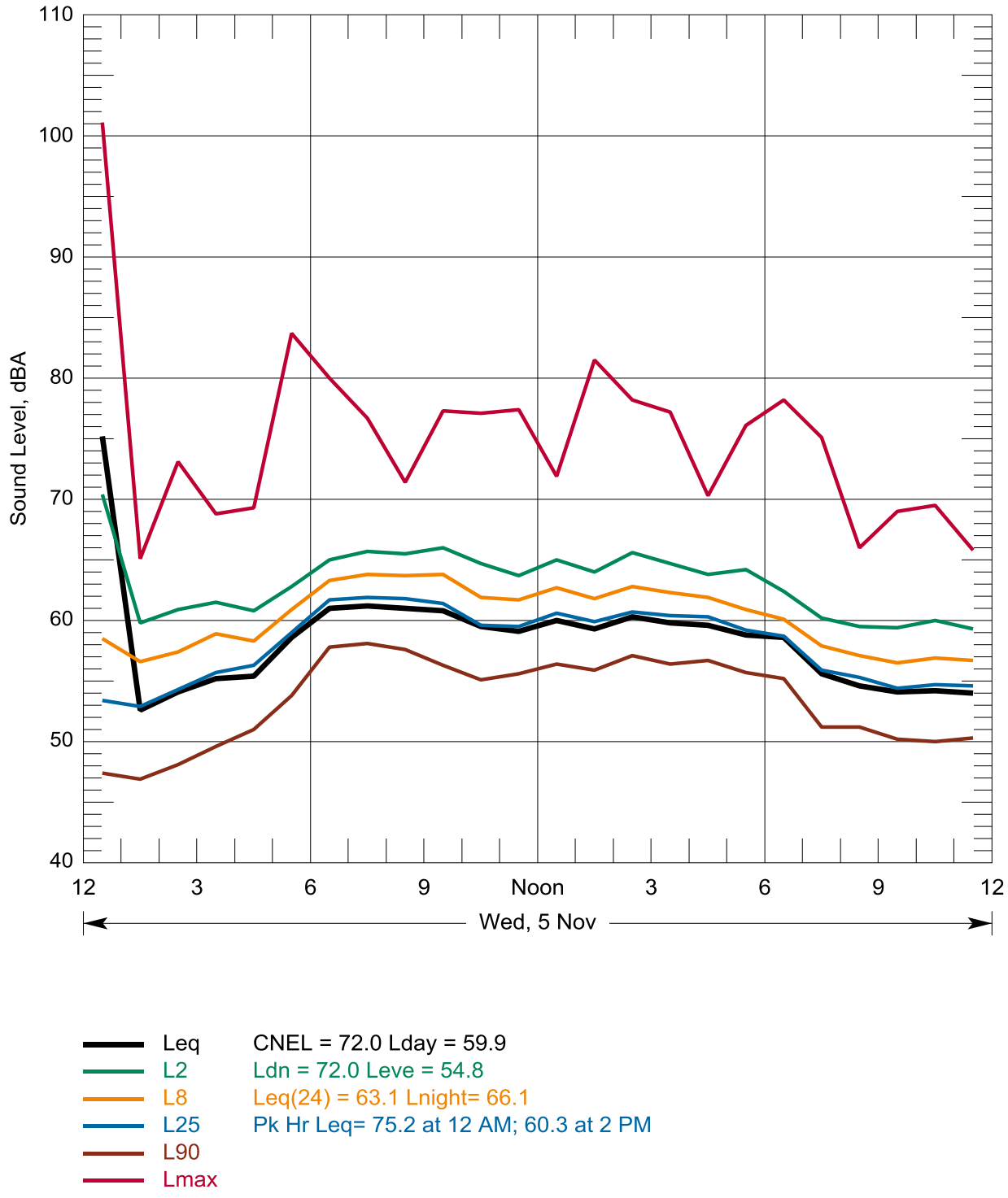

Figure A-16. Hourly Statistical Summary of Noise Levels on Nov 5, 2014 Location N2, 111-15th Avenue, Longview, WA

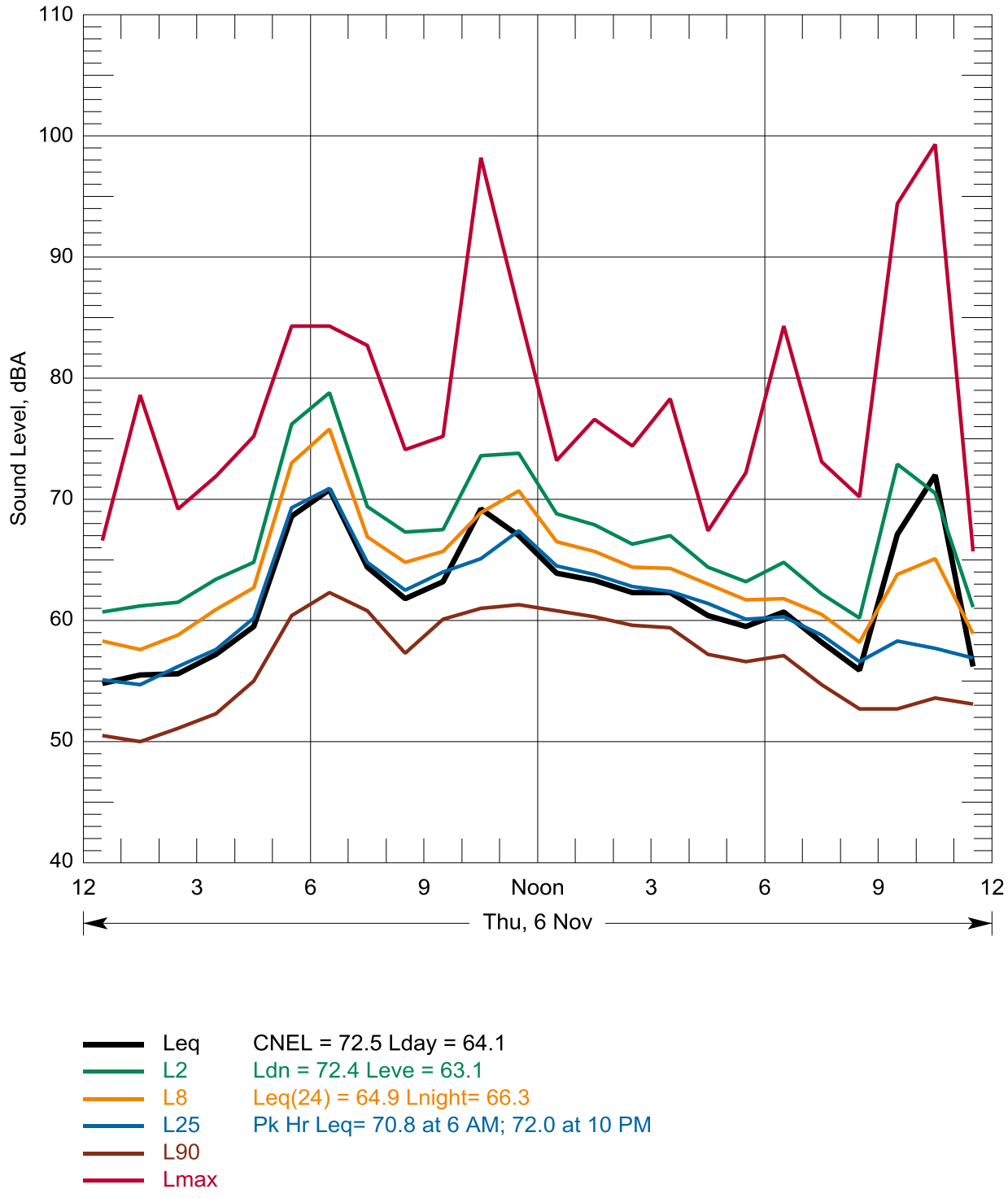

Figure A-17. Hourly Statistical Summary of Noise Levels on Nov 6, 2014 Location N2, 111-15th Avenue, Longview, WA

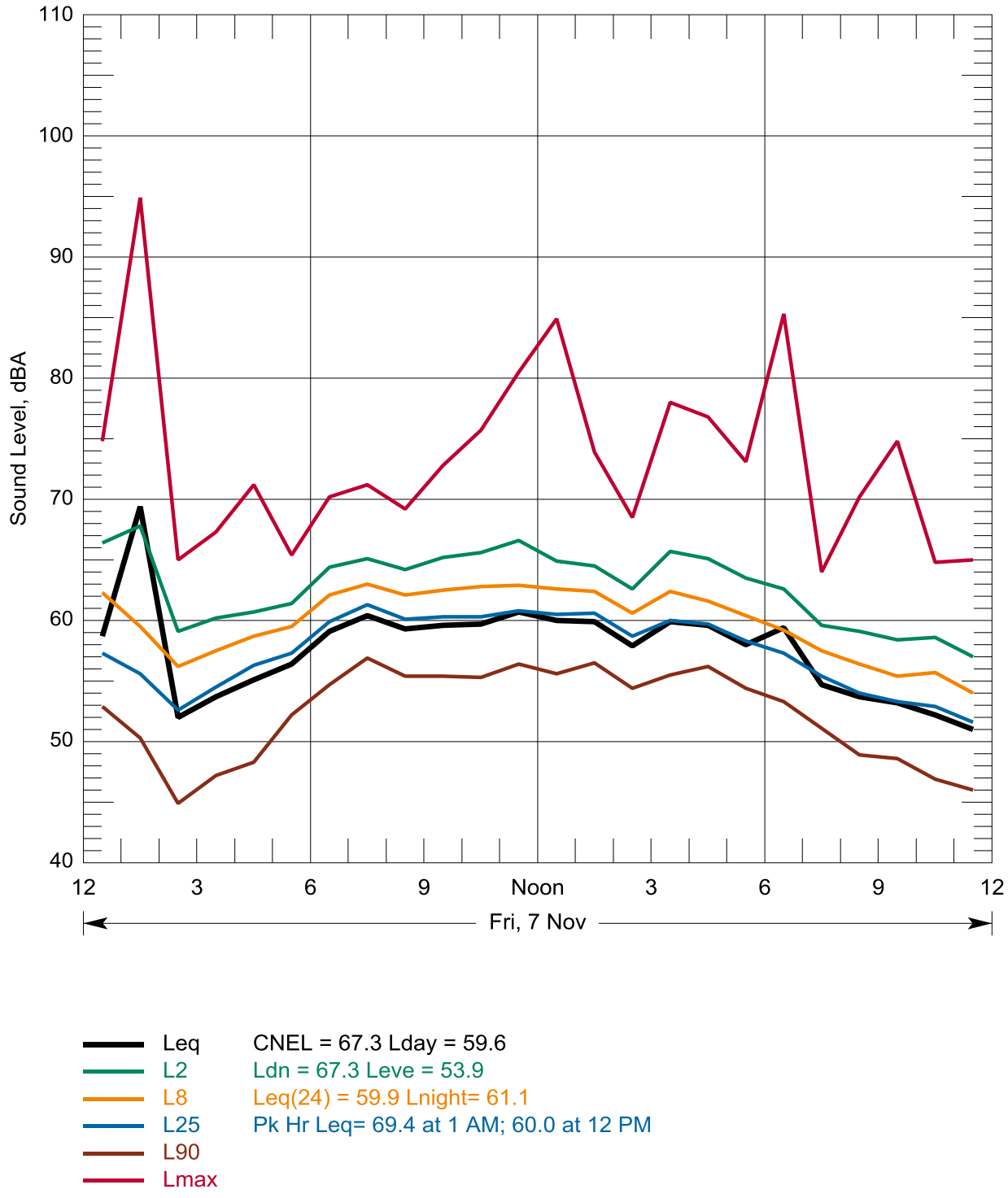

Figure A-18. Hourly Statistical Summary of Noise Levels on Nov 7, 2014 Location N2, 111-15th Avenue, Longview, WA

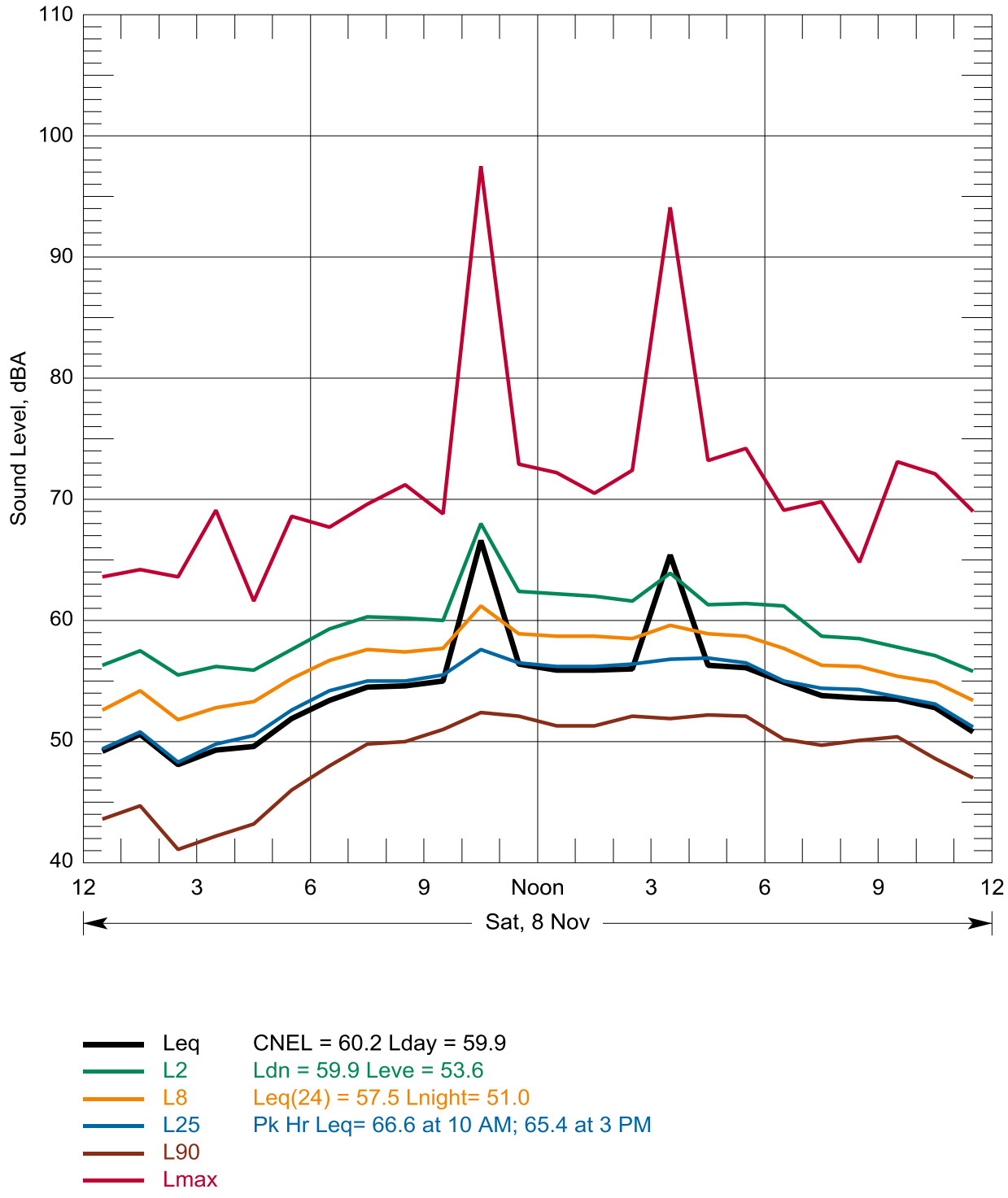

Figure A-19. Hourly Statistical Summary of Noise Levels on Nov 8, 2014 Location N2, 111-15th Avenue, Longview, WA

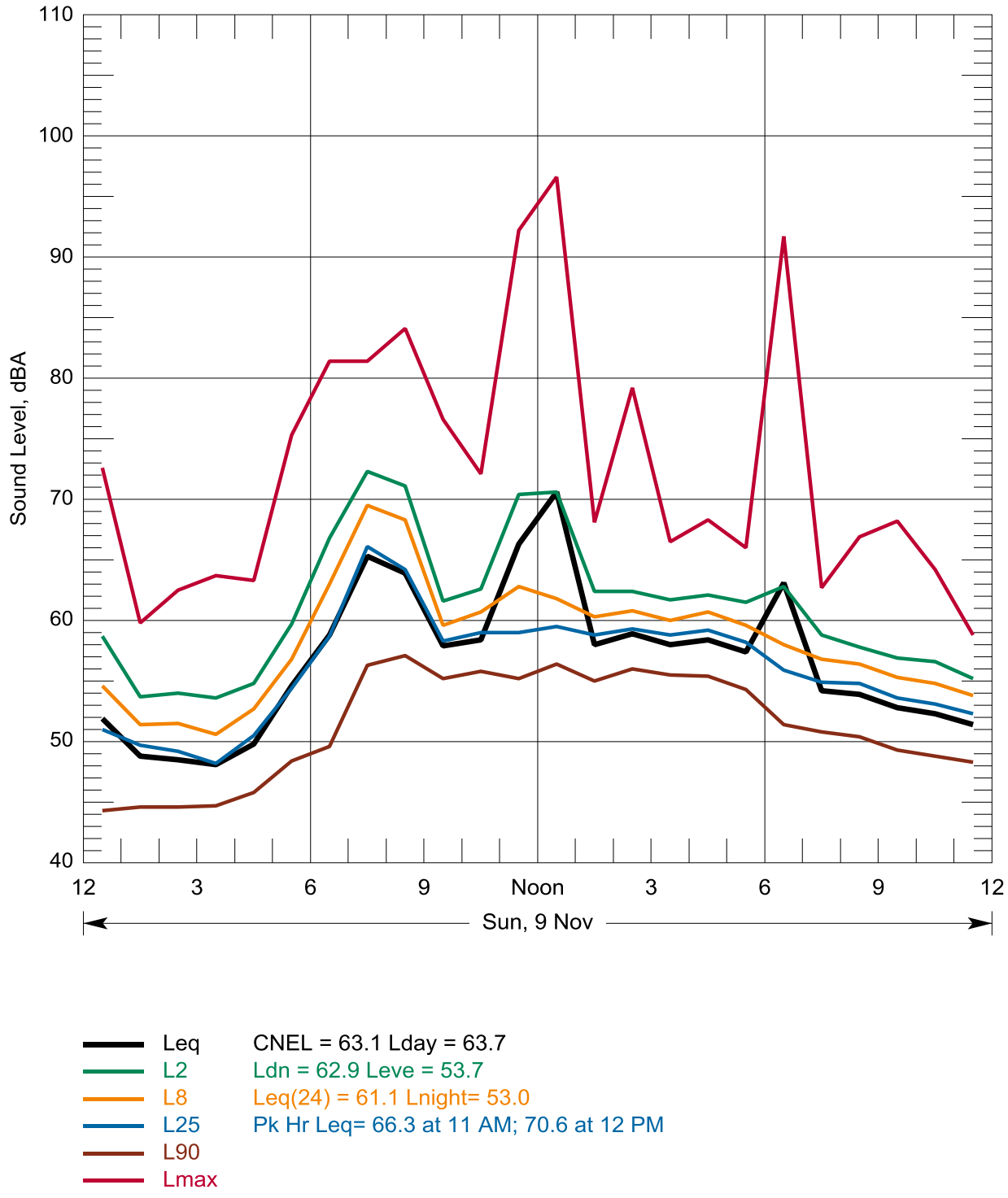

Figure A-20. Hourly Statistical Summary of Noise Levels on Nov 9, 2014 Location N2, 111-15th Avenue, Longview, WA

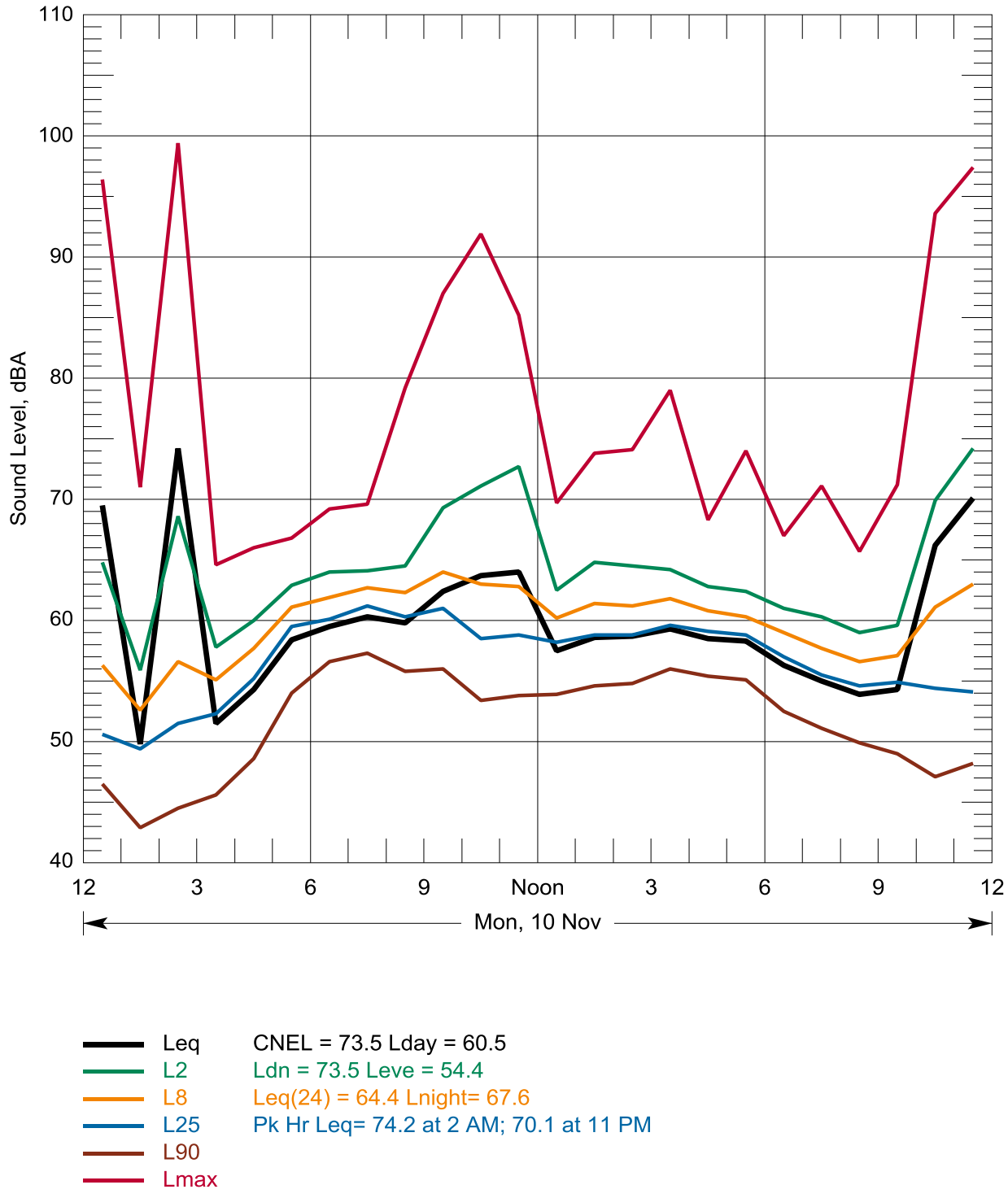

Figure A-21. Hourly Statistical Summary of Noise Levels on Nov 10, 2014 Location N2, 111-15th Avenue, Longview, WA

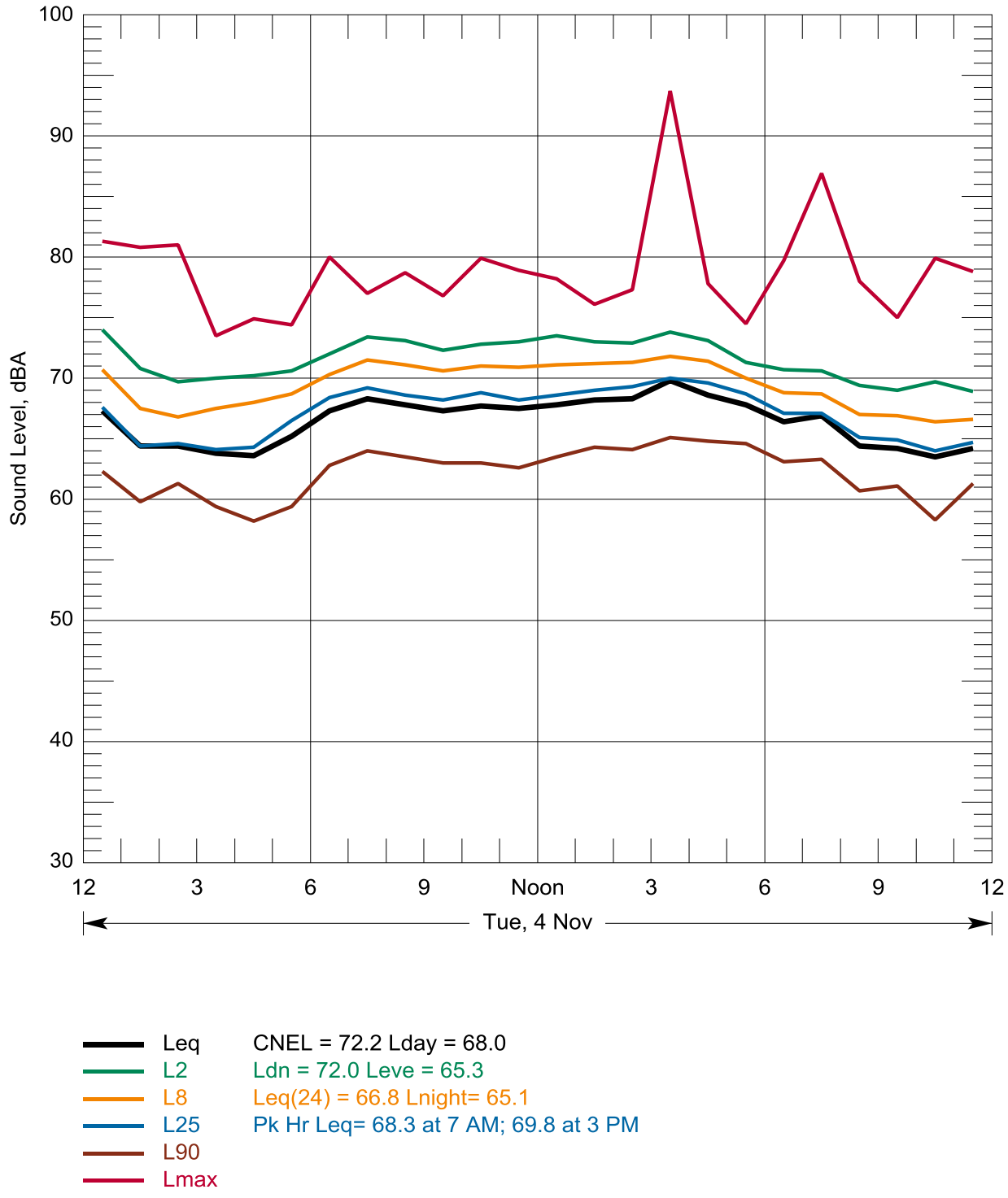

Figure A-22. Hourly Statistical Summary of Noise Levels on Nov 4, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

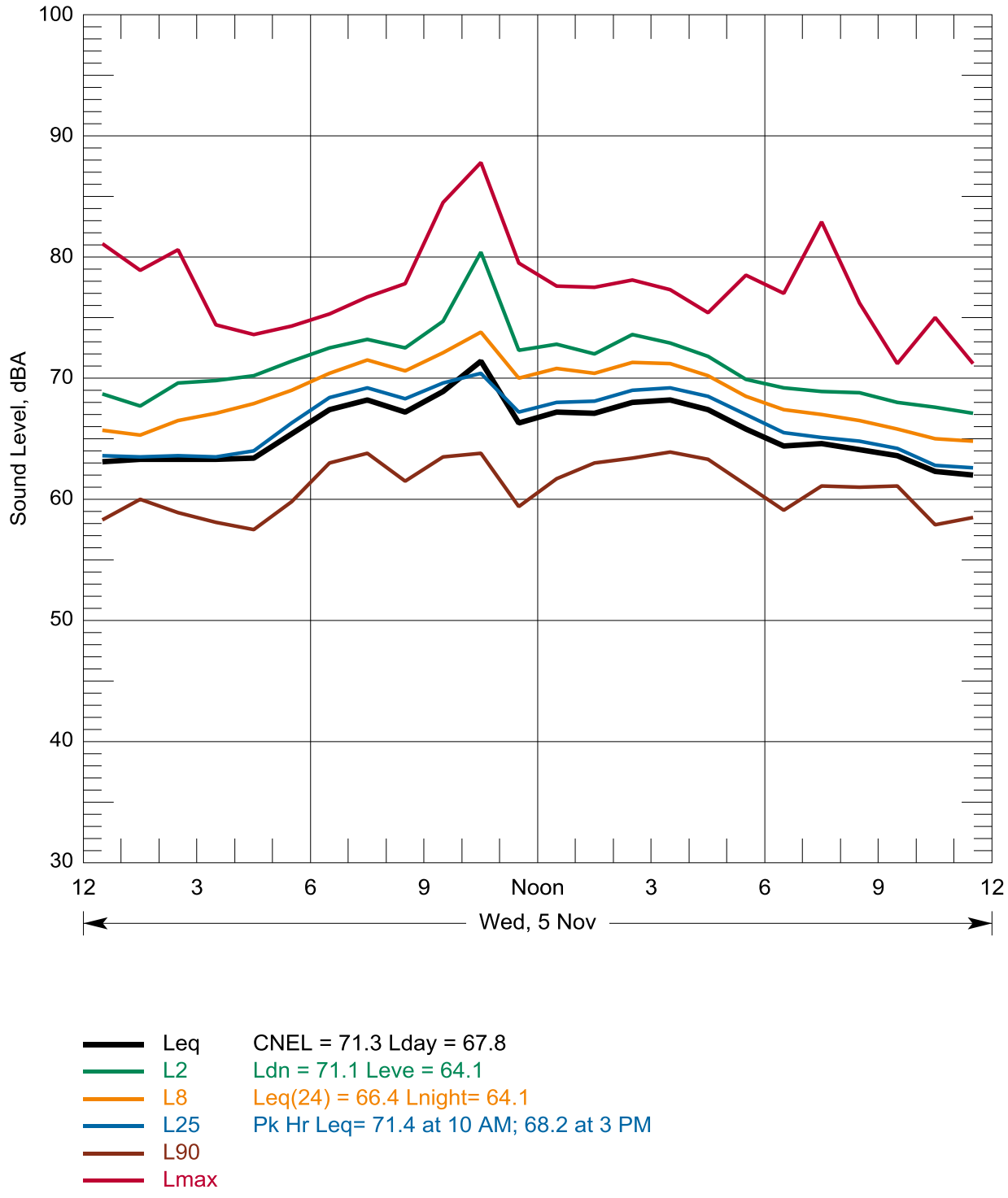

Figure A-23. Hourly Statistical Summary of Noise Levels on Nov 5, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

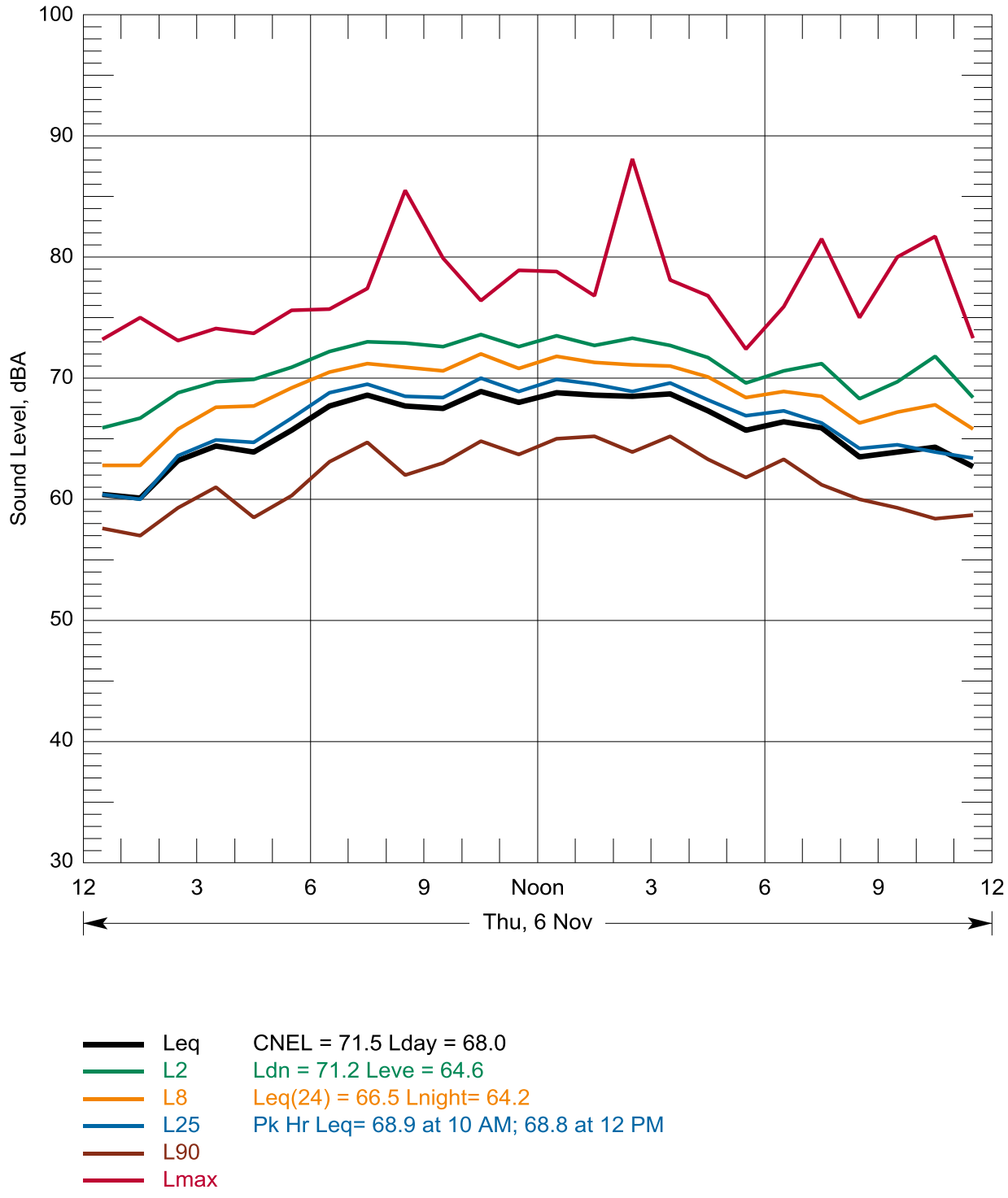

Figure A-24. Hourly Statistical Summary of Noise Levels on Nov 6, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

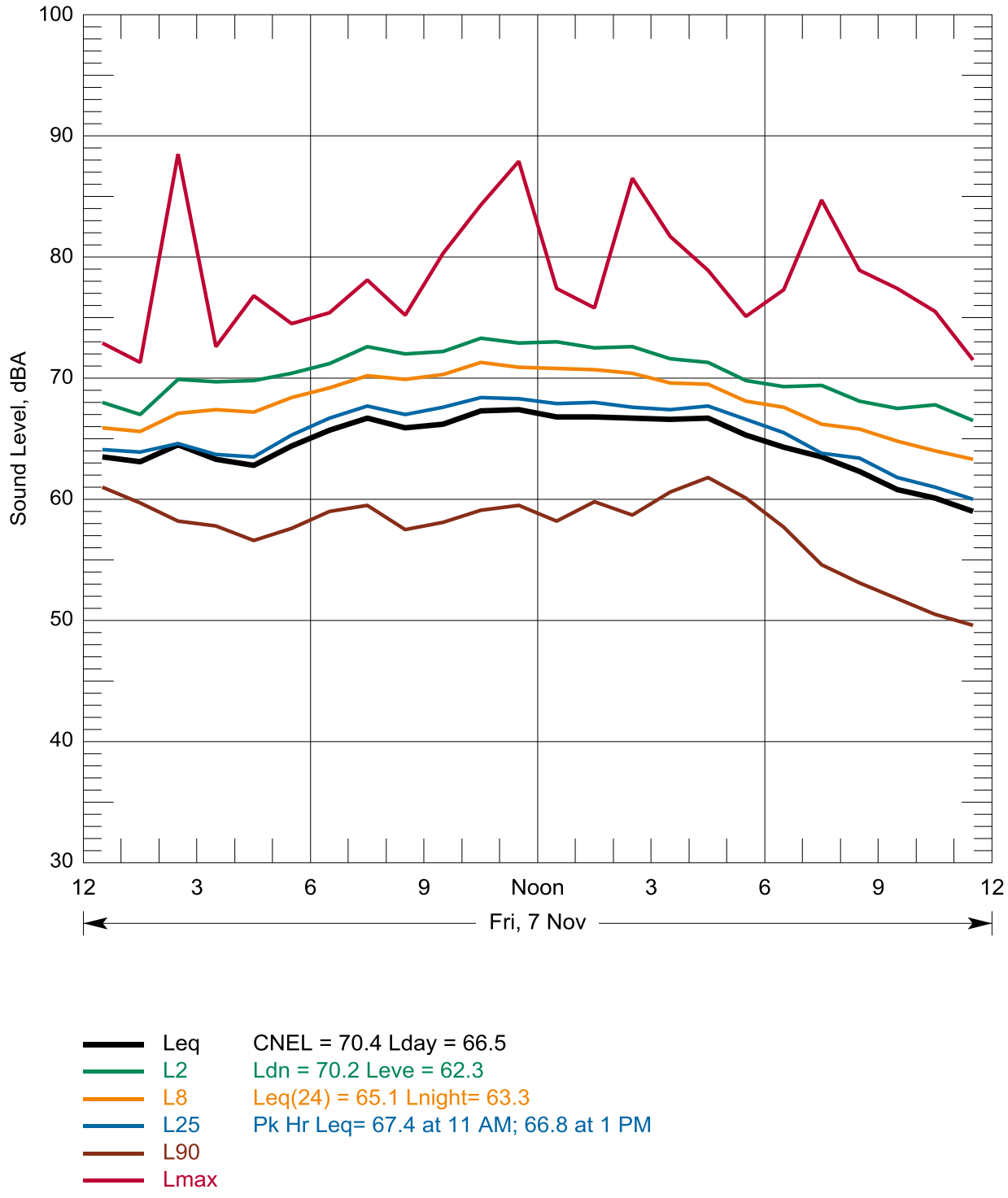

Figure A-25. Hourly Statistical Summary of Noise Levels on Nov 7, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

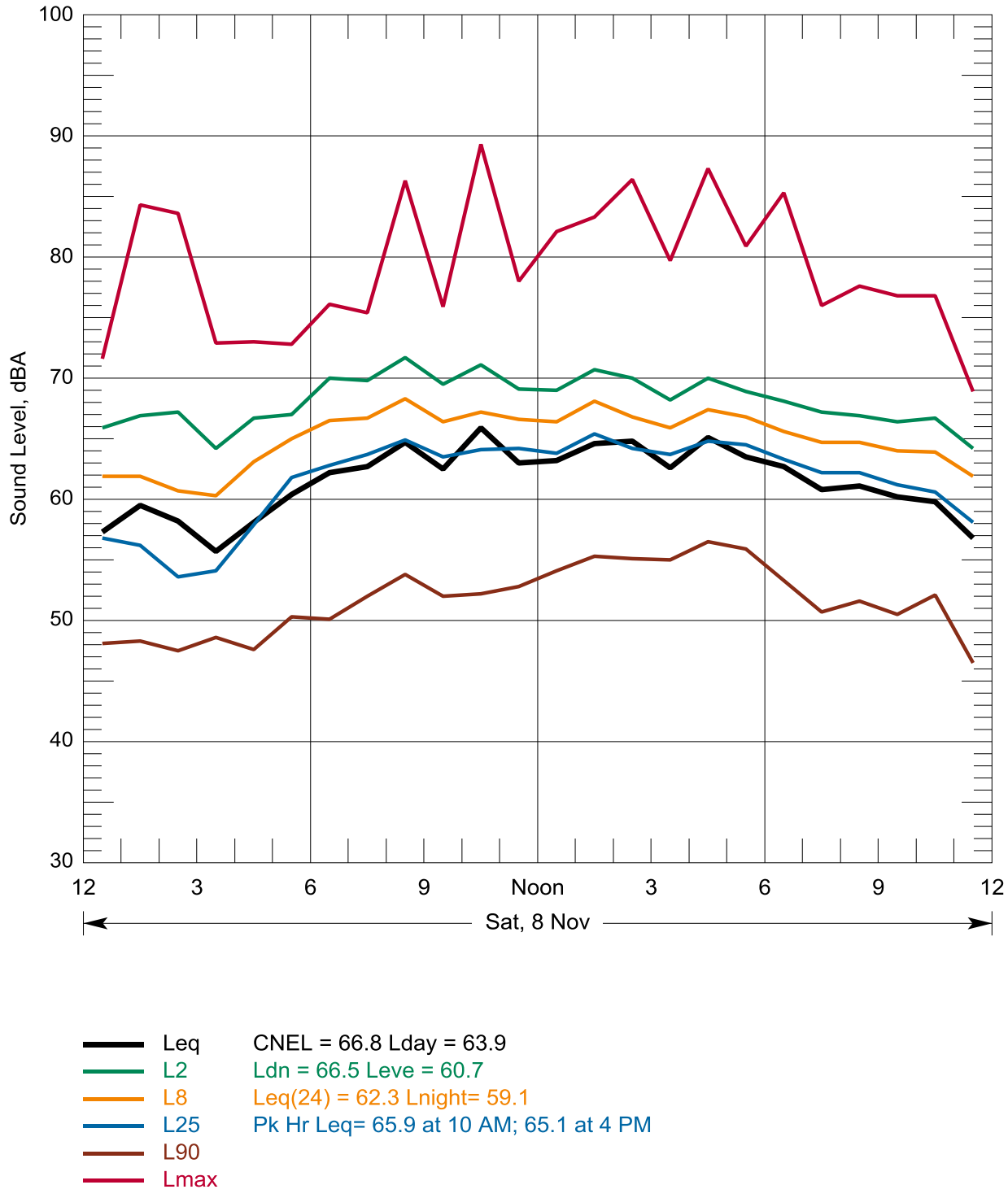

Figure A-26. Hourly Statistical Summary of Noise Levels on Nov 8, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

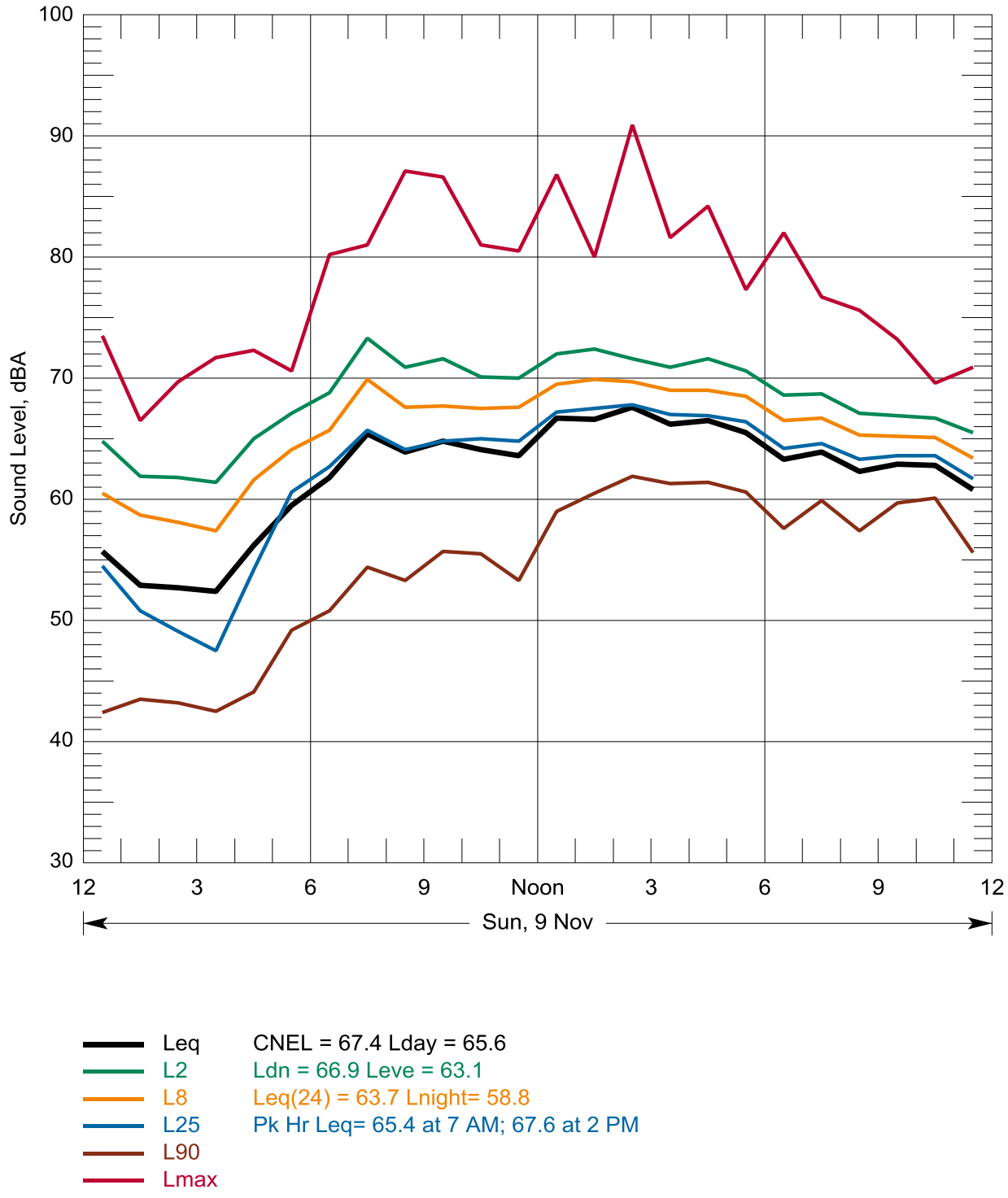

Figure A-27. Hourly Statistical Summary of Noise Levels on Nov 9, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

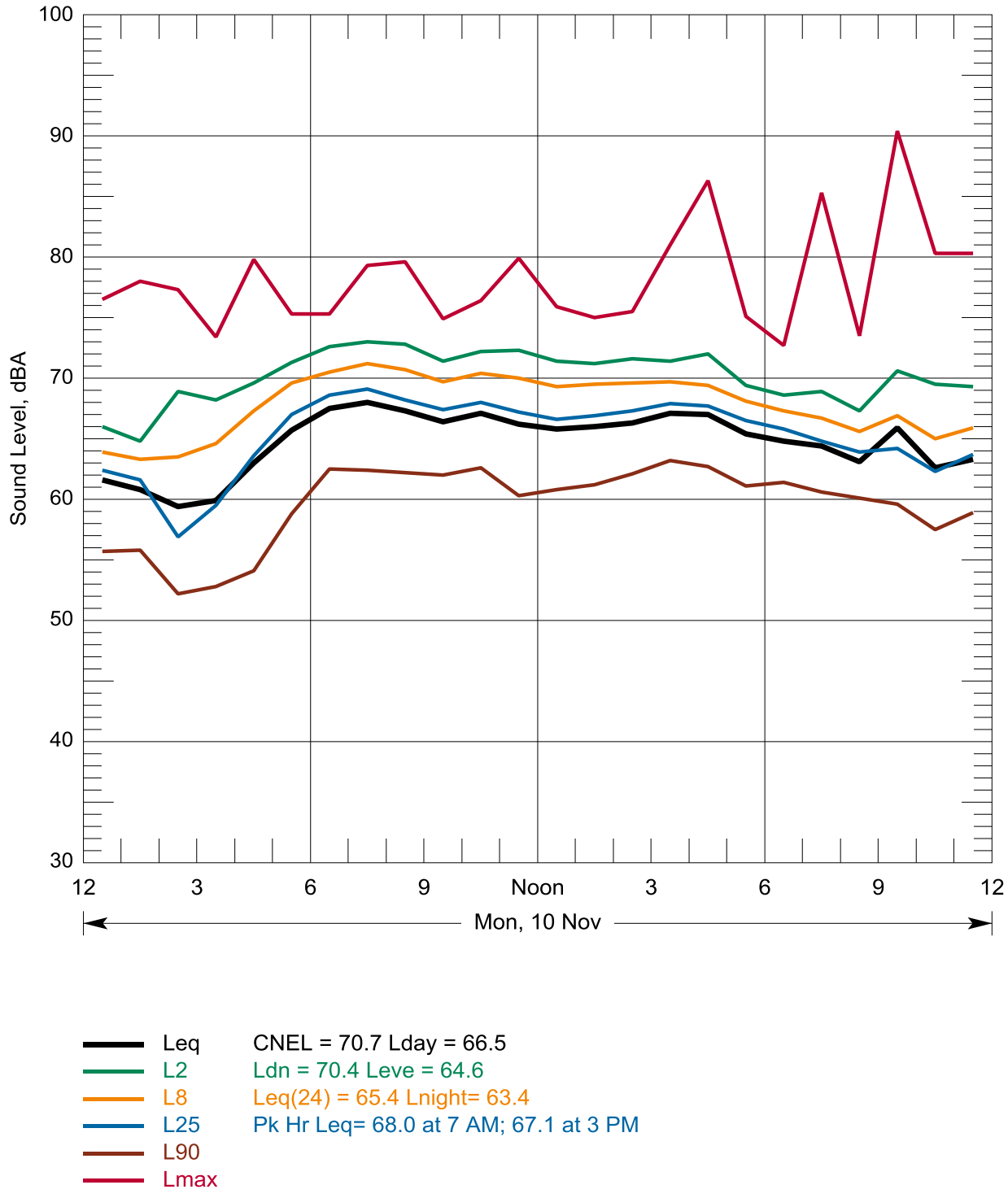

Figure A-28. Hourly Statistical Summary of Noise Levels on Nov 10, 2014 Location N3, 221 Beech Street at Alder St., Longview, WA

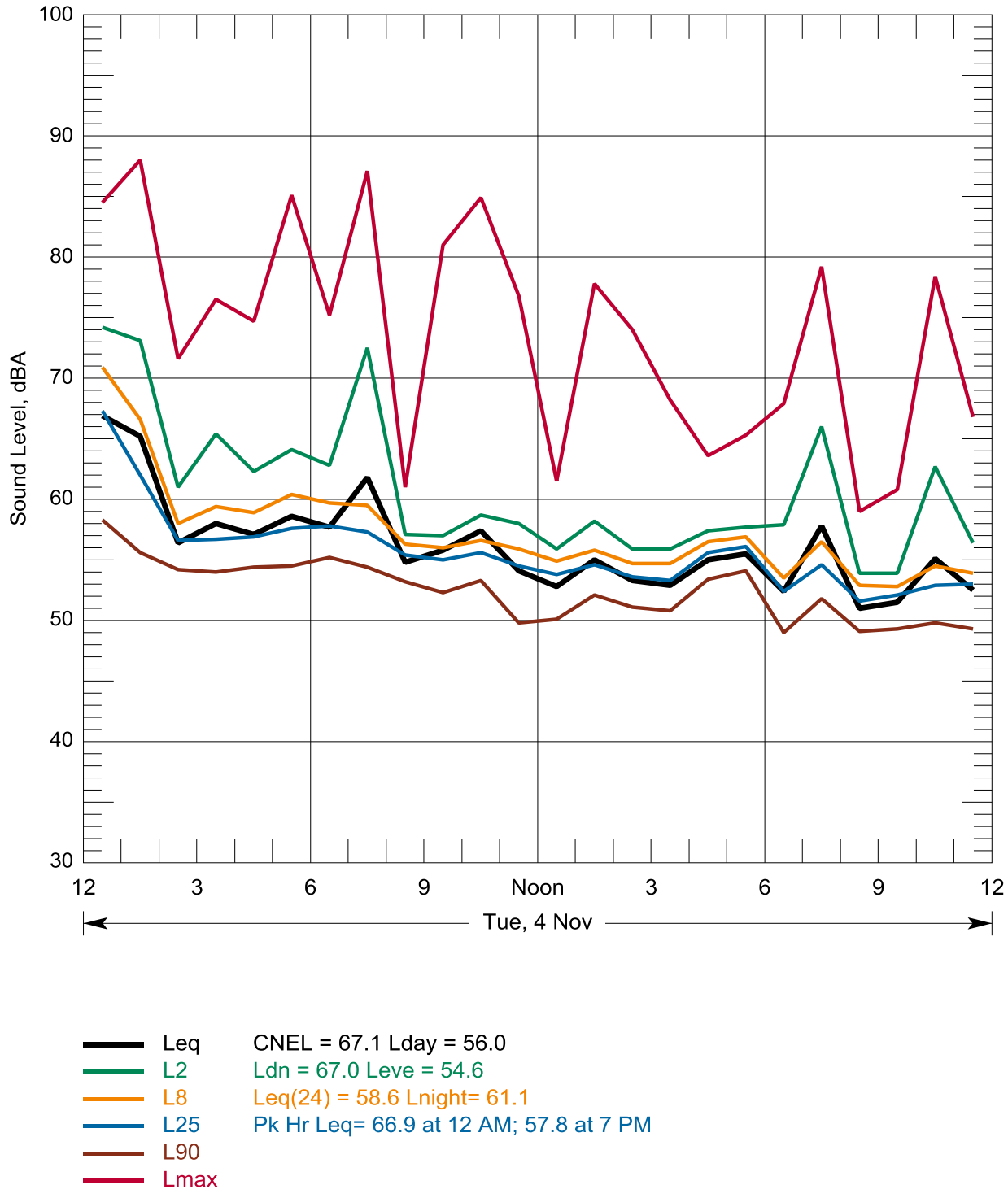

Figure A-29. Hourly Statistical Summary of Noise Levels on Nov 4, 2014 Location N4, 875-34th Avenue, Longview, WA

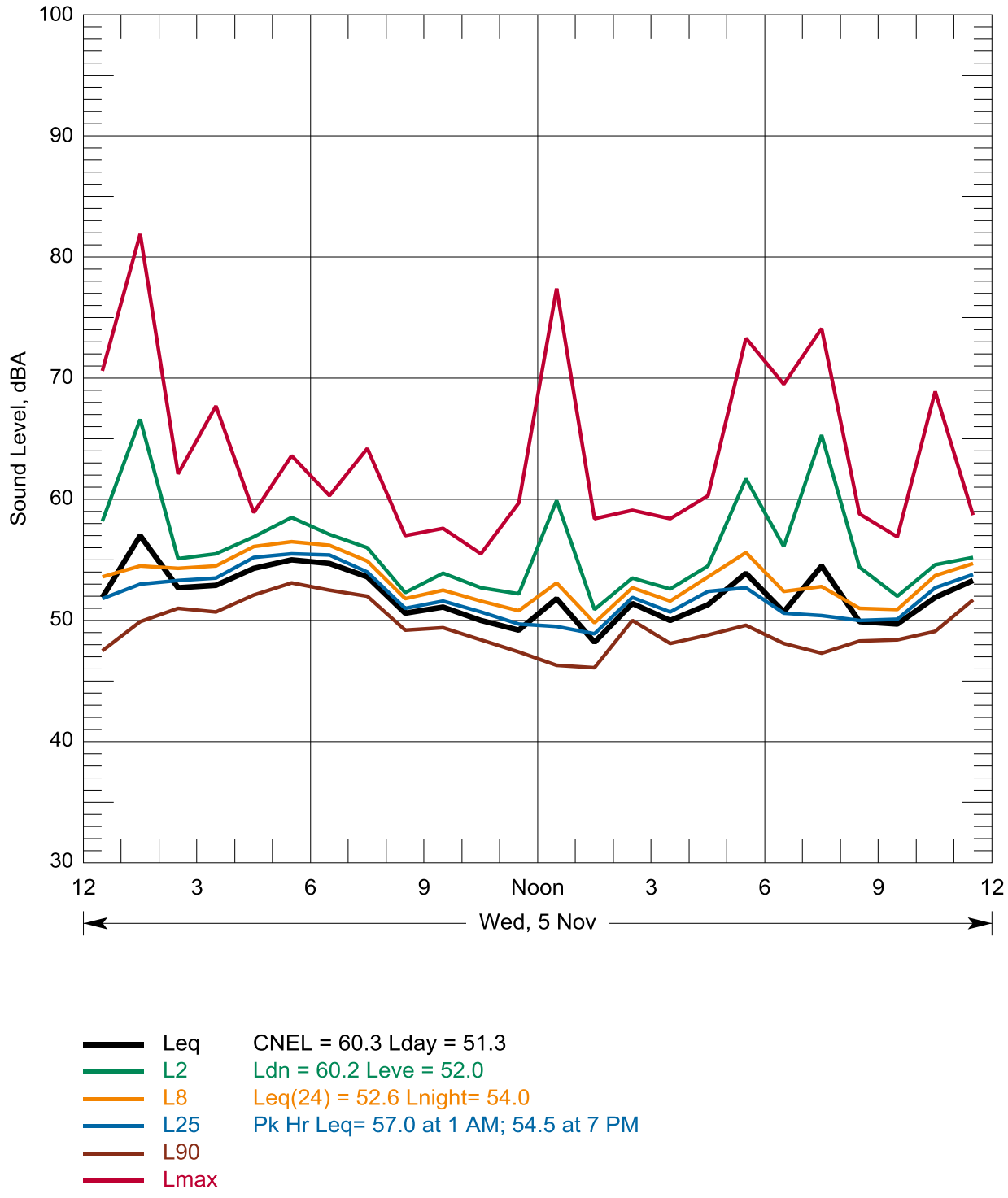

Figure A-30. Hourly Statistical Summary of Noise Levels on Nov 5, 2014 Location N4, 875-34th Avenue, Longview, WA

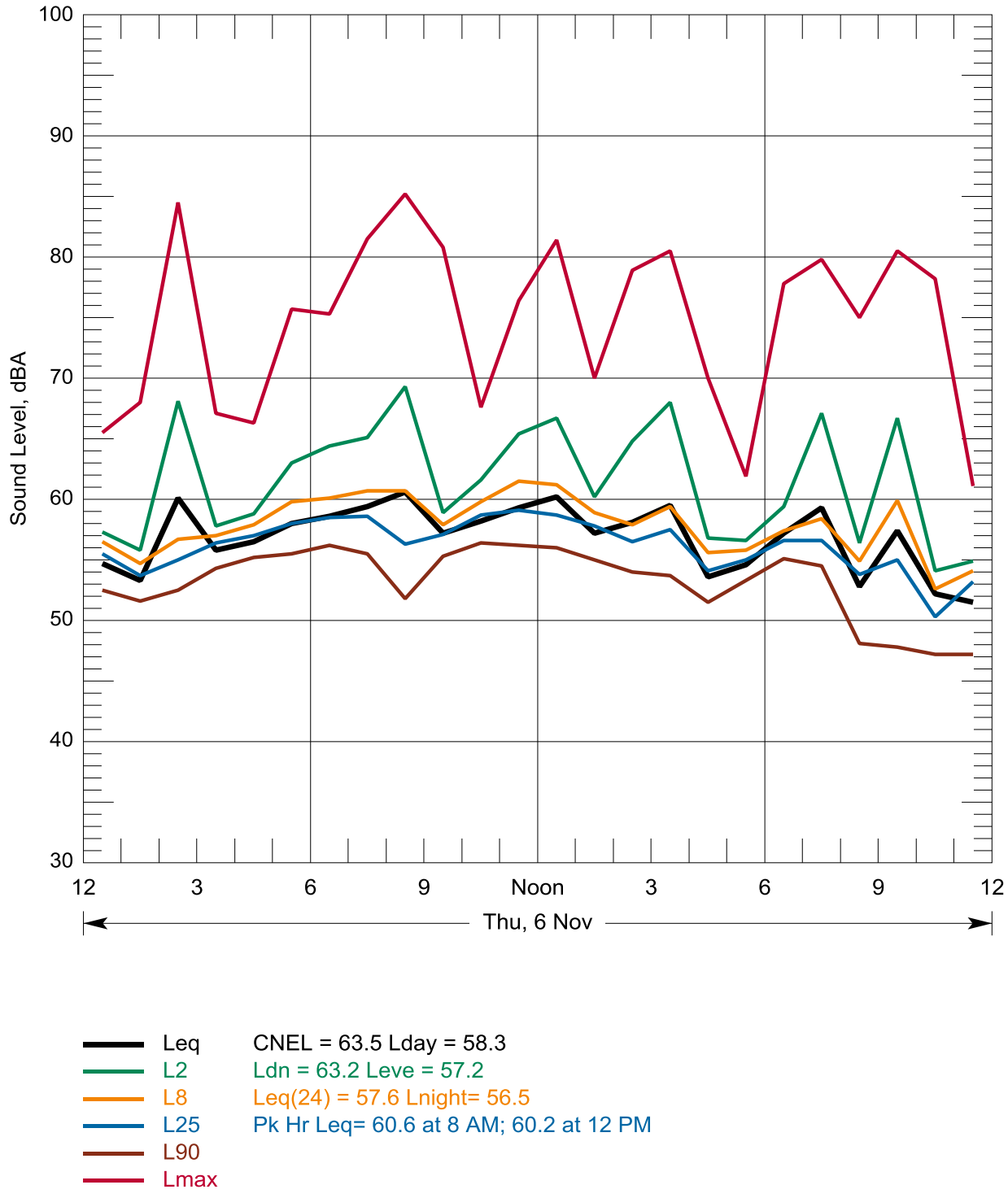

Figure A-31. Hourly Statistical Summary of Noise Levels on Nov 6, 2014 Location N4, 875-34th Avenue, Longview, WA

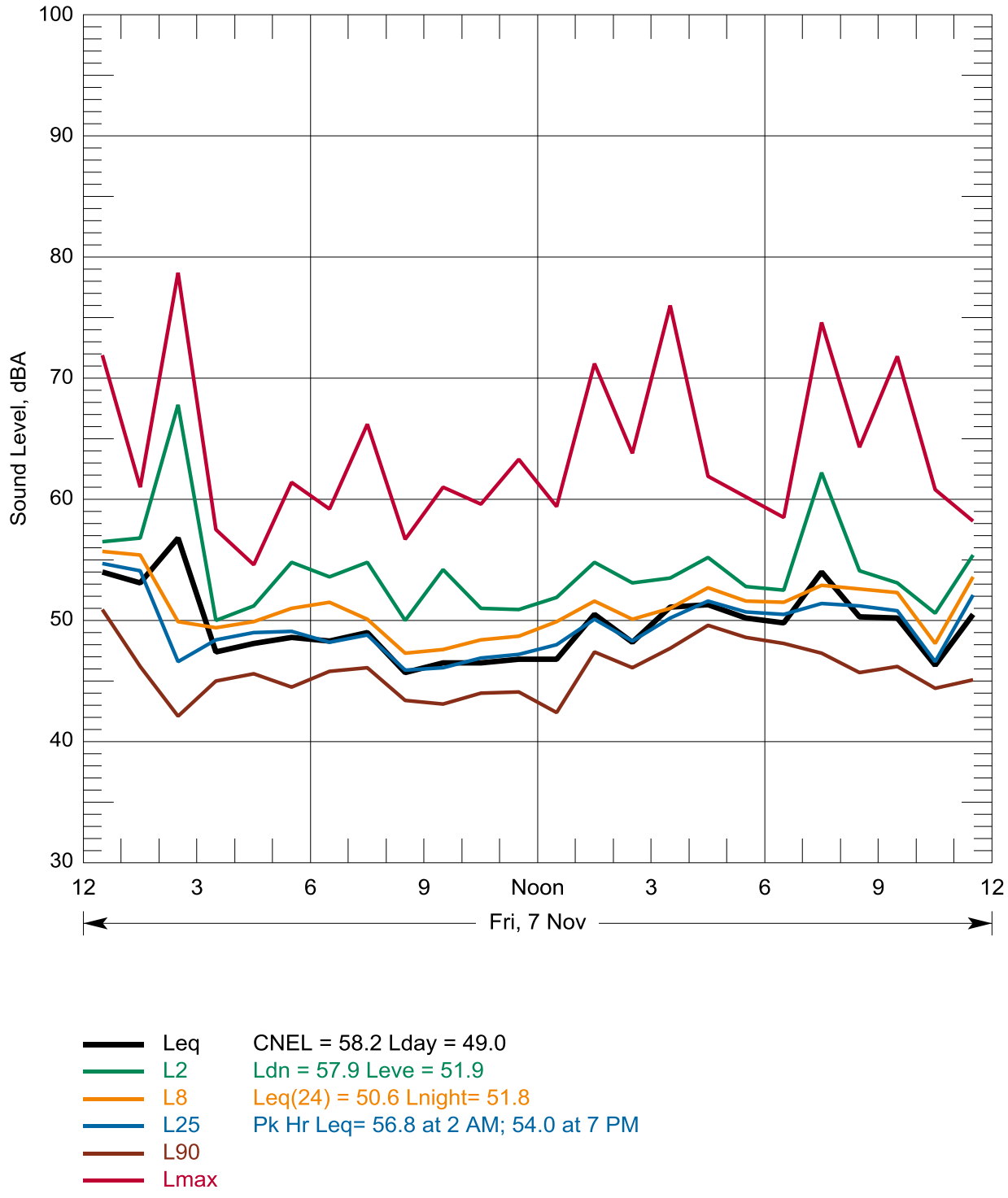

Figure A-32. Hourly Statistical Summary of Noise Levels on Nov 7, 2014 Location N4, 875-34th Avenue, Longview, WA

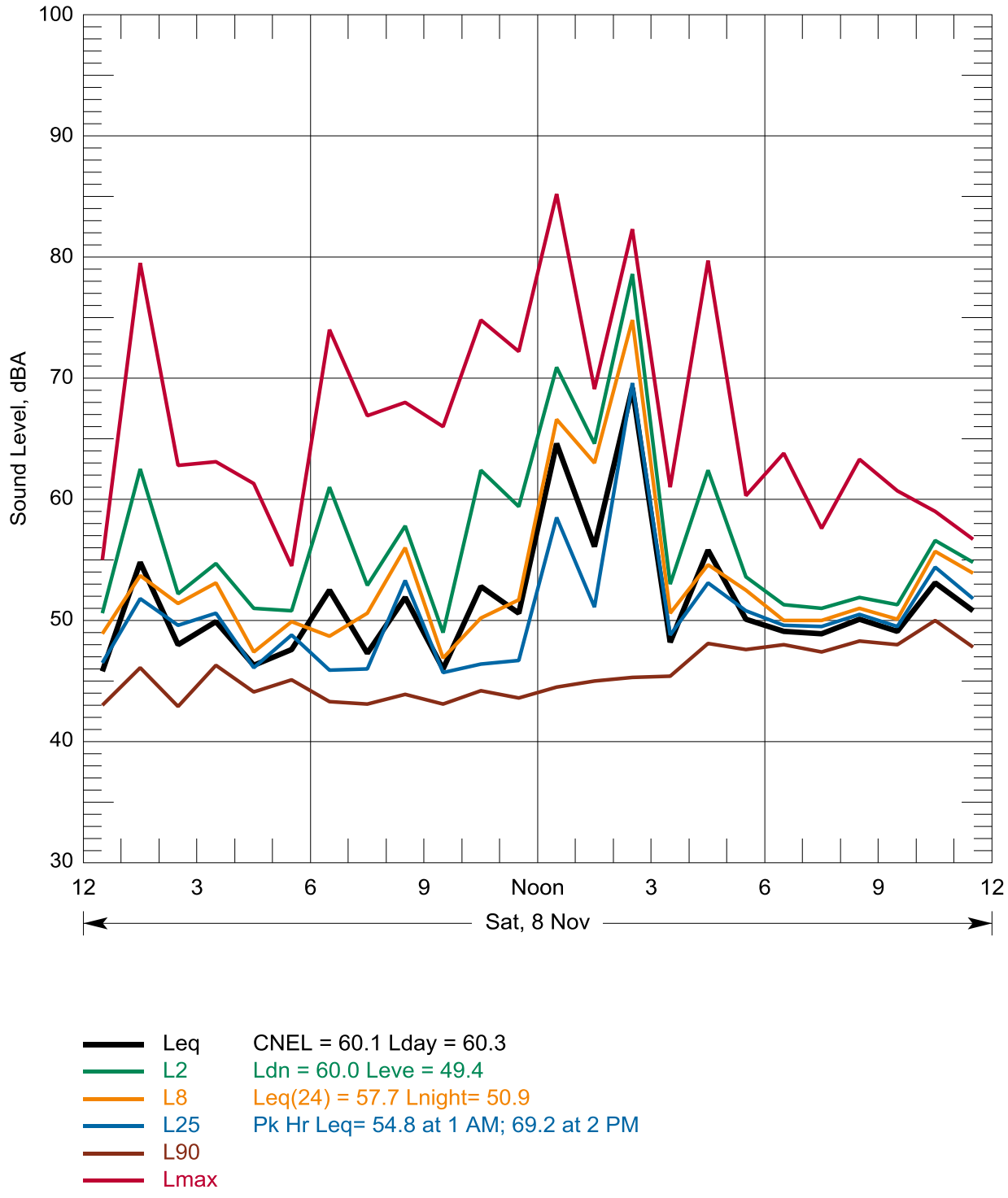

Figure A-33. Hourly Statistical Summary of Noise Levels on Nov 8, 2014 Location N4, 875-34th Avenue, Longview, WA

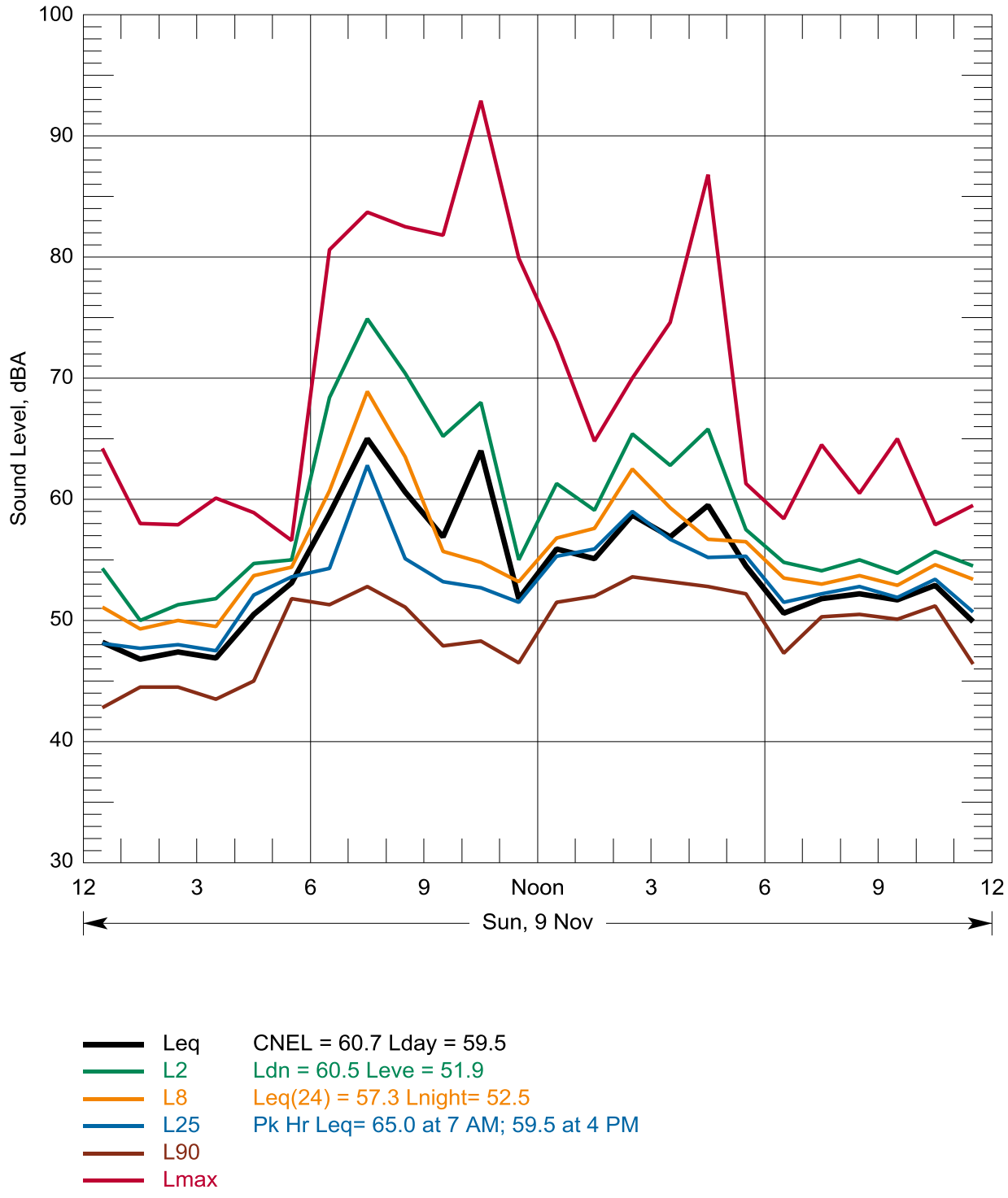

Figure A-34. Hourly Statistical Summary of Noise Levels on Nov 9, 2014 Location N4, 875-34th Avenue, Longview, WA

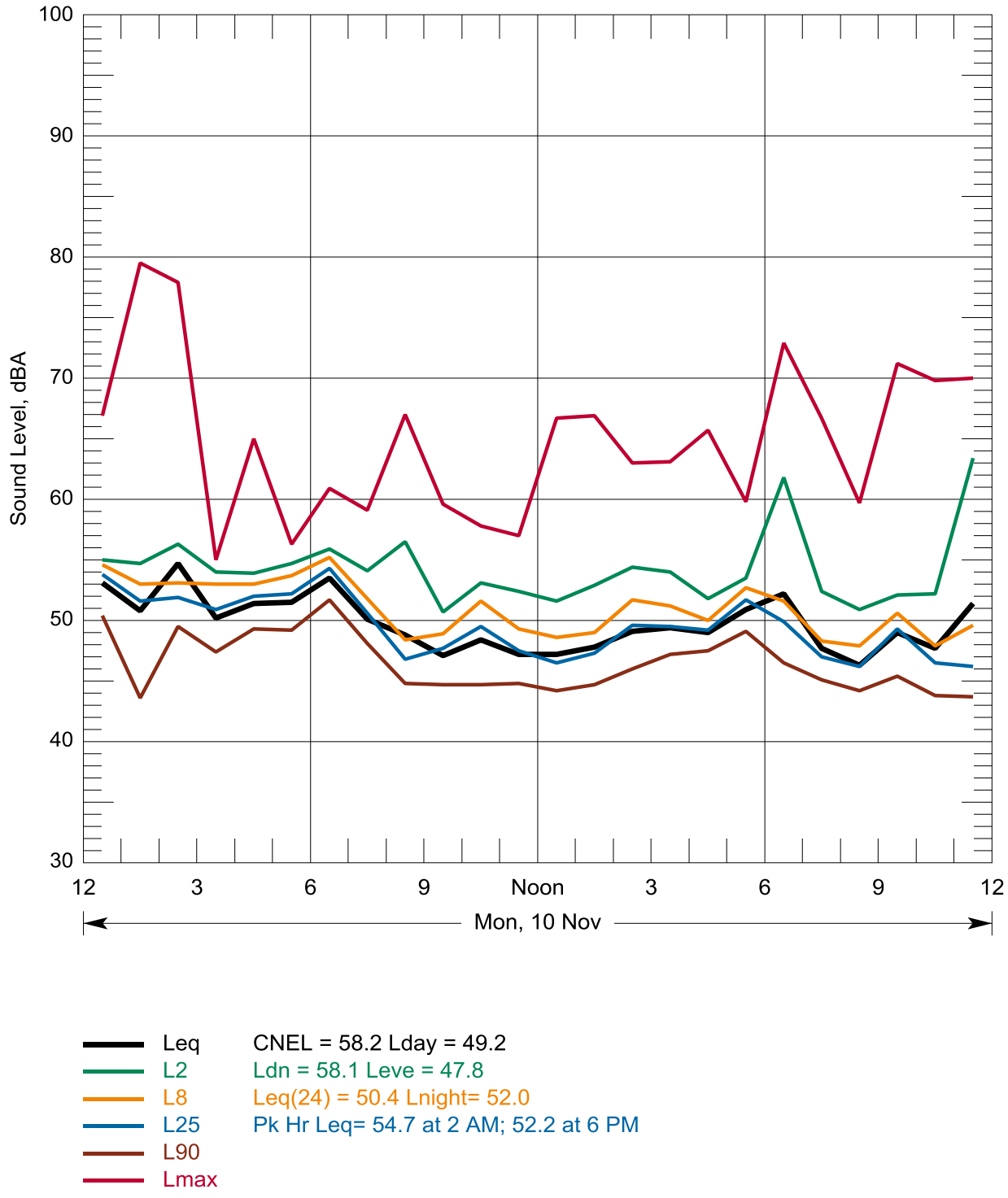

Figure A-35. Hourly Statistical Summary of Noise Levels on Nov 10, 2014 Location N4, 875-34th Avenue, Longview, WA

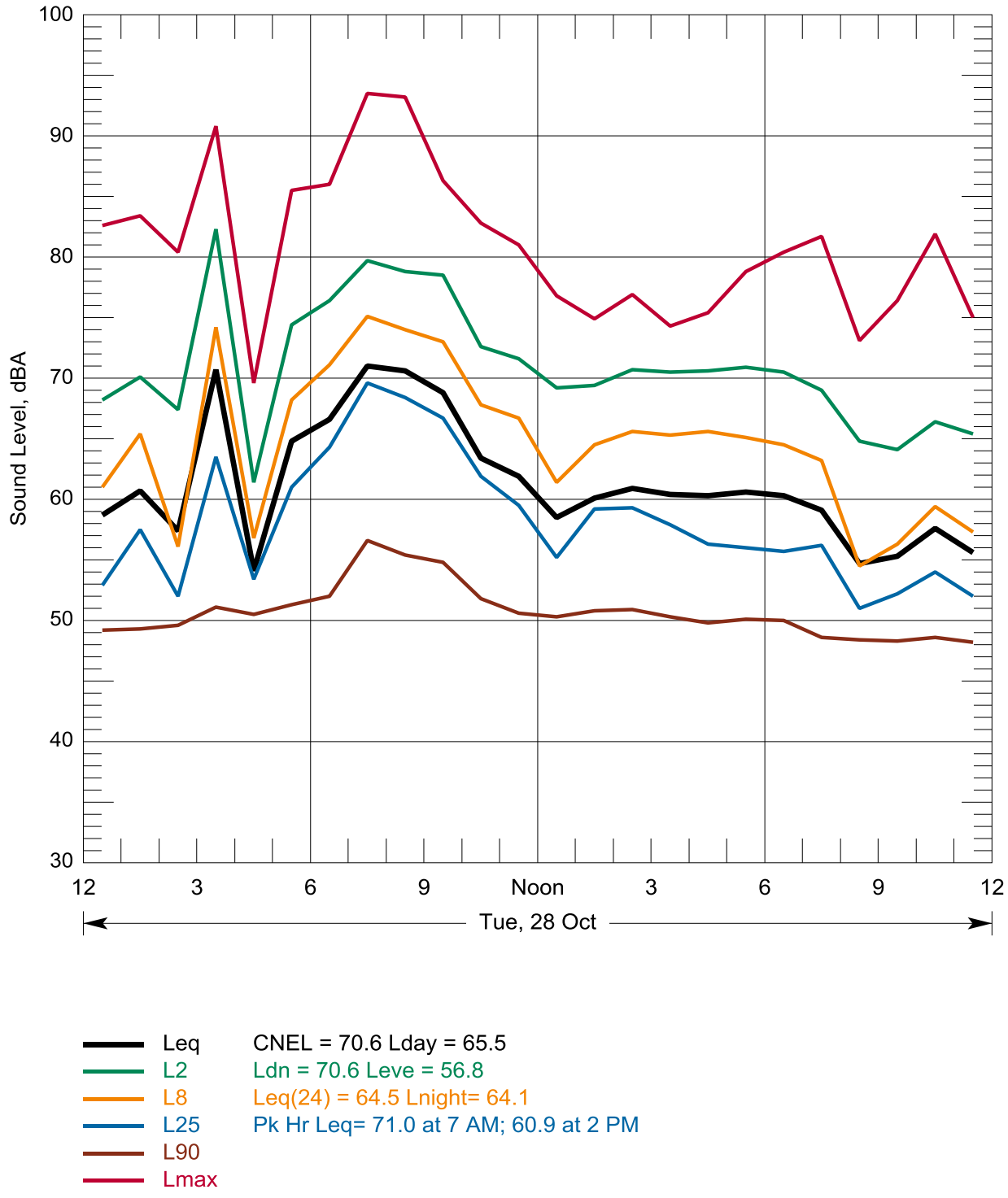

Figure A-36. Hourly Statistical Summary of Noise Levels on Oct 28, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

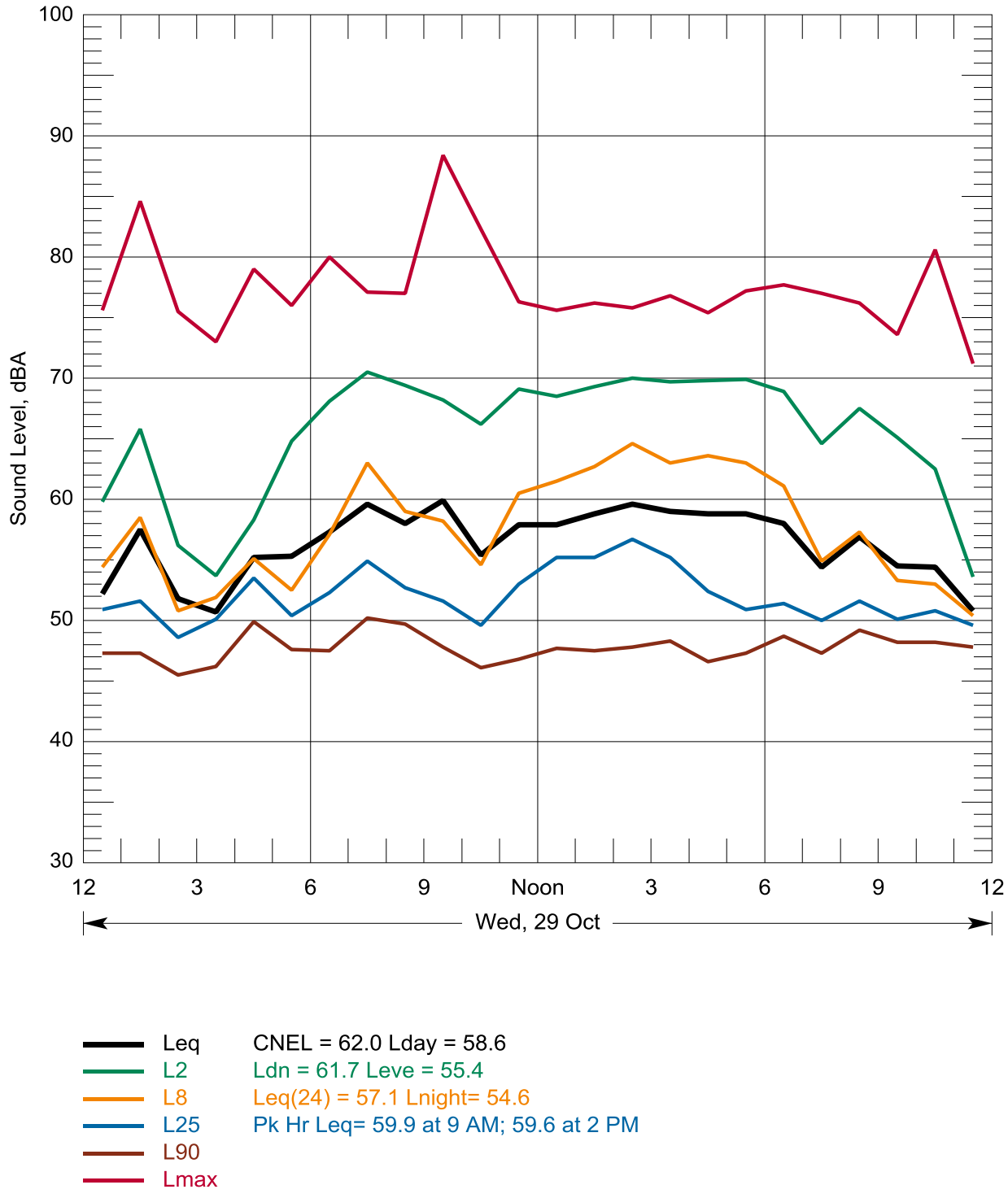

Figure A-37. Hourly Statistical Summary of Noise Levels on Oct 29, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

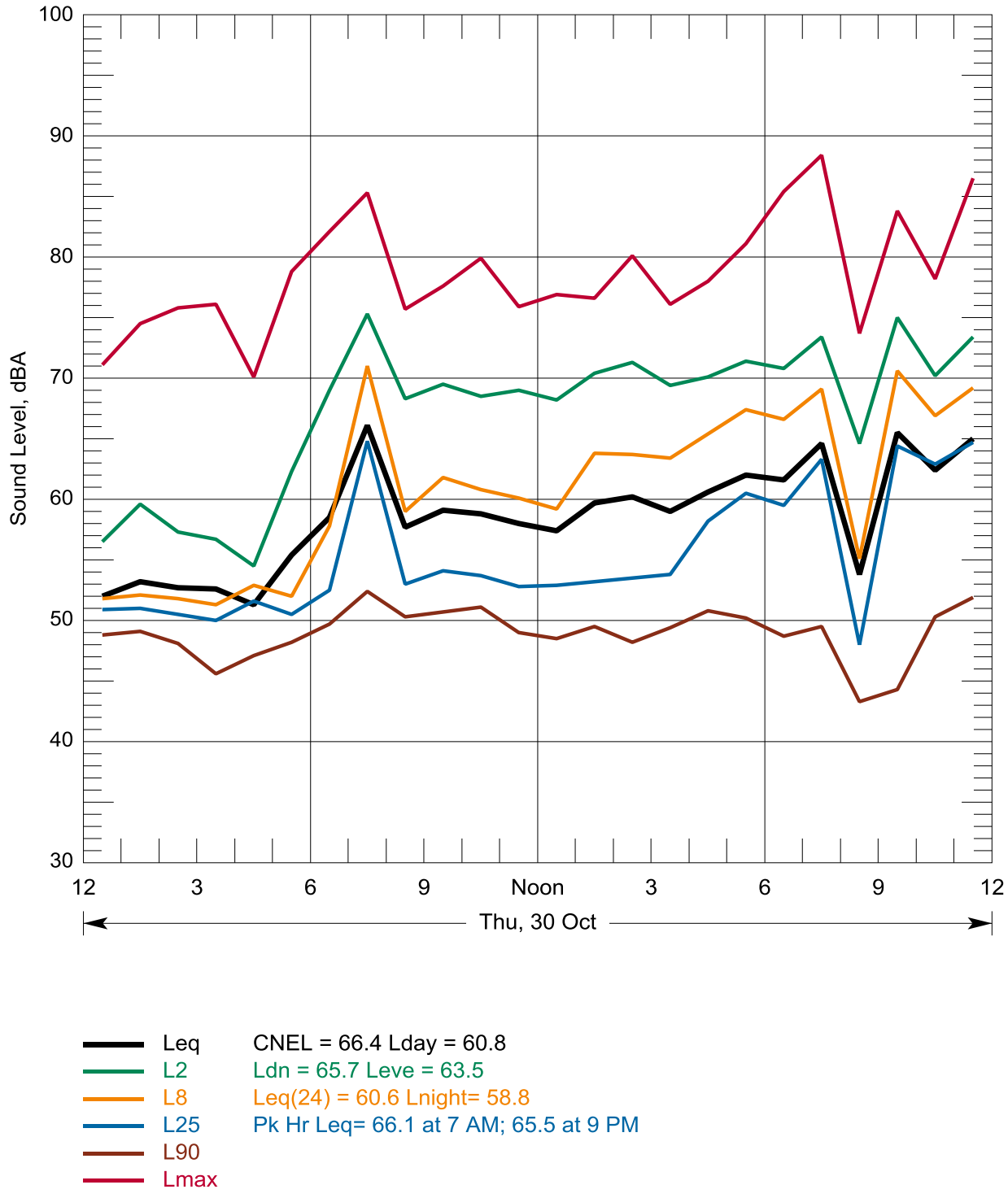

Figure A-38. Hourly Statistical Summary of Noise Levels on Oct 30, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

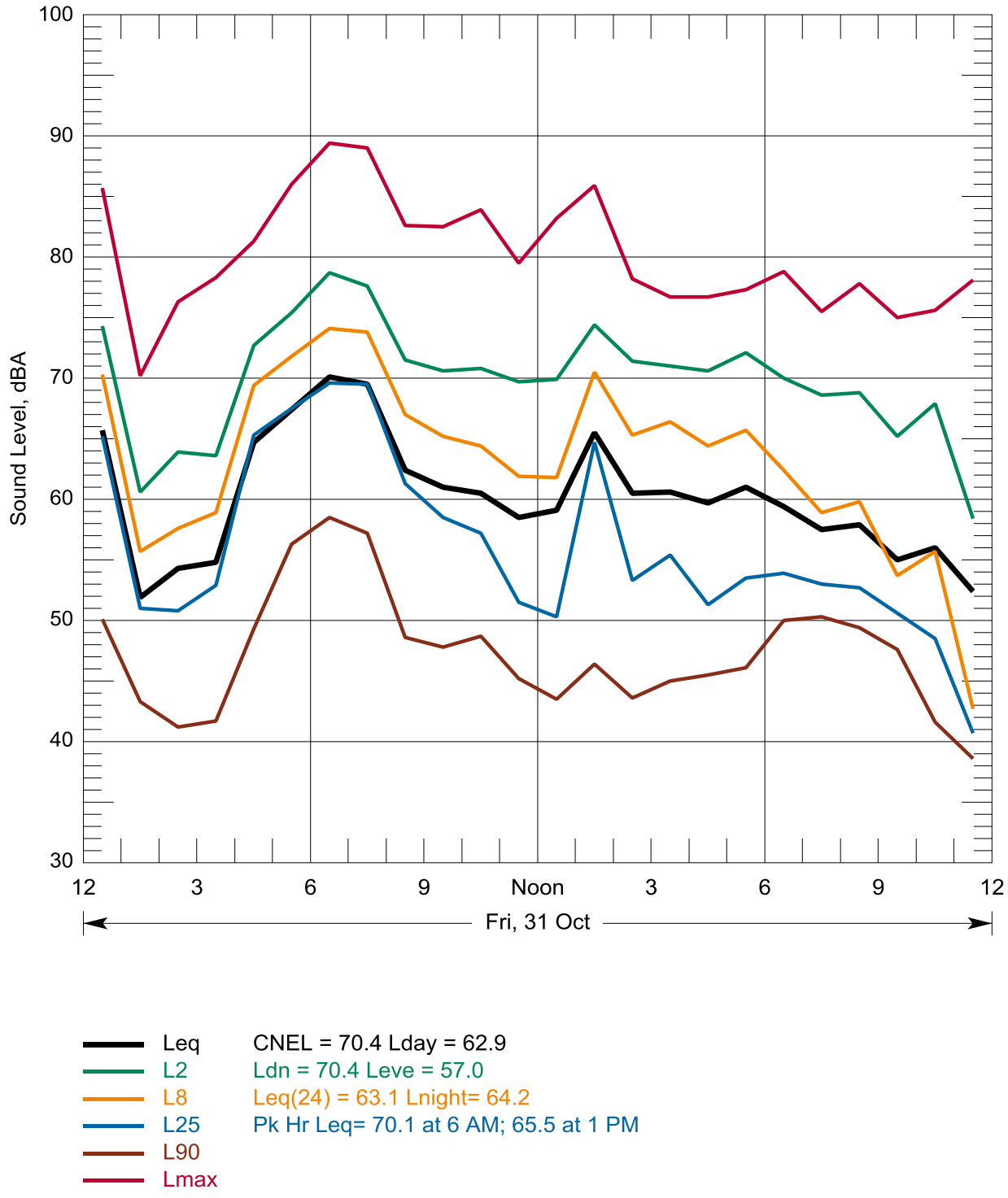

Figure A-39. Hourly Statistical Summary of Noise Levels on Oct 31, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

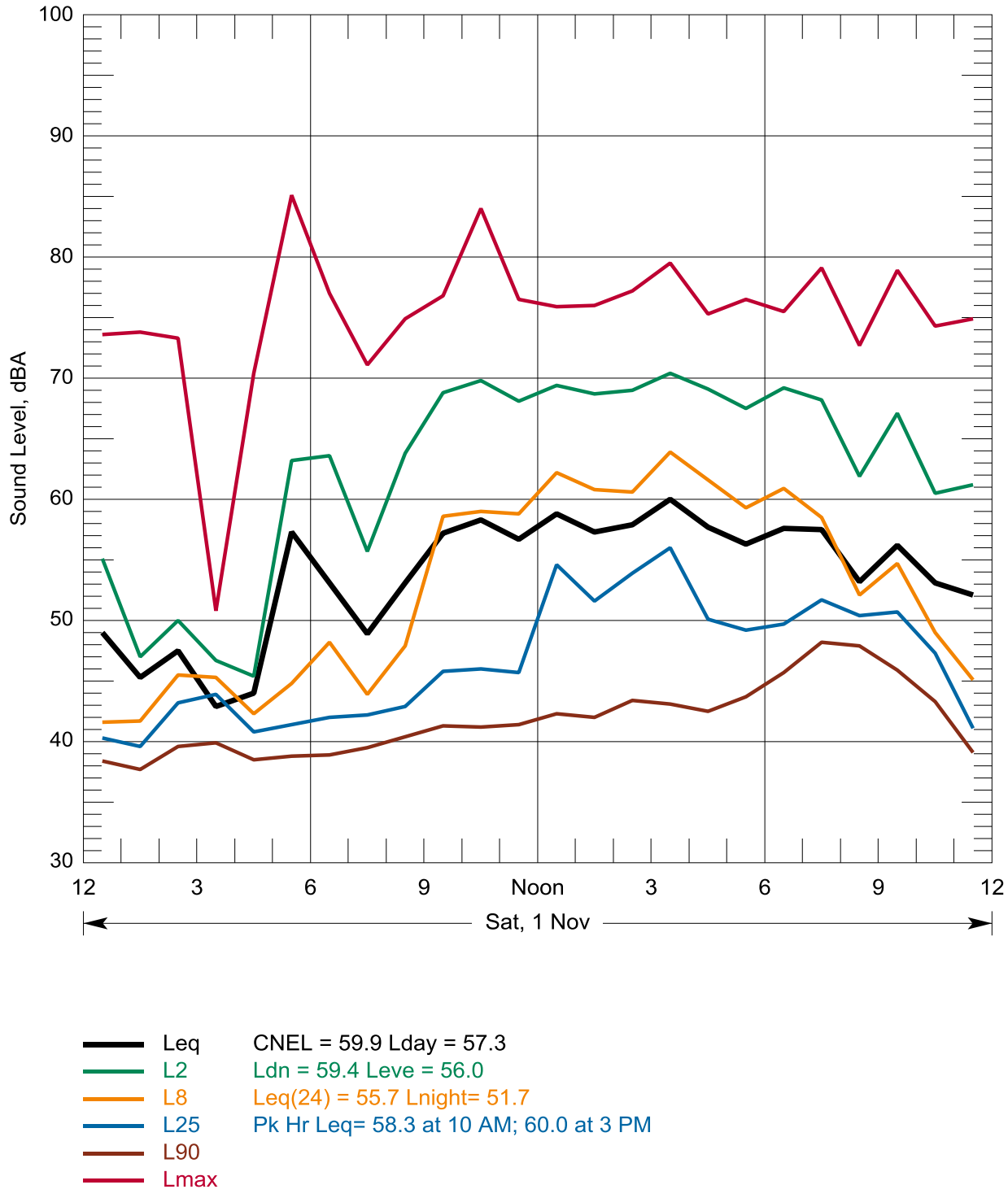

Figure A-40. Hourly Statistical Summary of Noise Levels on Nov 1, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

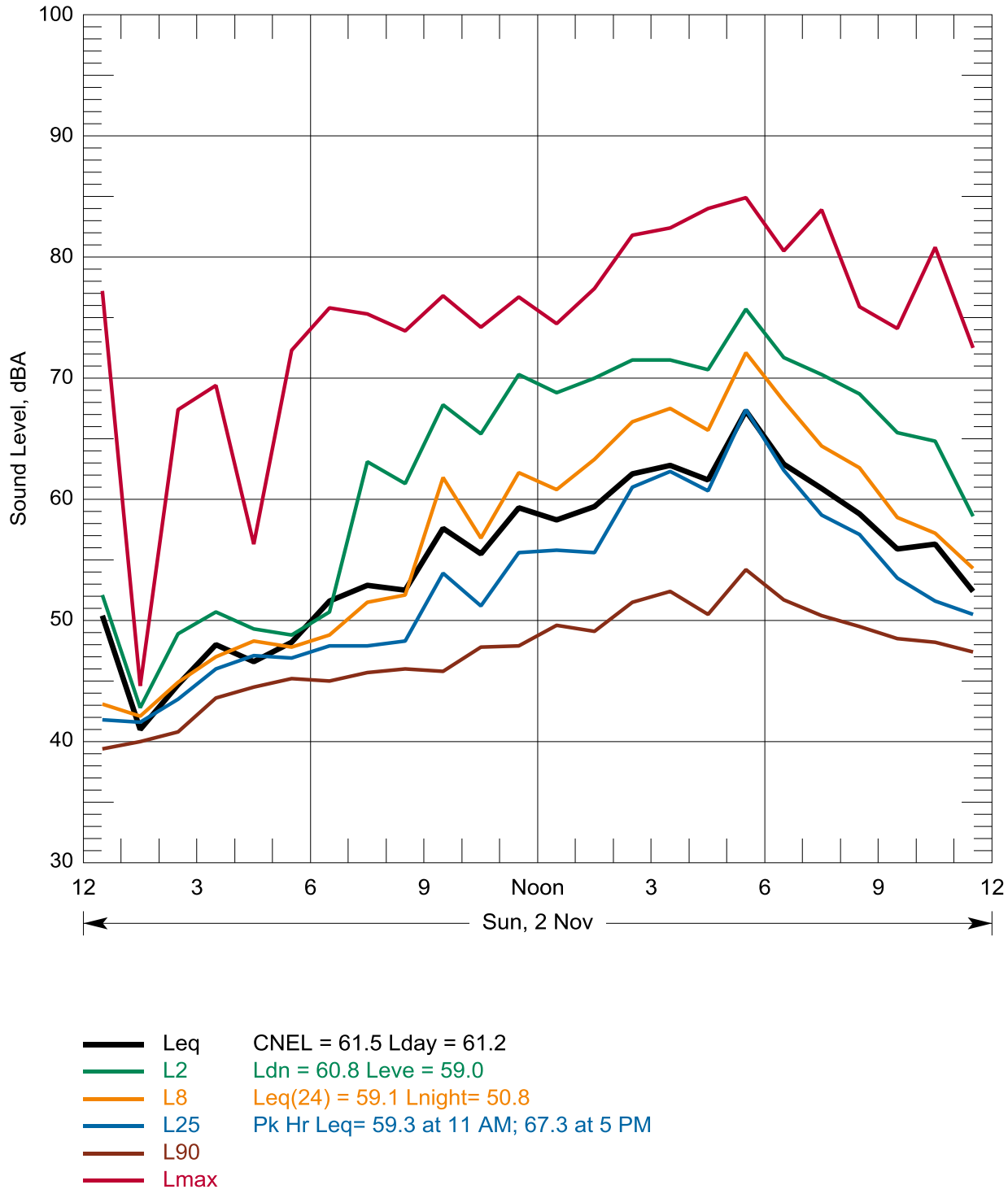

Figure A-41. Hourly Statistical Summary of Noise Levels on Nov 2, 2014 Location N5, 3600 Memorial Park Drive, Longview, WA

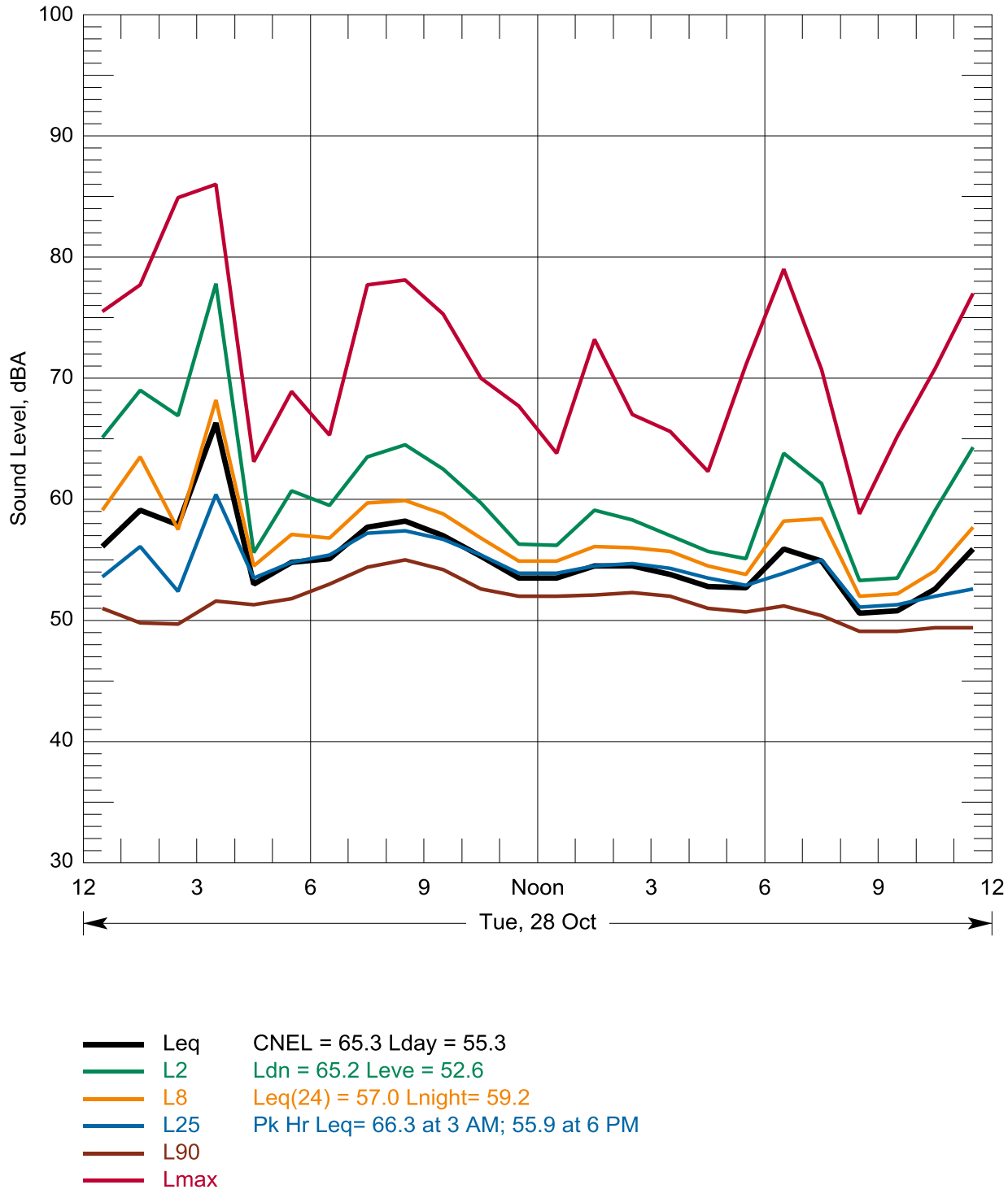

Figure A-42. Hourly Statistical Summary of Noise Levels on Oct 28, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

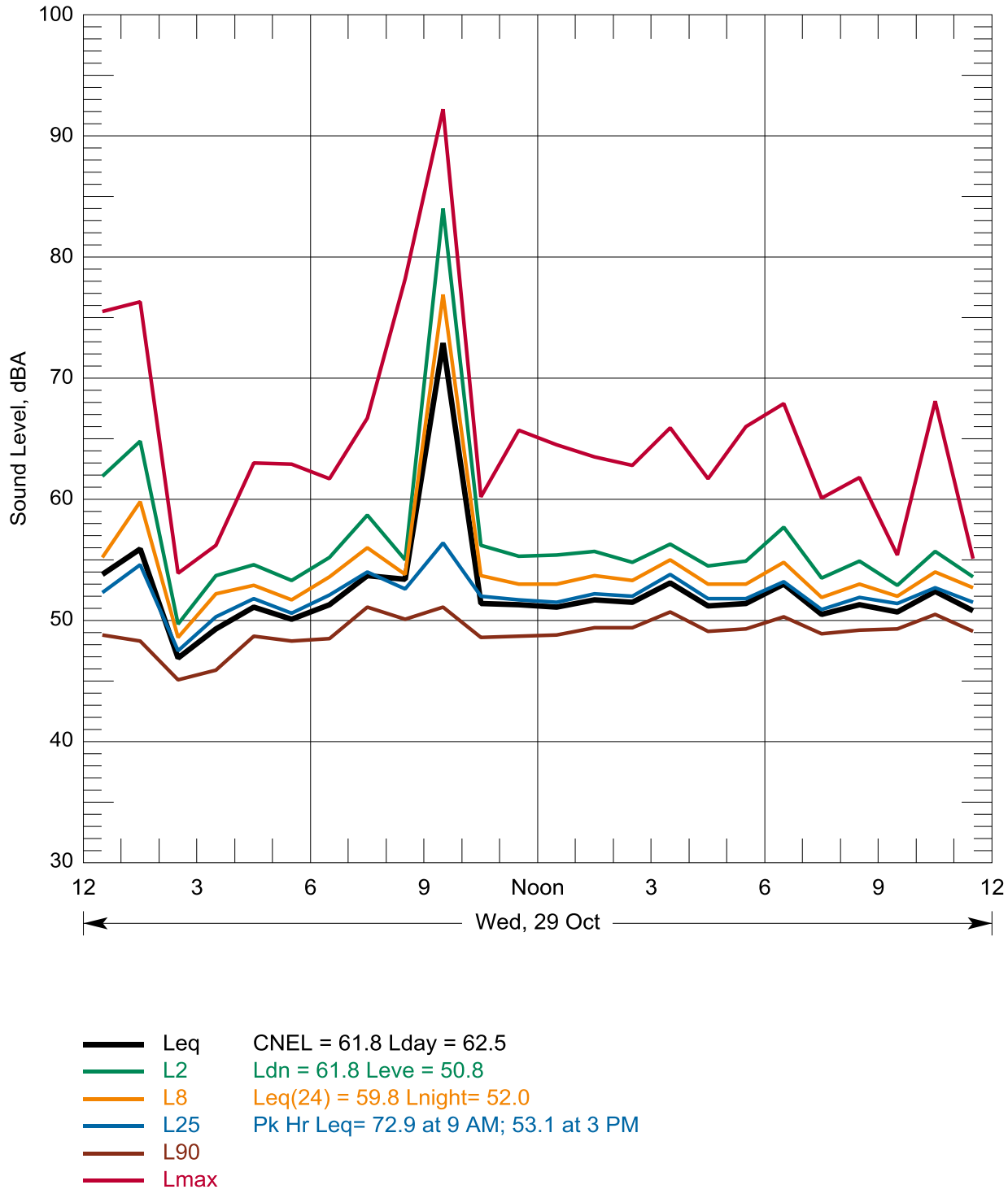

Figure A-43. Hourly Statistical Summary of Noise Levels on Oct 29, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

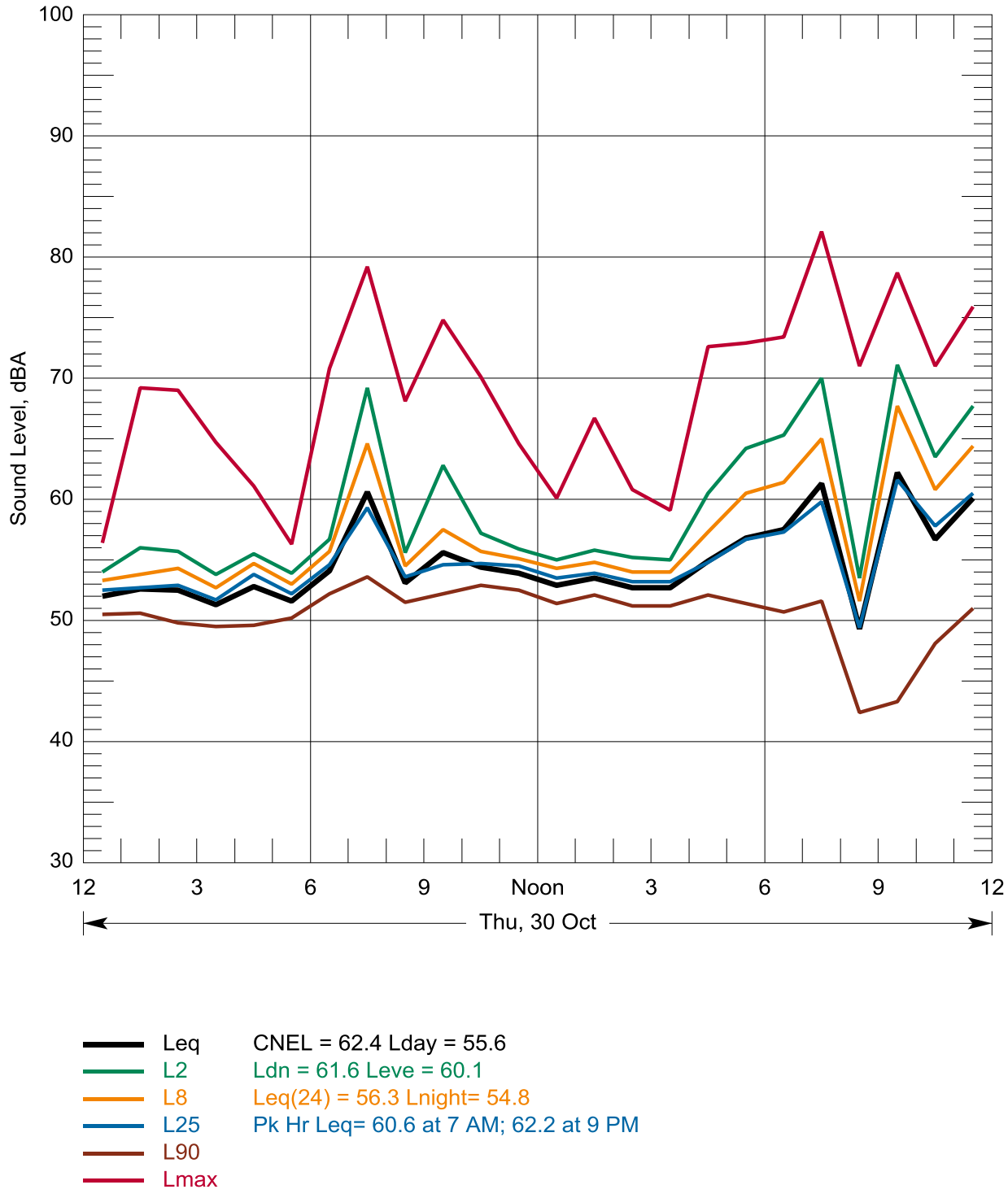

Figure A-44. Hourly Statistical Summary of Noise Levels on Oct 30, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

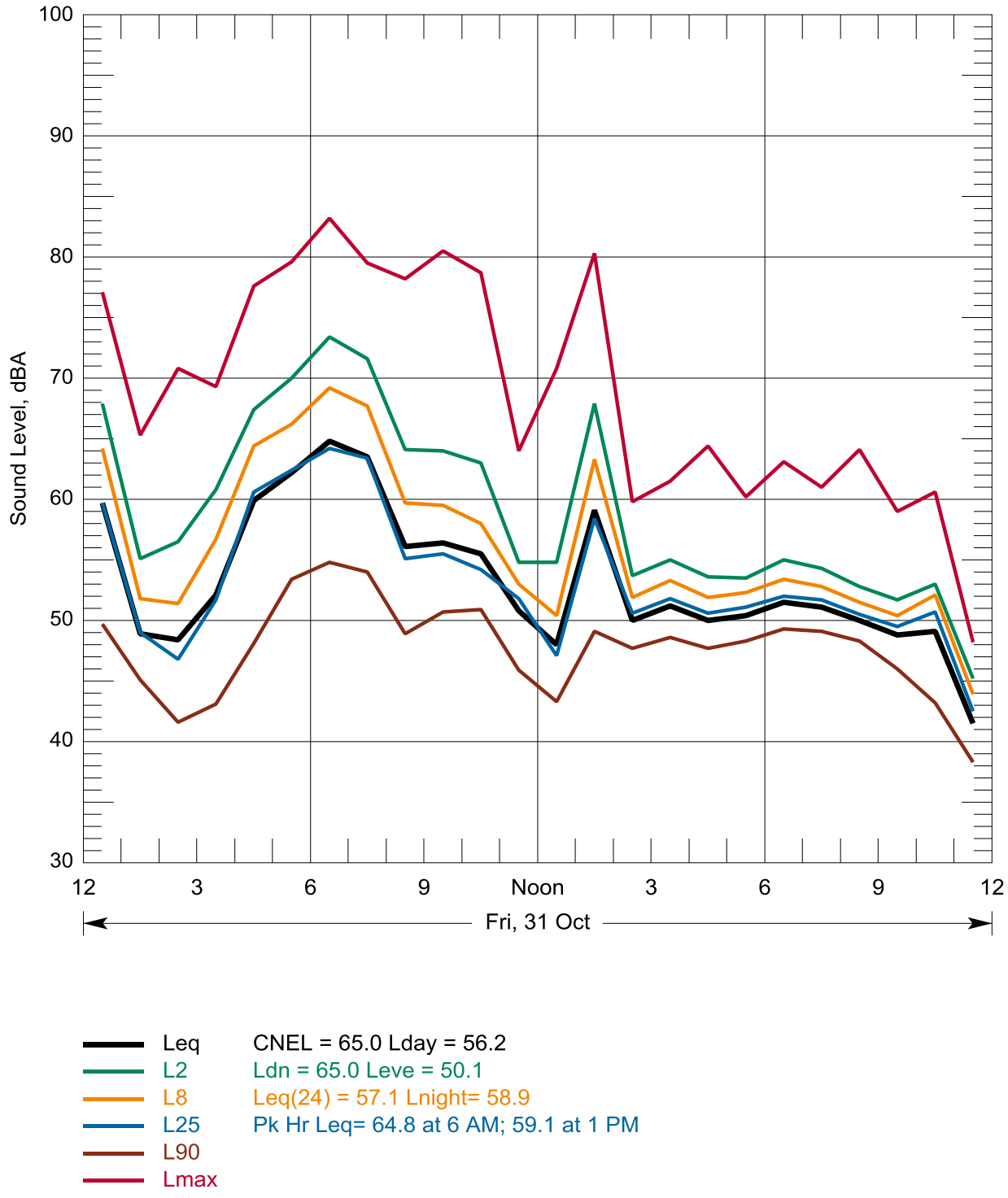

Figure A-45. Hourly Statistical Summary of Noise Levels on Oct 31, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

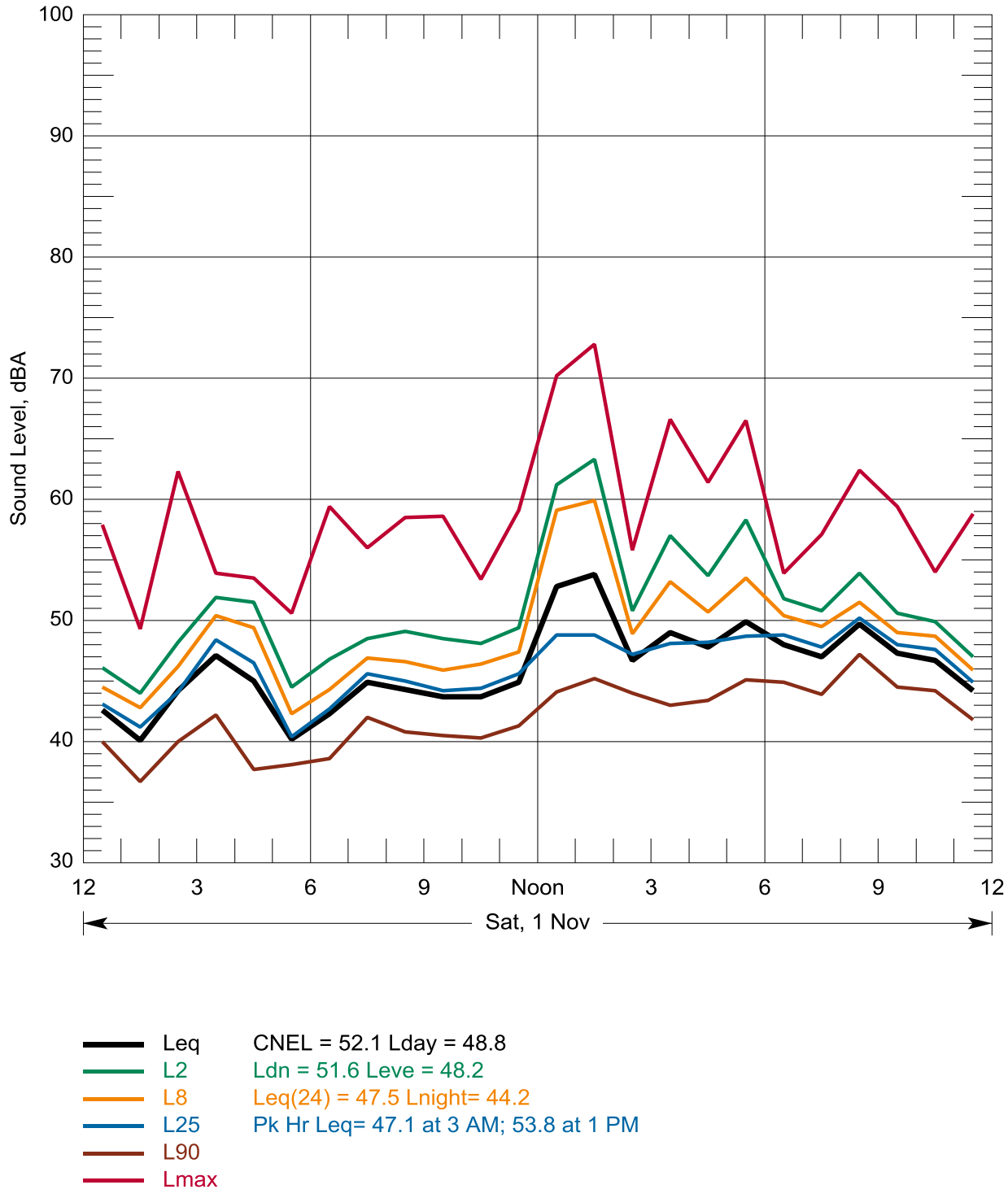

Figure A-46. Hourly Statistical Summary of Noise Levels on Nov 1, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

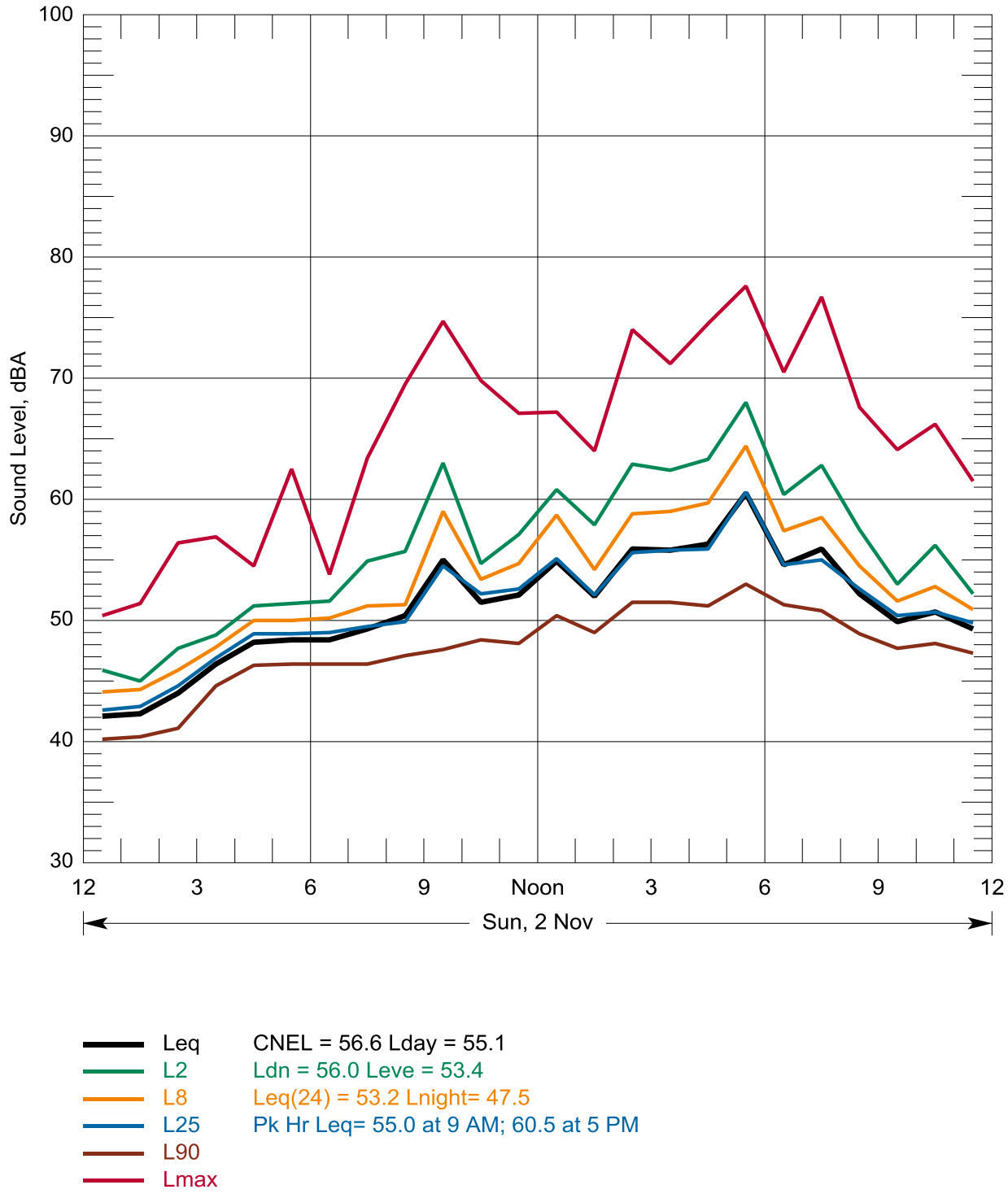

Figure A-47. Hourly Statistical Summary of Noise Levels on Nov 2, 2014 Location N6, 420 Rutherglen Drive, Longview, WA

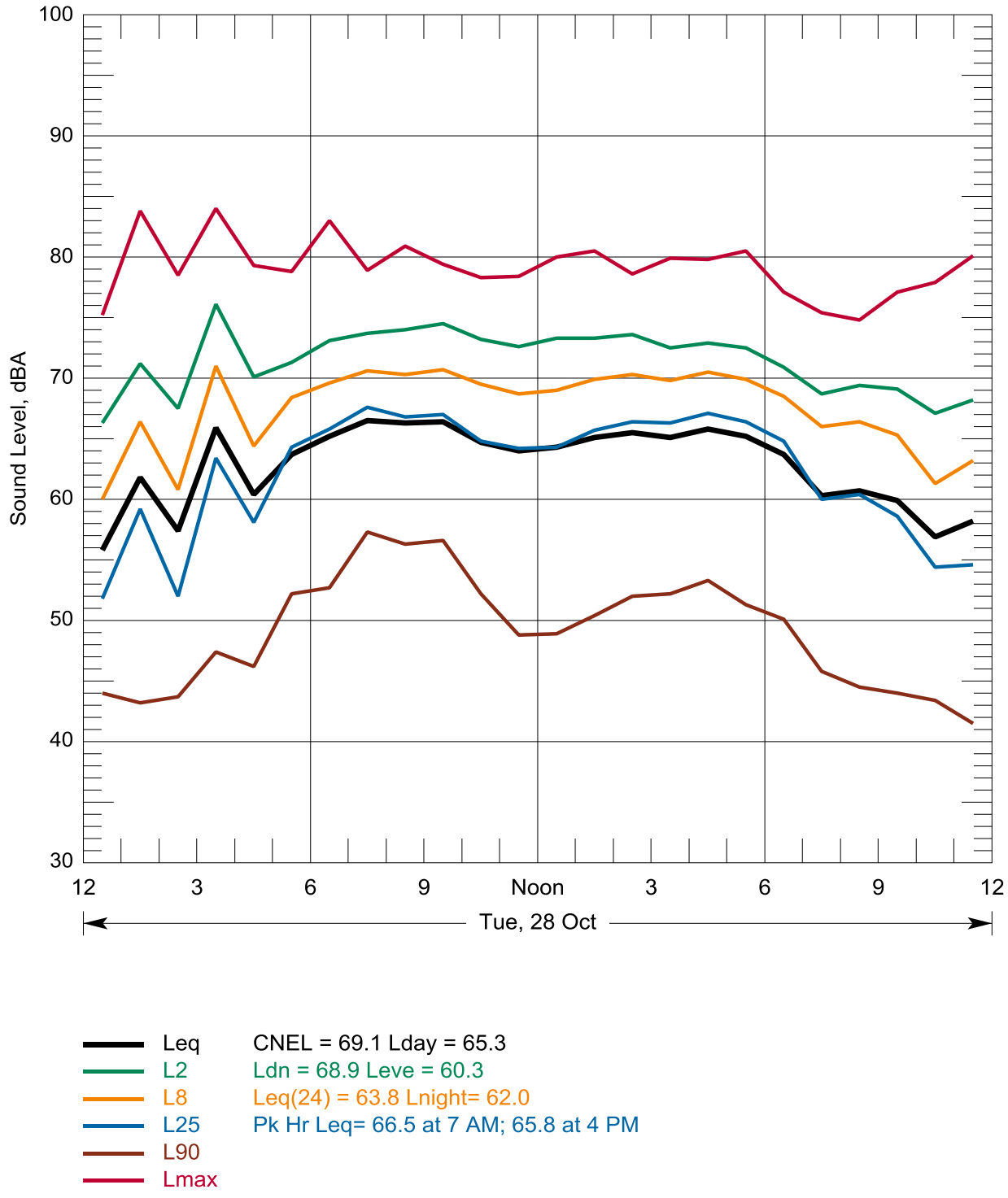

Figure A-48. Hourly Statistical Summary of Noise Levels on Oct 28, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

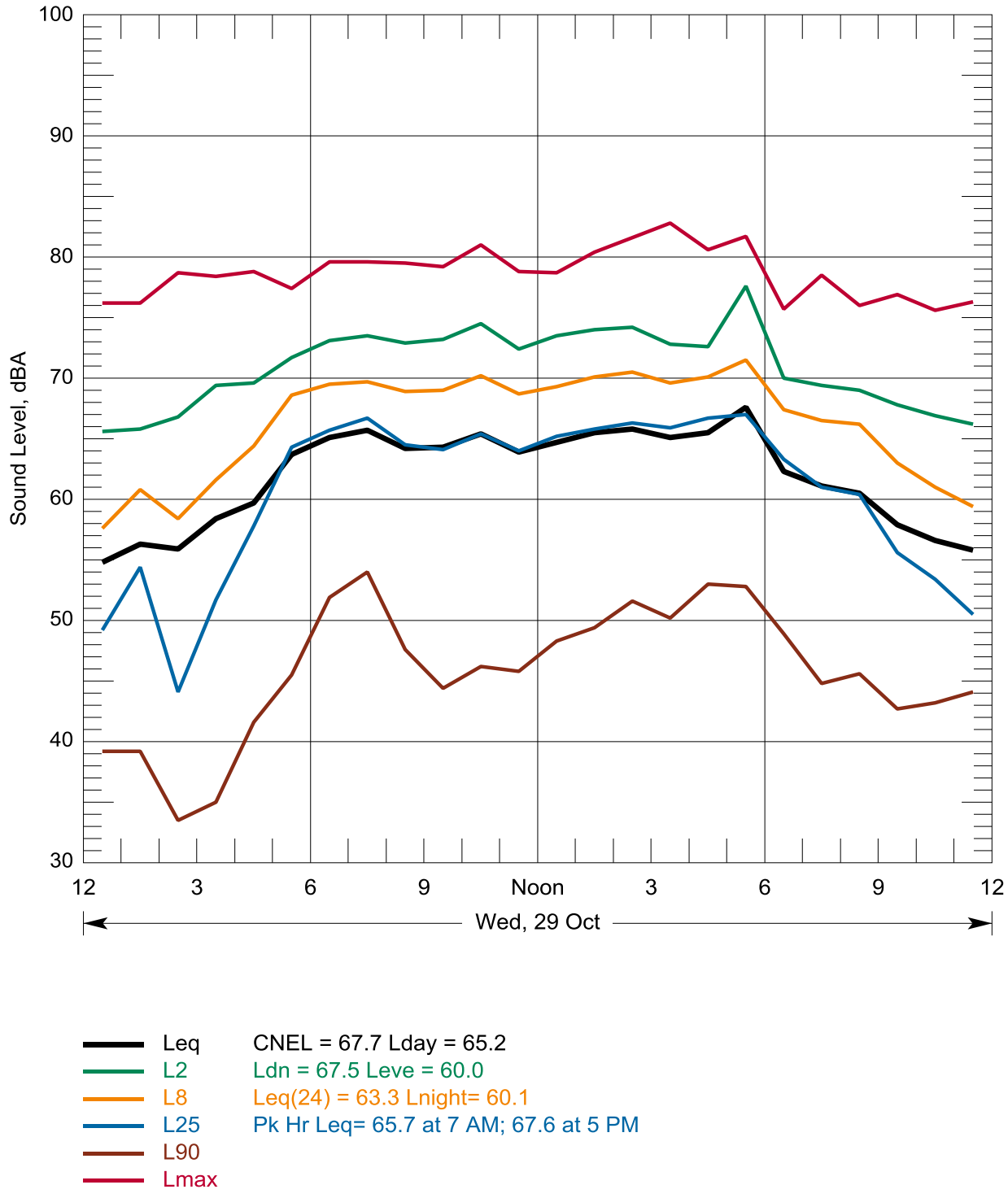

Figure A-49. Hourly Statistical Summary of Noise Levels on Oct 29, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

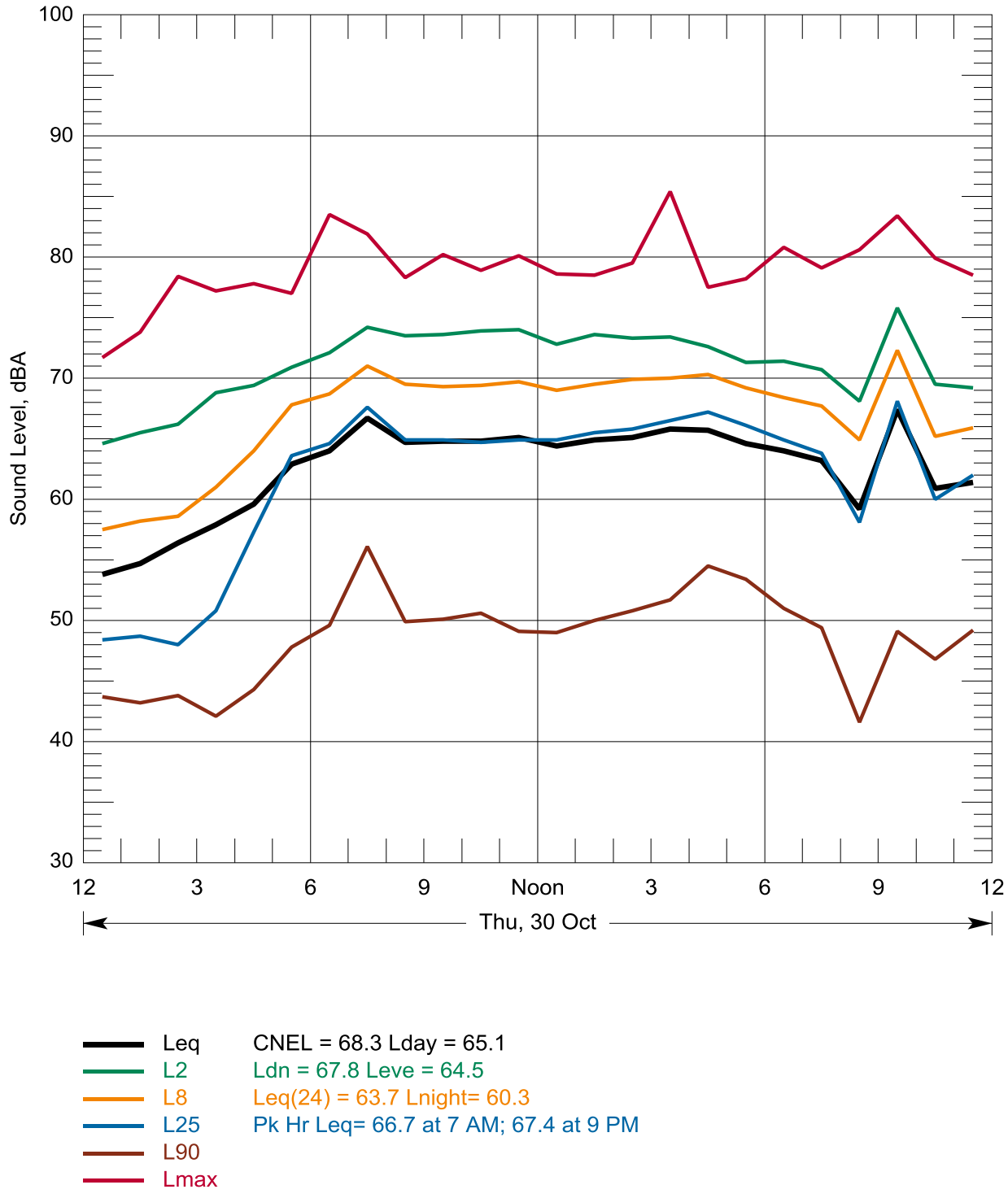

Figure A-50. Hourly Statistical Summary of Noise Levels on Oct 30, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

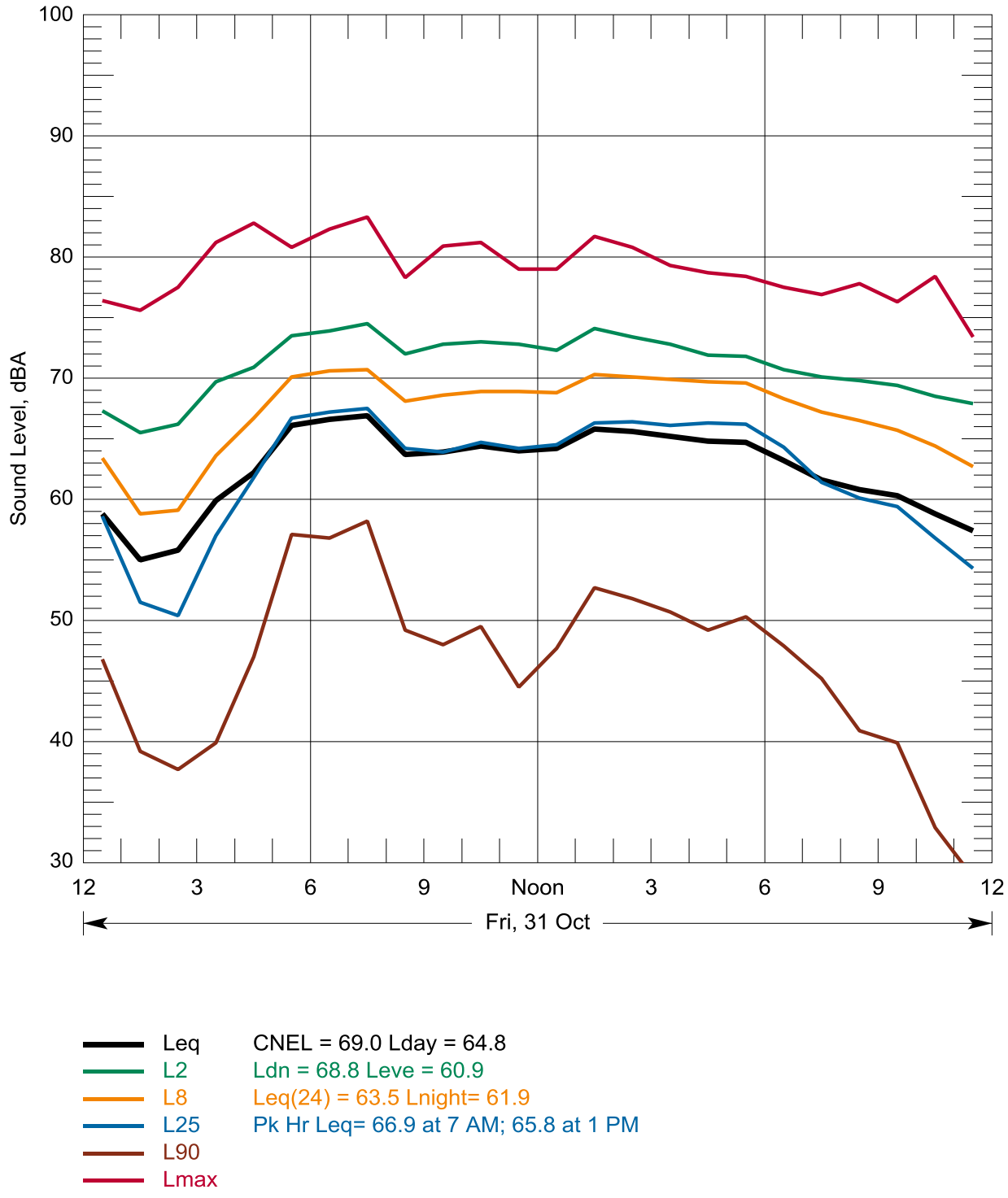

Figure A-51. Hourly Statistical Summary of Noise Levels on Oct 31, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

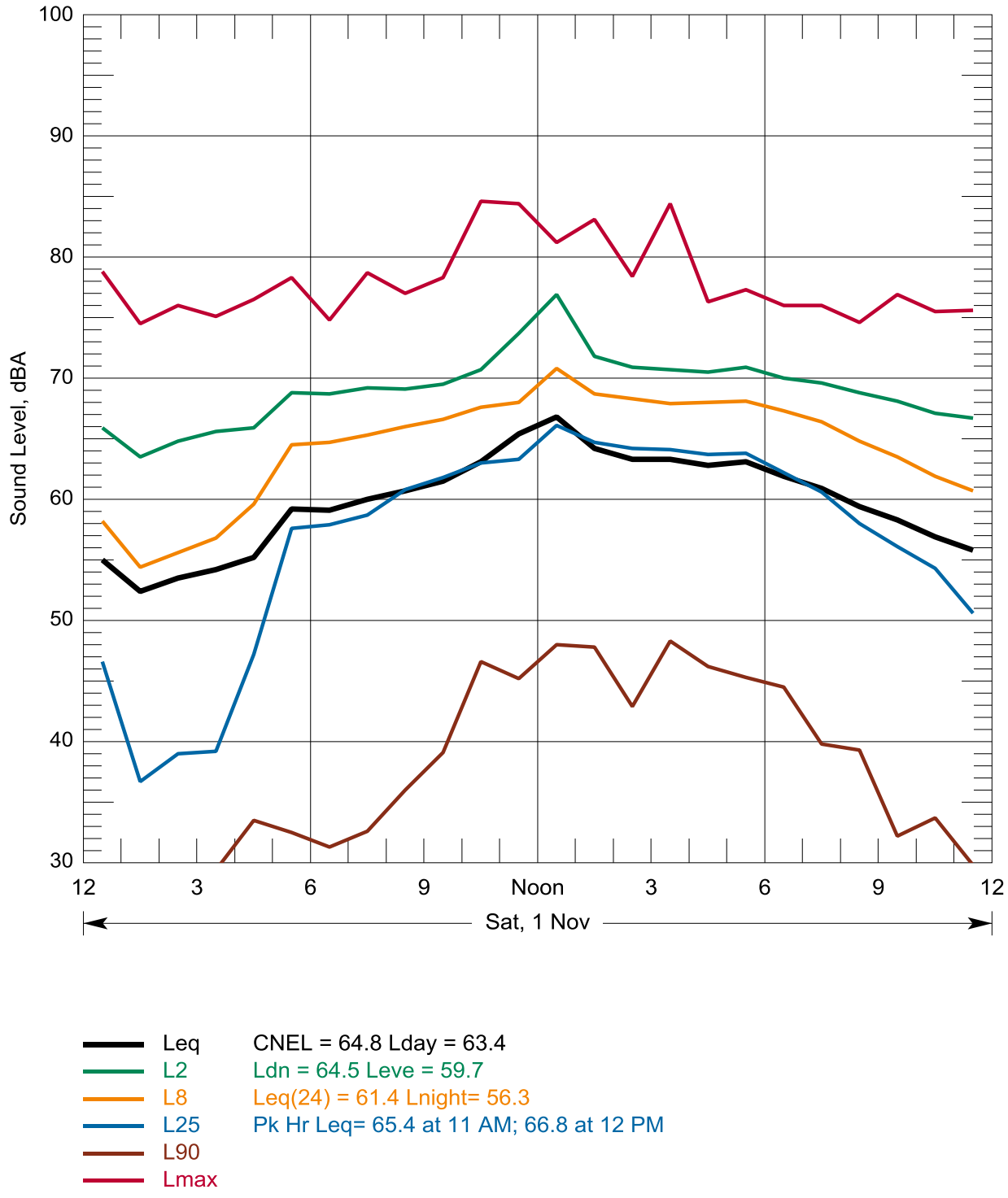

Figure A-52. Hourly Statistical Summary of Noise Levels on Nov 1, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

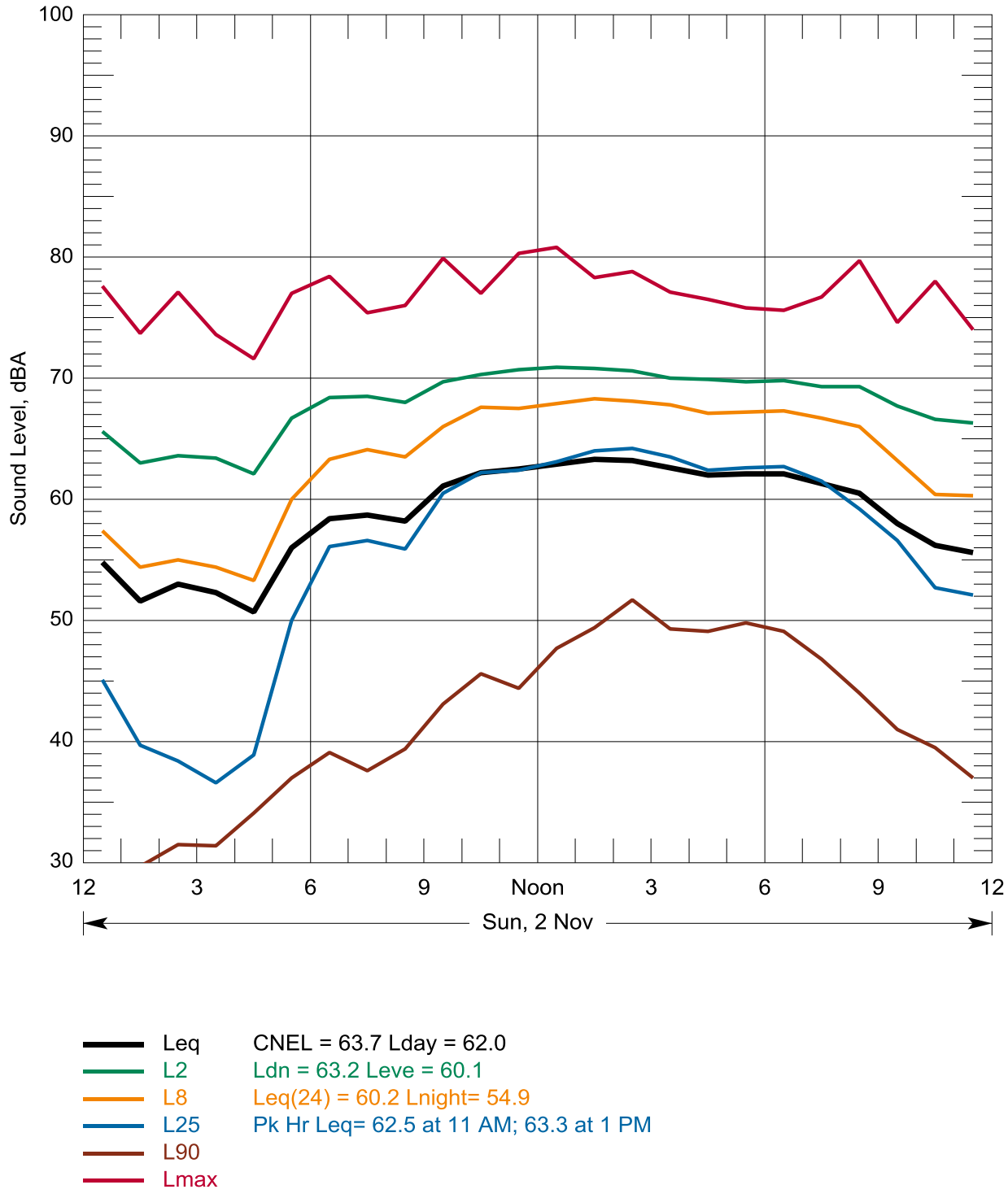

Figure A-53. Hourly Statistical Summary of Noise Levels on Nov 2, 2014 Location N7, 4723 Mount Solo Road, Longview, WA

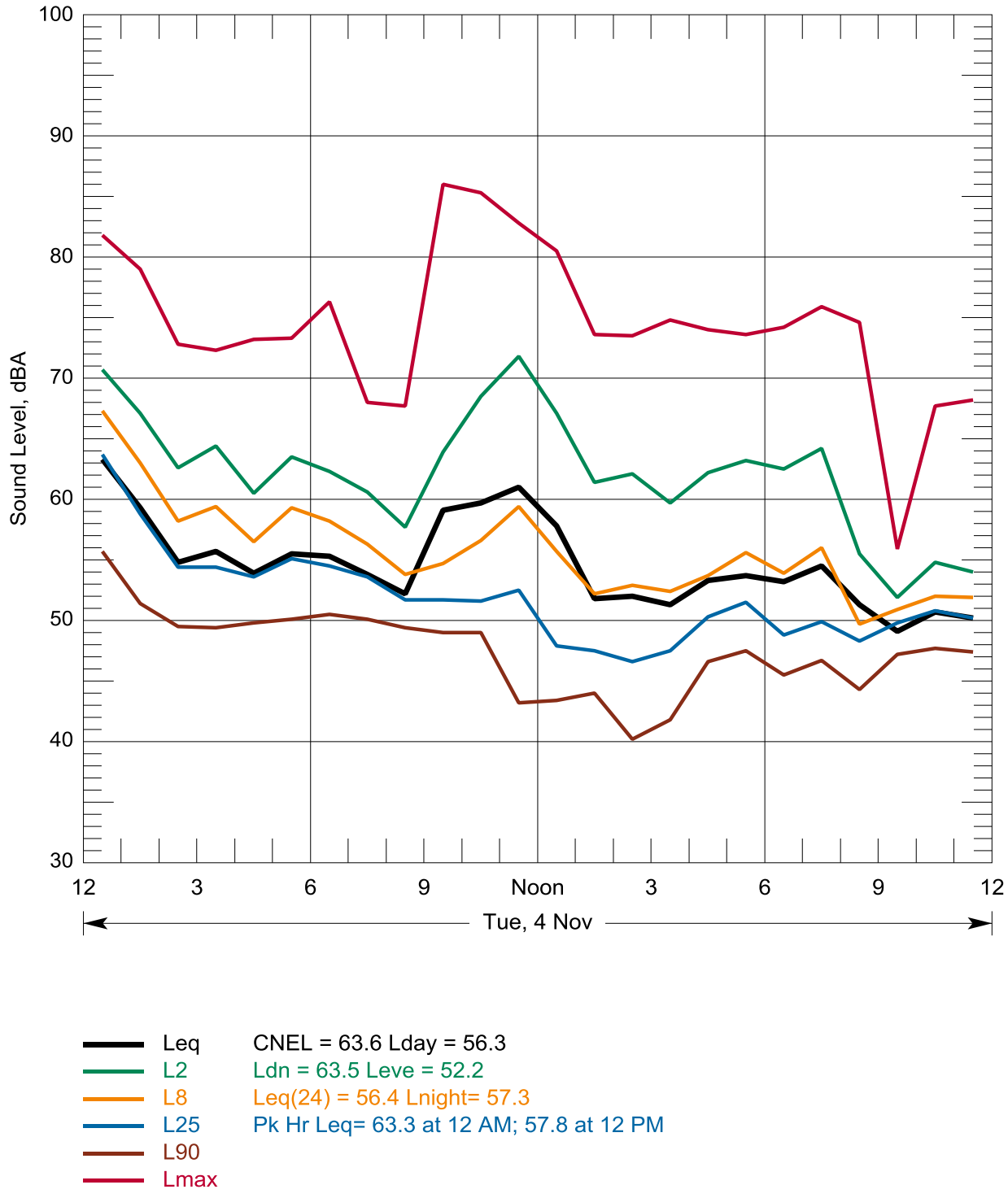

Figure A-54. Hourly Statistical Summary of Noise Levels on Nov 4, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

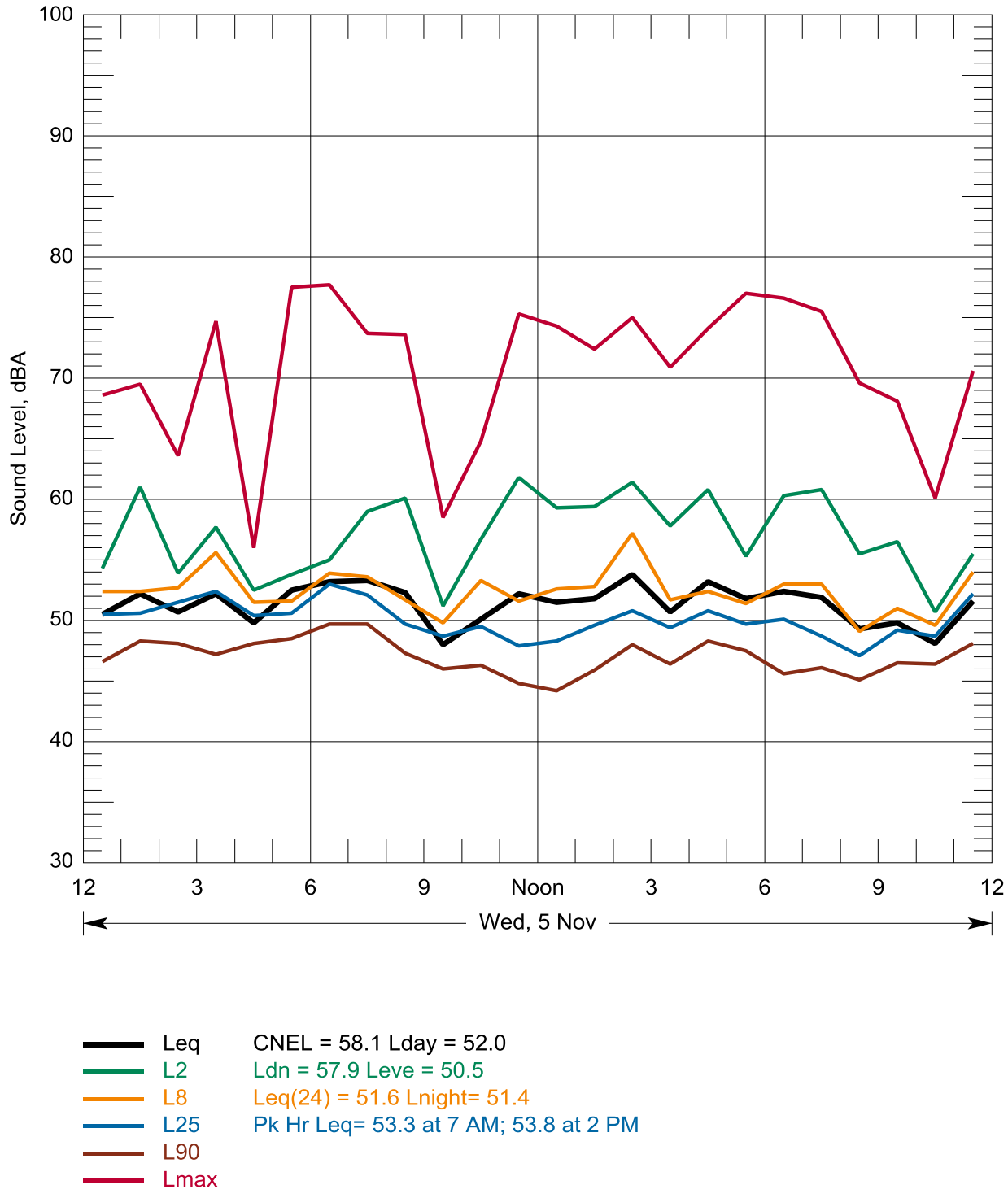

Figure A-55. Hourly Statistical Summary of Noise Levels on Nov 5, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

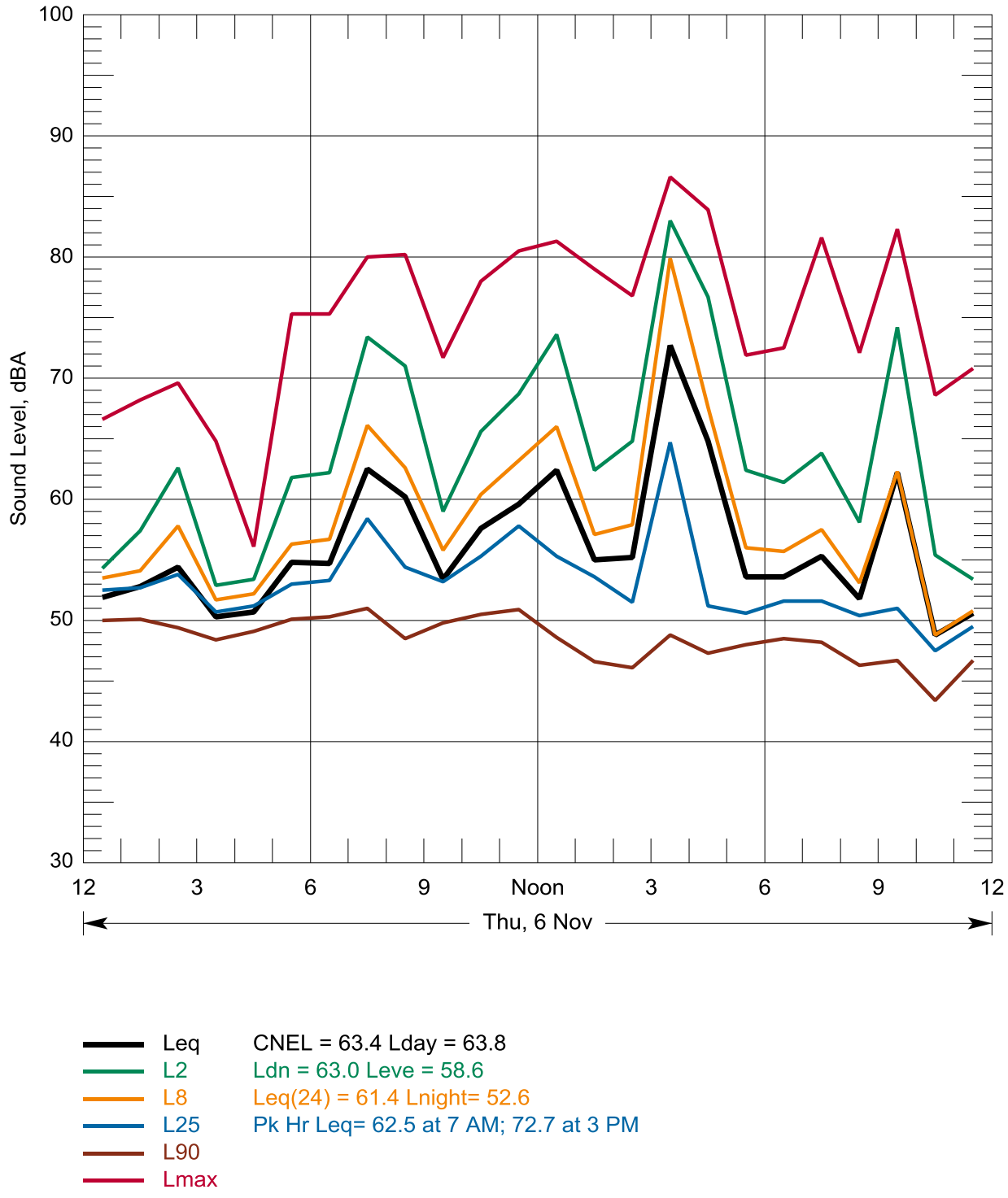

Figure A-56. Hourly Statistical Summary of Noise Levels on Nov 6, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

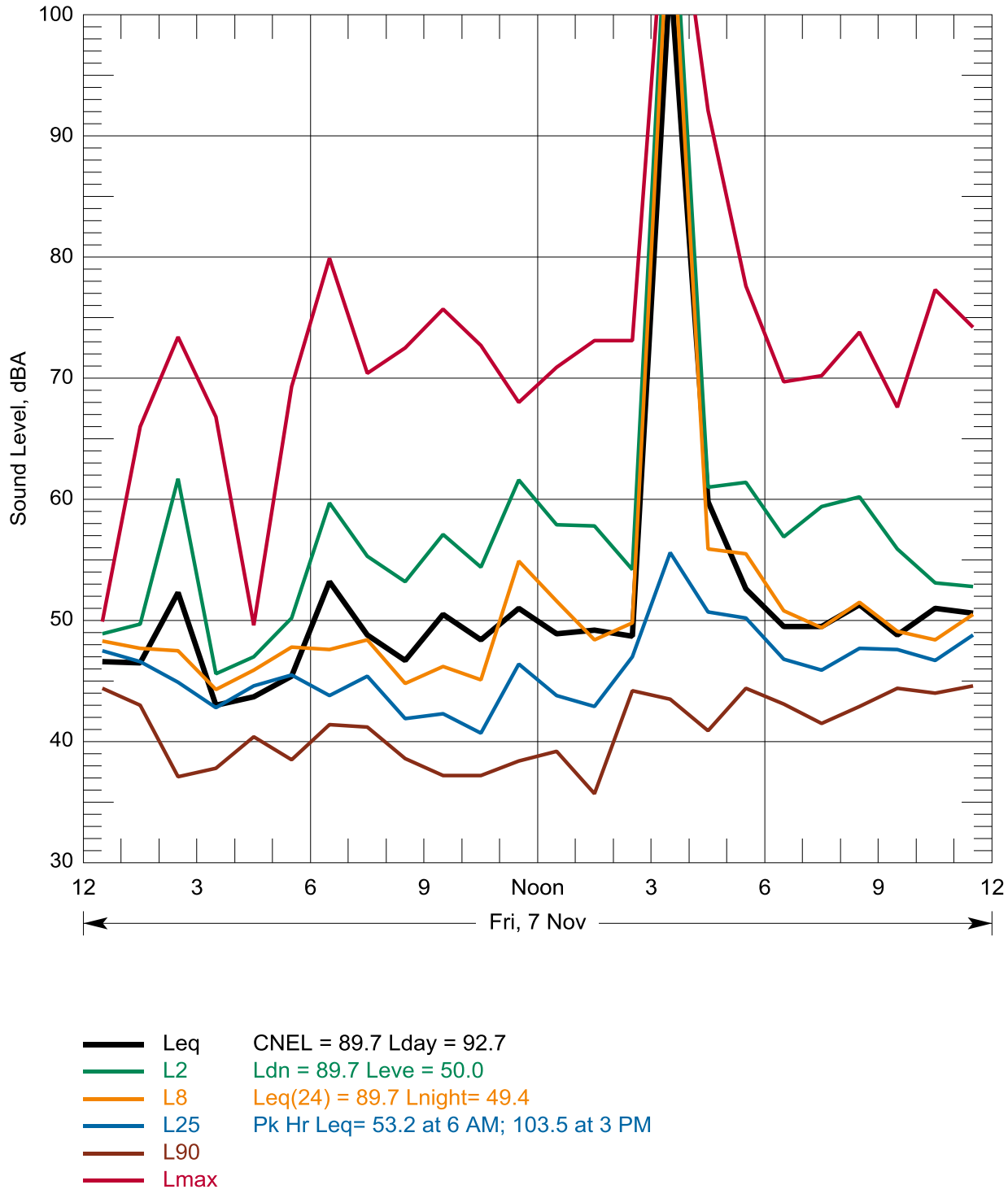

Figure A-57. Hourly Statistical Summary of Noise Levels on Nov 7, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

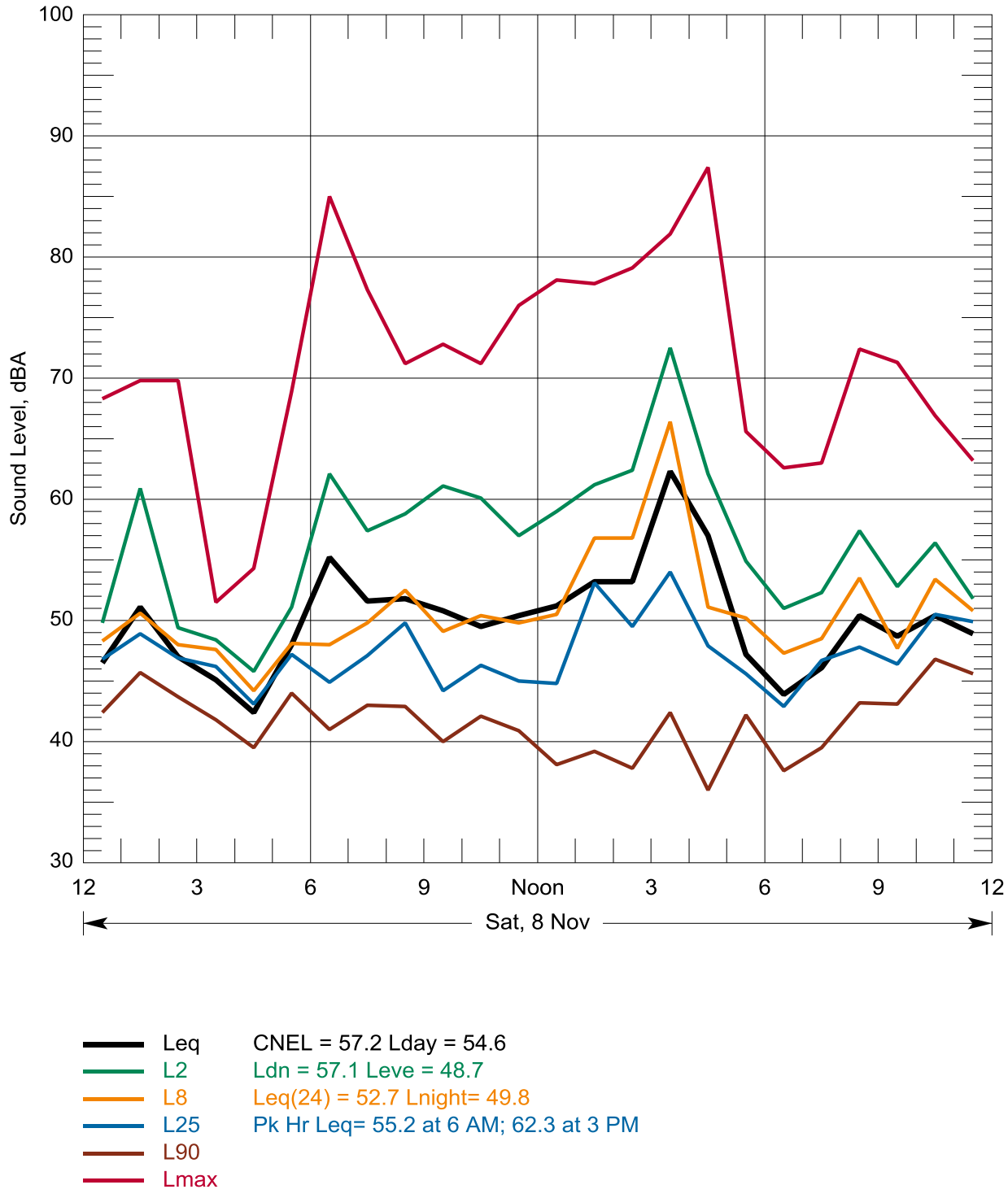

Figure A-58. Hourly Statistical Summary of Noise Levels on Nov 8, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

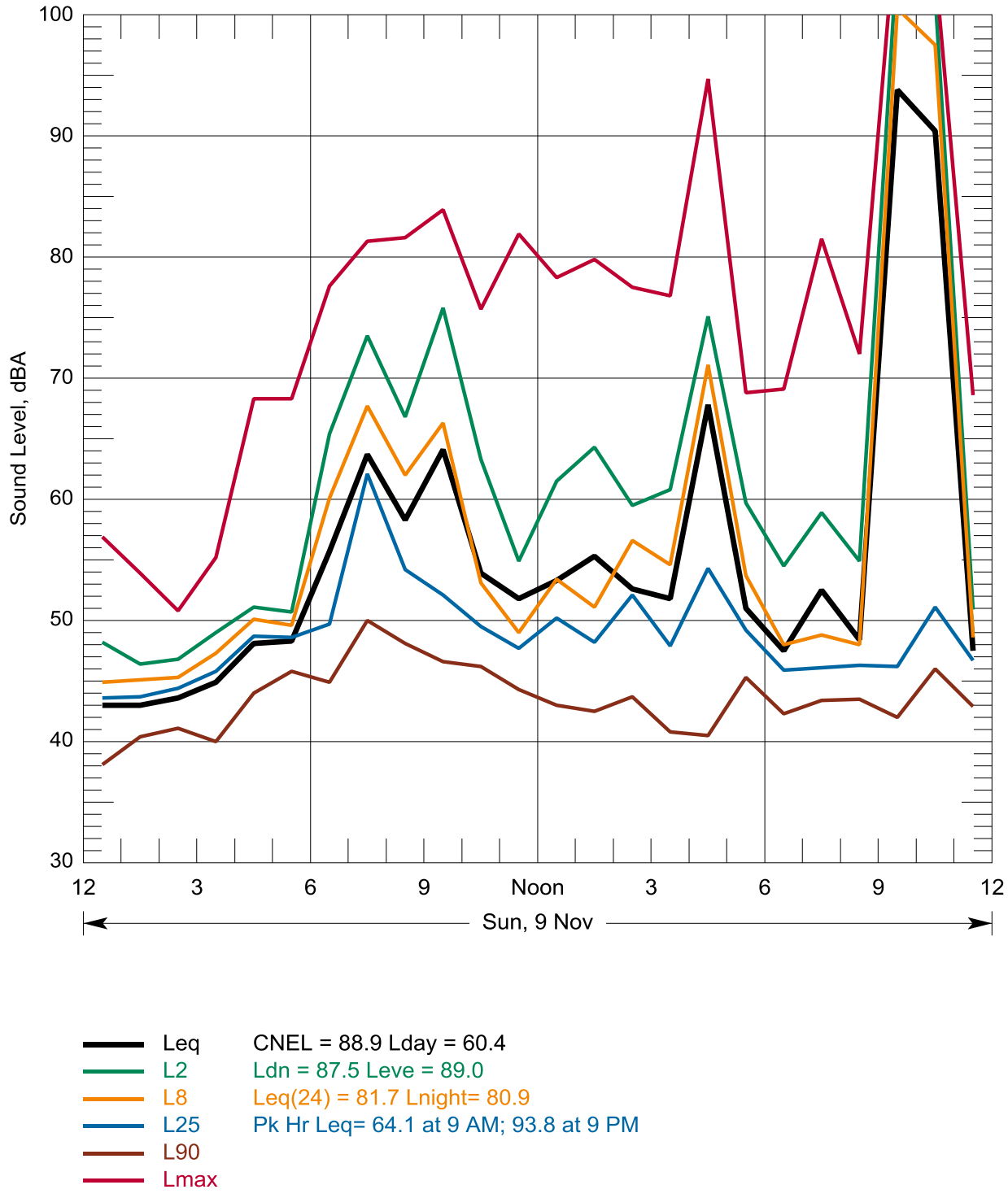

Figure A-59. Hourly Statistical Summary of Noise Levels on Nov 9, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

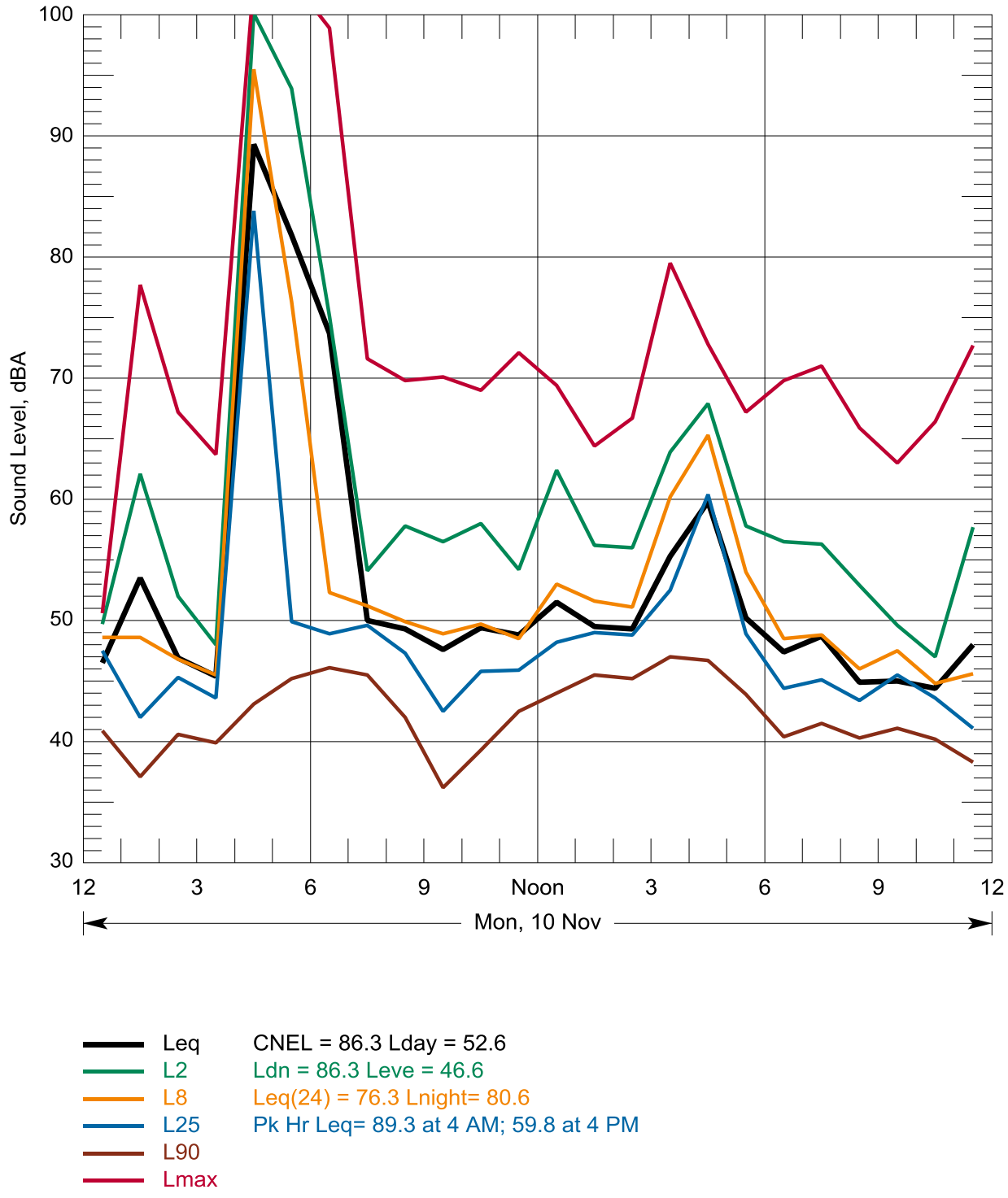

Figure A-60. Hourly Statistical Summary of Noise Levels on Nov 10, 2014 Location N8, 1719 Dorothy Avenue, Longview, WA

Appendix B

Construction Noise Impact Analysis

Appendix B
Construction Noise Impact Analysis

Table B-1 lists the predicted noise levels at noise-sensitive receivers in the study area during construction of the Proposed Action.

Table B-1. Predicted Construction Noise—Proposed Action

Address	Land Use	Construction $L_{eq,\ 8\ hour}$ (dBA)	Pile Driver L_{max} (dBA)	Construction + Pile Driver L_{max} (dBA)
104 Bradford Pl	Man. Home	79	80	83
114 Bradford Pl	SFR	72	76	78
4720 Mt. Solo Rd	SFR	63	67	68
4723 Mt. Solo Rd	Man. Home	62	66	68
4724 Solo Meadows Ln	SFR	62	66	67
4726 Mt. Solo Rd	Man. Home	62	66	68
4744 Mt. Solo Rd	SFR	61	65	66
4820 Mt. Solo Rd	SFR	60	64	66
4828a Mt. Solo Rd	SFR	60	64	65
4828b Mt. Solo Rd	SFR	60	63	65
4824 Mt. Solo Rd	SFR	60	64	65
115 Pioneer Mt Solo Cemetery Rd	SFR	59	63	65
120 Pioneer Mt Solo Cemetery Rd	SFR	58	62	64
Mt. Solo Cemetery	cemetery	59	63	64
130 Pioneer Mt. Solo Cemetery Rd	SFR	58	62	64
5006 Mt Solo Rd	SFR	58	62	63
5008 Mt Solo Rd	Man. Home	58	62	63
5005 Mt Solo Rd	SFR	58	61	63
5041 Mt Solo Rd	SFR	57	61	62
137 Ridgecrest Dr	SFR	58	62	63
141 Ridgecrest Dr	Man. Home	58	61	63
142 Ridgecrest Dr	SFR	58	62	63
149 Ridgecrest Dr	Man. Home	57	60	62
150 Ridgecrest Dr	Man. Home	57	61	63
160 Ridgecrest Dr	Man. Home	57	60	62
129 Ridgecrest Dr	Man. Home	59	63	64
103 Ridgecrest Ln	Man. Home	59	63	64
107 Ridgecrest Ln	Man. Home	58	62	64
111 Ridgecrest Ln	Man. Home	58	62	63
115 Ridgecrest Ln	SFR	59	62	64
127 Ridgecrest Ln	SFR	60	63	65
134 Ridgecrest Ln	SFR	60	64	65
120 Ridgecrest Ln	Man. Home	60	64	65

Address	Land Use	Construction $L_{eq,\ 8\ hour}$ (dBA)	Pile Driver L_{max} (dBA)	Construction + Pile Driver L_{max} (dBA)
108 Ridgecrest Ln	Man. Home	60	64	65
106 Ridgecrest Ln	Man. Home	60	63	65
116 Ridgecrest Dr	Man. Home	60	64	66
104 Ridgecrest Dr	Man. Home	62	66	68
124 Solo Meadows Ln	Man. Home	60	64	65
114 Solo Meadows Ln	Man. Home	61	65	67
110 Solo Meadows Ln	Man. Home	62	66	67
106 Solo Meadows Ln	SFR	62	66	68
101 Solo View Dr	Man. Home	63	67	68
107 Southcrest Ln	SFR	61	65	67
115 Southcrest Ln	SFR	60	64	65
125 Pionte Rd	SFR	60	63	65
108 Southcrest Ln	SFR	61	65	67
123 Solo View Dr	Man. Home	62	66	67
127 Solo View Dr	Man. Home	63	67	68
120 Bridgeview Ln	SFR	65	68	70
115 Bridgeview Ln	SFR	63	67	68
129 Solo View Dr	SFR	63	66	68
131 Solo View Dr	Man. Home	62	66	67
151 Solo View Dr	SFR	62	65	67
164 Rutherglen Dr	Man. Home	61	64	66
232 Rutherglen Dr	SFR	60	64	66
222 Rutherglen Dr	SFR	60	64	65
Evergreen St & 46th Ave	SFRs	58	61	63
44th Ave	SFRs	58	61	63
42nd Ave	SFRs	58	61	63
Alter St	SFRs	58	61	63
Olive Way	SFRs	58	61	63
2133 38th Ave	SFR	58	61	63
2137 38th Ave	SFR	58	61	63
38th Ave	SFRs	58	61	63
2185 38th Ave	MFR	57	61	62
36th Ave	SFRs	57	61	62
Shelly Pl	SFRs	58	62	63
Olive Ct	SFRs	57	60	62
Longview Memorial Park	cemetery	57	61	62
2017a 48th Ave	SFR	56	60	61
2017b 48th Ave	SFR	56	59	61
2018 48th Ave	Man. Home	56	60	61
Charles St	SFRs	56	60	61
Julie Pl	SFRs	56	60	62

Address	Land Use	Construction $L_{eq,\ 8\ hour}$ (dBA)	Pile Driver L_{max} (dBA)	Construction + Pile Driver L_{max} (dBA)
Zirkel Ct	SFRs	57	60	62

dBA = A-weighted decibel; SFRs = single-family residences, MFRs = multifamily residences

MILLENNIUM BULK TERMINALS–LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA AIR QUALITY TECHNICAL REPORT

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April 2017

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Contents

List of Tables ii
List of Figures iii
List of Acronyms and Abbreviations iv
Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.2.1 Current NAAQS and Washington State Ambient Air Quality Standards 1-7
1.2.2 Federal and State Air Toxics 1-8
1.2.3 Attainment Status 1-9
1.3 Study Area 1-9
Chapter 2 **Existing Conditions** **2-1**
2.1 Methods 2-1
2.1.1 Data Sources 2-2
2.1.2 Impact Analysis Approach 2-2
2.2 Existing Conditions 2-8
2.2.1 Project Area Air Quality Conditions 2-8
2.2.2 Cowlitz County Air Quality Conditions 2-11
2.2.3 Washington State Air Quality Conditions 2-11
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Construction 3-1
3.1.2 Operations 3-4
3.2 No-Action Alternative 3-21
Chapter 4 **Required Permits** **4-1**
Chapter 5 **References** **5-1**
5.1 Written References 5-1
5.2 Personal Communications 5-3

Appendix A. Air Quality Data

Tables

Table 1. Regulations, Statutes, and Guidance for Air Quality 1-5
Table 2. Federal and Washington State Ambient Air Quality Standards 1-8
Table 3. Operations Emissions and Source Type and Location of Detailed Methods 2-6
Table 4. Maximum Annual Estimated Construction Emissions 3-2
Table 5. Maximum Daily Estimated Construction Emissions 3-3
Table 6. Full Operations Maximum Annual Average Emissions 3-4
Table 7. AERMOD Modeling Results (Terminal Sources: Maintenance and Operations Equipment) 3-6
Table 8. AERMOD Modeling Results (Project Area Sources) 3-7
Table 9. AERMOD Modeling Results (Project Area and Study Area Sources) 3-8
Table 10. Maximum Annual Emissions Estimates in Cowlitz County for Locomotive and Commercial Marine Vessels for the Proposed Action in Comparison with the 2011 Cowlitz County Emissions Inventory 3-20
Table 11. Maximum Annual Emissions Estimates in Washington State for Locomotive and Commercial Marine Vessels for the Proposed Action in Comparison with the 2011 Statewide Emissions Inventory 3-21
Table 12. Estimated No-Action Alternative Annual Average Emissions from Rail, Vessel and Haul Trucks 3-22

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. Wind Data for Mint Farm 2001-2003, Supplemented with Portland International Airport for Missing Hours 2-10
Figure 4. Increased Diesel Particulate Matter Cancer Risk from Coal Export Terminal Sources—Fixed Emissions Scenario 3-10
Figure 5. Increased Diesel Particulate Matter Cancer Risk from All Operations in the Project Area—Fixed Emissions Scenario 3-11
Figure 6. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in the Kelso-Longview Area—Fixed Emissions Scenario 3-13
Figure 7. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in Cowlitz County—Fixed Emissions Scenario 3-14
Figure 8. Increased Diesel Particulate Matter Cancer Risk from Coal Export Terminal Sources— Average Lifetime Emissions Scenario 3-15
Figure 9. Increased Diesel Particulate Matter Cancer Risk from All Operation in the Project Area— Average Lifetime Emissions Scenario 3-16
Figure 10. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in the Kelso-Longview Area— Average Lifetime Emissions Scenario 3-18
Figure 11. Increased Diesel Cancer Risk from All Operation Sources in Cowlitz County— Average Lifetime Emissions Scenario 3-19

Acronyms and Abbreviations

°F	degrees Fahrenheit
Applicant	Millennium Bulk Terminals–Longview, LLC
BNSF	BNSF Railway Company
CFR	Code of Federal Regulations
CO	carbon monoxide
DPM	diesel particulate matter
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HAP	hazardous air pollutant
L/kg/day	liter per kilogram per day
lb/day	pounds per day
LVSW	Longview Switching Company
mg/kg/day	milligrams per kilogram per day
NAAQS	National Ambient Air Quality Standards
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NEPA	National Environmental Policy Act
NO_2	nitrogen dioxide
NO_x	nitrogen oxide
NSPS	New Source Performance Standards
NW AIRQUEST	Northwest International Air Quality Environmental Science and Technology Consortium
O_3	ozone
OLM	Ozone Limiting Method
PM	particulate matter
PM2.5	particulate matter less than or equal to 2.5 micrometers in diameter
PM10	particulate matter less than or equal to 10 micrometers in diameter
ppb	parts per billion
ppm	parts per millions
RCW	Revised Code of Washington
SEPA	Washington State Environmental Policy Act
SO_2	sulfur dioxide
SWCAA	Southwest Clean Air Agency
TAP	toxic air pollutant
tpy	tons per year
TSP	total suspended particules
µg/m^3	micrograms per cubic meter

UP	Union Pacific Railroad
USC	United States Code
VOC	volatile organic compound
WAC	Washington Administrative Code

Chapter 1
Introduction

This technical report assesses the potential air quality impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. This report describes the regulatory setting, establishes the methods for assessing potential air quality impacts, presents the historical and current air quality conditions in the study area, and assesses potential impacts.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

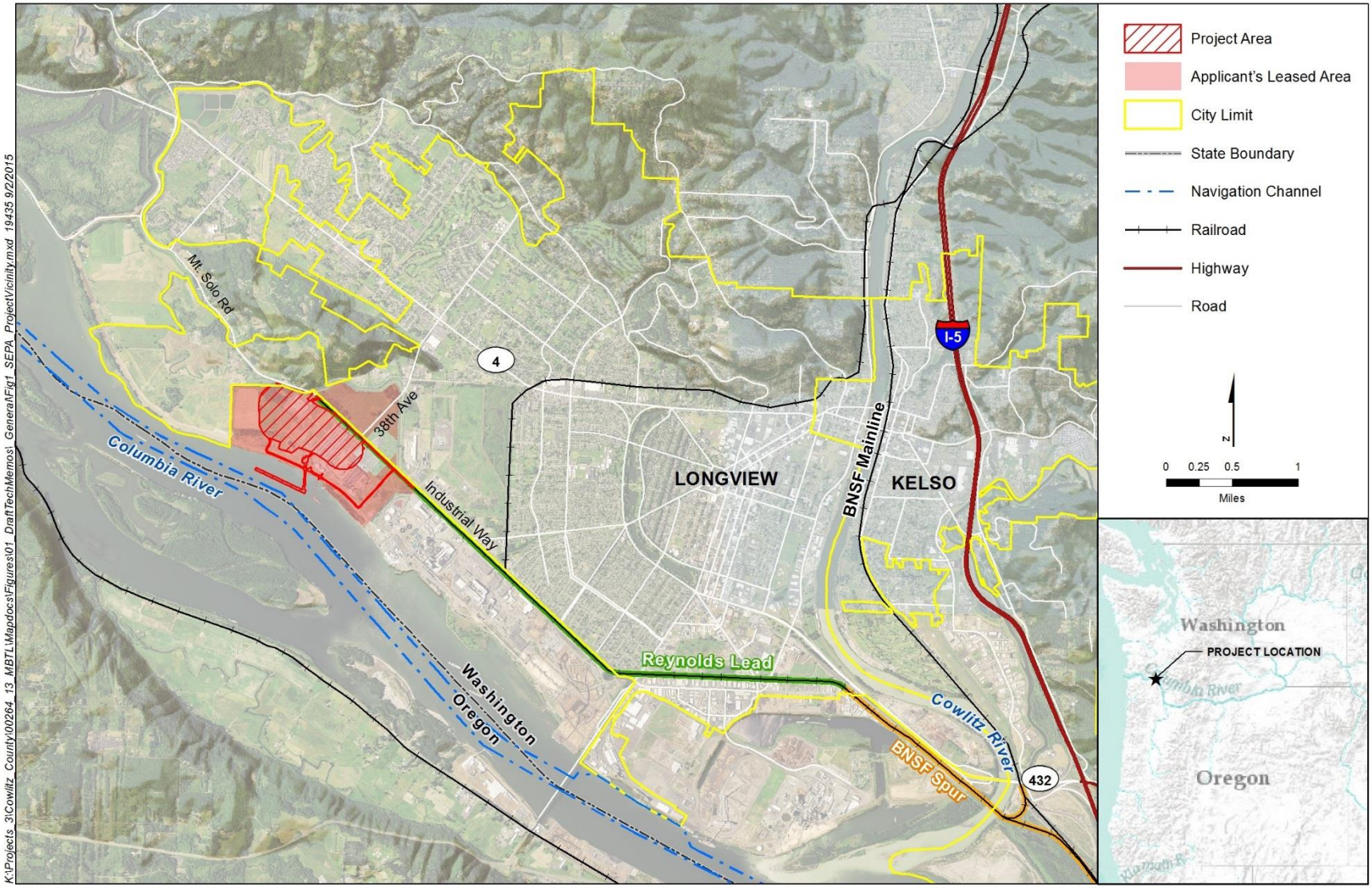
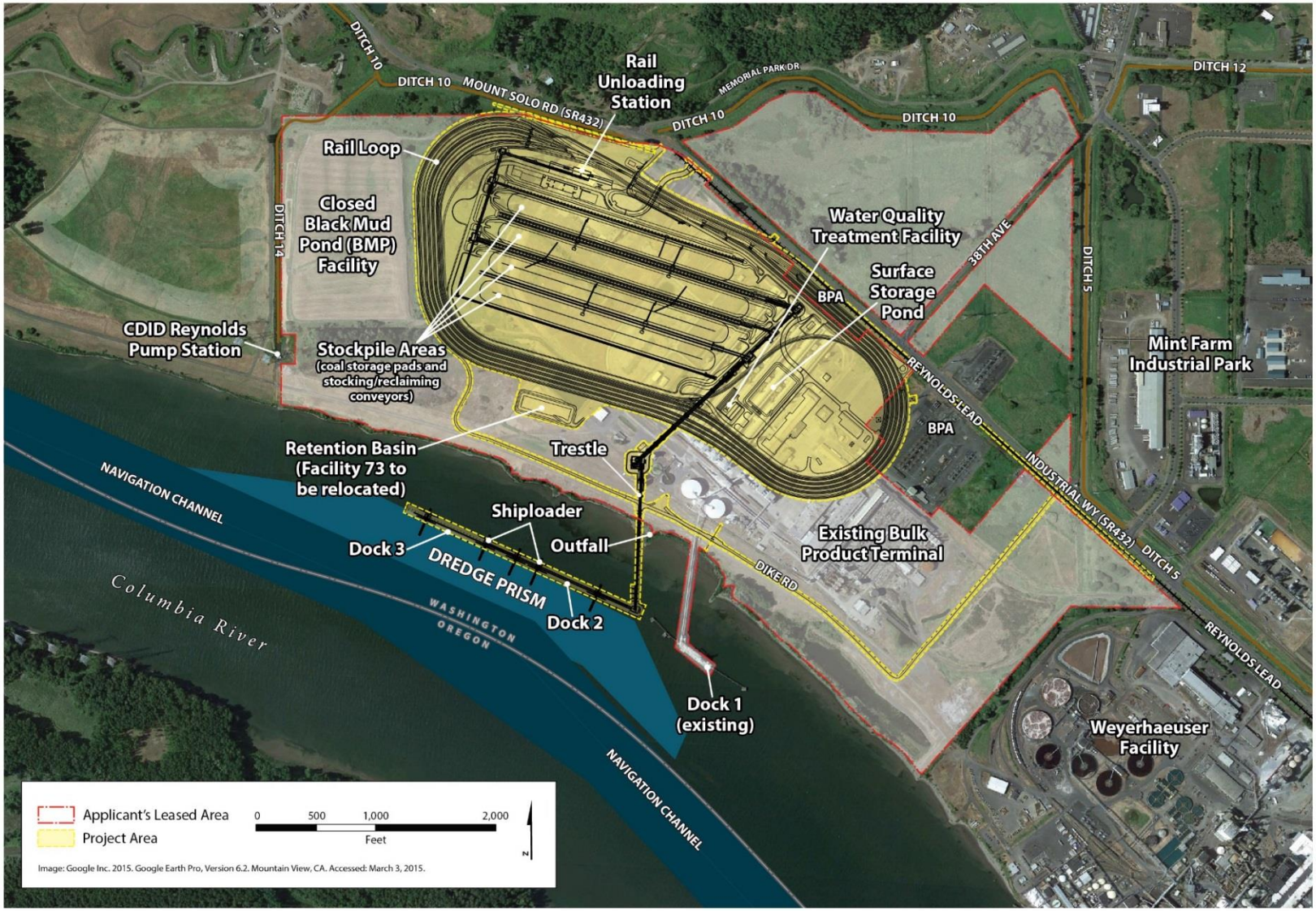


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

Different jurisdictions are responsible for the regulation of air quality. These jurisdictions and their regulations, statutes, and guidance that apply to air quality are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidance for Air Quality

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Clean Air Act and Amendments	As amended in 1970, 1977, and 1990, requires EPA develop and enforce regulations to protect the public from air pollutants and their health impacts.
National Ambient Air Quality Standards (EPA)	Specifies the maximum acceptable ambient concentrations for seven criteria air pollutants: CO, lead, NO_2, O_3, PM10 and PM2.5, and SO_2. Primary NAAQS set limits to protect public health, and secondary NAAQS set limits to protect public welfare. Geographic areas where concentrations of a given criteria pollutant exceed NAAQS are classified as nonattainment areas for that pollutant.

Regulation, Statute, Guideline	Description
State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Washington State General Regulations For Air Pollution Sources (WAC 173-400) and Washington State Clean Air Act (RCW 70.94)	Establishes the rules and procedures to control or prevent the emissions of air pollutants. Provides the regulatory authority to control emissions from stationary sources, reporting requirements, emissions standards, permitting programs, and the control of air toxic emissions.
Washington State Operating Permit Regulation (WAC 173-401)	Establishes the elements for the state air operating permit program.
Washington State Controls for New Sources of Toxic Air Pollutants (WAC 173-460)	Establishes the systematic control of new or modified sources emitting toxic air pollution to prevent air pollution, reduce emissions, and maintain air quality that will protect human health and safety.
Washington State Ambient Air Quality Standards (WAC 173-476)	Establishes maximum acceptable levels in the ambient air for particulate matter, lead, SO_2, NO_2, O_3, and CO. Washington State adopts current federal NAAQS in state regulations.
Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provide for the implementation of SEPA in Cowlitz County.
Southwest Clean Air Agency (SWCAA 400)	General regulations for regulating stationary sources of air pollution within Clark, Cowlitz, Lewis, Skamania, and Wahkiakum counties of Washington.

Notes:
USC = United States Code; NEPA = National Environmental Policy Act; CFR = Code of Federal Regulations; EPA = U.S. Environmental Protection Agency; CO = carbon monoxide; NO_2 = nitrogen oxides; O_3 = ozone; PM2.5 = particulate matter less than or equal to 2.5 micrometers in size; PM10 = particulate matter less than or equal to micrometers in size; SO_2 = sulfur dioxide; NAAQS = National Ambient Air Quality Standards; HAPs = hazardous air pollutants; WAC = Washington Administrative Code; RCW = Revised Code of Washington; SEPA = Washington State Environmental Policy Act; SWCAA = Southwest Clean Air Agency; CCC = Cowlitz County Code

The federal Clean Air Act and the Clean Air Act Amendments form the basis for a broad range of regulations that control allowable emissions and ambient concentrations of air pollutants in the environment. The National Ambient Air Quality Standards (NAAQS) were established by the U.S. Environmental Protection Agency (EPA) under authority of the Clean Air Act to protect the public from air pollution. Air pollutants for which there are NAAQS are called *criteria pollutants*. Geographic areas where concentrations of a given criteria pollutant exceed an ambient air quality standard are classified as *nonattainment areas* for that pollutant.

Under the federal Clean Air Act, the states are authorized to administer these programs and monitor air quality in different areas to determine if those areas are meeting the NAAQS. Under RCW 70.94, local counties can choose to form a county authority or join a multi-county authority. Cowlitz County is part of the multi-county air pollution control authority. The Southwest Clean Air Agency (SWCAA) maintains compliance with the NAAQS for most stationary source types of air pollutants via an air permitting programs (Revised Code of Washington [RCW] 70.94.053 and 70.94.057 and SWCAA 400-020). This authority includes the regulation of fugitive dust sources (SWCAA-400-040) as well as vented emissions.

Other federal air quality regulatory programs for major stationary sources include Prevention of Significant Deterioration, National Emission Standards for Hazardous Air Pollutants (NESHAPS), Title V Air Permitting Program, and New Source Performance Standards (NSPS). None of these programs is expected to apply to the Proposed Action because stationary source emissions are well below major source thresholds, and because current NESHAPS and NSPS standards do not apply to the proposed facility type. The state also has rules for toxic air pollutants (TAPs) that are applicable to stationary sources. These rules were established to provide systematic control of TAP emissions (which include both carcinogens and noncarcinogens) in order to maintain the protection of human health and safety.

EPA first began regulating on-road mobile sources in 1970 as part of the Clean Air Act. EPA was given the added regulatory authority under Section 213 in the 1990 Clean Air Act Amendments to control emissions from nonroad engines (e.g., construction equipment, locomotives, and vessels). An extensive number of exhaust emissions standards and regulations have been issued by EPA since 1990 on all classes of nonroad engines including construction equipment, locomotives, vessels, off-road vehicles, and lawn and garden equipment. Regulations that are relevant to the Proposed Action include locomotive emission standards for new and re-built locomotive engines and the North America Emission Control Area for marine vessels limiting the sulfur content in fuel oil. No provisions have been made to allow states (other than California) or local authorities to impose additional regulations on these source categories.

1.2.1 Current NAAQS and Washington State Ambient Air Quality Standards

Table 2 lists both the federal and state ambient air quality standards for six criteria air pollutants and total suspended particulates. Annual standards are never to be exceeded. Short-term standards are not to be exceeded more than once per year, unless noted. The NAAQS consist of primary standards and secondary standards. Primary standards are designed to protect public health, including protecting the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards are designed to protect public welfare from effects such as visibility reduction, soiling, and nuisance (e.g., preventing air pollution damage to vegetation).

Table 2. Federal and Washington State Ambient Air Quality Standards

	State and Federal	
Pollutant	**Primary**	**Secondary**
Carbon monoxide		
8-hour average[a]	9 ppm	No standard
1-hour average[a]	35 ppm	No standard
Ozone		
8-hour average[b,c]	0.070 ppm	0.070 ppm
Nitrogen dioxide		
1-hour average[d]	100 ppb	No standard
Annual average	53 ppb	53 ppb
Sulfur dioxide		
3-hour average[e]	No standard	0.50 ppm
1-hour average[f]	75 ppb	No standard
Lead		
Rolling 3-month average	0.15 µg/m^3	0.15 µg/m^3
PM10		
24-hour average[g]	150 µg/m^3	150 µg/m^3
PM2.5		
Annual average[h]	12 µg/m^3	15 µg/m^3
24-hour average[i]	35 µg/m^3	35 µg/m^3

Notes:

[a] Not to be exceeded on more than 1 day per calendar year as determined under the conditions indicated in 173 WAC 476.

[b] In December 2015, EPA lowered the federal standard for 8-hour ozone from 0.075 ppm to 0.070 ppm.

[c] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.070 ppm.

[d] 98th percentile of 1-hour daily maximum concentrations, averaged over 3 years.

[e] Not to be exceeded more than once per calendar year.

[f] 99th percentile of 1-hour daily maximum concentrations averaged over 3 years.

[g] Not to be exceeded more than once per year average over 3 years.

[h] Annual mean averaged over 3 years.

[i] 98th percentile averaged over 3 years.

Source: 173 WAC 476; U.S. Environmental Protection Agency 2012.

ppm = parts per million; ppb= parts per billion; PM10 = particulate matter with a diameter of less than or equal to 10 micrometers; PM2.5 = particulate matter with a diameter of less than or equal to 2.5 micrometers; µg/m^3 = micrograms per cubic meter

1.2.2 Federal and State Air Toxics

Under the federal Clean Air Act, EPA controls air toxics, which are pollutants known or suspected to cause cancer or other serious health effects, such as birth defects or reproductive effects. Examples of air toxics include benzene, formaldehyde, and toluene. EPA has identified 188 air toxics, which it refers to as hazardous air pollutants (HAPS). No ambient air quality standards have been established for HAPS, and instead EPA has identified all major industrial stationary sources that emit these pollutants and developed national technology-based performance standards to reduce their emissions. The performance standards are designed to ensure that major sources of HAPS are controlled, regardless of geographic location.

An action that requires a Notice of Construction application under WAC 173-400-110 is subject to the review requirements of controls for new sources of toxic air pollutants, except if emissions before control equipment of each toxic air pollutant from a new source are less than the applicable *de minimis* emission threshold for the toxic air pollutant listed in WAC 173-460-150 or if the increase in emissions from each modification is less than the applicable *de minimis* emission threshold for the toxic air pollutant listed in WAC 173-460-150. Southwest Clean Air Agency has a separate list of pollutants that may apply to emissions from this stationary source. The purpose is to establish the systematic control of new or modified sources emitting toxic air pollutants to prevent air pollution to the extent reasonably possible and maintain levels of air quality to protect human health.

1.2.3 Attainment Status

Based on monitoring information collected over a period of years, EPA and the Washington State Department of Ecology (Ecology) designate regions as being attainment or nonattainment areas for regulated air pollutants. Attainment status indicates that air quality in an area meets the federal, health-based ambient air quality standards. Nonattainment status indicates that air quality in an area does not meet those standards. If the measured concentrations in a nonattainment area improve to levels consistently below the federal standards, Ecology and EPA can reclassify the nonattainment area to a maintenance area. In this situation, Ecology and the local clean air agency are required to implement maintenance plans to ensure ongoing emissions reductions, and continuous compliance with the federal standards.

Cowlitz County is currently designated unclassifiable-attainment for all NAAQS. This designation means that EPA and Ecology expect the area to meet air quality standards despite a lack of monitoring data. Currently, Ecology and SWCAA only operate a particulate matter less than or equal to 2.5 micrometers in diameter (PM2.5) air quality monitor.

1.3 Study Area

The study area for direct impacts on air quality is the area in and near the project area that could be affected by construction and operation activities in the project area. The study area for indirect impacts includes Cowlitz County and accounts for rail operations in Cowlitz County and vessel activity on the Columbia River. An assessment of air quality impacts from Proposed Action-related trains and vessels for the routes in Washington State is also provided.

For inhalation health risks related to diesel particulate matter (DPM), the study area for direct impacts is the area that could be affected by operations in the project area and the study area for indirect impacts is the area that could be affected by terminal and rail operations in Cowlitz County.

Chapter 2
Existing Conditions

This chapter explains the methods for assessing the existing conditions and determining impacts, and describes the existing conditions in the study area as they pertain to air quality.

2.1 Methods

The air quality analysis evaluated emissions from construction and terminal operations.

Air emissions for the Proposed Action were estimated for carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxide (NO_x), particulate matter less than or equal to 10 micrometers in diameter (PM10), PM2.5, and sulfur dioxide (SO_2) to evaluate the impact on air quality. Because construction emissions are temporary and have a short period of activity, these emissions are only evaluated in comparison with emissions thresholds. Operations emissions, however, are evaluated in comparison to their impacts on air quality.

The method used to assess construction-related air quality impacts was designed to estimate the strength of emissions during the peak construction period and to identify the maximum daily emissions. Sources of construction emissions included emissions from construction equipment, river barges, fugitive dust from earthwork activity, vehicle crossing delays, and construction worker commute vehicles.

The air quality assessment for terminal operations considered on-site activities that would generate potential fugitive emissions of particulate matter from the handling and transfer of coal, including unloading coal from rail cars, transferring coal on conveyors, piling coal onto storage piles, and loading coal onto ships. The coal transfers would occur in enclosed areas (i.e., rotary coal car dump and conveyors), as well as areas that are not enclosed (i.e., coal piles and the unloading of rail cars). In addition, the air quality assessment considered locomotive exhaust emissions that occur during the unloading and movement of coal cars, hoteling emissions during vessel loading, emissions from tugs used to maneuver vessels into the terminal, and emissions from operations (e.g., loader) and maintenance equipment.

The operations emissions were assessed for their potential local air quality impacts using EPA's standard regulatory air dispersion model, AERMOD (Version 15181). AERMOD is the appropriate tool for this application as the air quality impacts are localized and AERMOD is designed to assess emissions for multiple point, area, and volume sources in simple and complex terrain, and uses hourly meteorological on-site data. AERMOD output results are compared to the federal and state ambient air quality standards presented in Table 2. Appendix A, *Air Quality Data,* provides details on emissions calculations.

An inhalation-only[1] health risk assessment was performed using the AERMOD dispersion model to assess the increased cancer risk associated with the Proposed Action-related increase in DPM emissions. The assessment was performed per California Environmental Protection Agency guidance using Ecology's evaluation and selection of available guidelines (Washington State Department of Ecology 2008).

2.1.1 Data Sources

The following sources of information were used to determine the potential impacts from the Proposed Action and the No-Action Alternative on air quality in the study area.

- Data and information on coal export terminal construction and operation (URS Corporation 2015).
- Northwest International Air Quality Environmental Science and Technology Consortium for existing conditions data (2015).
- California's Air Resource Board vessel transit emissions study (California Air Resources Board 2011).
- California Environmental Protection Agency's guidance manual for preparation of health risk assessments (California Environmental Protection Agency 2003).
- National Climatic Data Center Longview, Washington climate data (National Climatic Data Center 2011).
- U.S. Environmental Protection Agency air pollutant emissions factors (U.S. Environmental Protection Agency 1995a, 1995b, 1995c, 1996).
- U.S. Environmental Protection Agency's air modeling guidance (U.S. Environmental Protection Agency 2004, 2014).
- U.S. Environmental Protection Agency's vessel fuel consumption data (U.S. Environmental Protection Agency 2000).
- U.S. Environmental Protection Agency's NONROAD Model (U.S. Environmental Protection Agency 2009).
- U.S. Environmental Protection Agency's vessel exhaust emission standards (U.S. Environmental Protection Agency 2012).
- U.S. Environmental Protection Agency's national-scale air toxic assessment (U.S. Environmental Protection Agency 2011).
- Washington State Department of Ecology statewide emissions inventory levels (Washington State Department of Ecology 2014).

2.1.2 Impact Analysis Approach

The following sections describe the approach that was taken to evaluate the potential impacts of the Proposed Action and No-Action Alternative on air quality.

[1] The risk assessment only considered the cancer risk by the inhalation pathway because the risk contributions by other pathways of exposure are difficult to quantify and are known to be negligible relative to the inhalation pathway.

2.1.2.1 Construction Impact Analysis Approach

The Applicant has identified three construction scenarios:

- **Truck.** If material is delivered by truck, it is assumed that approximately 88,000 truck trips would be required over the construction period. Approximately 56,000 loaded truck trips would be needed during the peak construction year.
- **Rail.** If material is delivered by rail, it is assumed that approximately 35,000 loaded rail cars (350 loaded train trips or 700 total train trips) would be required over the construction period. Approximately two-thirds of the rail trips would occur during the peak construction year.
- **Barge.** If material is delivered by barge, it is assumed that approximately 1,130 barge trips would be required over the construction period. Approximately two-thirds of the barge trips would occur during the peak construction year. Because the project area does not have an existing barge dock, the material would be unloaded at an existing dock elsewhere on the Columbia River and transported to the project area by truck.

Emissions included in the construction analysis include those from barge and truck emissions associated with the delivery of construction supplies and materials, in addition to direct emissions from construction equipment exhaust and fugitive dust emissions. Earthwork activity would take place during the first 18 months of construction. Based on the frequency and duration of use and fuel types, emissions were estimated based on either the EPA AP-42 compilation of emissions factors or EPA's NONROAD2008a model for non-road construction equipment activity. A brief description and key assumptions are presented in the following sections for each source type.

Construction Equipment

Construction equipment exhaust emissions are the result of fuel combustion. This includes activity associated with rail infrastructure, construction of the conveyor and transfer stations, and surge bins, dock, and trestles. Combustion emissions estimates were obtained by applying the EPA NONROAD2008a emissions model (U.S. Environmental Protection Agency 2009) for nonroad equipment activity. Construction activity was assumed to occur 8 hours per day, 5 days per week, 52 weeks per year, with the exception of track laying machines, which were assumed to occur only 4 hours per day. Emissions factors were then combined with maximum numbers of equipment operated, duration of use, and horsepower to obtain annual emissions. Diesel particulate emissions were derived from PM10 emissions estimates for diesel-powered equipment, which included most on-site combustion sources as well as barges. Additional details on the approach are identified in Appendix A, *Air Quality Data,* for annual emissions and maximum daily emissions.

River Barges

Emissions estimates for barge engines were based on EPA's approach for large diesel engines (U.S. Environmental Protection Agency 1996). The river barge was assumed to use ultra-low sulfur diesel, with less than 15 parts per million (ppm) sulfur content. The barge positioning time was assumed to take 1 hour (0.5 hour in and 0.5 hour out), with 753 round trips during the peak construction period (average of 2.9 daily). Additional details on this approach are identified in Appendix A, *Air Quality Data,* for annual emissions and maximum daily emissions.

Fugitive Dust from Earthwork Activity

Fugitive dust emissions were estimated using a conservative approach for construction equipment (U.S. Environmental Protection Agency 1995a). This method uses a generic, all-inclusive, emissions factor of 1.2 tons particulate matter (PM)/acre-month for land preparation activities. Land clearing, excavation, earth moving (cut and fill), and other miscellaneous dust-generating activities that typically occur during construction are included as part of this emissions factor. All earthwork for the project area was assumed to occur evenly over a 1-year period, and the standard best management practice of watering to minimize fugitive dust emissions was assumed to be used as well. Additional details on this approach are identified in Appendix A, *Air Quality Data,* for annual emissions and maximum daily emissions.

Vehicle Delays at At-Grade Rail Crossings

Off-site emissions associated with vehicle delays at train crossings from construction-related locomotives transporting construction materials along the Reynolds Lead and BNSF Spur are included in the analysis.

Construction Worker Commute Vehicles

During peak construction, up to 200 construction workers may commute to the project area (ICF and DKS Associates 2017). Off-site emissions associated with commute vehicles for construction workers are included in the analysis. Additional details on this approach are identified in Appendix A, *Air Quality Data*.

2.1.2.2 Operations Impact Analysis Approach

The on-site transfer and storage of coal would create fugitive emissions of coal dust due to product movement and wind erosion. In addition, combustion emissions from rail and vessel movement, as well as some nonroad equipment emissions associated with the operation and maintenance of the terminal, are included in the analysis. The project area also includes emissions at Docks 2 and 3, as well as maneuvering to dock vessels at the terminal; these on-site emissions were considered in the analysis as well. The sections that follow describe the approach taken to address emissions associated with coal storage and handling, locomotive, vessel, vehicle delays at rail crossings, and employee commute vehicles as well as how emissions were characterized for air quality modeling. The following sections also describe the approach to evaluate the operations sources of DPM emissions for their potential contribution to the increase in inhalation cancer risk.

Coal Storage and Handling

Most on-site coal movement would occur in enclosed areas, including the rotary coal car dump and conveyors. Some transfer activities at the coal storage piles would not be enclosed; however, the conveyors, transfer towers, and the coal storage piles themselves would have systems in place for dust control (watering or dry fogging). Watering of the coal storage piles would help to reduce wind erosion. In general, the combination of these passive (enclosures) and active (watering, fogging) control systems would provide a high level of dust control (up to 99%); however, because these control systems would not operate with negative pressure and not all systems are enclosed, a more conservative 95% effectiveness assumption was used. This approach is consistent with a similar type facility that was issued a permit from Oregon Department of Environmental Quality for the Coyote Island Terminal at the Port of Morrow. To account for the reduction in emissions from

watering of the coal within the project area (URS Corporation 2014), a 95% effectiveness in reducing coal dust emissions was assumed in this analysis. Appendix A, *Air Quality Data,* presents this approach in detail (Table 3).

Locomotives

The impact analysis approach for rail operations used EPA projected emissions factors (grams per gallon [g/gal]) for line-haul locomotives, which are based on projected changes in locomotive fleet over the next 30 years (U.S. Environmental Protection Agency 2009). These emissions were based on locomotive engine load and associated fuel consumption during transport to and from the coal export terminal, the unloading of coal from train cars, and the total annual coal throughput. Key assumptions for rail included an estimated duration of 111 minutes (1.85 hours) to unload a 125-car unit train (ICF and Hellerworx 2017). It was assumed that all locomotives would use ultra-low-sulfur diesel (15 ppb sulfur). Appendix A, *Air Quality Data,* presents this approach in detail (Table 3).

Vessel

The impact analysis approach for vessel operations assumed that each vessel receiving coal would need three tugs to maneuver the ship, and would require 3 hours total time to assist with docking and departing operations. Further, it was estimated that an average of 13 hours would be needed to load each vessel with coal, and during this period, the vessel would be hoteling using auxiliary engines. The typical main and auxiliary engine size was based on Lloyd's Register of Ships Sea-web (Sea-Web 2015).[2] To comply with International Maritime Organization 2016 Emission Control Areas for North America, all vessels were assumed to use the maximum allowed sulfur content marine distillate fuel of 0.1% (1,000 ppm). It was also assumed that all tugboats would use ultra-low-sulfur diesel (15 ppb sulfur). To estimate the vessel emissions outside Cowlitz County but within Washington State, a one-way travel distance of 51.5 miles (Cowlitz County line to 3 nautical miles beyond the mouth of the Columbia River) was used in the analysis along with a round-trip travel time of 8.2 hours. Appendix A, *Air Quality Data,* presents this approach in detail (Table 3).

Vehicle Delays at At-Grade Rail Crossings

Off-site emissions associated with vehicle delays at at-grade rail crossings from Proposed Action-related trains on the Reynolds Lead and BNSF Spur are included in this analysis. Appendix A, *Air Quality Data,* presents this approach in detail (Table 3).

Employee Commute Vehicles

The impact analysis approach for employee vehicle emissions assumed approximately 135 vehicles commuting to and from the project area each day, and an average travel time of 24.1 minutes. Appendix A, *Air Quality Data,* presents this approach in detail (Table 3).

[2] The Sea-Web data is produced by IHS Global Limited. The data is based on Lloyd's Register of Ships Sea-web provided ship characteristics data for ships over 100 gross tons.

Table 3. Operations Emissions, Source Type, and Location of Detailed Methods

Source Type	Characterization for the Air Dispersion Modeling	Appendix A Section Detailing Calculation Methods
Handling and transfer of coal, including unloading coal from rail cars, transferring coal on conveyors, piling coal onto storage piles, and loading coal onto ships[a]	Volume	A6
Locomotive exhaust emissions that occur during moving, unloading, idling, and switching of rail cars	Line	A8a, A8b, and A8c
Maneuvering and hotel emissions during vessel loading and tug assist maneuvering	Point	A9a and A9b
Emissions from operations (e.g., loader) and maintenance equipment	Point	A10a and A10b
Coal dust from coal storage piles	Area	A4 and A5
Coal dust from moving rail cars	Line	A7

Characterizing Emissions for Air Quality Modeling

An air quality modeling impact assessment was conducted to assess the localized air quality impacts from operation of the terminal on air quality and assess the contribution from just terminal emissions, from all on-site activities, and from all activities, including off-site activities.

The air quality modeling methodology follows general EPA protocols used in air quality permitting. The methodology used is similar to the approach used in the *Air Quality Analysis Environmental Report* prepared by URS (URS Corporation 2015). One notable exception was the use of the Tier 3 level Ozone Limiting Method (OLM) to estimate NO_2 concentration. The OLM approach accounts for the NO_x to NO_2 conversion,[3] using EPA's default NO_2/NO_x equilibrium ratio of 0.9, an in-stack NO_2 to NO_x of 0.05 for locomotives,[4] an in-stack of NO_2 to NO_x of 0.20 for vessels (Alföldy et al. 2013), and an NO_2 to NO_x of 0.30 for on-site equipment (Wang et al. 2011). The OLM approach also requires the O_3 data. The nearest representative O_3 data available was from the Oregon Department of Environmental Quality's Sauvie Island monitor located on the Columbia River approximately 25 miles south-southeast of the project area. However, this site is not a year-round monitor, and other more distant and less representative sites would be needed to complete the analysis using monitored data. Instead, representative background concentrations for the study area were obtained from the Northwest International Air Quality Environmental Science and Technology Consortium (NW AIRQUEST), Washington State University, for 2009 through 2011.[5] The background ozone concentration for this location was 79 µg/m^3.

[3] Atmospheric chemistry changes NO to NO_2; the rate at which this conversion takes place is limited by the available ozone and sunlight.

[4] About 5% of NO_x freshly emitted from locomotives is in the form of NO_2 (Fritz pers. comm.).

[5] The consortium developed background design value estimates for 2009 through 2011, based on model-monitor interpolated products that provide realistic background design value estimates where nearby ambient monitoring data are unavailable. The work is sponsored by EPA Region 10, Ecology, and others. More information about the NW AIRQUEST tool can be found at http://www.lar.wsu.edu/nw-airquest/lookup.html.

The air quality model requires that emissions be characterized for use in AERMOD as four types of sources: point, volume, area, and line sources.[6] Each emissions source type characteristic is summarized below.

- **Point sources.** Vessels and tugboat emissions from vented stacks were characterized as point sources. The operating and maintenance equipment were also modeled as point sources spread across the terminal. Exhaust emissions from on-site operations and maintenance equipment were also based on the NONROAD model. Vessel emissions factors came from several sources, including California's Air Resource Board (CARB) *Emission Estimation Methodology for Ocean Going Vessels* (California Air Resource Board 2011), and EPA's *Federal Marine Compression-Ignition Engines, Exhaust Emission Standards* for highest tier engines—auxiliary and Tugs C2; main engine C3 (U.S. Environmental Protection Agency 2012). This analysis assumes that EPA's engine emissions standards are fully implemented by 2016, and that all vessels would be using these types of engines by the time the terminal would become fully operational.
- **Volume sources.** Coal transfer operations were characterized as volume sources, which included eight transfer towers, a rotary rail dump, surge bins work points, and two conveyors to load coal onto the vessels with emissions rates estimated based on the EPA AP-42, Chapter 13.2.4 approach (U.S. Environmental Protection Agency 1995b).
- **Area sources.** Area sources were used to model low-level ground releases. The four coal storage piles were modeled as area sources with emissions estimated following the EPA AP-42, Chapter 13.2.5 approach (U.S. Environmental Protection Agency 1995c).
- **Line sources.** Exhaust emissions from locomotives unloading operations and coal dust from moving rail cars were modeled as line sources. Coal dust particulate emissions were estimated following EPA's AP-42, Chapter 13.2.5 approach (U.S. Environmental Protection Agency 1995c), and locomotive exhaust emissions were estimated following EPA's NONROAD2008a model[7] (U.S. Environmental Protection Agency 2009).

Table 3 presents a list of emissions source types associated with operations and identifies how the source type is characterized in AERMOD. Appendix A, *Air Quality Data,* provides further details on emissions calculations.

Health Risk Assessment Impacts Approach

The operations sources of DPM emissions were also assessed for their potential increase in inhalation cancer risk using AERMOD. The model outputs DPM concentrations, which are then expressed in terms of cancer risk using the 80th percentile value breathing rate ((302 liters per kilogram per day [L/kg/day]) for residential receptors with a cancer potency value for diesel PM of 1.1 milligrams per kilogram per day (mg/kg/day)-1 and conservatively assuming that the receptors are exposed 24 hours per day for 70 years. This approach follows California's 2003 Office of Environmental Health Hazard Assessment Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments for a Tier 1 standard point estimate risk assessment approach. The results are presented in terms of increased inhalation cancer risk per million population. Two risk assessments were performed: one using DPM emissions fixed at when the facility reaches maximum operations (2028) and a second using integrated lifetime DPM emissions over 70 years.

[6] AERMOD User Guide (2004) provides additional information on the definition of these source types.
[7] Rail emissions were based on the national fleet Class-1 line-haul locomotive fleet.

The results from the modeling are discussed in terms of increased inhalation cancer risk per million people. To provide perspective on the increased cancer risk from the Proposed Action, results were compared with the countywide average inhalation cancer risk of 30 per million, as reported by EPA (2015) based on their most recent (2011) nationwide air toxic assessment. However, EPA does not include DPM in its cancer risk assessment, because it does not consider the data sufficient to quantitatively determine the diesel cancer potency factor. Because no baseline inhalation cancer risk for Cowlitz County that accounts for DPM is available,[8] the California Office of Environmental Health Hazard Assessment cancer potency value was applied to the EPA (2011) average Cowlitz County DPM concentration (1.14 μg/m^3) to establish a baseline for comparison in this analysis. The resulting countywide average inhalation cancer risk from DPM emissions is approximately 300 cancers per million. Thus, an increased risk of 10 cancers per million would represent an approximately 3% increase existing risk. Similarly, an increased risk of 30 cancers per million, would represent a 10% increase over existing levels.

2.2 Existing Conditions

The existing environmental conditions related to air quality in the study area are described below.

2.2.1 Project Area Air Quality Conditions

The following sections describe the meteorological conditions and background air quality conditions.

2.2.1.1 Prevailing Meteorology and Climate

The project area is located along the Columbia River in southwestern Washington, approximately 50 miles east of the Pacific Ocean. The region is characterized as a mid-latitude, west coast marine-type climate. The Cascade Range to the east has a large influence on the climate in Cowlitz County. The Cascade Range forms a barrier from continental air masses originating over the Columbia River Basin. The Cascades also induce heavy amounts of rainfall; as moist air from the west rises, it is forced to rise up the mountain slopes, which produces heavier rainfall on the western slopes of the Cascades and moderate rainfall amounts in the lower lying areas, such as Longview.

Summers in the region are mild and dry. Winters are cool, but typically wet and cloudy with a small range in daily temperature. The average annual precipitation in Longview is approximately 48 inches, with most precipitation falling during the months of November through March (National Climate Data Center 2011). Average annual rain events, taken as days with measured rain greater than 0.01-inch, are approximately 175 days per year, based on National Climatic Data Center summaries.

Due mostly to its geographical location, temperatures are usually mild. Days with maximum temperatures above 90 degrees Fahrenheit (°F) occur about 7 times per year on average. Days with a minimum temperature below 32°F occur about 57 times per year on average, and below 0°F temperatures occur only very rarely (none recorded between 1931 and 2006). Mean high

[8] Because the EPA 2002 health assessment document for diesel engine exhaust does not find data sufficient to quantitatively determine the diesel cancer potency factor.

temperatures range from the high 70s in the summer to mid-40s (°F) in winter, while average lows are generally in the low 50s in summer and mid-30s in winter.

Meteorological data collected by the Weyerhaeuser meteorological tower at the nearby Mint Farm Industrial Park between 2001 and 2003 indicates that the prevailing winds near the project area are from the west-northwest and southeast, following along the alignment of the Columbia River. In the fall and winter months (October through March), the winds are primarily from the southeast and east; the winds are typically from the west-northwest in the spring and summer months (April through September). Figure 3 shows the annual wind rose for the Mint Farm meteorological station for the three-year period from 2001 to 2003 with an average wind speed of 2.25 meters/second.

2.2.1.2 Project Area Background Air Quality

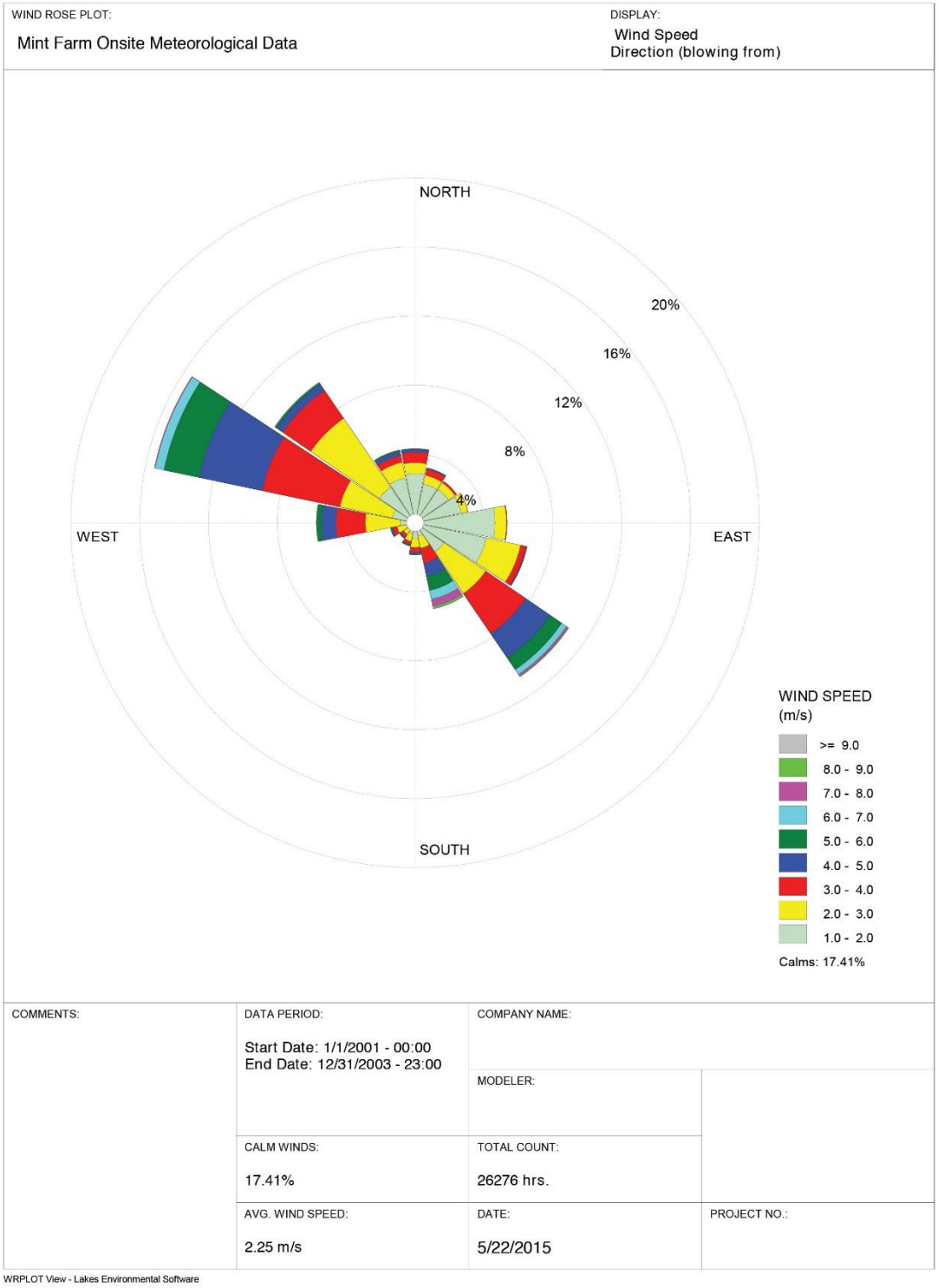
As discussed in Section 1.2.3, *Attainment Status*, Cowlitz County is attainment or unclassified for all criteria pollutants, indicating that air quality in the vicinity of the project area meets the federal and state ambient air quality standards shown in Table 2. The only available local air pollutant monitoring is for PM2.5. The monitor is operated by Ecology and is located at 1234 30th Avenue in Longview (Olympic School), approximately 1.5 miles east of the project area.

Beginning January 1, 2007, hourly data were made available for analysis and download at Ecology's monitoring data site (Washington State Department of Ecology 2015a). The four most recent years of complete data from this site (2013 through 2016) were reviewed and the 3-year average of 98th percentile is 19.3 $\mu g/m^3$. This 3-year average is well below the 24-hour 98th percentile PM2.5 standard of 35 $\mu g/m^3$. The maximum 3-year annual average PM2.5 concentration was 6.2 $\mu g/m^3$. The monitoring shows that PM2.5 levels in the Longview-Kelso area are well within the PM2.5 air quality standards. However this $PM_{2.5}$ monitor is not a Federal Reference Method or Federal Equivalence Method monitor, and thus, cannot be used to make formal designations of attainment status.

Concentrations of other criteria pollutants for the study area also are expected to be well within air quality standards, although no monitoring data are available. Estimated values based on air quality modeling are discussed in Section 3.1.2, *Operations*.

In addition, criteria pollutants results from the Longview air toxics study (Southwest Clean Air Agency 2007) showed that measured levels of toxic pollutants were below levels of concern for short-term and long-term exposures. The study found that, of the air toxics that could be directly monitored, the air toxics of most concern for potential health risk in Longview are acetaldehyde, arsenic, benzene, manganese, and formaldehyde, while DPM was identified as the most likely contributor to cancer risk in Washington State. No further studies on air toxic monitoring in the Longview-Kelso area has been conducted since that time. Regarding HAPs, the most recent national air toxic assessment (U.S. Environmental Protection Agency 2011) showed that Cowlitz County has an overall inhalation cancer risk of 30 cancers per million, which is slightly lower than the state and national averages of 40 cancers per million and below the national average of 40 cancers per million. However, the national air toxics assessment does not quantify cancer risk associated with exposure to DPM. A similar pattern emerges when DPM is included in the analysis, but with levels nearly ten times higher (Washington State Department of Ecology 2011).

Figure 3. Wind Data for Mint Farm 2001-2003, Supplemented with Portland International Airport for Missing Hours



2.2.2 Cowlitz County Air Quality Conditions

Cowlitz County is classified as attainment or unclassified for all air pollutants. Of the criteria air pollutants, only PM2.5 is currently being monitored in the county. The PM2.5 monitoring station located at the Olympic Middle School is a neighborhood-scale site, affected primarily by smoke from home heating. It is considered representative of the Longview-Kelso area and is used for curtailment calls during the home heating season. As described previously, the 3-year average is well below the 24-hour 98th percentile PM2.5 standard of 35 µg/m^3. Although it is not a reference instrument, it is considered a strong indicator of the relative air quality for the Longview-Kelso area. Air quality in other locations of Cowlitz County is generally as good as or better than in the Longview-Kelso area. Refer to Section 2.2.1.2, *Project Area Background Air Quality*, for additional information on existing air quality conditions.

2.2.3 Washington State Air Quality Conditions

As described in the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017), most loaded and empty trains would be expected to travel the same route between the Washington-Idaho State line and Pasco, Washington. West of Pasco, westbound loaded trains would travel to the project area along the Columbia River Gorge route, through Vancouver, to Longview Junction on the BNSF main line, and then along the BNSF Spur and Reynolds Lead to the project area. Empty trains would travel from the project area along the Reynolds Lead and BNSF Spur to Longview Junction, on the BNSF main line to Auburn, over Stampede Pass, then through Yakima and back to Pasco.

Air quality along the loaded portion of the rail route in eastern Washington from the Idaho border to Pasco is generally good. Spokane is a maintenance area for carbon monoxide, but has not had an exceedance of the carbon monoxide standard in over 10 years. Also in this region of the Columbia Plateau from spring through fall, high winds can combine with dry weather conditions to create dust storms, which can lead to extremely high levels of PM10. The state monitors for PM2.5 along this route, but in general the monitoring is below the state's goal to keep concentrations below 20 µg/m^3, which is well below the PM2.5 NAAQS of 35 µg/m^3. Air quality through the Columbia Gorge is generally good, with the primary concern focused on visibility impairment and regional haze issues; standards established to protect visibility are much lower than for health effects. The air quality from Vancouver up to Longview is generally good with PM2.5 being the pollutant of most concern; readings are generally below the state's goal to keep PM2.5 concentrations below 20 µg/m^3. The few days with higher levels mostly occur during the home heating season. Vancouver design values cannot be calculated because of data completeness issues.

Unloaded rail cars would pass from Longview through Tacoma, up to Auburn, and over the Cascades via Stampede Pass. The area east of Auburn experiences some of the highest ozone levels in western Washington, but these levels are below the NAAQS. The ozone monitoring site near Enumclaw has shown exceedances of the 8-hour ozone standard during the past 3 years (Washington State Department of Ecology 2015b).

Air quality from Stampede Pass through Yakima and back to Pasco is generally good but in the Yakima region recent monitoring data in the area has shown higher than usual levels of PM2.5 that contains nitrate. In Yakima, much of the PM2.5 comes from wood burning, with the highest levels occurring during the wintertime as a result of increased wood burning along with stagnant air conditions (Washington State Department of Ecology 2015b); nitrate accounts for up to one-quarter

of the wintertime PM2.5 in the Yakima area. High levels of daily PM2.5 are found in Ellensburg for 2 to 3 weeks each year. Unloaded rail cars would then pass along the same route from Pasco back to Spokane with the same air quality as described above.

Vessel traffic would traverse along the Columbia River between the project area and the mouth of the Columbia River. Wahkiakum and Pacific Counties are designated as attainment areas for criteria air pollutants.

With respect to HAPs, the 2005 EPA National-Scale Air Toxics Assessment was adjusted by Ecology to estimate cancer risk (Washington State Department of Ecology 2011). Inhalation cancer risks were highest in the major population centers along the rail route (i.e., Vancouver and Spokane), with a cancer risk of up to 500 cancers per million. For the smaller communities (i.e., Kelso-Longview, Spokane, Yakima, and Pasco), cancer risks were up to 300 cancers per million, although locations along the rail line have cancer risks of less than 75 cancers per million.[9]

[9] EPA released the results from the 2011 National-Scale Air Toxics Assessment in December 2015. The 2011 Ecology study uses the 2005 National-Scale Air Toxics Assessment.

Chapter 3
Impacts

This chapter describes the impacts on air quality that would result from construction and operation of the Proposed Action or the ongoing activities of the No-Action Alternative.

3.1 Proposed Action

Potential impacts on air quality from the construction and operation of the Proposed Action are described below.

3.1.1 Construction

The construction material delivery scenario with the highest emissions would be the barge scenario, which would deliver construction materials via barge and truck. Haul truck emissions are included for the truck trips needed to make deliveries of construction material from the barge dock to the project area.

Table 4 illustrates the maximum daily construction emission estimates. The maximum daily construction emissions occur early in the construction schedule with earthwork activity and with the delivery of construction of materials via barge and truck (Table 4). Maximum annual construction emission estimates for the peak construction year are shown in Table 5. The estimated emissions shown in Tables 4 and 5 assume the implementation of best management practices, including reduced idling measures, dust control measures to minimize soil disturbance, and the application of water along access roads to minimize track-out of soil.

The maximum annual construction-related emissions would be below the prevention of significance deterioration thresholds[10] established by EPA, as shown in Table 4. This means that although emissions of criteria air pollutants would occur during construction, they would not be expected to cause a substantial change in air quality or adversely affect sensitive receptors[11] near the project area.[12]

[10] The prevention of significance deterioration thresholds are the lowest thresholds that would define the emissions as less than a major modification to a major stationary source. This applies to areas in attainment with NAAQS.

[11] Sensitive air quality receptors are a facility or land use that houses or attracts members of a population who are particularly sensitive to the effects of air pollutants, such as children, the elderly, and people with illnesses. Examples of sensitive receptors include schools, hospitals, day care centers, convalescent facilities, senior centers, and parks or recreational facilities.

[12] While the study area is not a major stationary source subject to federal prevention of significant deterioration rules (40 CFR 52.21), the emission threshold levels were used to provide a threshold against which to evaluate potential impact from construction.

Table 4. Maximum Annual Estimated Construction Emissions

Source	Construction Emissions (tpy)								
	NO_x	**CO**	**VOCs**	**SO_2**	**TSP**	**PM10**	**PM2.5**	**HAPs**	**DPM**
Combustion Sources									
Equipment (in project area)	24.60	9.04	2.23	0.95	2.34	1.93	1.93	0.05	2.34
Haul Trucks (in project area)	4.06	0.88	0.18	0.01	0.23	0.19	0.13	0.004	0.23
Haul Trucks (in study area)[a]	9.37	2.04	0.41	0.03	0.54	0.44	0.31	0.010	0.54
Barges[b]	59.0	15.68	1.51	0.028	1.29	1.06	1.06	0.03	1.29
Passenger Commute Vehicles/Crossing-Delay (in study area)[a]	0.05	7.5	0.13	0.010	0.22	0.22	0.04	0.001	<0.001
Total Combustion Sources (project area)	**28.66**	**9.92**	**2.41**	**0.96**	**2.57**	**2.12**	**2.06**	**0.05**	**2.57**
Total Combustion Sources (all study area)[c]	**38.1**	**19.5**	**2.95**	**1.0**	**3.3**	**2.8**	**2.4**	**0.07**	**3.1**
Fugitive Sources									
Controlled Fugitive Earthwork (in project area)	-	-	-	-	12.00	5.87	1.22	-	-
Total Fugitive Sources	-	-	-	-	**12.00**	**5.87**	**1.22**	-	-
Total									
On-site construction emissions sources (in project area)	**28.7**	**9.9**	**2.41**	**0.96**	**14.6**	**7.99**	**3.28**	**0.05**	**2.6**
All construction emissions sources[c]	**38.1**	**19.5**	**2.95**	**1.0**	**15.3**	**8.7**	**3.6**	**0.07**	**3.1**
PSD significance thresholds (40 CFR 52.21)	**40**	**100**	**40**	**40**	**—**	**15**	**10**	**—**	**—**

Source: Combustion and fugitive emissions sources were obtained from various references, as described above under Section 2.1.2.1, *Construction Impact Analysis Approach*.

Notes:

[a] Not in the project area but within Cowlitz County.

[b] Not in study area. Based on barge maneuvering time for docking of 0.5 hour in and 0.5 hour out; does not include transit on the Columbia River.

[c] Rounded. Does not include barge emissions, but does include haul truck emissions to the project area.

"-" = not applicable

tpy = tons per year; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; TSP = total suspended particles; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; HAPs = hazardous air pollutants; DPM = diesel particulate matter; PSD = prevention of significance deterioration; CFR = Code of Federal Regulations

Table 5. Maximum Daily Estimated Construction Emissions

Source	Construction Emissions (lb/day)								
	NO_x	CO	VOCs	SO_2	TSP	PM10	PM2.5	HAPs	DPM
Combustion Sources									
Equipment (in project area)	229.6	82.89	20.4	8.67	21.49	17.66	17.66	0.42	21.5
Haul Trucks (in project area)	54.7	14.4	3.1	0.2	6.1	5.0	2.6	0.1	6.12
Haul Trucks (in study area)[a]	110.48	24.0	4.81	0.33	6.34	5.21	3.66	0.12	6.34
Barges[b]	454.7	120.8	11.6	0.21	9.90	8.14	8.14	0.61	9.9
Passenger Commute and Crossing Delay (in study area)[a]	1.43	20.0	0.35	0.03	0.58	0.58	0.11	0.01	<0.001
Total Combustion Sources (in project area)	**284.3**	**97.29**	**23.5**	**8.87**	**27.59**	**22.66**	**20.26**	**0.52**	**27.62**
Total Combustion Sources (all study area)[c]	**396.2**	**141.29**	**28.7**	**9.23**	**34.5**	**28.5**	**24.0**	**0.65**	**34.0**
Fugitive Sources									
Controlled Fugitive Earthwork	-	-	-	-	66.7	32.6	6.80	-	-
Total Fugitive Sources	-	-	-	-	**66.7**	**32.6**	**6.80**	-	-
Total									
Onsite construction emissions sources (in project area)	**284.3**	**97.29**	**23.5**	**8.87**	**94.3**	**55.3**	**27.1**	**0.52**	**27.6**
All construction emissions sources[c]	**396.2**	**141.29**	**28.7**	**9.23**	**101.21**	**61.1**	**30.8**	**0.65**	**34.0**

Notes:

Source: Combustion and fugitive emissions sources were obtained from various references, as described above under Section 2.1.2.1, *Construction Impact Analysis Approach*.

[a] Not in the project area, but within Cowlitz County.

[b] Not in project area. Based on barge maneuvering time for docking of 0.5 hour in and 0.5 hour out; does not include transit on the Columbia River

[c] Rounded. Does not include barge emissions, but does include haul truck emissions to the project area.

"-" = not applicable

lb/day = pounds per day; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; TSP = total suspended particles; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; HAPs = hazardous air pollutants; DPM = diesel particulate matter

3.1.2 Operations

Sources of air pollution from the Proposed Action would include fugitive emissions from coal handling, coal storage piles, emergency equipment, employee commute vehicles, and mobile source emissions from maintenance and operation of the coal export terminal, as well as emissions from trains and vessels used in transport. As presented in Table 6, rail and vessel transport would be the largest sources of emissions. The Proposed Action would produce small quantities of air pollutants from maintenance, operations, and emergency equipment. The table also shows fugitive emissions related to coal transfer and storage.

Table 6. Full Operations Maximum Annual Average Emissions[a]

	Maximum Annual Average Emissions (tpy)								
Source	**NO_x**	**CO**	**VOCs**	**SO_2**	**TSP**	**PM10**	**PM2.5**	**HAPs**	**DPM**
Fugitive Sources									
Coal Transfer (except piles):									
Material Handling	-	-	-	-	5.25	1.84	0.28	-	-
Coal Piles:									
Wind Erosion	-	-	-	-	3.05	2.59	0.40	-	-
Material Handling	-	-	-	-	2.62	0.92	0.14	-	-
Mobile Sources									
Maintenance/Operations/ Emergency Equipment:									
Combustion	4.36	1.45	0.37	0.20	0.38	0.31	0.31	0.01	0.38
Employee Commute\Crossing Delay	0.13	2.05	0.04	0.003	0.08	0.08	0.02	0.01	<0.01
Locomotive:									
Combustion (study area)[b]	23.3	10.18	0.80	0.036	0.60	0.50	0.48	0.11	0.60
Fugitive Dust (study area)[b]	-	-	-	-	1.03	0.88	0.13	-	-
Combustion (project area)	14.0	5.04	0.56	0.02	0.36	0.30	0.29	0.05	0.27
Fugitive Dust (project area)	-	-	-	-	3.68	3.13	0.48	-	-
Vessels:									
Combustion (study area)[b]	24.8	37.9	14.1	3.04	2.17	1.78	1.64	0.03	0.00
Combustion (project area)	23.3	65.9	15.3	4.52	1.27	1.05	1.02	0.08	0.56
Total: All Mobile Sources, Project Area and Study Area	89.89	122.5	31.17	7.82	9.57	8.03	4.37	0.29	1.82
Total – Project Area Sources	37.30	70.94	15.86	4.54	5.31	4.48	1.79	0.13	0.83
Fugitive Dust Only (project area)	-	-	-	-	15.63	9.36	1.43	-	-
Mobile Combustion Sources (project area)	41.66	72.4	16.23	4.74	5.69	4.79	2.10	0.14	1.21

Notes:

Source: Combustion and fugitive emissions sources were obtained from various references, as described in Section 2.1.2.2, *Operations Impact Analysis Approach*.

[a] Full operations = Maximum production (44 million metric tons per year).

[b] Study Area = Not included in the project area.

"-" = Not applicable.
tpy = tons per year; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; TSP = total suspended particles; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; HAPs = hazardous air pollutants; DPM = diesel particulate matter

3.1.2.1 Air Quality Impact Assessment

A modeling analysis was performed with the AERMOD dispersion model. The results from the modeling are compared with the NAAQS.

Two sets of emissions were developed. The first set was used to model the long-term (annual average concentrations), reflecting emissions over an entire year with train and vessel arrivals spread over the year to simulate the average activity at the terminal. The second set of emissions was used to determine the short-term (24-hour or less concentrations), reflecting peak emissions that could occur during the course of an hour. Peak activity included a coal train unloading at the terminal, a vessel loading with coal, and a second vessel docking at the terminal.

To assess impacts associated with the Proposed Action, the AERMOD model was used to predict the increase in criteria pollutant concentrations. The maximum modeled incremental increases for each pollutant and averaging time were added to applicable background concentrations. With the exception of PM2.5, the background concentrations were obtained from NW AIRQUEST, Washington State University, for 2009 through 2011.[13] These consortium values are typically recommended for use as background concentration by Ecology in air quality analyses when no representative monitoring data is available. The resulting total pollutant concentrations (background plus modeled concentration) were then compared with the appropriate NAAQS.

As described in Section 2.2, *Existing Conditions*, there is a monitoring program for PM2.5 in the Longview-Kelso area and the resulting data were used to estimate the background concentration for PM2.5. The method for comparing modeled impacts with added background concentrations to each NAAQS is dependent on the form of the standard, and thus varies by pollutant and averaging time. The differences are footnoted in the comparison tables (Tables 7, 8, and 9). For example, the 1-hour NO_2 NAAQS is based on the 98th percentile of 1-hour daily maximum concentration (8th highest 1-hour daily maximum for a full year of hourly values) across the 3 meteorological modeling years (2009 through 2011) plus the background concentration.

Table 7 summarizes the maximum predicted criteria pollutant concentrations due to maintenance and operations of the terminal only. This includes the material handling and moving of the coal and coal piles as well as exhaust emissions from mobile source equipment (e.g., loader and employee vehicles). In no case are the terminal-only estimated emissions in combination with the background concentrations anticipated to cause a violation of any NAAQS. The highest increase in concentration due to export terminal-only operation is the 24-hour PM10 impact, which would increase 88 $\mu g/m^3$, or about 59% of the PM10 NAAQS. The next highest increase in concentration due to export terminal-only operation is the 24-hour PM2.5 impact, which would increase 11.2 $\mu g/m^3$, or about 32% of the PM-2.5 NAAQS. Similarly, the 1-hour NO_2 impact would increase 18.8 $\mu g/m^3$, or about 10% of the NO_2 NAAQS. All other pollutants would increase less than 2% of the relevant NAAQS.

[13] The consortium developed background design value estimates for 2009 through 2011, based on model-monitor interpolated products that provide realistic background design value estimates where nearby ambient monitoring data are unavailable. The work is sponsored by EPA Regiol 10, Ecology, and others. More information about the NW AIRQUEST tool can be found at http://www.lar.wsu.edu/nw-airquest/lookup.html.

Table 7. AERMOD Modeling Results (Terminal Sources: Maintenance and Operations Equipment)[a]

Pollutant	Averaging Period	Modeled Impact (µg/m³)	Background[b,c] (µg/m³)	Total Predicted Concentration (µg/m³)	NAAQS (µg/m³)
CO	1 hour[d]	12.8	827	840	40,000
	8 hour[d]	5	600	605	10,000
NO_2	1 hour[e,f]	18.8	56.6	75.4	188
	Annual[f,g]	0.4	5.3	5.7	100
PM10	24 hour[h]	88	23	111	150
PM2.5	24 hour[i]	11.2	19.3	30.5	35
	Annual[j]	0.23	6.2	6.44	12
SO_2	1 hour[k]	1.2	14.7	15.9	196
	3 hour[l]	0.75	11.5	12.3	1,300

Notes:

[a] Coal export terminal operation sources include coal storage piles; rotary rail unloaders; mobile operation, maintenance, and emergency equipment; and employee vehicles.

[b] Background design value estimates for 2009 through 2011, based on model-monitor interpolated products (except PM2.5) sponsored by EPA Regionl 10, Ecology, and others. From NW AIRQUEST tool Washington State University (http://www.lar.wsu.edu/nw-airquest/lookup.html.)

[c] PM2.5 background based on Ecology's Kelso Monitor (2013 through 2016). The reported 24-hour value is the maximum of the 3-year average of the yearly 98th percentile of the daily concentration.

[d] Modeled impact is the highest 2nd high for each calendar year over the 3 modeled years..

[e] The NO_2 1-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[f] Modeled NO_2 impacts applied the Tier III Ozone Limiting Method (OLM), using an ozone background of 42 ppb, as per the NW AIRQUEST tool. For additional information regarding the modeling methodology, see Section 2.1.2.2, *Operations Impact Analysis Approach*.

[g] The NO_2 annual modeled impact is the maximum annual mean over the 3 modeled years.

[h] The PM10 24-hour modeled impact is the 2nd highest concentration over a 3-year period this is more conservative than the NAAQS compliance methodology of the 3-year average of the highest 2nd high concentration for each year.

[i] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[j] The PM2.5 annual modeled impact is the 3-year average of the annual mean.

[k] The SO_2 1-hour modeled impact is the 3-year average of the 99th percentile of the 1-hour daily maximum concentrations.

[l] The SO_2 3-hour modeled impact is not to be exceeded more than once per year.

µg/m³ = micrograms per cubic meter; NAAQS = National Ambient Air Quality Standards; CO = carbon monoxide; NO_2 = nitrogen dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; SO_2 = sulfur dioxide

Table 8 shows the modeling results for on-site sources (terminal emissions sources, plus cargo vessel and train operations while on-site). Estimated emissions from all project area operations, in combination with the background concentrations, would not exceed any NAAQS.

The highest increase in emissions due to export terminal operation plus cargo vessel and train operations is the 24-hour PM10 impact, which would increase 92.6 µg/m³, or about 62% of the PM10 NAAQS. The largest source of this increase is form the fugitive emissions from the coal piles, followed closely by material handling of the coal and, to a lesser extent, the unloading of the coal train. The next highest increase is the 1-hour NO_2 impact, which would increase 94.3 µg/m³, or about 50% of the NO_2 NAAQS. This increase is almost exclusively due to the line-haul locomotive emissions but the switch locomotive engine also contributes. Similarly, the 24-hour PM2.5 impact

would increase 11.9 μg/m^3, or about 34% of the PM2.5 NAAQS. All other pollutants would increase less than or equal to a 15% of the relevant NAAQS.

Table 8. AERMOD Modeling Results (Project Area Sources)[a]

Pollutant	Averaging Period	Modeled Impact (μg/m^3)	Background[b,c] (μg/m^3)	Total Predicted Concentration (μg/m^3)	NAAQS (μg/m^3)
CO	1 hour[d]	223	827	1,050	40,000
	8 hour[d]	51	600	651	10,000
NO_2	1 hour[d,e]	94.3	56.6	151	188
	Annual[f,g]	13.7	5.3	19	100
PM10	24 hour[h]	92.6	23	116	150
PM2.5	24 hour[i]	11.9	19.3	31.2	35
	Annual[j]	0.81	6.2	7.0	12
SO_2	1 hour[k]	10.6	14.7	25.3	196
	3 hour[l]	10.2	11.5	21.7	1,300

Notes:

[a] On-site sources include emissions from handling coal, coal storage piles, and mobile source exhaust emissions from the operation and maintenance of the facility.

[b] Background design value estimates for 2009 through 2011, based on model-monitor interpolated products (except PM2.5) sponsored by EPA Region 10, Ecology, and others. From NW AIRQUEST tool Washington State University (http://www.lar.wsu.edu/nw-airquest/lookup.html.)

[c] PM2.5 background based on Ecology's Kelso Monitor (2013 through 2016). The reported 24-hour value is the maximum of the 3-year average of the yearly 98th percentile of the daily concentration.

[d] Modeled impact is the highest 2nd high for each calendar year over the 3 modeled years.

[e] The NO_2 1-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[f] Modeled NO_2 impacts applied the Tier III Ozone Limiting Method (OLM), using an ozone background of 42 ppb, as per the NW-AIRQUEST tool. For additional information regarding the modeling methodology, see Section 2.1.2.2, *Operations Impact Analysis Approach*.

[g] The NO_2 annual modeled impact is the maximum annual mean over the 3 modeled years.

[h] The PM10 24-hour modeled impact is the 2nd highest concentration over a 3-year period this is more conservative than the NAAQS compliance methodology of the 3-year average of the highest 2nd high concentration for each year.

[i] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[j] The PM2.5 annual modeled impact is the 3-year average of the annual mean.

[k] The SO_2 1-hour modeled impact is the 3-year average of the 99th percentile of the 1-hour daily maximum concentrations.

[l] The SO_2 3-hour modeled impact is not to be exceeded more than once per year.

μg/m^3 = micrograms per cubic meter; NAAQS = National Ambient Air Quality Standards; CO = carbon monoxide; NO_2 = nitrogen dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less or equal to than 2.5 micrometers in diameter; SO_2 = sulfur dioxide

Table 9 shows the modeling results for all project area sources and study area sources (vessels arriving and departing from the terminal, assist tugs, trains arriving and departing from the terminal to approximately 5 miles out, and vehicle delay at at-grade crossings in the study area). These results are similar to the on-site sources. The highest increase in emissions due to export terminal operation plus cargo vessel and train operations is the 24-hour PM10 impact, which would increase 92.6 μg/m^3, or about 62% of the PM10 NAAQS. The largest source of this increase is from the fugitive emissions from the coal piles, followed closely by material handling of the coal and, to a lesser extent, the unloading of the coal train. The next highest increase is the 1-hour NO_2 impact, which would increase 94.3 μg/m^3, or about 50% of the NO_2 NAAQS. This increase is almost exclusively due to the line-haul locomotive emissions but the switch locomotive engine also

contributes. The 24-hour PM2.5 impact would increase 11.9 µg/m^3, or about 34% of the PM2.5 NAAQS. All other pollutants would increase no more than15% of the relevant NAAQS.

Table 9. AERMOD Modeling Results (Project Area and Study Area Sources)

Pollutant	Averaging Period	Modeled Impact (µg/m^3)	Background[a,b] (µg/m^3)	Total Predicted Concentration (µg/m^3)	NAAQS (µg/m^3)
CO	1 hour[c]	377	827	1,204	40,000
	8 hour[c]	99	600	699	10,000
NO_2	1 hour[c,d]	94.3	56.6	151	188
	Annual[e,f]	13.7	5.3	19.0	100
PM10	24 hour[g]	93.6	23	117	150
PM2.5	24 hour[h]	12.5	19.3	31.8	35
	Annual[i]	0.83	6.2	7.0	12
SO_2	1 hour[j]	10.6	14.7	25.3	196
	3 hour[k]	10.2	11.5	21.7	1,300

Notes:

[a] Background design value estimates for 2009 through 2011, based on model-monitor interpolated products (except PM2.5) sponsored by EPA Region 10, Ecology, and others. Source: NW AIRQUEST tool Washington State University (http://www.lar.wsu.edu/nw-airquest/lookup.html.)

[b] PM2.5 background based on Ecology's Kelso Monitor (2013 through 2016). The reported 24-hour value is the maximum of the 3-year average of the yearly 98th percentile of the daily concentration.

[c] Modeled impact is the highest 2nd high for each calendar year over the 3 modeled years.

[d] The NO_2 1-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[e] Modeled NO2 impacts applied the Tier III Ozone Limiting Method (OLM), using an ozone background of 42 ppb, as per the NW-AIRQUEST tool. For additional information regarding the modeling methodology, see Section 2.1.2.2, *Operations Impact Analysis Approach*.

[f] The NO_2 annual modeled impact is the maximum annual mean over the 3 modeled years.

[g] The PM10 24-hour modeled impact is the 2nd highest concentration over a 3-year period this is more conservative than the NAAQS compliance methodology of the 3-year average of the highest 2nd high concentration for each year.

[h] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of 1-hour daily maximum concentrations.

[i] The PM2.5 annual modeled impact is the 3-year average of the annual mean.

[k] The SO_2 1-hour modeled impact is the 3-year average of the 99th percentile of the 1-hour daily maximum concentrations.

[l] The SO_2 3-hour modeled impact is not to be exceeded more than once per year.

µg/m^3 = micrograms per cubic meter; NAAQS = National Ambient Air Quality Standards; CO = carbon monoxide; NO_2 = nitrogen dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; SO_2 = sulfur dioxide

3.1.2.2 Health Risk Impact Assessment

An inhalation-only health risk assessment was performed with the AERMOD dispersion model to assess increased cancer risk associated with increased DPM emissions related to the Proposed Action. Increased DPM exposure related to operations would be primarily from Proposed Action-related train locomotive diesel emissions. The risk assessment only considers the cancer risk by the inhalation pathway because the risk contributions by other pathways of exposure are difficult to quantify and are known to be negligible relative to the inhalation pathway.

The assessment looked at two scenarios.

- **Fixed emissions scenario.** Assumes DPM emissions in 2028 when the coal export terminal reaches maximum capacity.
- **Average lifetime emissions scenario.** Averages DPM emissions starting in 2018, reaching full capacity in 2028, and continuing at full capacity to reflect the cleaner Tier 4 locomotive engines gradually entering the fleet each year as older locomotives are retired.

A risk level of 1 cancer per million implies a likelihood that one person, out of 1 million people exposed to the same concentration of the same pollutant, would contract cancer if exposed continuously (24 hours per day/7 days per week) to that specific concentration over 70 years (an assumed lifetime)[14] per EPA (2015) guidance. This cancer risk would be in addition to any existing risk.

The cancer risk analysis follows standard approaches including use of the conservative assumption of continuous lifetime exposure. This overstates cancer risk even for residential uses where people typically spend more time, because individuals are mobile, spending time in locations other than their residence on an average day, and even changing residences over a lifetime. Cancer risk is further overstated for land uses where people spend less time, such as commercial and industrial locations.

To provide context for the increased cancer risk related to DPM, results can be compared with the countywide baseline of 300 cancers per million, developed for purposes of the analysis, as described in Section 2.1.2, *Impact Analysis Approach*. For example, an increased risk of 10 cancers per million would represent an approximately 3% increase over existing levels. Similarly, an increased risk of 30 cancers per million would represent an approximately 10% increase over existing levels.

Fixed Emissions Scenario (2028)

This section presents cancer risk based on the fixed emissions scenario. Figure 4 depicts increased inhalation cancer risk related to DPM emissions from coal export terminal sources (i.e., diesel-powered operation, maintenance, and emergency equipment). The contour for increased risk of 1 cancer per million extends across the width of the Columbia River and approximately 4 miles west of the project area and approximately 2.5 miles east of the project area. The 10 cancers per million risk contour is not shown on the figure, because no locations would experience increased risk levels at or above 10 cancers per million.

Figure 5 depicts increased inhalation cancer risk related to DPM emissions from all operation sources (i.e., terminal, rail, and vessel) in the project area. The contour for increased risk of 10 cancer per million extends across the Columbia River, approximately 1.3 mile southwest of the project area and approximately 0.1 mile northeast of the project area, and crosses Industrial Way near the northwest boundary of the project area. Portions of residential areas are within this contour.

[14] Consistent with EPA (2016) assumption for purposes of NATA risk characterization.

Figure 4. Increased Diesel Particulate Matter Cancer Risk from Coal Export Terminal Sources—Fixed Emissions Scenario

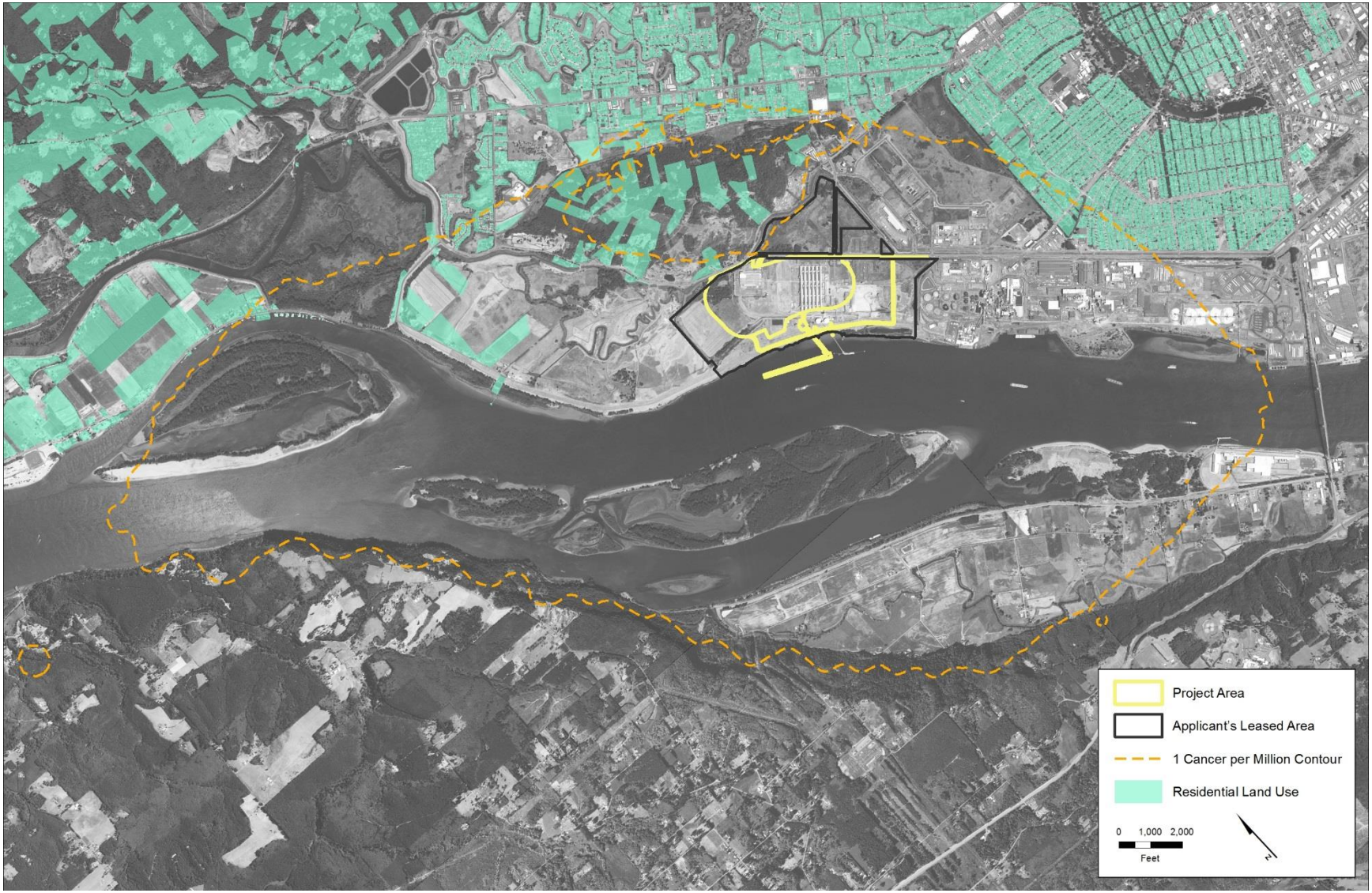


Figure 5. Increased Diesel Particulate Matter Cancer Risk from All Operations in the Project Area—Fixed Emissions Scenario

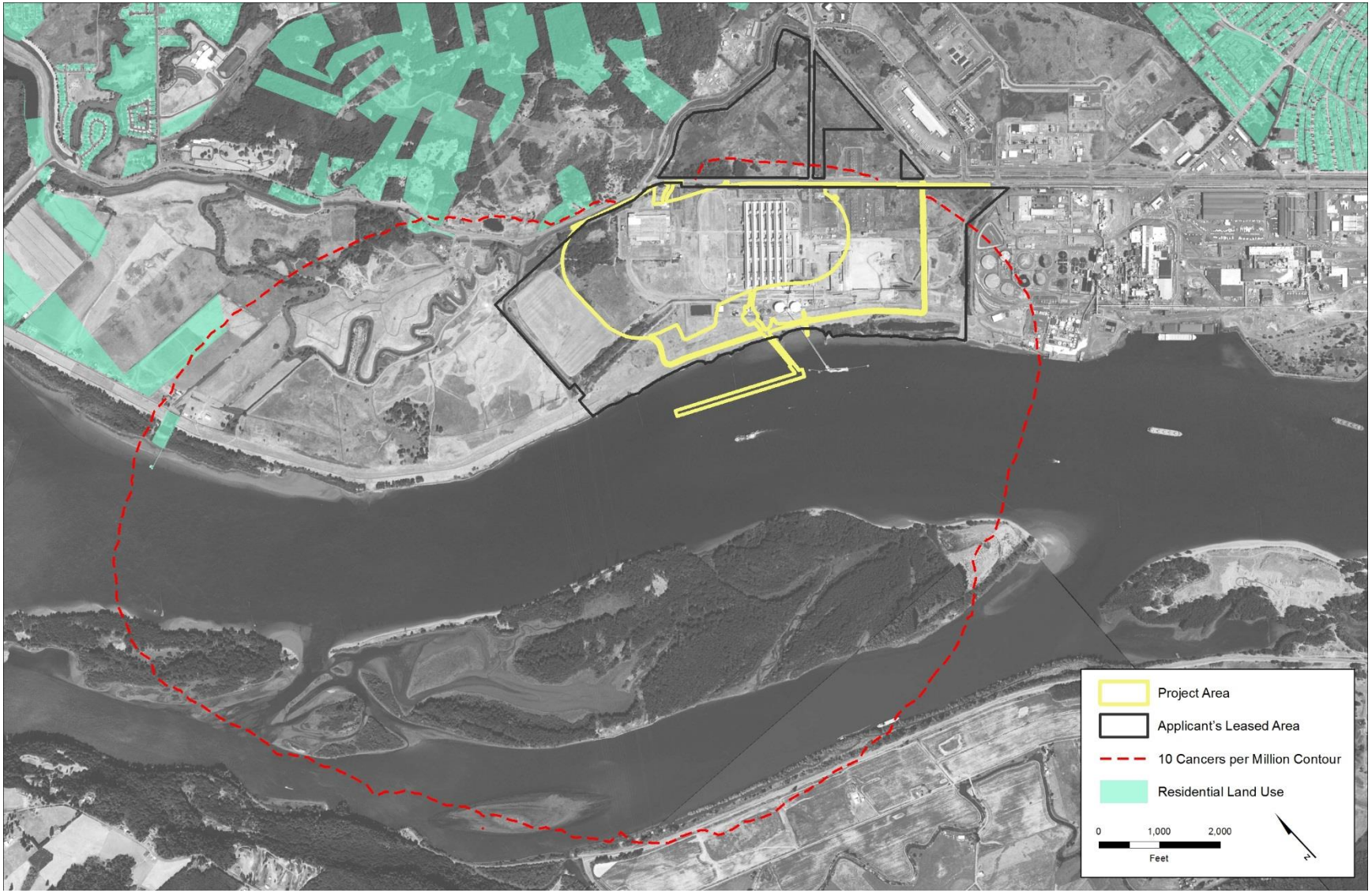


Figure 6 depicts increased inhalation cancer risk related to DPM emissions from all operation sources (terminal, rail, and vessel) in the Kelso-Longview area. The contour for increased risk of 10 cancers per million covers most of Longview south of Ocean Beach Highway as well as a portion of Kelso along the Interstate 5 corridor. The contour for increased risk of 30 cancers per million along the Reynolds Lead is approximately 3,000 feet across and extends into the Highland neighborhood. The highest increased risk level, 50 cancers per million, extends approximate 1,000 feet across along portions of the Reynolds Lead and borders the Highland neighborhood.

Figure 7 depicts increased inhalation cancer risk related to DPM emissions from all operations (terminal, rail, and vessel) in Cowlitz County. The contour for increased risk of 10 cancers per million along the BNSF main line is approximately 2 miles across throughout the county. The contour for increased risk of 30 cancers per million extends approximately 0.5 mile (or 0.25 mile on either side of the main line).

For further context, increased cancer risk related to emissions of DPM from rail locomotives can be compared to that of diesel trucks. For example, the increased risk of 30 cancers per million at 0.25 mile from the Reynolds Lead and BNSF Spur (a 7.1-mile segment of rail line) resulting from the locomotive emissions from 16 Proposed Action-related train trips per day would be equivalent to the increased risk resulting from the emissions from 1,100 diesel truck[15] trips per day along the same segment (i.e., 23 trucks per hour travelling in each direction).

Average Lifetime Emissions Scenario

This section presents cancer risk based on the average lifetime emissions scenario. Figure 8 depicts increased inhalation cancer risk related to DPM emissions from coal export terminal sources (i.e., diesel-powered operations, maintenance, and emergency equipment). The contour for increased risk of 1 cancer per million extends across the width of the Columbia River, approximately 4 miles west of the project area, and approximately 2.5 miles east of the project area. These results are essentially the same as depicted in Figure 4 for the fixed emission case, because changes in the emissions are estimated to be minimal for coal export terminal sources.

Figure 9 depicts increased inhalation cancer risk related to DPM emissions from all operation sources (i.e., terminal, rail, and vessel) in the project area. The contour for increased risk of 10 cancers per million extends across the Columbia River covering most of Lord Island, approximately 0.25 mile southeast of the project area, and crosses Industrial Way near the northwest boundary of the project area. A portion of one residential area is within this contour.

[15] Assumes current fleet heavy-duty trucks traveling at 55 miles per hour.

Figure 6. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in the Kelso-Longview Area—Fixed Emissions Scenario

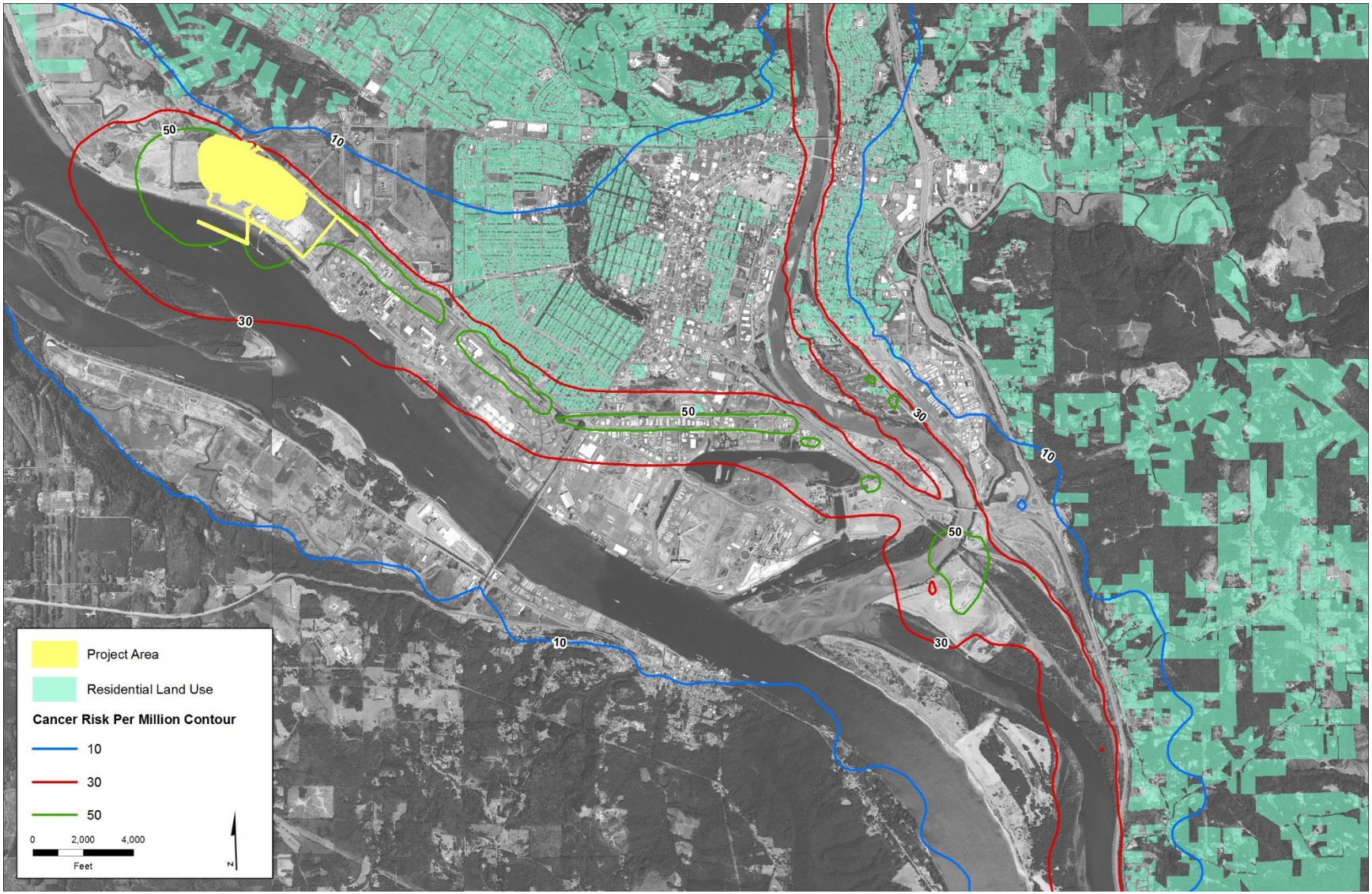


Figure 7. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in Cowlitz County—Fixed Emissions Scenario

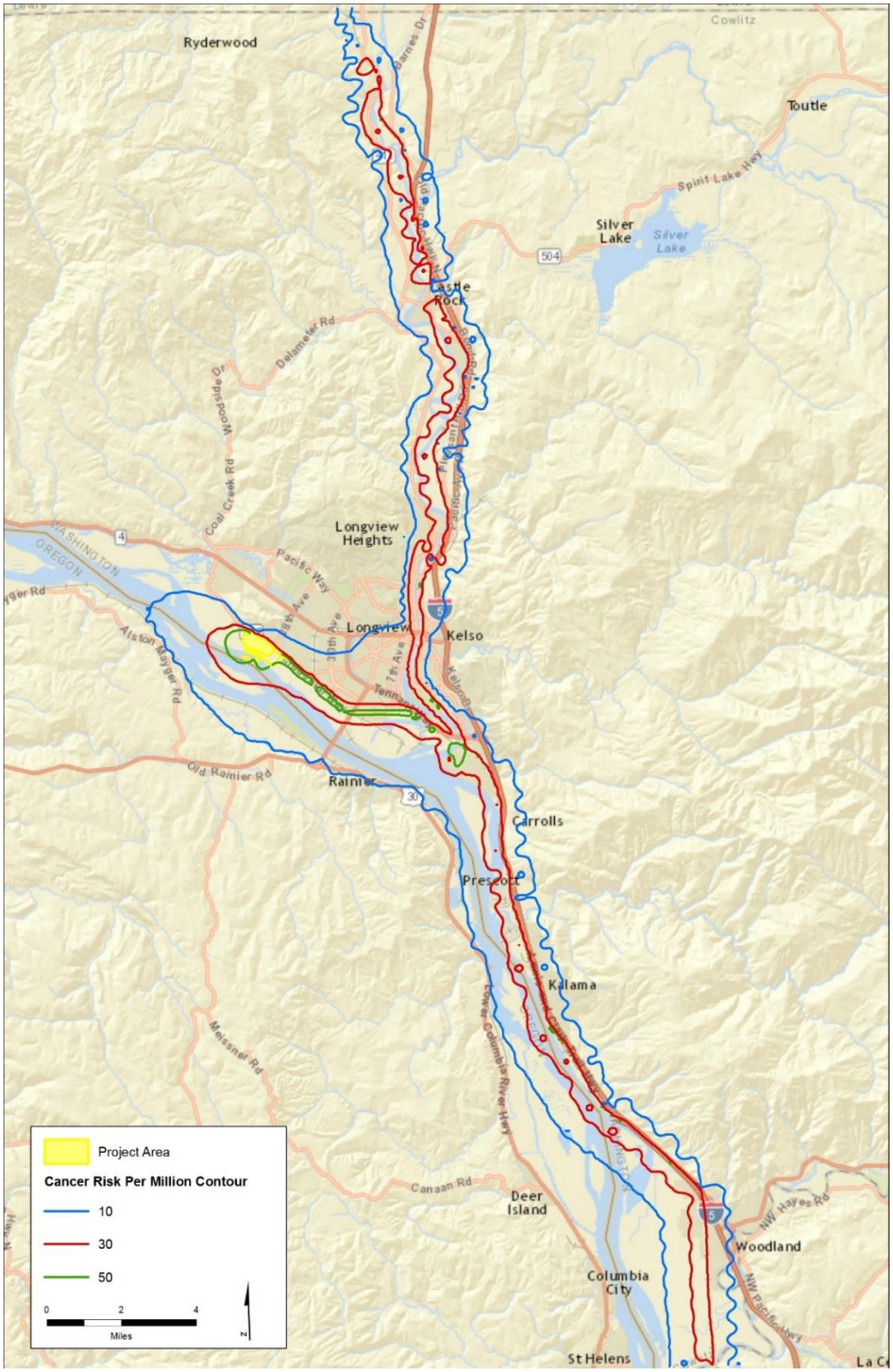


Figure 8. Increased Diesel Particulate Matter Cancer Risk from Coal Export Terminal Sources— Average Lifetime Emissions Scenario

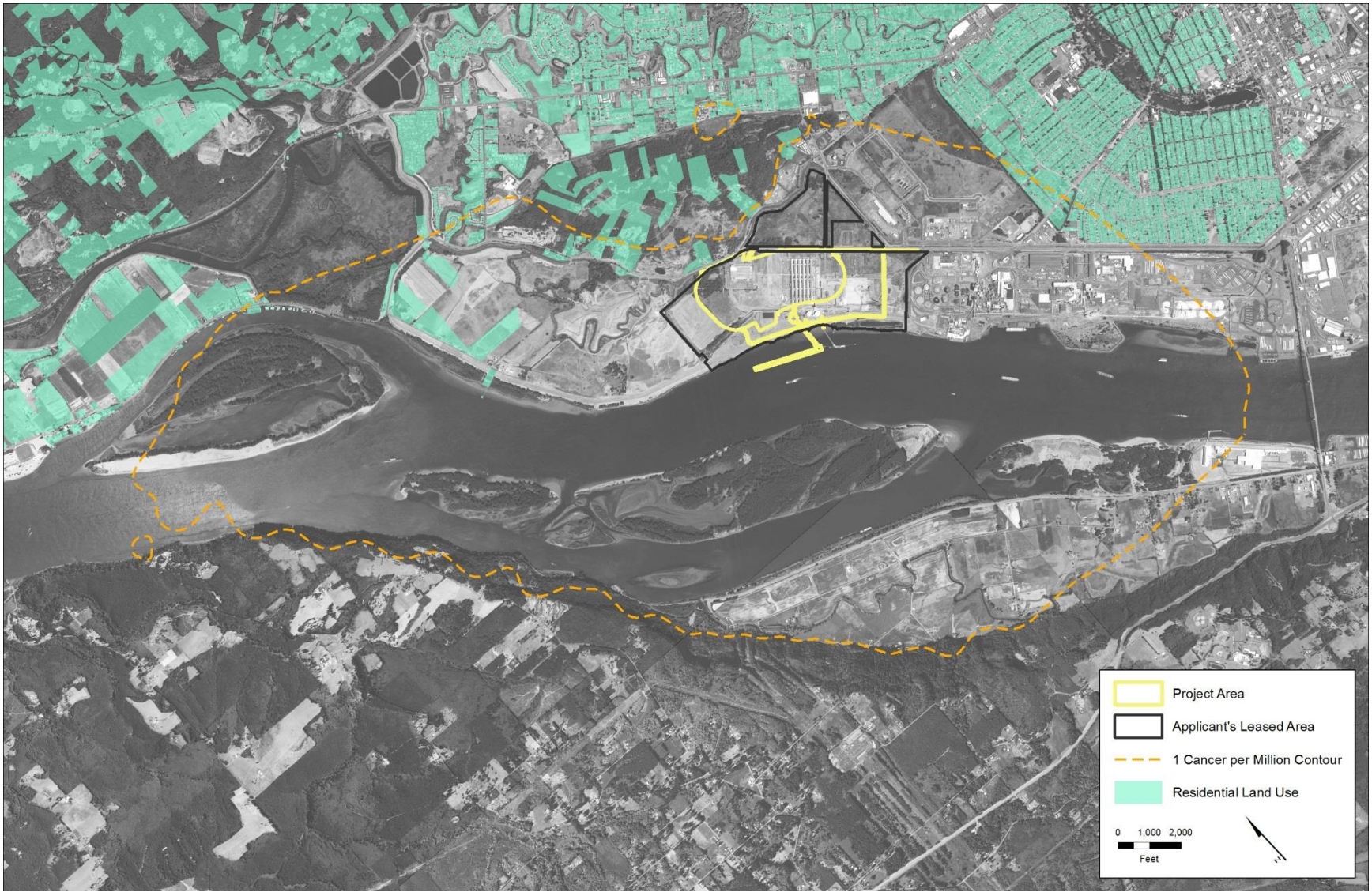


Figure 9. Increased Diesel Particulate Matter Cancer Risk from All Operation in the Project Area— Average Lifetime Emissions Scenario

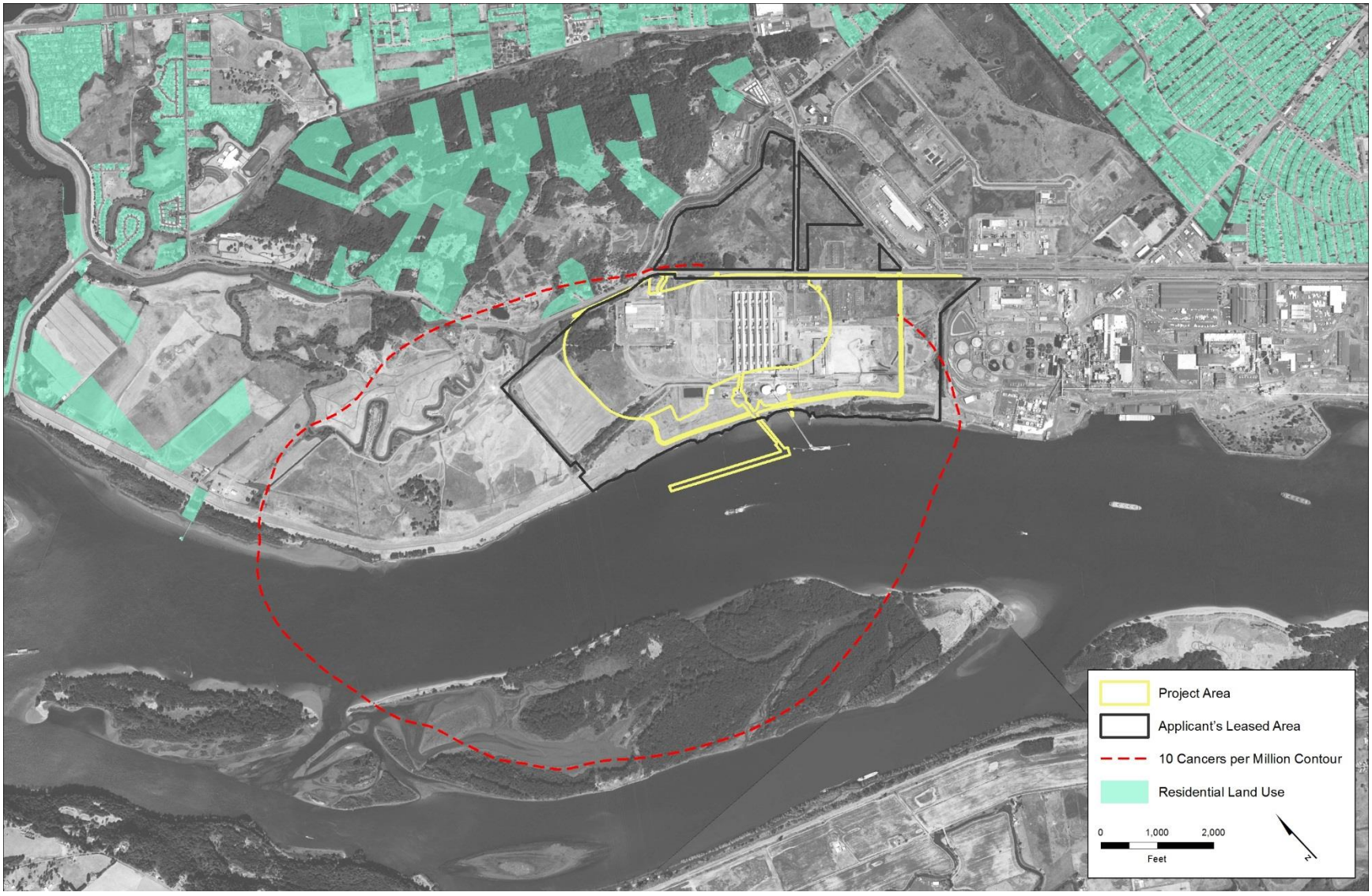


Figure 10 depicts increased inhalation cancer risk related to DPM emissions from all operation sources (i.e., terminal, rail, and vessel) in the Kelso-Longview area of Cowlitz County. The contour for increased risk of 10 cancers per million covers Longview south of Washington Way as well as a portion of Kelso along the Interstate 5 corridor. The contour for increased risk of 30 cancers per million along the Reynolds lead is approximately 2,000 feet across and extends up to approximately 600 feet into the Highland neighborhood. The highest increased risk level, 50 cancers per million, extends approximate 500 feet across along three small portions of the Reynolds Lead, approximately 1,200 feet across at the junction of the BNSF Spur and BNSF main line, and approximately 0.3 mile west and southwest of the project area boundary.

Figure 11 depicts increased inhalation cancer risk related to DPM emissions from all operation sources (i.e., terminal, rail, and vessel) in Cowlitz County. The contour for increased risk of 10 cancers per million along the BNSF mainline is approximately 1.5 miles across throughout Cowlitz County. The contour for increased risk of 30 cancers per million along the BNSF main line is up to approximately 0.4 mile wide (0.2 mile on either side of the main line).

For further context, increased cancer risk related to emissions of DPM from rail locomotives can be compared to that of diesel trucks. For example, the increased risk of 30 cancers per million at 1,000 feet from the Reynolds Lead and BNSF spur (a 7.1-mile segment of rail line) resulting from the locomotive emissions from 16 Proposed Action-related trains trips per day would be equivalent to the increased risk resulting from the emissions from 860 diesel truck[16] trips per day along the same segment (i.e., 18 trucks per hour travelling in each direction).

[16] Assumes current fleet heavy-duty trucks traveling at 55 miles per hour.

Figure 10. Increased Diesel Particulate Matter Cancer Risk from All Operation Sources in the Kelso-Longview Area— Average Lifetime Emissions Scenario

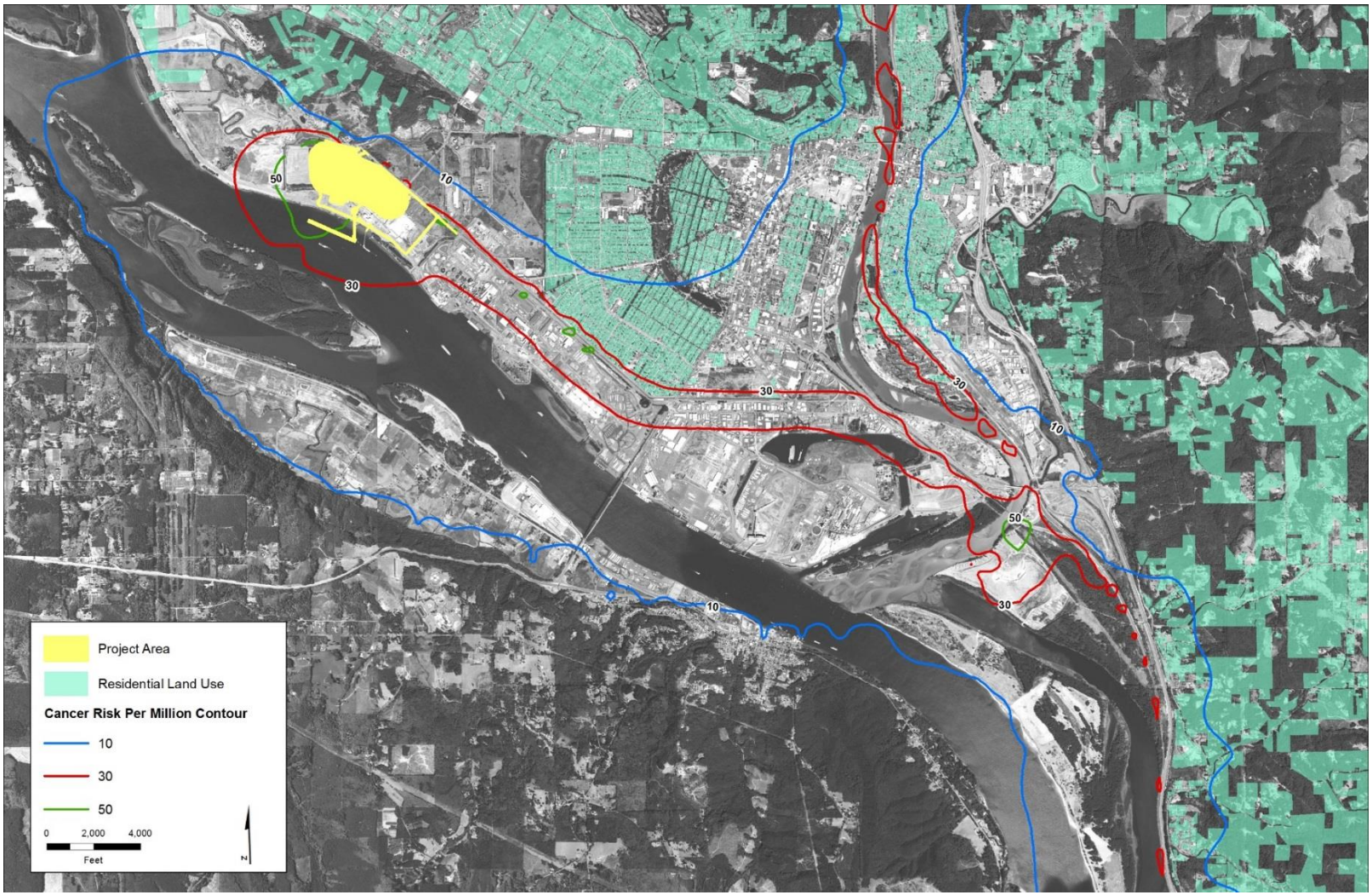
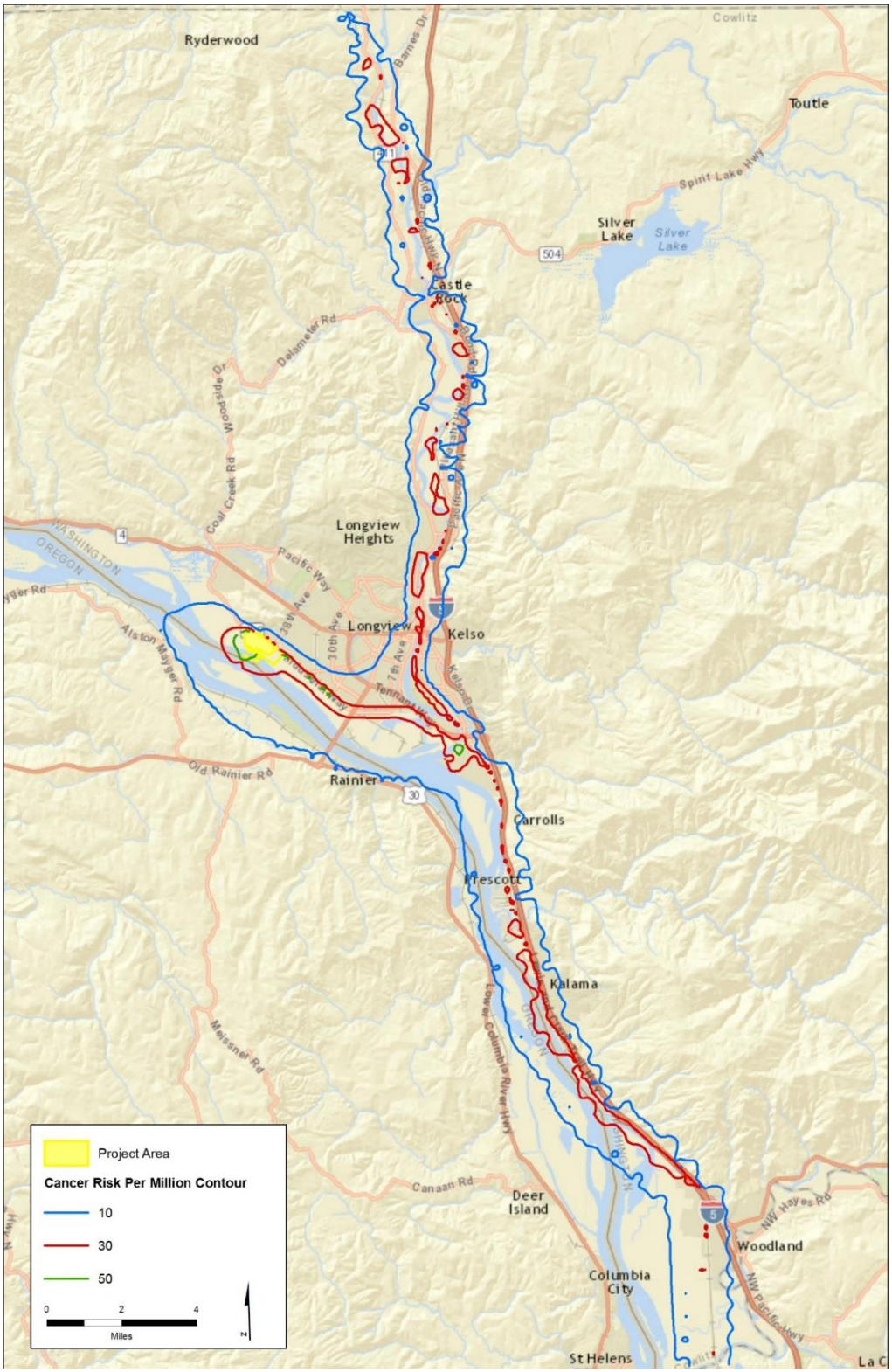


Figure 11. Increased Diesel Cancer Risk from All Operation Sources in Cowlitz County— Average Lifetime Emissions Scenario



3.1.2.3 Proposed Action and Cowlitz County Emissions Comparison

The pollutant emissions totals within Cowlitz County for the Proposed Action during maximum terminal throughput (Table 6) are shown in Table 10 with the 2011 Cowlitz County emissions inventory totals for locomotives and commercial marine vessels. Locomotive emissions would occur in the project area, on the Reynolds Lead and BNSF Spur, and on the BNSF main line in Cowlitz County. Vessel emissions would occur in the project area and on the Columbia River in Cowlitz County.

Table 10. Maximum Annual Emissions Estimates in Cowlitz County for Locomotive and Commercial Marine Vessels for the Proposed Action in Comparison with the 2011 Cowlitz County Emissions Inventory

	Maximum Annual Average Emissions (tpy)						
	NO_x	CO	VOCs	SO_2	PM10	PM2.5	DPM
Locomotive							
Proposed Action-related Emissions	51	20	1.9	0.07	3.7	1.5	1.15
Cowlitz County Emissions	789	137	43	6	23	23	23
Commercial Marine Vessels							
Proposed Action-related Emissions	48	104	29	7.6	2.8	2.7	0.6
2011 Cowlitz County Emissions	1,109	150	46	199	37	34	34

Notes:
Source: Washington State Department of Ecology 2014.
tpy = tons per year; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; DPM = diesel particulate matter

The largest locomotive emissions increase (as a percentage of existing rail emissions in Cowlitz County) for a single pollutant would be for PM10, which would increase by approximately 16%. The largest vessel emissions increase (as a percentage of existing commercial marine vessel emissions in Cowlitz County) for a single pollutant would be carbon monoxide and VOCs, which would increase approximately 69% and 63%, respectively. The increase in carbon monoxide emissions is primarily due to use of the auxiliary engines while vessels are docked. While this emission increase represents a substantial increase relative to the commercial marine vessel category, overall it represents a small increase (0.28% and 0.17%) in the total Cowlitz County carbon monoxide and VOC emissions. 0.17%) in the total Cowlitz County carbon monoxide and VOC emissions.

3.1.2.4 Proposed Action and Washington State Emissions Comparison

The pollutant emissions totals for the Proposed Action during maximum production throughout Cowlitz County combined with statewide emissions associated with the vessel and rail transport are shown in Table 11 in comparison with the 2011 Washington statewide emissions inventory totals for locomotives and commercial marine vessels. Locomotive emissions would occur along the rail routes described in Section 2.2.3, *Washington State Air Quality Conditions*.[17] Vessel emissions would

[17] For more information on the coal train routes, see the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017).

occur along the Columbia River between the project area and 3 nautical miles beyond the mouth of the Columbia River.

Table 11. Maximum Annual Emissions Estimates in Washington State for Locomotive and Commercial Marine Vessels for the Proposed Action in Comparison with the 2011 Statewide Emissions Inventory

	Maximum Annual Average Emissions (tpy)						
	NO_x	CO	VOCs	SO_2	PM10	PM2.5	DPM
Locomotive							
Proposed Action-related Emissions	2,261	984	78	3	51	47	58
2011 Statewide Emissions	15,026	2,536	810	95	430	428	428
Commercial Marine Vessels							
Proposed Action-related Emissions	161	276	93	21	11	10	10
2011 Statewide Emissions	20,486	2,521	782	11,529	1,213	1,021	1,021

Notes:
Source: Washington State Department of Ecology 2014.
tpy = tons per year; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; DPM = diesel particulate matter

The largest increase in locomotive emissions for any one pollutant would be carbon monoxide at 39%, followed by NO_x with a 15% increase. For commercial marine vessels, the relative increase is smaller with a maximum increase of 12% for VOCs and just under 11% for carbon monoxide.

3.2 No-Action Alternative

Under the No Action Alternative, the Applicant would not construct the export terminal and impacts on air quality related to construction and operation of the proposed export terminal would not occur. The Applicant would continue with current and future increased operations in the project area. The project area could be developed for other industrial uses including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement.

Expanded bulk terminal operations and maintenance would result in increased emissions of air pollutants. The Applicant has identified planned future rail and vessel operations for the No-Action Alternative. Emissions were estimated assuming that current and future operations would result in two daily trains arriving and departing the facility with an average rail car length of 30 cars carrying bulk product. Each train would be composed of two locomotives with an average of 26 vessels arriving and departing each year. In addition, truck haul emissions associated with the transport to the nearby Weyerhaeuser facility are included. The estimated emissions are shown in Table 12. The largest emissions for any single air pollutant would be NO_x at 4.4 tons per year. These emissions would be lower than emissions under the Proposed Action, which were shown not to cause a substantial change in air quality or adversely affect nearby population areas.

Table 12. Estimated No-Action Alternative Annual Average Emissions from Rail, Vessel and Haul Trucks

	Maximum Annual Average Emissions (tpy)								
Source	**NO_x**	**CO**	**VOCs**	**SO_2**	**TSP**	**PM10**	**PM2.5**	**HAPs**	**DPM**
Locomotive Combustion	3.1	1.4	0.11	0.01	0.08	0.07	0.06	0.01	0.06
Vessel Combustion	1.1	2.6	0.63	0.19	0.08	0.06	0.06	0.003	0.02
Haul Trucks	0.2	0.1	0.02	0.002	0.04	0.04	0.01	0.001	0.04
Total	**4.4**	**4.1**	**0.76**	**0.20**	**0.20**	**0.17**	**0.13**	**0.014**	**0.12**

Notes:
tpy = tons per year; NO_x = nitrogen oxide; CO = carbon monoxide; VOCs = volatile organic compounds; SO_2 = sulfur dioxide; PM10 = particulate matter less than or equal to 10 micrometers in diameter; PM2.5 = particulate matter less than or equal to 2.5 micrometers in diameter; TSP = total suspended particles; HAPs = hazardous air pollutants; DPM = diesel particulate matter

Chapter 4
Required Permits

The following permit would be required in relation to air quality for the Proposed Action.

- **Notice of Construction—Southwest Clean Air Agency.** Businesses and industries that cause, or have the potential to cause, air pollution are required to receive approval from the local air agency prior to beginning construction. These are requirements of Washington's Clean Air Act and apply statewide (Chapter 70.94 RCW). Businesses located in Cowlitz County are regulated by the SWCAA. SWCAA rules generally require an air permit for a stationary sources emitting more than 0.75 ton per year of PM10 or 0.5 ton per year of PM2.5[18]. It is anticipated that these levels would be exceeded and the Applicant would need to file a permit application and receive an approved Notice of Construction air permit prior to constructing, installing, establishing, or modifying any equipment or operations that may emit air pollution.

[18] Other criteria pollutants have higher emission threshold levels.

Chapter 5
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Appendix A
Air Quality Data

APPENDIX A1a
CONSTRUCTION EMISSIONS

SUMMARY

Source	Construction Emissions (tpy) [Maximum per Year]												
	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2e	CO2	CH4	N2O	DPM
COMBUSTION SOURCES													
Equipment (On-site)	24.6	9.04	2.23	0.95	2.34	1.93	1.93	4.55E-02	5,035	5,025.67	2.47E-01	1.22E-02	2.34
Haul Trucks (Off-site)[1]	9.37	2.04	0.41	0.03	0.54	0.44	0.31	0.010	3,161	3,159	5.91E-02	2.87E-03	0.54
Haul Trucks (On-site)[1]	4.06	0.88	0.18	0.01	0.23	0.19	0.13	0.004	1,369	1,368	2.56E-02	1.24E-03	0.23
Haul Trucks idle (On-site)[2]	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0	0.00E+00	0.00E+00	0.00E+00
Passenger Commute Vehicles (off-site)	0.51	7.38	0.13	0.01	-	0.22	0.04	-	1485.28	1482.77	0.02	0.01	-
Crossing Delay (Off-site)	0.0126	0.0798	0.0025	0.0001	-	0.0015	0.0006	0.0010	-	-	-	-	-
Barges (Off-site)	59.04	15.68	1.51E+00	2.77E-02	1.29E+00	1.06E+00	1.06E+00	7.90E-02	3,050	3,044	1.49E-01	7.38E-03	1.29
Trains:													
Combustion (Off-site)	18.48	8.06	0.64	2.85E-02	4.79E-01	3.94E-01	3.82E-01	8.57E-02	3,125	3,095	2.42E-01	7.88E-02	4.79E-01
Combustion (On-site)	0.71	3.11E-01	2.45E-02	1.10E-03	1.85E-02	1.52E-02	1.47E-02	3.31E-03	121	119	9.35E-03	3.04E-03	1.85E-02
Highest Combination for Transport (Trucks) - Combustion Only													
Total - Onsite only	28.6	9.9	2.41	0.97	2.58	2.12	2.06	4.99E-02	6,404	6,393	0.27	1.34E-02	2.58
Total - All Construction Sources in County	38.5	19.4	2.95	1.00	3.11	2.78	2.41	6.12E-02	11,051	11,035	0.35	2.34E-02	3.11
Total combustin													
FUGITIVE SOURCES													
Controlled Fugitive Earthwork	-	-	-	-	12.00	5.87	1.22	-	-	-	-	-	-
Total Fugitive Sources	-	-	-	-	12.00	5.87	1.22	-	-	-	-	-	-
Highest Combination for Transport (Trucks) - All Sources													
Total - Onsite only	28.6	9.9	2.41	0.97	14.58	7.99	3.28	4.99E-02	6,404	6,393	0.27	1.34E-02	2.58
Total - All Construction Sources in County	38.5	19.4	2.95	1.00	15.11	8.65	3.64	6.12E-02	11,051	11,035	0.35	2.34E-02	3.11
General Conformity *de minimis* levels for ozone mainte	100	100	100	100		100	100						

Note:
[1] For Haul truck TSP & HAPs, use same emission ratio as emission factor ratios for Large Diesel Engines (below): PM_{10} and $PM_{2.5}$ ratio to TSP; HAPs ratio to CO.
[2] See assumptions for surrogate idle/onsite in Tab A4 Material Transfer by Truck

INPUT DATA:

Major Construction Activities and Typical Equipment Fleets

Construction Equipment Type	Rail Infrastructure and Rotary Car Dump Station		Conveyors, Transfer Stations and Surge Bins		Shiploader, Dock, and Trestles	
	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)
Mobile Cranes (25-50t)[1]						
Mobile Cranes (50-150t)[1]						
Mobile Cranes (150-300t)[1]						
Water Trucks[2]	1	12	1	12	0	0
Dump Trucks	3	12	1	12	0	0
Dozers	1	5	0	0	0	0
Excavators[3]	1	9	2	12	1	3
Rollers	2	9	2	12	1	3
Graders	2	9	0	0	1	3
Compactors	2	9	2	12	1	3
Track Laying Machine	1	6	0	0	0	0
Drill Rigs	1	2	2	6	0	0
Impact Piling Rigs	2	6	2	6	2	6
Loaders[4]	1	12	1	12	1	9
River Barge	0	0	0	0	2	18
Generator	2	18	2	18	2	18
Air Compressor	2	18	2	18	2	18

Source: MBTL, *Noise Resource Report* , Appendix D-1 (URS, June 2014).
NOTES:
[1] Mobile cranes to be shared between the 3 areas. - removed here because not all material is onsite so crane work may not start the first year.
[2] Water truck to be shared between the 2 land areas.
[3] Excavators to be shared between the 3 areas.
[4] Loaders to be shared between the 3 areas.

Typical construction fleet may be modified with equivalent items as construction activities demand

Assume entire construction period for all 3 areas is: 18 months total
5 days/week

ONSITE EQUIPMENT (NON-BARGE) EMISSIONS

Note: using NONRoad T/Y as calculated which may assume 24/7, so conservative.

Equipment Type	Engine Size (hp)	Fuel	Maximum Units Onsite (per year)	EPA NONROAD SCC Number	EPA NONROAD model combustion emission factor (tons/yr per unit)					
					THC-Exhaust	CO-Exhaust	NOx-Exhaust	CO2-Exhaust	SO2-Exhaust	PM-Exhaust
Crane, 50 ton	165	Diesel	0	2270002045	5.15E-02	1.65E-01	6.50E-01	120.43	2.38E-02	5.04E-02
Crane, 150 ton	280	Diesel	0	2270002045	7.69E-02	2.12E-01	9.99E-01	201.70	3.88E-02	6.33E-02
Crane, 300 ton	450	Diesel	0	2270002045	8.22E-02	3.69E-01	1.44E+00	215.37	4.28E-02	7.47E-02
Water Trucks	350	Diesel	1	2270002051	3.06E-02	9.01E-02	3.12E-01	108.922	1.86E-02	3.49E-02
Dump Trucks	350	Diesel	4	*See Notes*	*3.06E-02*	*9.01E-02*	*3.12E-01*	*108.922*	*1.86E-02*	*3.49E-02*
Dozers	185	Diesel	0.4	2270002069	1.66E-01	8.15E-01	1.96E+00	437.06	8.46E-02	2.35E-01
Excavators	230	Diesel	2	2270002036	3.15E-01	1.24E+00	3.65E+00	977.30	1.79E-01	3.62E-01
Rollers	350	Diesel	3.8	2270002015	4.20E-02	1.70E-01	5.19E-01	110.57	2.12E-02	4.42E-02
Graders	185	Diesel	1.8	2270002048	5.49E-02	2.71E-01	6.48E-01	146.26	2.83E-02	7.85E-02
Compactors	25	Diesel	3.8	2270002009	2.47E-04	1.15E-03	2.15E-03	0.26	5.65E-05	1.78E-04
Track Laying Machine	*See Notes*	Diesel	0.5	*See Notes*	*1.96E-01*	*9.29E-01*	*2.35E+00*	*459.49*	*9.05E-02*	*2.51E-01*
Drill Rigs	*NONROAD Default*	Diesel	1.2	2270002033	4.12E-02	1.48E-01	5.47E-01	62.90	1.27E-02	3.29E-02
Impact Piling Rigs	*NONROAD Default*	Diesel	3	2270002033	*4.12E-02*	*1.48E-01*	*5.47E-01*	*62.90*	*1.27E-02*	*3.29E-02*
Loaders	140	Diesel	1	2270002060	1.96E-01	9.29E-01	2.35E+00	459.49	9.05E-02	2.51E-01
Generator	30	Diesel	6	2270006005	1.10E-01	4.39E-01	1.00E+00	119.95	2.48E-02	8.80E-02
Air Compressor	25	Diesel	6	2270006015	2.27E-04	1.17E-03	2.23E-03	0.29	6.30E-05	1.77E-04

NOTES:
Assume Dump Truck size/emissions same as Water Truck.
Assume Track Laying Machine uses 1 diesel locomotive and 1 front end loader engine (Harsco Rail, New Track Construction). Assume full-time locomotive used 4 hrs/day, 5 days/wk
Horsepower and weight estimates based on capacity ratings and industry specifications, or average ratings per equipment type. Where hp could not be assumed, an average hp rate in NONROAD for the equipment type was used.

Emission Rates for Onsite Equipment (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Crane, 50 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Crane, 150 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Crane, 300 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Water Trucks	0.31	0.09	0.03	0.02	0.03	0.03	0.03	0.000	109	0.0053	0.0003	109
Dump Trucks	1.25	0.36	0.12	0.07	0.14	0.11	0.11	0.002	436	0.0214	0.0011	437
Dozers	0.82	0.34	0.07	0.04	0.10	0.08	0.08	0.002	182	0.0089	0.0004	182
Excavators	7.30	2.48	0.63	0.36	0.72	0.60	0.60	0.012	1955	0.0960	0.0047	1958
Rollers	1.95	0.64	0.16	0.08	0.17	0.14	0.14	0.003	415	0.0204	0.0010	415
Graders	1.13	0.47	0.10	0.05	0.14	0.11	0.11	0.002	256	0.0126	0.0006	256
Compactors	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.000	1	0.0000	0.0000	1
Track Laying Machine	1.17	0.46	0.10	0.05	0.13	0.10	0.10	0.002	230	0.0113	0.0006	230
Drill Rigs	0.64	0.17	0.05	0.01	0.04	0.03	0.03	0.001	73	0.0036	0.0002	74
Impact Piling Rigs	1.64	0.44	0.12	0.04	0.10	0.08	0.08	0.002	189	0.0093	0.0005	189
Loaders	2.35	0.93	0.20	0.09	0.25	0.21	0.21	0.005	459	0.0226	0.0011	460
Generator	6.02	2.63	0.66	0.15	0.53	0.43	0.43	0.013	720	0.0353	0.0017	721
Air Compressor	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.000	2	0.0001	0.0000	2
Total Onsite Construction Equipment (tpy)	24.6	9.0	2.23	0.95	2.34	1.93	1.93	0.05	5026	0.25	0.01	5035

Note:
For PM_{10}, $PM_{2.5}$, HAPs, and GHGs (CH_4 and N_2O), use same emission ratio as emission factor ratios for Large Diesel Engines (below): PM_{10} and $PM_{2.5}$ ratio to TSP; HAPs ratio to CO, and; GHGs ratio to CO_2.

BARGE EMISSIONS

Barges for Construction	2		
Engine Size (propulsion)	3500	hp	
Total Barge Engines	7000	hp	(Maximum # Units per year))
Barge Positioning Time	1	hrs/ship (in-out)	(Conservative estimate)
Total Power per "Trip"	7,000	hp-hrs	
Construction Trips:	2.90	per day	(assume 2/3 of material imported during first year)
	753	per year	
Annual Power	5,271,666	hp-hrs/yr	
Annual Diesel Fuel Use	36,902	MMBtu/yr	
	270,095	gallons/yr	

Emission Factors for Barges

lb/MMBtu, fuel input

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Large Diesel Engines	3.20	0.8500	0.0819	0.002	0.07	0.06	0.06	0.00428	165	0.0081	0.0004	165

Source:

Emission factors from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines*(10/96). Assume Sulfur content of 0.0015% by weight (15 ppm). Assume TSP to PM10 ratio from Table 3.4-2, and PM2.5=PM10. Sum of HAPs factors from Table 3.4-3 and 3.4-4.
Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Emission Rates for Barges (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Construction - Barges	59.0	15.68	1.51	0.03	1.29	1.06	1.06	0.08	3044	0.15	0.007	3050

FUGITIVE DUST EMISSIONS

Methodology based on EPA AP-42 Chapter 13.2.3 Heavy Construction Operations

Assumed acreage for groundwork	100	acres
Assumed schedule for groundwork	1	year
	12	months
Annual Groundwork Operations	8.33	acres/month
AP-42 Emission Factor	1.2	tons PM/acre/month
Uncontrolled PM Emissions:	120.0	tons

Controlled Emissions (assume watering only; no factor included for natural control from precipitation)
Control %: 90 *WRAP Fugitive Dust Handbook, Table 9-4, Watering.*

PM_{10} and $PM_{2.5}$ Fractions of Total PM
(CARB Appendix A CEIDARS $PM_{2.5}$ and PM_{10} fractions of TSP; Fugitive Dust - Construction and Demolition)
(http://www.aqmd.gov/docs/default-source/ceqa/handbook/localized-significance-thresholds/particulate-matter-(pm)-2.5-significance-thresholds-and-calculation-methodology/appendix-a-updated-ceidars-table-with-pm2-5-fractions.doc?sfvrsn=2)

PM_{10} Fraction of Total PM	0.489
$PM_{2.5}$ Fraction of Total PM	0.102

Emission Rates for Fugitive Dust (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Construction - Fugitive Dust	-	-	-	-	12.00	5.87	1.22	-	-	-	-	-

APPENDIX A1b

CONSTRUCTION EMISSIONS

SUMMARY

Source	Construction Emissions (lb/day) [Maximum daily] NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2e	CO2	CH4	N2O	DPM
COMBUSTION SOURCES													
Equipment (On-site)	229.6	82.89	20.39	8.67	21.49	17.66	17.66	0.42	45,519	45,431	2.23	0.11	21.49
Haul Trucks (Off-site)[1]	110.48	24.00	4.81	0.33	6.34	5.21	3.66	0.12	37,259	37,232	6.96E-01	3.39E-02	6.34
Haul Trucks (On-site and project study area)[1]	54.7	14.4	3.1	0.2	6.1	5.0	2.6	0.1	18236.0	18,214	0.5	0.0	6.12
Passenger Commute Vehicles (off-site)	1.36	19.60	0.34	0.03	0.57	0.57	0.11	-	3944.46	3,938	0.04	0.02	-
Crossing Delay (Off-Site)[3]	0.07	0.44	0.01	0.00	0.01	0.01	0.003	0.01	-	-	-	-	-
Barges (Off-site)	454.7	120.79	11.64	0.21	9.90	8.14	8.14	0.61	23,492	23,446.50	1.15E+00	5.68E-02	9.90

[1] For Haul truck TSP & HAPs, use same emission ratio as emission factor ratios for Large Diesel Engines (below): PM_{10} and $PM_{2.5}$ ratio to TSP; HAPs ratio to CO.
[2] See assumptions for surrogate idle/onsite in Tab A4 Material Transfer by Truck
[3] Original assumption was 1 min/day for each of the 365 days, so T/Y value was divided bye 365 to get value per day.

INPUT DATA:

Major Construction Activities and Typical Equipment Fleets

Construction Equipment Type	Rail Infrastructure and Rotary Car Dump Station		Conveyors, Transfer Stations and Surge Bins		Shiploader, Dock, and Trestles	
	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)
Mobile Cranes (25-50t)[1]						
Mobile Cranes (50-150t)[1]						
Mobile Cranes (150-300t)[1]						
Water Trucks[2]	1	12	1	12	0	0
Dump Trucks	3	12	1	12	0	0
Dozers	1	5	0	0	0	0
Excavators[3]	1	9	2	12	1	3
Rollers	2	9	2	12	1	3
Graders	2	9	0	0	1	3
Compactors	2	9	2	12	1	3
Track Laying Machine	1	6	0	0	0	0
Drill Rigs	1	2	2	6	0	0
Impact Piling Rigs	2	6	2	6	2	6
Loaders[4]	1	12	1	12	1	9
River Barge	0	0	0	0	2	18
Generator	2	18	2	18	2	18
Air Compressor	2	18	2	18	2	18

Source: MBTL, *Noise Resource Report* , Appendix D-1 (URS, June 2014).
NOTES:
[1] Mobile cranes to be shared between the 3 areas. - removed here because not all material is onsite so crane work may not start the first year.
[2] Water truck to be shared between the 2 land areas.
[3] Excavators to be shared between the 3 areas.
[4] Loaders to be shared between the 3 areas.

Typical construction fleet may be modified with equivalent items as construction activities demand

Assume entire construction period for all 3 areas is: 18 months total
5 days/week

ONSITE EQUIPMENT (NON-BARGE) EMISSIONS

Equipment Type	Engine Size (hp)	Fuel	Maximum Units Onsite (per max	EPA NONROAD SCC Number	EPA NONROAD model combustion emission factor (tons/yr per unit) THC-Exhaust	CO-Exhaust	NOx-Exhaust	CO2-Exhaust	SO2-Exhaust	PM-Exhaust
Crane, 50 ton	165	Diesel	0	2270002045	5.15E-02	1.65E-01	6.50E-01	120.43	2.38E-02	5.04E-02
Crane, 150 ton	280	Diesel	0	2270002045	7.69E-02	2.12E-01	9.99E-01	201.70	3.88E-02	6.33E-02
Crane, 300 ton	450	Diesel	0	2270002045	8.22E-02	3.69E-01	1.44E+00	215.37	4.28E-02	7.47E-02
Water Trucks	350	Diesel	1	2270002051	3.06E-02	9.01E-02	3.12E-01	108.922	1.86E-02	3.49E-02
Dump Trucks	350	Diesel	4	*See Notes*	*3.06E-02*	*9.01E-02*	*3.12E-01*	*108.922*	*1.86E-02*	*3.49E-02*
Dozers	185	Diesel	1.0	2270002069	1.66E-01	8.15E-01	1.96E+00	437.06	8.46E-02	2.35E-01
Excavators	230	Diesel	2	2270002036	3.15E-01	1.24E+00	3.65E+00	977.30	1.79E-01	3.62E-01
Rollers	350	Diesel	5.0	2270002015	4.20E-02	1.70E-01	5.19E-01	110.57	2.12E-02	4.42E-02
Graders	185	Diesel	3.0	2270002048	5.49E-02	2.71E-01	6.48E-01	146.26	2.83E-02	7.85E-02
Compactors	25	Diesel	5.0	2270002009	2.47E-04	1.15E-03	2.15E-03	0.26	5.65E-05	1.78E-04
Track Laying Machine[5]	*See Notes*	Diesel	0.5	*See Notes*	*1.96E-01*	*9.29E-01*	*2.35E+00*	*459.49*	*9.05E-02*	*2.51E-01*
Drill Rigs	*NONROAD Default*	Diesel	3.0	2270002033	4.12E-02	1.48E-01	5.47E-01	62.90	1.27E-02	3.29E-02
Impact Piling Rigs	*NONROAD Default*	Diesel	6	2270002033	*4.12E-02*	*1.48E-01*	*5.47E-01*	*62.90*	*1.27E-02*	*3.29E-02*
Loaders	140	Diesel	1	2270002060	1.96E-01	9.29E-01	2.35E+00	459.49	9.05E-02	2.51E-01
Generator	30	Diesel	6	2270006005	1.10E-01	4.39E-01	1.00E+00	119.95	2.48E-02	8.80E-02
Air Compressor	25	Diesel	6	2270006015	2.27E-04	1.17E-03	2.23E-03	0.29	6.30E-05	1.77E-04

NOTES: 15.07692308
Assume Dump Truck size/emissions same as Water Truck.
[5] Assume Track Laying Machine uses 1 diesel locomotive and 1 front end loader engine (Harsco Rail, New Track Construction). Assume full-time locomotive used 4 hrs/day, 5 days/wk.
If max hour is needed, this should be 1.

Horsepower and weight estimates based on capacity ratings and industry specifications, or average ratings per equipment type. Where hp could not be assumed, an average hp rate in NONROAD for the equipment type was used.
factor to convert to lb/day (2000lb/T)/(5 day/week * 52 week/year) 7.692307692

Emission Rates for Onsite Equipment (lb/day)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Crane, 50 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Crane, 150 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Crane, 300 ton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0	0.0000	0.0000	0
Water Trucks	2.40	0.69	0.24	0.14	0.27	0.22	0.22	0.003	838	0.0411	0.0020	839
Dump Trucks	9.59	2.77	0.94	0.57	1.07	0.88	0.88	0.014	3351	0.1645	0.0081	3358
Dozers	15.10	6.27	1.28	0.65	1.81	1.48	1.48	0.032	3362	0.1650	0.0082	3369
Excavators	56.12	19.09	4.85	2.76	5.58	4.58	4.58	0.096	15035	0.7381	0.0364	15065
Rollers	19.97	6.54	1.61	0.81	1.70	1.40	1.40	0.033	4253	0.2088	0.0103	4261
Graders	14.95	6.25	1.27	0.65	1.81	1.49	1.49	0.031	3375	0.1657	0.0082	3382
Compactors	0.08	0.04	0.01	0.00	0.01	0.01	0.01	0.000	10	0.0005	0.0000	10
Track Laying Machine	9.03	3.57	0.75	0.35	0.96	0.79	0.79	0.018	1767	0.0868	0.0043	1771
Drill Rigs	12.63	3.41	0.95	0.29	0.76	0.63	0.63	0.017	1452	0.0713	0.0035	1454
Impact Piling Rigs	25.27	6.81	1.90	0.59	1.52	1.25	1.25	0.034	2903	0.1425	0.0070	2909
Loaders	18.06	7.14	1.50	0.70	1.93	1.59	1.59	0.036	3535	0.1735	0.0086	3541
Generator	46.27	20.26	5.07	1.14	4.06	3.34	3.34	0.102	5536	0.2718	0.0134	5547
Air Compressor	0.10	0.05	0.01	0.00	0.01	0.01	0.01	0.000	14	0.0007	0.0000	14
Max Onsite Construction Equipment (lb/day)	229.6	82.9	20.39	8.67	21.49	17.66	17.66	0.42	45431	2.23	0.11	45519

Note:
For PM_{10}, $PM_{2.5}$, HAPs, and GHGs (CH_4 and N_2O), use same emission ratio as emission factor ratios for Large Diesel Engines (below): PM_{10} and $PM_{2.5}$ ratio to TSP; HAPs ratio to CO, and; GHGs ratio to CO_2.

BARGE EMISSIONS

Barges for Construction	2		
Engine Size (propulsion)	3500	hp	
Total Barge Engines	7000	hp	(Maximum # Units per year))
Barge Positioning Time	1	hrs/ship (in-out)	(Conservative estimate for emissions at docking site)
Total Power per "Trip"	7,000	hp-hrs	
Construction Trips:	2.9	max per day	(only make deliveries 5 days per week)
Annual Power	20,300	hp-hrs/day	
Annual Diesel Fuel Use	142	MMBtu/day	
	1,040	gallons/day	

Emission Factors for Barges

lb/MMBtu, fuel input

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Large Diesel Engines	3.20	0.85	0.08	0.002	0.07	0.06	0.06	0.004	165	0.0081	0.0004	165

Source:

Emission factors from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Assume Sulfur content of 0.0015% by weight (15 ppm). Assume TSP to PM10 ratio from Table 3.4-2, and PM2.5=PM10. Sum of HAPs factors from Table 3.4-3 and 3.4-4.

Global Warming Potentials (GWPs):
CO_2 - 1
CH_4 - 25
N_2O - 298

Emission Rates for Barges (lb/day)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Construction - Barges	454.7	120.79	11.64	0.21	9.90	8.14	8.14	0.61	23447	1.15	0.057	23492

FUGITIVE DUST EMISSIONS

Methodology based on EPA AP-42 Chapter 13.2.3 Heavy Construction Operations

Assumed acreage for groundwork	100	acres	
Assumed schedule for groundwork	1	year	
	12	months	
Annual Groundwork Operations	8.33	acres/month	
AP-42 Emission Factor	1.2	tons PM/acre/month	
Uncontrolled PM Emissions:	666.7	lbs /1 day	10 tons for one month

Controlled Emissions (assume watering only; no factor included for natural control from precipitation):
Control %: 90 *WRAP Fugitive Dust Handbook, Table 9-4, Watering.*

PM_{10} and $PM_{2.5}$ Fractions of Total PM
(CARB Appendix A CEIDARS $PM_{2.5}$ and PM_{10} fractions of TSP; Fugitive Dust - Construction and Demolition)
(http://www.aqmd.gov/docs/default-source/ceqa/handbook/localized-significance-thresholds/particulate-matter-(pm)-2.5-significance-thresholds-and-calculation-methodology/appendix-a-updated-ceidars-table-with-pm2-5-fractions.doc?sfvrsn=2)

PM_{10} Fraction of Total PM	0.489
$PM_{2.5}$ Fraction of Total PM	0.102

Emission Rates for Fugitive Dust (lb/day)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Construction - Fugitive Dust	-	-	-	-	66.67	32.60	6.80	-	-	-	-	-

APPENDIX A1c

OPERATIONS COMMUTER EMISSIONS

	Operations Commuter Emissions (tpy)												
2018	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2e**	**CO2**	**CH4**	**N2O**	**DPM**
Passenger Commute Vehicles, Operations (off-site)	7.34E-02	1.06E+00	1.81E-02	1.52E-03	-	3.10E-02	5.90E-03	-	213	212.38	2.24E-03	1.02E-03	-
2028													
Passenger Commute Vehicles - Operations (off-site)	3.66E-02	1.07E+00	1.23E-02	1.97E-03	-	5.40E-02	9.07E-03	-	275	274.24	2.19E-03	1.60E-03	-
Crossing Delay (Off-Site)	9.78E-02	9.73E-01	2.36E-02	1.36E-03	-	2.75E-02	6.58E-03	9.19E-03	-	-	-	-	-
sum	0.13	2.05	0.04	0.0033	-	0.08	0.02	0.01	274.77	274.24	0.0022	0.00160	
2038													
Passenger Commute Vehicles Operations (off-site)	1.71E-02	4.67E-01	4.84E-03	1.05E-03	-	4.06E-02	7.77E-03	-	158	157.88	6.36E-04	9.90E-04	-
Crossing Delay (Off-Site)	2.87E-02	2.91E-01	7.83E-03	5.36E-04	-	1.15E-02	2.38E-03	3.06E-03	-	-	-	-	-

APPENDIX A1d

Material Haul Traffic

Assume Peak Year Truck Haul Traffic is 56,000 Round Trips (MTBL Supplementary Traffic Report Construction Traffic Analysis, March 2015)
Peak trips per day is capped at 330 trips (MTBL Supplementary Traffic Report Construction Traffic Analysis, March 2015)

		Number	Miles (RT)[1]	miles/year
Haul Trucks	Freeway @ 55mph	56000	32.8	1836800
	SR432 @ 35mph	56000	14.2	795200
				miles/day
Haul Truck	Freeway @ 55mph	330	32.8	10824
	SR432 @ 35mph	330	14.2	4686

[1]16.4 miles on the I-5 and 7.1 miles on WA-432 to MBTL

Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH4	N2O	CO2eq
2018										
Construction Annual				**T/year**						
Combo Short Haul Truck @ 55mph	9.37	0.44	0.31	0.03	2.04	0.41	3159.07	0.06	0.00	3161.40
Combo Short Haul Truck @ 35mph	4.06	0.19	0.13	0.01	0.88	0.18	1367.65	0.03	0.00	1368.66
Total:	13.43	0.63	0.44	0.04	2.92	0.58	4526.72	0.08	0.00	4530.06
Construction Max Day				**lbs/day**						
Combo Short Haul Truck @55 mph	110	5.2	3.7	0.3	24.0	4.8	37232	0.7	0.0	37259
Combo Short Haul Truck @ 35mph	55	5.0	2.6	0.2	14.4	3.1	18214	0.5	0.0	18236
Total:	165	10.2	6.3	0.5	38.4	7.9	55446	1.2	0.1	55495

Factors:	
453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
Global Warming Potentials (GWPs):	CO_2 - 1
	CH_4 - 25
	N_2O - 298

MOVES factors (g/mile) for surrogate idle were based on 2.5 mi/hr travel. So to get g/hr, multiply by 2.5 mi/hr. For onsite/idle, assume 0.25 hr. So factor is 2.5/.25 to get grams/trip.

mi/hr	2.5
hr	0.25
factor for 1/2 hr idle/trip	10

Mobile Source - Moves run for Cowlitz County, WY, 2018
Emission factors for Truck Exhaust

Emission factors for Truck Exhaust Emission Factors (gm/mile)												
Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH_4	N_2O	Benzene	Form	CO2eq
2018												
Short Haul Combo - diesel @ 55mph (Rural restricted)	4.63	0.22	0.15	0.01	1.01	0.20	1560.24	0.03	0.00	0.00	0.02	1561.39
Short Haul Combo - diesel @ 55mph (Urban un-restricted)	5.30	0.49	0.26	0.02	1.39	0.30	1763.06	0.05	0.00	0.00	0.03	1765.19
Short Haul Combo - diesel @ Idle (Rural unrestricted)	6.00	0.42	0.24	0.02	1.48	0.35	1927.59	0.06	0.00	0.00	0.03	1930.06

APPENDIX A1e Material Transfer by Rail (annual T/year)

LOCOMOTIVE EMISSIONS

5-year construction schedule (35,000 loaded rail cars)

Unit Trains (cars/train)	100	cars	=Millennium Coal Export Terminal Longview, Washington Traffic and Transportation, Resource Report, September 2014,URS Corporation'
Unit Trains Required	467	Trains/yr	6 trains per month' 'Millennium Coal Export Terminal Longview, Washington Traffic and Transportation, Resource Report, September 2014,URS Corporation'
	3	Locomotives/Train (full)	
	3	Locomotives/Train (empty)	
Engine Size:	4400	hp/locomotive	*Electro-Motive Diesel, GE Transportation* (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009* .)

Fuel Use per Train — Full Build-Out

ON SITE			
Loaded Train:	4.6%	Percent Load	Notch 1 setting and associatedd load @ 6 mph (202 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	607.2	hp	
	29	gallons/hr	
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	33	hp	
	2	gallons/hr	
OFF SITE			
Loaded Train:	65.4%	Percent Load	Notch 6 setting and associatedd load @ 40 mph (2876 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	8628	hp	
	415	gallons/hr	
Empty Train:	65.4%	Percent Load	Assume same notch 6 setting as loaded (conservative)
	8628	hp	
	415	gallons/hr	

Longview Short Line (Longview Switching Company (LSC) Track)

Offsite

Distance from Main Rail Line to Site:	7.10	miles	distance from GIS drawings per Danny Stratten (ICF) Feb 2014
Travel Time to Site:	0.71	hrs	DKS travel speed average of 10 mph
Total Power:	5721572	hp-hr/yr	
Total Fuel Use:	275076	gallons/yr	

Onsite

Onsite loop distance:	8727	ft	Per train average loop distance (Drawings 80552-500-GE-DLP-0020_RevA.pdf and 80552-500-ST-DAL-2019-00-RevA.pdf, WorleyParsons)
Travel Distance:	1.65	miles	(one loop onsite; does not include dump track time which is operated by electric indexing system)
Time per Train:	1.48	hours	time needed to unload the coal from 125 cars scaled from 125 coal cars
Total Power:	220776	hp-hr/yr	
Total Fuel Use:	10614	gallons/yr	

Total Fuel Use (On and Offsite) 285690 gallons/yr

Emission Factors (2028 full operation)

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:

[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.

[2] SO2 emission factor using S content of 15 ppm

[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2.

[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr.

[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.

[6] Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Offsite	1.85E+01	8.06E+00	6.36E-01	2.85E-02	4.79E-01	3.94E-01	3.82E-01	8.57E-02	3.10E+03	2.42E-01	7.88E-02	3.12E+03
Onsite	7.13E-01	3.11E-01	2.45E-02	1.10E-03	1.85E-02	1.52E-02	1.47E-02	3.31E-03	1.19E+02	9.35E-03	3.04E-03	1.21E+02
Total	1.92E+01	8.37E+00	6.61E-01	2.96E-02	4.98E-01	4.09E-01	3.97E-01	8.90E-02	3.21E+03	2.52E-01	8.18E-02	3.25E+03

APPENDIX A1f Material Transfer by Rail (Max Day)

LOCOMOTIVE EMISSIONS

5-year construction schedule (35,000 loaded rail cars)

Unit Trains (cars/train)	100	cars	=Millennium Coal Export Terminal Longview, Washington Traffic and Transportation, Resource Report, September 2014,URS Corporation'
Unit Trains Required	1.3	Trains/day	6 trains per month' 'Millennium Coal Export Terminal Longview, Washington Traffic and Transportation, Resource Report, September 2014,URS Corporation'
	3	Locomotives/Train (full)	Constinet with DKS traffic analysis
	3	Locomotives/Train (empty)	Constinet with DKS traffic analysis
Engine Size:	4400	hp/locomotive	*Electro-Motive Diesel, GE Transportation* (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009* .)

Fuel Use per Train — Full Build-Out

ON SITE			
Loaded Train:	4.6%	Percent Load	Notch 1 setting and associatedd load @ 6 mph (202 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	607.2	hp	
	29	gallons/hr	
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	33	hp	
	2	gallons/hr	
OFF SITE			
Loaded Train:	65.4%	Percent Load	Notch 6 setting and associatedd load @ 40 mph (2876 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	8628	hp	
	415	gallons/hr	
Empty Train:	65.4%	Percent Load	Assume same notch 6 setting as loaded (conservative)
	8628	hp	
	415	gallons/hr	

Longview Short Line (Longview Switching Company (LSC) Track)

Offsite			
Distance from Main Rail Line to Site:	7.10	miles	distance from GIS drawings per Danny Stratten (ICF) Feb 2014
Travel Time to Site:	0.71	hrs	DKS travel speed average of 10 mph
Total Power:	15927	hp-hr/yr	
Total Fuel Use:	766	gallons/yr	
Onsite			
Onsite loop distance:	8727	ft	Per train average loop distance (Drawings 80552-500-GE-DLP-0020_RevA.pdf and 80552-500-ST-DAL-2019-00-RevA.pdf, WorleyParsons)
Travel Distance:	1.65	miles	(one loop onsite; does not include dump track time which is operated by electric indexing system)
Time per Train:	1.48	hours	time needed to unload the coal from 125 cars scaled from 125 coal cars
Total Power:	615	hp-hr/yr	
Total Fuel Use:	30	gallons/yr	
Total Fuel Use (On and Offsite)	795	gallons/yr	

Emission Factors (2028 full operation)

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:
[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.
[2] SO2 emission factor using S content of 15 ppm
[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2.
[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr.
[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.
[6] Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Offsite	5.14E-02	2.24E-02	1.77E-03	7.93E-05	1.33E-03	1.10E-03	1.06E-03	2.39E-04	8.62E+00	6.75E-04	2.19E-04	8.70E+00
Onsite	1.98E-03	8.66E-04	6.83E-05	3.06E-06	5.15E-05	4.23E-05	4.10E-05	9.21E-06	3.32E-01	2.60E-05	8.46E-06	3.36E-01
Total	5.34E-02	2.33E-02	1.84E-03	8.23E-05	1.39E-03	1.14E-03	1.10E-03	2.48E-04	8.95E+00	7.01E-04	2.28E-04	9.03E+00

APPENDIX A2

CONSTRUCTION - 'NONROAD' MODEL EMISSIONS

EPA`s NONROAD Emissions Model
Core Model ver 2008a, 07/06/09
Jul 25 11:58:30: 2014
MBTL
2014
Options file used: C:\NONROAD\Projects\MBTL.OPT
Total for year: 2014
Tons/Year

Cnty	Sub	SCC	HP	Population	THC-Exhaust	CO-Exhaust	NOx-Exhaust	CO2-Exhaust	SO2-Exhaust	PM-Exhaust	Crankcase	Hot-Soaks	Diurnal	Displacement	Spillage	RunLoss	TankPerm	HosePerm	FuelCons.	Activity	LF	HPAvg
53015		2265003070	40	1.70E-03	1.53E-05	5.51E-04	4.18E-05	2.96E-02	6.10E-06	3.06E-06	0.00E+00	1.67E-07	7.96E-07	1.12E-05	6.70E-07	3.74E-07	0.00E+00	0.00E+00	3.01E+00	1.41E+00	7.80E-01	3.50E+01
53015		2265003070	75	6.63E-02	1.04E-03	3.81E-02	2.83E-03	1.92E+00	3.95E-04	1.96E-04	0.00E+00	6.50E-06	8.20E-05	7.25E-04	2.20E-05	1.78E-05	0.00E+00	0.00E+00	1.95E+02	5.49E+01	7.80E-01	5.82E+01
53015		2265003070	100	3.06E-02	8.13E-04	2.98E-02	2.22E-03	1.50E+00	3.09E-04	1.53E-04	0.00E+00	3.00E-06	3.79E-05	5.67E-04	1.72E-05	8.23E-06	0.00E+00	0.00E+00	1.53E+02	2.53E+01	7.80E-01	9.86E+01
53015		2265003070	175	1.19E-01	3.66E-03	1.34E-01	9.98E-03	6.76E+00	1.39E-03	6.90E-04	0.00E+00	1.17E-05	2.43E-04	2.55E-03	4.69E-05	3.20E-05	0.00E+00	0.00E+00	6.88E+02	9.85E+01	7.80E-01	1.14E+02
53015		2265003070	300	1.70E-03	1.14E-04	4.20E-03	3.12E-04	2.11E-01	4.36E-05	2.16E-05	0.00E+00	1.67E-07	7.61E-06	7.99E-05	6.70E-07	4.57E-07	0.00E+00	0.00E+00	2.15E+01	1.41E+00	7.80E-01	2.50E+02
53015		2267002057	40	3.32E-02	5.20E-05	1.84E-03	2.95E-04	1.52E-01	2.95E-06	1.60E-05	6.96E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E+01	1.37E+01	6.30E-01	2.90E+01
53015		2267002057	50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015		2267002057	75	2.23E-01	3.06E-03	8.60E-02	1.35E-02	2.40E+00	4.67E-05	2.42E-04	5.99E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.58E+02	9.20E+01	6.30E-01	6.59E+01
53015		2267002057	100	1.33E-03	2.21E-05	6.22E-04	9.74E-05	1.74E-02	3.38E-07	1.75E-06	4.33E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.58E+00	5.48E-01	6.30E-01	8.00E+01
53015		2267002057	175	2.65E-02	6.26E-04	1.76E-02	2.76E-03	4.92E-01	9.56E-06	4.94E-05	1.23E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.32E+01	1.10E+01	6.30E-01	1.13E+02
53015		2270002009	6	3.82E+00	2.92E-03	1.94E-02	2.14E-02	2.54E+00	5.47E-04	2.21E-03	3.10E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E+02	1.85E+03	4.30E-01	4.94E+00
53015		2270002009	11	1.71E+00	2.26E-03	1.50E-02	1.66E-02	1.97E+00	4.24E-04	1.71E-03	2.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E+02	8.26E+02	4.30E-01	8.55E+00
53015		2270002009	16	1.04E+00	1.87E-03	8.73E-03	1.63E-02	1.99E+00	4.28E-04	1.35E-03	2.03E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E+02	5.02E+02	4.30E-01	1.42E+01
53015		2270002009	25	9.57E-02	2.47E-04	1.15E-03	2.15E-03	2.63E-01	5.65E-05	1.78E-04	2.68E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.33E+01	4.63E+01	4.30E-01	2.04E+01
53015		2270002015	6	4.11E-01	6.24E-04	5.13E-03	4.78E-03	6.57E-01	1.41E-04	4.31E-04	9.20E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.82E+01	3.13E+02	5.90E-01	5.44E+00
53015		2270002015	11	7.72E-01	1.87E-03	1.54E-02	1.43E-02	1.97E+00	4.24E-04	1.29E-03	2.76E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E+02	5.87E+02	5.90E-01	8.69E+00
53015		2270002015	16	9.24E-01	2.79E-03	1.51E-02	2.76E-02	3.68E+00	7.91E-04	2.26E-03	4.08E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.26E+02	7.02E+02	5.90E-01	1.36E+01
53015		2270002015	25	1.66E+00	7.28E-03	3.95E-02	7.19E-02	9.60E+00	2.06E-03	5.88E-03	1.06E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.49E+02	1.26E+03	5.90E-01	1.97E+01
53015		2270002015	40	2.37E+00	8.94E-03	4.83E-02	1.58E-01	2.26E+01	4.40E-03	9.69E-03	1.54E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+03	1.80E+03	5.90E-01	3.25E+01
53015		2270002015	50	2.19E+00	1.17E-02	6.31E-02	2.06E-01	2.95E+01	5.74E-03	1.26E-02	2.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.61E+03	1.67E+03	5.90E-01	4.58E+01
53015		2270002015	75	2.22E+00	1.88E-02	1.78E-01	2.48E-01	3.97E+01	8.05E-03	2.30E-02	2.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.51E+03	1.69E+03	5.90E-01	6.07E+01
53015		2270002015	100	6.07E+00	7.16E-02	7.40E-01	8.22E-01	1.51E+02	2.98E-02	1.10E-01	1.24E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E+04	4.62E+03	5.90E-01	8.48E+01
53015		2270002015	175	5.63E+00	8.40E-02	3.99E-01	1.01E+00	1.97E+02	3.89E-02	1.08E-01	1.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E+04	4.28E+03	5.90E-01	1.32E+02
53015		2270002015	300	1.92E+00	4.20E-02	1.70E-01	5.19E-01	1.11E+02	2.12E-02	4.42E-02	6.31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.78E+03	1.46E+03	5.90E-01	2.17E+02
53015		2270002015	600	5.70E-01	2.34E-02	1.59E-01	3.93E-01	6.35E+01	1.26E-02	2.72E-02	3.82E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.61E+03	4.33E+02	5.90E-01	4.21E+02
53015		2270002033	11	1.78E-02	2.15E-05	1.41E-04	1.57E-04	1.85E-02	3.97E-06	1.63E-05	2.37E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.64E+00	8.28E+00	4.30E-01	8.00E+00
53015		2270002033	16	2.73E-02	4.94E-05	2.28E-04	4.24E-04	5.15E-02	1.11E-05	3.53E-05	5.57E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.56E+00	1.27E+01	4.30E-01	1.45E+01
53015		2270002033	25	6.15E-02	1.80E-04	8.32E-04	1.54E-03	1.88E-01	4.04E-05	1.29E-04	2.03E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+01	2.87E+01	4.30E-01	2.35E+01
53015		2270002033	40	1.05E+00	2.69E-03	1.22E-02	3.37E-02	4.29E+00	8.78E-04	2.61E-03	3.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E+02	4.88E+02	4.30E-01	3.15E+01
53015		2270002033	50	1.07E+00	3.91E-03	1.78E-02	4.89E-02	6.24E+00	1.28E-03	3.79E-03	5.05E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.52E+02	4.97E+02	4.30E-01	4.49E+01
53015		2270002033	75	1.73E+00	1.23E-02	6.46E-02	1.23E-01	1.39E+01	2.90E-03	1.19E-02	2.19E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E+03	8.06E+02	4.30E-01	6.18E+01
53015		2270002033	100	1.76E+00	1.71E-02	8.67E-02	1.63E-01	1.95E+01	4.00E-03	1.71E-02	3.29E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.72E+03	8.19E+02	4.30E-01	8.51E+01
53015		2270002033	175	2.58E+00	2.85E-02	1.07E-01	3.64E-01	3.99E+01	8.19E-03	2.41E-02	5.39E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.53E+03	1.20E+03	4.30E-01	1.32E+02
53015		2270002033	300	2.25E+00	4.12E-02	1.48E-01	5.47E-01	6.29E+01	1.27E-02	3.29E-02	7.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.57E+03	1.05E+03	4.30E-01	2.39E+02
53015		2270002033	600	1.29E+00	4.05E-02	1.88E-01	6.15E-01	6.77E+01	1.38E-02	3.33E-02	7.45E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.99E+03	6.03E+02	4.30E-01	4.47E+02
53015		2270002033	750	3.03E-01	1.42E-02	7.74E-02	2.22E-01	2.45E+01	4.98E-03	1.23E-02	2.60E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E+03	1.41E+02	4.30E-01	6.91E+02
53015		2270002033	1000	1.65E-01	1.39E-02	5.50E-02	1.93E-01	1.68E+01	3.42E-03	9.71E-03	2.43E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E+03	7.71E+01	4.30E-01	8.69E+02
53015		2270002033	1200	2.73E-03	2.78E-04	1.10E-03	3.85E-03	3.36E-01	6.82E-05	1.94E-04	4.86E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.97E+01	1.27E+00	4.30E-01	1.05E+03
53015		2270002033	2000	5.47E-03	7.93E-04	3.14E-03	1.10E-02	9.59E-01	1.95E-04	5.54E-04	1.39E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.49E+01	2.55E+00	4.30E-01	1.50E+03
53015		2270002036	6	2.05E-02	4.89E-05	3.97E-04	3.77E-04	5.19E-02	1.12E-05	3.22E-05	8.72E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.60E+00	2.24E+01	5.90E-01	6.00E+00
53015		2270002036	11	1.13E-01	3.59E-04	2.91E-03	2.77E-03	3.81E-01	8.20E-05	2.37E-04	6.41E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E+01	1.24E+02	5.90E-01	7.97E+00
53015		2270002036	16	2.34E-01	9.77E-04	5.20E-03	9.73E-03	1.30E+00	2.79E-04	7.97E-04	1.73E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E+02	2.55E+02	5.90E-01	1.31E+01
53015		2270002036	25	1.04E+00	7.14E-03	3.80E-02	7.11E-02	9.47E+00	2.04E-03	5.83E-03	1.26E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.39E+02	1.14E+03	5.90E-01	2.15E+01
53015		2270002036	40	2.16E+00	1.08E-02	5.30E-02	2.00E-01	3.01E+01	5.62E-03	1.15E-02	2.53E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.66E+03	2.35E+03	5.90E-01	3.30E+01
53015		2270002036	50	1.15E+00	8.01E-03	3.92E-02	1.47E-01	2.23E+01	4.15E-03	8.47E-03	1.87E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.97E+03	1.26E+03	5.90E-01	4.58E+01
53015		2270002036	75	8.92E-01	8.53E-03	8.81E-02	1.30E-01	2.31E+01	4.59E-03	1.10E-02	6.66E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E+03	9.74E+02	5.90E-01	6.13E+01
53015		2270002036	100	4.03E+00	5.70E-02	6.74E-01	7.03E-01	1.56E+02	2.98E-02	1.06E-01	8.68E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E+04	4.40E+03	5.90E-01	9.17E+01
53015		2270002036	175	1.50E+01	2.76E-01	1.39E+00	3.22E+00	7.88E+02	1.50E-01	4.20E-01	3.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.97E+04	1.64E+04	5.90E-01	1.38E+02
53015		2270002036	300	1.10E+01	3.15E-01	1.24E+00	3.65E+00	9.77E+02	1.79E-01	3.62E-01	3.84E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.64E+04	1.20E+04	5.90E-01	2.33E+02
53015		2270002036	600	2.91E+00	1.39E-01	8.58E-01	2.18E+00	4.56E+02	8.75E-02	1.73E-01	1.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.03E+04	3.18E+03	5.90E-01	4.11E+02
53015		2270002036	750	9.29E-02	7.56E-03	7.04E-02	1.22E-01	2.55E+01	4.89E-03	9.85E-03	1.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E+03	1.01E+02	5.90E-01	7.19E+02
53015		2270002036	1000	1.08E-01	1.83E-02	9.27E-02	2.72E-01	3.63E+01	6.98E-03	1.58E-02	2.22E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.21E+03	1.18E+02	5.90E-01	8.84E+02
53015		2270002036	1200	4.10E-03	9.42E-04	4.78E-03	1.40E-02	1.87E+00	3.60E-04	8.15E-04	1.14E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+02	4.48E+00	5.90E-01	1.20E+03
53015		2270002036	2000	4.10E-02	1.39E-02	7.04E-02	2.07E-01	2.76E+01	5.30E-03	1.20E-02	1.69E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.44E+03	4.48E+01	5.90E-01	1.77E+03
53015		2270002036	3000	1.37E-03	6.15E-04	3.12E-03	9.16E-03	1.22E+00	2.35E-04	5.32E-04	7.47E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+02	1.49E+00	5.90E-01	2.35E+03
53015		2270002045	25	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015		2270002045	40	1.72E-01	7.55E-04	3.82E-03	1.33E-02	1.88E+00	3.66E-04	7.96E-04	1.53E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+02	1.70E+02	4.30E-01	3.94E+01
53015		2270002045	50	2.73E-03	1.27E-05	6.42E-05	2.24E-04	3.15E-02	6.15E-06	1.34E-05	2.57E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E+00	2.71E+00	4.30E-01	4.17E+01
53015		2270002045	75	9.16E-02	7.91E-04	5.87E-03	1.07E-02	1.62E+00	3.30E-04	8.59E-04	1.04E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.43E+02	9.06E+01	4.30E-01	6.40E+01
53015		2270002045	100	8.85E-01	1.04E-02	7.08E-02	1.24E-01	2.16E+01	4.27E-03	1.25E-02	1.80E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.91E+03	8.77E+02	4.30E-01	8.81E+01
53015		2270002045	175	3.33E+00	5.15E-02	1.65E-01	6.50E-01	1.20E+02	2.38E-02	5.04E-02	8.61E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+04	3.30E+03	4.30E-01	1.45E+02
53015		2270002045	300	3.41E+00	7.69E-02	2.12E-01	9.99E-01	2.02E+02	3.88E-02	6.33E-02	1.17E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E+04	3.38E+03	4.30E-01	2.38E+02
53015		2270002045	600	2.10E+00	8.22E-02	3.69E-01	1.44E+00	2.15E+02	4.28E-02	7.47E-02	1.36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+04	2.08E+03	4.30E-01	4.12E+02
53015		2270002045	750	9.02E-02	5.44E-03	3.35E-02	1.01E-01	1.50E+01	2.98E-03	5.42E-03	8.90E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+03	8.93E+01	4.30E-01	6.69E+02
53015		2270002045	1000	2.60E-02	3.56E-03	1.27E-02	5.47E-02	5.70E+00	1.13E-03	2.53E-03	5.50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E+02	2.57E+01	4.30E-01	8.83E+02
53015		2270002045	1200	1.37E-03	2.27E-04	8.08E-04	3.49E-03	3.64E-01	7.23E-05	1.62E-04	3.51E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E+01	1.35E+00	4.30E-01	1.07E+03
53015		2270002048	40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015		2270002048	50	5.47E-03	3.69E-05	1.88E-04	6.67E-04	9.84E-02	1.87E-05	3.90E-05	2.15E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.70E+00	5.26E+00	5.90E-01	4.83E+01
53015		2270002048	75	3.96E-02	3.54E-04	3.56E-03	5.14E-03	8.79E-01	1.76E-04	4.47E-04	3.46E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.77E+01	3.81E+01	5.90E-01	5.95E+01
53015		2270002048	100	3.03E-01	3.80E-03	4.30E-02	4.59E-02	9.52E+00	1.84E-03	6.55E-03	6.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.41E+02	2.92E+02	5.90E-01	8.42E+01
53015		2270002048	175	3.10E+00	5.49E-02	2.71E-01	6.48E-01	1.46E+02	2.83E-02	7.85E-02	8.43E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E+04	2.98E+03	5.90E-01	1.41E+02
53015		2270002048	300	5.19E+00	1.36E-01	5.51E-01	1.62E+00	4.02E+02	7.51E-02	1.54E-01	1.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.56E+04	4.99E+03	5.90E-01	2.31E+02
53015		2270002048	600	5.93E-01	2.19E-02	1.40E-01	3.57E-01	6.80E+01	1.32E-02	2.66E-02	3.27E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.01E+03	5.71E+02	5.90E-01	3.42E+02
53015		2270002048	750	3.55E-02	2.78E-03	2.63E-02	4.68E-02	8.94E+00	1.74E-03	3.57E-03	4.09E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.90E+02	3.42E+01	5.90E-01	7.50E+02
53015		2270002051	175	8.20E-03	2.28E-04	1.04E-03	2.45E-03	7.53E-01	1.36E-04	3.56E-04	2.48E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.66E+01	1.35E+01	5.90E-01	1.61E+02
53015		2270002051	300	7.79E-01	3.06E-02	9.01E-02	3.12E-01	1.09E+02	1.86E-02	3.49E-02	2.22E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.63E+03	1.28E+03	5.90E-01	2.44E+02
53015		2270002051	600	1.65E+00	1.13E-01	5.80E-01	1.45E+00	3.97E+02	7.29E-02	1.44E-01	1.25E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.51E+04	2.71E+03	5.90E-01	4.20E+02
53015		2270002051	750	9.35E-01	1.04E-01	8.34E-01	1.35E+00	3.68E+02	6.76E-02	1.34E-01	1.15E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.25E+04	1.53E+03	5.90E-01	6.88E+02
53015		2270002051	1000	4.54E-01	1.03E-01	5.26E-01	1.41E+00	2.25E+02	4.13E-02	9.12E-02	8.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.99E+04	7.44E+02	5.90E-01	8.68E+02
53015		2270002051	1200	1.43E-01	4.34E-02	2.21E-01	5.93E-01	9.46E+01	1.74E-02	3.83E-02	3.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.37E+03	2.35E+02	5.90E-01	1.15E+03
53015		2270002051	2000	7.27E-01	3.41E-01	1.73E+00	4.66E+00	7.43E+02	1.36E-01	3.01E-01	2.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.57E+04	1.19E+03	5.90E-01	1.79E+03
53015		2270002051	3000	1.78E-01	1.13E-01	5.75E-01	1.54E+00	2.46E+02	4.52E-02	9.97E-02	9.19E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E+04	2.92E+02	5.90E-01	2.42E+03
53015		2270002057	16	5.47E-03	1.44E-05	7.92E-05	1.42E-04

53015	2270002060	11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270002060	16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270002060	25	1.37E-02	6.97E-05	3.78E-04	6.88E-04	9.18E-02	1.98E-05	5.63E-05	1.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.13E+00	1.04E+01	5.90E-01	2.28E+01
53015	2270002060	40	7.20E-01	2.88E-03	1.56E-02	5.08E-02	7.30E+00	1.42E-03	3.12E-03	4.92E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.45E+02	5.48E+02	5.90E-01	3.44E+01
53015	2270002060	50	8.27E-01	4.37E-03	2.36E-02	7.72E-02	1.11E+01	2.15E-03	4.73E-03	7.46E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.79E+02	6.29E+02	5.90E-01	4.54E+01
53015	2270002060	75	1.17E+00	1.01E-02	9.51E-02	1.33E-01	2.12E+01	4.31E-03	1.23E-02	1.28E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+03	8.89E+02	5.90E-01	6.17E+01
53015	2270002060	100	5.02E+00	5.98E-02	6.18E-01	6.86E-01	1.27E+02	2.49E-02	9.20E-02	1.03E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E+04	3.82E+03	5.90E-01	8.55E+01
53015	2270002060	175	1.27E+01	1.96E-01	9.29E-01	2.35E+00	4.59E+02	9.05E-02	2.51E-01	3.25E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.06E+04	9.67E+03	5.90E-01	1.36E+02
53015	2270002060	300	1.21E+01	2.81E-01	1.14E+00	3.47E+00	7.40E+02	1.42E-01	2.96E-01	4.22E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.55E+04	9.23E+03	5.90E-01	2.30E+02
53015	2270002060	600	8.90E+00	3.63E-01	2.47E+00	6.14E+00	9.91E+02	1.96E-01	4.24E-01	5.92E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.76E+04	6.77E+03	5.90E-01	4.19E+02
53015	2270002060	750	6.72E-01	4.28E-02	4.07E-01	7.67E-01	1.24E+02	2.45E-02	5.47E-02	6.88E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+04	5.12E+02	5.90E-01	6.92E+02
53015	2270002060	1000	3.28E-01	4.54E-02	2.40E-01	6.64E-01	7.53E+01	1.49E-02	3.85E-02	6.86E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.67E+03	2.50E+02	5.90E-01	8.66E+02
53015	2270002060	1200	6.83E-02	1.18E-02	6.25E-02	1.73E-01	1.96E+01	3.88E-03	1.00E-02	1.79E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E+03	5.20E+01	5.90E-01	1.08E+03
53015	2270002060	2000	4.02E-01	1.20E-01	6.34E-01	1.75E+00	1.99E+02	3.94E-02	1.02E-01	1.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E+04	3.06E+02	5.90E-01	1.87E+03
53015	2270002060	3000	1.50E-02	5.38E-03	2.85E-02	7.88E-02	8.94E+00	1.77E-03	4.57E-03	8.14E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.91E+02	1.14E+01	5.90E-01	2.24E+03
53015	2270002069	40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270002069	50	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270002069	75	1.52E-01	1.30E-03	1.30E-02	1.87E-02	3.19E+00	6.39E-04	1.64E-03	1.31E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E+02	1.42E+02	5.90E-01	5.80E+01
53015	2270002069	100	4.35E+00	5.62E-02	6.31E-01	6.77E-01	1.39E+02	2.68E-02	9.57E-02	9.10E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E+04	4.07E+03	5.90E-01	8.79E+01
53015	2270002069	175	9.84E+00	1.66E-01	8.15E-01	1.96E+00	4.37E+02	8.46E-02	2.35E-01	2.57E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.86E+04	9.21E+03	5.90E-01	1.36E+02
53015	2270002069	300	8.52E+00	2.23E-01	9.06E-01	2.67E+00	6.55E+02	1.23E-01	2.51E-01	2.99E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.79E+04	7.97E+03	5.90E-01	2.36E+02
53015	2270002069	600	4.31E+00	1.96E-01	1.26E+00	3.19E+00	5.99E+02	1.17E-01	2.35E-01	2.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.29E+04	4.04E+03	5.90E-01	4.25E+02
53015	2270002069	750	1.70E+00	1.23E-01	1.17E+00	2.09E+00	3.93E+02	7.65E-02	1.58E-01	1.83E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.47E+04	1.59E+03	5.90E-01	7.07E+02
53015	2270002069	1000	3.53E-01	5.68E-02	2.90E-01	8.52E-01	1.06E+02	2.07E-02	4.84E-02	7.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.39E+03	3.30E+02	5.90E-01	9.23E+02
53015	2270002069	1200	6.12E-01	1.14E-01	5.81E-01	1.71E+00	2.13E+02	4.14E-02	9.70E-02	1.54E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+04	5.73E+02	5.90E-01	1.07E+03
53015	2270002069	2000	2.73E-03	7.03E-04	3.58E-03	1.05E-02	1.31E+00	2.56E-04	5.99E-04	9.49E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.16E+02	2.56E+00	5.90E-01	1.47E+03
53015	2270006005	6	1.90E+01	1.32E-02	7.54E-02	9.35E-02	9.55E+00	2.05E-03	1.01E-02	1.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.47E+02	6.41E+03	4.30E-01	5.35E+00
53015	2270006005	11	1.89E+01	2.07E-02	1.18E-01	1.47E-01	1.50E+01	3.23E-03	1.58E-02	2.89E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E+03	6.40E+03	4.30E-01	8.42E+00
53015	2270006005	16	1.46E+01	2.30E-02	9.59E-02	1.70E-01	1.86E+01	4.01E-03	1.58E-02	3.36E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E+03	4.93E+03	4.30E-01	1.36E+01
53015	2270006005	25	2.30E+01	5.70E-02	2.37E-01	4.20E-01	4.61E+01	9.91E-03	3.90E-02	8.31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.09E+03	7.77E+03	4.30E-01	2.13E+01
53015	2270006005	40	3.80E+01	1.10E-01	4.39E-01	1.00E+00	1.20E+02	2.48E-02	8.80E-02	1.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+04	1.29E+04	4.30E-01	3.34E+01
53015	2270006005	50	5.20E+00	2.03E-02	8.10E-02	1.85E-01	2.21E+01	4.58E-03	1.62E-02	3.27E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.96E+03	1.76E+03	4.30E-01	4.52E+01
53015	2270006005	75	1.92E+01	9.86E-02	5.03E-01	9.35E-01	1.08E+02	2.26E-02	8.99E-02	1.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E+03	6.48E+03	4.30E-01	6.00E+01
53015	2270006005	100	2.33E+01	1.72E-01	8.48E-01	1.55E+00	1.90E+02	3.91E-02	1.62E-01	3.31E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.68E+04	7.88E+03	4.30E-01	8.64E+01
53015	2270006005	175	7.96E+00	6.81E-02	2.53E-01	8.19E-01	9.17E+01	1.89E-02	5.46E-02	1.29E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.12E+03	2.69E+03	4.30E-01	1.36E+02
53015	2270006005	300	4.43E+00	6.13E-02	2.17E-01	7.61E-01	8.95E+01	1.81E-02	4.66E-02	1.14E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E+03	1.50E+03	4.30E-01	2.38E+02
53015	2270006005	600	2.30E+00	4.83E-02	2.15E-01	6.95E-01	8.19E+01	1.66E-02	3.70E-02	8.83E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.24E+03	7.77E+02	4.30E-01	4.19E+02
53015	2270006005	750	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270006005	1000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270006005	1200	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270006005	2000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270006005	3000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53015	2270006015	6	1.11E-01	1.36E-04	1.06E-03	1.05E-03	1.40E-01	3.01E-05	9.69E-05	4.97E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E+01	9.02E+01	4.30E-01	5.57E+00
53015	2270006015	11	2.71E-01	5.68E-04	4.42E-03	4.35E-03	5.84E-01	1.26E-04	4.03E-04	2.07E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.17E+01	2.21E+02	4.30E-01	9.47E+00
53015	2270006015	16	3.69E-02	8.67E-05	4.49E-04	8.54E-04	1.12E-01	2.41E-05	6.77E-05	3.09E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.91E+00	3.01E+01	4.30E-01	1.33E+01
53015	2270006015	25	5.68E-02	2.27E-04	1.17E-03	2.23E-03	2.93E-01	6.30E-05	1.77E-04	8.09E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E+01	4.63E+01	4.30E-01	2.27E+01
53015	2270006015	40	2.09E+00	6.72E-03	3.45E-02	1.16E-01	1.59E+01	3.15E-03	7.31E-03	2.83E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+03	1.70E+03	4.30E-01	3.35E+01
53015	2270006015	50	1.44E+00	6.14E-03	3.15E-02	1.06E-01	1.46E+01	2.88E-03	6.69E-03	2.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E+03	1.18E+03	4.30E-01	4.43E+01
53015	2270006015	75	9.25E+00	7.19E-02	4.81E-01	9.03E-01	1.28E+02	2.62E-02	7.58E-02	1.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E+04	7.54E+03	4.30E-01	6.08E+01
53015	2270006015	100	1.20E+01	1.28E-01	7.97E-01	1.45E+00	2.30E+02	4.60E-02	1.46E-01	2.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E+04	9.82E+03	4.30E-01	8.39E+01
53015	2270006015	175	1.38E+00	1.73E-02	5.52E-02	2.25E-01	3.66E+01	7.31E-03	1.60E-02	3.01E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E+03	1.13E+03	4.30E-01	1.29E+02
53015	2270006015	300	1.24E+00	2.61E-02	7.35E-02	3.54E-01	6.18E+01	1.21E-02	2.09E-02	4.24E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E+03	1.01E+03	4.30E-01	2.43E+02
53015	2270006015	600	3.55E-01	1.43E-02	6.63E-02	2.31E-01	3.11E+01	6.23E-03	1.26E-02	2.49E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.75E+03	2.89E+02	4.30E-01	4.27E+02
53015	2270006015	750	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

APPENDIX A3a

SUMMARY OF EMISSIONS

Based on:

1 metric tonne = 1.1023 ton (short ton)

Facility Material Handling System Rating

Materials Handling System/Train Unload:	7500	metric tonnes/hr	8267	tons/hr
Reclaim and Vessel Loading:	6500	metric tonnes/hr	7165	tons/hr

Projected Operation

Operating hours	365	days/yr	
		Full Build-Out	
Coal Throughput	44	MM metric tons per year	
	49	MM tpy	
Unit Trains	8	trains/day	
Cars per Unit Train	125	cars/train	
Coal per Car	122.1	tons/car	
Onsite Tracks	8	number of tracks	
	840	ships/yr	Latest assumption on number of cargo ships Handymax size to move tl
tons of coal per ship	57,740	tons/vessel	
Hours to Unload one unit train	1.85	hours	

	Full Build-Out Pollutant Emissions (tpy)								
Source	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**DPM**
FUGITIVE SOURCES									
Coal Transfer (except piles):									
Material Handling	-	-	-	-	5.25	1.84	0.28	-	-
Coal Piles:									
Wind Erosion	-	-	-	-	3.05	2.59	0.40	-	-
Material Handling	-	-	-	-	2.62	0.92	0.14	-	-
MOBILE SOURCES									
Maint/Ops/Emergency Equipment:									
Combustion	4.36	1.45	0.37	0.20	0.38	0.31	0.31	0.01	0.38
Trains:									
Combustion (Off-site)	23.3	10.18	0.80	0.036	0.60	0.50	0.48	0.11	0.60
Fugitive (Off-site)	-	-	-	-	1.03	0.88	0.13	-	-
Conbustion (on-site)	13.95	5.04	0.56	0.02	0.36	0.30	0.29	0.05	0.27
Combustion unloading trani (On-site)	7.43	3.24	0.26	1.15E-02	0.19	0.16	0.15	3.45E-02	0.19
Combustion Idle (On-site)	2.07	0.90	7.14E-02	3.20E-03	5.38E-02	4.42E-02	4.29E-02	9.62E-03	5.38E-02
Combustion Switching (On-site)	4.44	0.90	0.23	3.17E-03	0.11	9.43E-02	9.15E-02	9.53E-03	2.69E-02
Fugitive (On-site)	-	-	-	-	3.68	3.13	0.48	-	-
Ships:									
Combustion (Off-site)	24.8	37.9	14.10	3.04	2.17	1.78	1.64	0.03	0.00
Combustion (On-site)	23.3	65.9	15.32	4.52	1.27	1.05	1.02	0.08	0.56
Total - All Sources, Onsite and Offsite	89.8	120.5	31.1	7.81	20.4	13.3	5.17	0.28	1.82
Total - Onsite Sources	41.6	72.4	16.24	4.74	16.62	10.13	2.91	0.14	1.22
Fugitives Only	-	-	-	-	14.60	8.47	1.29	-	-
Facility Equipment Combusion Only	4.36	1.45	0.37	0.20	0.38	0.31	0.31	0.01	0.38
Mobile Combustion Sources Only	41.58	72.43	16.24	4.74	2.02	1.66	1.62	0.14	1.22

PM From Combustion (tpy):	**TSP**	**PM_{10}**	**$PM_{2.5}$**
Total - Offsite Combustion	2.77	2.28	2.13
Total - Onsite Combustion	1.85	1.52	1.48
Total - Combustion	4.62	3.80	3.61

Washington State Emissions in tons per year

2011 Emissions Inventory for Cowlitz County

Select Sources (full summary in separate worksheet)	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**DPM**
Point Sources	3,616	2,507	671	791	-	182	172	-	-
Non-Road Mobile (Land-based, non-locomotive)	389	3,718	592	1	-	48	46	-	24
Railroad	789	137	43	6	-	23	23	-	23
Ships (commercial marine vessels)	1,109	150	46	199	-	37	34	-	34
Total All Source Categories	10,382	36,142	16,919	1,020	-	1,872	971	-	164

APPENDIX A3b

SUMMARY OF EMISSIONS

Based on:

1 metric tonne = 1.1023 ton (short ton)

Facility Material Handling System Rating

Materials Handling System/Train Unload:	7500	metric tonnes/hr	8267	tons/hr
Reclaim and Vessel Loading:	6500	metric tonnes/hr	7165	tons/hr

Projected Operation

Operating hours	365	days/yr

	Full Build-Out		
Coal Throughput	44	MM metric tons per year	
	49	MM tpy	
Unit Trains	8	trains/day	
Cars per Unit Train	125	cars/train	
Coal per Car	100	tons/car	
Onsite Tracks	8	number of tracks	
	840	ships/yr	Latest assumption on number of cargo ships Handymax size to move the coal (also see URS resrouce report on rail and transport Dec 2014
tons of coal per ship	57,740	tons/vessel	
Hours to Unload one unit train	1.85	hours	

	Full Build-Out Pollutant Emissions (tpy)								
Source	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2e**
FUGITIVE SOURCES									
Coal Transfer (except piles):									
Material Handling	-	-	-	-	5.25	1.84	0.28	-	-
Coal Piles:									
Wind Erosion	-	-	-	-	3.05	2.59	0.40	-	-
Material Handling	-	-	-	-	2.62	0.92	0.14	-	-
					5.67	3.51	0.54		
MOBILE SOURCES									
Maint/OpS/Emergency Equipment:									
Combustion	4.36	1.43	0.37	0.20	0.38	0.31	0.31	0.01	1,000
Trains:									
Combustion (Off-site)	23.3	10.18	0.80	0.04	0.60	0.50	0.48	0.11	3,946
Fugitive (Off-site)	-	-	-	-	1.03	0.88	0.13	-	-
Combustion (On-site)	7.43	3.24	0.26	1.15E-02	1.93E-01	0.16	0.15	3.45E-02	1,257
Combustion Idle (On-site)	2.07	0.90	7.14E-02	3.20E-03	5.38E-02	4.42E-02	4.29E-02	9.62E-03	351
Combustion Switching (On-site)	4.44	0.90	0.23	3.17E-03	0.11	9.43E-02	9.15E-02	9.53E-03	344
Fugitive (On-site)	-	-	-	-	3.68	3.13	0.48	-	-
Ships: (for diesel PM this only includes tugs)									
Combustion (Off-site)	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0
Combustion (On-site)	14	39	1.46	3.08	0.56	0.46	0.46	3.30E-02	5,335
Total - All Sources, Onsite and Offsite	56	55	3	3.33	23	14	3.51	0.20	12,232
Total - Onsite Sources	32.2	45.0	2.39	3.30	21.58	13.06	2.89	0.09	8,287
Fugitives Only	-	-	-	-	14.60	8.47	1.29	-	-
Facility Equipment Combusion Only	4.36	1.43	0.37	0.20	0.38	0.31	0.31	0.01	1,000
Mobile Combustion Sources Only	21.30	41.77	1.72	3.09	0.76	0.62	0.62	0.07	6,591.74

PM From Combustion (tpy):	**TSP**	**PM_{10}**	**$PM_{2.5}$**
Total - Offsite Combustion	0.60	0.50	0.48
Total - Onsite Combustion	1.14	0.94	0.93
Total - Combustion	1.74	1.43	1.41

Washington State Emissions in tons per year
2011 Emissions Inventory for Cowlitz County

Select Sources (full summary in separate worksheet)	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2e**	**DPM**
Point Sources	3,616	2,507	671	791	-	182	172	-	-	-
Non-Road Mobile (Land-based, non-locomotive)	389	3,718	592	1	-	48	46	-	-	24
Railroad	789	137	43	6	-	23	23	-	-	23
Ships (commercial marine vessels)	1,109	150	46	199	-	37	34	-	-	34
Total All Source Categories	10,382	36,142	16,919	1,020	-	1,872	971	-	-	164

APPENDIX A4

PILE INFORMATION

Bulk Density of Coal: 817 kg/m3 min (PRB coal; source Description of Facilites, September 2011)
929 kg/m3 max

Pile Dimensions:

	average L (ft)	Sfc W (ft)	Sfc Acres	Peak H (ft)	Mean H (ft)
Pile 1	2350	233	12.57	85	25
Pile 2	2350	233	12.57	85	25
Pile 3	2350	233	12.57	85	25
Pile 4	2350	233	12.57	85	25

From Millennium Coal Export Terminal, Applicant's Purpose and Need Description, Dec 2013
Coal pads vary between 2200 to 2500 ft in length
85 approximate coal stack height

	metric tonne	ton	
Pile 1	367,000	404,548	*(Stage 1 and 2)*
Pile 2	394,000	434,311	*(Stage 1 and 2)*
Pile 3	375,000	413,367	*(Full Build-Out Only)*
Pile 4	368,000	405,651	*(Full Build-Out Only)*

1,504,000 metric tonnes, total storage capacity

	Full Build-Out	
Annual Coal Throughput:	48,501,697	tpy
Average Pile Turnovers/yr:	29	
Pile Throughput:		
Pile 1	11,835,188	tpy
Pile 2	12,705,897	tpy
Pile 3	12,093,176	tpy
Pile 4	11,867,437	tpy

APPENDIX A5

PILE - WIND EROSION

(Methodology from AP-24, Section 13.2.5 and WRAP Fugitive Dust Handbook, Section 9.3)
Industrial Wind Erosion

Wind Erosion (emissions from pile activity are covered in Materials Handling (MH) section)
(Equation based on Western Regional Air Partnership [WRAP] Fugitive Dust Handbook, Section 9.3)

$$E(lb TSP/acre/yr) = 1.7 * \frac{s}{1.5} * \frac{365*(365-p)}{235} * \frac{f}{15} * r$$

Where:

s=	6.2	Silt Content, weight %. *(Mean value from EPA AP-42, Section 13.2.4, Table 13.2.4-1, Western Surface Coal Mining)*
p=	175	Number of Days with >= 0.01 inches of precipitation per year. (NCDC Climate Summary for Longview, 1931-2006.)
f=	8.78	Percentage of Time that the unobstructed wind speed exceeds 12 mph at mean pile height. *(Calculated from Weyerhaeuser Mint Farm Met Station Data, 2001-2003 (wind speed monitor at 10 meter height; mean pile height (by exposed area) ~ 25 ft*
r=		Particulate Matter Size Ratios (WRAP Fugitive Dust Handbook, Section 9.3).
	1	TSP
	0.85	PM10
	0.13	PM2.5

Uncontrolled Emission Rates:

TSP	1214	lb/acre/yr
PM10	1032	lb/acre/yr
PM2.5	158	lb/acre/yr

Controlled Emissions:

Control %:	90	*WRAP Fugitive Dust Handbook, Table 9-4, Watering.*

Exposed Pile Area	Acres
Pile 1	12.57
Pile 2	12.57
Pile 3	12.57
Pile 4	12.57

	Full Build-Out	
Total Area	50.28	acres

Total Controlled Emissions:

Pollutant	Full Build-Out	
TSP	3.05	tpy
PM10	2.59	tpy
PM2.5	0.40	tpy

APPENDIX A6

MATERIAL HANDLING

Transfer Operations (Pile Construction, Pile Removal)

(Methodology from AP-24, Section 13.2.4)

Aggregate Handling and Storage Piles

$$E\,(lb\ /\ ton\ ) = k * 0.0032\ * \left\{ \frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right\}$$

Where:

k=		Aerodynamic Particle Size Multiplier.*(EPA AP-42 Section 13.2.4.)*
	1	TSP
	0.35	PM10
	0.053	PM2.5
U=	5.04	Mean Wind Speed, mph. *(Calculated from Weyerhaeuser Mint Farm Met Station Data, 2001-2003 (wind speed monitor at 10 meter*
M=	4.5	Material Moisture Content, percent. (Mean value from EPA AP-42, Section 13.2.4, Table 13.2.4-1, Coal-fired Power Plants (as received). This value fits range given in Description of Facilities, September 2011 (1-6% surface; 13-18% total).)

Uncontrolled Emission Rates:

TSP	1.04E-03	lb/ton
PM10	3.64E-04	lb/ton
PM2.5	5.51E-05	lb/ton

Controlled Emissions:

Control %:	90	*WRAP Fugitive Dust Handbook, Table 9-4, Watering.*	
Natural Precipitation Mitigation Factor	(365-P)/365	*EPA AP-42, Section 13.2.2*	
P=	175	Number of Days with >= 0.01 inches of precipitation per year.*(NCDC Climate Summary for Longview, 1931-2006.)*	
		Full Build-Out	
Annual Coal Throughput		48501697	tpy
Annual Coal Throughput x2 (pile construct and reclaim)		97003394	tpy

Total Controlled Emissions:

Pollutant	Full Build-Out	
TSP	2.62	tpy
PM10	0.92	tpy
PM2.5	0.14	tpy

All Other Coal Handling Operations (Transfers, Conveyors)

All enclosed operations with dry fogging. Equipment is cleaned using a wet scraping technique; assumed cleaning particulate emissions are zer

Uncontrolled Emission Rates (same methodology as above)

TSP	1.04E-03	lb/ton
PM10	3.64E-04	lb/ton
PM2.5	5.51E-05	lb/ton

Controlled Emissions:

Control %:	95	Changed from 99%. (ICF) This reduced efficiency is consistent with a similar proposed facility in	
Natural Precipitation Mitigation Factor	(365-P)/365	*EPA AP-42, Section 13.2.2*	
P=	175	Number of Days with >= 0.01 inches of precipitation per year. (NCDC Climate Summary for Longview, 1931-2006.	
		Full Build-Out	
Annual Coal Throughput		48501697	tpy

Emission/Transfer Points:

Rail Dump	1
Transfer Tower 1	1
Transfer Towers 2-4	1
Transfer Towers 5-7	1
Surge Bin (WP9)	1
Surge Bin (WP10)	1
Transfer Tower 8	1
Conveyor to Ship	1

Total Controlled Emissions:

Pollutant	Full Build-Out	
TSP	5.25	tpy
PM10	1.84	tpy
PM2.5	0.28	tpy

APPENDIX A7

COAL CAR FUGITIVE EMISSIONS

(Methodology from AP-24, Section 13.2.5 and WRAP Fugitive Dust Handbook, Section 9.3)
Industrial Wind Erosion

Wind-related losses from Train Transport of Open Coal Cars
(Equation based on WRAP Fugitive Dust Handbook, Section 9.3))

$$E(lb TSP/acre/yr) = 1.7 * \frac{s}{1.5} * \frac{365*(365-p)}{235} * \frac{f}{15} * r$$

Where:

s=	6.2	Silt Content, weight %. *(Mean value from EPA AP-42, Section 13.2.4, Table 13.2.4-1, Western Surface Coal Mining)*
p=	175	Number of Days with >= 0.01 inches of precipitation per year.*(Calculated from Weyerhaeuser Mint Farm Met Station Data, 2001-2003. (Note: AP-42 Figure 13.2.2-1 shows 180 days, and NCDC Climate data indicates ~ 177 days.))*
f (moving train)=	100	Percentage of Time that the unobstructed wind speed exceeds 12 mph at mean pile height.*(Assumed 100% of time for moving train.)*
f (sitting train)=	8.78	Percentage of Time that the unobstructed wind speed exceeds 12 mph at mean 'pile' height.*(Calculated from Weyerhaeuser Mint Farm Met Station Data, 2001-2003 (wind speed monitor at 10 meter height; train car height with coal load = ~15 ft (4.6 m).)*
r=		Particulate Matter Size Ratios (WRAP Fugitive Dust Handbook, Section 9.3).
	1	TSP
	0.85	PM10
	0.13	PM2.5

Uncontrolled Emission Rates for Moving Trains:

TSP	13824	lb/acre/yr
PM10	11750	lb/acre/yr
PM2.5	1797	lb/acre/yr

Uncontrolled Emission Rates for Sitting Trains:

TSP	1214	lb/acre/yr
PM10	1032	lb/acre/yr
PM2.5	158	lb/acre/yr

Train car exposed surface area:	518	ft2
Area/coal amount (by 1 car):	4.24	ft2/ton coal

	Full Build-Out	
Annual Coal Throughput:	48501697	tpy
Coal/car:	122.1	tons
Cars/train:	125	cars
Total Exposed Area:	4720	acres

Off-site	Full Build-Out	
Distance from main rail line to site:	7.10	miles
Time Moving Car Exposed:	0.71	hrs

Surfactant Efficiency Factor (control) 0.61 (Based on Cowlitz County monitoring study from moving coal trains prior to Pasco surfacta

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Offsite Emissions:

Pollutant	Full Build-Out	
TSP	1.03	tpy
PM10	0.88	tpy
PM2.5	0.13	tpy

On-site	Full Build-Out		
Onsite loop distance:	1.65	miles	
Dumper facility loop:	13236	ft	Drawing 80552-500-ST-DAL-2019-00-RevA.pdf, WorleyParsons
	2.51	miles	
Total onsite distance for transport:	4.16	miles	Includes only loaded travel; assumes full cars for complete staging loop
Train Speed:	2	mph	and dump loop distances.
Time Moving Car Exposed:	2.25	hrs	
Time Moving Car Exposed:	2.25	hrs	Heyl & Patterson, Martin Engineering (coal dumper and chute mnftrs), BNSI
Unloading Time:	1.85	hrs	Railway [total time]; apply a conservative estimate for time waiting to unloa
Time Sitting Car Exposed:	3.18	hrs	Assume time of exposure during unloading is only 1/2 of tota
			unloading time.

Onsite Emissions:

Pollutant	Full Build-Out	
TSP	3.68	tpy
PM10	3.13	tpy
PM2.5	0.48	tpy

APPENDIX A8a

LOCOMOTIVE EMISSIONS - Moving and Unloading

	Full Build-Out		
Coal Throughput	48501697	tons/yr	='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!(
Coal/car	122.1	tons	'='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!
Unit Trains (cars/train)	125	cars	'='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!
Unit Trains Required	2920	Trains/yr	
	4	Locomotives/Train (full)	
	4	Locomotives/Train (empty)	
			Electro-Motive Diesel, GE Transportation (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or
Engine Size:	4400	hp/locomotive	ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive,*Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009*.)

Fuel Use per Train	Full Build-Out		
ON SITE			
Loaded Train:	4.6%	Percent Load	Notch 1 setting and associatedd load @ 6 mph (202 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 200
	809.6	hp	
	39	gallons/hr	
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004
	44	hp	
	2	gallons/hr	
OFF SITE			
Loaded Train:	9.9%	Percent Load	Notch 2 setting and associatedd load @ 12 mph (435 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 200
	1742.4	hp	
	84	gallons/hr	
Empty Train:	9.9%	Percent Load	Assume same notch 2 setting as loaded (conservative)
	1742.4	hp	
	84	gallons/hr	

Longview Short Line (Longview Switching Company (LSC) Track			
Offsite			
Distance from Main Rail Line to Site:	7.10	miles	distance from GIS drawings per Danny Stratten (ICF) Feb 201
Travel Time to Site:	0.71	hrs	DKS travel speed average of 10 mph
Total Power:	7224687	hp-hr/yr	
Total Fuel Use:	347341	gallons/yr	
Onsite			
Onsite loop distance:	8727	ft	Per train average loop distance (Drawings 80552-500-GE-DLP-0020_RevA.pdf and 80552-500-ST-DAL-2019-00-RevA.pdf, WorleyParsons)
Travel Distance:	1.65	miles	(one loop onsite; does not include dump track time which is operated by electric indexing systen
Time per Train:	1.85	hours	time needed to unload the coal from 125 cars
Total Power:	2300739	hp-hr/yr	
Total Fuel Use:	110612	gallons/yr	
Total Fuel Use (On and Offsite)	457953	gallons/yr	

Emission Factors (2028 full operation)

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:
[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.
[2] SO2 emission factor using S content of 15 ppm
[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2
[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-h
[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.
[6] Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Offsite	23	10.2	0.80	0.04	0.60	0.50	0.48	0.11	3908	0.31	0.10	3946
Onsite	7	3.2	0.26	0.01	0.19	0.16	0.15	0.03	1245	0.10	0.03	1257
Total	31	13.4	1.06	0.05	0.80	0.66	0.64	0.14	5153	0.40	0.13	5202

APPENDIX A8b

LOCOMOTIVE EMISSIONS - Trains waiting to leave (on-site) 5 hours

	Full Build-Out		
Coal Throughput	48501697	tons/yr	='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!C17*1000000
Coal/car	122.1	tons	'='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!C20
Unit Trains (cars/train)	125	cars	'='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!C19
Unit Trains Required	2920	Trains/yr	
	4	Locomotives/Train (full)	
	4	Locomotives/Train (empty)	
Engine Size:	4400	hp/locomotive	*Electro-Motive Diesel, GE Transportation* (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009* .)

Fuel Use per Train	Full Build-Out		
ON SITE			
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	44	hp	
	2	gallons/hr	
Onsite			
Time per Train:	5.00	hours	time idling
Total Power:	642400	hp-hr/yr	
Total Fuel Use:	30885	gallons/yr	
Total Fuel Use (Onsite, idle)	30885	gallons/yr	

Emission Factors (2028 full operation)

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:
[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.
[2] SO2 emission factor using S content of 15 ppm
[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2.
[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr.
[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.
[6] Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Onsite	2	0.9	0.07	0.00	0.05	0.04	0.04	0.01	348	0.03	0.01	351
Total	2	0.9	0.07	0.00	0.05	0.04	0.04	0.01	348	0.03	0.01	351

APPENDIX A8c

SWITCH LOCOMOTIVE EMISSIONS

	Full Build-Out		
Days/year	365	Trains/yr	
Hours/day	8	hours	
	1	Locomotives/Train (empty)	
Engine Size:	4400	hp/locomotive	*Electro-Motive Diesel, GE Transportation* (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009* .)

Fuel Use per Train	Full Build-Out		
ON SITE			
Loaded Train:	4.6%	Percent Load	Notch 1 setting and associatedd load @ 6 mph (202 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	1619.2	hp	
	78	gallons/hr	
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	11	hp	
	1	gallons/hr	
Empty Train:	9.9%	Percent Load	Assume same notch 2 setting as loaded (conservative)
	435.6	hp	
	21	gallons/hr	

Emission Factors (2028 full operation) — g/gal

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera[1] (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314
2028 Large Switch (g/gal)	132	26.6	6.9	0.094	3.41	2.8	2.72	0.28	10217	0.80	0.26	10314

Sources:

[1] NOx, CO, VOC, SO2, PM10, PM2.5 2028 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.

[2] SO2 emission factor using S content of 15 ppm

[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2.

[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr.

[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.

[6] Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Switch - Move (50%)	0.11	2.26E-02	5.87E-03	7.99E-05	2.90E-03	2.38E-03	2.31E-03	2.41E-04	8.69	6.80E-04	2.21E-04	8.77
Switch - Idle (50%)	4.44	0.90	0.23	3.17E-03	0.11	9.43E-02	9.15E-02	9.53E-03	344.04	2.69E-02	8.76E-03	347.33
Total	4.56	0.92	0.24	3.25E-03	0.12	9.67E-02	9.38E-02	9.77E-03	353	2.76E-02	8.98E-03	356

APPENDIX A8d

LOCOMOTIVE EMISSIONS Emissions in Washington State Except Cowlitz County

Locomotive Fuel Use:		20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009*.)
	Fuel Consumption			
		31,470,397	gallons	2028 fully operational (consistent with GHG analysis
		1,386,221	gallons	
total		32,856,619	gallons	
	Factors			
		453.6	grams per lb	
		2000	lb per ton	

for total train fuel consumption within state (diesel) other than in Cowlitz county per GHG report/analysis based on 402 miles inbound and 490.2 miles outbound

additional fuel consumption within Cowlitz County main line (17.9 miles in bound to Longview Jct; 21.4 miles outbound from Longview Jct to north county line)

Emission Factors (2028 full operation)

		NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera	(g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:

[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.

[2] SO2 emission factor using S content of 15 ppm

[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2

[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr

[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.

[6] Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Offsite	2,209	963	76	3	57	47	45.7	10.25	370035	29.0	9	373,565.85

APPENDIX A8e

LOCOMOTIVE EMISSIONS (No Action Alternative)

	Full Build-Out		
Coal Moved	2,673,990	tons/yr	
Coal/car	122.1	tons	'='D:\Documents\millineum\URS Air Qualty Studies for Millineum Coal Terminal\January 2015 appx L\[4 - Air Quality Appendix L-Mod ICF.xlsx]Operations Summary (ICF)'!C
Unit Trains (cars/train)	30	cars	Same assumption as Noise Study
30-car Trains Required	730	Trains/yr	
	2	Locomotives/Train (full)	
	2	Locomotives/Train (empty)	
Engine Size:	4400	hp/locomotive	*Electro-Motive Diesel, GE Transportation* (http://www.getransportation.com/locomotives/locomotives/ac4400-and-dash-series-locomotives); GE AC4400CW (4400hp) or ElectroMotive Diesel SD70Ace (4300hp). Also consistent with DKS traffic analysis
Locomotive Fuel Use:	20.8	bhp-hr/gal	(conversion for large line-haul locomotive, *Emission Factors for Locomotives, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009* .)

Fuel Use per Train	Full Build-Out		
ON SITE			
Loaded Train:	4.6%	Percent Load	Notch 1 setting and associatedd load @ 6 mph (202 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	404.8	hp	
	19	gallons/hr	
Idle Train:	0.25%	Percent Load	Idle setting and associated load (11 hp) @idle based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	22	hp	
	1.1	gallons/hr	
OFF SITE			
Loaded Train:	9.9%	Percent Load	Notch 2 setting and associatedd load @ 12 mph (435 hp) based on data from CARB Roseville Railyard Study for 4300 HP loco engine (October, 2004)
	871.2	hp	
	42	gallons/hr	
Empty Train:	9.9%	Percent Load	Assume same notch 2 setting as loaded (conservative)
	871.2	hp	
	42	gallons/hr	

Longview Short Line (Longview Switching Company (LSC) Track)			
Offsite			
Distance from Main Rail Line to Site:	7.10	miles	distance from GIS drawings per Danny Stratten (ICF) Feb 2014
Travel Time to Site:	0.71	hrs	DKS travel speed average of 10 mph
Total Power:	903086	hp-hr/yr	
Total Fuel Use:	43418	gallons/yr	
Onsite			
Time per Train:	0.44	hours	time needed to unload the coal from 125 cars under action is 1.85 hours, assume 30/125 *1.85 = 0.444 hours to unload No Action coal train
Total Power:	68544	hp-hr/yr	
Total Fuel Use:	3295	gallons/yr	
Total Fuel Use (On and Offsite)	46713	gallons/yr	

Emission Factors (2028 full operation)

	NOx	CO	VOC	SO2	TSP	PM10	PM2.5	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
2028 National Locomotive Fleet Avera (g/gal)	61	26.6	2.1	0.094	1.58	1.3	1.26	0.28	10217	0.80	0.26	10314

Sources:
[1] NOx, CO, VOC, SO2, PM10, PM2.5 2025 emission factors from: *Emission Factors for Locomotives*, EPA, Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Table 5,6,7, Line-Haul Emission Factors. From text: $PM_{2.5}$ = 0.97* PM_{10}.
[2] SO2 emission factor using S content of 15 ppm
[3] TSP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Based on ratio of total particulate to PM10 in diesel engines, as given in Table 3.4-2.
[4] HAP emission factor from: *EPA AP-42, Section 3.4 Large Stationary Diesel and All Stationary Duel-fuel Engines* (10/96). Total HAPs from Tables 3.4-3 and 3.4-4, sum of HAPs as indicated by footnote b. For diesel fuel: 7000 Btu/hp-hr.
[5] *Direct Emissions from Mobile Combustion Sources*, EPA, Office of Air and Radiation, EPA-430-K-08-004, May 2008. N_2O and CH_4 from Table A-6.
Global Warming Potentials (GWPs): CO_2 - 1; CH_4 - 25; N_2O - 298

Emission Rates (tpy)

Full Build-Out	**NO_x**	**CO**	**VOC**	**SO_2**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**HAPS**	**CO2**	**CH4**	**N2O**	**CO2e**
Offsite	3	1.3	0.10	0.004	0.08	0.06	0.06	0.01	489	0.04	0.01	493
Onsite	0	0.1	0.01	0.000	0.01	0.00	0.00	0.00	37	0.00	0.00	37
Total	3.14	1.4	0.11	0.005	0.08	0.07	0.06	0.01	526	0.04	0.01	531

APPENDIX A9a

CARGO VESSEL EMISSIONS

Tugs/Ship	3		(Conservative estimate)
Tug Engine Size (propulsion)	4000	hp	
Tug Positioning Time	3	hrs/ship (in-out)	(Conservative estimate)
Tug Load Factor (Manuvering)	31%	Percent Load	(Engine load factor for Assist Tugs, from Port of Long Beach Air Emissions Inventory - 2011 (POLB, July 2012).)
Panamax Size Engine	16368	hp	
Handymax Size Engine	10153	hp	
Panamax auxillary engine size	3039	hp	
Handymax Auxilliary Engine Size	1885	hp	
Main Engine Load (loaded in transit)	37%	Percent Load	Main Engine Load (manuvering) 2% Percent Load*
Main Engine Load (unloaded in transit)	37%	Percent Load	
Auxillary Engine Load (transit)	17%	Percent Load	Auxillary Engine Load (manuvering) 45% Percent Load
Number of ship call in 2028	840		
Percent of calls by Panamax	80	percent	
Percent of call by Handymax	20	percent	
Ship Berth Time ((Hoteling)	13	hrs	
Main Ship (Manuvering)	1.0	hrs	
Trannsit Time within Cowlitz county	0.90	hrs	Lower bound speeds in the open reaches of the Columbia River Channel are 12 knots, somewhat slower speeds when fully loaded (assumed 10 knots). See: Marine Traffic Technical Report, Feb 2015 , pages 37 and page 49.

On-site		Full Operation (2028)		
Coal Throughput		48,501,697	tons/yr	
Ships/yr (Panamax)		672	number	
	Annual Power (aux eng)	3,574,005	hp-hrs/yr	0.1 %S Marine Distillate Fuel (2015 onward)
	Annual Power (main eng)	219,987	hp-hrs/yr	0.1 %S Marine Distillate Fuel
Ships/yr (Handymax)		168	number	
	Annual Power (aux eng)	554,302	hp-hrs/yr	0.1 %S Marine Distillate Fuel
	Annual Power (main eng)	34,115	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
Tugs/yr		2,520	number	
	Annual Power	9,374,400	hp-hrs/yr	diesel low sulfur (15 ppm S)
Off-site				
Ships/yr (Panamax)				
	Annual Power (main)	7,363,914	hp-hrs/yr	0.1 %S Marine Distillate Fuel
	(aux)	628,211		
Ships/yr (Handymax)				
	Annual Power (main)	1,141,964	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
	(aux)	97,431		

Emission Factors

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Maine Engine Manuvering (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Maine Engine Manuvering (lb/hp-hr))	0.006	0.00822	0.003	0.001	0.000500	0.000411	0.000378	0.000007	0.967	0.0001151	0.0000007	0.970
Aux Engine T4 Transit, Manuver , Hotel (g/KW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Aux Engine T4 Transit, Manuver , Hotel (lb/hp-hr))	0.0030	0.0082	0.0003	0.0007	0.0001	0.0001	0.0001	0.00001	1.13	0.00015	0.00000	1.14
Main Engine Transit Mode (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Main Engine Transit Mode (lb/hp-hr)	0.006	0.00822	0.00329	0.00066	0.00050	0.00041	0.00038	0.00001	0.967	0.000115	0.000001	0.970
Tug (Tier 4 compliant post 2016) (g/kW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Tug (Tier 4 compliant post 2016) (lb/bhp-hr)	0.003	0.00822	0.00031	0.00066	0.00012	0.00010	0.00010	0.000007	1.13	0.00015	0.00000	1.14

Source:
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Bas
Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011. Tables II-6, II-7 (main engines) and Table II-8 Auxilary Engine only for PM10, PM2.5 and CO2;
Other Emissions Factros from USEPA Marine Compression Ignition Exhaust Emission Standards for highest Tier engines (auxillary and Tugs C2; main engine C3) all standars fully impletemented by 2016 assume all engines by 2028 comply with these sta
For C3 engines assume lowest engine speed which corresponds with highest emission rate See: http://www.epa.gov/otaq/standards/nonroad/marineci.htm

HAP Emission factors from: *EPA AP-42, Section 3.4;* Sum of HAPs factors from Table 3.4-3 and 3.4-4.
Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Travel Distance:

Ship Miles	11.35	miles	Travel distance from berth site in Longview, west along Columbia River to Cowlitz County line (one-way

Emission Rates (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
2028 Operational Emissions Marine Vessels												
Ships (Cargo and Tugs) - (Onsite)	23	66	15.3	4.5	1.3	1.0	1.0	0.08	8062	1.0	0.0047	8089
Ships (cargo transit) - (Offsite)	25	38	14.1	3.0	2.2	1.8	1.6	0.03	4523	0.5	0.0030	4537
Total	48	104	29.4	7.6	3.4	2.8	2.7	0.11	12584	1.6	0.01	12627

Table II-5: OGV Auxiliary Engine Load Characteristics (percent load)
Bulk Carrier/General Cargo

Load Factor (%)	
Hoteling	10%
Maneuvering	45%
Transit	17%

ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline"
Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011.
Data http://www.arb.ca.gov/msei/categories.htm#ogv_category

Load Factors for Main Engine based on Propeller Law Equation assuming 11 knots transit in river and 4 kno

Engine	Cruise	Transit	Maneuver
Propulsion	83%	37%	2%

* Need to apply low load adjustment factor to main engine manuvering
Low load adjustment factor for low load manuvering

At full cruise engines run at 83% of capacity with maximum speed of 15.3 knots
Propeller equation $LF = (AS/MS)^3$
where **LF** = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

Auxillary Engine Load (hoteling) 10% Percent Load

Classification	DWT Range	Main Engine (kW)	Auxiliary Engine (kW)	Main Engine (hp)	Auxiliary Engine (kW)
HandyMax	40,000 - 60,000	7577	1407	10153.18	1885.38
PanaMax	60,000 - 100,000	12215	2268	16368.1	3039.12

Source: Sea-Web (http://www.sea-web.com)
The sea-web data is produced by IHS Global Limited, headquartered in Bracknell, England. The data is based on Lloyd's Register of Ships Sea-ewb provided shi characteristics c
Based on the ships currently in service (2014) that have stopped at US ports.

Low Speed Adjustment for Main Engine During Ship Manuvering
Based on the Propeller law used to estimate shps propulsion loads, based on law that the propulsion power varies by the cube of the speed. Transit speed was assumed to average 11 knots and maneuver speed 4 knots.

		NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2
	2% load	54.8	41.9	23.6			2.34			2853.6
	20% load	11.9	4.2	0.7			0.32			869.1
Adjustment	Ratio Increase	4.6	10	31.6	1	7.29	7.29	7.29	31.62	3.28

Pollutant	Exponent (x)	ntercept (b)	efficient (a)	
PM	1.5	0.2551	0.0059	Slow speed adjustment Ratio of emision rates at 20% load to manuvering Load 2%
NOx	1.5	10.4496	0.1255	emission rate (g/kW-hr) = a (fractional load)^-x + b
CO	1	0	0.8378	
HC	1.5	0	0.0667	
SO2			2.3735	only applies to fuel sulfur flow no adjustment for low loads
CO2	1	648.6	44.1	

Source: USEPA, 2000. US Environmental Protection Agency, Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data, February, 2000, EPA420-R-00-002.

APPENDIX A9b

CARGO VESSEL EMISSIONS

Tugs/Ship	3		(Conservative estimate)			
Tug Engine Size (propulsion)	4000	hp				
Tug Positioning Time	3	hrs/ship (in-out)	(Conservative estimate)			
Tug Load Factor (Manuvering)	31%	Percent Load	(Engine load factor for Assist Tugs, from Port of Long Beach Air Emissions Inventory - 2011 (POLB, July 2012).)			
Panamax Size Engine		hp				
Handymax Size Engine		hp				
Panamax auxillary engine size		hp				
Handymax Auxilliary Engine Size		hp				
Main Engine Load (loaded in transit)		Percent Load		Main Engine Load (manuvering)	2%	Percent Load*
Main Engine Load (unloaded in transit)		Percent Load				
Auxillary Engine Load (transit)	17%	Percent Load		Auxillary Engine Load (manuvering)	45%	Percent Load
Number of ship call in 2028	840					
Percent of calls by Panamax	80	percent				
Percent of call by Handymax	20	percent				
Ship Berth Time ((Hoteling)	13	hrs				
Main Ship (Manuvering)	1.0	hrs				
Trannsit Time within Cowlitz county	0.90	hrs	Lower bound speeds in the open reaches of the Columbia River Channel are 12 knots, somewhat slower speeds when fully loaded (assumed 10 knots). See: Marine Traffic Technical Report, Feb 2015 , pages 37 and page 49.			

On-site		Full Operation (2028)		
Coal Throughput		48,501,697	tons/yr	
Ships/yr (Panamax)			number	
	Annual Power (aux eng)		hp-hrs/yr	0.1 %S Marine Distillate Fuel (2015 onward)
	Annual Power (main eng)		hp-hrs/yr	0.1 %S Marine Distillate Fuel
Ships/yr (Handymax)			number	
	Annual Power (aux eng)		hp-hrs/yr	0.1 %S Marine Distillate Fuel
	Annual Power (main eng)		hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
Tugs/yr		2,520	number	
	Annual Power	9,374,400	hp-hrs/yr	diesel low sulfur (15 ppm S)
Off-site				
Ships/yr (Panamax)				
	Annual Power (main)	-	hp-hrs/yr	0.1 %S Marine Distillate Fuel
	(aux)	-		
Ships/yr (Handymax)				
	Annual Power (main)	-	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
	(aux)	-		

Emission Factors

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Maine Engine Manuvering (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Maine Engine Manuvering (lb/hp-hr))	0.006	0.008	0.003	0.001	0.000500	0.000411	0.000378	0.000007	0.967	0.0001151	0.0000007	0.970
Aux Engine T4 Transit, Manuver , Hotel (g/KW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Aux Engine T4 Transit, Manuver , Hotel (lb/hp-hr))	0.0030	0.0082	0.0003	0.0007	0.0001	0.0001	0.0001	0.00001	1.13	0.00015	0.00000	1.14
Main Engine Transit Mode (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Main Engine Transit Mode (lb/hp-hr)	0.006	0.00822	0.00329	0.00066	0.00050	0.00041	0.00038	0.00001	0.967	0.000115	0.000001	0.970
Tug (Tier 4 compliant post 2016) (g/kW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Tug (Tier 4 compliant post 2016) (lb/bhp-hr)	0.003	0.00822	0.00031	0.00066	0.00012	0.00010	0.00010	0.000007	1.13	0.00015	0.00000	1.14

Source:
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baselin
Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011. Tables II-6, II-7 (main engines) and Table II-8 Auxilary Engine only for PM10, PM2.5 and CO2;
Other Emissions Factros from USEPA Marine Compression Ignition Exhaust Emission Standards for highest Tier engines (auxillary and Tugs C2; main engine C3) all standars fully impletemented by 2016 assume all engines by 2028 comply with these standar
For C3 engines assume lowest engine speed which corresponds with highest emission rate See: http://www.epa.gov/otaq/standards/nonroad/marineci.htm

HAP Emission factors from: *EPA AP-42, Section 3.4;* Sum of HAPs factors from Table 3.4-3 and 3.4-4.
Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Travel Distance:

Ship Miles	11.35	miles	Travel distance from berth site in Longview, west along Columbia River to Cowlitz County line (one-way)

Emission Rates (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
2028 Operational Emissions Marine Vessels												
Ships (Cargo and Tugs) - (Onsite)	14	39	1.5	3.1	0.6	0.5	0.5	0.03	5317	0.7	0.0031	5335
Ships (cargo transit) - (Offsite)	0	0	0.0	0.0	0.0	0.0	0.0	0.00	0	0.0	0.0000	0
Total	14	39	1.5	3.1	0.6	0.5	0.5	0.03	5317	0.7	0.00	5335

Table II-5: OGV Auxiliary Engine Load Characteristics (percent load)
Bulk Carrier/General Cargo
Load Factor (%)
Hoteling 10%
Maneuvering 45%
Transit 17%
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline"
Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011.
Data http://www.arb.ca.gov/msei/categories.htm#ogv_category

Load Factors for Main Engine based on Propeller Law Equation assuming 11 knots transit in river and 4 knots manuvering

Engine	Cruise	Transit	Maneuver
Propulsion	83%	37%	2%

At full cruise engines run at 83% of capacity with maximum speed of 15.3 knots
Propeller equation $LF = (AS/MS)^3$
where **LF** = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

* Need to apply low load adjustment factor to main engine manuvering
Low load adjustment factor for low load manuvering

Auxillary Engine Load (hoteling) 10% Percent Load

Classification	DWT Range	Main Engine (kW)	Auxiliary Engine (kW)	Main Engine (hp)	Auxiliary Engine (kW)
HandyMax	40,000 - 60,000	7577	1407	10153.18	1885.38
PanaMax	60,000 - 100,000	12215	2268	16368.1	3039.12

Source: Sea-Web (http://www.sea-web.com)
The sea-web data is produced by IHS Global Limited, headquartered in Bracknell, England. The data is based on Lloyd's Register of Ships Sea-ewb provided shi characteristics data for shios over 100 gross tons.
Based on the ships currently in service (2014) that have stopped at US ports.

Low Speed Adjustment for Main Engine During Ship Manuvering
Based on the Propeller law used to estimate shps propulsion loads, based on law that the propulsion power varies by the cube of the speed. Transit speed was assumed to average 11 knots and maneuver speed 4 knots.

		NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2
	2% load	54.8	41.9	23.6			2.34			2853.6
	20% load	11.9	4.2	0.7			0.32			869.1
Adjustment	Ratio Increase	4.6	10	31.6	1	7.29	7.29	7.29	31.62	3.28

Pollutant	Exponent (x)	ntercept (b)	efficient (a)	
PM	1.5	0.2551	0.0059	Slow speed adjustment Ratio of emision rates at 20% load to manuvering Load 2%
NOx	1.5	10.4496	0.1255	emission rate (g/kW-hr) = a (fractional load)^-x + b
CO	1	0	0.8378	
HC	1.5	0	0.0667	
SO2			2.3735	only applies to fuel sulfur flow no adjustment for low loads
CO2	1	648.6	44.1	

Source: USEPA, 2000. US Environmental Protection Agency, Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data, February, 2000, EPA420-R-00-002.

APPENDIX A9c

CARGO VESSEL EMISSIONS (CAP emissions within State of WA except Cowlitz County)

Panamax Size Engine	16368	hp			
Handymax Size Engine	10153	hp			
Panamax auxillary engine size	3039	hp			
Handymax Auxilliary Engine Size	1885	hp			
Main Engine Load (loaded in transit)	37%	Percent Load	Main Engine Load (manuvering)	2%	Percent Load*
Main Engine Load (unloaded in transit)	37%	Percent Load			
Auxillary Engine Load (transit)	17%	Percent Load	Auxillary Engine Load (manuvering)	45%	Percent Load

Number of ship call in 2028	840		
Percent of calls by Panamax	80	percent	
Percent of call by Handymax	20	percent	
Ship Berth Time ((Hoteling)	13	hrs	
Main Ship (Manuvering)	1.0	hrs	
Trannsit Time round trip Cowlitz county line to 3 nn	4.10	hrs	Lower bound speeds in the open reaches of the Columbia River Channel are 12 knots, somewhat slower speeds when moving upriver (assumed 10 knots). See: Marine Traffic Technical Report, Feb 2015 , pages 37 and page 49.

On-site Full Operation (2028)

Ships/yr (Panamax)			672	number	
Ships/yr (Handymax)			168	number	
Off-site					
Ships/yr (Panamax)					
	Annual Power	(main)	33,406,867	hp-hrs/yr	0.1 %S Marine Distillate Fuel
		(aux)	2,849,919		
Ships/yr (Handymax)					
	Annual Power	(main)	5,180,594	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
		(aux)	442,001		

Emission Factors

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Maine Engine Manuvering (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Maine Engine Manuvering (lb/hp-hr))	0.006	0.008	0.003	0.001	0.000500	0.000411	0.000378	0.000007	0.967	0.0001151	0.0000007	0.970
Aux Engine T4 Transit, Manuver , Hotel (g/KW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Aux Engine T4 Transit, Manuver , Hotel (lb/hp-hr))	0.0030	0.0082	0.0003	0.0007	0.0001	0.0001	0.0001	0.00001	1.13	0.00015	0.00000	1.14
Main Engine Transit Mode (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Main Engine Transit Mode (lb/hp-hr)	0.006	0.00822	0.00329	0.00066	0.00050	0.00041	0.00038	0.00001	0.967	0.000115	0.000001	0.970
Tug (Tier 4 compliant post 2016) (g/kW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Tug (Tier 4 compliant post 2016) (lb/bhp-hr)	0.003	0.00822	0.00031	0.00066	0.00012	0.00010	0.00010	0.000007	1.13	0.00015	0.00000	1.14

Source:
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baselir Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011. Tables II-6, II-7 (main engines) and Table II-8 Auxilary Engine only for PM10, PM2.5 and CO2;

For C3 engines assume lowest engine speed which corresponds with highest emission rate See: http://www.epa.gov/otaq/standards/nonroad/marineci.htm

HAP Emission factors from: *EPA AP-42, Section 3.4;* Sum of HAPs factors from Table 3.4-3 and 3.4-4.
Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Travel Distance:

Ship Miles	51.49	miles	Travel distance from Cowlitz County line to 3 nautical miles beyond the mouth of the Columbia River (one-way)

Emission Rates (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
2028 Operational Emissions Marine Vessels												
Ships (cargo transit) - (Offsite)	113	172	64.0	13.8	9.8	8.1	7.5	0.15	20518	2.5	0.0138	20584
Total	113	172	64.0	13.8	9.8	8.1	7.5	0.15	20518	2.5	0.01	20584

Table II-5: OGV Auxiliary Engine Load Characteristics (percent load)
Bulk Carrier/General Cargo
Load Factor (%)
Hoteling 10%
Maneuvering 45%
Transit 17%
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011.
Data http://www.arb.ca.gov/msei/categories.htm#ogv_category

Load Factors for Main Engine based on Propeller Law Equation assuming 11 knots transit in river and 4 knots manuvering

Engine	Cruise	Transit	Maneuver
Propulsion	83%	37%	2%

At full cruise engines run at 83% of capacity with maximum speed of 15.3 knots
Propeller equation $LF = (AS/MS)^3$
where **LF** = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

* Need to apply low load adjustment factor to main engine manuvering
Low load adjustment factor for low load manuvering

Auxillary Engine Load (hoteling) 10% Percent Load

Classification	DWT Range	Main Engine (kW)	Auxiliary Engine (kW)	Main Engine (hp)	Auxiliary Engine (kW)
HandyMax	40,000 -	7577	1407	10153.18	1885.38
PanaMax	60,000 -	12215	2268	16368.1	3039.12

Source: Sea-Web (http://www.sea-web.com)
The sea-web data is produced by IHS Global Limited, headquartered in Bracknell, England. The data is based on Lloyd's Register of Ships Sea-ewb provided shi characteristics data for shios over 100 gross tons. Based on the ships currently in service (2014) that have stopped at US ports.

Low Speed Adjustment for Main Engine During Ship Manuvering
Based on the Propeller law used to estimate shps propulsion loads, based on law that the propulsion power varies by the cube of the speed. Transit speed was assumed to average 11 knots and maneuver speed 4 knots.

		NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2
	2% load	54.8	41.9	23.6			2.34			2853.6
	20% load	11.9	4.2	0.7			0.32			869.1
Adjustment	Ratio Increase	4.6	10	31.6	1	7.29	7.29	7.29	31.62	3.28

Pollutant	Exponent (x)	Intercept (b)	Coefficient (a)	
PM	1.5	0.2551	0.0059	Slow speed adjustment Ratio of emision rates at 20% load to manuvering Load 2%
NOx	1.5	10.4496	0.1255	emission rate (g/kW-hr) = a (fractional load)^-x + b
CO	1	0	0.8378	
HC	1.5	0	0.0667	
SO2			2.3735	only applies to fuel sulfur flow no adjustment for low loads
CO2	1	648.6	44.1	

Source: USEPA, 2000. US Environmental Protection Agency, Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data, February, 2000, EPA420-R-00-002.

APPENDIX A9d

CARGO VESSEL EMISSIONS

Tugs/Ship	3		(Conservative estimate)
Tug Engine Size (propulsion)	4000	hp	
Tug Positioning Time	3	hrs/ship (in-out)	(Conservative estimate)
Tug Load Factor (Manuvering)	31%	Percent Load	(Engine load factor for Assist Tugs, from Port of Long Beach Air Emissions Inventory - 2011 (POLB, July 2012).)
Panamax Size Engine	16368	hp	
Handymax Size Engine	10153	hp	
Panamax auxillary engine size	3039	hp	
Handymax Auxilliary Engine Size	1885	hp	
Main Engine Load (loaded in transit)	37%	Percent Load	Main Engine Load (manuvering) 2% Percent Load*
Main Engine Load (unloaded in transit)	37%	Percent Load	
Auxillary Engine Load (transit)	17%	Percent Load	Auxillary Engine Load (manuvering) 45% Percent Load
Number of ship call in 2028	26		
Percent of calls by Panamax	0	percent	
Percent of call by Handymax	100	percent	
Ship Berth Time ((Hoteling)	13	hrs	
Main Ship (Manuvering)	1.0	hrs	
Trannsit Time within Cowlitz county	0.90	hrs	Lower bound speeds in the open reaches of the Columbia River Channel are 12 knots, somewhat slower speeds when fully loaded (assumed 10 knots). See: Marine Traffic Technical Report, Feb 2015 , pages 37 and page 49.

On-site			Full Operation (2028)		
Coal Throughput			48,501,697	tons/yr	
Ships/yr (Panamax)			0	number	
	Annual Power	(aux eng)	-	hp-hrs/yr	0.1 %S Marine Distillate Fuel (2015 onward)
	Annual Power	(main eng)	-	hp-hrs/yr	0.1 %S Marine Distillate Fuel
Ships/yr (Handymax)			26	number	
	Annual Power	(aux eng)	85,785	hp-hrs/yr	0.1 %S Marine Distillate Fuel
	Annual Power	(main eng)	5,280	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
Tugs/yr			78	number	
	Annual Power		290,160	hp-hrs/yr	diesel low sulfur (15 ppm S)
Off-site					
Ships/yr (Panamax)					
	Annual Power	(main)	-	hp-hrs/yr	0.1 %S Marine Distillate Fuel
		(aux)	-		
Ships/yr (Handymax)					
	Annual Power	(main)	176,733	hp-hrs/yr	0.1 %S Marine Distillate Fuel (or 1000 ppm)
		(aux)	15,079		

Emission Factors

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
Marine Engine Manuvering (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Marine Engine Manuvering (lb/hp-hr))	0.006	0.00822	0.003	0.001	0.000000	0.000411	0.000378	0.000007	0.967	0.0001151	0.0000007	0.970
Aux Engine T4 Transit, Manuver , Hotel (g/KW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Aux Engine T4 Transit, Manuver , Hotel (lb/hp-hr))	0.0030	0.0082	0.0003	0.0007	0.0001	0.0001	0.0001	0.00001	1.13	0.00015	0.00000	1.14
Main Engine Transit Mode (g/KW-hr)	3.4	5.0	2.0	0.40	0.3041	0.25	0.23	0.00428	588	0.07	0.0004	590
Main Engine Transit Mode (lb/hp-hr)	0.006	0.00822	0.00329	0.00066	0.00050	0.00041	0.00038	0.00001	0.967	0.000115	0.000001	0.970
Tug (Tier 4 compliant post 2016) (g/kW-hr)	1.8	5.0	0.19	0.40	0.073	0.060	0.060	0.004	690.0	0.09	0.0004	692
Tug (Tier 4 compliant post 2016) (lb/bhp-hr)	0.003	0.00822	0.00031	0.00066	0.00012	0.00010	0.00010	0.000007	1.13	0.00015	0.00000	1.14

Source:
ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baselir
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For C3 engines assume lowest engine speed which corresponds with highest emission rate See: http://www.epa.gov/otaq/standards/nonroad/marineci.htm

HAP Emission factors from: *EPA AP-42, Section 3.4;* Sum of HAPs factors from Table 3.4-3 and 3.4-4.
Global Warming Potentials (GWPs): CO_2 - 1
CH_4 - 25
N_2O - 298

Travel Distance:

Ship Miles	11.35	miles	Travel distance from berth site in Longview, west along Columbia River to Cowlitz County line (one-way)

Emission Rates (tpy)

	NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2	CH4	N2O	CO2e
2028 Operational Emissions Marine Vessels												
Ships (Cargo and Tugs) - (Onsite)	0.6	1.8	0.3	0.1	0.02	0.03	0.03	0.00	221.61	0.03	0.00	222.4
Ships (cargo transit) - (Offsite)	0.5	0.8	0.3	0.1	0.05	0.04	0.03	0.00	93.97	0.01	0.00	94.3
Total	1.1	2.6	0.63	0.19	0.07	0.06	0.06	0.003	315.6	0.04	0.0002	316.6

Table II-5: OGV Auxiliary Engine Load Characteristics (percent load)
Bulk Carrier/General Cargo

Load Factor (%)	
Hoteling	10%
Maneuvering	45%
Transit	17%

ARB, 2011a. Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Regulations "Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" Appendix D, Emission Estimation Methodology for Ocean Going Vessels, May 2011.
Data http://www.arb.ca.gov/msei/categories.htm#ogv_category

Load Factors for Main Engine based on Propeller Law Equation assuming 11 knots transit in river and 4 knots manuvering

Engine	Cruise	Transit	Maneuver
Propulsion	83%	37%	2%

At full cruise engines run at 83% of capacity with maximum speed of 15.3 knots
Propeller equation $LF = (AS/MS)^3$
where **LF** = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

* Need to apply low load adjustment factor to main engine manuvering
Low load adjustment factor for low load manuvering

Auxillary Engine Load (hoteling) 10% Percent Load

Classification	DWT Range	Main Engine (kW)	Auxiliary Engine (kW)	Main Engine (hp)	Auxiliary Engine (kW)
HandyMax	40,000 - 60,000	7577	1407	10153.18	1885.38
PanaMax	60,000 - 100,000	12215	2268	16368.1	3039.12

Source: Sea-Web (http://www.sea-web.com)
The sea-web data is produced by IHS Global Limited, headquartered in Bracknell, England. The data is based on Lloyd's Register of Ships Sea-ewb provided shi characteristics data for shios over 100 gross tons. Based on the ships currently in service (2014) that have stopped at US ports.

Low Speed Adjustment for Main Engine During Ship Manuvering
Based on the Propeller law used to estimate shps propulsion loads, based on law that the propulsion power varies by the cube of the speed. Transit speed was assumed to average 11 knots and maneuver speed 4 knots.

		NO_x	CO	VOC	SO_2	TSP	PM_{10}	$PM_{2.5}$	HAPS	CO2
	2% load	54.8	41.9	23.6			2.34			2853.6
	20% load	11.9	4.2	0.7			0.32			869.1
Adjustment	Ratio Increase	4.6	10	31.6	1	7.29	7.29	7.29	31.62	3.28

Pollutant	Exponent (x)	Intercept (b)	Coefficient (a)	
PM	1.5	0.2551	0.0059	Slow speed adjustment Ratio of emision rates at 20% load to manuvering Load 2%
NOx	1.5	10.4496	0.1255	emission rate (g/kW-hr) = a (fractional load)^-x + b
CO	1	0	0.8378	
HC	1.5	0	0.0667	
SO2			2.3735	only applies to fuel sulfur flow no adjustment for low loads
CO2	1	648.6	44.1	

Source: USEPA, 2000. US Environmental Protection Agency, Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data, February, 2000, EPA420-R-00-002.

APPENDIX A9e

Material Haul Traffic MTBL to Weyerhauser

					Full Build-Out			
				Coal Moved	2,673,990	tons/yr		
		Number	Miles (RT)[1]	miles/year	Carrying Capacity of Haul Truck	51000	lbs/load	Based on 77,000 lb GVWR for a 26,000 lb curb weight haul truck
Haul Trucks								Large Capacity Dump Truck
	SR432 @ 35mph	104,862	2.0	209,725	Loads per year	104,862	trips per year	
						287	trips per day	
					Round trip distance	2.0	miles	Weyerhauser to Milleneum

Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH4	N2O	CO2eq	HAP
2028											
Construction Annual				**T/year**							
Combo Short Haul Truck @ 35mph	0.23	0.04	0.01	0.00	0.10	0.02	237.87	0.01	0.00	238.41	0.001
Total:	0.23	0.04	0.01	0.002	0.10	0.02	237.87	0.01	0.00	238.41	

Factors:	
453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
Global Warming Potentials (GWPs):	CO_2 - 1
	CH_4 - 25
	N_2O - 298

MOVES factors (g/mile) for surrogate idle were based on 2.5 mi/hr travel. So to get g/hr, multiply by 2.5 mi/hr. For onsite/idle, assume 0.25 hr. So factor is 2.5/.25 to get grams/trip.

mi/hr	2.5
hr	0.25
factor for 1/2 hr idle/trip	10

Mobile Source - Moves run for Cowlitz County, WY, 2028
Emission factors for Truck Exhaust

Emission factors for Truck Exhaust
Emission Factors (gm/mile)

Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH_4	N_2O	Benzene	Form	CO2eq
2018												
Short Haul Combo - diesel @ 35mph (Urban un-restricted)	9.82E-01	1.71E-01	4.41E-02	8.86E-03	4.38E-01	9.24E-02	1.03E+03	6.01E-02	2.77E-03	9.16E-04	1.41E-02	1.03E+03
Short Haul Combo - diesel @ idle (Rural unrestricted)	6.00	0.42	0.24	0.02	1.48	0.35	1927.59	0.06	0.00	0.00	0.03	1930.06

APPENDIX A10a

OPERATIONS AND MAINTENANCE EQUIPMENT

Equipment Information

Equipment Type	Estimated Engine Size (hp)	Fuel	Number of Units Full Build-Out	EPA SCC Number	EPA NONROAD model combustion emission factor (tons/yr per unit) THC-Exhaust	CO-Exhaust	NOx-Exhaust	CO2-Exhaust	SO2-Exhaust	PM-Exhaust
Loader (miscellaneous use)	300	Diesel	1	2270002060	2.81E-01	1.14E+00	3.47E+00	7.40E+02	1.42E-01	2.96E-01
Bobcat (sump cleaning)	50	Diesel	2	2270002057	7.50E-03	4.18E-02	1.29E-01	1.83E+01	3.60E-03	8.27E-03
10-Ton Truck (sump cleaning)	300	Diesel	2	2270002051	3.06E-02	9.01E-02	3.12E-01	1.09E+02	1.86E-02	3.49E-02
Crane (miscellaneous use)	50	Diesel	1	2270002045	1.27E-05	6.42E-05	2.24E-04	3.15E-02	6.15E-06	1.34E-05
Forklift (miscellaneous use)	40	Propane	1	2267002057	5.20E-05	1.84E-03	2.95E-04	1.52E-01	2.95E-06	1.60E-05
Maintenance Trucks (eg. Ford F150)	300	Gasoline	4	2265003070	1.14E-04	4.20E-03	3.12E-04	2.11E-01	4.36E-05	2.16E-05

Note:
For PM_{10}, $PM_{2.5}$, and HAPs, use same emission ratio as emission factor ratios for Large Diesel Engines (see Construction worksheet): PM_{10} and $PM_{2.5}$ ratio to TSP, and; HAPs ratio to CO.

Annual Emissions (tpy)

Full Build-Out (tpy)	NO_x	CO	VOC	SO_2	TSP	PM10	PM2.5	HAPS	CO2e
Loader (miscellaneous use)	3.47	1.14	0.28	0.14	0.30	0.24	0.24	0.01	740
Bobcat (sump cleaning)	0.26	0.08	0.01	0.01	0.02	0.01	0.01	0.00	37
10-Ton Truck (sump cleaning)	0.62	0.18	0.06	0.04	0.07	0.06	0.06	0.00	218
Crane (miscellaneous use)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Forklift (miscellaneous use)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Maintenance Trucks (eg. Ford F150)	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1
Full Build-Out Total (tpy)	4.36	1.42	0.36	0.19	0.38	0.31	0.31	0.01	996

EMERGENCY EQUIPMENT

Emergency Diesel Fire Water Pump and Emergency Generator Emission Rates (Tier 4 compliant non-road engines) Required by 2015

One 200 Hp (149 KW) Fire Water Pump and Two (2) 30 Hp (22.37 kW) Emergency Generator; Planned operation of the units will be limited to a half hour per week for readiness testing, and one eight-hour test per year, as specified by the National Fire P
Both generator and fire water pump will be fueled with ultra low sulfur diesel.

Pollutant	NO_x	CO	VOC	SO_2	TSP	PM10	PM2.5	HAPS	CO2e
Emission Factor (g/KWH)	0.4	3.5	0.19	1.25	0.02	0.02	0.0194	2.47E-03	699.1
Equipment Number	1	1	1	1	1	1	1	1	1
Hours per year	34	34	34	34	34	34	34	34	34
Rating (KW)	149.14	149.14	149.14	149.14	149.14	149.14	149.14	149.14	149.14
Emission Rate (g/yr)	2028.3	17747.7	963.4	6338.5	101.4	101.4	98.4	12.5	3.54E+06
Emission Rate (ton/yr)	0.002236	0.019563	0.001062	0.006987	0.000112	0.000112	0.000108	0.000014	3.91
Emission Factor (g/KWH)	0.335	5.5	4.335	1.25	0.03	0.03	0.0291	2.47E-03	699.1
Equipment Number	2	2	2	2	2	2	2	2	2
Hours per year	34	34	34	34	34	34	34	34	34
Rating (KW)	22.371	22.371	22.371	22.371	22.371	22.371	22.371	22.371	22.371
Emission Rate (g/yr)	509.61	8366.75	6594.52	1901.54	45.64	45.64	44.27	3.76	1.06E+06
Emission Rate (tpy)	5.62E-04	9.22E-03	7.27E-03	2.10E-03	0.0000503	0.0000503	0.0000488	0.0000041	1.17
Total (tpy)	0.00280	0.02879	0.00833	0.00908	0.00016	0.00016	0.00016	1.79481E-05	5.08

Sources: AP-42, Chapter 3.3, Table 3.3-1 for emission factors other than NOX, VOC, and PM. USEPA, Nonroad Emission Factors for Tier 4 engines for Nox, PM, CO and VOC. (Office of Transportation and Air Quality EPA-420-B-16-022, March 2016)

Grand Total Full Build-Out	4.36	1.45	0.37	0.20	0.38	0.31	0.31	0.01	1001

APPENDIX A10b

OPERATIONS AND MAINTENANCE EQUIPMENT

Equipment Information

Equipment Type	Estimated Engine Size (hp)	Fuel	Number of Units Full Build-Out	EPA SCC Number	EPA NONROAD model combustion emission factor (tons/yr per unit) THC-Exhaust	CO-Exhaust	NOx-Exhaust	CO2-Exhaust	SO2-Exhaust	PM-Exhaust
Loader (miscellaneous use)	300	Diesel	1	2270002060	2.81E-01	1.14E+00	3.47E+00	7.40E+02	1.42E-01	2.96E-01
Bobcat (sump cleaning)	50	Diesel	2	2270002057	7.50E-03	4.18E-02	1.29E-01	1.83E+01	3.60E-03	8.27E-03
10-Ton Truck (sump cleaning)	300	Diesel	2	2270002051	3.06E-02	9.01E-02	3.12E-01	1.09E+02	1.86E-02	3.49E-02
Crane (miscellaneous use)	50	Diesel	1	2270002045	1.27E-05	6.42E-05	2.24E-04	3.15E-02	6.15E-06	1.34E-05
Forklift (miscellaneous use)	40	Propane	0	2267002057	5.20E-05	1.84E-03	2.95E-04	1.52E-01	2.95E-06	1.60E-05
Maintenance Trucks (eg. Ford F150)	300	Gasoline	0	2265003070	1.14E-04	4.20E-03	3.12E-04	2.11E-01	4.36E-05	2.16E-05

Note:
For PM_{10}, $PM_{2.5}$, and HAPs, use same emission ratio as emission factor ratios for Large Diesel Engines (see Construction worksheet): PM_{10} and $PM_{2.5}$ ratio to TSP, and; HAPs ratio to CO.

Annual Emissions (tpy)

Full Build-Out (tpy)	NO_x	CO	VOC	SO_2	TSP	PM10	PM2.5	HAPS	CO2e
Loader (miscellaneous use)	3.47	1.14	0.28	0.14	0.30	0.24	0.24	0.01	740
Bobcat (sump cleaning)	0.26	0.08	0.01	0.01	0.02	0.01	0.01	0.00	37
10-Ton Truck (sump cleaning)	0.62	0.18	0.06	0.04	0.07	0.06	0.06	0.00	218
Crane (miscellaneous use)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Forklift (miscellaneous use)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Maintenance Trucks (eg. Ford F150)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Full Build-Out Total (tpy)	4.36	1.40	0.36	0.19	0.38	0.31	0.31	0.01	995

EMERGENCY EQUIPMENT

Emergency Diesel Fire Water Pump and Emergency Generator Emission Rates (Tier 4 compliant non-road engines) Required by 2015

One 200 Hp (149 KW) Fire Water Pump and Two (2) 30 Hp (22.37 kW) Emergency Generator; Planned operation of the units will be limited to a half hour per week for readiness testing, and one eight-hour test per year, as specified by the National Fire Protection Association's NFPA 25.
Both generator and fire water pump will be fueled with ultra low sulfur diesel.

Pollutant	NO_x	CO	VOC	SO_2	TSP	PM10	PM2.5	HAPS	CO2e
Emission Factor (g/KWH)	0.4	3.5	0.19	1.25	0.02	0.02	0.0194	2.47E-03	699.1
Equipment Number	1	1	1	1	1	1	1	1	1
Hours per year	34	34	34	34	34	34	34	34	34
Rating (KW)	149.14	149.14	149.14	149.14	149.14	149.14	149.14	149.14	149.14
Emission Rate (g/yr)	2028.3	17747.7	963.4	6338.5	101.4	101.4	98.4	12.5	3.54E+06
Emission Rate (ton/yr)	0.002236	0.019563	0.001062	0.006987	0.000112	0.000112	0.000108	0.000014	3.91
Emission Factor (g/KWH)	0.335	5.5	4.335	1.25	0.03	0.03	0.0291	2.47E-03	699.1
Equipment Number	2	2	2	2	2	2	2	2	2
Hours per year	34	34	34	34	34	34	34	34	34
Rating (KW)	22.371	22.371	22.371	22.371	22.371	22.371	22.371	22.371	22.371
Emission Rate (g/yr)	509.61	8366.75	6594.52	1901.54	45.64	45.64	44.27	3.76	1.06E+06
Emission Rate (tpy)	5.62E-04	9.22E-03	7.27E-03	2.10E-03	0.0000503	0.0000503	0.0000488	0.0000041	1.17
Total (tpy)	0.00280	0.02879	0.00833	0.00908	0.00016	0.00016	0.00016	1.79481E-05	5.08

Sources: AP-42, Chapter 3.3, Table 3.3-1 for emission factors other than NOX, VOC, and PM. USEPA, Nonroad Emission Factors for Tier 4 engines for Nox, PM, CO and VOC. (Office of Transportation and Air Quality EPA-420-B-16-022, March 2016)

Grand Total Full Build-Out	4.36	1.43	0.37	0.20	0.38	0.31	0.31	0.01	1000

APPENDIX A11

Washington State Emissions in tons per year
2011 Emissions Inventory

COWLITZ COUNTY EMISSIONS							
Category	**CO**	**NOx**	**PM10**	**PM2.5**	**DSPM2.5**	**SO2**	**VOC**
AIR	125	2	3	2		0	4
BOAT	887	74	5	5	0	0	298
CONS							549
CONST			523	55			
F_COMM	6	2	5	5		0	0
F_RES	5	13	0	0	0	3	1
FERT							
FIRE	68	1	7	6		1	16
FOOD	14		35	33			5
GAS_TRANS							696
GASSTN							138
LIVE							
MISC	8	1	2	2		0	2
NAT	3,361	59					11,443
NRM	3,718	389	48	46	24	1	592
OB_nonRES	117	6	24	21		0	7
OB_Res	162	8	38	33		1	22
ORM	22,852	4,281	157	130	83	13	1,649
POTW							2
PT	2,507	3,616	182	172	0	791	671
ROADS			381	93			
RR	137	789	23	23	23	6	43
RWC	2,026	31	290	290		5	346
SHIP	150	1,109	37	34	34	199	46
SOLV							390
TILL_HARV			109	22			
Total	**36,142**	**10,382**	**1,872**	**971**	**164**	**1,020**	**16,919**

Source: Compiled from data in Ecology's *Washington State 2011 County Emissions Inventory* (April 25, (http://www.ecy.wa.gov/programs/air/EmissionInventory/AirEmissionInventory.htm)

NOTES:
1) Source Category Abbreviations

Abbreviation	**Source Category Description**
AIR	Aircraft: military, commercial, general aviation
BOAT	Recreational boats
CONS	Commercial and consumer solvents
CONST	Construction
F_COMM	Commercial fuel use: natural gas, oil, LPG
F_RES	Residential fuel use: natural gas, oil, LPG
FERT	Fertilizer application
FIRE	Wildfires
FOOD	Food and Kindred Products
GAS_TRANS	Aviation gas storage and transport, petroleum gas cans, bulk plants, and truck transport
GASSTN	Gasoline stations
LIVE	Livestock wastes
MISC	Structure and motor vehicle fires, Cremation, Dental alloy production, Bench scale reagents, Fluor
NAT	Natural emissions from soil and vegetation
NRM	Nonroad mobile except locomotives
OB_nonRES	Agricultural and silvicultural burning
OB_Res	Residential outdoor burning: yard waste, trash
ORM	Onroad mobile sources
POTW	Publicly owned treatment works
PT	Point sources
ROADS	Paved and unpaved road dust
RR	Locomotives
RWC	Woodstoves, fireplaces, inserts
SHIP	Commercial marine vessels
SOLV	Dry cleaning, graphic arts, surface coating: industrial
TILL_HARV	Agricultural tilling and harvesting

2) Pollutant Abbreviations

Abbreviation	**Pollutant Name**
PM10	particulate matter less than or equal to 10 microns in diameter
PM2.5	particulate matter less than or equal to 2.5 microns in diameter
DSPM 2.5	particulate matter less than or equal to 2.5 microns in diameter from diesel combustion
SO2	sulfur dioxide
NOx	nitrogen oxides
VOC	volatile organic hydrocarbons
CO	carbon monoxide

APPENDIX A12

MBTL EIS -- GRADE CROSSING EMISSIONS INVENTORY -- SUMMARY OF EXHAUST EMISSIONS BY GRADE CROSSING (TONS/YEAR)

Pollutants (tons/year)	2018		2028		2038	
	No Action	Incremental Increase	No Action	Incremental Increase	No Action	Incremental Increase
Criteria Pollutants						
CO	3.28E-02	4.70E-02	3.60E-02	9.37E-01	1.30E-02	2.78E-01
NOx	5.19E-03	7.43E-03	3.62E-03	9.42E-02	1.29E-03	2.74E-02
PM10	6.31E-04	9.03E-04	1.02E-03	2.64E-02	5.17E-04	1.10E-02
PM2.5	2.33E-04	3.34E-04	2.44E-04	6.33E-03	1.07E-04	2.28E-03
SO2	3.19E-05	4.56E-05	5.03E-05	1.31E-03	2.40E-05	5.12E-04
VOC	1.04E-03	1.49E-03	8.72E-04	2.27E-02	3.51E-04	7.48E-03
Hazardous Pollutants						
Acetaldehyde	7.20E-05	1.03E-04	6.05E-05	1.57E-03	2.44E-05	5.19E-04
Acrolein	1.04E-05	1.49E-05	8.72E-06	2.27E-04	3.51E-06	7.48E-05
Benzene	1.34E-05	1.92E-05	1.13E-05	2.93E-04	4.53E-06	9.66E-05
1,3-Butadiene	8.31E-07	1.19E-06	6.98E-07	1.81E-05	2.81E-07	5.99E-06
Ethylbenzene	6.51E-06	9.32E-06	5.47E-06	1.42E-04	2.20E-06	4.69E-05
Formaldehyde	2.26E-04	3.23E-04	1.90E-04	4.93E-03	7.64E-05	1.63E-03
n-Hexane	5.62E-06	8.04E-06	4.72E-06	1.23E-04	1.90E-06	4.05E-05
Toluene	3.12E-05	4.46E-05	2.62E-05	6.80E-04	1.05E-05	2.24E-04
Xylene	3.95E-05	5.65E-05	3.32E-05	8.62E-04	1.33E-05	2.84E-04

Data from: MTBL EIS grade xing emission

APPENDIX A13a

Commuter traffic

Assume a mean travel time of 24.1 minutes (http://quickfacts.census.gov/qfd/states/53/53015.html)

Assumed each worker is a single occupant; Used the on-road average emission rate for 2018 MOVES - 35 mph.

Labor	Number					
Phase 1&2		Time (min) - round trip	Speed (miles/hr)	Days/year	miles/year	miles/day
Peak Employees	200	48.2	35	753.0952	4234905	5623.333

Assume a 50/50 Split between gasoline and E-85

Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH4**	**N2O**	**CO2eq**
2018										
Construction Annual				**T/year**						
Passenger Vehicle - Gas+E-85	5.13E-01	2.16E-01	4.12E-02	1.06E-02	7.38E+00	1.26E-01	1.48E+03	1.57E-02	7.11E-03	1.49E+03
Construction Max Day				**lbs/day**						
Passenger Vehicle - Gas+E-85	1.36E+00	5.75E-01	1.09E-01	2.82E-02	1.96E+01	3.35E-01	3.94E+03	4.16E-02	1.89E-02	3.94E+03

Conversion Factors:	
453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
24	hrs/day
Global Warming Potentials (GWPs):	CO_2 - 1
	CH_4 - 25
	N_2O - 298

Mobile Source - Moves run for Cowlitz County, WA, 2018
Emission factors for Commuting Vehicles Exhaust

	Emission Factors for Commuting Vehicles Emission Factors (gm/mile)											
Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH_4**	**N_2O**	**Benzene**	**Form**	**CO2eq**
2018												
Passenger Gas (at 35mph)	1.61E-01	4.77E-02	1.01E-02	2.14E-03	1.96	3.61E-02	321.38	2.71E-03	1.75E-03	1.19E-03	4.44E-04	321.97
Passenger E-85 (at35 mph)	5.88E-02	4.50E-02	7.59E-03	2.42E-03	1.20	1.80E-02	313.88	4.00E-03	1.30E-03	2.92E-04	3.59E-04	314.37

APPENDIX A13b

Commuter traffic

Assume a mean travel time of 24.1 minutes (http://quickfacts.census.gov/qfd/states/53/53015.html)

Assumed each worker is a single occupant; Used the on-road average emission rate for 2018 MOVES - 35 mph.

Labor	Number					
	75	Time (min) - round trip	Speed (miles/hr)	Days/year	miles/year	miles/day
Employees: 5 day/week	14	48.2	35	260	102344.7	
Employees: 7 day/week	61	48.2	35	294	504244.3	
Total					606589	

Assume a 50/50 Split between gasoline and E-85 (tons per year)

Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH4	N2O	CO2eq
2018										
Construction Annual				**T/year**						
Passenger Vehicle - Gas+E-85	0.073440066	0.030989402	0.005901277	0.0015225	1.056885	0.018075	212.3848	0.002244	0.00101911	212.7446

Conversion Factors:

453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
24	hrs/day
Global Warming Potentials (GWPs)	CO_2 - 1
	CH_4 - 25
	N_2O - 298

Mobile Source - Moves run for Cowlitz County, WA, 2018
Emission factors for Commuting Vehicles Exhaust

Emission Factors for Commuting Vehicles
Emission Factors (gm/mile)

Project Year	NOx	PM10	PM2.5	SO2	CO	VOC	CO2	CH_4	N_2O	Benzene	Form	CO2eq
2018												
Passenger Gas (at 35mph)	1.61E-01	4.77E-02	1.01E-02	2.14E-03	1.96	3.61E-02	321.38	2.71E-03	1.75E-03	1.19E-03	4.44E-04	321.97
Passenger E-85 (at35 mph)	5.88E-02	4.50E-02	7.59E-03	2.42E-03	1.20	1.80E-02	313.88	4.00E-03	1.30E-03	2.92E-04	3.59E-04	314.37

APPENDIX A13c

Commuter traffic

Assume a mean travel time of 24.1 minutes (http://quickfacts.census.gov/qfd/states/53/53015.html)

Assumed each worker is a single occupant; Used the on-road average emission rate for 2028 MOVES - 35 mph.

Labor	Number					
	135	Time (min) - round trip	Speed (miles/hr)	Days/year	miles/year	miles/day
Employees: 5 day/week	25	48.2	35	260	182758.3333	
Employees: 7 day/week	110	48.2	35	294	909293	
Total					1092051.333	

Assume a 50/50 Split between gasoline and E-85

Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH4**	**N2O**	**CO2eq**
2028										
Construction Annual				**T/year**						
Passenger Vehicle - Gas+E-85	0.037	0.054	0.009	0.002	1.073	0.012	274.24	0.0022	0.0016	274.77

Conversion Factors:	
453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
24	hrs/day
Global Warming Potentials (GWPs)	CO_2 - 1
	CH_4 - 25
	N_2O - 298

Mobile Source - Moves run for Cowlitz County, WA, 2028

Emission factors for Commuting Vehicles Exhaust

Emission Factors for Commuting Vehicles												
Emission Factors (gm/mile)												
Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH_4**	**N_2O**	**Benzene**	**Form**	**CO2eq**
2028												
Passenger Gas (at 35mph)	3.35E-02	4.54E-02	7.98E-03	1.52E-03	1.01	9.15E-03	228.62	1.35E-03	1.33E-03	3.08E-04	1.09E-04	229.05
Passenger E-85 (at35 mph)	2.74E-02	4.44E-02	7.09E-03	1.75E-03	0.77	1.12E-02	227.01	2.29E-03	1.33E-03	1.93E-04	2.14E-04	227.46

APPENDIX A13d

Commuter traffic

Assume a mean travel time of 24.1 minutes (http://quickfacts.census.gov/qfd/states/53/53015.html)

Assumed each worker is a single occupant; Used the on-road average emission rate for 2038 MOVES - 35 mph.

Labor	Number					
	135	Time (min) - round trip	Speed (miles/hr)	Days/year	miles/year	miles/day
Employees: 5 day/week	25	48.2	35	260	182758.3	
Employees: 7 day/week	110	48.2	35	294	909293	
Total					1092051	

Assume a 50/50 Split between gasoline and E-85

Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH4**	**N2O**	**CO2eq**
2038										
Construction Annual				**T/year**						
Passenger Vehicle - Gas+E-85	0.0171	0.0406	0.0078	0.0011	0.4673	0.0048	157.8767	0.0006	0.0010	158.2

Conversion Factors:	
453.59	g/lb
2000	lbs/ton
5280	ft/mile
3.78541	l/gal
24	hrs/day
Global Warming Potentials (GWPs):	CO_2 - 1
	CH_4 - 25
	N_2O - 298

Mobile Source - Moves run for Cowlitz County, WY, 2038
Emission factors for Commuting Vehicles Exhaust

Emission Factors for Commuting Vehicles
Emission Factors (gm/mile)

Project Year	**NOx**	**PM10**	**PM2.5**	**SO2**	**CO**	**VOC**	**CO2**	**CH_4**	**N_2O**	**Benzene**	**Form**	**CO2eq**
2038												
Passenger Gas (at 35mph)	2.84E-02	6.75E-02	1.09E-02	1.75E-03	0.78	8.05E-03	262.30	1.06E-03	1.65E-03	2.44E-04	8.62E-05	262.82
Passenger E-85 (at 35 mph)	0.00E+00	0.00E+00	2.00E-03	0.00E+00	0.00	0.00E+00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00

APPENDIX A13e

Construction Emissions (tpy) [Maximum per Year]									
Source	**NOx**	**CO**	**VOC**	**SO2**	**TSP**	**PM10**	**PM2.5**	**HAPS**	**DPM**
COMBUSTION SOURCES									
Equipment (Onsite)	24.6	9.04	2.23	0.95	2.34	1.93	1.93	0.05	2.34
Haul Trucks (Onsite & Offsite)	13.43	2.92	0.585	0.040	0.77	0.63	0.44	0.015	0.77
Passenger Vehicles (Offsite)	0.53	7.46	0.129	0.0107	0.218	0.218	0.042		
Barges (Offsite)	59.04	15.68	1.511	0.028	1.29	1.06	1.06	0.08	1.29
Total Combustion Sources	97.59	35.1	4.46	1.03	4.62	3.84	3.47	0.14	4.40
Total (on-site and off-site)	38.5	19.4	2.9	1.0	3.3	2.8	2.4	0.1	3.1
FUGITIVE SOURCES									
Controlled Fugitive Earthwork	-	-	-	-	12.0	5.87	1.22	-	
Total Fugitive Sources	-	-	-	-	12.0	5.87	1.22	-	
Total - All Construction Sources	97.6	35.1	4.46	1.03	16.6	9.70	4.69	0.14	4.40

Construction Emissions (lb/day) [Maximum daily]									
Source	**NOx**	**CO**	**VOC**	**SO2**	**TSP**	**PM10**	**PM2.5**	**HAPS**	**DPM**
COMBUSTION SOURCES									
Equipment (Onsite)	229.6	82.9	20.4	8.67	21.5	17.66	17.66	0.42	21.5
Haul Trucks (Onsite & Offsite)	165.22	38.41	7.93	0.48	12.45	10.24	6.29	0.19	12.45
Passenger Vehicles (Offsite)	1.431	20.033	0.349	0.029		0.583	0.113		
Barges (Offsite)	454.7	120.8	11.6	0.21	9.90	8.14	8.14	0.61	9.9
Total Combustion Sources	850.9	262.1	40.3	9.40	43.8	36.6	32.2	1.22	43.8
Total minus barges	396.22	141.33	28.66	9.18	33.94	28.48	24.07	0.61	33.94
	54.7	14.4	3.1	0.2	6.1	5	2.6	0.1	
	284.26	97.29	23.49	8.87	27.59	22.66	20.26	0.52	21.49
FUGITIVE SOURCES									
Controlled Fugitive Earthwork	-	-	-	-	66.7	32.6	6.8	-	
Total Fugitive Sources	-	-	-	-	66.7	32.6	6.80	-	
Total - All Construction Sources	850.9	262.1	40.3	9.40	110.5	69.2	39.0	1.22	43.8

Facility Only (Material Handling, Maintenance and On-site Equipment) Pollutant Emissions (tpy)									
Source	**NOx**	**CO**	**VOC**	**SO2**	**TSP**	**PM10**	**PM2.5**	**HAPs**	**DPM**
FUGITIVE SOURCES									
Coal Transfer (except piles):									
Material Handling	-	-	-	-	5.25	1.84	0.28	-	-
Coal Piles:									
Wind Erosion	-	-	-	-	3.05	2.59	0.40	-	-
Material Handling	-	-	-	-	2.62	0.92	0.14	-	-
MOBILE SOURCES									
Maintenance/Operations Equipment:									
Combustion	4.36	1.45	0.37	0.20	0.38	0.31	0.31	7.17E-03	0.38
Total - onsite	4.36	1.45	0.37	0.20	11.30	5.66	1.13	7.15E-03	0.38

On-Site Ship and Train Pollutant Emissions (tpy)									
Source	**NOx**	**CO**	**VOC**	**SO2**	**TSP**	**PM10**	**PM2.5**	**HAPs**	**DPM**
Trains:									
Combustion (On-site)	13.95	5.04	0.56	1.78E-02	0.36	0.30	0.29	5.36E-02	0.27
Fugitive (On-site)	-	-	-	-	3.68	3.13	0.48	-	-
Ships:									
Combustion (On-site)	23.3	65.9	15.3	4.52	1.27	1.05	1.02	7.58E-02	0.56
Total - transport	37.2	71.0	15.9	4.54	5.31	4.47	1.78	3.75E-02	0.84

	Total Pollutant Emissions (tpy)								
Source	**NOx**	**CO**	**VOC**	**SO2**	**TSP**	**PM10**	**PM2.5**	**HAPS**	**DPM**
FUGITIVE SOURCES									
Coal Transfer (except piles):									
Material Handling	-	-	-	-	5.25	1.84	0.28	-	-
Coal Piles:									
Wind Erosion	-	-	-	-	3.05	2.59	0.40	-	-
Material Handling	-	-	-	-	2.62	0.92	0.14	-	-
MOBILE SOURCES									
Maintenance/Operations Equipment:									
Combustion	4.36	1.45	0.37	0.20	0.38	0.31	0.31	7.17E-03	0.38
Trains:									
Combustion (Off-site)	23.3	10.2	0.80	3.60E-02	0.60	0.50	0.48	0.11	0.60
Fugitive (Off-site)	-	-	-	-	1.03	0.88	0.13	-	-
Combustion (On-site)	14.0	5.04	0.56	1.78E-02	0.36	0.30	0.29	5.36E-02	0.27
Fugitive (On-site)	-	-	-	-	3.68	3.13	0.48	-	-
Ships:									
Combustion (Off-site)	24.8	37.9	14.1	3.04	2.17	1.78	1.64	3.25E-02	0.00
Combustion (On-site)	23.3	65.9	15.3	4.52	1.27	1.05	1.02	0.08	0.56
Total - All Sources, Onsite and Offsite	89.8	120.5	31.1	7.81	20.4	13.3	5.17	0.28	1.82

MILLENNIUM BULK TERMINALS–LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA COAL TECHNICAL REPORT

COAL DUST EMISSIONS, COAL SPILLS ANALYSIS, AND SULFUR DIOXIDE AND MERCURY EMISSIONS ANALYSIS

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Contents

List of Tables iv
List of Figures v
List of Acronyms and Abbreviations vi

PROJECT DESCRIPTION

Project Description 1
Project Description 1
Proposed Action 1
No-Action Alternative 4

COAL DUST EMISSIONS

Chapter 1 Introduction 5
1.1 Regulatory Setting 5
1.1.1 BNSF Coal Dust Requirements 6
1.2 Study Area 7
Chapter 2 Existing Conditions 8
2.1 Methods 8
2.1.1 Data Sources 8
2.1.2 Impact Analysis 9
2.2 Existing Conditions 15
2.2.1 Applicant's Leased Area 15
2.2.2 Cowlitz County 16
2.2.3 Washington State 16
2.2.4 Coal Dust Monitoring 17
Chapter 3 Impacts 23
3.1 Proposed Action 23
3.1.1 Construction: Direct and Indirect Impacts 23
3.1.2 Operations: Direct Impacts 23
3.1.3 Operations: Indirect Impacts 26
3.2 No-Action Alternative 32
Chapter 4 References 33
4.1 Written References 33
4.2 Personal Communications 34

COAL SPILLS ANALYSIS

Chapter 1 Introduction 37
1.1 Regulatory Setting 37
1.2 Study Area 37
Chapter 2 Existing Conditions 38
2.1 Cowlitz County 38
2.1.1 Aquatic Environments 38
2.1.2 Terrestrial Environments 39
2.1.3 Built Environment 40
2.2 Washington State 40
2.2.1 Aquatic Environment 40
2.2.2 Terrestrial Environment 40
2.2.3 Built Environment 41
Chapter 3 Impacts 42
3.1 Aquatic Environments 43
3.1.1 Physical Effects 43
3.1.2 Chemical Effects (Toxicity) 44
3.2 Terrestrial Environments 45
3.3 Built Environment 46
Chapter 4 References 48

SULFUR DIOXIDE AND MERCURY EMISSIONS ANALYSIS

Chapter 1 Introduction 51
1.1 Assessment Approach 51
1.2 Overview of Methods for Mercury and SO2 Assessment 52
1.2.1 Literature Review 52
1.2.2 Emission Inventory, GCTM, and Concentration Estimate 52
1.2.3 Application to the Five Coal Market Assessment Scenarios 53
1.2.4 Uncertainty 53
Chapter 2 Mercury Assessment 54
2.1 Introduction 54
2.2 Studies and Findings 57
2.3 Application of the GCTM to the Coal Market Assessment Scenarios 62
2.3.1 Results from Scenario Comparison 62
2.3.2 Uncertainty 63

Chapter 3 Sulfur Dioxide Assessment 66
3.1 Introduction 66
3.2 Studies and Findings 66
3.3 Application of the GCTM Model to the IPM Scenarios 68
3.4 Uncertainty 69
Chapter 4 References 71

Appendix A Particulate Matter Measurements in Support of Assessing Coal Emissions from Haul Trains Measurements Report

Tables

Table 1. Regulations, Statutes, and Guidelines Applicable to Coal Dust 5
Table 2. Coal Dust Total Suspended Solids Emissions Rates at Maximum Throughput 9
Table 3. Particle Size Distribution for Coal Dust Deposition Analysis 10
Table 4. Coal Trains for Coal Deposition, Concentration, and Particle Size Analysis 19
Table 5. Estimated Maximum Annual and Monthly Coal Dust Deposition 23
Table 6. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line—Reynolds Lead and BNSF Spur 26
Table 7. Estimated Maximum and Average Monthly Coal Dust Deposition—Reynolds Lead and BNSF Spur 27
Table 8. Estimated Maximum PM10 and PM2.5 Concentrations 50 and 100 Feet from Rail Line—BNSF Main Line, Cowlitz County 27
Table 9. Estimated Maximum and Average Monthly Coal Dust Total Suspended Particulate Deposition—BNSF Main Line, Cowlitz County 28
Table 10. Maximum Concentrations of Trace Elements Compared with Acceptable Source Impact Levels—BNSF Main Line, Cowlitz County 28
Table 11. Estimated Maximum PM10 and PM2.5 Concentrations 50 and 100 Feet from Rail Line—BNSF Main Line, Columbia Gorge 30
Table 12. Estimated Maximum and Average Monthly Coal Dust Total Suspended Particulate Deposition—BNSF Main Line, Columbia River Gorge 30
Table 13. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line for Loaded Coal Train —BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge) 31
Table 14. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line for Unloaded Coal Train —BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge) 31
Table 15. Estimated Maximum and Average Monthly Coal Dust Deposition from Loaded Coal Rail Cars — BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge) 32
Table 16. Estimated Maximum and Average Monthly Coal Dust Deposition from Unloaded Coal Rail Cars—BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge) 32
Table 17. Annual and Episodic Net Mercury (Hg) Concentration in Washington State as Elemental (Hg^0), Oxidized Mercury (Hg^{II}), and Total Mercury (pg/m^3) by Scenario 65
Table 18. Annual Hg^{II} Net Deposition Amounts in Washington State (mg/km2/yr) by Scenario 65
Table 19. Annual Sulfate Concentration in Washington State from Coal Exported to Asia from the Proposed Action-related Coal (ng/m^3) Scenario 69

Figures

Figure 1. Project Vicinity 2
Figure 2. Proposed Action 3
Figure 3. Coal Dust Monitoring Site Location 13
Figure 4. Coal Dust Emissions Adjustment Curve Based on Observed to Modeled Coal Dust Concentrations 20
Figure 5. Train 20: Whatcom County Field Study, Bow, WA, September 9, 2015 21
Figure 6. Estimated Maximum Monthly Coal Deposition (g/m^2/month) Near the Project Area 24
Figure 7. Estimated Maximum Annual Coal Deposition (g/m^2/year) Near the Millennium Bulk Terminal 25
Figure 8. Anthropogenic Mercury Emissions Source Contribution 55
Figure 9. Global Mercury Cycle (metric tons/year) 56
Figure 10. HYSPLIT Back-Trajectory for the Mount Bachelor Observatory Episode (April 25, 2004) 58
Figure 11. Distribution of Annual Asian Mercury Emissions (milligrams per year) from (a) Anthropogenic, (b) Natural, (c) Land Re-emission + Ocean Emission, and (d) Biomass Burning Used in the GEOS-Chem Model 60
Figure 12. Maps of March–May 2004 Concentrations and Relative Percentage of Asian Hg^0 61
Figure 13. Maps of March–May 2004 Concentrations and Relative Percentage of Asian HgII 61
Figure 14. Maps of March–May 2004 Concentrations and Relative Percentage of Asian Total Hg Deposition 62
Figure 15. Asian Anthropogenic Enhancements of Sulfate Concentrations in Surface Air during Spring 2001 as Simulated by the GEOS-Chem Model 67
Figure 16. Time Series of Sulfate Concentration in Surface Air at White Pass, Washington. 68

Acronyms and Abbreviations

$\mu g/m^2$	micrograms per square meter
$\mu g/m^3$	microns per cubic meter
AERMOD	AMS/EPA Regulatory Model
Applicant	Millennium Bulk Terminals—Longview, LLC
ASIL	acceptable source impact level
BNSF	BNSF Railway Company
CO	carbon monoxide
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
g	gram
g/m^2	grams per square meter
GCTM	global chemical transport modeling
Hg	mercury
Hg^0	mercury in elemental form
Hg^{II}	gas-phased oxidized mercury
IPM	Integrated Planning Model
km	kilometer
LVSW	Longview Switching Company
mg/km^2-year	milligrams per square kilometer per year
mph	miles per hour
MT/year	metric tons per year
NAAQS	National Ambient Air Quality Standards
ng/m^3	nanograms per cubic meter
NO_2	nitrogen oxides
O_3	ozone
O-M	observed-to-modeled comparison
OH	hydroxyl radical
PAHs	polycyclic aromatic hydrocarbons
pg/m^3	picograms per cubic meter
PHS	Priority Habitats and Species
PM10	particles with a mean diameter of less than 10 microns
PM2.5	particles with a mean diameter of less than 2.5 microns
RCW	Revised Code of Washington
Reynolds facility	Reynolds Metal Company facility
SO_2	sulfur dioxide
SWCAA	Southwest Clean Air Agency
TSP	total suspended particulates
UP	Union Pacific Railroad
WAC	Washington Administrative Code

Project Description

This technical report assesses the potential coal impacts (coal dust, coal spills, and sulfur dioxide and mercury emissions) of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative.

Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP, and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

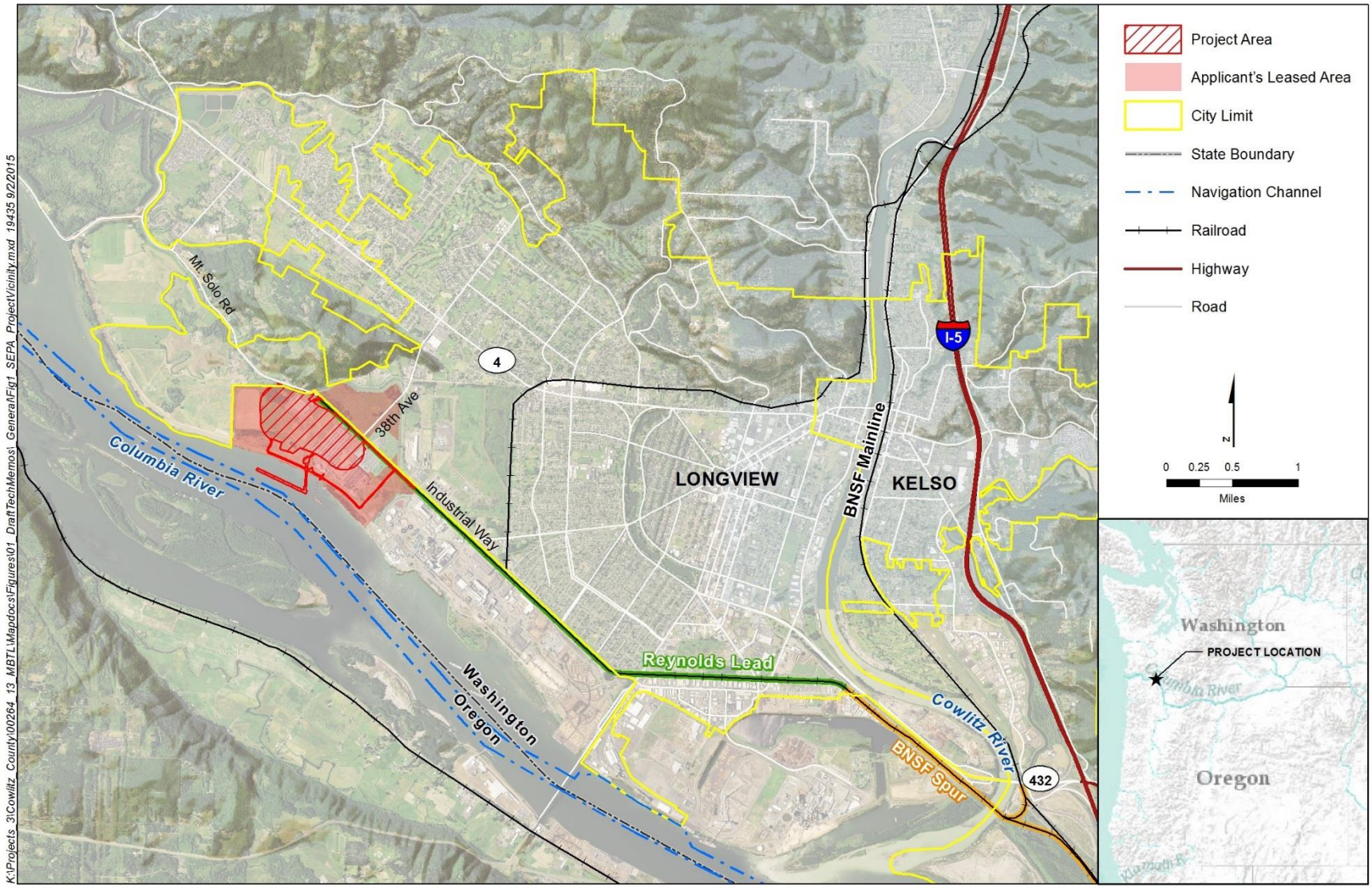
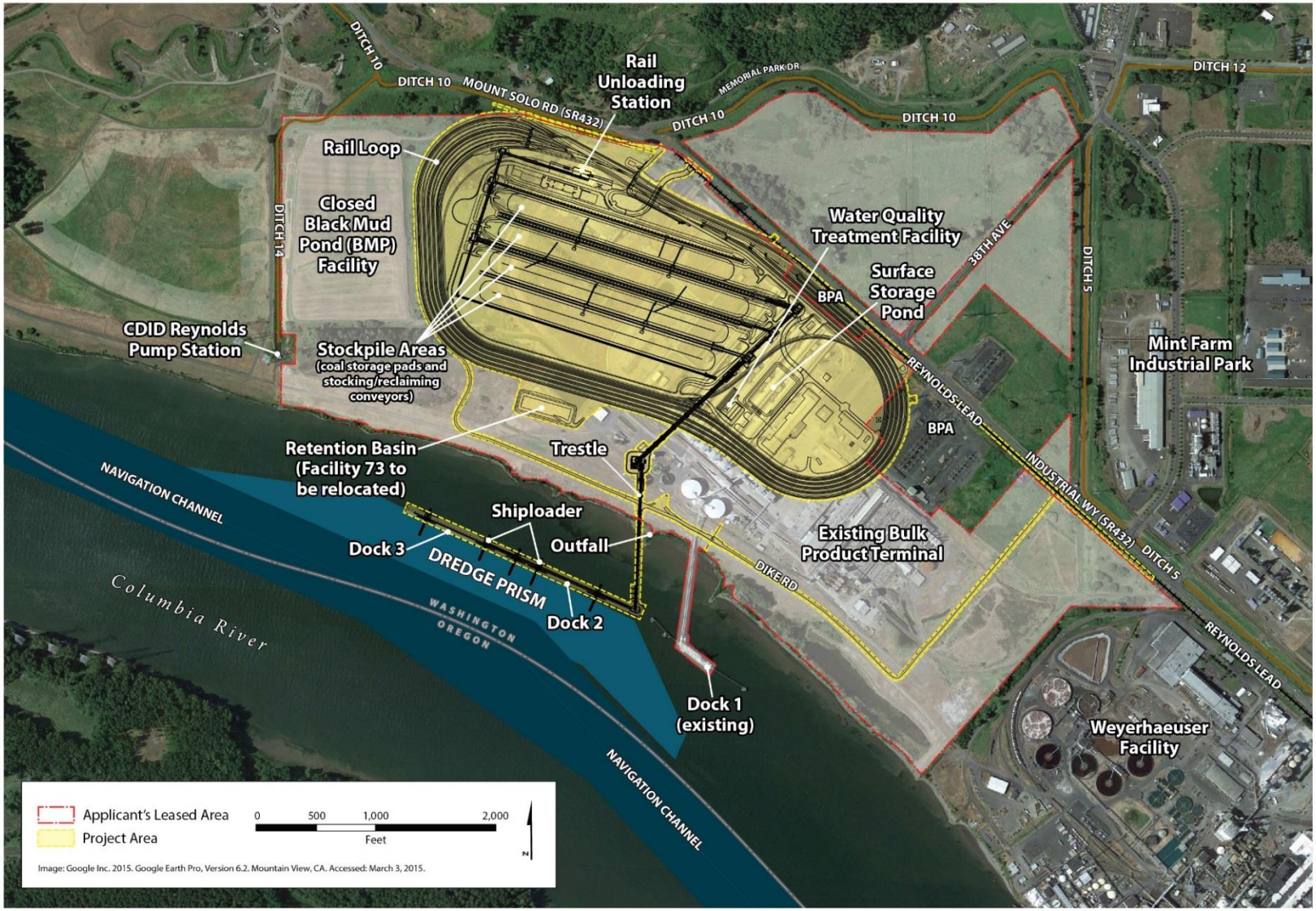


Figure 2. Proposed Action



No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

Coal Dust Emissions

Chapter 1
Introduction

This chapter assesses potential coal dust exposure resulting from the proposed Millennium Bulk Terminals—Longview project Proposed Action and No-Action Alternative. This chapter describes the regulatory setting, establishes the method for assessing potential coal dust impacts, presents the historical and current conditions in the study area, and assesses potential impacts.

1.1 Regulatory Setting

Regulations, statutes, and guidelines that apply to consideration of potential coal dust in the environment are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidelines Applicable to Coal Dust

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 et seq.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Clean Air Act and Amendments	As amended in 1970, 1977, and 1990, requires EPA to develop and enforce regulations to protect the public from air pollutants and their health impacts.
National Ambient Air Quality Standards	Specifies the maximum acceptable ambient concentrations for seven criteria air pollutants: CO, O_3, NO_2, SO_2, lead, PM10 and PM2.5, and. Primary NAAQS set limits to protect public health, and secondary NAAQS set limits to protect public welfare. Geographic areas where concentrations of a given criteria pollutant exceed a NAAQS are classified as nonattainment areas for that pollutant.
State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Washington State General Regulations For Air Pollution Sources (WAC 173-400) and Washington State Clean Air Act (RCW 70.94)	Establishes the rules and procedures to control or prevent the emissions of air pollutants. Provide the regulatory authority to control emissions from stationary sources, reporting requirements, emissions standards, permitting programs, and the control of air toxic emissions.
Local	
Southwest Clean Air Agency (SWCAA 400)	Regulates stationary sources of air pollution in Clark, Cowlitz, Lewis, Skamania, and Wahkiakum Counties.
Cowlitz County SEPA Regulations (Cowlitz County Code 19.11)	Provide for the implementation of SEPA in Cowlitz County.

Regulation, Statute, Guideline	Description

Notes:
EPA = U.S. Environmental Protection Agency; CO = carbon monoxide; O_3 = ozone; NO_2 = nitrogen oxides; SO_2 = sulfur dioxide; PM2.5 = particulate matter up to 2.5 micrometers in size; PM10 = particulate matter up to 10 micrometers in size; NAAQS = National Ambient Air Quality Standards; WAC = Washington Administrative Code; RCW = Revised Code of Washington; SWCAA = Southwest Clean Air Agency

In occupational settings (such as coal mines), exposure to airborne coal dust is regulated by agencies such as the Occupational Safety and Health Administration and the Mine Safety and Health Administration. In nonoccupational settings (such as outdoor exposures) exposure to coal dust in combination with all other types of particulate matter and dust in the ambient air is regulated by the U.S. Environmental Protection Agency (EPA). The federal regulation that applies to particulate matter is a part of the National Ambient Air Quality Standards (NAAQS). These standards apply to particle sizes with diameter of less than or equal to 10 micrometers (PM10) and particles with a mean diameter of less than or equal to 2.5 micrometers (PM2.5) (40 Code of Federal Regulations 50). The NAAQS were established under the authority of the Clean Air Act to protect human health, including sensitive populations such as children and the elderly, with a margin of safety.

No federal or state guidelines or standards identify acceptable levels of ambient dust deposition. Washington Administrative Code (WAC) 173-400-040(3) relates to fallout but does not provide a reference level: "No person shall cause or allow the emission of particulate matter from any source to be deposited beyond the property under direct control of the owner or operator of the source in sufficient quantity to interfere unreasonably with the use and enjoyment of the property upon which the material is deposited." The New Zealand Ministry of Environment *Good Practice Guide for Assessing and Managing the Environmental Effects of Dust Emissions* (New Zealand Ministry of Environment 2001) cites acceptable levels of dust deposition and identifies two benchmarks for dust nuisance impacts[1] above current background levels.

- 4.0 grams per square meter per month (g/m^2/month) for industrial or sparsely populated locations. This equates to an approximate visible layer of dust on outdoor furniture or windowsills.
- 2.0 g/m^2/month for sensitive residential locations. This is the benchmark for the analysis.

A highly visible dust, such as black coal dust, will cause visible soiling at lower levels than other types of dust. British Columbia, Canada, has a less stringent maximum desirable level for average dustfall in a residential area of 5.1 g/m^2/month and for nonresidential areas of 8.7 g/m^2/month (British Columbia Ministry of Environment 2014).

1.1.1 BNSF Coal Dust Requirements

Per the BNSF Coal Loading Rule,[2] BNSF has imposed a tariff (a schedule of shipping rates and requirements) that requires coal shippers in Wyoming and Montana to control coal dust emissions from rail cars. One method allowed by the tariff is to use one of topper agents (surfactants) that, along with shaping the load profile, have been shown to reduce average coal dust emissions by at least 85%. This is most commonly done by loading coal cars with a modified loading chute that

[1] *Nuisance level* refers to the level of dust deposition that affects the aesthetics, look, or cleanliness of surfaces but not the health of humans and the environment.

[2] For more information, see http://www.bnsf.com/customers/what-can-i-ship/coal/coal-dust.html

produces a rounded profile of the top of the coal load. This shaped profile limits the loss of coal dust from wind while the train is moving.

In addition to the shaped profile, topper agents (i.e., surfactants) are applied to the surface of the coal mound to limit coal dust loss. The topper agent must be applied before leaving the coal mine area. In addition, in 2014, BNSF constructed and began operating a surfactant spray facility along its main line in Pasco, Washington, where coal trains traveling west along the main line route through the Columbia River Gorge are sprayed with a topper agent to lessen potential coal dust release from rail cars. The Safe Harbor provision in BNSF's Coal Loading Rule identifies five acceptable topper agents and application rates that BNSF states have been shown to reduce coal dust losses by at least 85% when used in conjunction with coal load profiling. A shipper can use any of the five approved topping agents.[3]

1.2 Study Area

The study area for direct impacts is the area in and near the project area that could be affected by construction and operation activities in the project area.

The study area for indirect impacts differs for each co-lead agency.

- **Cowlitz County and Washington State Department of Ecology (Ecology).** The areas within 1,000 feet of the Reynolds Lead and BNSF Spur.
- **Ecology only.** The areas within 1,000 feet of the rail routes for Proposed Action-related trains on BNSF main line routes in Washington State.

[3] For more information, see http://www.bnsf.com/customers/what-can-i-ship/coal/include/dust-toppers.xls

Chapter 2
Existing Conditions

This chapter describes the methods for assessing the existing conditions and determining impacts, and the existing conditions in the study area as they pertain to coal dust emissions.

2.1 Methods

This section describes the methods used to characterize existing conditions and assess the potential impacts of the Proposed Action and No-Action Alternative on coal dust emissions.

2.1.1 Data Sources

The following sources of information were used to identify the potential impacts of the Proposed Action and No-Action Alternative on coal dust in the study area.

- *Millennium Coal Export Terminal, Longview, Washington, Air Quality Environmental Report.* (URS Corporation 2015).
- *Final Report Environmental Evaluation of Fugitive Coal Dust Emissions from Coal Trains Goonyella, Blackwater and Moura Coal Rail Systems Queensland Rail Limited* (Connell Hatch 2008).
- *Duralie Extension Project, Air Quality Assessment* (Heggies 2009).
- *Analysis of Carry-Back at the RG Tanna Coal Terminal (Draft), Exploration & Mining* (Commonwealth Scientific and Industrial Research Organisation 2007).
- *Diesel particulate matter and coal dust from trains in the Columbia River Gorge, Washington State* (Jaffe et al. 2015).
- *Inorganic composition of fine particles in mixed mineral dust– pollution plumes observed from airborne measurements during ACE-Asia* (Maxwell-Meier et al. 2004).
- Information from the Applicant about anticipated coal handling and transfer activities in the project area.
- Information from the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017) on the rail routes of Proposed Action-related trains through Washington State.
- *Coal Train PMCA Study, Appendix A, Gateway Pacific Terminal at Cherry Point: Train Emission and Coal Dust Assessment in Washington* (NewFields 2016).

Operations of the Proposed Action would result in coal dust emissions from the handling and transfer of coal related to rail unloading, ship loading, conveyor transfer and coal-pile storage. Coal transfers would occur in enclosed areas (e.g., rotary coal car dump facility and approximately one-third of conveyors) and unenclosed areas (e.g., coal storage piles).

Over the last 10 years, air quality monitoring studies have collected information on the deposition and ambient concentration levels of coal dust associated with coal train operations. These studies have been conducted in various locations, including Australia, Canada, and the United States (with

two recent studies in Washington State). However, the available documentation from these studies often does not provide information on all factors that affect coal dust emissions from trains. Also, there are many differences between the Australian coal trains, which have been studied the most extensively, and U.S. coal trains. Some of these limitations of the Australian studies are as follows.

- Size of the coal rail car (Australia cars have about a 30% smaller surface area).
- Distance over which the coal is transported (coal through Washington is coming from greater distances).
- Shaping of the coal (often not described in Australian studies).
- Application and type of topping agent (surfactant) to minimize coal dust emissions (often not described in Australian studies).
- Lower humidity than in western Washington.

2.1.2 Impact Analysis

The following sections describe the impact analysis methods for the coal export terminal and for Proposed Action-related coal trains. For operations of the proposed coal export terminal, air quality modeling was performed for the sources of coal dust (transfer handling of the coal from rail to storage piles, fugitive emissions from coal storage piles, transfer and handling of coal from piles to ship).

2.1.2.1 Coal Export Terminal

Coal dust emissions sources were assessed for their potential air quality impacts using the AMS/EPA Regulatory Model (AERMOD) Version 15181.

The potential for coal dust emissions from the coal export terminal and impacts on the area surrounding the coal export terminal were estimated using AERMOD Version 15181. AERMOD was used because impacts would be localized, and the model is designed to estimate emissions for multiple point, area, and volume sources in simple and complex terrain, and uses hourly local meteorological data. In addition, AERMOD estimates the deposition of particulates (such as coal dust) using information on the particulates' emissions rate and particle sizes.

The modeling estimated the near-field coal dust deposition impacts from coal dust emissions at planned full operational capacity of the coal export terminal. Table 2 summarizes the sources of coal dust emissions and their estimated annual average emissions rates that were used in the analysis.

Table 2. Coal Dust Total Suspended Solids Emissions Rates at Maximum Throughput

Operation	Annual Average TSP Emissions Rate (tons per year)
Coal pile wind erosion	3.05
Coal pile development and removal	2.62
Vessel transfer and conveyors	5.25
Train unloading	3.68
Total	**14.60**

Notes:
TSP = total suspended particulates

Coal dust emissions were characterized as two source types: volume and area. Coal transfer operations were characterized as volume sources, which included eight transfer towers, a rotary rail dump, surge bins work points, and two conveyors to load coal onto the ships with emissions rates estimated based on EPA AP-42, Section 13.2.4. Area sources are used to model low-level ground releases. The four coal piles were modeled as area sources with the emissions estimated following the EPA AP-42, Section 13.2.5 approach. The coal dust emissions from tandem rotary unloaders that would unload the coal were modeled as a volume source with emissions estimated following the EPA AP-42, Section 13.2.5 approach. Weyerhaeuser's Mint Farm meteorological station was used in the analysis for the years 2001 to 2003. This station is located approximately 0.5 mile southeast of the project area.

In general the modeling approach built on the approach in the *Millennium Coal Export Terminal, Longview, Washington, Air Quality Environmental Report* (URS Corporation 2015) which provides further details on the air quality modeling. The changes applied included modeling for the deposition of the coal particles and a more conservative assumption about the effectiveness of full enclosures and spray/fogging for conveyors. A 95% reduction effectiveness was assumed for the enclosed conveyor and spray/fogging systems, which is consistent with a similar facility's permit from the Oregon Department of Environmental Quality (2013).

No information was available on the particle size distribution for Powder River Basin or Uinta Basin coal for particle sizes smaller than 65 microns that would be received at the coal export terminal; however data were available from 11 coal mines in Australia (Katestone 2009). The coal type with the highest near-field deposition, from the Moranbah North mine, was used in the Applicant's deposition analysis, as shown in Table 3.

Table 3. Particle Size Distribution for Coal Dust Deposition Analysis

	Mean Mass Diameter Size Range (microns)					
	65–42.5	**42.5–30**	**30–20**	**20–10**	**10–3.75**	**3.75–0.5**
Mass Fraction	0.143	0.147	0.196	0.245	0.218	0.051

2.1.2.2 Coal Trains

For the rail transport of the coal to the coal export terminal, air quality modeling was conducted based on the coal dust emissions estimated from a moving train with some adjustments in the emission rates based on the air quality monitoring study as described in Section 2.2.4, *Coal Dust Monitoring*.[4]

Two recent coal train studies included an assessment of coal dust from passing coal trains operating in Washington State. Analyses of data from these studies were used to better characterize coal dust emissions and air quality impacts.

[4] In the Columbia River Gorge, additional adjustments included an effective wind speed to determine the strength of the coal dust emissions. The effective wind speed is the speed of the train plus the component of the ambient wind in the direction of the train If the wind component is opposite the direction of the train then the component is subtracted.

Cowlitz County Field Program

As part of the analysis for the environmental impact statement, a field study to collect data on coal dust emanating from passing coal trains in Cowlitz County was undertaken. Appendix A, Particulate *Matter Measurements in Support of Assessing Coal Emissions from Haul Trains Measurements Report*, contains a detailed report on the study including the sampling program, laboratory analysis, quality assurance, and results. The objective of the sampling program was to collect coal dust data at a location in Cowlitz County under conditions that were conducive to coal dust emissions from passing coal trains. Data collected during the first 2 weeks in October 2014, were suitable to allow a small sample to be collected to improve knowledge regarding coal dust emissions and improve the reliability of the assessment of potential impacts. This analysis used the data collected during the field study to evaluate coal train emissions estimates based on studies done in Australia, to verify their applicability to similar projects in the United States, and to evaluate the potential future impacts from the increased transport of coal to the coal export terminal via rail. Because only a limited number of coal trains travel to the Applicant's leased area per week and travel at low speeds, a sampling network was deployed in southern Cowlitz County along the BNSF main line just north of the Lewis River where several loaded coal trains passby (Figure 3).

Data collected at the site included the following elements.

- Continuous airborne particulate matter using a size-segregating laser-based optical scattering technique with data recorded at a 10-second time resolution. Measurements were made at the anticipated downwind (east) side of the tracks.
- Short-term particulate matter deposition using deposition plates on both sides of the tracks that sampled during triggered events with a train passage.
- Short-term airborne particulate matter on both sides of the tracks using impaction sampling techniques triggered during selected train passages.
- Integrated 24-hour airborne particulate matter using filter-based techniques with measurements primarily focused on the anticipated downwind (east) side of the tracks.
- Meteorological measurements of wind speed, wind direction, temperature, humidity and solar radiation at a 30-second time resolution to document the conditions during the sampling events.
- Train speed and video recording (documenting the number of coal cars, etc.)

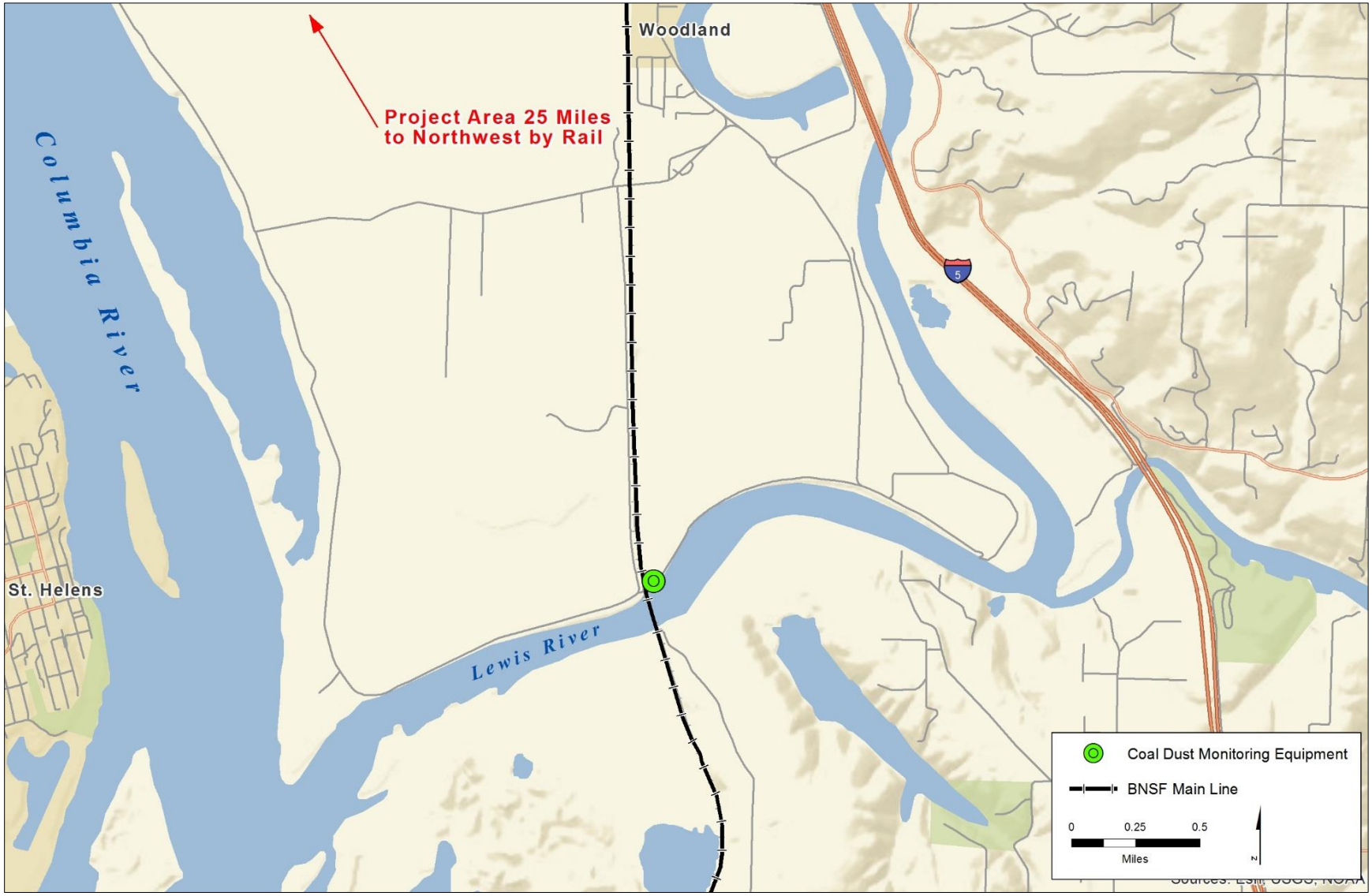
To determine the coal particle concentrations from the collected samples, analytical methods were developed to evaluate the coal particle concentrations in the three different types of measurements and collection devices: fallout of particles (deposition plates for approximately 20 microns and larger); airborne concentrations in the optical microscopy size range (Air-O-Cell slit impaction cassettes 3 to 100 microns); and particles in the "respirable" size range (less than 3 microns). All data collected during the measurement program were processed and validated prior to using in the coal dust analysis.

A total of 23 coal trains were observed during the study period (October 2014) and samples were obtained for 22 of the trains.[5] Of the 22 coal train sample sets collected, 11 were submitted to the laboratory for full analyses, along with two noncoal freight trains for comparison. Prior to the start of the study period, it was verified with the receivers of the coal trains (TransAlta Power Plant near

[5] The other data were not analyzed because the train came to a complete stop on the section of track being studied.

Centralia and Westshore Terminals in British Columbia, Canada) originated in the Powder River Basin and surfactant was applied at the mine. At the time of this study the BNSF Pasco spray station was not yet operational and no additional surfactant material was being applied to the coal.

Figure 3. Coal Dust Monitoring Site Location



To improve the reliability of the impact assessment, results from the coal dust monitoring study were used to compare with the air dispersion and emissions modeling using the information observed at the air quality monitoring site (e.g., meteorology, train speed, number of coal cars). Findings from the comparison of modeled data to monitored data were then used to adjust the emissions estimates to produce the best fit with the observed data. The revised emissions estimates were then adjusted to reflect the projected activity levels along the rail line during full operation and the impact assessed.

Air quality modeling was performed using AERMOD for the periods when wind direction was clearly across the tracks and when a complete set of deposition plates and impaction samplers were recorded at the site. This resulted in four periods (sample sets 6, 21, 22, and 25) in which suitable measurements were made to use with the model.

A key input to the modeling is the emissions factor used to characterize the amount of coal dust from moving, fully loaded coal rail cars. The approach used the equation reported in the Connell-Hatch study (Connell-Hatch 2008). This equation has since been used in a number of environmental impact assessments in Australia (GHD 2012; Heggies 2009).

The emissions factor for the rate of coal dust emitted (total suspended particulate [TSP]-sized) is expressed in metric units of grams (g) of TSP per kilometer (km) of rail per metric ton of coal moved as follows.

$$\text{Emissions Factor (loaded coal train)} = 0.0000378(V)^2 - 0.000126(V) + 0.000063$$
where V is the speed of the train (km/h)

This equation was developed from the analysis of coal dust loss (without mitigation) and a minimum air velocity needed for particle lift-off from a wind tunnel study over a variety of wind speeds. The approach assumed no significant rainfall and so likely represents an overestimate for western Washington State. This emission factor was further adjusted by 1.34 to account for the larger-sized rail cars used to transport coal in the United States (44.12 square meters) versus those used in Australia (30.37 square meters) (Connell-Hatch 2008). Each loaded rail car was estimated to hold 122 tons of coal and an 85% emission reduction effectiveness[6] was applied based on best practice of shaping the coal for transport by rail to minimize fugitive emissions and the application of a topping agent at the mine. Emission rates were also estimated for the unloaded train based on a study (Commonwealth Scientific and Industrial Research Organisation 2007) of the amount of coal carry-back found in returning rail cars. Over a 6-month survey period at the Port of Gladstone Australia, the average amount of coal carry-back was 0.36 ton per car and the worst-case was 0.93 ton per car, which was observed in June following 2 months of heavy rainfall that increased the stickiness of the coal. This worst-case coal carry-back value was used in this assessment for the empty rail cars, and no emissions reductions were applied for coal shaping or application of topping agent. Emissions rates for each operations setting were calculated and used in the AERMOD dispersion model using representative meteorological data.

The study measured the fugitive emissions of coal from the passing trains with a set of air samplers on each side of the tracks to measure the upwind "background" concentrations and deposition and

[6] BNSF tariffs require shippers to control coal dust emissions through use of load profiling and application of an approved topping agent or other measures to reduce emissions by at least 85 percent (BNSF Price List 6041-B and Appendices A and B, issued September 19, 2011). This surfactant efficiency factor was refined for this analysis using the monitoring study as described in Section 2.2.4, *Coal Dust Monitoring.*

the downwind concentrations and deposition—the difference being the contributions of the passing trains. A variety of sampling techniques captured the specific emissions from the coal train hauling activities. Short-term measurements using deposition plates, impaction samplers, and continuous particulate matter measurements were used to resolve individual train events, while longer averaging intervals of particulate matter (24 hours) were collected using filter-based collection media to help relate the more standard methods of measurement to the shorter-term type sampling (train event). During the study period, high time-resolution meteorological measurements were made to capture wind flow and document the upwind and downwind environment during each train passing. The meteorological measurements also provided needed data on temperature, humidity, transport, and atmospheric stability that were used in the coal train modeling.

Whatcom County Field Program

To support the environmental impact statement for the proposed Gateway Pacific Coal Export Terminal in Whatcom County, Washington, data were collected on coal dust and train emissions from passing loaded and unload coal trains in Whatcom County (NewFields 2016). The report contains a detailed description of the field monitoring program, laboratory methods, analysis, and quality control. The objective of the sampling program was primarily focused on assessing coal train emissions for particles matter and their health related composition for particles less than 10 microns (largest particles for which health based standards are set). Particulate matter monitoring data (Dust Trak PM10, PM2.5 and PM1) collected at the Bow, Washington site during August and September 2015, was available for analysis to potentially to improve knowledge regarding coal dust emissions and improve the reliability of the assessment of potential impacts. A total of 30 coal trains passed by the site during the study period but at relatively slow average speeds (18 miles per hour [mph]). Because coal dust emissions are roughly proportional to the square of the train speed, a subset of the highest loaded coal trains was analyzed. In addition, a small number of empty coal trains and freight trains were analyzed for comparison with the coal trains.

2.2 Existing Conditions

The existing environmental conditions related to coal dust exposure in the study area are described below.

2.2.1 Applicant's Leased Area

The existing bulk product terminal in the Applicant's leased area currently receives 1 to 2 coal trains per week, consisting of 25 to 30 coal rail cars. Coal is stored in silos in the Applicant's leased area, adjacent to the project area, and transferred via truck to the Weyerhaeuser facility, 1 mile to the southeast. Because the coal is stored in silos and only 1 to 2 trains are received each week, coal dust emissions are estimated to be small and confined almost entirely within the Applicant's leased area. Operations at the existing bulk product terminal comply with the air permit issued by the Southwest Clean Air Agency.

2.2.2 Cowlitz County

Approximately two loaded coal trains per day, consisting of approximately 125 cars, typically operate along the BNSF main line northbound in Cowlitz County (Western Organization of Resource Councils 2014).

Cowlitz County is classified as an attainment area or unclassified for both PM10 and PM2.5. Of these two pollutants only PM2.5 is currently being monitored. The PM2.5 monitoring station located at Olympic Middle School is a neighborhood-scale site, affected primarily by smoke from home heating. It is considered representative of the Longview-Kelso area and is used for curtailment calls[7] during the home heating season. The estimated 24-hour design value in 2014 was 18 micrograms per cubic meter (µg/m^3) (Washington State Department of Ecology 2015). While not a reference instrument, it is considered a strong indicator of the relative PM2.5 concentration of the Longview-Kelso area. Air quality in other locations of Cowlitz County is generally as good as or better than in the Longview-Kelso area.

2.2.3 Washington State

In 2014, 2 to 4 coal trains per day operated within Washington State, typically consisting of approximately 125 rail cars, mainly along the BNSF main line (Western Organization of Resource Councils 2014, The Herald of Everett Washington 2013). Coal dust emissions associated with the operations of these trains occurs mostly along the BNSF main line routes because of the high operating speeds of the trains. Most of the coal dust deposition, as well as the highest concentration of coal dust in the air, occurs within the railroad right-of-way.

The following paragraphs describe the existing air quality conditions for the route that would be used for the proposed project (for westbound-loaded trains and eastbound-unloaded trains).

Air quality along the rail route in eastern Washington State from Spokane to Pasco is generally good. Spokane is a maintenance area for carbon monoxide, but has not had an exceedance of the carbon monoxide standard in over 10 years. From spring through fall in this region of the Columbia Plateau, high winds can combine with dry weather conditions to create dust storms that can lead to extremely high levels of PM10. The state monitors for PM2.5 along this route but in general, the monitoring is below the state's goal of keeping concentrations below 20 µg/m^3, well below the PM2.5 NAAQS of 35 µg/m^3.

Air quality through the Columbia River Gorge is also generally good, the primary concern being visibility impairment and regional haze issues, with these issues occurring at much lower concentration levels than for health effects. Air quality from Vancouver north to Longview is generally good with PM2.5 being the pollutant of most concern. Readings are generally well below the state's goal of keeping concentrations below 20 µg/m^3.

The rail route between Tacoma and Auburn over the Cascades via Stampede Pass passes through the only PM2.5 maintenance area in the state, the Tacoma-Pierce County PM2.5 maintenance area. The primary cause of poor air quality in the nonattainment area is residential wood burning during periods with colder-than-average temperatures and low wind speeds. The area east of Auburn does experience some of the highest ozone levels in Western Washington but are below the NAAQS.

[7] When meteorological conditions indicate the probability that PM 2.5 levels are likely to exceed EPA standards, the Department of Ecology and Local Air Authorities are authorized to issue a burn ban or other restriction.

Air quality from Stampede Pass through Ellensburg to Yakima and back to Pasco is generally good but recent monitoring data has shown a high fraction of the PM2.5 concentration to be nitrates in the Yakima region. In Yakima, much of the PM2.5 comes from wood burning with highest levels in the wintertime due to increased wood burning and stagnate conditions. Up to one-fourth of PM2.5 may be in the form of nitrate during the wintertime (Washington State Department of Ecology 2014). In addition, air quality in the Ellensburg area has, in recent years, shown that residents breathe unhealthy levels of PM2.5 2 to 3 weeks each year (Washington State Department of Ecology 2013).

2.2.4 Coal Dust Monitoring

This section describes the findings from the Cowlitz County field program and Whatcom County field program.

Cowlitz County Field Program

The Cowlitz County field program was described in Section 2.1.2, *Impact Analysis*. Appendix A, *Particulate Matter Measurements in Support of Assessing Coal Emissions from Haul Trains Measurements Report,* provides details of the program. A total of 23 coal trains were observed during the study period and samples were obtained for 22 of the trains. Of the 22 sample sets collected, 11 were submitted to the laboratory for full analyses, along with two noncoal freight trains for comparison (Table 4). The other sample sets were not analyzed for several reasons; the most common being that the train came to a complete stop on the section of track being studied.

Coal-like particle deposition amounts were 350 micrograms per square meter (µg/m^2) upwind and 1,140 µg/m^2 downwind on average per coal train, based on the upwind/downwind deposition plates located 15 meters from the track. Based on the collected data, this increase in mass appears to be fugitive coal dust emissions from the coal cars passing, as coal-like concentrations for deposition plates collected during noncoal train passage were notably very low (averaging 25 µg/m^2).

The maximum increase in the 24-hour PM-2.5 concentration from coal dust associated with the passing of two (2) unit coal trains traveling at an average speed of 41.5 mph in Cowlitz County at 40meters downwind was 1.33 µg/m^3. In a recent study by Jaffe et al (2015), where $PM_{2.5}$ monitoring data was collected in the Columbia River Gorge, the authors reported the maximum increase observed during the study in the 2-minute average $PM_{2.5}$ concentration of 232 µg/m^3 from the passage of a single coal train traveling at 44.5 mph located 20 meters from the rail line. These results are generally consistent with the results found in the coal dust monitoring study in Appendix A, *Particulate Matter Measurements in Support of Assessing Coal Emissions from Haul Trains Measurements Report,* when the 2-minute average $PM_{2.5}$ concentration is expressed in terms of the regulatory averaging period as the average increase in $PM_{2.5}$ concentration over 24 –hours for two coal trains per day would be:

$$\left(2\frac{trains}{day}\right) x \left(2\frac{min}{train}\right) * \frac{232\ \mu g/m^3}{60\frac{min}{hr} * \frac{24hr}{day}} = 0.65\ \mu g/m^3$$

Overall, air concentrations of coal-like particles, measured from the impaction samplers downwind from the track for periods with “winds across the tracks” averaged 16.5 µg/m^3 during the

approximate 2-minute coal train passage, compared to 0.6 µg/m^3 from similarly placed upwind samplers.[8]

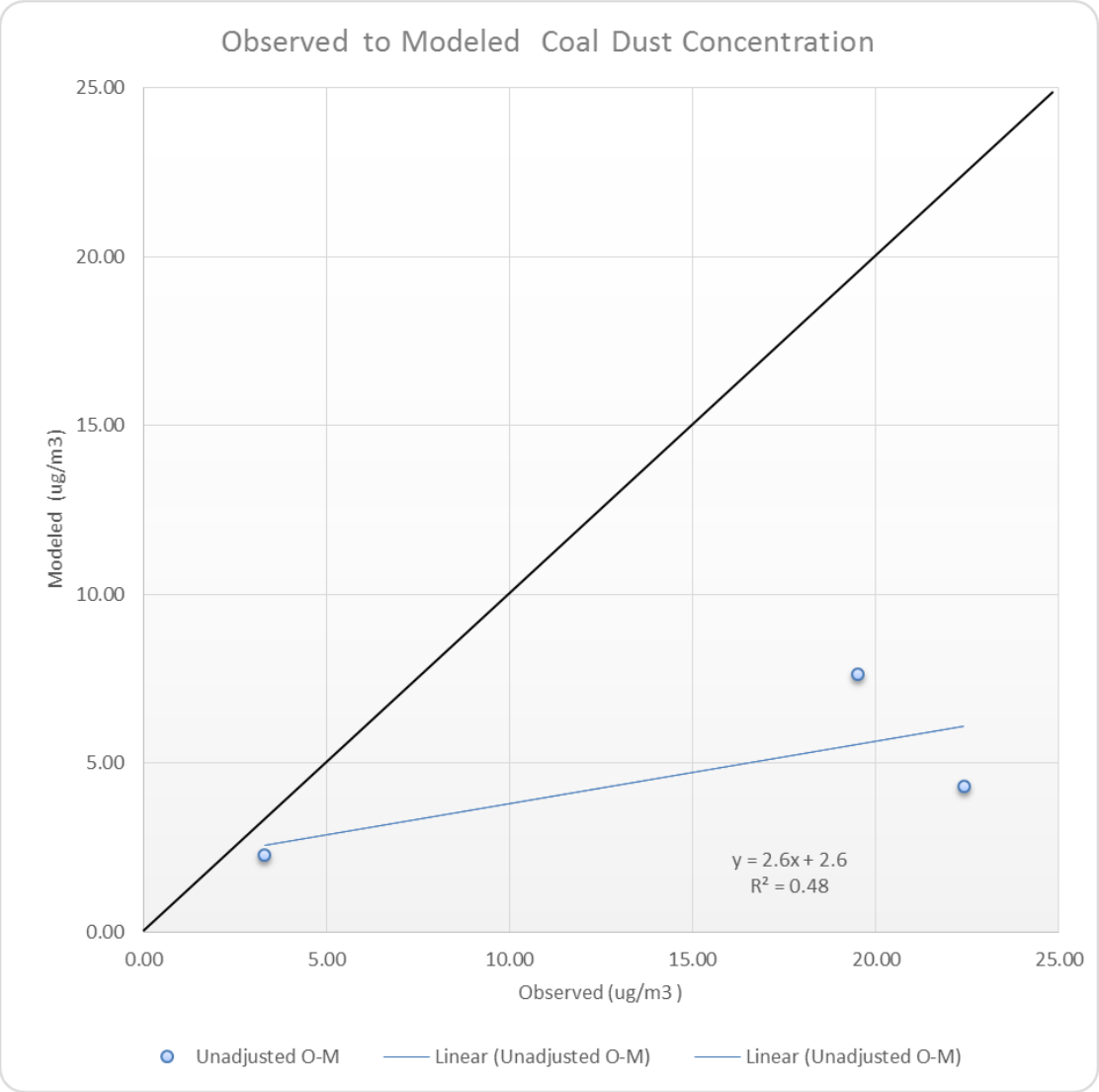
Air quality modeling results for coal train dust emissions in comparison with observations are shown in Figure 4 for the observed-to-modeled (O-M) concentration comparison and the ideal 1:1 ratio between observed and modeled concentration. Only three periods were modeled for comparison because sample sets 12, 13, and 18 had only one of the upwind and downwind measurement pairs. Sample set 15 had the winds nearly parallel to the track, and sample sets 24 and 25 had a new sampling configuration. Using a best-fit linear regression to these O-M data points suggests that the coal dust emissions reduction effectiveness at this location is 61% effective, rather than 85% reported at the time when the surfactant is first applied. Subsequent air quality modeling of the coal trains used this lower estimate of 61% for the surfactant efficiency.

[8] Iron-oxide concentrations measured during this same time period averaged 11.3 µg/m^3 on the downwind side and 1.5 µg/m^3 on the upwind side. The origin of the iron oxide is mostly likely from train wheels grinding against steel rails. This may contribute additional particulate matter to the near field air concentration, as well as deposition.

Table 4. Coal Trains for Coal Deposition, Concentration, and Particle Size Analysis

Sample Set	Date	Arrival Time Depart Time	Passage Time	Speed (mph)	Cars		Total	Est. Train Length (miles)	Comments
					Coal	Other			
1	10/1/2014	18:30:17 18:32:16	0:01:59	40	126		130	1.3	
3	10/2/2014	17:53:33 17:55:07	0:01:34	53	119		123	1.4	Stopped sampling 1 minute after train passage because of road traffic
6	10/3/2014	10:22:34 10:24:48	0:02:14	38	125		129	1.4	Sampled for 107 cars
12	10/5/2014	16:04:36 16:06:49	0:02:13	37	124		128	1.4	
13	10/6/2014	4:25:01 4:26:54	0:01:53	44	122		126	1.4	
15	10/6/2014	17:57:20 17:59:05	0:01:45	41	126		130	1.2	
18	10/8/2014	5:00:14 5:01:54	0:01:40	43	125		129	1.2	
21	10/10/2014	5:22:42 5:24:21	0:01:39	43	124		129	1.2	
22	10/10/2014	7:30:22 7:32:07	0:01:45	40	125		129	1.2	
24	10/12/2014	12:58:01 12:59:34	0:01:33	48	122		126	1.2	New sample configuration
25	10/13/2014	9:47:54 9:49:48	0:01:54	43	125		129	1.4	New sample configuration
7	10/3/2014	16:29:18 16:31:05	0:01:47	46		112	115	1.4	Freight train
14	10/6/2014	16:13:18 16:15:03	0:01:45	38		111	114	1.1	Freight train

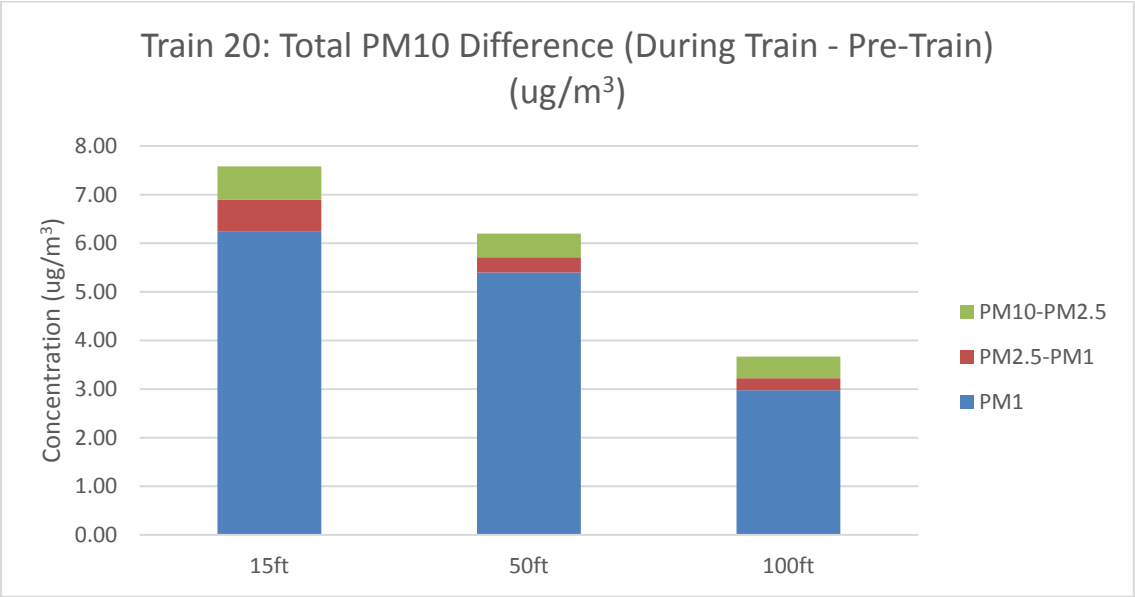
Figure 4. Coal Dust Emissions Adjustment Curve Based on Observed to Modeled Coal Dust Concentrations



Whatcom County Field Program

Nine coal trains were identified as suitable for further analysis because they had relatively high train speeds (average train speed 28 mph) during pass-by and had complete DusTrak measurements at sampling distances perpendicular to the railroad track at 15, 50, and 100 feet. These second-by-second particulate matter data were analyzed for periods before, during, and after train passage with concentrations plotted by particle size bins for the difference between before and during train passage. Figure 5 shows an example for Train 20, with a train speed 33 mph, 3 locomotives in front and 1 in back, and 126 loaded coal cars.

Figure 5. Train 20: Whatcom County Field Study, Bow, WA, September 9, 2015



Key findings from this analysis of the nine trains were as follows.

- PM10, PM2.5, and PM1 data show that nearly all of the mass is less than 1 micron in size, indicating that primarily diesel exhaust emissions were measured.
- Second-by-second analysis shows no variation between PM1 and PM10.
- Microscopy analysis of the particulate matter showed that no more than 0.21% was coal particles for any size category.

A number of factors likely contributed to limited observations of coal dust.

- The Bow site is a location near Puget Sound with prevailing westerly winds, frequent high humidity, and/or rainfall conditions.
- Slow train speeds.
- Reapplication of surfactant at the Pasco, Washington BNSF surfactant facility.
- Study was limited to measurement of particle sizes no larger than 10 microns, while the majority coal dust mass is expected to be found in larger-sized particles.

Despite these limitations a model to monitor comparison was performed for particles of less than 10 microns. For the 9 trains, only 5 had ambient wind speeds for which a model to monitor comparison is possible but 1 of the 5 was eliminated from comparison because rainfall occurred near the time of the monitoring, which suppresses coal dust emissions. Key findings from the comparison are as follows.

- Cowlitz County estimated that 61% surfactant efficiency leads to overestimated modeled particulate matter concentrations.
- Accounting for the Pasco surfactant facility that began operation in early 2015, the best fit of monitor to modeled concentration suggests a 99.7% surfactant efficiency. This is in agreement with the microscopy analysis that found little of the particulate matter data was coal dust.

Overall, the findings from the Whatcom County field program support the Cowlitz County field program, but the slow train speeds and particulate matter size limitation limit this support. The Whatcom County data also suggest that coal dust emissions are reduced with the use of surfactant, this conclusion is limited by the location and slow train speeds.

Analysis of a few empty coal trains and freight trains revealed similar patterns to the coal trains, with the vast majority of mass found in the PM1 bin. The freight trains showed PM10 and PM2.5 fractional amounts similar to those found for coal trains, suggesting that a sizeable fraction of the coarse particles at this location are due to abrasive processes from wheels and track interactions as well as brakes.

Chapter 3
Impacts

This chapter describes the impacts of coal dust that would result from the Proposed Action and No-Action Alternative.

3.1 Proposed Action

This section describes the impacts of coal dust that would result from the Proposed Action.

3.1.1 Construction: Direct and Indirect Impacts

Construction of the Proposed Action would not include any coal-handling activities. No direct or indirect impacts from coal dust would occur during construction of the Proposed Action.

3.1.2 Operations: Direct Impacts

As stated previously, the assessment for the Proposed Action was modeled using the AERMOD dispersion model. This included coal dust handling from the rail unloading, loading onto vessels, and wind erosion emissions from the coal piles.

3.1.2.1 Site-Specific Operations Impacts—Deposition

To assess the coal dust deposition impacts from the on-site operations was conducted based on full terminal operations. Table 5 presents these deposition amounts and shows both the estimated maximum annual coal dust deposited, based on a 3-year modeling period, and the estimated maximum monthly deposition, along with a comparison to the benchmark for the analysis.

Table 5. Estimated Maximum Annual and Monthly Coal Dust Deposition

Location	Maximum Annual Deposition (g/m^2/year)	Maximum Monthly Deposition (g/m^2/month)	Benchmark for Analysis (g/m^2/month)
Fence line	1.99	0.40	2.0

Notes:
g/m^2/year = grams per square meter per year; g/m^2/month = grams per square meter per month

The estimated maximum coal dust deposition from coal export terminal operations would be below the benchmark for the analysis. The highest estimated monthly deposition amounts would be near Mount Solo Road, as shown in Figure 6.

The spatial extent of the estimated maximum annual coal dust deposition near the coal export terminal is shown in Figure 7, which shows the maximum annual deposition near the coal export terminal. This shows that within a few thousand feet of the coal export terminal, the annual cumulative deposition of coal dust is estimated to be less than 0.1 g/m^2.

Figure 6. Estimated Maximum Monthly Coal Deposition (g/m^2/month) Near the Project Area

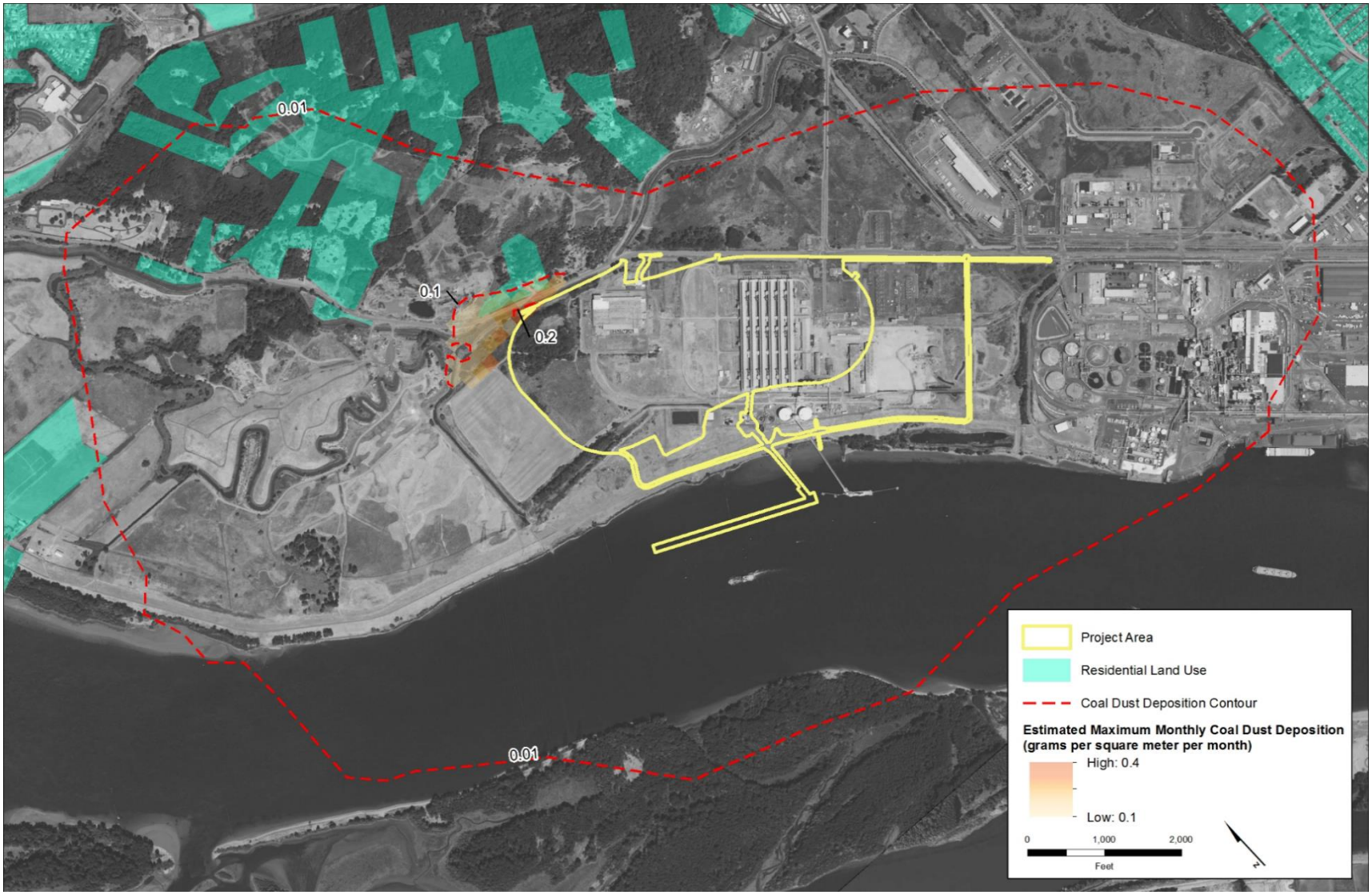
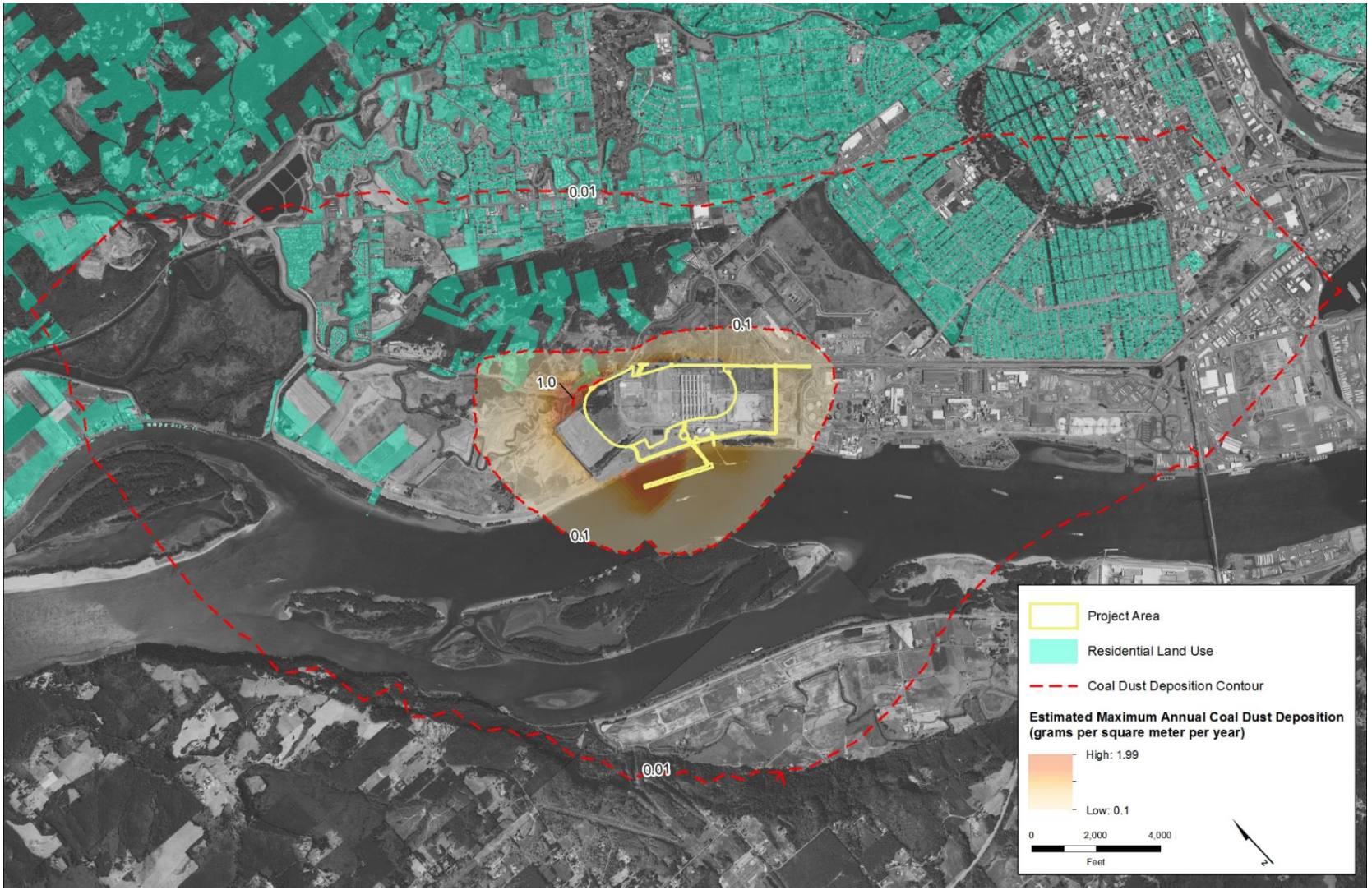


Figure 7. Estimated Maximum Annual Coal Deposition (g/m^2/year) Near the Millennium Bulk Terminal



3.1.3 Operations: Indirect Impacts

3.1.3.1 Cowlitz County

Reynolds Lead and BNSF Spur

To assess the coal dust air quality and deposition impacts from Proposed Action-related train operations, an air quality dispersion modeling using AERMOD was conducted based on an average speed of 10 mph for trains along the Reynolds Lead and BNSF Spur and the planned activity level of an average of eight loaded and eight unloaded Proposed Action-related trains per day. Results are presented in Table 6 showing the estimated maximum coal dust concentration (including background) relative to the PM10 and PM2.5 standard at 100 feet from the rail line. The closest maximum model residential receptor is located 180 feet on the north side of the rail line. These estimated concentrations are below the NAAQS standards. Further distances would experience even lower concentrations as concentrations decrease by about 50% another 160 feet from the rail line.

Table 6. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line—Reynolds Lead and BNSF Spur

Pollutant	Averaging Period	Maximum Modeled Impact (µg/m³)	Background[a] (µg/m³)	Total Concentration (µg/m³)	NAAQS (µg/m³)
PM10	24 hour[b]	0.28	28.0	28.3	150
PM2.5	24 hour[c]	0.05	16.0	16.05	35
	Annual[d]	0.01	5.3	5.31	12

Notes:

[a] Background concentrations are monitoring design values from Northwest International Air Quality Environmental Science and Technology Consortium (2015).

[b] The PM10 24-hour modeled impact is 3-year average of the high 2nd high concentration.

[c] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of the daily maximum concentrations.

[d] Modeled impact is the high 2nd high over the 3 modeled years.

NAAQS = National Ambient Air Quality Standards; µg/m³ = micrograms per cubic meter

The same modeling approach was used to determine the coal dust TSP deposition. Table 7 reports the results for the estimated maximum increase in deposition from Proposed Action-related train operations for the closest maximum modeled residential receptor (a distance of 180 feet from the rail line). Modeling indicates that the maximum monthly deposition would occur during July. The highest-estimated monthly deposition would be below the benchmark for the analysis.

Table 7. Estimated Maximum and Average Monthly Coal Dust Deposition—Reynolds Lead and BNSF Spur

Material	Distance (feet)	Average Maximum Monthly Deposition (g/m^2/month)	Maximum Monthly Deposition (g/m^2/month)	Benchmark for Analysis (g/m^2/month)
Coal Dust	180	0.013	0.017	2.0
Coal Dust	340	0.006	0.008	2.0

Notes:
g/m^2/month = grams per square meter per month

BNSF Main Line in Cowlitz County

To assess potential coal dust air quality and deposition impacts from Proposed Action-related trains traveling to the coal export terminal on the BNSF main line, air quality modeling was conducted based on an average 50 mph speed on the BNSF main line near Woodland and Kalama, Washington. Table 8 presents the results that show the maximum coal dust concentration (including background) at 50 and 100 feet in comparison with the PM10 and PM2.5 standards. Estimated concentrations are higher than concentrations estimated for the Reynolds Lead and BNSF Spur because of the higher train speeds on the BNSF main line that enhance the entrainment (dust lift-off) of coal particles from the open rail cars. However, in all cases, these concentrations remain below the NAAQS.

Table 8. Estimated Maximum PM10 and PM2.5 Concentrations 50 and 100 Feet from Rail Line—BNSF Main Line, Cowlitz County

Pollutant	Averaging Period	Distance from Rail Line (feet)	Modeled Impact ($\mu g/m^3$)	Background[a] ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
PM10	24 hours[b]	50	30.0	28.0	58.0	150
		100	23.0	28.0	51.0	150
PM2.5	24 hours[c]	50	4.5	21.0	25.5	35
		100	3.8	21.0	24.8	35
	Annual[d]	50	2.1	5.9	8.0	12
		100	1.7	5.9	7.6	12

Notes:
[a] Background concentrations are monitoring design values for Woodland, Washington (Northwest International Air Quality Environmental Science and Technology Consortium 2015).
[b] The PM10 24-hour modeled impact is 3-year average of the high 2nd high concentration.
[c] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of the daily maximum concentrations.
[d] Modeled impact is the annual average over the 3 modeled years.
$\mu g/m^3$ = micrograms per cubic meter

The same modeling approach was used to estimate coal dust TSP deposition along the BNSF main line in Cowlitz County. The results show the estimated increase in deposition at distances of 50, 100, and 150 feet from the rail line (Table 9). The deposition amounts are higher than the Reynolds Lead because of the higher train speeds. Estimated maximum monthly deposition would occur during

January. The estimated maximum monthly deposition is above the benchmark for the analysis up to 100 feet.[9]

Table 9. Estimated Maximum and Average Monthly Coal Dust Total Suspended Particulate Deposition—BNSF Main Line, Cowlitz County

Material	Distance (feet)	Average Monthly Deposition (g/m^2/month)	Maximum Monthly Deposition (g/m^2/month)	Benchmark for Analysis (g/m^2/month)
Coal Dust	50	2.2	3.1	2.0
Coal Dust	100	1.4	2.3	2.0
Coal Dust	150	1.0	1.8	2.0

Notes:
g/m^2/month = grams per square meter per month

Table 10 compares the maximum trace element concentrations found in coal dust for the Proposed Action-related trains operating along the BNSF main line location with their respective acceptable source impact levels (ASILs). ASILs are screening concentrations for toxic air pollutant in the ambient air, and are based on the levels established in WAC 173-460-150 for stationary sources but are shown here for comparison purposes. The fraction of trace elements found in coal is based on the maximum fraction of these elements found in two Powder River Basin coal beds (Stricker et al. 2007) in combination with the coal dust air quality modeling. All of the predicted maximum concentrations of these trace elements in coal dust are less than their respective ASILs. Chromium (VI) is likely substantially lower than as shown in the table as the percent of chromium as chromium (VI) was conservatively assumed the same as coal fly ash, which is a post-combustion coal residual. This process is known to increase substantially the percentage of chromium as chromium (VI) (Stam et al. 2011).

Table 10. Maximum Concentrations of Trace Elements Compared with Acceptable Source Impact Levels—BNSF Main Line, Cowlitz County

Substance[a]	Maximum Concentration ($\mu g/m^3$)	ASIL ($\mu g/m^3$)	Averaging Time	Percentage of ASIL (%)
Arsenic and inorganic arsenic compounds	0.000062	0.000303	Annual	20.4
Beryllium and compounds	0.000007	0.000417	Annual	1.8
Cadmium and compounds	0.000002	0.000238	Annual	0.7
Chromium (VI)[b]	0.0000047	0.00000667	Annual	70.4
Cobalt as metal dust and fume	0.00013	0.1	24 hour	0.1
Copper, dusts and mists	0.0015	100	1 hour	0.002
Lead compounds	0.000038	0.0833	1 year	0.046
Manganese dust and compounds	0.00093	0.04	24 hour	2.3
Mercury, aryl and inorganic	0.000005	0.09	24 hour	0.005

[9] These modeled results are comparable to those found during recent monitoring conducted by Corporation of Delta (2014) that reported coal dust deposition amounts ranging from 2 to 10 g/m^2/month (July 2013, April 2014, and October 2014) for an average of six 125-car loaded coal trains passing each day at an average speed of 35 mph (Brotherston pers. comm). The dust fall monitor was located 66 feet from the BNSF main line.

Substance[a]	Maximum Concentration (µg/m³)	ASIL (µg/m³)	Averaging Time	Percentage of ASIL (%)
Nickel and compounds	0.000031	0.0042	Annual	0.74
Selenium compounds	0.000065	20	24 hour	0.0003
Vanadium compounds	0.000732	0.2	24 hour	0.37
Crystal silica (PM4 -respirable) daily average	0.94[c]	3.0	8 hour	31

Notes:

[a] The fraction of trace elements found in coal is based on the maximum fraction of these elements found in two Powder River Basin coal beds (Stricker et al. 2007) in combination with the coal dust air quality modeling

[b] Chromium (VI) is likely substantially lower than as shown in the table because the percent of chromium as chromium (VI) was conservatively assumed the same as coal fly ash, which is a post-combustion coal residual. Combustion is known to increase substantially the percentage of chromium as chromium (VI) (Stam et al. 2011).

[c] Based on analysis of coal dust sample from field program. Total crystal silica fraction in coal dust is the sum of the crystal silica quartz and silicate fractions.

ASIL = acceptable source impact level; µg/m³ = micrograms per cubic meter

BNSF Main Line in the Columbia River Gorge

To assess potential coal dust air quality and deposition impacts from Proposed Action-related trains traveling to the coal export terminal on the BNSF main line through the Columbia River Gorge, air quality modeling was conducted based on an average 50-mph train speed on the BNSF main line near Dallesport, Washington using 2014 The Dalles Municipal Airport meteorological data. Table 11 presents the results that show the maximum coal dust concentration (including background) at 50 and 100 feet in comparison with the PM10 and PM2.5 standards. Estimated concentrations are somewhat lower than those estimated for the BNSF main line in Cowlitz County because of the higher average wind speeds in the Columbia River Gorge, which increases dispersion, although the full effect is offset by the enhanced entrainment (coal dust lift-off) when the ambient wind is blowing toward the train. In all cases, these concentrations remain below the NAAQS.

Table 11. Estimated Maximum PM10 and PM2.5 Concentrations 50 and 100 Feet from Rail Line—BNSF Main Line, Columbia Gorge

Pollutant	Averaging Period	Distance from Rail Line (feet)	Modeled Impact (µg/m³)	Background[a] (µg/m³)	Total Concentration (µg/m³)	NAAQS (µg/m³)
PM10	24 hours[b]	50	18.8	56.0	74.8	150
		100	14.1	56.0	70.1	150
PM2.5	24 hours[c]	50	2.9	19.0	21.9	35
		100	2.2	19.0	21.2	35
	Annual[d]	50	0.94	6.1	7.0	12
		100	0.75	6.1	6.9	12

Notes:
[a] Background concentrations are monitoring design values for Columbia Hills Historical State Park, Washington (Northwest International Air Quality Environmental Science and Technology Consortium 2015).
[b] The PM10 24-hour modeled impact is the high 2nd high concentration.
[c] The PM2.5 24-hour modeled impact is the 98th percentile of the daily maximum concentrations.
[d] Modeled impact is the annual average.
µg/m³ = micrograms per cubic meter

The same modeling approach was used to estimate coal dust TSP deposition along the BNSF main line in the Columbia River Gorge. The results show the estimated increase in deposition from the Proposed Action-related trains at distances of 50, 100, and 150 feet from the rail line (Table 12). The deposition amounts are similar to those along the BNSF main line in Cowlitz County. The estimated maximum monthly deposition would occur during June. The estimated maximum monthly deposition is above the benchmark for the analysis at 50 feet.

Table 12. Estimated Maximum and Average Monthly Coal Dust Total Suspended Particulate Deposition—BNSF Main Line, Columbia River Gorge

Material	Distance (feet)	Average Maximum Monthly Deposition (g/m²/month)	Maximum Monthly Deposition (g/m²/month)	Benchmark Used for Analysis (g/m²/month)
Coal Dust	50	2.2	2.6	2.0
Coal Dust	100	1.5	1.9	2.0
Coal Dust	150	1.0	1.4	2.0

Notes:
g/m²/month = grams per square meter per month

3.1.3.2 Washington State

To assess the coal dust air quality and deposition impacts in other locations in the state, air quality modeling was performed for 8 loaded and 8 unloaded[10] Proposed Action-related trains moving at an average speed of 50 mph along the BNSF main line running in a southwest-northeast orientation in eastern Washington[11] using Moses Lake meteorological data. Results are presented in Table 13 for loaded trains showing the maximum coal dust concentration (including background) relative to

[10] Because emissions from unloaded coal trains are highest after drying following unloading, the impacts were only evaluated in eastern Washington following return via Stampede Pass.

[11] This is the general orientation of the main line running from the Tri-Cities to Spokane.

the PM10 and PM2.5 standard. The maximum concentrations occur at a distance of 100 feet. These concentrations fall off by 50% another 100 feet away from the rail line. These concentrations plus background are all below the NAAQS standards. Table 14 shows the results for unloaded trains. These concentrations are well below the NAAQS standards and the combined exposures from loaded and unloaded coal cars remains below the NAAQS.

Table 13. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line for Loaded Coal Train —BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge)

Pollutant	Averaging Period	Modeled Impact (µg/m³)	Background[a] (µg/m³)	Total Concentration (µg/m³)	NAAQS (µg/m³)
PM10	24 hour[b]	24.2	101	125	150
PM2.5	24 hour[c]	2.8	24.2	27.0	35
	Annual[d]	0.92	8.9	9.83	12

Notes:
[a] Background for PM10 is the maximum high second high 24-hour average over the 3-year period (2012–2014) from Kennewick or Spokane. The background PM2.5 from the Spokane monitor from the 2012–2014 period.
[b] The PM10 24-hour modeled impact is 3-year average of the high 2nd high concentration.
[c] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of the daily maximum concentrations.
[d] Modeled impact is the annual average over the 3 modeled years based on Moses Lake meteorological data (2010–2012).
µg/m³ = micrograms per cubic meter

Table 14. Estimated Maximum PM10 and PM2.5 Concentrations 100 Feet from Rail Line for Unloaded Coal Train —BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge)

Pollutant	Averaging Period	Modeled Impact (µg/m³)	Background[a] (µg/m³)	Total Concentration (µg/m³)	NAAQS (µg/m³)
PM10	24 hour[b]	0.24	101	101.2	150
PM2.5	24 hour[c]	0.03	24.2	24.23	35
	Annual[d]	0.01	8.9	8.91	12

Notes:
[a] Background for PM10 is the maximum high second high 24-hour average over the 3-year period (2012–2014) from Kennewick or Spokane. The background PM2.5 from the Spokane monitor from the 2012–2014 period.
[b] The PM10 24-hour modeled impact is 3-year average of the high 2nd high concentration.
[c] The PM2.5 24-hour modeled impact is the 3-year average of the 98th percentile of the daily maximum concentrations.
[d] Modeled impact is the annual average over the 3 modeled years based on Moses Lake meteorological data (2010–2012).
µg/m³ = micrograms per cubic meter

The same modeling approach was used to determine the coal dust TSP deposition in eastern Washington (Table 15) for loaded and unloaded Proposed Action-related trains (Table 16). The results show the increase in deposition from Proposed Action-related rail operations located about 100 feet from the rail line. Maximum monthly deposition occurs during December. The monthly deposition is well below the benchmark for the analysis for both loaded and unloaded trains. The

maximum concentration of trace metals would be less than that found in Cowlitz County, which did not show concentrations above the ASIL.

Table 15. Estimated Maximum and Average Monthly Coal Dust Deposition from Loaded Coal Rail Cars —BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge)

Material	Distance (feet)	Average Maximum Monthly Deposition (g/m^2/month)	Maximum Monthly Deposition (g/m^2/month)	Benchmark for Analysis (g/m^2/month)
Coal Dust	100	0.73	0.88	2.0
Coal Dust	200	0.27	0.52	2.0

Notes:
g/m^2/month = grams per square meter per month

Table 16. Estimated Maximum and Average Monthly Coal Dust Deposition from Unloaded Coal Rail Cars—BNSF Main Line, Washington State (Outside Cowlitz County and the Columbia River Gorge)

Material	Distance (feet)	Average Maximum Monthly Deposition (g/m^2/month)	Maximum Monthly Deposition (g/m^2/month)	Benchmark for Analysis (g/m^2/month)
Coal Dust	100	0.018	0.022	2.0
Coal Dust	200	0.011	0.021	2.0

Notes:
g/m^2/month = grams per square meter per month

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the Proposed Action and impacts related to coal dust from construction and operation of the Proposed Action would not occur. The Applicant would continue with current and future operations in the project area. The project area could be developed for other industrial uses, including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement. Petroleum coke transfer would have minimal coal dust emissions because the material is stored in a building and the transfer from vessel occurs through vacuum unloader.

Chapter 4
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Coal Spills Analysis

Chapter 1
Introduction

1.1 Regulatory Setting

There are no known statutes, regulations, or guidelines at the federal, state, or local level that are specific to spills of elemental unprocessed coal. However, there could be federal, state, or local requirements (e.g., permits) that may be required for clean-up activities related to a coal spill after-the-fact, depending on the location and extent of the coal spill, and nature of the response and clean-up actions. Any spill into a jurisdictional waterbody would likely be treated as an unauthorized discharge under the federal Clean Water Act and the state Water Pollution Control Act and clean-up activities would be permitted after-the-fact. Federal, state, or local requirements (e.g., permits) could be required for clean-up activities related to a coal spill, depending on the location and extent of the spill, and nature of the response and clean-up actions. Any coal spill into a jurisdictional waterbody would likely be treated as an unauthorized discharge under the federal Clean Water Act and the state Water Pollution Control Act.

1.2 Study Area

The coal spill study area includes the project area where coal handling would occur, including the dock areas where coal would be loaded onto vessels in the Columbia River. The coal spill study area also includes areas along the rail line corridor(s) in Cowlitz County and Washington State where trains would operate, transporting coal to the coal export terminal; coal transport to the coal export terminal would likely follow the BNSF and UP routes described for loaded coal trains in the SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017). The size and extent of a coal spill cannot be predicted and would depend on various factors such as location of the incident (dock or railway), train speed, surrounding topography, adjacent structures, and characteristics of the adjacent natural and aquatic environment (e.g., terrestrial vegetation and habitat types, lentic (still) or lotic (flowing) surface waters.

This is a qualitative evaluation of coal spills and the study area focuses on the aquatic (e.g., surface waters and wetlands), terrestrial (e.g., vegetation/habitat), and built environments because these could be affected most directly by spilled coal.

Chapter 2
Existing Conditions

Descriptions of existing conditions relative to terrestrial and aquatic habitats and species, and the built environment for the Proposed Action can be found in the SEPA Vegetation Technical Report (ICF 2017a), SEPA Surface Water and Floodplains Technical Report (ICF 2017b), SEPA Fish Technical Report (ICF 2017c), SEPA Wildlife Technical Report (ICF 2017d), SEPA Land and Shoreline Use Technical Report (ICF and BergerAbam 2017), and SEPA Water Quality Technical Report (ICF 2017e).

The existing conditions in the rail line study area are described for two areas: Cowlitz County and those portions of Washington State beyond Cowlitz County.

2.1 Cowlitz County

The environment in Cowlitz County can be described in three broad categories:

- Aquatic habitats (i.e., rivers, streams, surface waters, and wetlands).
- Terrestrial habitats (i.e., deciduous and coniferous forests, and disturbed areas).
- The various built environments associated with rural, residential, agricultural, commercial, and industrial areas.

2.1.1 Aquatic Environments

Aquatic environments in Cowlitz County include surface waters (e.g. streams, rivers, wetlands) that are intersected by or adjacent to the rail line. These surface waters are important components of the natural environment, providing habitat for fish, wildlife, and vegetation. Major rivers in the study area include the Columbia River, Cowlitz River, Kalama River, North Fork Lewis River, and Toutle River, and there are many smaller streams, such as Ostrander Creek, Salmon Creek, and Mill Creek, most of which are tributaries to the Columbia River. These rivers and streams are known to, or have the potential to, support various species of fish, including salmonids, such as Chinook salmon, chum salmon, coho salmon, sockeye salmon, pink salmon, steelhead, and bull trout. Steelhead and coho salmon spawning habitat has been identified at the Kalama River rail crossing (Washington Department of Fish and Wildlife 2015a). Five of these salmonid species are federally protected under the Endangered Species Act: Chinook salmon, chum salmon, coho salmon, steelhead, and bull trout. Eulachon, a small anadromous fish, and green sturgeon are also federally protected under the Endangered Species Act and are found in rivers and streams in the study area. Critical habitat is designated in several study area streams for Chinook salmon, chum salmon, steelhead, bull trout, and eulachon. Other fish, amphibian, and reptile species may also utilize surface waters in the study area, such as the Pacific pond turtle, Dunn's salamander, western toad, leopard dace, and Pacific lamprey.

Wetlands are also an aquatic environment of concern in the study area. The National Wetland Inventory (U.S. Fish and Wildlife Service 2015) maps wetlands along much of the rail study area within Cowlitz County, with higher concentrations where the rail is closer to the Columbia River and

outside of developed areas (e.g., outside the cities of Kalama and Longview, and agricultural areas). Noted higher wetland concentrations occur south of the confluence of the Cowlitz River with the Columbia River and around the confluence of the Kalama River with the Columbia River. Wetlands mapped along the rail line include Palustrine[12] Emergent, Palustrine Scrub Shrub, and Palustrine Forested wetlands, with various hydrologic regimes. Wetlands provide habitat that can support a variety of wildlife species, including birds, mammals, amphibians, and reptiles. A review of Washington Priority Habitats and Species (PHS) data (Washington Department of Fish and Wildlife 2015b) indicates several large areas of waterfowl concentrations and cavity nesting ducks associated with various wetland habitats. Species identified with these habitat areas include downy woodpeckers, green backed herons, great horned owl, short-eared owl, goldeneyes, and wood ducks. Waterfowl concentrations in the southern part of Cowlitz County in the rail study area (just north of the North Fork Lewis River) include dusky and cackling Canada geese, tundra swans, and sandhill cranes; this area provides seasonal migration habitat for these species.

2.1.2 Terrestrial Environments

The terrestrial environment along the rail line includes a mix of natural habitats (forest, shrub, herbaceous upland), disturbed and developed areas (i.e., rural and urban areas), and agricultural areas. South of Longview and the confluence of the Cowlitz and Columbia Rivers, terrestrial vegetation and wildlife habitat conditions improve compared to the more industrial and urban character of the cities of Longview and Kelso, with some forested areas, wetlands, and ash mounds (associated with the eruption of Mount St. Helens in 1980 and subsequent dredging of the Cowlitz River to remove the mud and ash from the river). South of the Kalama River near the town of Kalama, terrestrial conditions again revert to more industrial and urban land uses. From the town of Kalama south to Martin Island, habitat conditions revert to areas of forests and wetland areas interspersed with rural development. From Martin Island south to the Cowlitz-Clark County line, the BNSF rail corridor intersects primarily agricultural land and rural development, with the exception of the city of Woodland, which has some commercial, urban, and residential development.

Representative wildlife in the study area may include black-tailed deer, red fox, coyote, raccoon, striped skunk, beaver, Oregon and grey-tailed vole, red-tailed hawk, Cooper's hawk, Canada geese, mallard and northern pintail ducks, great blue heron, white-breasted nuthatch, chipping sparrow, and a variety of amphibians and reptiles (Commission for Environmental Cooperation 2011). A review of PHS data (Washington Department of Fish and Wildlife 2015b) for terrestrial habitats indicates small areas of oak woodlands in a few places along the rail line; species associated with this habitat include various woodpeckers, migrant birds, reptiles, invertebrates, and the western gray squirrel (Washington Department of Fish and Wildlife 1998). In addition, two osprey point locations are mapped within 300 feet of the rail line; no further information is provided (Washington Department of Fish and Wildlife 2015b). No designated critical habitat for federally protected species under the jurisdiction of the U.S. Fish and Wildlife Service is mapped in the terrestrial environment near the rail line corridor(s) potentially used to transport coal.

[12] Palustrine wetlands are inland wetlands which generally lack flowing water, contain ocean-derived salts in concentrations of less than 0.5 parts per thousand (ppt), and are non-tidal.

2.1.3 Built Environment

The built environment in the rail line study area in Cowlitz County consists of structures and infrastructure associated with urban, rural, and commercial/industrial land uses. More developed areas around Longview, Kalama, and Woodland are dominated by industrial facilities and residential neighborhoods. Less-developed rural areas are found in-between these more urbanized areas. Structures include housing, commercial and industrial buildings, and associated infrastructure such as roads, bridges, and transmission and utility lines.

2.2 Washington State

Washington State beyond Cowlitz County has various and substantially different types of natural and built environmental conditions. Beyond Cowlitz County, the BNSF rail corridor (rail study area) primarily travels through three ecoregions, including the Cascades, Eastern Cascades Slopes and Foothills, and Columbia Plateau (Commission for Environmental Cooperation 2006), which is the largest ecoregion the rail study area passes through. In general, similar categories for the natural and built environment are applicable at the statewide scale (i.e., natural [aquatic and terrestrial] environments and built environments).

2.2.1 Aquatic Environment

The aquatic environment in Washington State beyond Cowlitz County includes many rivers and streams that are intersected or adjacent to the rail corridor. Many rivers and streams in the rail study area in Clark and Skamania Counties support or have the potential to support the same fish species described for Cowlitz County, as well as similar amphibian and reptile species. However, east of Skamania County (e.g., Klickitat and Benton Counties) the ecological conditions transition to the drier climate of the Columbia Plateau in Eastern Washington (i.e., east of the Cascade Mountains). As a result, smaller tributary streams originating in this ecoregion are generally ephemeral; most summer precipitation is evaporated or transpired, leaving little water for streamflow (Commission for Environmental Cooperation 2011). These conditions may be one factor limiting potential fish distribution. For example streams that support salmonids are much less prevalent in the drier region of eastern Washington compared to western Washington (Washington Department of Fish and Wildlife 2015a). Wetlands occur in the Columbia Plateau, but many have been drained and altered (Commission for Environmental Cooperation 2011).

2.2.2 Terrestrial Environment

The vast majority of the rail study area beyond Cowlitz County is within the Columbia Plateau ecoregion (Commission for Environmental Cooperation 2011). This ecoregion has dry desert and steppe climates, marked by hot, dry summers and cold winters, and consists of shrub-steppe vegetation communities. Vegetation is typically dominated by sagebrush, bitterbrush, bluebunch, needle- and thread-, Idaho fescue, and Sandberg's bluegrass. Numerous annual and perennial flowers often grow in the spaces between the shrubs and bunchgrass. Shrub-steppe historically dominated the landscape of the ecoregion, but much of it has been degraded, fragmented, and isolated from other similar habitats due to conversion to croplands (Washington Department of Fish and Wildlife 2015c).

Representative wildlife of the Columbia Plateau include mule deer, pronghorn antelope (last reintroduced in 2011 at the Yakama Indian Reservation), coyote, black-tailed jackrabbit, ground squirrels, American kestrel, golden eagle, red-tailed hawk, western meadowlark, savanna sparrow, western diamondback rattlesnake, greater sage-grouse, sage sparrows, sage thrashers, and pygmy rabbits, in addition to many other birds, mammals, reptiles, and insects (Commission for Environmental Cooperation 2011 and Washington Department of Fish and Wildlife 2015c). Shrub-steppe communities can also support federally protected species, including the pygmy rabbit and Spalding's catchfly, and the Washington Department of Fish and Wildlife considers shrub-steppe a priority habitat under the PHS program.

The Cascades and Eastern Cascade Slopes and Foothills ecoregions make up a smaller area intersected by the rail study area and mostly coincide with Clark, Skamania, and Klickitat Counties. Typical vegetation in the Cascades ecoregion at lower elevations include Douglas fir, western hemlock, western red cedar, big leaf maple, and red alder; representative wildlife includes black-tailed deer, black bear, coyote, beaver, river otter, pileated woodpecker, and northern goshawk. Typical vegetation in the Eastern Cascades Slopes and Foothills ecoregion includes open forests of ponderosa pine and some lodgepole pine, with sagebrush and steppe vegetation at lower elevations. Representative wildlife species in this ecoregion include black bear, black-tailed deer, mule deer, cougar, wolverine, coyote, yellow-bellied marmot, bald and golden eagles, Cooper's hawk, and osprey (Commission for Environmental Cooperation 2011). PHS data (Washington Department of Fish and Wildlife 2015b) indicate various priority habitats and species along the rail line study area, including talus slope and cliffs/bluffs habitats, bald eagle concentrations and breeding areas, and western pond turtle regular occurrence areas.

2.2.3 Built Environment

The built environment in the rail study area in Washington (beyond Cowlitz County) consists of structures and infrastructure associated with urban, rural, agricultural, and industrial land uses. More developed areas occur along the southern BNSF corridor around Ridgefield, Vancouver, Stevenson, Camas, Washougal, Kennewick, Walla Walla, Richland, Pasco, and Spokane, while to the north more developed areas include Tacoma, Seattle, Everett, Wenatchee, and Yakima. These areas are dominated by a mix of commercial, industrial, and residential land uses. Less-developed rural areas are found in-between these urban areas. Structures include housing, industrial buildings, commercial buildings, and associated infrastructure such as roads, bridges, and transmission and utility lines.

Large-scale coal spills from operation of the coal export terminal and trains transporting coal to the terminal could potentially affect the aquatic, terrestrial, and built environments. Such an event could occur as a result of a train incident (collision and/or derailment) or to a lesser extent during coal handling at the coal export terminal that occurs outside the rail loop (i.e., trestle and docks). Potential effects on the natural environment from a coal spill would likely be more pronounced during a train incident compared to a spill occurring in the confines of the coal export terminal for two reasons: (1) the absence of terrestrial and aquatic environments within the already developed project area compared to the presence of various terrestrial and aquatic resources along the rail line throughout the state, and (2) the amount of coal that could be spilled during operations at the coal export terminal would likely be relatively low when compared to a spill resulting from a train incident or derailment. Additionally, coal would be contained within the rail loop during operations. The magnitude of the potential impact from a coal spill on the aquatic, terrestrial, and built environments would depend on the location of the spill, the volume of the spill, and success of efforts to contain and clean-up the spill.

A coal spill during operations of the coal export terminal could occur. Direct impacts resulting from a spill during coal handling at the coal export terminal would likely be relatively minor because the amount of coal that could be spilled during operations would be relatively small and because of the absence of terrestrial and aquatic environments that exist within the areas to be developed and the contained nature of the coal export terminal and features of the terminal (e.g., fully enclosed belt conveyors over water, transfer towers, and shiploaders).

Further, it is unlikely that coal handling within the upland portions of the project area would result in a spill of coal that would affect the Columbia River as the rail loop and stockpile areas would be contained, and other areas adjacent to the coal export terminal are separated from the Columbia River by an existing levee, which would prevent coal from being conveyed from upland areas adjacent to the rail loop to the Columbia River. Coal could be spilled during vessel loading operations; however, such a spill would be caused by human error or equipment malfunction and would be expected to result in a limited release of coal into the environment due to safeguards to prevent such operational errors resulting in a spill. These include start-up alarms, dock containment measures to contain spillage/rainfall/runoff, and enclosed shiploaders.

The potential impact of a coal spill from train operations is directly related to the probability of a train incident occurring. A train incident (collision/derailment) risk analysis was developed by ICF (2017f) to estimate the number of train incidents that could potentially occur during coal transport (i.e., loaded coal trains) within Cowlitz County and Washington State. In Cowlitz County, the predicted number of loaded coal train incidents is approximately one every 2 years. The predicted number of loaded coal train incidents within Washington State is approximately five per year (ICF 2017f).

Not every incident of a loaded coal train would necessarily result in a rail car derailment and/or a spill of coal. A train incident could involve just one or two rail cars or multiple rail cars, and could include derailment in certain circumstances. Not all of the coal cars that may derail in any train incident would necessarily result in some or all of their contents spilling, depending on the nature of

the incident (i.e., size of train, speed of the train, terrain where incident occurs). A broad range of spill sizes, from a partial rail car to multiple rail cars, could potentially occur from loaded unit coal trains as the result of a train incident (ICF 2017f).

In addition, containment and clean-up efforts for coal spills associated with both operations and rail transport factor significantly into the ultimate fate of a coal release and its potential impact on the environment. It is assumed that coal spills in the terrestrial and built environments would be easier to contain and clean up than if such spills were to occur in the aquatic environment because coal would be on the ground surface and visible, response time would be more swift, and clean-up equipment would likely have easier access to the spill site. The impacts from unintended or coal releases on the aquatic, terrestrial, and built environments are described in the context of the train incident risk analysis and the containment and clean-up measures to remove the spilled coal.

3.1 Aquatic Environments

Coal is transported over land and water throughout the world. However, there is little existing literature and research regarding the effects of unburnt coal on the aquatic environment.

The most comprehensive literature review on the potential impacts of unburnt coal in the aquatic environment was conducted by Ahrens and Morrisey (2005). Their review summarized the potential physical and chemical (toxicity) effects of unburnt coal released into the aquatic environment; the following summarizes these effects and draws heavily from their review.

3.1.1 Physical Effects

In sufficient quantities, coal can have measurable physical effects on aquatic organisms and habitats similar to suspended and deposited sediments (which are well documented). The potential physical effects of increased coal in the aquatic environment are likely to dominate over potential toxic chemical effects (see below) of coal (Ahrens and Morrisey 2005). The physical effects of coal on aquatic organisms and the aquatic environment can include abrasion, smothering, diminished photosynthesis, alteration of sediment texture and stability, reduced availability of light, temporary loss of habitat, and diminished respiration and feeding for aquatic organisms. The magnitude of these potential impacts would depend on the amount and size of coal particles suspended in the water and settling on the bed/organisms (which will, in turn, depend on rate of flow and patterns of water movement), duration of coal exposure, and existing water clarity (Ahrens and Morrisey 2005). Therefore, depending on the circumstances of a coal spill and the existing conditions of a particular aquatic environment (e.g. lake, stream, wetland), the physical effects on aquatic organisms and habitat from introduced coal could vary significantly and range from no perceptible impact (i.e., relatively small spill followed by rapid and complete clean-up) to more severe impacts that could include reduced growth, reproduction, and abundance; elevated mortality; and altered population and community structure (i.e., large spill that impacts significant habitat and/or species with prolonged and more invasive clean-up effort).

Similarly, clean up of coal released into the aquatic environment could result in temporary impacts to habitat, such as smothering, alteration of sediment composition, temporary loss of habitat, and diminished respiration and feeding for aquatic organisms. The time required for recovery of the aquatic environment and resources would depend upon the extent and duration of clean-up efforts and the environment in which the incident occurred. For benthic organisms, such as

macroinvertebrates, recolonization rates of temporarily disturbed benthic habitats range from 30 to 45 days (National Marine Fisheries Service 2003). Aquatic vegetation would likely require more time to recolonize benthic habitats temporarily disturbed by clean-up efforts, with the duration dependent upon site-specific conditions (i.e., water depth, water clarity, water velocity, substrate type).

3.1.2 Chemical Effects (Toxicity)

Some research suggests that the bioavailability of contaminants in coal is limited, and that at levels of coal contamination at which estimates of bioavailable concentrations of contaminants might give cause for concern, the acute physical effects are likely to be more harmful than the chemical effects (Ahrens and Morrisey 2005). However, the variable chemical properties of coal and the aquatic environment in which it might occur, may give rise to circumstances in which contaminant mobility and bioavailability is enhanced. Coal can be a source of acidity, salinity, trace metals, polycyclic aromatic hydrocarbons (PAHs), and chemical oxygen demand (a measure of organic pollutants found in water), and interactions between coal and water could result in the alteration of pH and salinity, release of trace metals and PAHs, and an increase in chemical oxygen demand. However, if and how much these alterations occur in the aquatic environment and whether the alterations are significant enough to be potentially toxic to aquatic organisms depends on many factors, notably the type of coal, the relative amount of time the coal is exposed to water and broken down, dilution, buffering, and bioavailability.

Because of these unknown factors it is difficult to evaluate specifically what would happen in the event of a coal spill in the aquatic environment. For example, the acidity-generating potential of coal is largely a function of sulfur content, with sulfur-rich coals generally producing low pH levels in water and sulfur-poor coal generally producing more pH-neutral water (Ahrens and Morrisey 2005). The low pH of sulfur-rich coal further favors dissolution and release of metal ions such as iron, copper, manganese, chromium, and zinc compared to sulfur-poor coal (Anderson and Youngstrom 1976 in Ahrens and Morrisey 2005).[13]

Coal from the Powder River basin and Uinta Basin are low-sulfur coal. However, to provide a sense of the worst-case, more sulfur-rich coal is considered in the context of impacts to water quality. In general, how sulfur-rich coal could affect the aquatic environment largely depends on the context in which the coal is present. In the context of a coal stockpile at an export terminal that is exposed to rain water, the leachate generated from sulfur-rich coal could result in stormwater runoff with low pH levels and metal ion concentrations that could potentially be released into the environment if not contained and treated prior to discharge (operation of the coal export terminal would require a federal and state permit for any discharge of stormwater from the facility; effluent would be required to meet state and federal water quality criteria). In the context of coal released into a large flowing river like the Columbia River (e.g., from train derailment or during vessel loading), acidity could be immediately buffered by the river's naturally occurring bicarbonate concentrations, which would limit the release of metals, potentially resulting in imperceptible changes in the aquatic environment. Further, if any metals were released, their concentrations would likely be diluted by the river's velocity and discharge volumes. In this scenario, any negative impacts on aquatic

[13] It should be noted that the coal export terminal would primarily handle western U.S. coal from the Powder River Basin, and to a lesser extent the Uinta Basin; the sulfur content of coal from these basins is poor—the lowest sulfur content from U.S. domestic sources (Grette Associates, LLC 2014). This suggests that there would be a much lower acidity-generating potential (i.e., low pH levels) and lower potential metal release in the aquatic environment.

organisms, assuming chemicals were bioavailable, would likely be localized and kept in the immediate vicinity of the coal. In smaller streams and lakes, the impact could be more pronounced, but the extent of any impact would depend on site-specific conditions as well as the amount of coal released into the system.

Despite the variable factors and uncertainty of potential effects of coal spilled into the aquatic environment, some research suggests that under certain conditions chemicals released from coal could interfere with metabolizing enzymes and metal detoxification proteins, destabilize and increase permeability of membranes, and bioaccumulate in the tissue of aquatic organisms (Ahrens and Morrisey 2005). Whether there would be any measurable impact would depend on a variety of factors, but could potentially result in reduced growth, reproduction, and abundance; elevated mortality; and altered population and community structure (Ahrens and Morrisey 2005).

Depending on the circumstances of a coal spill and the existing conditions of a particular aquatic environment (e.g., stream, lake, wetland), the chemical effects on aquatic organisms and habitats could vary significantly and range from no perceptible impact to more severe impacts. A recent coal train derailment and coal spill in Burnaby, British Columbia, in 2014, and subsequent clean-up and monitoring efforts provide some insight into the potential impact of coal spilled on the aquatic environment (i.e., Silver Creek and Burnaby Lake). Phase one of the effort involved removing as much coal as possible from the terrestrial and aquatic environment; a total of approximately 143 tonnes of mixed coal, organic and mineral fines were removed using a vacuum-truck system and hand tools (Borealis Environmental Consulting 2015). Some coal was left in place in the stream and lake because it was considered impractical to remove additional coal without concomitant removal of significant volumes of native substrate and potential disturbance of riparian habitats. Post clean-up water quality and biota studies were then conducted to determine the potential short- and long-term impacts from the residual coal that remained in the aquatic environment. The study included four major elements: water quality, sediment quality, sediment leachate toxicity, and bioaccumulation potential. The study's summary results state that water quality was generally consistent with provincial and/or federal guidelines protective of aquatic life. Sediment concentrations of three metals and PAHs exceeded sediment guidelines, which indicated a potential for adverse effects on aquatic biota, requiring additional laboratory toxicity tests regarding the bioavailability of these metals and PAHs. The toxicity test results determined all samples to be nontoxic to all species tested (fish, invertebrate, and algae), except at one sample site, which yielded marginal effects on the survival of benthic macroinvertebrates. The bioaccumulation potential results indicated no potential at any sample site, except for one sample site where PAHs present have the slight potential to accumulate in benthic invertebrates in that sample area. The overall conclusion of the weight-of-evidence evaluation was that there are potentially minor impacts in the coal spill study area, and that these impacts are restricted to a small, localized area of the stream and lake. Further, no additional mitigation was recommended (as any removal of residual coal mixed with sediments was determined to pose a greater risk to environmental receptors); it was not anticipated that higher trophic levels would experience any adverse effects; and impacts beyond the spatial extent of the area assessed would be unlikely (Borealis Environmental Consulting 2015).

3.2 Terrestrial Environments

Coal released as the result of a spill into the terrestrial environment could physically damage and smother vegetation and terrestrial habitat. The potential for this impact within the confines of the

coal export terminal would be low because of the developed nature of the coal export terminal, which has little to no existing vegetation or suitable terrestrial habitat, and containment measures which would already be in place during operations. Vegetation and terrestrial habitat immediately adjacent to the rail line would be susceptible to impacts from a coal spill, but the area adjacent to the rail line is generally disturbed from rail right-of-way maintenance (i.e., routine mowing and trimming of vegetation), and provides little high quality habitat and vegetation diversity, as well as higher incidences of nonnative plant species. There would be a greater risk of affecting more natural and undisturbed vegetation and habitats if a coal spill were to occur beyond these maintained areas or the rail right-of-way. Herbaceous vegetation would be more susceptible to damage and smothering from a coal spill compared to more rigid, woody vegetation like shrubs and trees, which would be able to better withstand the weight and force of a coal spill, depending upon the magnitude of the spill. The magnitude of potential impacts would depend on the size (volume) and extent (area) of the coal spill.

The physical impact of coal spilled on vegetation would range from minor plant damage to complete loss of vegetation until assumed restoration measures would be implemented. Some plant species may be more sensitive to these impacts than others may, and a coal spill could create an opportunity for nonnative plants to thrive and outcompete damaged native plants, although nonnative plants would likely sustain similar damage. Coal dust associated with a coal spill could also cover vegetation, resulting in reduced light penetration and photosynthesis, which could lead to reduced vegetation density and plant diversity. More tolerant plant species could benefit from decreased competition, particularly nonnative species that could outcompete native species. The magnitude of potential coal dust impact would depend on duration of exposure, tolerance of vegetation, and aggressiveness of nonnative species.

Ground disturbance related to clean-up of coal spilled during operations may further affect vegetation by either removing or further damaging it. Any pieces of residual coal that might remain on the ground after a clean-up effort could leach chemicals from exposure to rain, which could damage or kill vegetation. However, if this were to occur, the impact area would generally be highly localized and limited to the extent of the spill, and unlikely to disrupt the overall plant ecosystem.

Coal spilled into the terrestrial environment could also affect wildlife that may be in the area during a coal spill. It is unlikely that wildlife would be present within the confines of the coal export terminal due to the lack of vegetation and suitable habitat in the developed facility, presence of surrounding facility fences that would limit wildlife movement and presence of humans and machinery during operations. Wildlife present along the rail line during a train incident or derailment, and that are unable to escape the area, could be harmed by direct physical contact if rail cars derail. Depending on the size of the coal spill, wildlife could sustain injuries from blunt force trauma as the rail car derails and coal is spilled, and if the spill is severe enough, could smother and die. Smaller and less mobile species would be at a higher risk than larger and more mobile species. However, it is anticipated that most wildlife would have already moved out of the immediate area along the track because of the relatively loud sounds and vibrations generated from oncoming and passing trains.

3.3 Built Environment

Coal spills in the built environment could potentially affect structures in the event of a large and concentrated coal spill associated with a train incident and/or derailment; however, more likely

impacts on the built environment would include the potential disruption and delay of traffic, reduced access to business and services, and disruption of utility services. Although clean up of coal in the built environment would likely commence immediately and access to the spill would be relatively uninhibited, there could be some delays and detours for vehicles, bicyclists, and pedestrians. Access to businesses, industries, services, and first responders could also be blocked or restricted. These impacts would likely be short-term and temporary burdens until removal and clean-up efforts were completed. The magnitude of these impacts would depend on the location and extent of a coal spill.

Chapter 4
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Sulfur Dioxide and Mercury Emissions Analysis

Chapter 1
Introduction

This chapter assesses the potential impacts in Washington State resulting from the combustion of Millennium Bulk Terminals–Longview coal exported to Asia and combusted in Asia. The air pollutants that could affect Washington State, given the distant location, are emissions of mercury (Hg) and sulfur dioxide (SO_2). These pollutants are chemically transformed, deposited, and, in some cases, re-emitted[14].

Mercury is mostly (53%) released to the atmosphere in elemental form (Hg^0), with another 37% released as gas-phased oxidized mercury (Hg^{II}), and 10% as particle bound mercury. Hg^0 is oxidized to Hg^{II} by ozone and hydroxyl radical (OH) in the atmosphere; however, this process is relatively slow, and, because Hg^0 is relatively insoluble in water and has a low deposition velocity, it stays in the atmosphere for long periods. Hg^{II} is lost from the atmosphere through wet and dry deposition; however, in cloudy regions Hg^{II} can be reduced back to Hg^0; thus, a portion of the Hg^{II} Particle-bound mercury is rapidly removed from the atmosphere through deposition and is found only close to the source.

The process for SO_2 entering the atmosphere is similar to mercury's process. The atmospheric chemistry responsible for the conversion of SO_2 to particulate sulfate is primarily through the oxidation of SO_2 by the hydroxyl radical in the absence of clouds or fog. The rate of this conversion process increases with both increasing temperature and relative humidity. The conversion of SO_2 to sulfate via aqueous solution chemistry in clouds and fog is more complex and dependent on several variables, including concentrations of the principal oxidants (hydrogen peroxide and ozone), ammonia, droplet size, and composition. The speed of the reaction can vary from less than 1% SO_2 converted per hour to a maximum of about 10% converted per hour at high temperature and relative humidity. Competing with the conversion to sulfate is the removal process that includes loss to cloud droplets, rainout, and washout and loss to sea salt aerosols at the ocean's surface.

Because this chemical transformation and removal process of Hg and SO_2 is complicated, the best approach for assessing the impacts is through chemical transport modeling.

1.1 Assessment Approach

The objective of this assessment is to determine how much of the mercury and sulfate levels that would be found over Washington State could be attributable to the mercury and sulfur emitted from coal combustion in Asia (from coal that passed through the coal export terminal). The assessment was conducted in a four-step process.

1. Conduct a literature review of the current state of the science for the air monitoring and modeling of SO_2 and Hg in the Pacific Northwest.

[14] Chemically transformed meaning the pollutants interact with other chemicals in the atmosphere to form other air pollutants. Deposited meaning the pollutant is deposited to the earth surface. Re-emitted meaning pollutants which are first deposited to the surface of the earth but are later re-emitted to the atmosphere due mostly to changes in meteorological or physical oceanic conditions.

2. Use the best understanding of the source-to-receptor relationship from the global chemical transport modeling (GCTM) that has been done to date and apply those findings to answer the objective of this study.
3. To apply the findings from the GCTM, compare the emission inventory for mercury and SO_2 used in the modeling with the projected air emissions of mercury and SO_2 in Asia (China, Japan, South Korea, Hong Kong, and Taiwan) for each of the five incremental scenarios completed using the Integrated Planning Model (IPM). This model was used to conduct the coal market assessment. Finally, identify the impacts from a long-range transport episode and on an annual basis.
4. The literature review and emission inventory uncertainties provide an upper bound on the mercury and SO_2 attributable to coal that passed through the coal export terminal.

This report discusses each of these four steps and presents the findings from this assessment. Because the two pollutants' (SO_2 and mercury) chemical fate and behavior in the atmosphere is very different, the final part of the report addresses mercury and SO_2 separately.

1.2 Overview of Methods for Mercury and SO_2 Assessment

This section provides an overview of the methods for the mercury and SO_2 assessment.

1.2.1 Literature Review

This step involved identifying, gathering, and reviewing peer-reviewed literature published in the past 15 years on the fate and transport of mercury and SO_2 emissions injected into the atmosphere from Asian countries where coal would be burned and any impact analyses completed to assess the impacts of the emissions in the Pacific Northwest of the United States and British Columbia, Canada. The best understanding of the fate and transport of those emissions would be used in assessing the fraction of the coal consumed and the impact in Washington State using a GCTM used to determine impacts in the Pacific Northwest.

1.2.2 Emission Inventory, GCTM, and Concentration Estimate

To determine the concentration or deposition amounts over Washington State from coal consumed, the emission source strength for each country of interest was collected as used in the fate and transport GCTM. The resulting concentration or deposition from the GCTM modeling was then adjusted for the projected country emissions for when the Applicant would become operational relative to the GCTM baseline modeling year. Finally, the projected concentration or deposition was adjusted for the fractional amount of coal to country emissions. This is expressed mathematically in the equation below and then simplified in the following step.

$$X_{tt} = X_{00} \times \frac{EA_{tt}}{EA_{00}} \times \frac{EA_{MTBL,tt}}{EA_{tt}},$$

Which simplifies to:

$$X_{tt} = X_{00} \times \frac{EA_{MTBL,tt}}{EA_{00}} \qquad \text{(Equation 1)}$$

Where *tt* is the forecast year, 00 is the baseline year of the GCTM modeling, *X* is the concentration or deposition at the representative location, *EA* is East Asia SO_2 or mercury emissions from all sources, and *MBTL* is the SO_2 or mercury emission from Proposed Action-related coal.

1.2.3 Application to the Five Coal Market Assessment Scenarios

Each emission rate (mercury or SO_2) for the five SEPA Coal Market Assessment Technical Report (ICF 2017) scenarios was applied to future years of the five IPM scenarios for three future years (2025, 2030, and 2040) when the coal export terminal would be operational. Estimates of the concentrations and deposition are determined for each scenario on annual and episodic bases. More information about the scenarios can be found in the SEPA Coal Market Assessment Technical Report.

1.2.4 Uncertainty

Based on the literature review on uncertainty an upper-bound estimate was developed on the possible coal combustion impact on mercury and sulfate concentration and deposition impact in Washington State. This is explained in the following sections.

Chapter 2
Mercury Assessment

Over 40 peer-review publications were found during the literature review, which spanned approximately the past 15 years. The studies included mercury emission inventories, emission projections, coal consumption in Asia, air monitoring studies in the Pacific Northwest and British Columbia, Canada, and global transport chemical modeling studies focused on assessing the fate and transport from Asia to North America. Also included in the assessment is the United Nations Environment Programme Global Mercury Assessment (United Nations Environment Programme 2013) report, which contains the most recent estimate of global mercury emissions.

The following discusses the nature of the emissions of mercury, how those pollutants behave and change in the atmosphere, and the form of those pollutants once they reach Washington State. This discussion is followed by a description of the papers most relevant to this study, with emphasis on the key findings from those papers as used in developing the impact assessment for the coal burning.

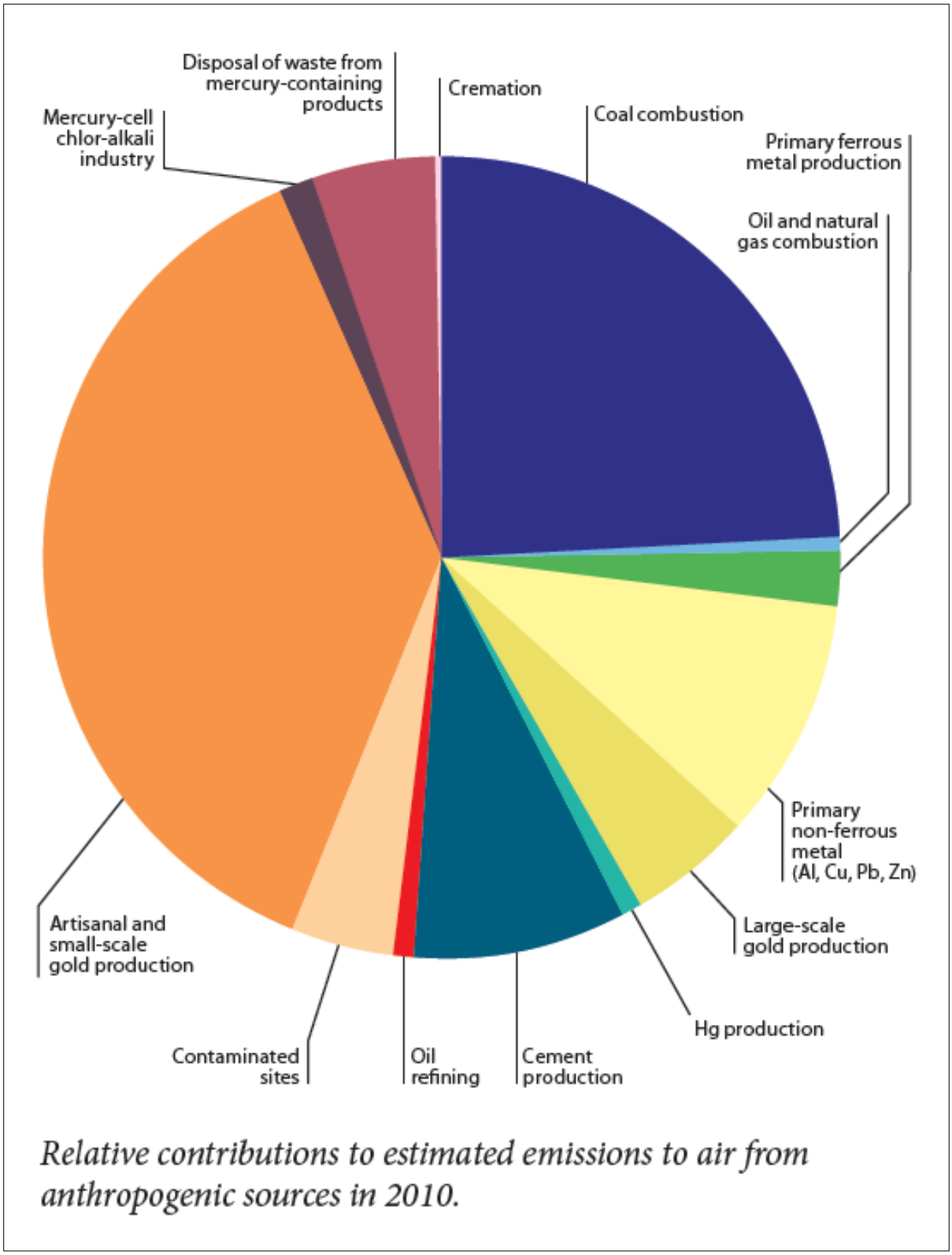
2.1 Introduction

Mercury is a naturally occurring element and is found throughout the world. Many natural sources of mercury emit mercury into the atmosphere, including the weathering of mercury-containing rocks, volcanoes when they erupt, and geothermal activity. Most recent models of the flow of mercury through the environment (United Nations Environment Programme 2013) find that natural sources account for about 10% of the annual mercury emission.

Anthropogenic sources of mercury emissions account for about 30% of the total amount of mercury entering the atmosphere each year. Globally, the largest source of emissions within this category is from artisanal and small-scale gold mining (estimated at 37%), followed by coal combustion (24%). The next largest sources are from the primary production of non-ferrous metals (aluminum, copper, lead, and zinc) and cement production. These sources together account for about 80% of the annual anthropogenic emission of mercury. Figure 8 shows the estimated emissions by anthropogenic source category.

The third category of mercury emissions is re-emissions, which account for about 60% of the mercury emitted to the air annually. Mercury previously deposited from air onto soils, surface waters, and vegetation from past emissions can be emitted back to the air. Re-emission is a result of the conversion of inorganic and organic forms of mercury to elemental mercury, which is volatile and therefore readily returns to the air. Mercury may be deposited and re-emitted many times as it cycles through the environment.

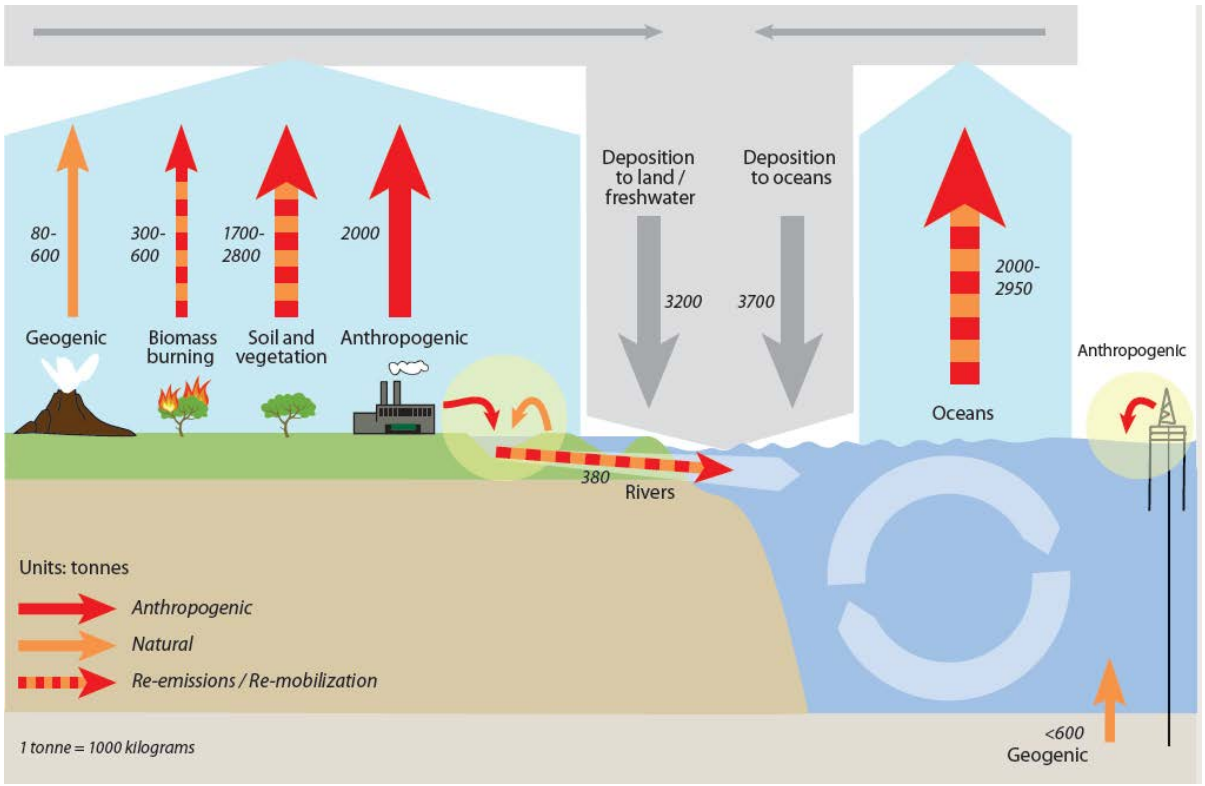
Figure 8. Anthropogenic Mercury Emissions Source Contribution



Source: United Nations Environment Programme 2013.

Re-emitted mercury should not be considered a natural source—it may originally have been either natural or anthropogenic, but by the time it is re-emitted, its specific origin cannot be identified other than from atmospheric modeling. Estimating re-emission rates is done using global modeling approaches based on data of atmospheric levels of mercury and an understanding of chemical transformations and other processes that affect how mercury moves between air, land, and water. The models act to balance the amount of mercury in circulation at any given time consistent with observational data. This analysis conservatively assumes that the re-emitted mercury is all anthropogenic. Figure 9 shows the current global mercury emission cycle.

Figure 9. Global Mercury Cycle (metric tons/year)



Source: United Nations Environment Programme 2013.

Mercury is largely released in its elemental form, which has a lifetime in the atmosphere of between 6 and 24 months, and therefore can be transported globally. The chemical speciation of mercury has been further studied by Pacyna et al. (2006). Across industries, about 53% of mercury in gases is in Hg^0 (elemental form), 37% is Hg^{II} (gas-phased oxidized mercury), and 10% is particle-bound mercury. This is important as the latter two phases of mercury have much shorter lifetimes—days or weeks—which mean they are deposited close to the source.

Mercury deposited in its elemental form is an inorganic compound. Inorganic mercury can be converted to organic methylmercury, which is of concern because of known toxicological effects on highly exposed or sensitive populations. Although mercury is a globally dispersed contaminant, it is normally a problem only where the rate of natural formation of organic methylmercury from inorganic mercury is greater than the reverse reaction (U.S. Geological Survey 2000).

After conversion to this methylated form, mercury can bioaccumulate up the food chain beginning with microorganisms that are consumed by fish, which may be consumed by larger fish. Organic methylmercury is the only form of mercury that accumulates appreciably in fish (U.S. Geological Survey 2000). Such bioaccumulation can result in high levels of mercury in some fish, which is one of the primary sources of human exposure to organic methylmercury. However, because human exposure to organic methylmercury occurs almost exclusively through fish consumption and varies by type and amount of fish consumed, variations in human exposure to organic methylmercury are based on individual fish consumption patterns (National Research Council 2000). Organic methylmercury can also be released back to the atmosphere by volatilization (U.S. Geological Survey 2000).

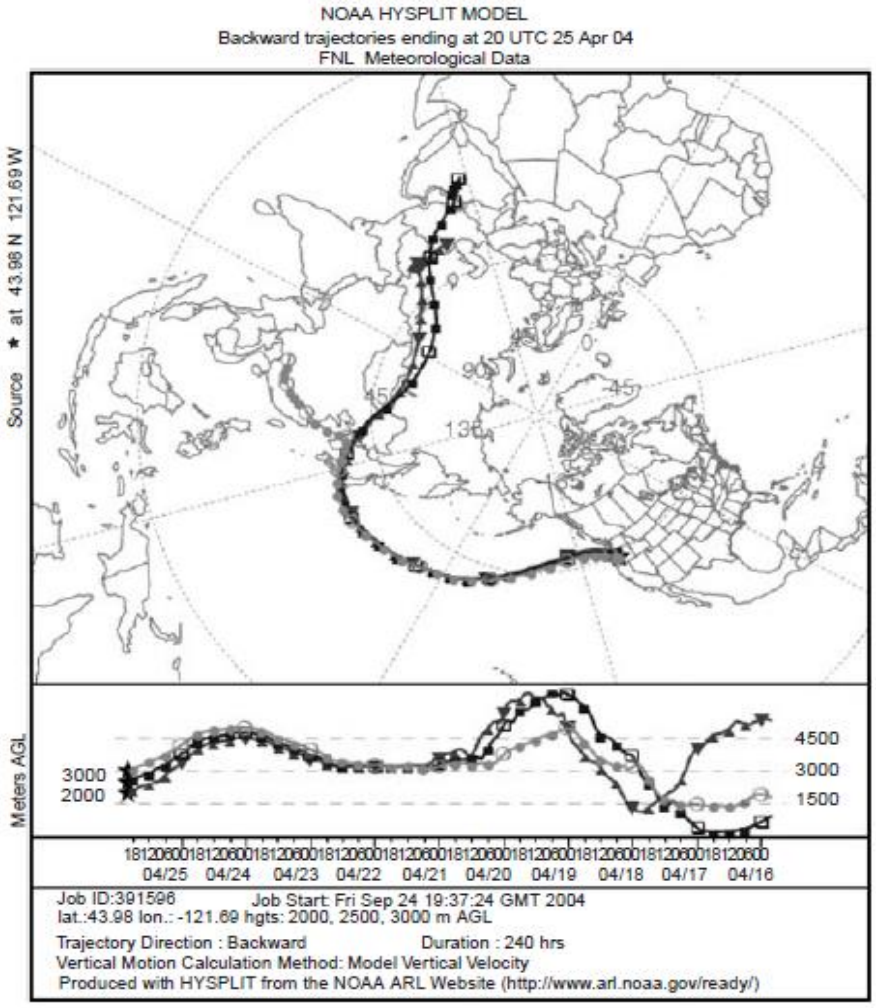
Environments that are known to favor the production of organic methylmercury include certain types of wetlands, dilute low-pH lakes in northeast and north central United States, parts of the Florida Everglades, newly flooded reservoirs, and coastal wetlands, particularly along the Gulf of Mexico, Atlantic Ocean, and San Francisco Bay (U.S. Geological Survey 2000).

2.2 Studies and Findings

A number of observational studies have examined the long-range transport of Asian mercury emissions to North America (Jaffe et al. 2003, 2005; Weiss-Penzias et al. 2006). Weiss-Penzias et al. found that total mercury (elemental + reactive and particle) over the period from March 28 to May 19, 2004, at Mount Bachelor, Oregon (44.0° N, 121.7° W) had periods where the air mass originated from East Asia, with an average increase in total mercury during these periods of 0.16 nanograms per cubic meter (ng/m^3) attributable to emissions from northern China, Korea, and Japan. This was based on the analysis of thousands of back trajectories using the National Oceanic and Atmospheric Administration's HYSPLIT trajectory model and mercury-to-carbon monoxide measurement ratios. Two pollution events within this period were examined in detail, which showed that travel time from East Asia to the Pacific Northwest was about ten days. Back-trajectories for the April 25, 2004, episode at several elevations above and below the Mount Bachelor site elevation, along with back-trajectories for the same date on the corners of a 1° x 1° box around the Mount Bachelor location and at multiple elevations, all showed similar flow from East Asia (Figure 10).

Because of the large amount of coal consumed in East Asia, which is projected to increase, and because studies show long-range transport from East Asia to North America is a frequent occurrence, several global modeling studies have been conducted to explore the impact of mercury emissions from East Asia on North America. The first such assessment was presented by Seigneur et al. (2004), who reported that Asian mercury emissions were estimated to contribute between 5 and 36% of the total mercury concentration in the United States. The most extensive modeling study of East Asian mercury emission impacts on the Pacific Northwest was conducted by Strode et al. (2008). That study included both global modeling of mercury and an observational analysis and comparison of the models' findings using the Mount Bachelor monitored mercury data.

Figure 10. HYSPLIT Back-Trajectory for the Mount Bachelor Observatory Episode (April 25, 2004)

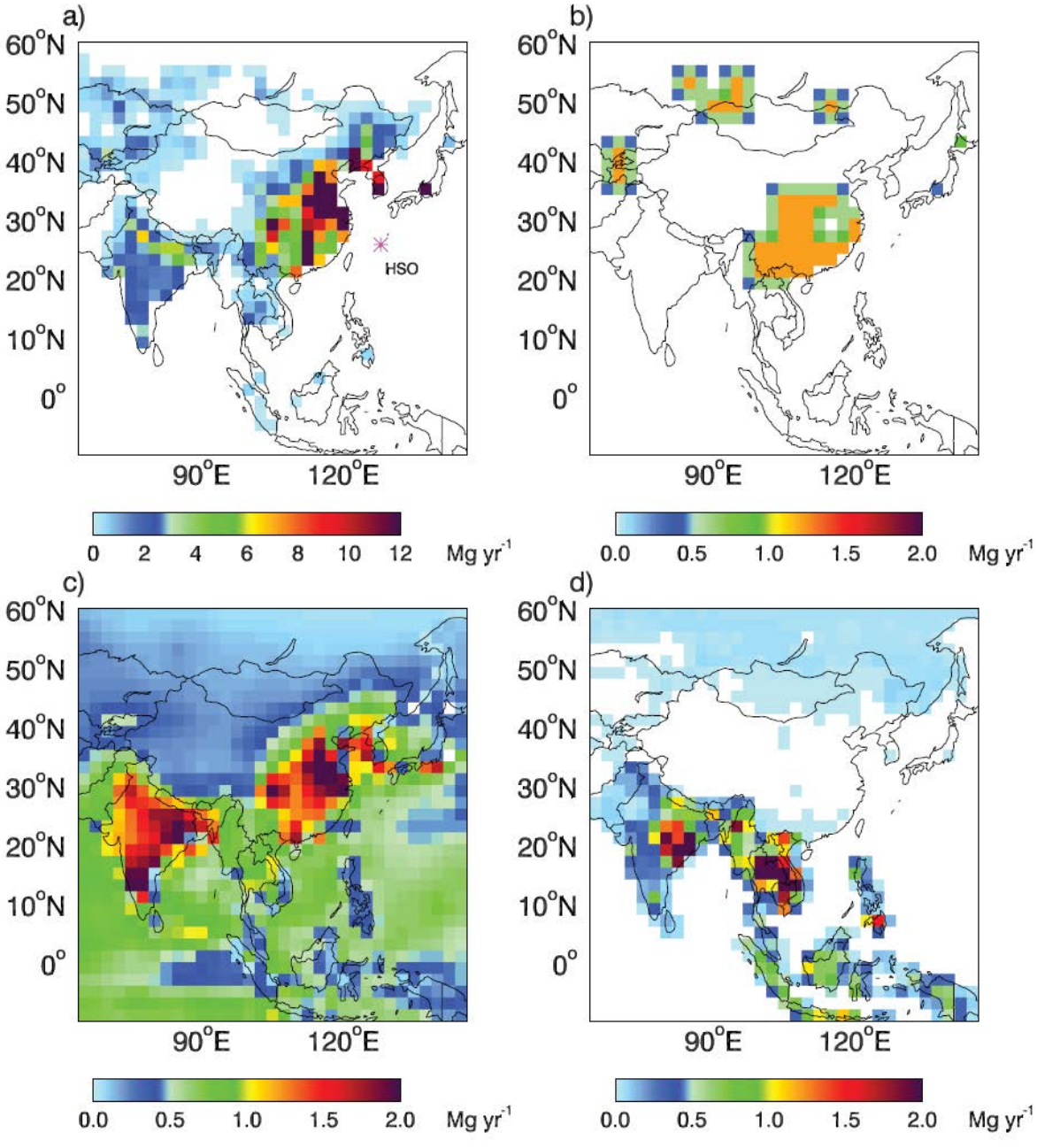


The GCTM used in this study was the GEOS-Chem global tropospheric chemistry model (Atmospheric Chemistry Modeling Group 2015). The model was run for the meteorological year 2004 with a model horizontal resolution of 2° latitude by 2.5° longitude. Hourly output from the model was extracted from the grid boxes corresponding to Mount Bachelor. The model includes emission, transport, deposition, and chemistry and is coupled to an ocean mixed layer. The model includes mercury entering the ocean mixed layer through deposition or ocean mixing whereby it is converted in the ocean to elemental mercury and then emitted to the atmosphere through gas-exchange, or it can be lost to the deep ocean through mixing and sinking of particles.

The model simulation includes global emissions from anthropogenic sources (Pacyna et al. 2006; Wilson et al. 2006), biomass burning, and natural emissions plus re-emissions from land and ocean. Figure 11 shows the distribution of anthropogenic, land, and biomass burning emissions over Asia (defined here as 9°S–60°N, 65°–146°W). For this region, anthropogenic emissions are 610 metric tons per year (MT/year) of Hg^0, 380 MT/year of Hg^{II}, and 100 MT/year of particle Hg. Natural emissions of 100 MT/year Hg are located primarily in southeast China. Land re-emissions of 310 MT/year Hg are distributed throughout the region, with large emissions from southeast China and

India. All sources of Hg emissions are needed for evaluating the modeling results. At the Mount Bachelor Observatory, the mean model total Hg concentration was 1.61 ± 0.09 ng/m^3. This compared to an observed mean of 1.53 ± 0.19 ng/m^3, yielding a mean model bias of just 5% for total mercury. In addition to identifying the source of emissions, the GCTM tagged emissions from biomass burning, land, and ocean emissions as well as anthropogenic emissions by region. For Asia, anthropogenic mercury includes both direct emission from Asia and ocean re-emission for previously deposited Asian anthropogenic mercury.

Figure 11. Distribution of Annual Asian Mercury Emissions (milligrams per year) from (a) Anthropogenic, (b) Natural, (c) Land Re-emission + Ocean Emission, and (d) Biomass Burning Used in the GEOS-Chem Model



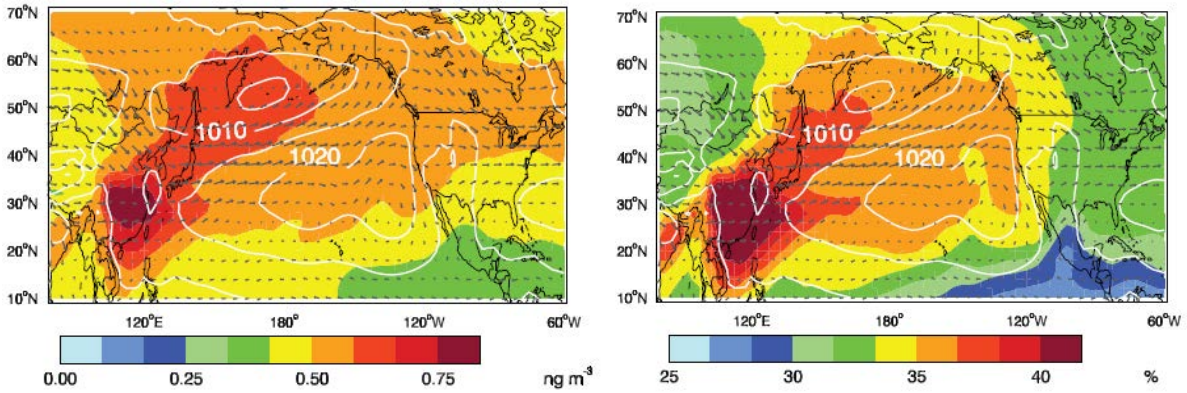
Source: Strode et al. (2008)

The model results showed that the Asian anthropogenic percent contribution to Hg^0 at Mount Bachelor shows little variability between seasons, with an Asian anthropogenic contribution of 18% in spring (0.29 ng/m^3 for Hg^0 and 0.015 ng/m^3 for Hg^{II}) and in the annual average. This source-to-receptor relationship is value applied to determine the contribution of the Proposed Action using Equation 1. The modeling results also show that the largest Asian Hg^0 contribution occurred on April 28, when the Asian sources accounted for 41% of Hg^0 (1.18 ng/m^3). Additionally, the modeling

study showed that the regional contribution of Hg^{II} deposition (wet and dry) at Mount Bachelor was 14% (~ 2,900 milligrams per square kilometer per year (mg/km^2-year) from Asian anthropogenic emissions. Finally, the model shows that mercury reaches the Mount Bachelor location only in the form of Hg^0 and Hg^{II}; therefore, the following focuses only on these two forms of mercury.

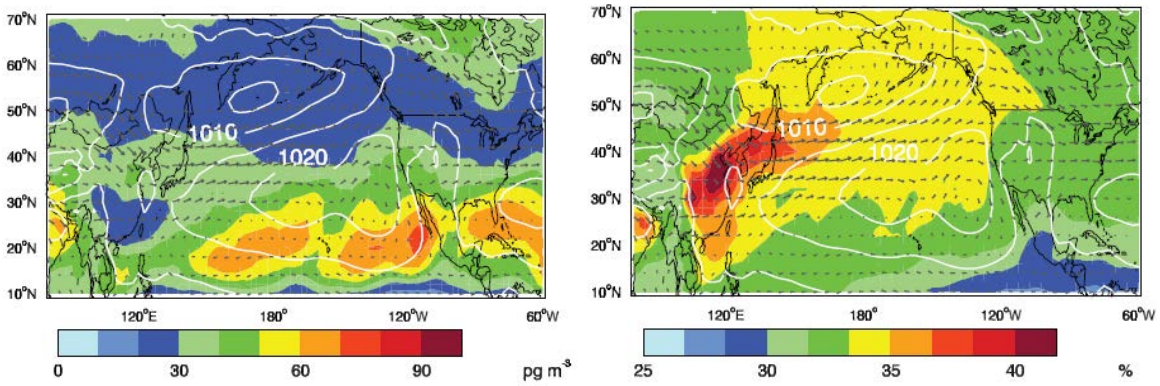
The general trans-Pacific transport of mercury from Asia to North America is shown in Figure 12. The different mechanisms by which Asian Hg^0 reaches North America affect the latitudinal distribution of their contributions. Hg^0 is transported to the northeast from Asia with the prevailing winds. Consequently, the Asian influence is largest over Alaska, western Canada, and the northwestern United States. The relative contribution of Asian emissions to the Hg^0 concentration is no more than 36%.

Figure 12. Maps of March–May 2004 Concentrations and Relative Percentage of Asian Hg^0



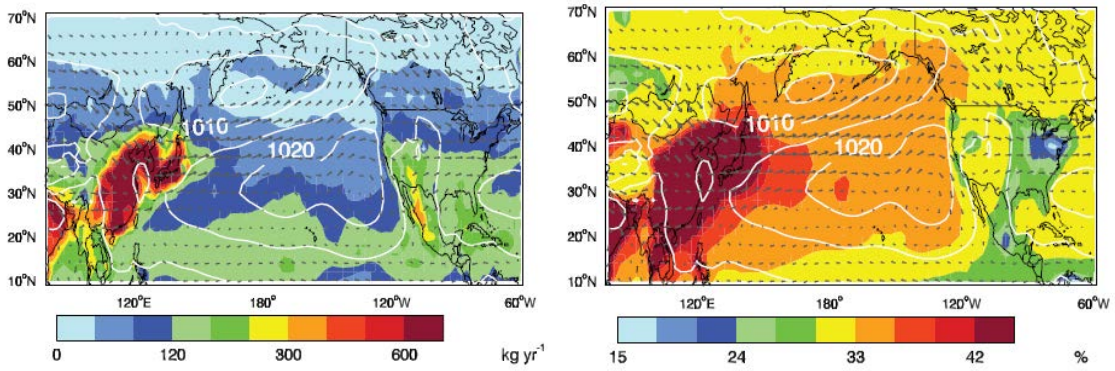
In contrast, Asian emissions influence North American Hg^{II} concentrations from oxidation of the global Asian Hg^0 pool within the atmosphere, rather than by direct transport of Hg^{II} from the emission source. The Asian Hg^{II} contribution is largest at low latitudes where high oxidant concentrations and descending dry air lead to higher concentration levels of Hg^{II} (Figure 13).

Figure 13. Maps of March–May 2004 Concentrations and Relative Percentage of Asian HgII



Asian Hg^{II} deposition follows a similar pattern to Asian Hg^{II} concentration as both wet and dry deposition depend on Hg^{II} concentrations (Figure 14).

Figure 14. Maps of March–May 2004 Concentrations and Relative Percentage of Asian Total Hg Deposition



2.3 Application of the GCTM to the Coal Market Assessment Scenarios

For each of the five SEPA Coal Market Assessment Technical Report (ICF 2017) scenarios (IPM scenarios), emissions of mercury for 2025, 2030, and 2040 were used in Equation 1 as the defining the Proposed Action's emission source strength ($EA_{MBTL,tt}$). The development methodology for the mercury emissions is described in the IPM modeling. The baseline year emission rate for the GCTM modeling was the year 2000. GCTM modeled concentration and deposition results (X_{00}) are available for just anthropogenic Hg^0 and Hg^{II}, so that each contribution to total Hg can be reported. However, X_{00} is based on total Asian Hg emissions, which include additional Asian countries where Proposed Action-related coal would not be consumed. Thus, rather than using the total Asian anthropogenic emissions, which total approximately 610 MT/year for Hg^0 and 380 MT/year for Hg^{II}, this study used a more conservative emission total for just the countries that would potentially consume the Proposed Action-related coal: Japan, Korea, China (includes Hong Kong), and Taiwan. The total Hg emission (as found in Pacyna et al. 2006) for these countries was 408 MT/year for Hg^0 and 285 MT/year for Hg^{II}. This conservatively assumes that only Asian emissions from these countries contribute to the portion of Asian mercury in Washington State. The X_{00} is based on the modeled concentrations as reported for Mount Bachelor, which lies within the same grid box as the Proposed Action.

2.3.1 Results from Scenario Comparison

To estimate the episodic concentration it was conservatively assumed that during an episode all of the impact in Washington State from Asia only occurs in the country with Proposed Action-related coal mercury emissions. This greatly increases the scaling ratio and conservatively estimates the episodic mercury impact.

Table 17 shows annual and episodic concentrations from Proposed Action source coal (Proposed Action minus the No Action) in 2025, 2030, and 2040 for Hg^0, Hg^{II}, and total Hg. Overall, the differences between the three scenarios relative to the No Clean Power Plan scenario are relatively small, with the maximum total Hg emissions ranging from 0.42 to 0.57 picogram per cubic meter (pg/m^3) and the maximum episodic emission ranging from 0.53 to 0.71 for pg/m^3. In general, the

mercury concentration remains about the same as in 2025. In all cases elemental mercury (Hg^0) is the dominate form of Hg. Strode et al. (2008) found the annual average Asian-originated Hg^0 for Mount Bachelor was 0.29 ng/m^3 or 290 pg/m^3 in 2000. Assuming that overall growth in coal burning is balanced with reductions in mercury emissions due to application of control technology implemented under the 2013 Minamata Convention on Mercury,[15] the fraction of Hg^0 exposure in Washington State from the Proposed Action in 2040 would be less than 0.2%. Similarly, the Hg^{II} annual average for Mount Bachelor is 150 pg/m^3 and the maximum Proposed Action-related concentration would be 0.039 pg/m^3 or less than 0.1%. The episodic maximum for Hg^0 shows slightly higher concentrations over the annual average; still, the maximum Hg^0 contribution of 0.82 pg/m^3 in 2025 or 0.65 pg/m^3 in 2040 from the coal exported from the proposed coal export terminal relative to the episodic Hg^0 at Mount Bachelor of 1,180 pg/m^3 is a contribution of less than 0.1%.

Table 18 shows the annual net Hg deposition amounts associated with coal (exported from the proposed coal export terminal) over Washington State for the proposed action minus the No Action by year, starting in 2025. In the first 5 years, the deposition amounts are approximately the same for the Lower and Upper Bound scenarios, while the deposition amounts for the Energy Policy and No Clean Power Plan scenarios are slightly lower. By 2040, the No Clean Power Plan shows the lowest mercury deposition, with a maximum deposition amount of 5.7 milligrams per square kilometer per year (mg/km^2/yr). The maximum mercury deposition is found for the Lower Bound scenario in 2040. This amount represents less than 0.3% of the total Asian-sourced mercury deposition over Washington State as estimated by Strode et al. (2008) at 2,900 mg/km2/yr.

2.3.2 Uncertainty

As with any estimate of impacts a level of uncertainty is inherent in the analysis. The largest source of uncertainties comes from the global estimates of mercury emissions to the air. These stem from various sources, including the availability of information on activity levels, but mainly from the lack of information concerning the mercury content of some raw materials and the validity of the assumptions regarding processes and technologies used to reduce mercury emission releases. However, recent methods used to produce the global inventory for 2010 (United Nations Environment Programme 2013) were compared with a number of national inventories and emissions reported under other systems covering the same period, and in general the level of agreement was found to be good. Other studies have also reported the average uncertainty associated with anthropogenic industrial emission of mercury at ±30% (Pirrone et al. 2010). In the Pacyna et al. (2006) study, the accuracy of the emission inventory was estimated by source categories as fuel combustion ±25%, various industrial process ±30%, and waste disposal a factor of 2–5. Note that the dominant emissions are from fuel combustion and industrial processes.

Historically, Asian emissions have been most uncertain from China given the uncertainties in activity levels due partly to the rapid changes, type, and amount of coal combusted and level of controls. However, the recent work of Zhang et al. (2015) using a probabilistic process-based approach based on information of the mercury content in fuel and raw materials, the production process, and Hg removal efficiencies obtained from field tests yielded more accurate emission

[15] The Minamata Convention on Mercury is a global treaty established to protect human health and the environment from the adverse effects of mercury. Controlling the anthropogenic releases of mercury throughout its lifecycle has been a key factor in shaping the obligations under the convention (United Nations Environment Programme 2013).

estimates and lowered uncertainties. They estimate total mercury emissions from China at 356 MT/year or about 40% lower than the number used in the GTCM modeling. The study also included was better understanding of the spatial allocation of those emissions.

Another source of uncertainty is the chemistry in the atmospheric transport model. The largest uncertainty in the atmospheric mercury models is the chemical mechanism used to determine how mercury changes forms in the air. Improved experimental data will help improve model performance by making sure that the correct reactions are simulated. The processes that lead from deposition to re-emission also need to be better understood. Advances in this area are showing improvement, with model results becoming closer to estimates based on experimental data (United Nations Environment Programme 2013). However these chemical transformation uncertainties are, in general, less than the emission inventory uncertainties.

Given these uncertainties the mercury impacts in Washington State would be within ±50% of the estimates presented earlier and could be further reduced if GCTM modeling were specifically performed to assess the impacts for the countries expected to import the coal from the proposed export terminal, by using the most recent Asian mercury inventories and applying the advances in understanding atmospheric mercury chemistry.

Table 17. Annual and Episodic Net Mercury (Hg) Concentration in Washington State as Elemental (Hg^0), Oxidized Mercury (Hg^{II}), and Total Mercury (pg/m^3) by Scenario

Hg^0	2025	2030	2040	Hg^{II}	2025	2030	2040	Hg^{Tot}	2025	2030	2040
2015 U.S. and International Energy Policy Scenario											
Annual	0.48	0.43	0.47	Annual	0.035	0.032	0.035	Annual	0.51	0.46	0.50
Episodic	0.58	0.53	0.57	Episodic	0.06	0.05	0.05	Episodic	0.64	0.58	0.62
Lower Bound Scenario											
Annual	0.51	0.51	0.53	Annual	0.038	0.038	0.039	Annual	0.55	0.55	0.57
Episodic	0.62	0.62	0.65	Episodic	0.06	0.06	0.06	Episodic	0.68	0.68	0.71
Upper Bound Scenario											
Annual	0.51	0.44	0.48	Annual	0.038	0.033	0.035	Annual	0.55	0.47	0.51
Episodic	0.62	0.54	0.58	Episodic	0.06	0.05	0.06	Episodic	0.68	0.59	0.64
No Clean Power Plan Scenario											
Annual	0.47	0.46	0.40	Annual	0.035	0.034	0.029	Annual	0.50	0.49	0.42
Episodic	0.82	0.80	0.48	Episodic	0.09	0.09	0.05	Episodic	0.91	0.89	0.53

Table 18. Annual Hg^{II} Net Deposition Amounts in Washington State (mg/km2/yr) by Scenario

2025	2030	2040
2015 U.S. and International Energy Policy Scenario		
6.8	6.2	6.7
Lower Bound Scenario		
7.3	7.3	7.6
Upper Bound Scenario		
7.3	6.3	6.8
No Clean Power Plan Scenario		
6.7	6.6	5.7

Notes:
mg/km^2yr = milligrams per square kilometer per year

Chapter 3
Sulfur Dioxide Assessment

Over two dozen peer-review publications were found during the literature review, which spanned approximately the past 15 years. The studies included SO_2 emission inventories, emission projections, coal consumption in Asia, air monitoring studies in the Pacific Northwest and across the United States for impacts associated with the long-range transport of Asian SO_2 emissions, and global transport chemical modeling studies focused on assessing the fate and transport from Asia to North America.

The following discusses the nature of the SO_2 emissions, how SO_2 behaves and changes in the atmosphere, and its form once it reaches Washington State. This discussion is followed by a description of the papers most relevant to this study, with emphasis on the key findings from those papers as used in developing the impact assessment for coal combustion related to the Proposed Action.

3.1 Introduction

Worldwide natural sources of SO_2 make up about one-quarter to one-third of the global budget. The primary sources are volcanoes and the atmospheric oxidation of oceanic dimethyl sulfide, with a small additional fraction from wildfires (Intergovernmental Panel on Climate Change 2001). Anthropogenic SO_2 emissions originate chiefly from fossil fuel combustion, with coal combustion the largest source, representing about 53% of all anthropogenic sources of SO_2 globally. Other important anthropogenic sources of SO_2 include the burning of petroleum products for both transportation and industrial process (26%) and the smelting of metals (9%). In China, the country with the highest SO_2 emission rates, coal combustions is responsible for about 84% of the total SO_2 emissions (Ohara et al. 2007).

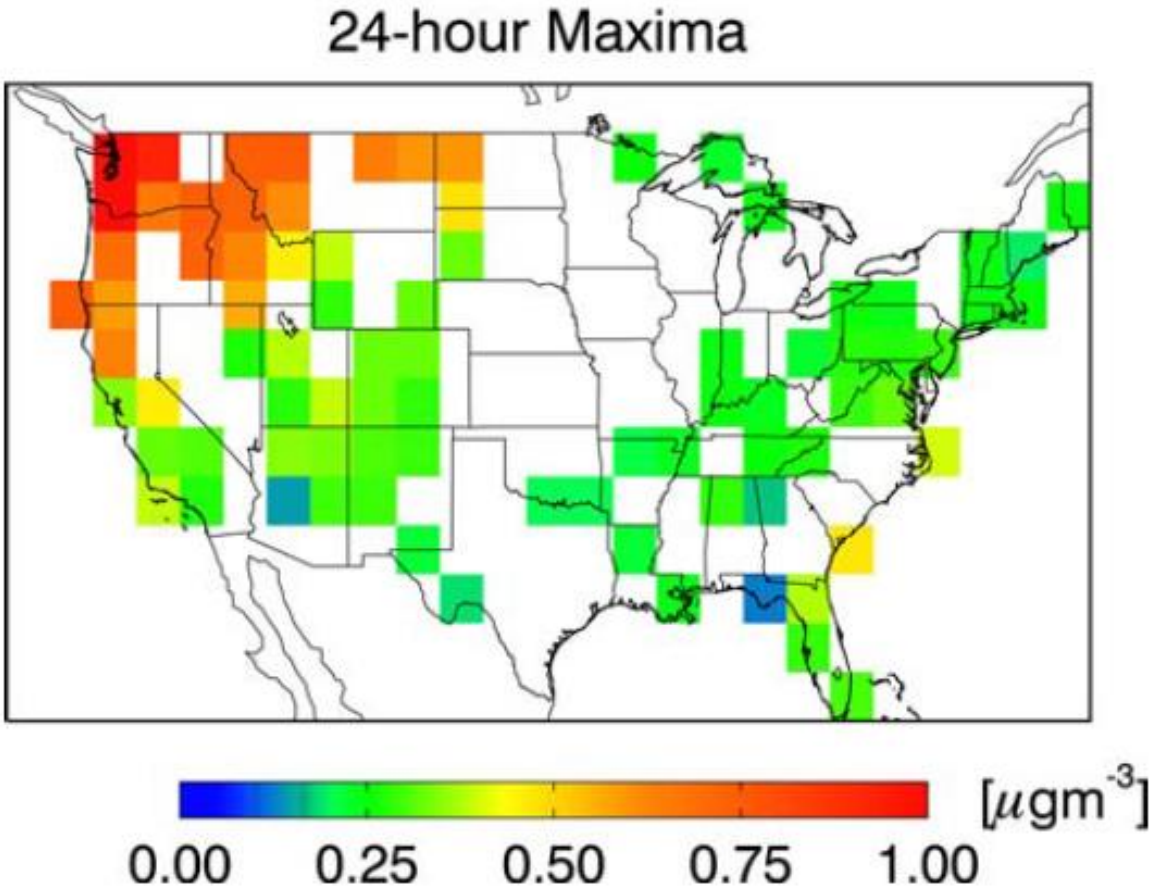
The emissions of SO_2 lead to sulfur deposition primarily in the local to regional scale, with the remainder of SO_2 converted to sulfate aerosol available for long-range transport. This availability occurs when the major SO_2 removal processes from loss to cloud droplets and rainout in the free troposphere is absent and the air is lifted above the boundary layer, preventing the other important removal process by interaction with sea salt aerosols or ocean surface. These conditions occur most frequently during the spring (Maxwell-Meier et al. 2004) and are documented in global chemical transport models. Because nearly all sulfur deposition occurs with the first 1,000 kilometers from the point of origin, sulfur deposition of Asian emissions over Washington State will not be determined.

3.2 Studies and Findings

Long-range transport of Asian anthropogenic sulfate emissions across the Pacific Ocean was first documented in the 1980s from observations at island sites (Prospero et al. 1985; Huebert et al. 2001).

Aircraft observations of transpacific Asian plumes over the northeast Pacific (Andreae et al. 1988; Price et al. 2003) provided subsequent evidence of sulfate aerosol transport in the lower free troposphere. Similarly, ground- and aircraft-based observations in the Pacific Northwest have identified episodes of trans-Pacific transport of sulfate aerosols (Jaffe et al. 2003; McKendry et al. 2008). Heald et al. (2006), using satellite imagery, GEOS-Chem (GCTM) mode, and surface air monitoring data for the western United States, demonstrated the high sulfate aerosol concentration due to trans-Pacific pollutant transport. They found that the springtime Asian sulfate aerosol enhancements were greatest in Washington State (White Pass) and southern British Columbia, with maximum 24-hour enhancements reaching approximately 1.5 µg/m^3 (Figure 15). This source-to-receptor relationship is applied to determine the contribution of the Proposed Action using Equation 1 for estimating maximum episodic impact.

Figure 15. Asian Anthropogenic Enhancements of Sulfate Concentrations in Surface Air during Spring 2001 as Simulated by the GEOS-Chem Model



Source: Heald et al. 2006.
Note: The color scale is saturated at 1 µg/m^3.

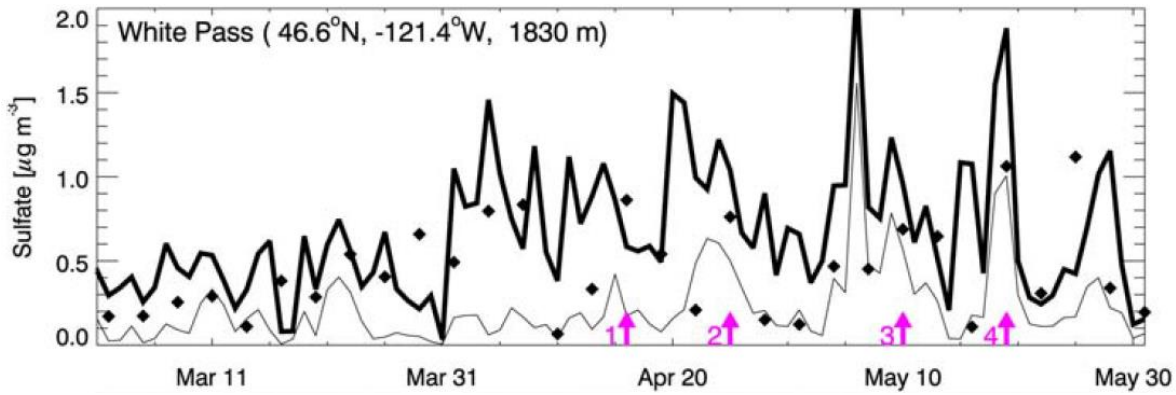
Park et al. (2004) used the GCTM model for two full-year simulations, which showed that 30% of the annual average background sulfate in both the western and eastern United States was due to trans-Pacific Asian transport. In Park et al. (2006), GCTM modeling with improved chemistry showed that the annual average sulfate concentration in the western United States due to trans-Pacific Asian

transport was 0.10 µg/m^3. This source-to-receptor relationship is value applied to determine the contribution of the Proposed Action using Equation 1.

3.3 Application of the GCTM Model to the IPM Scenarios

For each of the five IPM scenarios, emissions of SO_2 for 2025, 2030, and 2040 were used in Equation 1 as the defining emission source strength ($EA_{MBTL,tt}$) for the Proposed Action. The development methodology for the SO_2 emissions is described in the IPM modeling (ICF 2017). The baseline year emission rate for the GCTM modeling was based on 1999–2000 global anthropogenic emissions. GCTM modeled concentrations (X_{00}) are available based on total Asian SO_2 emissions, which include additional Asian countries where Proposed Action-related coal will not be consumed. Thus, rather than using the total Asian anthropogenic emissions, which totals some 42,800 MT/year, a more conservative emission total was used for just the countries that will potentially consume the coal exported from the proposed coal export terminal: Japan, Korea, China (includes Hong Kong), and Taiwan. The total SO_2 emissions (as found in Ohara et al. 2007) for these countries were 29,800 MT/year. These were adjusted downward to reflect the SO_2 emission source strength used in the GCTM by Park et al. (2006). This conservatively assumes that only Asian emissions from these countries contribute to the portion of Asian sulfate concentration in Washington State. The X_{00} is based on the modeled concentrations as reported for the western United States, as the annual average SO_2 concentration is more uniformly dispersed. To estimate the episodic concentration, based on Equation 1, the 24-hour maximum modeled sulfate concentration of 1.5 µg/m^3 (Heald et al. 2006) was used as modeled at White Pass, Washington (Figure 16).

Figure 16. Time Series of Sulfate Concentration in Surface Air at White Pass, Washington.



Note: The diamonds are observations, the thin blue line is the Asian anthropogenic contribution in the GCTM, and the thick black line the total GCTM values. The pink arrows are the start of transpacific event as observed midway in the Pacific.

Table 19 shows the annual and episodic sulfate concentrations from coal exported to Asia from the proposed coal export terminal for the Proposed Action minus the No Action by year starting in 2025. Overall, the Lower Bound and 2015 U.S. and International Energy Policy scenarios are similar in magnitude for the first 5 years. The Upper Bound and No Clean Power Plan scenarios are similar but more than double the concentrations from the Lower Bound and 2015 U.S. and International Energy Policy scenarios. By 2040, all scenarios have similar concentrations, although the No Clean Power

Plan scenario has the lowest concentrations amongst the four scenarios. Park et al. (2006) found the annual average Asian sulfate concentration for Washington State at 0.10 µg/m^3 or 100 ng/m^3 in 2000. Assuming that overall growth in coal combustion is balanced with reductions in SO_2 emissions due to application of additional control technology, the maximum Proposed Action coal source contribution would represent less than 0.2% of the Asian sulfate concentration in Washington State in 2040.

Episodic maximum shows substantially higher concentrations over the annual average; still, the maximum increase in sulfate concentration of 6.30 ng/m^3 in 2025 from the Proposed Action coal would represent 0.42% of the episodic maximum Asian source sulfate concentration determined at White Pass, Washington, of 1,500 ng/m^3 (Heald et al. 2006).

Table 19. Annual Sulfate Concentration in Washington State from Coal Exported to Asia from the Proposed Action-related Coal (ng/m^3) Scenario

	2025	2030	2040
2015 U.S. and International Energy Policy Scenario			
Annual	0.14	0.16	0.15
Episodic	2.12	2.38	2.21
Lower Bound Scenario			
Annual	0.13	0.13	0.16
Episodic	1.91	1.92	2.35
Upper Bound Scenario			
Annual	0.42	0.14	0.17
Episodic	6.30	2.07	2.52
No Clean Power Plan Scenario			
Annual	0.31	0.29	0.12
Episodic	4.63	4.33	1.81

Notes:
ng/cm^3 = nanogram per cubic meter

3.4 Uncertainty

As with any estimate of impacts, a level of uncertainty is inherent in the analysis. The largest source of uncertainty is associated with the Asian SO_2 emissions. One approach to estimating the level of uncertainty in the inventories is to compare the estimated SO_2 emissions developed by different researchers using different methods for development. Ohara et al. (2007) reports on inventory projects for SO_2 emissions in East Asia, presenting ranges from a low of 22.6 million MT/year to 42.9 million MT/year, with an average of 31.5 million MT/year, suggesting an uncertainty of approximately ±35%. Historically, Asian emissions have been most uncertain from China, in terms of total SO_2 emissions, due to uncertainties in activity levels, rapid changes in the type and amount of coal combusted, and level of controls. Sulfur content of Chinese coals varies from 0.6 to 2.1%. In recent years, refinements in the understanding of the sulfur content in the coal and improved understanding of coal plants control technology efficiencies and their use have led to a better understanding of the SO_2 emission rates.

Another approach to estimating uncertainty is to compare modeled versus observed sulfate for the Pacific Northwest sulfate monitoring sites. This allows an estimation of error bounds on the global chemical transport modeling to better estimate Asian sulfate pollution influence. This approach was used by Heald et al. (2006), who estimated a ±50% uncertainty in the model results for Asian sulfate enhancements over the northwest United States.

Given these level of uncertainties, the SO_2 impacts in Washington State would be within ±50% of the estimate presented earlier and could be further reduced if GCTM modeling were specifically performed to assess the impacts for the countries expected to import the Proposed Action-related coal and by using the most recent Asian SO_2 inventories.

Chapter 4
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Appendix A

Particulate Matter Measurements in Support of Assessing Coal Emissions from Haul Trains Measurements Report

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PARTICULATE MATTER MEASUREMENTS IN SUPPORT OF ASSESSING COAL DUST FROM COAL HAULING TRAINS

MEASUREMENTS REPORT



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March 31, 2015

TABLE OF CONTENTS

Section **Page**

1. INTRODUCTION
   - 1.1 Overview of the Study 1-1
   - 1.2 Overview of the Field Activities 1-1
   - 1.3 Overview of the Data Processing and Analysis 1-2

2. SAMPLING PROGRAM
   - 2.1 Sampling Strategy 2-1
   - 2.2 Measurements and Equipment 2-2

3. LABORATORY ANALYSIS
   - 3.1 Initial Testing of Coal Samples 3-1
   - 3.2 Deposition Plates 3-9
   - 3.3 Air-O-Cell CSI Air Samples 3-10
   - 3.4 MiniVol Filter Samples 3-10

4. QUALITY ASSURANCE
   - 4.1 Acceptance Tests 4-1
   - 4.2 Field Quality Assurance/Quality Control (QA/QC) 4-1
   - 4.3 Laboratory Analyses and Data Processing 4-2

5. RESULTS
   - 5.1 Train Traffic 5-1
   - 5.2 Optical Characteristics of Samples 5-3
   - 5.3 Coal Concentrations 5-5
   - 5.4 MiniVol Gravimetric Samples and DustTrak DRX Data 5-8
   - 5.5 MiniVol $PM_{2.5}$ Scanning Electron Microscopy Analyses 5-10
   - 5.6 Iron Oxide Analyses 5-14

6. KEY FINDINGS AND RECOMMENDATIONS 6-1

APPENDICES

- A SUMMARY OF ANALYTICAL RESULTS A-1
- B SAMPLE EAA ANALYTICAL REPORT – OPTICAL MICROSCOPY B-1

1. INTRODUCTION

This field study program was designed to collect information on coal dust that may emanate from passing trains hauling coal, with the focus on 1 micron and greater sized particles that may be emitted. The study was not designed to measure mass emission rate from diesel fueled locomotives, as that has been extensively studied and reliable emission rates have been developed by the U.S. Environmental Protection Agency (EPA), and the newest and future operating fleets of locomotives are all certified to the emission standards. This section provides an overview of the study performed, the field activities included in the study, and the processing and analysis of the data collected.

1.1 Overview of the Study

The overall sampling program was designed to collect data at a location in Cowlitz County under conditions that were conducive to periods when fugitive coal dust could be measured from the passing coal trains. A one-month planning window in October 2014 provided two weeks for suitable sample collection in the field. The goal was to complete the sample collection prior to the arrival of the rainy season that typically starts in October/November. Equipment was prepared in late September with the deployment to the field and start of sampling on October 1, 2014. The primary sampling was conducted during the first half of the month, prior to the change from dry to prevailing rainy conditions. Specific train sampling was terminated on October 13 when the weather pattern shifted from a dry to wet pattern and daily rainfall began. A state of readiness was maintained until October 22, when the extended forecast showed that rainy conditions were expected to persist, and the sampling program was decommissioned.

The study was designed to measure the fugitive coal dust from passing trains hauling coal with a set of samplers on each side of the tracks to measure the upwind “background” concentrations and deposition, and the downwind concentrations and deposition, the difference being the contribution of the passing trains. A variety of sampling techniques were employed to capture the specific coal dust from the coal hauling activities. Short-term measurements using deposition plates, impaction samplers, and continuous particulate matter (PM) measurements were used to resolve individual train events, while longer averaging intervals (24-hour) of particulate matter were collected using filter-based collection media to help relate the more standard methods of measurement to the shorter term (train event) type sampling. For the duration of the study period, continuous meteorological measurements were made to aid in the analysis of wind flow and document the upwind and downwind environment during each train passing. The meteorological measurements also provided needed data on temperature, humidity, transport, and atmospheric stability that can be used in the modeling of the coal dust from the trains.

1.2 Overview of the Field Activities

The sampling network was deployed in southern Cowlitz County just north of the Lewis River. Trains hauling coal all originated from the south so that any trains reaching the region crossed the bridge over the river, giving a couple of minutes warning prior to the train arrival and final identification of the train type. Approximately 50 trains (coal, freight, and passenger) passed the sampling network each day. Over the study period, an average of two of these trains per day were hauling coal, with the arrival time of the trains being random. This required a constant

state of readiness of the sampling network for triggering a sampling event with no more than one or two minutes of advance notice.

A temporary shelter was placed at the sampling site and served as the field headquarters for the duration of the sampling program. Sample preparation, documentation, and entry of data into the project database were performed in this field headquarters. Included in the headquarters was a Digital Video Recording (DVR) system to document the train activities as well as provide an additional measure of security for the network. From this base of operations the following measurements and sampling were conducted:

- Continuous airborne particulate matter using a size-segregating laser-based optical scattering technique with data recorded at a 10-second time resolution. Measurements were made at the anticipated downwind (east) side of the tracks.
- Short-term particulate matter deposition using deposition plates on both sides of the tracks that sampled during triggered events with a coal train passage. Note: throughout the study period, only loaded coal trains passed through the study location. Thus, for the remainder of this report, "coal train" refers to a loaded coal train. In addition, all coal trains were northbound.
- Short-term airborne particulate matter on both sides of the tracks using impaction sampling techniques triggered during selected train passages.
- Long-term (24-hour) airborne particulate matter using filter-based techniques with measurements primarily focused on the anticipated downwind (east) side of the tracks.
- Meteorological measurements of wind speed, wind direction, temperature, humidity, and solar radiation at a high time resolution of 30 seconds to document the conditions during the sampling events.
- Video documentation for train identification, counting of train cars/locomotives, and calculating train speeds.
- Train speed measurements by hand-held radar.
- Bulk sample collection of selected coal samples to aid in the "fingerprinting" of coal and assessment of coal in the soil adjacent to the tracks.
- Train types and characteristics to describe the type, number of engines, number of cars, speed, and other descriptors to document the environment.

A rotating shift of three technicians provided 24-hour coverage of the field sampling effort.

1.3 Overview of the Data Processing and Analysis

All data collected during the measurement program were processed and validated prior to performing analyses. For all of the particulate sampling that required a known flow rate, the samplers were calibrated prior to, and following the sampling program using National Institute of Standards and Technology (NIST) traceable flow measurement standards. This included the real-time optical particle sampler, 24-hour filter, and impaction samplers. These calibrated flows were then used to calculate the total flow through the sampling devices and related final concentration values. Meteorological sensors were calibrated prior to the field program and the calibrations checked following the installation. The most accurate time stamp and maintenance of the time was with the digital data logger used to record the meteorological data. The time on this system was set at the program outset and used as the common time for samples collected. Data downloaded from the continuous particulate monitor were adjusted to match the digital data logger time stamp prior to the merging of the data in the final database. The final database

of this continuous data was loaded into the T&B Systems data display system, which is based on the Vista Data Vision software package. All train passage data (train arrival times) were then added to the database, with coal trains also having the time that the last car or locomotive passed. The display system then had all meteorological and DRX data merged with the train passage information, ready for analysis.

Collection of the deposition plate, impaction, and filter sampled media were all labeled with unique sample identifiers and laboratory chain of custody forms used to transfer the samples to the respective laboratories. Chester LabNet conducted the gravimetric analyses of the conventional MiniVol sampler filters. The vast majority of the laboratory analyses were conducted by Environmental Analysis Associates, Inc. (EAA). At EAA, the deposition plate samples were first screened optically to determine if there were visible particles collected. Plates were then rinsed with the material suspended on a slide for more detailed analysis using optical microscopy. The exposure times noted during collection were then used with exposed area in the dish to determine the deposition rate into the plates. Impaction sampled cartridges were opened and the glass cover slip removed that contained the sample and the slide prepared for analysis. Samples collected were analyzed using optical microscopy, and depending on the location of the sample and other criteria, the samples were also analyzed using Scanning Electron Microscopy (SEM), and compared against samples collected of known coal material. For the majority of the samples, the optical techniques provided the appropriate analysis results. The resulting particle counts, sizing, and estimated mass information were then used with the sample collection duration (and related flow rate) to calculate concentrations per unit volume. Longer term filter measurement samples were pre- and post-weighed by the laboratory to determine the mass increase during the sample collection and concentrations calculated based on the total flow through the samples.

Throughout the collection and data processing efforts, appropriate logs, calibration checks, and a variety of calculation cross-checks were employed to provide a quality controlled final data set for analysis. These checks included using multiple methods to calculate train speeds, duplicate counting of key trains for the number of locomotives and cars, and field and laboratory quality control samples for blanks and sample fingerprinting.

2. SAMPLING PROGRAM

The sampling program was focused on collection of airborne and deposition data for coal dust from trains specifically used for hauling coal. This section presents the sampling strategy used in designing and implementing the measurement program and the equipment used for the collection of the data.

2.1 Sampling Strategy

The goal of this study was to collect particulate matter and meteorological data along the BNSF mainline tracks during periods without precipitation and relatively low humidity, with the objective to collect up to 14 days of data during the month of October 2014, prior to the onset of the winter rainy season. Ambient air particulate matter was measured using several techniques. These included dust fall (or deposition plates), impaction samplers, filter-based collection media, and laser-based light scattering methods. The meteorology during the sampling program was documented using an on-site measurement system with sensors for wind, temperature, humidity, and solar radiation. For the entire study, video recording from multiple cameras documented the timing and speed of the trains, cargo type (passenger, freight, coal), as well as the number of engines and cars associated with each train.

A site survey was conducted at the study outset to select an appropriate location for the sampling. Several prospective sites were chosen based on Google Earth images and a field survey performed to refine the candidate sites. Key goals in selection of a sampling location included:

- Locations associated with faster train speeds and minimal braking (some braking adds sand to the braking process, which potentially increases silica levels).
- Locations adjacent to grade crossings and/or public State-owned facilities to simplify permission logistics and placement of samplers.
- Meteorology conducive to upwind/downwind sampling in as predictable a manner as possible.
- Minimal local non-train sources , such as vehicular traffic.
- Power to operate the sampling program equipment.
- Security for equipment during potential “non-attended” time periods.
- Cellular service for appropriate voice and data communications.
- Appropriate exposure for sampling on both the “upwind” and “downwind” sides of the track.
- Permission for access and operations 24-hours per day.

On the basis of the survey performed, a site was selected at the southern edge of Cowlitz County that met the goals listed above. **Figure 2-1** shows the sampling location and surrounding area. A distinct advantage of the selected site was the underpass available to allow movement to either side of the tracks when a train was present. Because of the proximity to the Lewis River, given the low terrain elevation and overall orientation of the tracks, the wind direction was anticipated to cross the tracks in a general west to east flow. Review of past data from meteorological stations in the vicinity also showed that type of flow pattern.

As the schedule for the anticipated time of passage of trains hauling coal was unknown, the sampling network was required to be in a state of attended operational readiness 24 hours per day, allowing initiation of sampling immediately when a coal train was recognized. This required 24-hour staffing of the sampling network and an immediate trigger system for train-specific sampling events based upon visual identification of the appropriate train type, with sampling starting on both sides of the tracks simultaneously.



Figure 2-1. General study area, showing the Lewis River.

The overall goal of the individual sampling events was to capture the coal dust that may be emitted as the trains hauling coal passed. The sampling was designed to monitor dust deposition at various distances away from the tracks, airborne dust concentrations downwind of the train, and a general size distribution of the aerosol on the downwind side of the tracks, both with and without train passages, and with the differing train types (passenger, coal, freight). Samples collected were analyzed for mass, particle count, and composition. For the train-specific samples, the samples were started once the front engines passed, and sampling continued for one to five minutes after the last car or locomotive passed. All of the sampling times were documented in field logs, with the timing of the events verified using the available video from the DVR system.

Summarized below is a description of the individual sampling platforms and samples collected.

2.2 Measurements and Equipment

The measurements made included the following:

- Continuous airborne particulate matter using a laser-based optical scattering technique.

- Particulate matter deposition using deposition plates.
- Short-term airborne particulate matter using impaction techniques.
- Long-term airborne particulate matter using filter-based techniques.
- Meteorology.
- Video documentation.
- Train speed by hand-held radar measurements.
- Bulk soil sample collection.

Each of these methods is described below.

Continuous Airborne Particulate Matter

At the anticipated downwind side of the tracks (east side), a TSI DustTrak DRX was located at the 45 meter "downwind" location, adjacent to the meteorological sensor mast and 24-hour MiniVol samplers. The DRX is a battery operated, data-logging, light-scattering laser photometer used commonly in air quality studies that provides real-time aerosol mass readings, simultaneously measuring both mass and size fraction in the size range cut points of PM_1, $PM_{2.5}$, PM_4, PM_{10} and "Total" size ranges. Data were collected and stored for the duration of the monitoring effort in 10-second averages. Data were downloaded from the system every three days, with a zero check and flow verification performed at each of the download times. **Figure 2-2** shows the tripod mounted case that housed the DRX, adjacent to the MiniVols and meteorological station.



Figure 2-2. Instruments placed at the anticipated downwind side of the tracks. Measurements included the real-time DRX, MiniVols, and weather station.

Particulate Matter Deposition

Particle deposition was measured using a customized sampling mechanism designed specifically for this study. While deposition sampling has been commonly conducted during air

quality studies, the operational parameters for this study were uncommon in that they required that the samplers be manually and simultaneously activated for a relatively short sample duration (typically about 7 minutes), exposing the deposition plates only when coal trains (and an occasional freight train, as a control) were passing by the sampling network. Sterile laboratory-grade 100-millimeter (mm) deposition plates were used for the sampling. The deposition plates were placed inside 150-mm-diameter round canisters, 50 mm below the lip of the canister. The height of the sample plate was 1 meter above ground level. The canister lids were in place during non-sampling periods, protecting the plates from any unwanted deposition until the desired sampling period. Opening of the sample canister to expose the plate was performed by remote control using a radio transmitter operated by the on-site technician when a desired sample period was to start. When triggered, the lid was opened by a servo that would completely remove it and leave it attached to the side of the canister, exposing the inside deposition plate to any particles that fall into the canister. The complete lid removal ensured that there was nothing above the sampler opening to influence the collection sample, such as a lid partially open.

Upon completion of the sampling period, the lids were manually placed back over the canister by the technician until the plates were retrieved. The short distance to all sample canisters allowed this covering within a few-minute time period. Upon retrieval, each of the sample plates was given a unique pre-printed identifier and sticker placed on the plate lid, and the lid placed over the sample. Rubber bands were then used to affix the plate top and bottom, and the entire unit was placed in a small zip type bag. In this manner, if a plate lid did come off during transport, the contents would be retained in the bag. **Figure 2-3** shows the sampler with the lid over the plate. **Figure 2-4** shows the exposed plate inside the sample canister. **Figure 2-5** shows the placement in the field at the location nearest to the tracks.



Figure 2-3. Deposition plate sampler with the lid covering the sampling media.



Figure 2-4. Deposition plate sampler with the lid in the off position exposing the sample plate.



Figure 2-5. Placement of two deposition plate samplers on the east side of the tracks. In this configuration, both samplers were located 5 meters from the track.

Short-Term Airborne Particulate Matter

During train passages, ambient air samples were collected using the Air-O-Cell CSI (Collector for SEM Identification) sample cartridges. The Air-O-Cell CSI sample cartridges have been used in a number of sampling programs including forensic investigation of air quality, indoor air quality studies to trace the origin of allergens and pollutants, and outdoor studies to look at ambient concentrations and counts of a variety of organic and inorganic materials. This collection media allowed an ambient air sample to be collected over a short time duration (e.g., the period of a train passage) that is not possible with conventional ambient air sampling media. The sample was collected using a "slit" type inlet with an adhesive media below the slit to capture and hold the sampled particles. The Air-O-Cell CSI has a D50 cut point of 1 micron, efficiently collecting particles greater than 1 micron on the media. The technology for collection of enough sample over the required short time duration to analyze for particles less than 1 micron, such as that performed using a pre-filter cyclone separator, does not yet exist for ambient level concentrations. **Figure 2-6** shows the sample cartridge. **Figure 2-7** provides a diagram of the air flow path through the cartridge with the impaction of the sample on the collection media.

Air flow through the Air-O-Cell CSI was provided using a 12-volt vacuum pump at a flow of 15 liters per minute (lpm). A radio receiver was mounted in the pump/battery case that provided the received signal to trigger both the Air-O-Cell CSI and the above described deposition plates simultaneously with a train passage. While the deposition canisters remained open after the

sample signal was turned off, the pump system would respond immediately to stop the sampling at the conclusion of the sampling period. **Figure 2-8** shows the pump/battery system in the case that was placed at the base of the tripod. **Figure 2-9** shows the system with the 2-meter vacuum tube leading to the sample cartridge mounted at 1.5 meters above ground level on the tripod.



Figure 2-6. Air-O-Cell CSI sample cartridge.

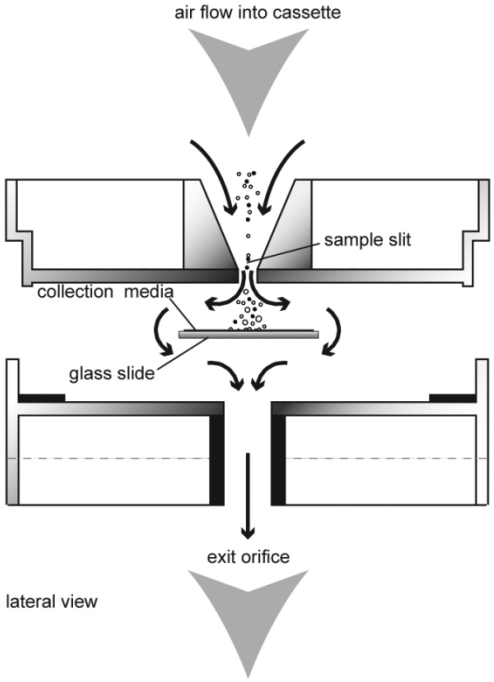


Figure 2-7. Air flow path through the Air-O-Cell CSI cartridge.



Figure 2-8. Battery and pump system with radio receiver for triggering the Air-O-Cell CSI and deposition plate samplers.



Figure 2-9. Air-O-Cell sampling system mounted on a tripod with the pump and battery in the case at the bottom of the tripod.

Long-Term Airborne Particulate Matter

Twenty-four hour average particulate matter concentrations were measured on both sides of the tracks using MiniVol medium volume samplers. These samplers have been used in many large air quality studies, collecting data that correlate well with EPA-approved reference measurement samplers. The samplers are battery powered and integrate the samples over a 24-hour period. The filter collection typically occurred from 1600 to 1600 each day with filters and batteries serviced during the change out period. On the west side (anticipated to be upwind), one $PM_{2.5}$ sampler was operated using polycarbonate filters to collect data for mass and SEM analysis to help understand the fraction of coal in a 24-hour sample relative to other particulate matter. On the east side (anticipated to be downwind), three sets of samples were collected. $PM_{2.5}$ and PM_{10} were collected on Teflon filters and an additional sampler collected $PM_{2.5}$ on polycarbonate filters, similar to the upwind location. The Teflon filters were analyzed for mass, with the option to also analyze for elemental content using XRF (X-ray fluorescence). The polycarbonate filters were analyzed using SEM for the coal fraction. Figure 1 shows the samplers on the east (anticipated downwind) side of the tracks.

Meteorology

The meteorological station consisted of a 3-meter mast for the wind sensor, and temperature, relative humidity (RH), and solar radiation measured at 2 meters. The meteorological equipment all meet EPA specifications required for air quality studies. All data were recorded on a Campbell Scientific CR1000 data logger with averaging intervals of 30 seconds and one hour. Data were downloaded from the station daily. Power for the station was provided from a solar charged battery system. The sensors used are summarized below:

- Wind speed and wind direction – RM Young 05305 AQ Wind Monitor.
- Temperature/relative humidity – RM Young Model 41382 temperature/RH sensor.
- Solar radiation – Licor LI-200.

The mounting and sensors was shown in Figure 2-2.

Video Documentation

Video images of train passages were documented using a Swann DVR9-4200 digital video recorder. The system provided motion–activated, 15 frames per second video with 960H DVD quality resolution. Infrared illumination at night provided a visual range up to 25 meters. Cameras were located in areas to allow documentation of the train types and the ability to replay the videos to count the train cars and calculate the train speeds. This video record became the primary method to perform the speed measurements and car counts for each of the coal train passages. Track distances within the field of view of key cameras were quantified and combined with the known camera frame rate to calculate the speed of the passing trains. These calculated speeds and the number of cars from the video were used for each of the train passages, except when the view was obstructed by fog. Under the foggy conditions, the in-field observations from the field technicians were used. All videos collected were converted from H.264 to AVI format for viewing in Microsoft Windows and other viewer environments.

On October 6 at 0900, camera 2 was moved closer to the tracks to obtain a closer view of the passing trains to improve the IR illumination of the cars at night. The locations of the video cameras were again changed mid-day on October 10 to further improve the train identification during the nighttime hours by having an additional camera located closer to the tracks to

optimize the network. This third camera was mounted on the RV once it too was moved closer to the tracks. During this move, cameras 1 and 2 maintained their same positions with only slight changes in rotation to optimize the pictures. The setup of the system with camera locations is shown in **Figure 2-10**. Camera 3 on the RV looked toward the northwest. Camera 1 looked to the south, while camera 2 looked to the west-southwest.

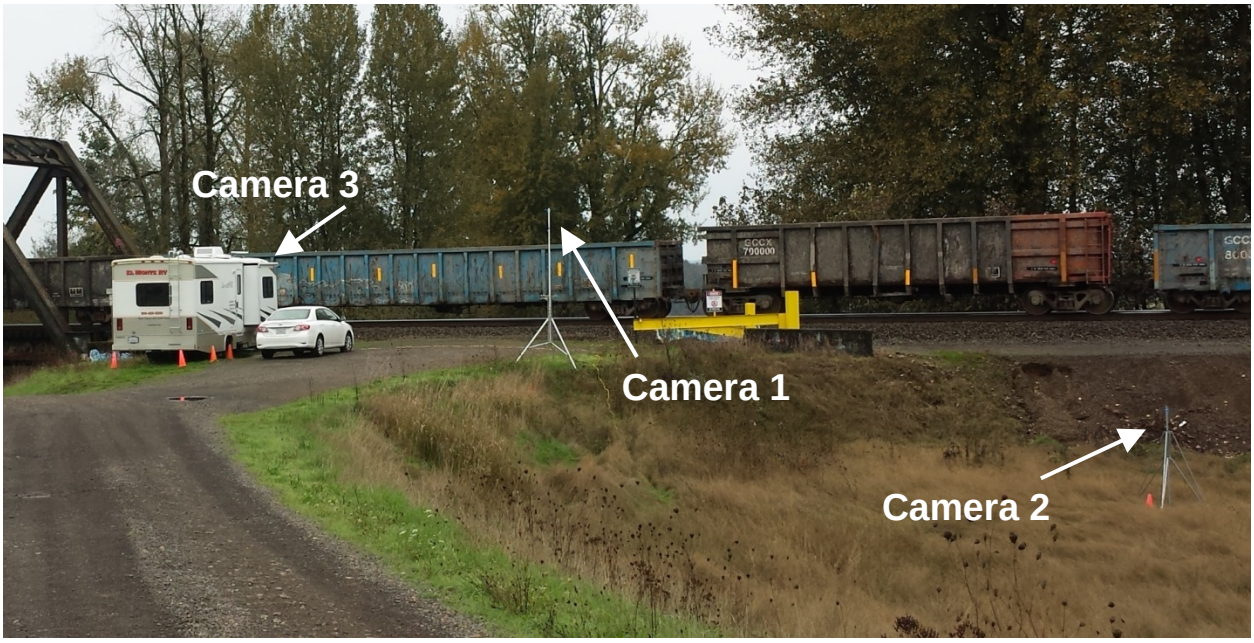


Figure 2-10. Locations of the cameras for documenting the train passages.

Train Speed by Hand-Held Radar Measurements

A Bushnell Speedster III radar speed gun was used to measure the speed of passing trains. The unit measures the relative speed of a target as it approaches (or departs) the unit. If the target is in a direct line then the measurements are accurate. Moving away from the direct line, (i.e., measuring off-axis) decreases the accuracy by biasing the measurements low. For any of the measurements made with the unit, a cosine correction for the off-axis readings was applied to maintain the accuracy of the speeds. Measurements made with the Speedster III were considered backup to the visual measurements made using the DVR post-processing method and were used when the DVR method was not possible due to video obscuration by either fog or a distance too far from the camera.

Bulk Soil Sample Collection

Two types of bulk samples were collected for analysis. The first was from visible coal at a public grade crossing between the study location and the terminus for the coal trains, with the sample placed in a plastic bag and shipped to the laboratory for analysis. This sample provided a “fingerprint” of the material that was anticipated in the both the deposition plate and Air-O-Cell CSI samples, and allowed a more positive identification of coal-like material in the microscopic analysis. The second type of bulk samples were soil samples collected at the study locations, immediately outside of the right-of-way of the rail line (about 5 meters from the rails). These samples were collected to see if there was any deposition of coal-like particles into the soil

adjacent to the tracks where the public has access. These samples are discussed in more detail in Section 3.1.

Sampling Network

The sampling network was designed to place the primary measurements in the prevailing downwind direction of the tracks, with measurements upwind to document the concentrations entering the study domain. On the basis of the original meteorological analyses, **Figure 2-11** shows the initial sampling locations. The MiniVols collected the 24-hour samples, plates and Air-O-Cell CSI units collected short-term samples, and the meteorological station was collocated with the MiniVols at the "downwind" location. Following the first several sample days, selected samples from the deposition plates were shipped to the laboratory for a preliminary screening analysis to determine what was being measured in the network and if the sampling strategy should be modified. The initial screening showed little, if any material being deposited in the plates. As a result, it was recommended that the network be moved closer to the tracks in an attempt to bring the deposition levels up to where they could be more readily detected. On October 10 the network was relocated to collect closer in samples. **Figure 2-12** shows the locations of the samplers following the move. As part of the move, an additional deposition sampler was added to the west side of the network to help capture particle fall. **Table 1-1** describes the locations of all samplers before and after the change in the network. The distances from the tracks represent the distance to the nearest rail.

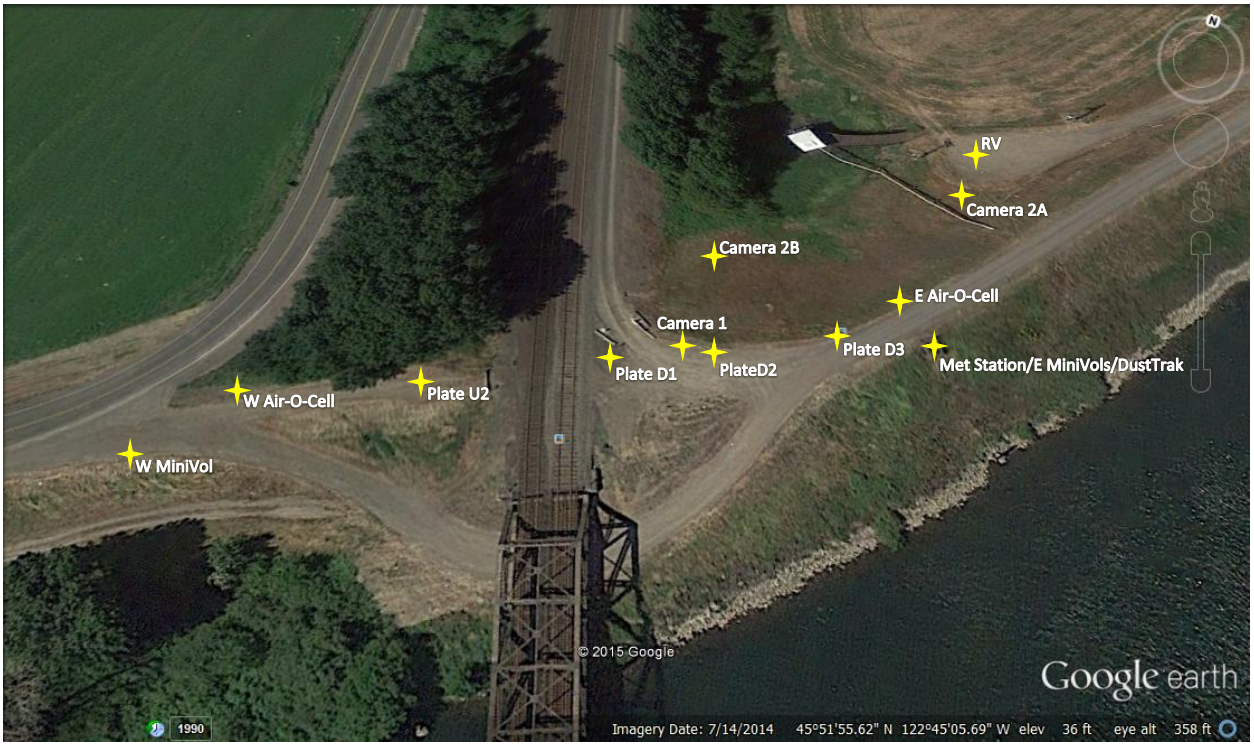


Figure 2.11. Location of the sampling network from the initial sampling on October 1 through mid-day on October 10.

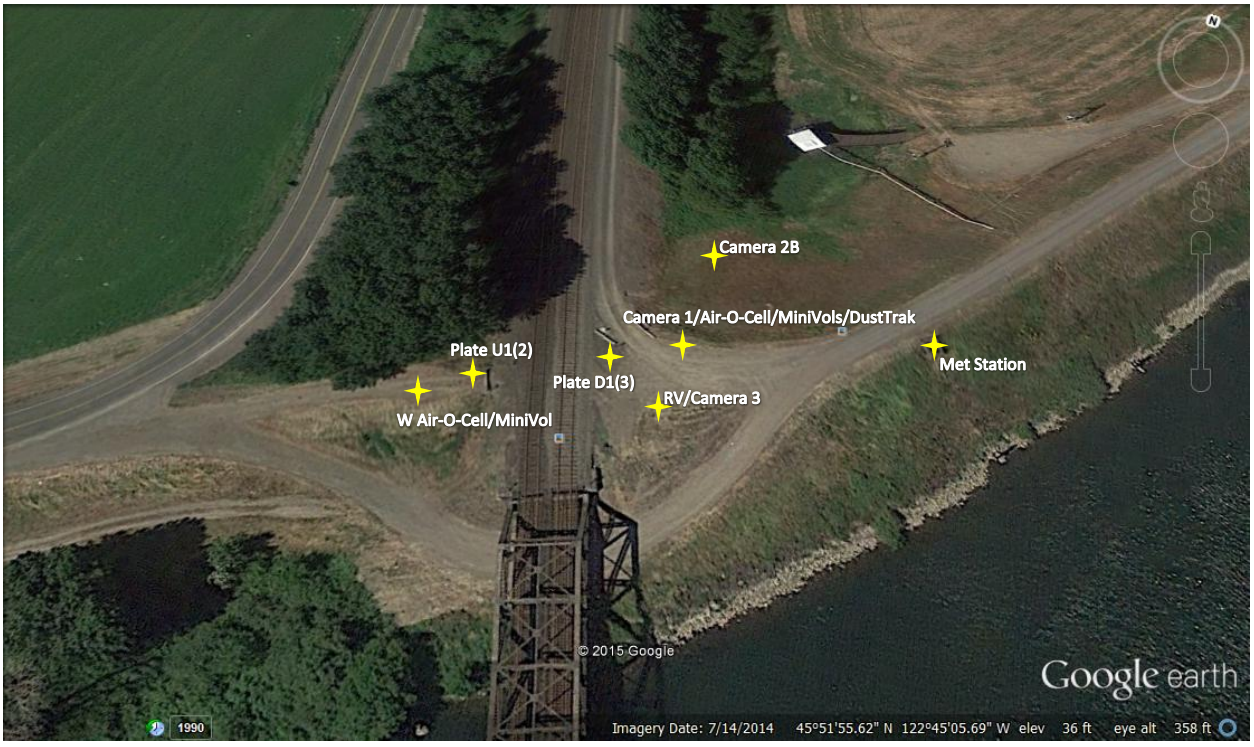


Figure 2-12. Location of the sampling network from mid-day on October 10 through the end of the sampling program.

Table 2-1. Summary of equipment.

Measurement	Measurement Location		Make/Model	Sampling parameters
	Prior to mid-day (10/10)	Starting mid-day (10/10)		
Continuous Airborne Particulate Matter	45 meters (m) east	15 m east	TSI DustTrak DRX	10-second averages
Particulate Matter Deposition	Plate 1 – 5 m east Plate 2 – 15 m east Plate 3 – 30 m east Plate 4 – 5 m west	Plate 1 – 5 m east Plate 2 – 5 m east Plate 3 – 5 m east Plate 4 – 5 m west Plate 5 – 5 m west (samples separated by 2 m)	T&B Deposition Plate Samplers	Sample is taken after the engine of a train passed the sample location and continued for a time after the last car or engine passed
$PM_{2.5}$ SEM $PM_{2.5}$ SEM $PM_{2.5}$, PM_{10} Mass	45 m west 43 m east 43 m east	15 m west 15 m east 15 m east	Airmetrics MiniVol	Integrated 24-hour samples from ~1600 to 1600 local time.
Short-term Particulate Matter	40 m west 40 m east	15 m west 15 m east	Zefon Air-O-Cell CSI with T&B Pump System	Sample is taken after the engine of a coal train passes the sample location. Analysis by optical or scanning electron microscopy.
Wind Speed	45 m east, 3 m high		RM Young 05305 AQ Wind Monitor	1-second scan, 30-second and hourly averages
Temperature	45 m east, 2 m high		RM Young Model 41382	1-second scan, 30-second and hourly averages
Humidity	45 m east, 2 m high		RM Young Model 41382	1-second scan, 30-second and hourly averages
Solar Radiation	45 m east, 2 m high		Licor LI-200 Pyranometer	1-second scan, 30-second and hourly averages

3. LABORATORY ANALYSIS

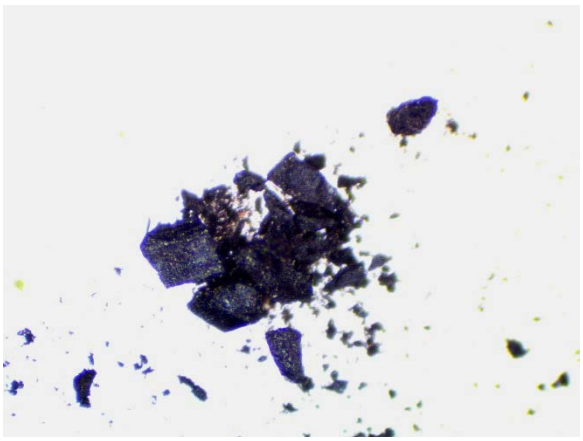
EAA developed specific analytical methods designed to evaluate the potential coal particle concentrations in the three different types of measurements and collection devices: fallout of particles (deposition plates for ~20 micrometers [µm] and larger); airborne concentrations in the optical microscopy size range (Air-O-Cell slit impaction cassettes 3–100 µm); and particles in the "respirable" size range (MiniVol samplers <3 µm). These methods were developed during the initial Optical and Scanning Electron Microscopy analysis of random coal samples, and examination of selected samples collected from the on-site monitoring.

3.1 Initial Testing of Coal Samples

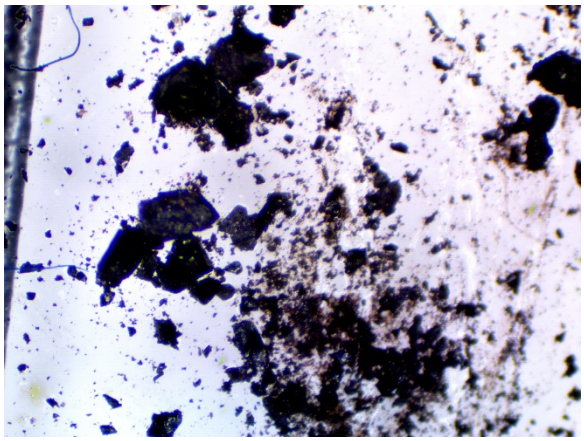
Two randomly collected coal samples were examined by both Optical and Scanning Electron Microscopy to determine the identifying properties of the coal. Based on this examination, the coal samples were found to have very similar "microscopic" and chemical (elemental) properties.

Optical Properties

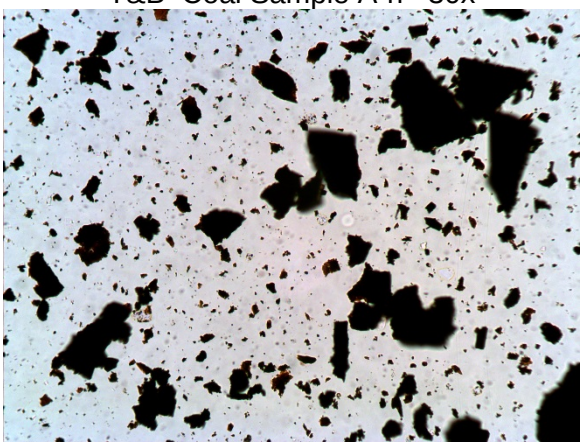
The coal samples appear granular and black/brown with an orange tint present in very thin areas of the particle. This condition was observed in both transmitted light and reflected light. Particles less than approximately 20 µm also have a brown/orange coloring and are a mixture of both angular and rounded particles. The optical properties of the coal, especially the brown-orange-tint coloration in very thin particles, can be used as an indicator to differentiate the coal from other biogenic or organic particles in the sample. Based on examination of the samples collected at the test area, similar potential "look-alike" particles were found, including fire residue, diesel soot, tire rubber, asphalt, and a significant amount of iron oxide. Iron oxide flakes were found to be a significant particle type in all of the air samples collected during the passage of trains, as well as in the bulk soil samples collected in proximity to the railroad tracks. As a result, it was very important to distinguish these particles from "coal-like" particles. Example micrographs of the coal samples and other types of "look-alike" particles are shown in **Figure 3-1**. The abbreviation "rl" refers to reflected light illumination and "bf" refers to bright field transmitted light illumination.



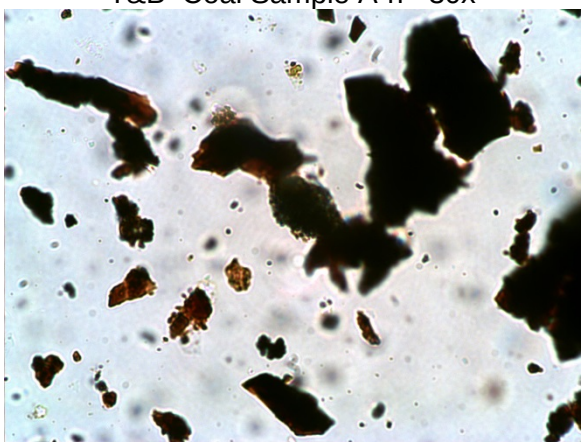
T&B Coal Sample A-rl ~30x



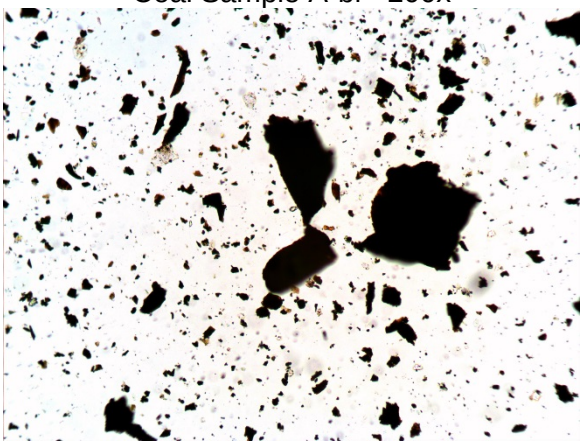
T&B Coal Sample A-rl ~30x



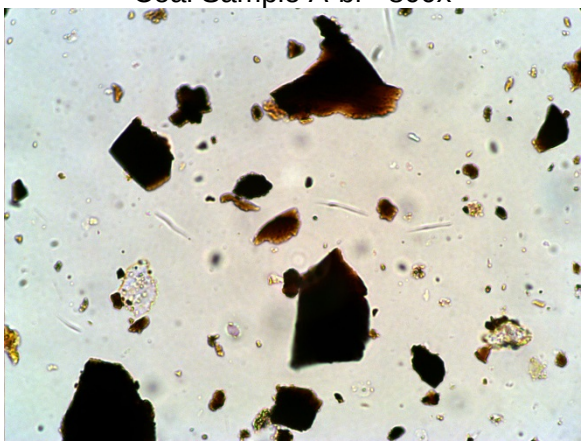
Coal Sample A-bf ~200x



Coal Sample A-bf ~800x



Coal Sample B-bf ~200x



Coal Sample B-bf ~800x

Figure 3-1. Example micrographs of coal samples under differing light and magnification.

Three bulk soil samples were also collected from the vicinity of the railroad tracks to look for the presence of coal particles. All three soil samples were obtained on the east side of the tracks, approximately 5 meters from the tracks. Locations were chosen where track ballast was light and the soil surface exposed. Soil was scraped from the top layer of these exposed areas using a clean utensil and placed in a petri dish (the same type of dish used for the deposition sampling). Review of the sample locations during a rain event revealed that the exposed area

where sample #1 was obtained consisted of a spot that runoff from the area first collected in and then flowed out of. Thus, both concentration and depletion of deposited material are a possibility at this location. The location for sample #2 was at the end of the short road leading up to the tracks, and had the possibility of being impacted by foot traffic. Of the three samples, sample #3's location appeared to be the location with the least possibility of disturbances that could potentially impact deposited concentrations. Coal was found in all three samples as well as significant amounts of iron oxide particles and the expected soil minerals including quartz and other feldspar and clay minerals. The highest relative concentrations of coal were observed in sample #1. Example micrographs of the bulk soil samples are shown in **Figures 3-2**, **3-3,** and **3-4** for each of three bulk samples.

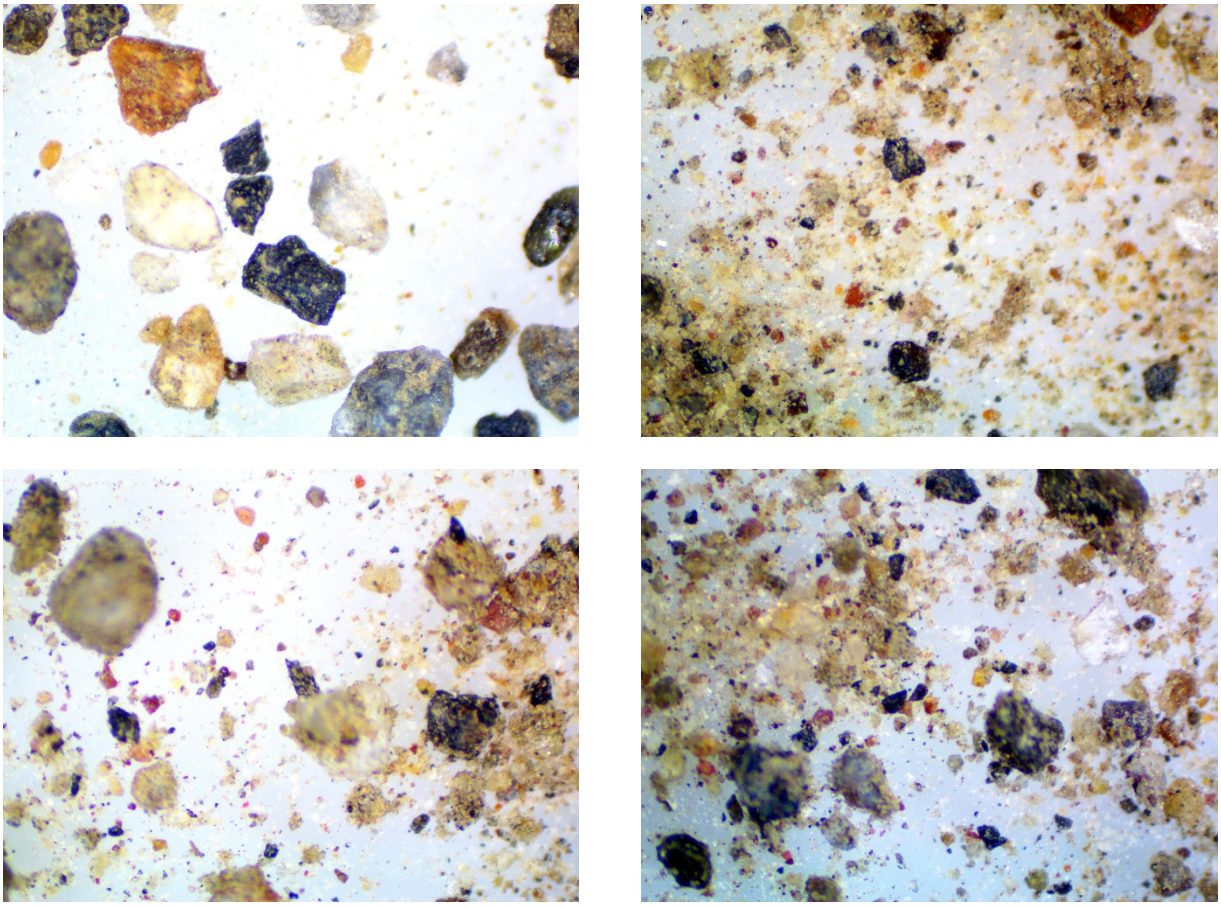


Figure 3-2. Bulk soil sample #1 – rl - 30x, with high amounts of coal and iron-oxide flakes. Horizontal field of view at 30x is 3.7 mm (3,700 µm).

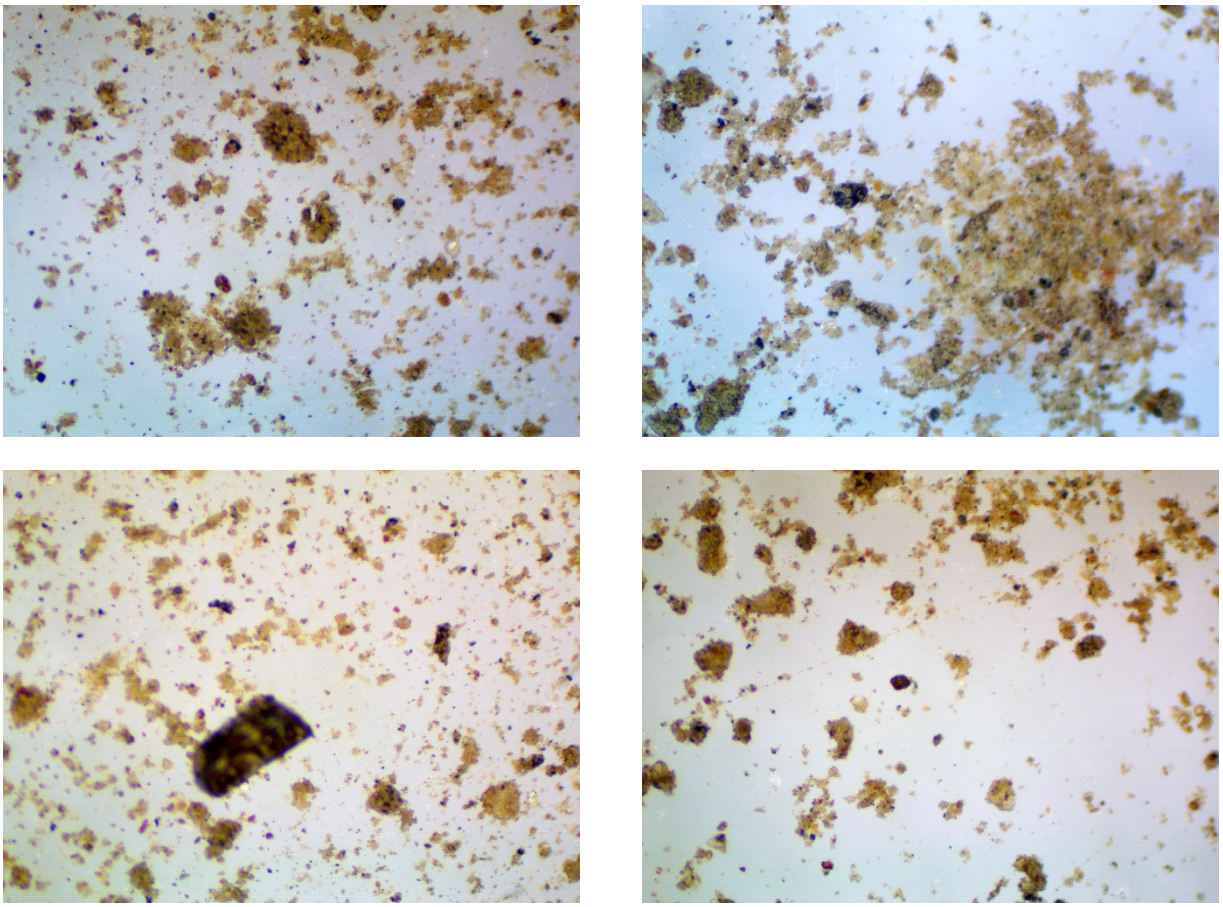


Figure 3-3. Bulk soil sample 2 – rl - 30x, with low to moderate amounts of coal and fine iron-oxide flakes.

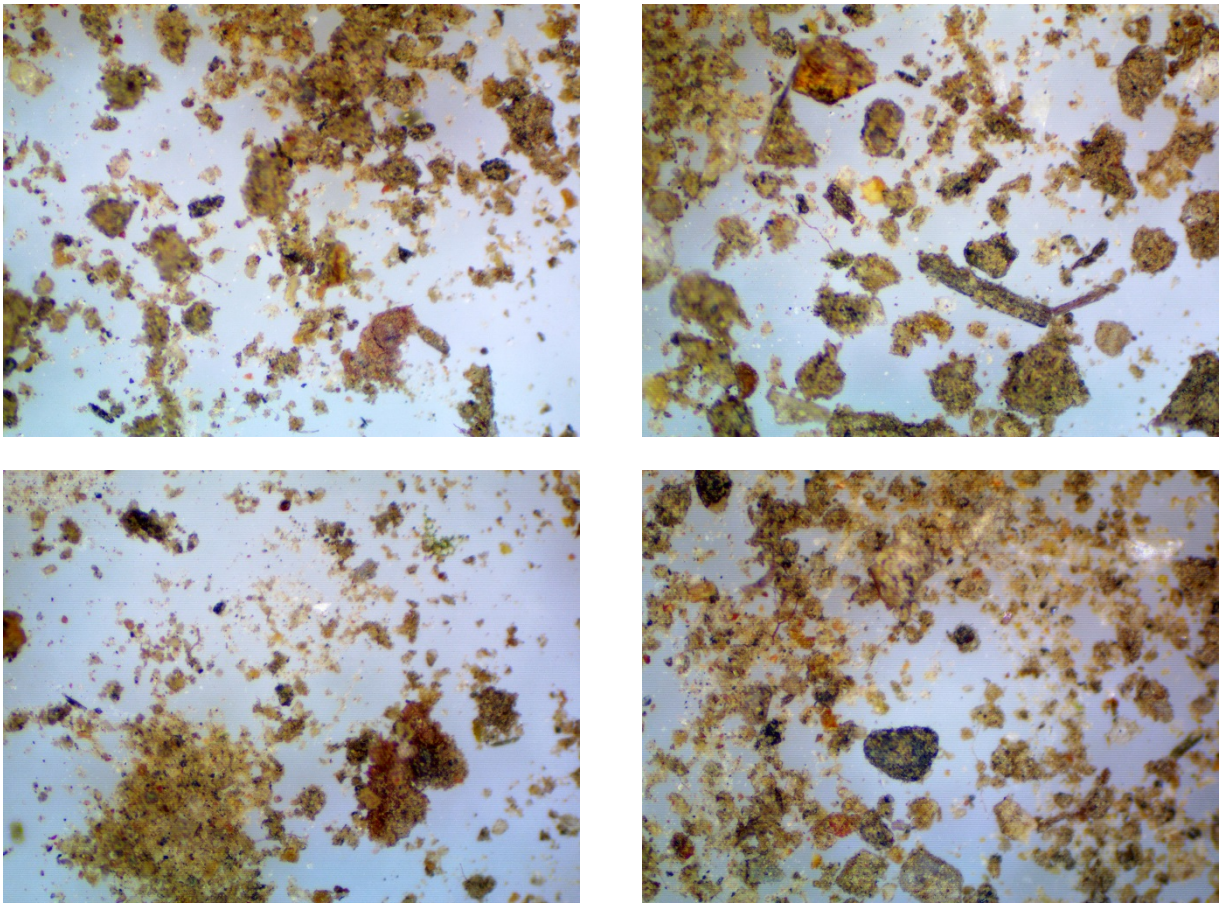
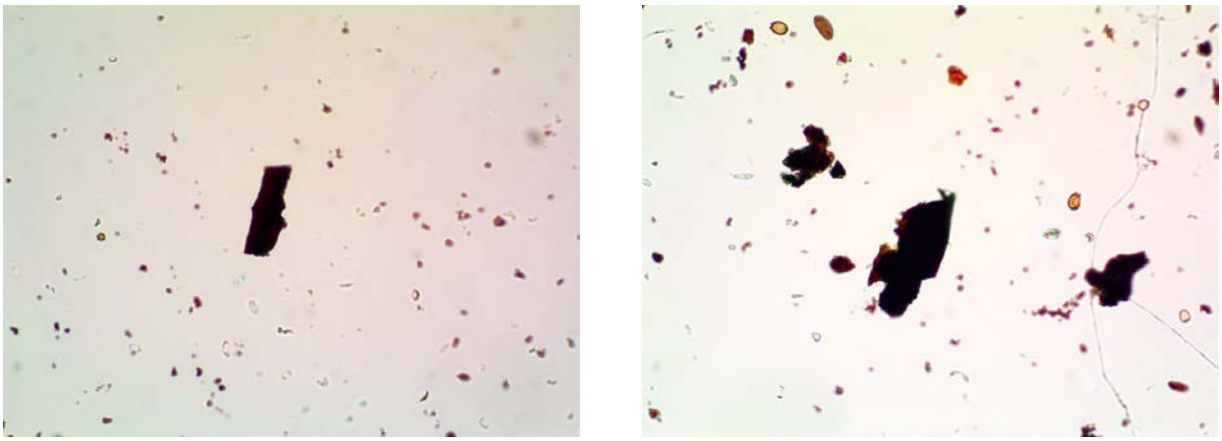


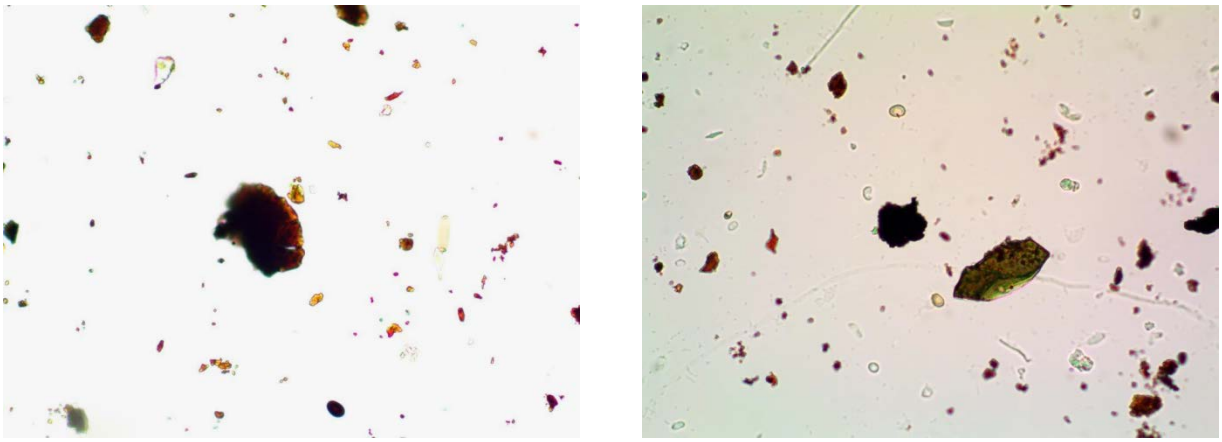
Figure 3-4. Bulk soil sample 3 – rl - 30x, with moderate amounts of coal and iron-oxide flakes.

Particle Classifications Used During Analysis

Examples of the coal-like particles (e.g. soot) encountered during the analysis and their respective classification codes are provided below in **Figure 3-5**. The coal-like particles are differentiated from the "Iron-oxide" classifications based on the uniform coloration edge texture, and internal texture observed in the coal particles and not observed in the iron-oxide particles. The iron-oxide particles have rough edge and internal texture from mechanical and corrosion "pitting."



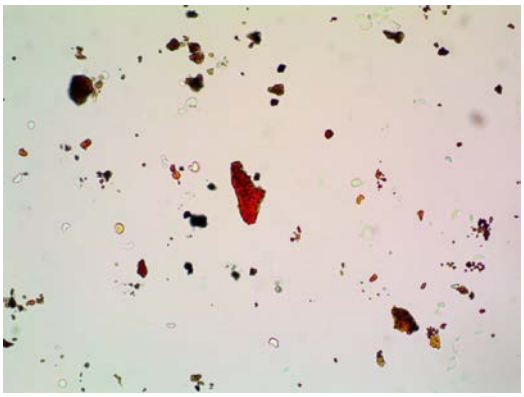
Angular “Coal-like” (AC) U4-016

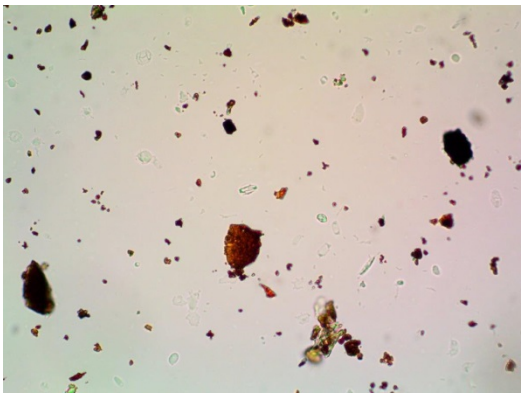


Rounded “Coal-like” (RC) U4-016

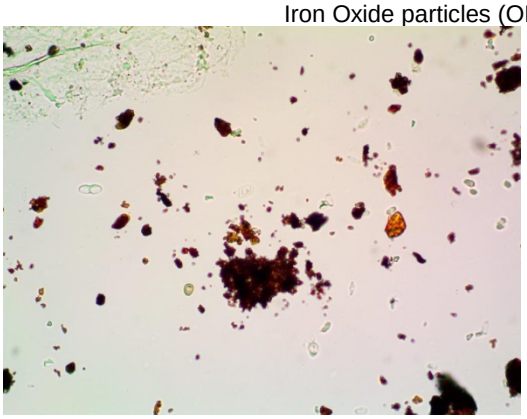
Figure 3-5. Angular (AC) and rounded (RC) samples in the same CSI sample at 600x. Horizontal field of view at 600x is 185 µm.

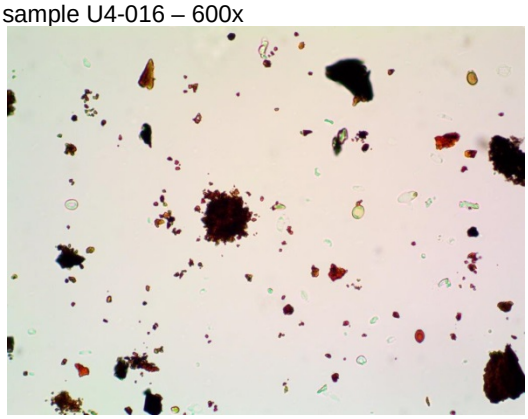
Examples of the common “non-coal” particles encountered during the analysis, and are the basis for the non-coal particle classifications, are shown in **Figure 3-6**.





Iron Oxide particles (OR) CSI air sample U4-016 – 600x

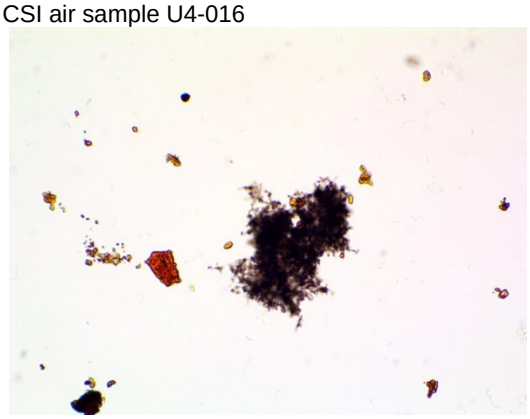




Iron Oxide cluster (OC) particles CSI air sample U4-016



Soot-like (SL) – CSI air sample 600x



~ 900x



Quartz (Q) – CSI air sample

Figure 3-6. Common non-coal particles observed in the samples.

The optical properties of actual coal samples include an orange tinged color when the thin sections or edges of the particles are examined. There is a uniform gradation of coloration from dark brown to orange with the relative thickness of particle. The interior and edge texture of the particles are relatively uniform and without any granular texture that would be indicative of corrosion or pitting. As described below, this morphology is used as an identifying feature separating the coal-like particles from other sources (e.g., diesel soot). This required the use of automated SEM/X-ray techniques to help decide on the morphological parameters required to separate coal-like from non-coal particle types.

Elemental Chemistry Properties (Dispersive X-ray Analysis)

Both of the coal samples (labeled as A & B) exhibit similar morphological and chemical properties. The compositions of both samples are a mixture of highly carbonaceous particles (over 90% carbon and oxygen), carbonaceous silicates, carbonaceous alumino-silicates (clays), and iron-containing carbonaceous silicates. Approximately 30% of the coal particles analyzed in sample B were also found to contain a simultaneous presence of iron and sulfur exceeding weight percentages of 1%. These low concentrations can only reliably be detected in particles larger than approximately 2 µm in thickness. Minor amounts of quartz, and iron oxide particles were also identified. The orange "tint" to the particles is likely due to the presence of iron in both of the coal samples.

Based on the initial X-ray analysis of both coal samples, a particle "classification" library was developed to analyze the collected air samples. The following classifications found in the coal samples were developed into a rule-based particle recognition and classification system for the automated SEM/X-ray analysis of the filter samples. A chi square fit analysis (based on the theoretical elemental weight percent) was used to "classify" particles within the sample. The major coal classifications decided upon for this project are given below:

Carbon-H	Highly carbonaceous particles (carbon/oxygen > 90%)
CMgAlFe silicate	Carbonaceous aluminum silicates (Fe and Mg present)
AlSi silicate	Aluminum silicate particles (low carbon)
MgAlSi carbon	Carbonaceous particles (MgAlSi present)
AlSiFe silicate	Aluminum silicate particles (Fe)
Quartz	Quartz – silicon dioxide
FeC oxide	Iron oxide particles with carbon present

Coal particles found with Sulfur (S) present – additional categories based on analysis of coal sample B:

AlSiS carbon	Carbonaceous coal (Al, Si and sulfur [S] present
CaFeS carbon	Carbonaceous coal (Ca, Fe, and sulfur [S] present

Because numerous "biogenic" particles in the outdoor environment may have similar carbon chemistry (carbon and oxygen ratios) when compared to the "highly carbonaceous" particles (Carbon-H) found in the source coal particles, a high percentage of these particles cannot be differentiated by the carbon/oxygen chemistry ratio alone. As a result, particles collected on air filter samples covering the "respirable" size range (<3 µm) cannot be reliably differentiated using the "Carbon-H" classification portion of the X-ray analysis. Thus, a large percentage of the highly carbonaceous particles (Carbon-H) collected over a 24-hour time period may be naturally occurring, and not from a coal source. The "Carbonaceous Silicate" classifications can be used

to differentiate coal-like from non-coal particles. Upon examination of the actual Air-O-Cell CSI air samples, the large category of potentially interfering particles has been shown to be iron oxide particles. These particles are likely related to the abrasion of the train rails and can be differentiated from the coal-like particles.

3.2 Deposition Plates

Analysis of the deposition plates showed very little "visible" particle deposition. As a result, direct analysis of the plates could not be performed. Therefore, the dust collected within the deposition plate was concentrated by washing with deionized water into a 25-mm filter funnel loaded with a 0.4 µm pore size mixed cellulose ester filter. By transferring to a filter with a smaller deposition area, the particles are concentrated by approximately 35-fold. The diameter of the deposition plate was 100 mm with an area of approximately 7854 mm^2. The deposition diameter of the transfer filter was ~17 mm with an effective area of 227 mm^2.

The filters were then dried and infiltrated with Triacetin to make them transparent for examination by optical microscopy. Potential coal particles on the filter were quantified in two (2) ways;

1) The entire filter was first screened at approximately 10x to locate any large potential coal-like particles, or areas of the filter where the particle density was highest. The field-by-field analysis was started at this location in order to have the analysis represent a worst-case scenario. The actual detection of any "large coal-like particles" using low power microscopy was a rare occurrence. Particle concentrations were quantified as the number of coal-like particle per deposition plate.

2) The size distribution of particles were calculated according to the following classifications.

   Coal-like Carbonaceous particles:

Code	Description
AC	Angular Carbonaceous – Black/brown/orange-tinged – (coal-like)
RC	Rounded Carbonaceous – Black/brown/orange-tinged – (coal-like)

   Note: The interior of the particles must have a smooth/non-corrosion morphology

   Other Potential "look-alike" particles (not associated with coal):

Code	Description
OR	Orange tinged Iron-oxide (corrosion morphology present)
OC	Orange tinged Iron-oxide aciniform cluster (corrosion morphology present)
I	Indeterminate Opaque – (likely biogenic or other brown/black particles)
SL	Soot-like black aciniform (not associated with coal)
Q	Quartz
M	Other unidentified minerals

Both Bright Field and Polarized Light Microscopy were employed during the analysis to classify and measure particles. The particles were classified using optical properties including their shape, texture, and coloration as compared to the actual submitted coal samples. The particles with coal-like morphology were then counted and sized and the results reported as a numerical concentration (particles/deposition plate). The size distribution was also reported for coal-like particles and the estimated mean particles sizes and theoretical mass concentrations of coal-like particles were reported as estimated micro-grams per settling plate (µg/plate).

3.3 Air-O-Cell CSI Air Samples

Initial examination of the Air-O-Cell CSI samples showed moderate surface particle deposition and good discrimination of coal-like particles from other biogenic particle classifications. Initial comparisons between the actual measured upwind and downwind locations showed a differential in the concentration and distribution of the particle classifications. Coal-like particles were observed to be more prevalent in the downwind samples. Both Bright Field and Polarized Light Microscopy were employed during the analysis. The same classifications for Optical Microscopy were used as with the deposition plate samples described above.

The particles with "coal-like" morphology were analyzed by Optical Microscopy using two types of reporting formats:

1). Numerical Concentrations: The numerical concentrations of particles were reported as particles/cubic meter of air (particles/m^3) in each particle classification given above, and based on the sampling times and volumes reported during sampling.

2). Size Distribution & Estimated Mass: The samples were separately analyzed for the size distribution of particles in the carbonaceous classifications (only) that are consistent with coal particles (see reports for Sample U2-025). A known percentage of the sample was analyzed and the size distribution statistics and estimated mass concentrations were calculated. The resulting mean particles sizes and theoretical mass concentrations of coal-like particles are reported as micro-grams per cubic meter of air (µg/m^3).

3.4 MiniVol Filter Samples

MiniVol filter samples were collected in an attempt to examine and chemically analyze the respirable (<3 µm) size fraction of dust emitted from the passing coal trains. The 24-hour duration MiniVol filter samples showed very low surface deposition in both the upwind and downwind locations. Any coal concentrations will also likely be masked by background biogenic particles that continue to be collected during the "non-train passage" sampling period. Because the biological particles contain carbon and oxygen ratios similar to a percentage of carbon/coal particles found in samples of the actual coal, the ability to differentiate coal-like particles from non-coal related particles was diminished. Analysis of the two collected coal samples showed high percentages of particles with primarily carbon and oxygen. These samples also showed highly carbonaceous alumino-silicate and iron silicate particles that can be readily differentiated from non-coal particles using the automated SEM analysis. However, these particles were found in a lower concentration. When these observations were combined with the dilution of "non-train passage air," the value of the MiniVol samples was significantly diminished. Collection of a sufficiently concentrated air sample in the "respirable" size range will require both a sample with more concentrated particle deposition (higher volume/flow rates), and a collection

interval that only samples during the passage of coal trains. Based on these initial observations, it was determined that further analyses of the collected MiniVol filters using SEM would provide no additional information, and no additional samples were analyzed.

It must also be recognized, that the inability to detect significant coal particles in the respirable size fraction over a 24-hour period (as measured during the initial sampling) also indicates that coal-like particles in the respirable range appears to be low.

4. QUALITY ASSURANCE

The quality assurance efforts implemented throughout the program were designed to create a data set of known quality suitable for the study goals.

4.1 Acceptance Tests

All instrumentation used for collection of data in the field underwent evaluation and acceptance testing before the start of the field program. The study included the use of automated deposition samplers that were designed and constructed specifically for this sampling effort. The TSI DustTrak DRX Aerosol Monitor used was obtained from a rental agency (EcoRental Solutions) and upon receipt was checked using the manufacturers procedures for the zero and flow checks. The instrument was then allowed to run overnight to confirm operation.

4.2 Field Quality Assurance/Quality Control (QA/QC)

Calibrations

All equipment were calibrated during installation using known standards and procedures consistent with EPA guidelines and/or manufacture recommendations:

- MiniVol Samplers – The sampler's internal flow meter (a rotameter) was calibrated against an NIST-certified Bios flow meter. Flows were confirmed to be operating within 5% of the sampler's design flow rate of 5 lpm, which is necessary for maintaining the cutpoints of the impactors.
- Air-O-Cell CIS Samplers – The operational flow rate of 15 lpm was confirmed at the beginning and end of the study using an NIST-certified Bios flow meter.
- DustTrak DRX – The operational flow rate of the DRX was verified at the beginning and end of the study using an NIST-certified Bios flow meter. The zero response of the instrument was verified using the manufacturer-supplied HEPA filter used to produce particulate-free air.
- Wind Speed – The RM Young wind speed sensor was calibrated using a certified selectable speed anemometer drive connected to the sensor shaft to simulate wind speeds the operating range of the sensor.
- Wind Direction – The RM Young wind speed sensor was calibrated by aiming the sensor at a landmark of known orientation and through rotation of the sensor to known directions and comparison to the data logger output values.
- Temperature – The RM Young temperature and relative humidity sensor was compared at multipoint points to known standards of temperature and humidity.
- Solar Radiation – The Licor pyranometer was compared to a recently certified unit at multiple times during the day.

Field QC

Study-specific sample forms were designed to collect required sampling information. In addition, the forms provided a checklist for conducting routine quality control during the study. Key elements of the quality control effort include the following:

- Battery voltages for all equipment were checked on a daily basis, and batteries changed as required.
- The zero response of the DustTrak DRX was checked every three days using the HEPA filter supplied by the manufacturer. The zero response did not deviate more than 0.001 $\mu g/m^3$ from zero over the course of the study.
- MiniVol flow rates were recorded at the beginning and end of each sample period.
- Field blanks were collected for each of the sample media used during the study, This included filed blanks for the MiniVol samplers, deposition plates, and Air-O-Cell CSI samplers. All blanks were handled in the same manner as normal samples, and in actuality were samples that for one reason or another did not have the sample pump turned on (in the case of the CSI samples) or were not exposed to ambient air (in the case of the deposition plates). Thus, using the deposition plates as an example, the blanks included the process of removing the lid of the petri dish, inserting the dish into the sampler, closing the top of the sampler, and repeating the reversed process to remove the petri dish. The samples were then analyzed by the laboratories as normal samples using the same procedures used to analyze the collected samples. No coal-like particles were found on the five blank deposition samples. Coal-like concentration for the five CSI blank samples average an equivalent concentration of 0.12 $\mu g/m^3$.

Sample Chain-of-Custody

Sample chain-of-custody was controlled from the field to the laboratory using chain-of-custody forms to document and verify handling of the sampling media.

4.3 Laboratory Analyses and Data Processing

Continuous meteorological and DRX instrumentation data were loaded into the T&B Systems data display system, which is based on the Vista Data Vision software package. All train passage data (train arrival times) were then added to the database, with coal trains also having the time that the last car or locomotive passed. This allowed for quick review of data for reasonableness and to identify any data quality issues. This review did reveal an issue with the solar radiation data where, due to an installation siting oversight, it became clear that the wind sensor shaded the radiation sensor at times, and under specific wind direction conditions. The 30-second data were edited, removing the invalid data, and the hourly averages were recalculated for solar radiation.

Data from EAA were submitted to T&B as five- to six-page reports for each sample analyzed (an example report can be found in Appendix B). Key data from these reports were then compiled into spreadsheets in order to better review the data and to allow for analysis of the data. The compiled data were verified independently by a second reviewer. Appendix A contains these summaries. An important task in this effort, given the large number of samples sent to the EAA, was to verify that reports were received for each of the samples submitted. Review of the compiled data indicated that near-zero readings for the Air-O-Cell CSI sampler located across the tracks on the west occurred during the middle of the study. This was the sampler that could not be manually confirmed to be sampling during the passage of the train, due to the number of tasks occurring during train passage sampling and the far proximity of this sampler from the other sampling efforts. Midway through the study, a disconnected wire associated with the control of this sampler was discovered, apparently due to minor vandalism and/or an inadvertent unplugging of the sampler at night. The near-zero readings correspond to three days prior to

this discovery, supporting the conclusion that sampling issues had occurred. These samples were designated as field blanks and excluded from the upwind/downwind analysis used to support the conclusions in this report.

Review of the laboratory data also revealed an issue with the calculation of mass concentrations for the deposition plate and CSI sampler data. EAA, when calculating the mass concentrations, simplified the calculations by taking a mean of the particle diameters and using this and the total number of particles identified to calculate particle volume and mass. Review showed that this approach had the possibility of significantly underreporting the mass, since mass increases as the cube of the particle radius, and even a few large particles can contribute enormously to the mass content of a sample. The analytical reports contained details on all particles identified during the analyses, including particle diameter. T&B Systems used the data in the reports to calculate the mass of each particle individually, and sum these up to obtain a more representative estimate of mass concentration for each sample.

5. RESULTS

Detailed summaries of the analytical results are presented in Appendix A. An example laboratory analysis report is presented in Appendix B..

The data supplied EAA contains considerable information regarding the deposition plate samples and Air-O-Cell CSI samples, including size distribution and particle characterization. The results presented here focus on the primary goal of the study, to characterize coal dust concentration in air and deposition from the coal hauling trains. Note that when comparing the data in Appendix A with that reported in the analytical reports, the mass concentrations in Appendix A will be higher than those in the reports for the reason discussed in Section 4.3, above.

A number of issues impacted sample collection for this study, including the following:

- While the study enjoyed 10 days of little to no precipitation, rainy weather dominated the area beginning October 14, and the study was terminated on October 20.
- In designing the study, a limited number of viable sampling locations were identified in Cowlitz County. The chosen location was picked for several reasons as described in Section 2, including that it appeared to offer the best possibility of cross-track winds, which review of available local meteorological data showed to consist of westerly winds (flowing west to east) for this time of the season. The samplers and deposition plates were laid out in a grid based on this assumption, with the majority of the measurements located on the east side of the tracks. However, winds with an easterly component were much more common during the study than anticipated based on available data, with only four of the 25 trains monitored occurring during winds with the expected westerly component. This impacted the goals in identifying gradients in deposition rates, and limited the usefulness of the DustTrak and MiniVol PM_{10} and $PM_{2.5}$ data.
- The relative humidity at this site was higher than anticipated, with nighttime fog common during the study period. It is unknown whether this might affect release of coal from trains that passed by the monitoring location.

5.1 Train Traffic

All train traffic was recorded and documented during the 11 days of active sampling. Train traffic data are summarized in **Table 5-1**. The number of freight trains indicated includes those that were hauling coal.

Table 5-1. Train traffic during study.

Date	Type	Northbound				Southbound		
		No. of Trains	Average Speed (mph)	Average No. of Cars/Train	No. of Stopped Trains	No. of Trains	Average Speed (mph)	Average No. of Cars/Train
1-Oct	Freight	9	41	111		7	44	78
(partial day)	Passenger	2	70	11		1	70	10
2-Oct	Freight	22	41	91	2	20	37	89
	Passenger	4	61	11		6	60	10
3-Oct	Freight	26	34	94	3	20	23	90
	Passenger	4	70	11		6	70	11
4-Oct	Freight	27	37	93	1	17	31	88
	Passenger	4	61	11		5	60	12
5-Oct	Freight	21	20	108	5	13	35	89
	Passenger	5	66	13		4	68	11
6-Oct	Freight	33	33	100	4	14	34	103
	Passenger	6	60	13		6	60	11
7-Oct	Freight	29	30	94	6	19	42	79
	Passenger	5	62	12		5	66	11
8-Oct	Freight	28	38	102	3	20	42	91
	Passenger	5	67	12		5	62	12
9-Oct	Freight	28	42	89	2	21	36	98
	Passenger	5	67	12		5	68	11
10-Oct	Freight	16	34	88	2	8	36	52
	Passenger	1	74	13		0	0	0
12-Oct	Freight	23	42	98	3	10	32	86
	Passenger	5	70	11		4	62	11

Due to work north of the site, northbound trains (and only northbound trains) would sometimes stop at the location of the sampling to allow southbound trains to pass. The duration of the stop would vary from 10 to 50 minutes. This affects the average northbound freight speed because the trains that stopped were generally traveling at a lower speed than other rail traffic when they passed the sampling location. There were more northbound trains in a given day than southbound, and generally northbound trains had more cars and apparently more locomotives. About the same number of passenger trains came from the north as from the south, and their speeds were in the 65–70 mph range, with 11–13 cars.

Figure 5-1 shows the distribution of train traffic over a one-week period during the study. The plot shows that the distribution of train traffic is relatively uniform through the day. While some gaps in traffic are noted, they do not appear to be limited to a particular time of the day. Passenger train traffic is predictably limited primarily to the period from 9 a.m. to 9 p.m. Coal trains occur at a consistent rate of about two per day, though there is no apparent pattern concerning when during the day they passed.

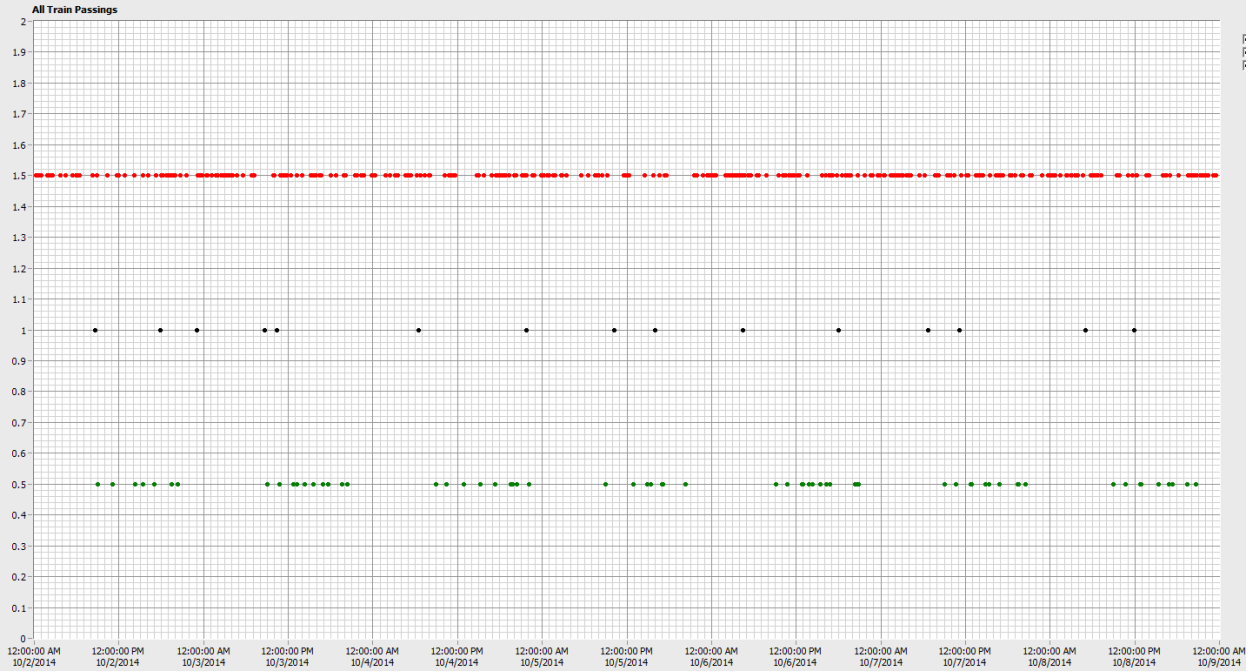


Figure 5-1. Train traffic during one-week period. Red dots = freight train; black dot = coal train; green dots = passenger train.

During the 11 days of active monitoring, 23 coal trains were observed, and samples were obtained during passage of 22 of the trains. All coal trains were northbound, and no empty coal trains were observed. **Table 5-2** presents a descriptive summary of the coal trains observed and the sampling conducted. Note that the last two trains in the summary are actually non-coal freight trains sampled as controls.

Of the 22 coal train sample sets collected, 11 where submitted to the laboratory for full analyses. These are highlighted in green in Table 5-2. The remaining 11 sample sets were not analyzed for several reasons, the most common of which was that the train stopped on the section of track being studied. Between the variable and relatively low speeds of these trains (see Table 5-2) and the confounding issues created by either sampling or not sampling while the train was stopped, it was determined that analytical data from these sample sets would not provide useful data for this study. The other reasons for not analyzing sample sets were due to measurement issues or vehicle traffic in the area adjacent to the samplers that would have confounded results.

5.2 Optical Characteristics of Samples

Deposition Plates

Based on the deposition plate analysis, quantitative information can be obtained; however, the results are likely to be less conclusive than the Air-O-Cell CSI samples because of the lower number of identifiable particles collected, and reliance on passive collection.

Table 5-2. Summary of coal train activity, and sampling and analyses activity (green highlighted sets had laboratory analysis).

						Engines		Cars				
Sample Set	Date	Arrival Time	Depart Time	Passage Time	Speed	Front	Back	Coal	Other	Total	Estimated Train Length (miles)	Comments
1	10/1/2014	18:30:17	18:32:16	0:01:59	40	3	1	126		130	1.3	
2	10/2/2014	8:34:08	8:35:55	0:01:47	44	3	1	122		126	1.3	Sampled only last 70 cars, closest plate malfunctioned
3	10/2/2014	17:53:33	17:55:07	0:01:34	53	2	2	119		123	1.4	Stopped sampling 1 minute after train passage because of road traffic.
4	10/2/2014	23:02:25	23:13:46	0:11:21	19 to 0 to 31	3	1	165		169		Train stopped
5	10/3/2014	8:38:59	8:40:38	0:01:39	43	3	1	114		118	1.2	Sampled for 89 cars. Pickup on road during sampling
6	10/3/2014	10:22:34	10:24:48	0:02:14	38	3	1	125		129	1.4	Sampled for 107 cars
8	10/4/2014	1:59:51	2:01:31	0:01:40	46	2	1	89		92	1.3	Nightime. Tech not absolutely sure cars contained coal
	10/4/2014	6:24:08	6:25:43	0:01:35	52	3	1	121		125	1.4	Not sampled because of very heavy dew
9	10/4/2014	11:43:33	11:44:27	0:00:54	38	2	0	25	24	51	0.6	Half freight, half coal
10	10/4/2014	21:46:53	22:26:31	0:39:38	15 to 0 to 26	4	0	126		130		Train stopped for 35 minutes, passed by 2 trains
11	10/5/2014	10:12:10	10:42:33	0:30:23	22 to 0 to 22	3	1	122		126		Train stopped for 25 minutes, passed by 1 train
12	10/5/2014	16:04:36	16:06:49	0:02:13	37	3	1	124		128	1.4	
13	10/6/2014	4:25:01	4:26:54	0:01:53	44	3	1	122		126	1.4	
15	10/6/2014	17:57:20	17:59:05	0:01:45	41	3	1	126		130	1.2	
16	10/7/2014	6:42:10	6:43:01	0:00:51	47	3	0	72		75	0.7	2 cars on levy road during sampling
17	10/7/2014	11:07:47	11:30:56	0:23:09	9 to 0 to 16	3	1	123		127	NA	Train stopped for 25 minutes
18	10/8/2014	5:00:14	5:01:54	0:01:40	43	3	1	125		129	1.2	
19	10/8/2014	11:55:26	12:05:14	0:09:48	13 to 0 to 16	3	1	124		128	NA	Train stopped for 5 minutes
20	10/10/2014	3:13:17	3:21:32	0:08:15	16 to 0 to 16	3	1	126		130		Train stopped for 1 minute
21	10/10/2014	5:22:42	5:24:21	0:01:39	43	3	2	124		129	1.2	
22	10/10/2014	7:30:22	7:32:07	0:01:45	40	2	2	125		129	1.2	
24	10/12/2014	12:58:01	12:59:34	0:01:33	48	3	1	122		126	1.2	New sample configuration
25	10/13/2014	9:47:54	9:49:48	0:01:54	43	3	1	125		129	1.4	New sample configuration
7	10/3/2014	16:29:18	16:31:05	0:01:47	46	2	1		112	115	1.4	Freight train
14	10/6/2014	16:13:18	16:15:03	0:01:45	38	2	1		111	114	1.1	Freight train

Examination of the initially selected deposition plate samples (both upwind and downwind) show very low but visible surface deposition of particles. The settled coal-like particles range in size from 10–50 microns. The concentration of the collected dust through filtration on to a small sized filter does provide usable particle concentrations in the locations closest to the train tracks.

Air-O-Cell CSI Air Samplers

Very low particle deposition (both upwind and downwind) was observed on the CSI impaction samples analyzed by Optical Microscopy. Although particles were visible down to approximately 1 µm, only particles greater than approximately 3 µm in diameter can be classified. Particle sizes ranged from 1 µm to approximately 100 µm. A higher ratio of particles less than 3 µm to those greater than 3 µm was observed by SEM.

24-Hour Filter Samples

Examination of the initially selected filter samples (both upwind and downwind) showed very low surface deposition of particles when examined by SEM, with the particle sizes ranging from 0.5 µm to 10 µm. The majority of the deposited particles (numerical concentration) were less than 1 µm in diameter. X-ray analysis results showed predominantly iron oxide containing particles (>80% of all particles analyzed). Lower concentrations of carbonaceous particles (biogenic mold spores, plant fragments, and insect dropping fragments) were detected. Concentrations of particles with a morphology consistent with coal particles were rarely detected.

5.3 Coal Concentrations

Table 5-3 summarizes the concentrations of coal-like material identified on the deposition plates and CSI air samples analyzed for this study. Note that in this table, “upwind” and “downwind” refer to actual meteorological conditions during sampling, based on the wind direction relative to the direction of the tracks at the sampling location (160º/340º). For example, remembering that there were three deposition plates east of the tracks and one plate west of the tracks, for Sample Set 3 when winds are coming more from the west, the three plates ended up being on the downwind side of the tracks, but end up being upwind for Sample Set 22, with winds from the east.

While the range of concentrations measured across the number of samples collected makes definitive conclusions difficult, a review of the data does point to a number of likely conclusions, as listed below:

Deposition Plates

- In reviewing the data from the plates, it is worth emphasizing that particles were rarely identifiable visually on the plates, as discussed in some detail in Section 3. In addition, it is important to note that no coal-like particles were identified in any of the field blank samples, as discussed in Section 4. Note also that all the deposition plates were all analyzed for a single coal train event.
- Looking first at data from the revised sampling configuration, concentrating on Sample Set 25, the potential for large variability in concentrations collected by different plates is readily evident. Looking at samples collected on the downwind side (as defined by the

measured wind direction) and only the material identified as coal-like, two plates located at the same distance from the track collected notably different concentrations of 2,591 µg/m^2 and 59 µg/m^2. Eighty percent of the 2,591 µg/m^2 sample is due to one 84.1 µm diameter particle (about the diameter of a human hair) that was collected on this plate. In general, deposition plates showing higher deposition concentrations are due to a large particle deposited on the sample. For example, the 2,234 µg/m^2 concentration shown for Sample Set 18 is due entirely to a single 96.7 µm diameter particle.

- Concentrating on the largest, primary data set with winds across the tracks, the data show that coal particles fall on both the upwind and downwind sides of the tracks. This is likely due to the wake created by the train itself, which was observed by the technicians conducting the sampling but not quantified during this study. The data do, however, show higher deposition on the downwind side of the train. This is most representatively observed by looking at the averages of the samplers located 15 meters from the tracks, which were obtained both upwind and downwind for all sample sets regardless of the wind direction. The average for the downwind coal-like samples is 890 µg/m^2 versus 334 µg/m^2 for the upwind samples.
- Based on the data obtained from sampling two non-coal freight trains (Sample Sets 7 and 14), concentrations of coal-like material for non-coal freight trains are lower than those for coal trains, averaging just 28 µg/m^2 for the non-coal trains, compared to either the upwind or downwind averages (334 and 890 µg/m^2, respectively) stated above.
- The data collected show apparent variability from train to train. This is demonstrated by the data from Sample Set 18, which show notably higher deposition amounts than those for the other sample sets. Conversely, results for Sample Set 1 are consistently low—at essentially the same deposition as those reported for the non-coal freight trains described above.
- The variability shown in the sampling results prevents estimation of a change in deposition as a function of distance from the track.

Air-O-Cell CSI Air Samplers

- Review of the data revealed that there was a period during which the CSI sampler west of the tracks was not operating correctly, which limits the number of sample sets that have both an upwind and downwind CSI sample. Un-run samples, however, were used instead as field blanks. Results from these field blanks showed consistently low coal-like concentrations (0.0, 0.0, 0.0, 0.0, and 0.6 µg/m^3, for an average of 0.1 µg/m^3 for the five samples).
- Despite the above issue, there were six upwind/downwind sample pairs for six individual coal train pass-bys, five of which show a significant upwind/downwind difference in concentrations. Concentrating on the primary data set obtained during across-track winds, the averaged downwind concentration is 9.4 µg/m^3 for the coal-like particles compared to 1.5 µg/m^3 for the upwind samples of coal-like particles. Sample Set 1 is the lone outlier in this data set, with upwind concentrations higher than downwind concentrations. However, it is worth noting that the crosswind component of the wind was particularly low for this sample set, with the wind speed recorded during this 2-minute period as only 0.3 meter per second, and the wind direction just 20º off of the track direction of 160º. It is possible that the train's wake played a bigger role than the winds in this case. If Sample Set 1 is removed from the calculations, the average concentrations are 11.3 and 0.6 µg/m^3 for the downwind and upwind samplers, respectively. The upwind concentrations are consistent with the concentrations measured during the non-coal freight train passages.

Table 5-3. Summary of coal-like concentrations off of coal trains.

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
Winds across tracks	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
	1	10/1/2014	1830	40	0.3	140	75	5.1	0.2	18.3	31.1	39.7		28.4	
	3	10/2/2014	1755	53	1	310	56	0.3	8.6		204.3		2.9	17.5	92.6
	6	10/3/2014	1022	38	2	20	70	1.9	5.2	45.2	121.5	1347.3		101.5	
	12	10/5/2014	1602	37	2	310	49		0.5				426.5	950.7	145.6
	13	10/6/2014	424	44	1	70	89	0.6		148.2	134.3	741.0		120.3	
	18	10/8/2014	500	43	0.9	30	87	2.5		0.0	2233.5	1399.9		6934.4	
	21	10/10/2014	521	43	0.9	60	97	0.1	19.6	11.7	17.0	40.8		1484.8	
	22	10/10/2014	730	40	1.3	80	97	0.1	22.5	76.7	55.7	31.6		379.1	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
New sampling configuration	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	15 m	15 m	5 m	5 m	5 m	5 m	5 m	5 m
Winds across tracks	25	10/13/2014	947	41	2.5	85	87	0.41	26.5	22.7	9.6	90.6	2590.9	59.4	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
Winds parallel to tracks	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
	15	10/6/2014	1800	45	1.5	340	54	15.1		38.3	56.8	155.9		33.3	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
New sampling configuration	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	15 m	15 m	5 m	5 m	5 m	5 m	5 m	5 m
Winds parallel to tracks	24	10/12/2014	1258	50	1.2	160	83	6.76		46.9	64.1	44.9	5.5	0.0	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
Freight Train	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
Winds across tracks	7	10/3/2014	1627	46	0.8	230	29		0.4	15.5	42.1	11.1		17.8	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
Freight Train	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
Winds parallel to tracks	14	10/6/2014	1613	38	2	340	49	1.1		60.7	16.5	36.3		25.3	

- Similar to the deposition plates, there is evidence of train-to-train variability in emitted coal-like concentrations. Looking at Sample Set 21, the measured downwind concentration is significantly higher than for other trains. This is supported by the downwind deposition plate for this sample set, which has one of the highest concentrations of the study. Sample Set 22 also shows both a high downwind CSI concentration and moderately high deposition plate concentrations.
- Higher concentrations were monitored by the CSI sampler when it was moved closer to the tracks (from a distance of 40 meters to a distance of 15 meters), as evidenced by the Sample Set 25 data.
- One of the goals of the study was to investigate the effect of train speed on the source strength of coal dust from the train. The small number of samples and the relatively consistent speed of the passing coal trains (averaging about 43 mph) make conclusions regarding the effect of train speed difficult. However, it can be observed that for the fast train observed (Sample Set 3 – 53 mph) the downwind concentration is amongst the highest of the study, whereas for the slowest train (Sample Set 12 – 37 mph), the downwind concentration is amongst the lowest. However, the highest concentration measured with the original configuration (22.5 $\mu g/m^3$ – Sample Set 22) occurred for a train traveling at 40 mph, indicating that speed may not be the only factor affecting coal dust source strength..
- Similarly, the data were reviewed to see if relative humidity was correlated with measured coal dust. With the highest concentrations noted during a period when relative humidity was 97% (Sample Sets 21 and 22), this does not appear to be an obvious factor based on the data collected. If average humidity during coal transport does affect coal dust source strength, measurements at a single location would not be representative of the entire haul route in any case.

5.4 MiniVol Gravimetric Samples and DustTrak DRX Data

The data collected from the DRX were anticipated to be used to help understand the differing size distribution of coal dust and particulate matter from the different train types. However, the usefulness of the data is questionable under the observed study conditions due to the high humidity during much of the study period and the resulting drift in the instrument baseline. Laser-based photometers have known issues under high humidity, and this is apparent with the collected data. Many of the nighttime and early morning hours also had extensive fog, as documented with the video taken at the site and measured relative humidity. **Figure 5-2** shows the diurnal pattern of $PM_{2.5}$ during the period of October 3 through October 6 when the largest diurnal swings in relative humidity occurred. The values are averaged RH and $PM_{2.5}$ within each of the hourly periods that reflect the close correlation of high RH values with the higher $PM_{2.5}$ values. Additionally, as the RH increases past about 90%, the noise in the values increases significantly. As a result, not much can be done to remove the influence of humidity on the data when the RH reaches 80 to 90%. This makes correlating the DRX to the collected filter samples to establish a “K” correction factor for calibration inappropriate because during the study period there were always times within each 24 hour period that had high humidity. The best use of the DRX data is therefore to look at any potential relative values during periods when the humidity was lower and wind directions were appropriate to carry coal dust from the train to the location of the DRX. Use of the DRX in future studies should be restricted to applications and time periods with lower humidity, or different instrumentation should be used to measure the size-segregated data under the varying humidity conditions in the study region.

Despite the limitations of the DRX data collected in this study, a comparison of the DRX data with the filter-based MiniVol data was conducted by calculating 24-hour average concentrations obtained from the DRX corresponding to the MiniVol sample times and comparing them with the MiniVol 24-hour averages. These results are presented in **Table 5-4**.

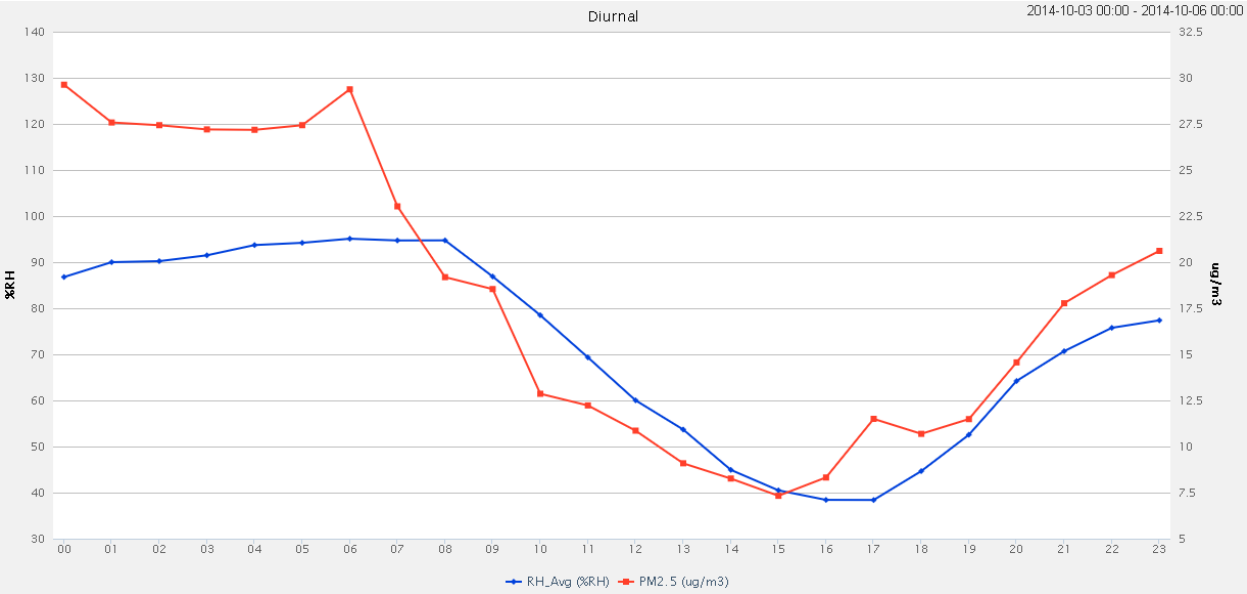


Figure 5-2. Diurnal variation of relative humidity and $PM_{2.5}$ during a three-day period showing the correlation of concentration to humidity.

Table 5-4. MiniVol/DustTrak DRX data and comparison.

		Filter (ug/m^3)		DRX (ug/m3)				Filter/DRX Ratio	
Date	RH	PM 2.5	PM 10	PM1	PM 2.5	PM 4	PM 10	PM 2.5	PM 10
10/1/2014	79.5	9.2	17.4	19.7	21.3	24.1	26.9	0.432	0.647
10/2/2014	69.2	8.6	15.2	17.7	18.7	20.7	21.2	0.460	0.717
10/3/2014	74.5	8.9	16.6	18.2	19.4	22.5	23.9	0.459	0.695
10/4/2014	72.2	11.5	20.2	16.7	17.4	18.4	19.7	0.661	1.025
10/5/2014	70	9.6	19.9	15.2	15.7	16.4	18.1	0.611	1.099
10/6/2014	74.1	7.6	17.2	13.1	14	15.7	17.9	0.543	0.961
10/7/2014	75.8	7	17.5	11.9	12.4	13.2	15.2	0.565	1.151
10/8/2014	82.4	10	14	20.7	21.7	23.2	24.4	0.461	0.574
10/9/2014	83.9	8.1	20.6	24.4	25.4	26.9	28.3	0.319	0.728
10/12/2014	84.6	19.1	16.7	18.4	19.6	20.6	21	0.974	0.795
Study Average	76.6	8.9	17.5	17.6	18.6	20.2	21.7	0.501	0.839

It should be noted that MiniVol samples were changed around 4 p.m. each day. The final sample on October 12 was actually conducted over a 32-hour period in order to include sampling through the end of the study, which was defined by an approaching rain storm.

In reviewing the data, the $PM_{2.5}$ sample dated October 12 (highlighted in yellow on Table 5-4) stands out for a number of reasons. The concentration is notably higher than that for any of the other days. In addition, it is higher than the reported PM_{10} concentration for that day, while the PM_{10} concentration appears to be very similar to those for the other days. Finally, the Filter/DRX ratio is notably different—almost twice the average. For this reason, the $PM_{2.5}$ results for October 12 are considered highly questionable, and have been removed from the calculation of the study averages.

Comparisons with the average relative humidity for the sample period revealed no definitive relationships, though there is a weak correlation between relative humidity and the Filter/DRX ratio ($r = -0.50$ and -0.68 for $PM_{2.5}$ and PM_{10}, respectively), with lower factors associated with higher relative humidity. This is consistent with observations that higher humidity causes an over-reporting of the concentration, and thus requires a lower "K" factor to correct it.

Based on the above comparison, possible "K" correction factors for the DRX data would be 0.50 for the $PM_{2.5}$ data and 0.84 for the PM_{10} data, with some possibility of adjusting these factors for humidity. However, while these factors may be fairly representative for 24-hour averages, their use for shorter time periods (e.g., 1-hour) has not been confirmed with this study.

5.5 MiniVol $PM_{2.5}$ Scanning Electron Microscopy Analyses

As discussed in Section 3.4, the usefulness of the SEM analysis of the 24-hour $PM_{2.5}$ filters collected for this study was found to be limited. This is due to the relatively small amounts of coal being emitted (two train events). Nevertheless, five samples were analyzed to explore further the potential use of this analysis as a tool to extract more information about the ambient concentrations of coal. These samples were as follows:

- Coal sample A – A portion of Coal Sample A was pulverized and fractionated by settling through a water column until the average particle diameter was less than approximately 10 µm. This sample was then analyzed by automated SEM with size discrimination to only analyze particles from 0.5 µm to 5.0 µm in diameter. This preparation procedure was performed in order to simulate coal-like particles that may be found in the "respirable" size range on the ambient air $PM_{2.5}$ samples.
- Samples U4-008 and D4-008 – A 24-hour sample pair was collected during a period when no coal trains passed.
- Samples U4-009 and D4-009 – A 24-hour sample pair was collected during a period when two coal trains passed, immediately following the sample pair above (U4-008 and D4-008). Specifically, these were the trains identified in Table 5-3, above, as Sample Sets 21 and 22, both of which showed strong upwind/downwind gradients for coal-like particles. Both trains passed under similar meteorological (upwind/downwind) conditions. Furthermore, the percentage of across-track upwind/downwind periods for this sample pair were virtually identical to the "no coal train" sample pair, above (80% toward the downwind sampler versus 20% toward the upwind sampler – a 4:1 ratio).

Analysis reports for these and other samples discussed in this section are included in Appendix C.

Figure 5-3 summarizes the results of the analysis of the coal sample. As can be seen, the composition of the coal can be divided into essentially four categories: AlSi carbon (carbonaceous aluminum silicates), Carbon H (highly carbonaceous, >80% carbon), CMgAlFe silicate (carbonaceous silicates, low concentrations of magnesium, aluminum, and iron), and quartz. However, for both CMgAlFe silicate and quartz, the concentrations are extrapolated from a single larger particle, and therefore should not be considered conclusive. Notably missing from this sample is iron oxide (FeC oxide), supporting the assumption that any iron oxide is likely coming from the steel rails.

Figure 5-4 presents a similar summary for the downwind "coal train" ambient air sample. Several differences between this sample and the coal sample are apparent. Most obvious is the increase in the percentage of Carbon H, and the notable difference in the Carbon H to AlSi carbon ratio. Almost half of the mass analyzed by SEM in the "respirable" size range was classified as Carbon H. Optical Microscopy examination of the Air-O-Cell CSI samples (as discussed in previous sections) showed that a significant percentage of carbonaceous particles are likely biologically derived (mold spores, pollen, carbonaceous fragments). The <3 µm size range of particles cannot be accurately classified by Optical Microscopy because of their small sizes. Thus, an important discriminatory was to estimate the portion of Carbon H particles that are potentially coal-like in nature versus those that are organic.

Another very noticeable difference between the two figures is the presence of iron oxide (Fe oxide) in the ambient sample, which again was not detected in the coal sample. This, again, is consistent with the assumption that the primary source of iron oxide concentrations in the air samples are from the train rails.

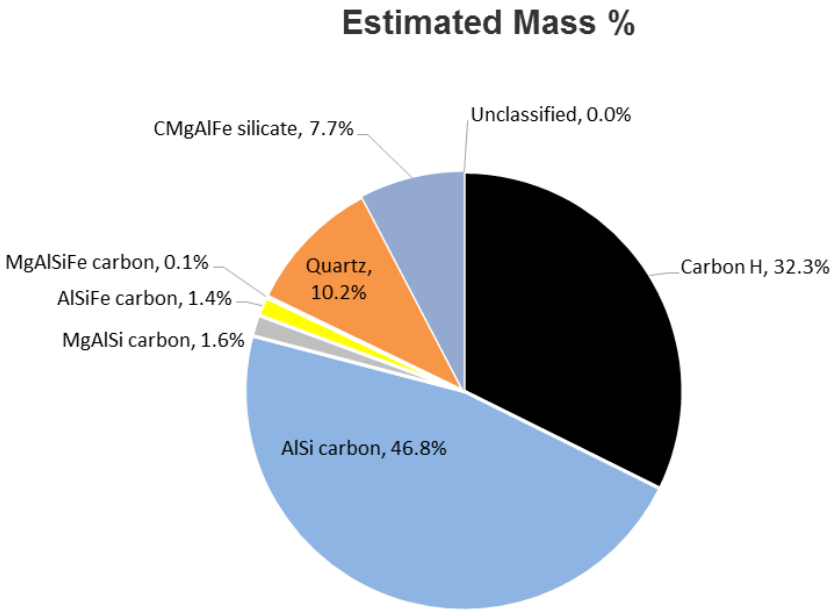


Figure 5-3. Relative mass concentration for coal sample #1 in the respirable range.

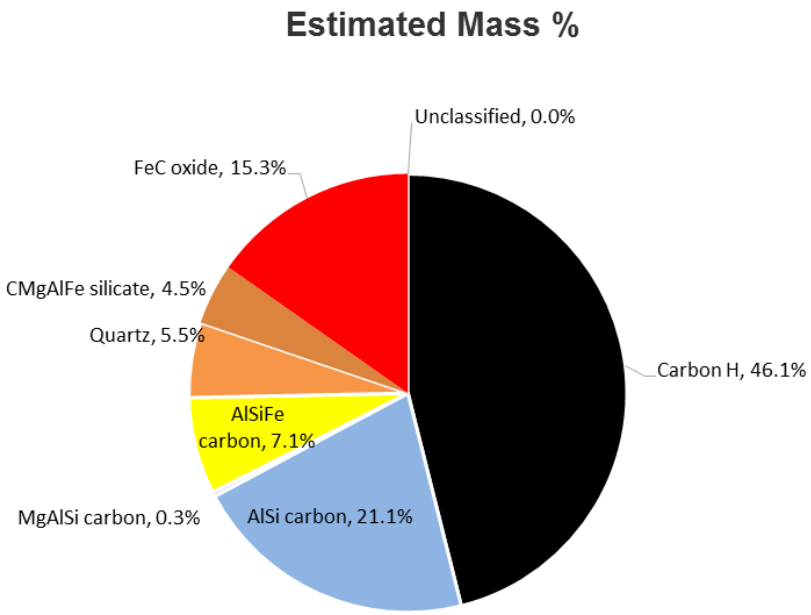


Figure 5-4. Relative mass concentration for downwind "coal train" sample.

Table 5-5 summarizes the concentration data for the five samples. The sample pair collected when no coal trains passed are very similar. The only classifications that show any significant difference between upwind and downwind concentrations are the iron classifications (FeC oxide and AlSiFe carbon), which are not unexpectedly higher downwind than upwind due to the abrasive mass loss from wheels with the steel rail. Furthermore, concentrations for this pair for the two most prevalent coal-related compounds (Carbon H, and AlSi carbon) are almost identical to the upwind sample "coal trains" sample (D4-009), supporting the conclusion that all three of these concentrations could be representative of "background" concentrations. The possible contribution due to the coal-related classifications can therefore be calculated simply as the difference between the downwind and upwind concentrations for the two coal-related classifications (Carbon H, and AlSi carbon). This produces an estimated upper bound for coal-like contribution of 1.33 µg/m^3 for two trains.

This conclusion, however, should be evaluated taking into account the limitations associated with this methodology. Based on the experience of EAA, the variability in microscopic particle counting will range from a relative standard deviation (RSD) of 0.15 to 0.30. This normal variability is essentially a 50 to 100% difference between two compared "numerical" values (i.e., the difference between detecting 5 particle counts and 10 particle counts). When this variability between numerical counts is further extrapolated to the calculation of mass concentrations, this variability will be even higher. As a result, the upwind and downwind mass concentrations given in Table 5-5 are not statistically different and are within the statistical variability of the method. In other words, the data may indicate a "trend" for the coal-like mass concentrations in a downwind sample (i.e., U4-009) to be higher than in upwind samples (D4-009). However, these two samples are not statistically different. Recognizing these limitations, and for purposes of a upper-bound analysis, it is assumed in Table 5.5 that the "trend" between upwind and downwind samples is indicative of a coal-like contribution.

Table 5-5. SEM analysis of 24-hour $PM_{2.5}$ samples (all values in µg/m^3)

Sample ID	Description	Carbon H	AlSi carbon	MgAlSi carbon	AlSiFe carbon	MgAlSiFe carbon	Quartz	CMgAlFe silicate	FeC oxide	FeMgAlSi carbon	Unclassified	Total
Coal A	Coal sample	1.130	1.630	0.050	0.050	0.000	0.360	0.270	0.000	0.000	0.000	3.490
D4-008-SEM	Upwind, no coal trains	1.205	0.451	0	0.017	0.067	0	0.045	0.010	0	0	1.795
U4-008-SEM	Downwind, no coal trains	1.014	0.541	0	0.274	0.040	0.013	0	0.109	0	0	1.991
D4-009-SEM	Upwind, 2 coal trains	0.991	0.456	0	0.336	0	0.003	0.330	0.173	0.097	0.058	2.444
U4-009-SEM	Downwind, 2 coal trains	1.907	0.874	0.014	0.296	0	0.229	0.187	0.632	0	0	4.139
	Net difference (downwind - upwind) for sample pair 009	0.916	0.418									1.334

Because the use of the Carbon H category appears to be non-specific for coal particles in the ambient environment, an effort was made to look for other chemical indicators for coal particles, particularly for vanadium and manganese, two elements that typically can be found at trace levels in coal. This investigation was performed by conducting additional SEM analyses of both coal samples A and B (labeled as coal samples #1 and #2, respectively, in the lab reports) at longer X-ray acquire times and using a particle definition library refined for identifying trace particles. While manganese and vanadium were only detected at levels greater than 1% in a single isolated particle in each sample, the analyses did reveal a potential simultaneous relationship between elevated sulfur (S >1%) and iron (Fe >4%) in many coal particles, with the ratio of sulfur to iron consistently in the 1:4 to 1:5 range. This simultaneous presence of elevated sulfur and iron was only noticeable when the analysis was performed on particles larger than approximately 2 µm, and when longer X-ray acquire times were utilized. This is directly due to the increased electron beam penetration into the background collection media when the particles are very small. As a result, the X-ray spectra reflects the carbon and oxygen chemistry of the sample media as well as the sample. This effect reduces the detection efficiency of trace elements such as sulfur. Thus, the possibility of identifying sulfur during a reanalysis of $PM_{2.5}$ sample U4-009, even using the longer X-ray acquire times and the modified definition library, was marginal at best. No sulfur containing particles (let alone the detection of both sulfur and iron) were identified in sample U4-009.

Furthermore, of the two coal samples, only coal sample B revealed the consistent presence of sulfur and iron at the ratios described above for particles greater than 2 µm. A total of 46 out of 188 particles analyzed contained S>1%, 26 of which also contained iron in the 1:4 to 1:5 ratio. In contrast, for coal sample A, while 27 of the 188 particles had S>1%, only one particle had iron at the 1:5 (sulfur to iron) ratio. The ratio of sulfur to iron is important if sulfur is to be used a potential tracer. In ambient samples, there are other particle sources that will contain sulfur or iron, and this ratio would appear to be a possible way to differentiate coal from these other sources. Thus, there is a potential in future studies to use this methodology to estimate coal contributions, provided total particulate concentrations rather than $PM_{2.5}$ are collected. The reason for the differences between the two coal samples needs to be resolved (possibly due to different coal sources) before this potential “tracer” can be used to differentiate biogenic carbon sources from coal particles.

5.6 Iron Oxide Analyses

In addition to investigating coal-like concentrations observed during the sampling effort, iron oxide concentrations were reviewed due to the likely presence of iron from the interaction between the rails and train wheels and their potential contribution to $PM_{2.5}$ and PM_{10} concentrations. **Table 5-6** summarizes the iron concentration from the deposition plate and CSI Air-O-Cell sampling. For the purposes of this table, iron oxide and iron oxide cluster concentrations have been summed into a single concentration.

- There is considerable variability in the deposition plate results, again demonstrated by the downwind results for Sample Set 25, where two similarly positioned samples collected significantly different concentrations. Furthermore, some of the highest concentrations are reported by the deposition sampler located farthest from the tracks (Sample Sets 15 and 22), with no consistent concentration gradients as a function of distance from the tracks. A likely source of this variability is due to unusually high variability in iron oxide concentrations for the sample blanks. Iron oxide concentrations for the five blank samples were as follows, with one particularly high concentration:

121.5, 0.0, 49.8, 7,596.3, and 14.2 µg/m^2. This is in stark contrast to the blank concentrations reported for coal-like particles for same plates, which averaged only 0.1 µg/m^2 for the five blank samples. Again, it should be noted that blanks were obtained using all sampling procedures short of actually exposing the sample during a train passage (see discussion in Section 4.2). It is possible that the sampling equipment's continual exposure to iron oxide, which would occur from all trains, makes it difficult to load and unload the sampler without occasionally knocking an accumulated particle off of the sampler and into the deposition plate.

- The Air-O-Cell CSI samples also show more variability and less upwind/downwind correlation in the iron oxide results than in the coal-like results. However, unlike the deposition plates, the blank samples for the CSI samples showed no elevated concentrations, averaging only 0.1 µg/m^3 for five blank samples.
- Despite the complicating issues of the deposition plate blanks, the variability noted in the iron oxide results compared against the coal-like results may be due to the source mechanism. Assuming that iron oxide concentrations are being emitted at the rail level, then dispersion of the particles is dependent on the more random winds generated by the wake of the train. In contrast, coal dust emanates predominantly from the very top of the coal cars, where local crosswinds may have a more significant influence.
- There is no apparent difference in the iron oxide concentrations between the coal trains and the non-coal (freight) trains. This is most apparent when looking at the deposition plate concentrations, with concentrations for the freight trains falling along the same range as those for the coal trains, with the same degree of variability. The CSI concentrations for the non-coal trains are on the low end, but still easily fall within the variability noted for the for coal trains.
- The relationship between the $PM_{2.5}$ and PM_{10} ratio of iron oxide could be of interest for this study. While the study took samples for these two fractions, comparison of the PM_{10} results for the CSI samples with the $PM_{2.5}$ SEM results is problematic for a number of reasons:
  - The analytical methods are inherently different. The optical method used for the CSI samples manually identifies the particles, whereas the SEM analysis automatically infers iron oxide based on the mineral analytical spectrum.
  - The sample periods are very different, with the CSI samples collected for a few minutes and only while a train is present, whereas the SEM samples are integrated over a 24-hour period, which included only about 90 minutes of the 24-hour period when trains were present.
  - Similarly, the CSI samples are obtained over a short period when winds are essentially from a given direction, whereas the 24-hour SEM samples include a mix of both upwind and downwind conditions.

  With this in mind, the SEM $PM_{2.5}$ samples U4-009 (the predominantly downwind sample) and D4-009 (the predominantly upwind sample) showed 24-hour iron oxide concentrations of 0.173 and 0.632 µg/m^3 respectively, as described in Section 5.5. Note that this is consistent with the 4:1 downwind versus upwind ratio noted for these samples. During the same period, two trains were monitored (Sample Sets 21 and 22, discussed above), with reported iron oxide concentrations of 1.8 and 13.8 µg/m^3. These concentrations represent particles predominantly in the 2.5 to 10 µm range.

Table 5-6. Iron Concentrations

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
Winds across tracks	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
	1	10/1/2014	1830	40	0.3	140	75	23.7	1.7	80.9	16.6	231.4		113.8	
	3	10/2/2014	1755	53	1	310	56	0.6	17.0		22.5		16.9	90.2	28.9
	6	10/3/2014	1022	38	2	20	70	6.3	1.7	179.1	371.1	44.6		36.3	
	12	10/5/2014	1602	37	2	310	49		98.8		806.5		4312.9	146.8	72.0
	13	10/6/2014	424	44	1	70	89	1.8		572.6	168.3	58.5		96.6	
	18	10/8/2014	500	43	0.9	30	87	6.2		70.8	28.8	18414.5		960.9	
	21	10/10/2014	521	43	0.9	60	97	0.0	13.8	2.2	3496.9	4200.0		10.2	
	22	10/10/2014	730	40	1.3	80	97	0.0	1.8	3979.4	952.6	170.5		66.2	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
New sampling configuration	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	15 m	15 m	5 m	5 m	5 m	5 m	5 m	5 m
Winds across tracks	25	10/13/2014	947	41	2.5	85	87	0.8	22.0	11.7	423.7	42.5	5514.2	252.9	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
Winds parallel to tracks	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
	15	10/6/2014	1800	45	1.5	340	54	35			1167.6		63.4	78.7	2859.4

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
New sampling configuration	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	15 m	15 m	5 m	5 m	5 m	5 m	5 m	5 m
Winds parallel to tracks	24	10/12/2014	1258	50	1.2	160	83	54.9		547.7	155.0	158.2	142.2	71.7	

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	Upwind	Downwind	Upwind			Downwind		
Freight Train	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
Winds across tracks	7	10/3/2014	1627	46	0.8	230	29		0.3		108.9		3206.2	896.9	24.9

								CSI Sampler (ug/m3)		Deposition Plates (ug/m2)					
	Sample			Speed	WS	WD	RH	East	West	East of Tracks			West of Tracks		
Freight Train	Set	Date	Time	(mph)	(m/s)	(deg)	(%)	40 m	40 m	30 m	15 m	5 m	5 m	15 m	30 m
Winds parallel to tracks	14	10/6/2014	1613	38	2	340	49	5.2			4.3		177.5	282.5	51.4

6. KEY FINDINGS

The overall sampling program was conducted during the fall of 2014. Throughout the preparatory process, a key objective was to have a monitoring system in place before the weather patterns changed from the dry summer to wet weather patterns in order to measure fugitive coal dust when they would not be mitigated by precipitation and/or high humidity. While the first half of October had favorable (dry) conditions for the study, the weather patterns shifted mid-month with a change to a rainy pattern for the latter half of the month.

The principal challenge of the study design was to attempt to measure coal dust from passing coal trains from fixed ground-based samplers located along the tracks. This operational parameter necessitated using a sampling and analysis methodology that relied on identifying individual particles collected during the train passage.

Key findings of the study can be summarized as follows:

- No coal dust was visible to the technicians in the study area, including any form of deposition on the sampling support equipment. The largest particle collected by any of the deposition plates had a diameter of 97 µm (about the diameter of a human hair), and only nine coal-like particles with diameters greater than 50 µm were identified during analysis. The largest coal-like particle identified by the CSI air sampler was 58 µm.
- Coal-like particle deposition concentrations, based on the upwind/downwind deposition plates located 15 meters from the track, averaged 400 $\mu g/m^2$ upwind and 890 $\mu g/m^2$ downwind on average per coal train. Based on the collected data, the bulk of these concentrations appear to be fugitive coal dust from the coal cars, as coal-like concentrations for deposition plates collected during non-coal train passage were notably lower (averaging 28 $\mu g/m^2$). While detectable concentrations were obtained, the measured deposition values are consistent with the lack of visual evidence of coal residual in the area.
- Air concentrations of coal-like particles greater than 3 µm, measured from samplers located 40 meters downwind from the track, averaged 11.3 $\mu g/m^3$ per coal train, compared to 0.6 $\mu g/m^3$ from similarly placed upwind samplers.
- The collected data indicate that there is train-to-train variability in the amount of coal emitted, with some coal trains showing concentrations similar to those measured for non-coal trains.

In addition to the above, the following observations were made:

- As discussed in Section 5, the usefulness of the DRX data was compromised to a significant degree by the high humidity conditions associated with season in which the study occurred and possibly inherent to the site itself. Use of the DRX in future studies should be restricted to applications that are at lower humidity, or different (and more costly) instrumentation should be used to measure the size-segregated data across varying humidity conditions.
- The use of the deposition plates successfully achieved the study goal of identifying coal dust specifically during the passage of a coal train; however, little material was collected from the approximately two loaded coal trains per day that passed by the monitoring site. While the data collected indicate that some coal particle deposition occurred, quantifying the results at the concentrations observed is somewhat problematic because a few relatively large particles collected during some sampling events can significantly affect

the interpreted results. Even if samples were combined, the total particle count is still small due to low deposition rates, which limits the quantitative conclusions that can be drawn from the data.

- The Air-O-Cell CSI method of sampling provided the best means of identifying coal-like particles given the limited amount of fugitive coal dust from the rail coal hauling operations. Given the high particle resolution for the short duration of sampling, use of this method could be further refined to help establish the gradient of airborne coal as the distance increases from the tracks, providing more definitive information than the deposition plates.

Appendix A

Summary of Analytical Results

Air-O-Cell CSI Sampler Results in µg/m^3

Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks | Dist = Distance from tracks

Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unident-ified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Acinifor m	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
1	D4-001	CSI	Up	40	ug/m3	0.3	75	40	0.3	4.8		22.8	0.9		0.3	430.0	5.1	23.7	459.1	
1	U4-001	CSI	Down	40	ug/m3	0.3	75	40	0.1	0.1		1.2	0.5		0.6	461.0	0.2	1.7	463.5	
3	D4-003	CSI	Down	40	ug/m3	1.0	56	53	5.9	2.7	7.4	15.4	1.6		855.6	10.6	8.6	17.0	899.2	Vehicle on dirt road during sampling
3	U4-003	CSI	Up	40	ug/m3	1.0	56	53	0.2	0.2	0.2	0.6			0.1	1.3	0.4	0.6	2.6	
6	D4-006	CSI	Up	40	ug/m3	2.0	70	53	0.7	1.2		2.8	3.5			1.3	1.9	6.3	9.5	
6	U4-006	CSI	Down	40	ug/m3	2.0	70	38	0.6	4.6	0.2	1.2	0.5	7.5		1.4	5.2	1.7	16.0	
7	D4-007	CSI	Down	40	ug/m3	0.8	29	46	0.3	0.1		0.3			0.2	50.0	0.4	0.3	50.9	
12	U4-012	CSI	Up	40	ug/m3	2.0	49	37								2.3	0	0.0	2.3	Sampler apparently did not run
12	D4-012	CSI	Down	40	ug/m3	2.0	49	37		0.5	0.5	88.9	9.9		0.1	77.1	0.5	98.8	177.0	
13	D4-013	CSI	Up	40	ug/m3	1.0	89	44	0.5	0.1		1.8			6.2	10.8	0.6	1.8	19.4	
14	D4-014	CSI	Parallel	40	ug/m3	2.0	49	38	0.7	0.4	0.4	2.2	3.0	1.2	0.2	1.3	1.1	5.2	9.4	
14	U4-014	CSI	Parallel	40	ug/m3	2.0	49	38	0.6	0.0		0.3			4.8	1.2	0.63	0.3	6.9	Sampler apparently did not run
15	D4-015	CSI	Parallel	40	ug/m3	1.5	54	41	14	1.1		30.8	4.2		0.6	0.4	15.1	35.0	51.1	
15	U4-015	CSI	Parallel	40	ug/m3	1.5	54	41	0.01							4.3	0.01	0.0	4.3	Sampler apparently did not run
18	D4-018	CSI	Up	40	ug/m3	0.9	87	43	0.5	2.0		5.5	0.7	0.4		6.9	2.5	6.2	16.0	
18	U4-018	CSI	Down	40	ug/m3	0.9	87	43								11.3	0	0.0	11.3	Sampler apparently did not run
21	D4-021	CSI	Up	40	ug/m3	0.9	97	43	0.1	0.0						0.6	0.1	0.0	0.7	
21	U4-021	CSI	Down	40	ug/m3	0.9	97	43	1.5	18.1		11.7	2.1	0.2		1.2	19.6	13.8	34.8	Large coal particle captured (44 um)
22	D4-022	CSI	Up	40	ug/m3	1.3	97	40	0.0	0.1				0.1		6.9	0.1	0.0	7.1	
22	U4-022	CSI	Down	40	ug/m3	1.3	97	40	0.2	22.5		1.8			0.6	4.0	22.7	1.8	29.1	Large coal particle captured (58 um)
24	D2-024	CSI	Parallel	15	ug/m3	1.2	83	48	5.67	1.1	1.4	45.5	9.4		0.8	0.4	6.76	54.9	64.3	
24	U2-024	CSI	Blank	15	ug/m3	1.2	83	48	0.001			0.3			1.8	10.6	0.001	0.3	12.7	Sampler did not run
25	D2-025	CSI	Up	15	ug/m3	2.5	87	43	0.26	0.2		0.2	0.6	1.0	0.9	6.1	0.41	0.8	9.2	
25	U2-025	CSI	Down	15	ug/m3	2.5	87	43	26.1	0.4	0.5	10.1	11.9	0.5	0.3	1.8	26.54	22.0	51.7	

Air-O-Cell CSI Sampler Results in particles/m^3

	Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks										Dist = Distance from tracks									
Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unident-ified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Acinifor m	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
1	D4-001	CSI	Up	40	P/m3	0.3	75	40	833.3	1250.0		2083.3	208.3		208.3	5416.7	2083	2291.6	10000	
1	U4-001	CSI	Down	40	P/m3	0.3	75	40	868.1	347.2	173.6	3993.1	173.6		347.2	3125.0	1215	4166.7	9028	
3	D4-003	CSI	Down	40	P/m3	1.0	56	53	2725	817	2180	5450	272		1907	4905	3542	5722.0	18256	
3	U4-003	CSI	Up	40	P/m3	1.0	56	53	163	488	349	349	23	23	558	2721	651	372.0	4674	
6	D4-006	CSI	Up	40	P/m3	2.0	70	38	3324	1995	665	6317	1995			2992	5319	8311.2	17287	
6	U4-006	CSI	Down	40	P/m3	2.0	70	38	3491	6483	2493	4488	997	1496		4987	9973	5485.3	24435	
7	D4-007	CSI	Down	40	P/m3	0.8	29	46	553	221	332	442			111	3648	774	442.0	5307	
12	U4-012	CSI	Up	40	P/m3	2.0	49	37			20					153	0	0.0	173	Sampler apparently did not run
12	D4-012	CSI	Down	40	P/m3	2.0	49	37		1562	7028	23428	2343		781	6247	1562	25771.0	41389	
13	D4-013	CSI	Up	40	P/m3	1.0	89	44	776	621		1242			931	8692	1397	1241.7	12262	
14	D4-014	CSI	Parallel	40	P/m3	2.0	49	38	1674	558	1563	4353	223	335	223	1116	2232	4576.0	10045	
14	U4-014	CSI	Parallel	40	P/m3	2.0	49	38	19	29		10			48	86	48	10.0	192	Sampler apparently did not run
15	D4-015	CSI	Parallel	40	P/m3	1.5	54	41	9601	1130	1130	31627	1130		2259	2259	10731	32757.0	49136	
15	U4-015	CSI	Parallel	40	P/m3	1.5	54	41	12			36			12	349	12	36.0	409	Sampler apparently did not run
18	D4-018	CSI	Up	40	P/m3	0.9	87	43	1042	651	521	1563	130	130		2344	1693	1693.0	6381	
18	U4-018	CSI	Down	40	P/m3	0.9	87	43								56	0	0.0	56	Sampler apparently did not run
21	D4-021	CSI	Up	40	P/m3	0.9	97	43	648	748	598	50		249		150	1396	50	2443	
21	U4-021	CSI	Down	40	P/m3	0.9	97	43	3491	1496	748	6732	499	249		748	4987	7231	13963	
22	D4-022	CSI	Up	40	P/m3	1.3	97	40	332	1108	443	55		388		499	1441	55	2826	
22	U4-022	CSI	Down	40	P/m3	1.3	97	40	1496	1828		3491		166	166	831	3324	3491	7979	
24	D2-024	CSI	Parallel	15	P/m3	1.2	83	48	5682	1420	473	24621	1894		1420	1420	7102	26515	36930	
24	U2-024	CSI	Blank	15	P/m3	1.2	83	48	10			30			30	172	10	30	242	Sampler did not run
25	D2-025	CSI	Up	15	P/m3	2.5	87	43	748	873	499	748	249	374	748	1870	1621	997	6109	
25	U2-025	CSI	Down	15	P/m3	2.5	87	43	5984	1995	499	19947	1496	499	499	1995	7979	21443	32914	

Deposition Plate Results in µg/m^2

	Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks										Dist = Distance from tracks									
Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unidentified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Acinifor m	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
1	D3-001	Plate	Up	30	ug/m2	0.3	75	40	13.6	4.7	0.1	80.9				1710.6	18.3	80.9	1809.9	
1	D2-001	Plate	Up	15	ug/m2	0.3	75	40	12.3	18.8	0.8	16.6			369.4	943.8	31.1	16.6	1361.7	
1	U2-001	Plate	Down	15	ug/m2	0.3	75	40	25.2	3.2	2.4	113.8				5484.0	28.4	113.8	5628.6	
1	D1-001	Plate	Up	5	ug/m2	0.3	75	40	36.7	3.0	13.8	231.4			578.8	4186.3	39.7	231.4	5050.0	
3	D3-003	Plate	Down	30	ug/m2	1.0	56	53	25.2	67.4	1.8	28.9			38.0	535.6	92.6	28.9	696.8692	
3	D2-003	Plate	Down	15	ug/m2	1.0	56	53	14.5	3.0	4.3	90.2			534.0	15092.1	17.5	90.2	15738.11	
3	U2-003	Plate	Up	15	ug/m2	1.0	56	53	2.8	201.5	0.2	22.5			178.2	1856.2	204.3	22.5	2261.354	
3	D1-003	Plate	Down	5	ug/m2	1.0	56	53	0.9	2.0		16.9			9924.6	1046.2	2.9	16.9	10990.6	
6	D3-006	Plate	Up	30	ug/m2	2.0	70	38	19.8	25.4	0.2	179.1			5632.8	3894.2	45.2	179.1	9751.5	
6	D2-006	Plate	Up	15	ug/m2	2.0	70	38	22.9	98.6	8.0	371.1			543.4	1174.4	121.5	371.1	2218.4	
6	U2-006	Plate	Down	15	ug/m2	2.0	70	38	4.7	96.8	1.2	36.3			1295.6	864.6	101.5	36.3	2299.2	
6	D1-006	Plate	Up	5	ug/m2	2.0	70	38	101.0	1246.3	3800.3	44.6			125.0	570.8	1347.3	44.6	5888.0	Captured 65 um coal particle
7	D3-007	Plate	Down	30	ug/m2	0.8	29	46	10.9	4.6	5.5	24.9			10.6	423.1	15.5	24.9	479.6	
7	D2-007	Plate	Down	15	ug/m2	0.8	29	46	2.4	39.7	1.6	896.9			8.4	752.5	42.1	896.9	1701.5	
7	U2-007	Plate	Up	15	ug/m2	0.8	29	46	1.6	16.2	3.4	108.9			33.8	620.6	17.8	108.9	784.5	
7	D1-007	Plate	Down	5	ug/m2	0.8	29	46	8.5	2.6	0.1	3206.2			171.4	5171.9	11.1	3206.2	8560.7	
12	D3-012	Plate	Down	30	ug/m2	2.0	49	37	71.8	73.8	3.3	72.0			163.6	1560.2	145.6	72.0	1944.7	
12	D2-012	Plate	Down	15	ug/m2	2.0	49	37	933	17.7	1.3	146.8			730.0	1034.2	950.7	146.8	2863.0	Captured 56 um coal particle
12	D1-012	Plate	Down	5	ug/m2	2.0	49	37	426.5		94.2	43.4	4269.5		430.0	3079.4	426.5	4312.9	8343.0	
13	D3-013	Plate	Up	30	ug/m2	1.0	89	44	41.5	106.7	5.3	572.6			354.2	1259.4	148.2	572.6	2339.7	
13	D2-013	Plate	Up	15	ug/m2	1.0	89	44	13.8	120.5	11.3	168.3			59.4	22327.3	134.3	168.3	22700.6	
13	U2-013	Plate	Down	15	ug/m2	1.0	89	44	44.7	75.6	1.1	96.6				1655.8	120.3	96.6	1873.8	
13	D1-013	Plate	Up	5	ug/m2	1.0	89	44	652.2	88.8	1.5	58.5		24.4	887.2	2330.2	741.0	58.5	4042.8	Captured 58 um coal particle
14	D3-014	Plate	Parallel	30	ug/m2	2.0	49	38	1.7	59.0	0.4	51.4			106.4	715.4	60.7	51.4	934.3	
14	D2-014	Plate	Parallel	15	ug/m2	2.0	49	38	8.4	8.1	4.3	282.5			80.6	706.3	16.5	282.5	1090.2	
14	U2-014	Plate	Parallel	15	ug/m2	2.0	49	38	21.3	4.0	7.1	4.3			1561.2	2471.2	25.3	4.3	4069.1	
14	D1-014	Plate	Parallel	5	ug/m2	2.0	49	38	35.8	0.5	0.8	177.5			1270.4	508.7	36.3	177.5	1993.7	
15	D3-015	Plate	Parallel	30	ug/m2	1.5	54	41	31.5	6.8	0.1	2859.4			90.8	196.9	38.3	2859.4	3185.5	
15	D2-015	Plate	Parallel	15	ug/m2	1.5	54	41	49.1	7.7	122.5	74.8			14.4	864.6	56.8	74.8	1133.1	
15	U2-015	Plate	Parallel	15	ug/m2	1.5	54	41	30.6	2.7	49.1	932.9	234.7		3174.8	5204.0	33.3	1167.6	9628.8	
15	D1-015	Plate	Parallel	5	ug/m2	1.5	54	41		155.9	15.9	63.4			2814.2	433.7	155.9	63.4	3483.1	

Deposition Plate Results in µg/m^2 (continued)

Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks — Dist = Distance from tracks

Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unidentified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Aciniform	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
18	D3-018	Plate	Up	30	ug/m2	0.9	87	43			18.2	70.8				545.6	0	70.8	634.6	
18	D2-018	Plate	Up	15	ug/m2	0.9	87	43		2233.5	322.3	18.2	10.6			221.7	2233.5	28.8	2806.3	One single large coal particle (89 um)
18	U2-018	Plate	Down	15	ug/m2	0.9	87	43	15.5	6918.9	15.7	960.9			4481.4	108.3	6934.4	960.9	12500.7	Captured 97 um coal particle
18	D1-018	Plate	Up	5	ug/m2	0.9	87	43	1305.2	94.7	6.2	18414.5			4202.6	4664.8	1399.9	18414.5	28688.0	
21	D3-021	Plate	Up	30	ug/m2	0.9	97	43	11.7		7.8	2.2			812.8	7392.1	11.7	2.2	8226.6	
21	D2-021	Plate	Up	15	ug/m2	0.9	97	43	8.7	8.3	9.4	3496.9		0.3		5833.5	17.0	3496.9	9357.1	
21	U2-021	Plate	Down	15	ug/m2	0.9	97	43	1409.3	75.5	1.2	10.2			1042.6	2716.9	1484.8	10.2	5255.7	Captured 72 um coal particle
21	D1-021	Plate	Up	5	ug/m2	0.9	97	43	40.3	0.5	0.3	4200.0				3441.2	40.8	4200.0	7682.3	
22	D3-022	Plate	Up	30	ug/m2	1.3	97	40	15.0	61.7	0.8	3679.4		0.8	1116.8	2297.5	76.7	3679.4	7172.0	
22	D2-022	Plate	Up	15	ug/m2	1.3	97	40	41.1	14.6	296.6	936.0	16.6		1665.6	7458.5	55.7	952.6	10429.0	
22	U2-022	Plate	Down	15	ug/m2	1.3	97	40	0.2	378.9	1.8	66.2			4.6	19533.7	379.1	66.2	19985.4	
22	D1-022	Plate	Up	5	ug/m2	1.3	97	40	22.1	9.5	2.6	170.5			728.0	3695.2	31.6	170.5	4627.9	
24	D1-024	Plate	Parallel	5	ug/m2	1.2	83	48	34.1	12.8		547.7			14.8	1871.5	46.9	547.7	2480.9	
24	D1-024b	Plate	Parallel	5	ug/m2	1.2	83	48	63.1	1.0	0.5	153.2	1.8		105.6	497.1	64.1	155.0	822.3	Captured 58 um coal particle
24	D1-024c	Plate	Parallel	5	ug/m2	1.2	83	48		44.9	5.5	158.2				577.1	44.9	158.2	785.7	
24	U1-024	Plate	Parallel	5	ug/m2	1.2	83	48	4.6	0.9		142.2			96.0	1713.8	5.5	142.2	1957.5	
24	U1-024b	Plate	Parallel	5	ug/m2	1.2	83	48			5.5	71.7			47.6	6478.1	0	71.7	6602.9	
25	D1-025	Plate	Up	5	ug/m2	2.5	87	43	20.4	2.3	145.5	11.7			762.4	1481.9	22.7	11.7	2424.2	
25	D1-025b	Plate	Up	5	ug/m2	2.5	87	43	3.3	6.3	2.0	423.7			168.6	4166.7	9.6	423.7	4770.6	
25	D1-025c	Plate	Up	5	ug/m2	2.5	87	43	60.8	29.8	2.8	42.5			2.0	3572.7	90.6	42.5	3710.6	
25	U1-025	Plate	Down	5	ug/m2	2.5	87	43	2165.1	425.8	0.4	5514.2			405.6	253.3	2590.9	5514.2	8764.4	Captured 84 um coal particle
25	U1-025b	Plate	Down	5	ug/m2	2.5	87	43	3	56.4	0.1	252.9			4.4	458.8	59.4	252.9	775.6	
26	D1-026 A	Plate	Blank	5	ug/m2						3.1	121.5				731.5	0	121.5	856.1	
26	D1-026 B	Plate	Blank	5	ug/m2						3.0					120.4	0	0.0	123.4	
26	D1-026 C	Plate	Blank	5	ug/m2						2.5	49.8				154.0	0	49.8	206.3	
26	U1-026	Plate	Blank	5	ug/m2						1723.8	7596.3			10059.4	9247.7	0	7596.3	28627.2	
26	U1-026 b	Plate	Blank	5	ug/m2						66.3	14.2			1563.4	1228.5	0	14.2	2872.4	
	Water Blank		Water Blank		ug/m2					0.3	3.7	2.5				478.5	0.3	2.5	485.0	

Deposition Plate Results in particles/m^2

Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks

Dist = Distance from tracks

Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unidentified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Aciniform	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
1	D3-001	Plate	Up	30	P/m2	0.3	75	40	32625.8	20391.1	4078.2	12234.7				134581.6	53017	12235	203912	
1	D2-001	Plate	Up	15	P/m2	0.3	75	40	45572.6	51269.2	22786.3	11393.2			5696.6	148111.0	96842	11393	284829	
1	U2-001	Plate	Down	15	P/m2	0.3	75	40	52950.1	29416.7	29416.7	17650.0				164733.7	82367	17650	294167	
1	D1-001	Plate	Up	5	P/m2	0.3	75	40	44073.5	18888.6	12592.4	31481.1			18888.6	188886.4	62962	31481	314811	
3	D3-003	Plate	Down	30	P/m2	1.0	56	53	25122	25122	14355	28711			7178	39477	50244	28711	139965	
3	D2-003	Plate	Down	15	P/m2	1.0	56	53	26782	16069	16069	32139			16069	160694	42851	32139	267822	
3	U2-003	Plate	Up	15	P/m2	1.0	56	53	22786	51269	11393	22786			22786	153808	74055	22786	284828	
3	D1-003	Plate	Down	5	P/m2	1.0	56	53	14355	7178		10767			10767	50244	21533	10767	93311	
6	D3-006	Plate	Up	30	P/m2	2.0	70	38	9832	24581	9832	29497			29497	142570	34414	29497	245811	
6	D2-006	Plate	Up	15	P/m2	2.0	70	38	40438	50547	10109	15164			5055	131422	90985	15164	252735	
6	U2-006	Plate	Down	15	P/m2	2.0	70	38	39151	52201	19576	32626			19576	163129	91352	32626	326258	
6	D1-006	Plate	Up	5	P/m2	2.0	70	38	79752	53168	26584	46522			6646	119628	132920	46522	332300	
7	D3-007	Plate	Down	30	P/m2	0.8	29	46	14355	17944	14355	10767			14355	107665	32299	10767	179441	
7	D2-007	Plate	Down	15	P/m2	0.8	29	46	7178	10767	3589	10767			3589	82543	17945	10767	118433	
7	U2-007	Plate	Up	15	P/m2	0.8	29	46	14355	3589	14355	25122			3589	111254	17944	25122	172264	
7	D1-007	Plate	Down	5	P/m2	0.8	29	46	13803	18404	4601	27606			23005	142633	32207	27606	230052	
12	D3-012	Plate	Down	30	P/m2	2.0	49	37	4687	14062	23437	18750			9375	149999	18749	18750	220310	
12	D2-012	Plate	Down	15	P/m2	2.0	49	37	68723	76358	45815	45815			7636	137445	145081	45815	381792	
12	D1-012	Plate	Down	5	P/m2	2.0	49	37	33967		81521	27174	13587		20380	163042	33967	40761	339671	
13	D3-013	Plate	Up	30	P/m2	1.0	89	44	61087	45815	15272	38179			38179	183260	106901.7	38179	381791.8	
13	D2-013	Plate	Up	15	P/m2	1.0	89	44	50547	15164	25274	35383			5055	121313	65711	35383	252735	
13	U2-013	Plate	Down	15	P/m2	1.0	89	44	35888	59814	17944	29907				155517	95702	29907	299070	
13	D1-013	Plate	Up	5	P/m2	1.0	89	44	43648	24249	19399	33949		9700	9700	101846	67897	33949	242489	
14	D3-014	Plate	Parallel	30	P/m2	2.0	49	38	11215	16823	11215	28038			39253	173835	28038	28038	280379	
14	D2-014	Plate	Parallel	15	P/m2	2.0	49	38	41183	11767	11767	23533			29417	176500	52950	23533	294167	
14	U2-014	Plate	Parallel	15	P/m2	2.0	49	38	41410	18404	18404	18404			13803	124229	59814	18404	234654	
14	D1-014	Plate	Parallel	5	P/m2	2.0	49	38	34508	6902	13803	34508			34508	220852	41410	34508	345081	
15	D3-015	Plate	Parallel	30	P/m2	1.5	54	41	4934	4934	4934	49342			9868	172696	9868	49342	246708	
15	D2-015	Plate	Parallel	15	P/m2	1.5	54	41	9375	14062	46875	18750			9375	107812	23437	18750	206249	
15	U2-015	Plate	Parallel	15	P/m2	1.5	54	41	14062	14062	42187	28125	9375		18750	107812	28125	37500	234373	
15	D1-015	Plate	Parallel	5	P/m2	1.5	54	41		18750	23437	18750			14062	121874	18750	18750	196873	

Deposition Plate Results in particles/m^2 (continued)

Position: Down=Downwind, Up=Upwind, Parallel=Wind along tracks — Dist = Distance from tracks

Sample Set	Sample ID	Type	Position	Dist (m)	Units	WS (m/s)	RH (%)	Train Speed (mph)	Angular Coal-like	Rounded Coal-like	Unidentified Opaque	Iron Oxide	Iron Oxide Cluster	Soot-like-Aciniform	Quartz	Other Minerals	Total Coal	Total Iron Oxide	Total	Comment
18	D3-018	Plate	Up	30	P/m2	0.9	87	43			51448	40015				194358	0	40015	285821	
18	D2-018	Plate	Up	15	P/m2	0.9	87	43		4687	56250	14062	4687			126562	4687	18749	206248	
18	U2-018	Plate	Down	15	P/m2	0.9	87	43	71777	123046	20508	82031			41015	174315	194823	82031	512692	
18	D1-018	Plate	Up	5	P/m2	0.9	87	43	81565	130503	48939	130503			97878	326258	212068	130503	815646	
21	D3-021	Plate	Up	30	P/m2	0.9	97	43	45492		10109	20219			5055	171860	45492	20219	252735	
21	D2-021	Plate	Up	15	P/m2	0.9	97	43	41183	17650	17650	29417		5883		182384	58833	29417	294167	
21	U2-021	Plate	Down	15	P/m2	0.9	97	43	66256	22085	11043	22085			16564	138032	88341	22085	276065	
21	D1-021	Plate	Up	5	P/m2	0.9	97	43	33128	11043	22085	44170				165639	44170	44170	276065	
22	D3-022	Plate	Up	30	P/m2	1.3	97	40	35185	49259	7037	56296		7037	28148	168887	84443	56296	351847	
22	D2-022	Plate	Up	15	P/m2	1.3	97	40	52012	36409	15604	20805	5201		5201	124829	88421	26006	260061	
22	U2-022	Plate	Down	15	P/m2	1.3	97	40	9444	51944	9444	14167			4722	146387	61388	14167	236108	
22	D1-022	Plate	Up	5	P/m2	1.3	97	40	17650	23533	11767	5883			23533	211801	41183	5883	294167	
24	D1-024	Plate	Parallel	5	P/m2	1.2	83	48	39876	35445		44307			8861	88613	75321	44307	217102	
24	D1-024b	Plate	Parallel	5	P/m2	1.2	83	48	67921	16823	16823	112151	5608		5608	50468	84744	117759	275402	
24	D1-024c	Plate	Parallel	5	P/m2	1.2	83	48		14062	9375	18750				56250	14062	18750	98437	
24	U1-024	Plate	Parallel	5	P/m2	1.2	83	48	28711	10767		3589			7178	71777	39478	3589	122022	
24	U1-024b	Plate	Parallel	5	P/m2	1.2	83	48			4687	14062			9375	107812	0	14062	135936	
	Water Blank		Water Blank		P/m2					3589	10767	3589				32300	3589	3589	50245	
25	D1-025	Plate	Up	5	P/m2	2.5	87	43	78302	45676	78302	19576			26101	78302	123978	19576	326259	
25	D1-025b	Plate	Up	5	P/m2	2.5	87	43	36809	50612	36809	32208			13803	59814	87421	32208	230055	
25	D1-025c	Plate	Up	5	P/m2	2.5	87	43	75918	89721	55213	20705			6902	96623	165639	20705	345082	
25	U1-025	Plate	Down	5	P/m2	2.5	87	43	58995	44246	9832	29497			14749	88492	103241	29497	245811	
25	U1-025b	Plate	Down	5	P/m2	2.5	87	43	35888	17944	4486	94207			13458	58319	53832	94207	224302	
26	D1-026 A	Plate	Blank	5	P/m2						18750	28125				93749	0	28125	140624	
26	D1-026 B	Plate	Blank	5	P/m2						28125					79687	0	0	107812	
26	D1-026 C	Plate	Blank	5	P/m2						18750	28125				117187	0	28125	164062	
26	U1-026	Plate	Blank	5	P/m2						74013	24671			98684	419405	0	24671	616773	
26	U1-026 b	Plate	Blank	5	P/m2						28125	4687			4687	126562	0	4687	164061	

Appendix B

Sample EAA Analytical Report – Optical Microscopy

Optical Microscopy Air Sample - Summary Report

Air-O-Cell CSI Cassette - Size Range - Particles >3.0um

Client Name : T& B Systems
Contact : Mr. Bob Baxter
Client Project# : 4300
Client Sample # : U4-006
Sample Description : Not specified
Analysis Method : Bright Field/Polarized Light Microscopy
Analysis Magnifcation : 600
Scale (µm/div.) : 3
Total particles counted : 49
Sample volume (m^3) : 0.047

Analysis Date : 2/2/15
EAA Project # : 14-0402
EAA Sample # : U4-006
Fields Counted / passes : 2
Field area cted (mm^2) : 0.640
Field area (mm^2) : 15.0
% of sample counted : 4%
Particles / mm^2 : 77
Particles / sample : 1148
Estimated Particles / m^3 : 24435

Particle Classification	Part. Cted	Mean (um)	Num. %	* Mass %	* S.G.	Particles / Sample	Particles / m^3	Mass ug/m^3
Angular Coal-like	7	5.7	14.3%	7.3%	1.3	164	3491	0.43
Rounded Coal-like	13	6.9	26.5%	25.0%	1.3	305	6483	1.47
Unidentified opaque	5	4.9	10.2%	3.1%	1.0	117	2493	0.15
Iron oxide	9	4.6	18.4%	18.3%	4.0	211	4488	0.91
Iron oxide cluster	2	7.9	4.1%	7.5%	3.0	47	997	0.76
Soot-like-Aciniform	3	16.0	6.1%	21.2%	1.0	70	1496	3.22
Quartz								
Other Minerals	10	5.3	20.4%	17.7%	2.5	234	4987	0.99
Total counted :	49					Total particle mass (ug/m^3) :		7.9

** The calculated mass/m^3 is based on estimates of the average particle size & specific gravity (S.G.) and should be used as a rough comparative estimates.*

Definitions

Angular Coal-like : Angular brown/orange particles with uniform interior texture and edges consistent with a coal standard.
Rounded Coal-like : Rounded brown/orange particles with uniform interior texture consistent with a coal standard
Iron oxide : Brown to orange tinged individual particles with irregular and pitted morphology consistent with corrosion.
Iron Oxide -" cluster" : Clusters of brown to orange tinged particles with irregular and pitted morphology consistent with corrosion. Clusters include an assemblage of imacted particles of similar composition. The size is estimated as the diameter of the entire cluster.
Soot-like aciniform : Black fine particles with "aciniform" morphology consistent with vehicular diesel emissions.
Quartz : Particles with optical polarized light characteristics of the mineral quartz.
Other minerals : All other crystalline and non-crystalline translucent particles.

Analysis Method : Bright Field/Polarized Light Microscopy

Analyst : Daniel M. Baxter Date : 2/2/15

NUMERICAL SIZE DISTRIBUTION ANALYSIS
(Optical Microscopy - Total Sample Statistics)

Client Name: T& B Systems
Contact : Mr. Bob Baxter
Client Project# : 4300
Client Sample # : U4-006
Sample Description : Not specified
Analysis Method : Bright Field/Polarized Light Microscopy
Analysis Magnifcation : 600
Scale (µm/div.) : 3.00
Total particles counted : 49 Particles/mm^2 : 77

Analysis Date : 2/2/15
EAA Project # : 14-0402
EAA Sample # : U4-006

SIZE DISTRIBUTION STATISTICS				MORPHOLOGY STATISTICS (all particles)			
Description	**Mean**	Std.Dev.	95%CL	**Description**	**Mean**	Std.Dev.	95%CL
Arith. Mean Aerodynamic Dia.(µm)	6.4	±4.8	±1.3	Aspect Ratio	1.3	±0.44	±0.12
Arith. Mean Projected Dia.(µm)	6.2	±4.5	±1.3	Particle Sphericity	0.9	±0.09	±0.02
Median aerodynamic dia.(µm)	4.8			Particle counts / mm^2		38	
Numerical Mode (size category)	1.6			Field area counted (mm^2)		1.2800	
Skewness	3.0			Estimated particle area (mm^2)		0.00030	
Kurtosis	12.1			Area covered by particles (%)		0.0%	

Numerical Size Distribution (µm >= aerodynamic stated size)

Particle Size (µm)	**>=0.2**	**>=0.4**	**>=0.8**	**>=1.6**	**>=3.1**	**>=6**	**>=13**	**>=25**	**>=50**	**>=100**	**>=200**
Midpoint size (µm)	0.3	0.6	1.2	2	5	9	19	38	75	150	>=200
Cumulative Count	49	49	49	49	31	16	3	1			
Individual Count				18	15	13	2	1			
Individual Numerical %				36.7%	30.6%	26.5%	4.1%	2.0%			
Cumulative Numerical %				36.7%	67.3%	94%	98%	100%			

*** **Estimated Aerodynamic Mass (Volume) Distribution**

Particle Size (µm)	**>=0.2**	**>=0.4**	**>=0.8**	**>=1.6**	**>=3.1**	**>=6**	**>=13**	**>=25**	**>=50**	**>=100**	**>=200**
Individual Volume %				5.7%	15.1%	34.5%	17.1%	27.6%			
Cumulative Volume %				5.7%	20.9%	55%	72%	100%			

* All numerical size distribution statistics are based on the estimated arithmetic mean diameter.
** The largest size category is reported in bimodal distributions.
*** The estimated mass distribution is based on particle volume in each size catagory, and uses an estimate of particle specific gravity.

Statistical Parameter Definitions:

Geometric Aerodynamic Diameter	Geometric mean of feret length, width, and approximate thickness using the sphericity coefficient.
Geometric Projected Diameter	Geometric mean of particle size based on length and width and not accounting for particle thickness.
Median	Number in the middle of a distribution; that is, half the values are greater than the median, and half the values below.
Mode	Most frequently occurring size category/range in a size distribution
Skewness	Degree of symmetry of a population around its mean. Positive skewness indicates a distribution with an asymmetric tail towards more positive values. Negative skewness indicates an asymmetric tail towards more negative values.
Kurtosis	Relative peakedness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.
95% C.L.	95% Confidence Limit (i.e. probability that 95% of time the mean value will fall within the specified size range).
Aspect Ratio	Ratio of the particle longest projected length divided by the particle width
Particle Sphericity	Measure of effective particle size based on the formula (thickness ^2 / (length*width))^0.333
Roundness	Measure of the shape or irregularity of the particle = 0.07948*(perimeter)^2/area. Higher values indicate more angularity
Surface area covered	Theoretical percent area occupied by particles (projected particle area / total area examined)

Analyst : Daniel M. Baxter Date : 2/2/15

COMPOSITION SIZE & MASS DISTRIBUTION ANALYSIS

(Report Detail)

Client Name : T& B Systems
Contact : Mr. Bob Baxter
Client Project# : 4300
Client Sample # : 14-0402
Sample Description : U4-006
Analysis Method : Bright Field/Polarized Light Microscopy
Total particles counted : 49
Analysis Magnifcation : 600

Analysis Date : 02/02/15
EAA Project # : 14-0402
EAA Sample # : U4-006
Scale (µm/div.) : 3.00
Total particles counted : 49

Mineral Category	Numerical Count	Individual Count % >= stated aerodynamic size(µm) >=0.2	>=0.4	>=0.8	>=1.6	>=3.1	>=6	>=13	>=25	>=50	>=100	>=200
Angular Coal-like	7				4.1%	6.1%	4.1%					
Rounded Coal-like	13				14.3%	2.0%	6.1%	4.1%				
Unidentified opaque	5				4.1%	4.1%	2.0%					
Iron oxide	9				8.2%	8.2%	2.0%					
Iron oxide cluster	2						4.1%					
Soot-like-Aciniform	3						4.1%		2.0%			
Quartz												
Other Minerals	10				6.1%	10.2%	4.1%					

Mineral Category	Category Code	Count %	* Estimated Mass %	Mean Size (µm)	Aspect Ratio	Roundness Mean	>3.13	<3.13
Angular Coal-like	ac	14.3%	7.3%	5.7	1.21	3.58	4.14	2.18
Rounded Coal-like	rc	26.5%	25.0%	6.9	1.29	2.42	2.02	2.77
Unidentified opaque	i	10.2%	3.1%	4.9	1.40	2.04	2.21	1.80
Iron oxide	or	18.4%	18.3%	4.6	1.28	1.82	2.21	2.15
Iron oxide cluster	oc	4.1%	7.5%	7.9	1.50	2.06	2.06	
Soot-like-Aciniform	sl	6.1%	21.2%	16.0	1.24	1.38	1.38	
Quartz	q							
Other Minerals	m	20.4%	17.7%	5.3	1.25	2.50	2.72	1.98

INDIVIDUAL SIZE DISTRIBUTION COUNT DATA Page 1

Client Name: T& B Systems
Client Project# : 4300
EAA Project # : 14-0402

Client Sample # : U4-006
EAA Sample # : U4-006

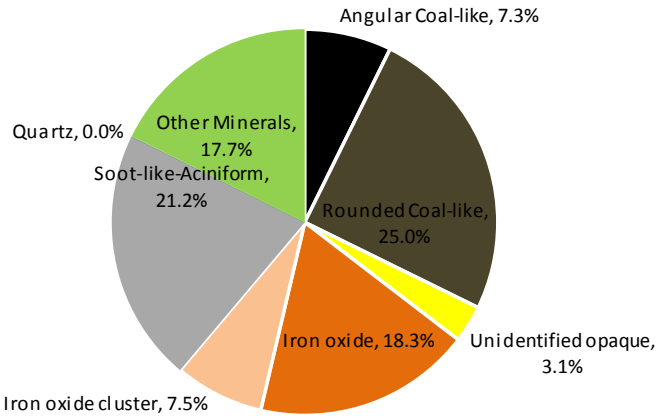
Particle Number	Particle Type	L feret (µm)	I feret (µm)	Proj. L (µm)	Thickness est. (µm)	Projected Dia.(µm)	Mean Dia.(µm)	Aspect Ratio	Round Coeff.	Particle Sphericity
1	m	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.28	1.0
2	i	3.0	3.0	3.0	3.0	3.0	3.0	1.00	2.52	1.0
3	ac	6.0	6.0	6.0	6.0	6.0	6.0	1.00	6.65	1.0
4	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.39	1.0
5	rc	9.0	9.0	9.0	9.0	9.0	9.0	1.00	3.73	1.0
6	m	6.0	3.0	6.0	3.0	4.5	4.8	2.00	5.07	0.8
7	m	6.0	6.0	6.0	6.0	6.0	6.0	1.00	1.88	1.0
8	rc	24.0	9.0	24.0	9.0	16.5	17.3	2.67	1.64	0.7
9	or	6.0	6.0	6.0	6.0	6.0	6.0	1.00	1.22	1.0
10	or	3.0	3.0	3.0	3.0	3.0	3.0	1.00	0.99	1.0
11	sl	36.0	21.0	36.0	21.0	28.5	30.1	1.71	1.15	0.8
12	or	6.0	3.0	6.0	3.0	4.5	4.8	2.00	0.97	0.8
13	oc	9.0	6.0	9.0	6.0	7.5	7.9	1.50	2.19	0.9
14	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	3.83	1.0
15	rc	3.0	1.5	3.0	1.5	2.3	2.4	2.00	6.18	0.8
16	rc	9.0	9.0	9.0	9.0	9.0	9.0	1.00	1.46	1.0
17	i	9.0	9.0	9.0	9.0	9.0	9.0	1.00	1.28	1.0
18	rc	21.0	12.0	21.0	12.0	16.5	17.4	1.75	2.26	0.8
19	or	3.0	3.0	3.0	3.0	3.0	3.0	1.00	3.36	1.0
20	rc	6.0	6.0	6.0	6.0	6.0	6.0	1.00	1.32	1.0
21	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.45	1.0
22	ac	6.0	6.0	6.0	6.0	6.0	6.0	1.00	2.88	1.0
23	or	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.54	1.0
24	or	3.0	3.0	3.0	3.0	3.0	3.0	1.00	2.71	1.0
25	rc	12.0	9.0	12.0	9.0	10.5	10.9	1.33	1.69	0.9
26	i	6.0	3.0	6.0	3.0	4.5	4.8	2.00	3.68	0.8
27	ac	3.0	3.0	3.0	3.0	3.0	3.0	1.00	3.48	1.0
28	ac	3.0	3.0	3.0	3.0	3.0	3.0	1.00	0.87	1.0
29	ac	9.0	9.0	9.0	9.0	9.0	9.0	1.00	5.64	1.0
30	ac	9.0	6.0	9.0	6.0	7.5	7.9	1.50	2.15	0.9
31	sl	9.0	9.0	9.0	9.0	9.0	9.0	1.00	1.63	1.0
32	m	6.0	6.0	6.0	6.0	6.0	6.0	1.00	1.30	1.0
33	m	6.0	3.0	6.0	3.0	4.5	4.8	2.00	2.40	0.8
34	or	9.0	6.0	9.0	6.0	7.5	7.9	1.50	3.30	0.9
35	i	6.0	3.0	6.0	3.0	4.5	4.8	2.00	1.66	0.8
36	or	6.0	6.0	6.0	6.0	6.0	6.0	1.00	1.38	1.0
37	or	6.0	3.0	6.0	3.0	4.5	4.8	2.00	0.95	0.8
38	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	0.82	1.0
39	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.71	1.0
40	m	6.0	6.0	6.0	6.0	6.0	6.0	1.00	5.53	1.0
41	m	9.0	6.0	9.0	6.0	7.5	7.9	1.50	1.81	0.9
42	rc	3.0	3.0	3.0	3.0	3.0	3.0	1.00	4.03	1.0
43	sl	9.0	9.0	9.0	9.0	9.0	9.0	1.00	1.35	1.0
44	m	9.0	9.0	9.0	9.0	9.0	9.0	1.00	1.08	1.0
45	m	3.0	3.0	3.0	3.0	3.0	3.0	1.00	2.70	1.0
46	oc	9.0	6.0	9.0	6.0	7.5	7.9	1.50	1.92	0.9
47	m	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.96	1.0
48	ac	6.0	3.0	6.0	3.0	4.5	4.8	2.00	3.40	0.8
49	i	3.0	3.0	3.0	3.0	3.0	3.0	1.00	1.08	1.0
50										

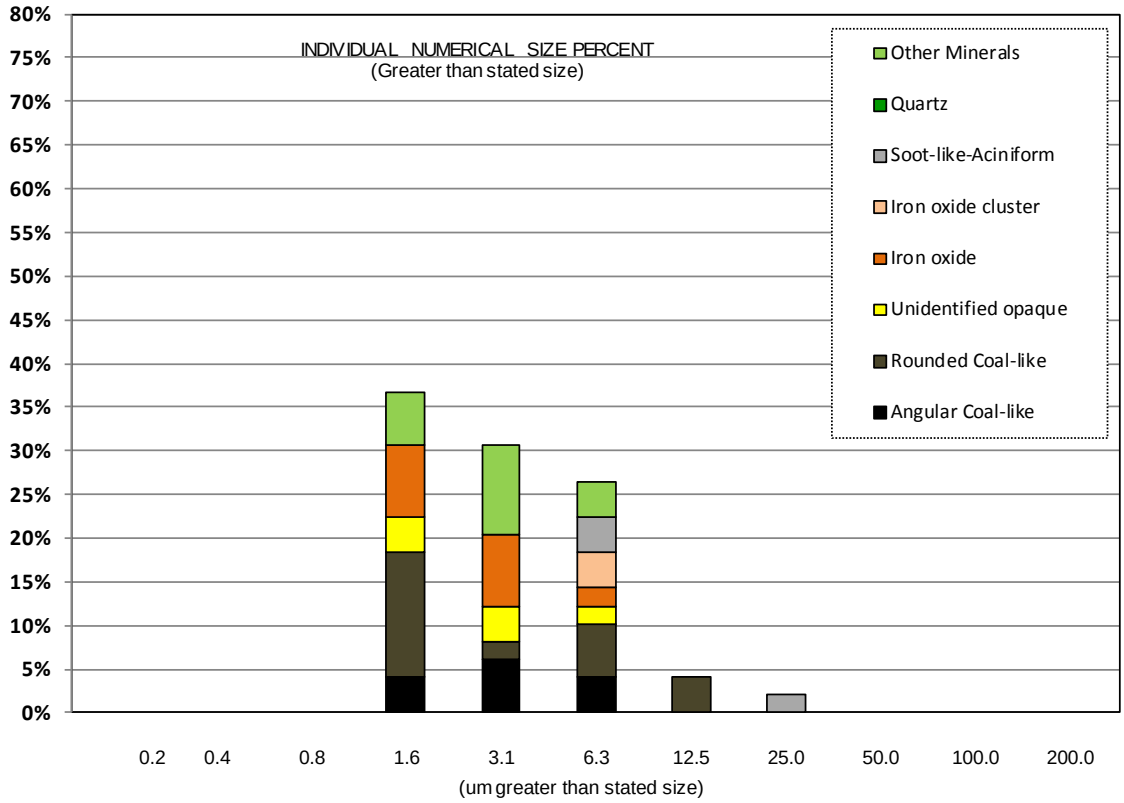
Optical Microscopy -Grapical Report - Mass & Size Distribution

Client Name : T& B Systems
Contact : Mr. Bob Baxter
Client Project# : 4300
Client Sample # : U4-006
Sample Description : Not specified
Analysis Method : Bright Field/Polarized Light Microscopy

Analysis Date : 2/2/15
EAA Project # : 14-0402
EAA Sample # : U4-006

Estimated Mass %





MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA GREENHOUSE GAS EMISSIONS TECHNICAL REPORT

PREPARED FOR:

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IN COOPERATION WITH:
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Contents

List of Tables iii
List of Figures vi
List of Acronyms and Abbreviations vii
Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-7
Chapter 2 **Existing Conditions** **2-1**
2.1 Greenhouse Effect 2-1
2.2 Methods 2-4
2.2.1 Data Sources 2-4
2.2.2 Impact Analysis 2-5
2.3 Existing Conditions 2-51
2.3.2 Cowlitz County 2-51
2.3.3 Washington State 2-52
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Upland and Wetland Land-Cover Change 3-1
3.1.2 Dock Dredging During Terminal Construction and Operations—Sediment Carbon 3-2
3.1.3 Coal Extraction 3-2
3.1.4 Rail Transport 3-9
3.1.5 Vehicle-Crossing Delay 3-10
3.1.6 Coal Export Terminal Construction 3-11
3.1.7 Coal Export Terminal Operation—Equipment Operation 3-14
3.1.8 Coal Export Terminal Operation—Electricity Consumption 3-15
3.1.9 Employee Commuting 3-15
3.1.10 Vessel Idling and Tugboat Use at Coal Export Terminal 3-16
3.1.11 Helicopter and Pilot Boat Trips 3-16
3.1.12 Vessel Transport 3-17
3.1.13 Coal Combustion 3-18
3.1.14 Induced Natural Gas Consumption 3-19

3.1.15 Net Greenhouse Gas Emissions 3-20
3.2 No-Action Alternative 3-40
Chapter 4 **Supplementary Data 4-1**
4.1 Interpolated Results from Coal Market Assessment 4-1
Chapter 5 **References 5-1**
5.1 Written References 5-1
5.2 Personal Communications 5-6

Tables

Table 1. Regulations, Statutes, and Guidance for Greenhouse Gases 1-5
Table 2. Global Warming Potentials 2-3
Table 3. Scenarios in the Coal Market Assessment 2-13
Table 4. Upland Emission Factors 2-19
Table 5. Wetland Emission Factors 2-20
Table 6. Sediment Carbon Assumptions 2-21
Table 7. U.S. Mining Coal Extraction Factors 2-23
Table 8. International Underground and Surface Mining Coal Extraction Factors 2-26
Table 9. Mass of Coal Train Components 2-29
Table 10. Coal Supply Regions and Distances to Washington State 2-30
Table 11. Emission Factors from Rail Diesel Fuel 2-30
Table 12. Coal Types and Distances within Washington State beyond Cowlitz County 2-31
Table 13. Rail Distances Traveled within Cowlitz County 2-31
Table 14. Emission Factors for Locomotives 2-32
Table 15. Weighted Vehicle Fleet Mix for Cowlitz County, 2028 2-33
Table 16. Activity Data for Vehicle Delay in Cowlitz County, 2028 2-34
Table 17. Major Construction Activities and Typical Equipment Fleets 2-35
Table 18. Construction Equipment Activity Data and Emission Factors 2-36
Table 19. Barge Activity and Energy Use for Coal Export Terminal Construction 2-37
Table 20. Emission Factors for Construction Barges 2-37
Table 21. Terminal Material Mass and Emission Factors 2-38
Table 22. Coal Export Terminal Equipment and Emission Factors – Dredging Equipment 2-40
Table 23. Coal Export Terminal Equipment and Emission Factors – Mobile Combustion and Emergency Equipment 2-41
Table 24. Coal Export Terminal Equipment and Emission Factors – Maintenance Dredging 2-41
Table 25. Monthly and Annual Electricity Demand for Coal Export Terminal 2-42
Table 26. Average Fuel Mix and Fuel-Specific Emission Factor for the Cowlitz Public Utilities District Region 2-42
Table 27. Emission Factors for Idling Vessels and Tugboats 2-43
Table 28. Annual Helicopter and Pilot Boat Transfers per Vessel, 2028 2-44
Table 29. Helicopter and Pilot Boat Trips and Nautical Miles Travelled 2-44
Table 30. Helicopter Fuel Consumption 2-45

Table 31. Combustion Emissions for Aviation Gasoline 2-45
Table 32. Factors for Pilot Boat Fuel Consumption 2-45
Table 33. Combustion Emissions for Residual Fuel 2-46
Table 34. Emission Factors for Vessels in Transit 2-47
Table 35. Average Vessel Characteristics 2-47
Table 36. Auxiliary Engine and Boiler loads 2-48
Table 37. Vessel Emission Factors by Equipment Type 2-48
Table 38. Emission Factors by Vessel Type 2-48
Table 39. Net Change in Nautical Miles Traveled by Proposed Action-Related Vessels 2-49
Table 40. Heat Content and Carbon Coefficients for U.S. and Asian Reference Coals 2-50
Table 41. Current Vessel Transport Activities in the Project Area 2-51
Table 42. Vegetation Removal, Soil Disturbance, and Wetland Loss Emissions ($MtCO_2e$) 3-1
Table 43. Potential Loss of Sediment Carbon from Dock Dredging ($MtCO_2e$) 3-2
Table 44. Emissions from Coal Extraction ($MMTCO_2e$) 3-3
Table 45. Range of Coal Mine Methane Emission Factors for Coal Extraction 3-6
Table 46. Locomotive Emissions from Extraction Sites to Washington State ($MMTCO_2e$) 3-9
Table 47. Locomotive Emissions within Washington State (Excluding Cowlitz County) ($MMTCO_2e$) 3-10
Table 48. Locomotive Operation Emissions within Cowlitz County ($MMTCO_2e$) 3-10
Table 49. Vehicle-Crossing Delay Emissions from Fossil Fuel Combustion from Vehicles Idling within Cowlitz County ($MtCO_2e$) 3-11
Table 50. Coal Export Terminal Construction Emissions ($MtCO_2e$) 3-12
Table 51. Embedded Emissions in Construction Materials ($MtCO_2e$) 3-13
Table 52. Emissions from Dredging during Construction – Fuel Use ($MtCO_2e$) 3-14
Table 53. Coal Export Terminal Operation Emissions from Mobile Combustion ($MtCO_2e$) 3-14
Table 54. Dredging Emissions during Operations – Fuel Use ($MtCO_2e$) 3-15
Table 55. Coal Export Terminal Operation—Indirect Emissions from Electricity Consumption ($MtCO_2e$) 3-15
Table 56. Employee Commuting ($MtCO_2e$) 3-15
Table 57. Emissions from Vessel Idling and Tugboat Use at Coal Export Terminal ($MtCO_2e$) 3-16
Table 58. Emissions from Helicopter and Pilot Boat Trips for Pilot Transfers to Vessels ($MtCO_2e$) 3-16
Table 59. Emissions from Vessel Transport within Cowlitz County ($MMTCO_2e$) 3-17
Table 60. Emissions from Vessel Transport within Washington State (Excluding Transport within Cowlitz County) ($MMTCO_2e$) 3-17

Table 61. Net Emissions from Changes in International Vessel Transport to Asian Markets ($MMTCO_2e$) 3-18
Table 62. Net Emissions from Coal Combustion ($MMTCO_2e$) 3-19
Table 63. Net Emissions from Natural Gas Substitution in the United States ($MMTCO_2e$) 3-20
Table 64. Direct Emissions (Generated in Cowlitz County) for the Proposed Action ($MMTCO_2e$) 3-21
Table 65. Emissions Generated within Washington State, Excluding Cowlitz County ($MMTCO_2e$) 3-21
Table 66. Net (Direct and Indirect) Emissions for the Proposed Action Excluding Coal Extraction ($MMTCO_2e$) 3-22
Table 67. Net Emissions (Direct + Indirect) for the Proposed Action Including Coal Extraction ($MMTCO_2e$) 3-23
Table 68. Net Emissions (Direct and Indirect) Excluding Coal Extraction by Phase ($MMTCO_2e$) 3-36
Table 69. Net Emissions (Direct and Indirect) Including Coal Extraction by Phase ($MMTCO_2e$) 3-37
Table 70. No-Action Alternative Annual Average Emissions from Rail, Vessel, and Haul Trucks Operating within Cowlitz County ($MMTCO_2e$) 3-41
Table 71. Interpolated Coal Market Assessment Results, 2015 U.S. and International Energy Policy 4-2
Table 72. Interpolated Coal Market Assessment Results, Lower Bound 4-3
Table 73. Interpolated Coal Market Assessment Results, Upper Bound 4-4
Table 74. Interpolated Coal Market Assessment Results, No Clean Power Plan 4-5
Table 75. Interpolated Coal Market Assessment Results, Cumulative 4-6
Table 76. Coal Extraction by Region (Million Metric Tons) 4-7

Figures

Figure 1. Project Vicinity 1-3
Figure 2. Proposed Action 1-4
Figure 3. Model of the Natural Greenhouse Effect 2-2
Figure 4. Coal Export Stages and GHG Analysis Boundaries 2-6
Figure 5. Annual Coal Throughput, 2018-2038 2-17
Figure 6. Rail Transport of Coal to the Project Area 2-29
Figure 7. Net GHG Emissions from Coal Extraction by Country and U.S. Coal Basin for 2015 U.S. and International Energy Policy Scenario 3-4
Figure 8. Net GHG Emissions from Coal Extraction by Country and U.S. Coal Basin for No Clean Power Plan, Lower Bound, Upper Bound, and Cumulative Scenarios 3-5
Figure 9. Range of Net GHG Emissions from Coal Extraction for the 2015 Energy Policy Scenario 3-7
Figure 10. Range of Net GHG Emissions from Coal Extraction for the No CPP, Lower Bound, Upper Bound, and Cumulative Scenarios 3-8
Figure 11. Total Net Emissions for Each Scenario, Excluding Coal Extraction 2018-2038 ($MMTCO_2e$) 3-24
Figure 12. Total Net Emissions for Each Scenario, Including Coal Extraction 2018-2038 ($MMTCO_2e$) 3-25
Figure 13. No Clean Power Plan—Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038 3-30
Figure 14. Lower Bound – Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038 3-32
Figure 15. Upper Bound – Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038 3-33
Figure 16. 2015 U.S. and International Energy Policy—Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038 3-35
Figure 17. Cumulative Scenario—Net Annual Emissions, 2018–2038 3-40

Acronyms and Abbreviations

°F	degrees Fahrenheit
Applicant	Millennium Bulk Terminals—Longview, LLC
AR4	IPCC Fourth Assessment Report
BNSF	BNSF Railway Company
Btu	British thermal unit
Btu/lb	British thermal units per pound
CCC	Cowlitz County Code
CFR	Code of Federal Regulations
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
eGRID	Emissions & Generation Resource Integrated Database
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
GHG	greenhouse gas
GMI	Global Methane Initiative
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation Model
GWP	global warming potential
hp	horsepower
IPCC	Intergovernmental Panel on Climate Change
$kgCO_2e$	kilograms of carbon dioxide equivalent
$kgCO_2e/MWh$	kilograms of carbon dioxide equivalent per megawatt hour
$kgCO_2e/Mt$	kilograms of carbon dioxide equivalent per metric ton
kWh	kilowatt hour
LVSW	Longview Switching Company
MJ	megajoule
MMBtu	million British thermal units
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
MOVES	MOtor Vehicle Emission Simulator
$MtCO_2e$	metric tons of carbon dioxide equivalent
MWh	megawatt hour
NEPA	National Environmental Policy Act
RCW	Revised Code of Washington
SEPA	Washington State Environmental Policy Act
UNFCC	United Nations Framework Convention on Climate Change
UP	Union Pacific Railway
USC	United States Code
WAC	Washington Administrative Code

Chapter 1
Introduction

This technical report assesses the potential greenhouse gas (GHG) emissions impacts of the proposed Millennium Bulk Terminals—Longview project (Proposed Action) and No-Action Alternative. For the purposes of this assessment, GHG emissions include the emissions from construction and operation of the Proposed Action as well as the indirect, market-influenced transportation, coal extraction, and end-use fossil fuel combustion emissions from operations. This report describes the regulatory setting, establishes the methods for assessing potential GHG emissions impacts, presents current GHG emissions in the study area, and assesses potential net GHG emissions from the Proposed Action and the No-Action Alternative.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington, along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east

in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

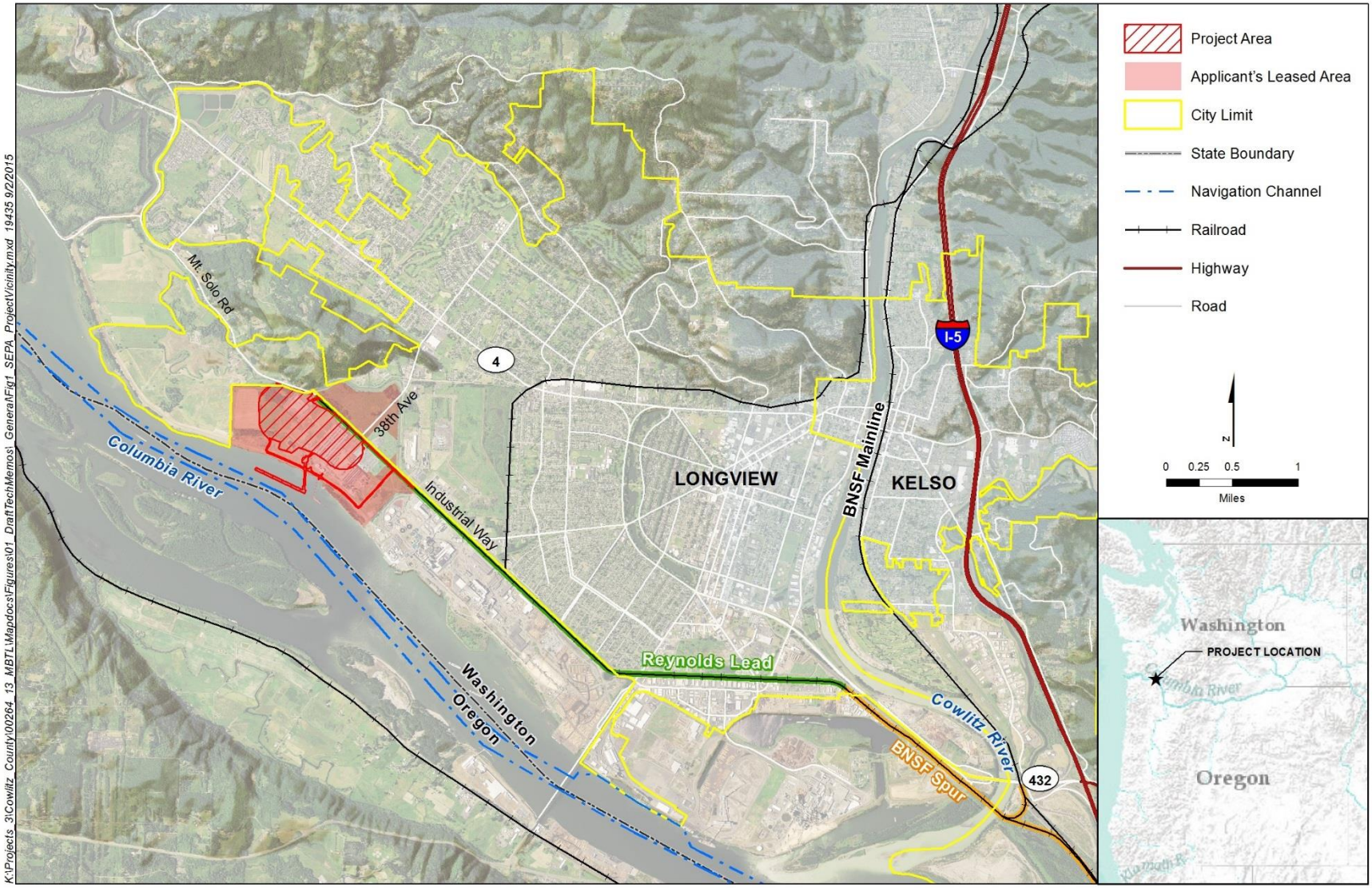
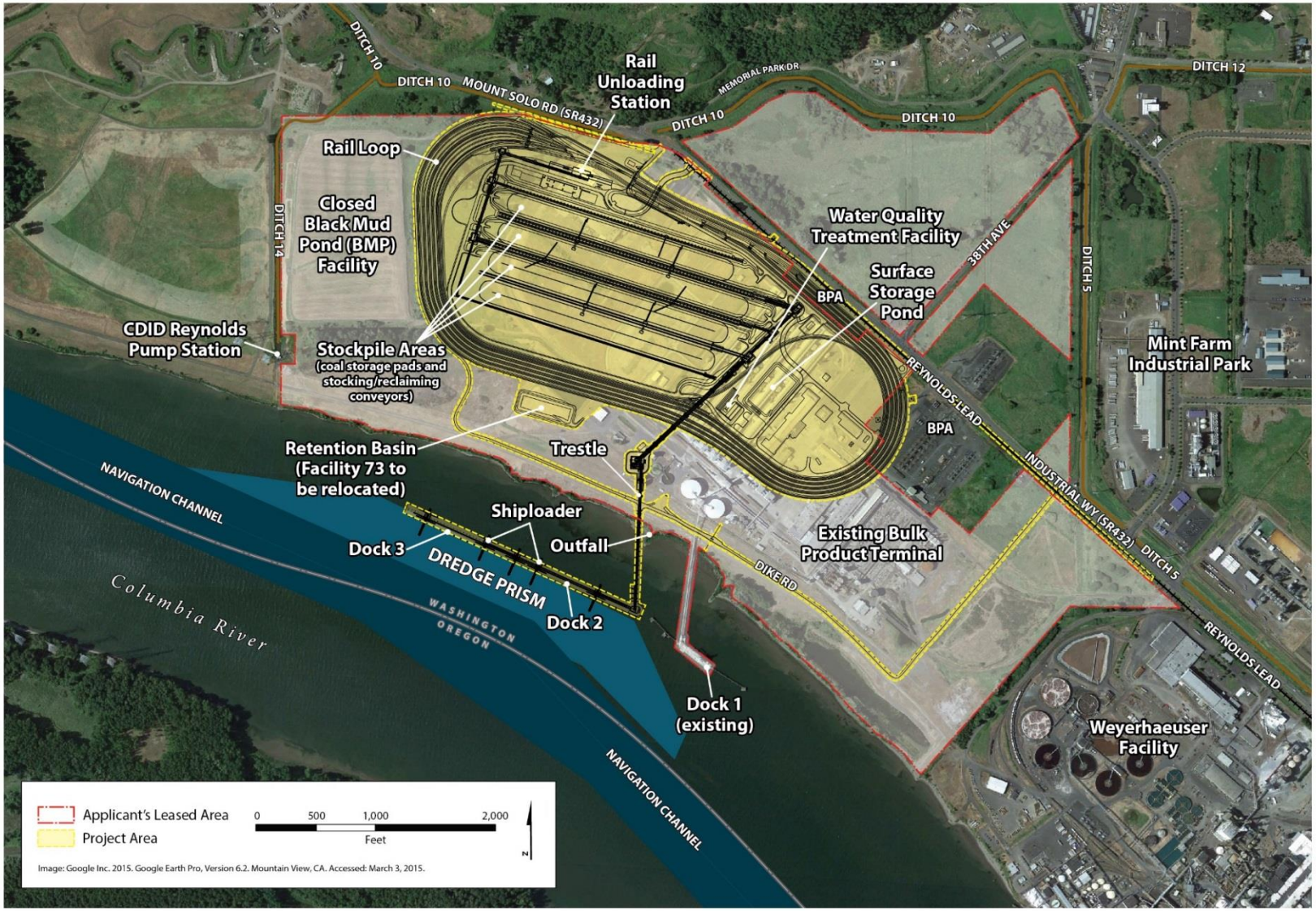


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

The jurisdictional authorities and corresponding regulations, statutes, and guidance for determining potential impacts on GHG emissions are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidance for Greenhouse Gas Emissions

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality Regulations for Implementing NEPA (49 CFR 1105).
Clean Air Act of 1963 (42 USC 7401) as amended	In 2007, the U.S. Supreme Court ruled that GHGs are air pollutants under the Clean Air Act.
Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units	In 2015, under the Clean Power Plan, EPA set state-specific target emission reductions to reduce CO_2 emissions in the power sector by 32% below 2005 levels by 2030 (80 FR 64661). The rate-based CO_2 emission goal for Washington state is 983 pounds of CO_2 per net MWh (80 FR 64962) and the mass-based CO_2 emission goal for Washington state for the 2 year block of 2030–2031 is 21,478,344 short tons of CO_2 (80 FR 64963) (or a final goal of 10,739,172 short tons of CO_2 (80 FR 64825).
United States Submittal to the United Nations Framework on Climate Change	United States and other nations submitted Intended Nationally Determined Contribution to the United Nations in 2015.

Regulation, Statute, Guideline	Description
State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.
Limiting Greenhouse Gas Emissions (RCW 70.235)	Requires state to reduce overall GHG emissions as compared to a 1990 baseline and report emissions to the governor bi-annually. Specific goals include achieving 1990 GHG emissions levels by 2020; 25% below 1990 levels by 2035; and 50% below 1990 levels by 2050 or 70% below the state's expected emissions that year.
Washington Clean Air Act (RCW 70.94)	Establishes rules regarding preservation of air quality and penalties for violations. CO_2 mitigation fees are evaluated as part of the permit required by the Clean Air Act (RCW 70.94.892) to reflect requirements from RCW 80.70. RCW 70.94.151 states that the department will be responsible for adopting rules requiring reporting of emissions defined by 70.235.010 from facility, source, site, or fossil fuel supplier that meet or exceed 10,000 metric tons of CO_2e annually.
Washington Carbon Pollution and Clean Energy Action (Executive Order 14-04, 2014)	In April 2014, Governor Inslee established the Governor's Carbon Emissions Reduction Taskforce to provide recommendations to the 2015 legislative session on the design and implementation of a carbon emissions limits and market mechanisms program for Washington State. The task force delivered its findings in November 2014, noting that a harmonized, comprehensive emissions-based or price-based policy approach would add unique features to an overall carbon emission reduction policy framework.
Washington Clean Air Rule (WAC 173-442)	Establishes requirements to cap and reduce GHG emissions. Parties covered under the Clean Air Rule are required to reduce their covered GHG emissions along an emission reduction pathway by reducing their emissions or by obtaining emission reductions from other covered parties, in-state emission reduction projects, or out-of-state emissions market (cap & trade) programs. The Clean Air Rule covers two-thirds of Washington's GHG emissions.
Washington's Leadership on Climate Change (Executive Order 09-05, 2009)	In 2009, Governor Gregoire ordered the state to assess the effectiveness of various GHG reduction strategies by estimating emissions, quantifying necessary reductions, and identifying strategies and actions that could be used to meet the 2020 target. Assessments were done across multiple sectors and sources of emissions, including industrial facilities, the electricity sector, low-carbon fuel standards, vehicle miles traveled, coal plants, and forestry.
Path to a Low-Carbon Economy: An Interim Plan to Address Washington's Greenhouse Gas Emissions (2010)	The second Climate Comprehensive Plan report to the Governor and State Legislature outlines a plan to achieve emission reductions to 1990 levels by 2020, as required by RCW 70.235.

Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provides for the implementation of SEPA in Cowlitz County.

Notes:

[a] In 2009, EPA proposed the Endangerment Finding and the Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act. The Endangerment Findings determined that the current and projected concentrations for carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorinated chemicals, and sulfur hexafluoride posed a threat to the health and welfare of current and future generations (U.S. Environmental Protection Agency 2009). This sets the legal foundation for regulating GHG emissions from sources of these six well-known GHGs, such as vehicles, industrial facilities, and power plants.

[b] Light duty vehicles include passenger cars, light-duty trucks, and medium-duty passenger vehicles.

USC = United States Code; CFR = Code of Federal Regulations; EPA = U.S. Environmental Protection Agency; FR = *Federal Register*; CO_2 = carbon dioxide; MWh = megawatt per hour; CO_2e = carbon dioxide equivalent; GHG = greenhouse gas; WAC = Washington Administrative Code; RCW = Revised Code of Washington; SEPA = Washington State Environmental Policy Act; CCC = Cowlitz County Code

1.3 Study Area

GHG emissions contribute to the global greenhouse effect, which is the process by which the Earth retains heat (Section 2.1, *Greenhouse Effect*). GHGs emitted anywhere in the globe affect the global environment.[1] The study area for GHG emissions for Cowlitz County as a Washington State Environmental Policy Act (SEPA) co-lead agency is defined as Cowlitz County. GHG emissions for the Washington State Department of Ecology as a SEPA co-lead agency is based on the expected rail and vessel transportation routes and emissions from the combustion of coal. While the study areas for the co-lead agencies are different, the analysis used the same approach to calculate GHG emissions attributable to the Proposed Action.

[1] Some short-lived climate pollutants, such as black carbon, have only a local impact and are not considered in this analysis.

Chapter 2
Existing Conditions

This chapter introduces the greenhouse effect, which is the primary consequence of GHG emissions. The chapter then describes the sources of information and methods used to characterize the existing conditions and assess the potential impacts of the Proposed Action.

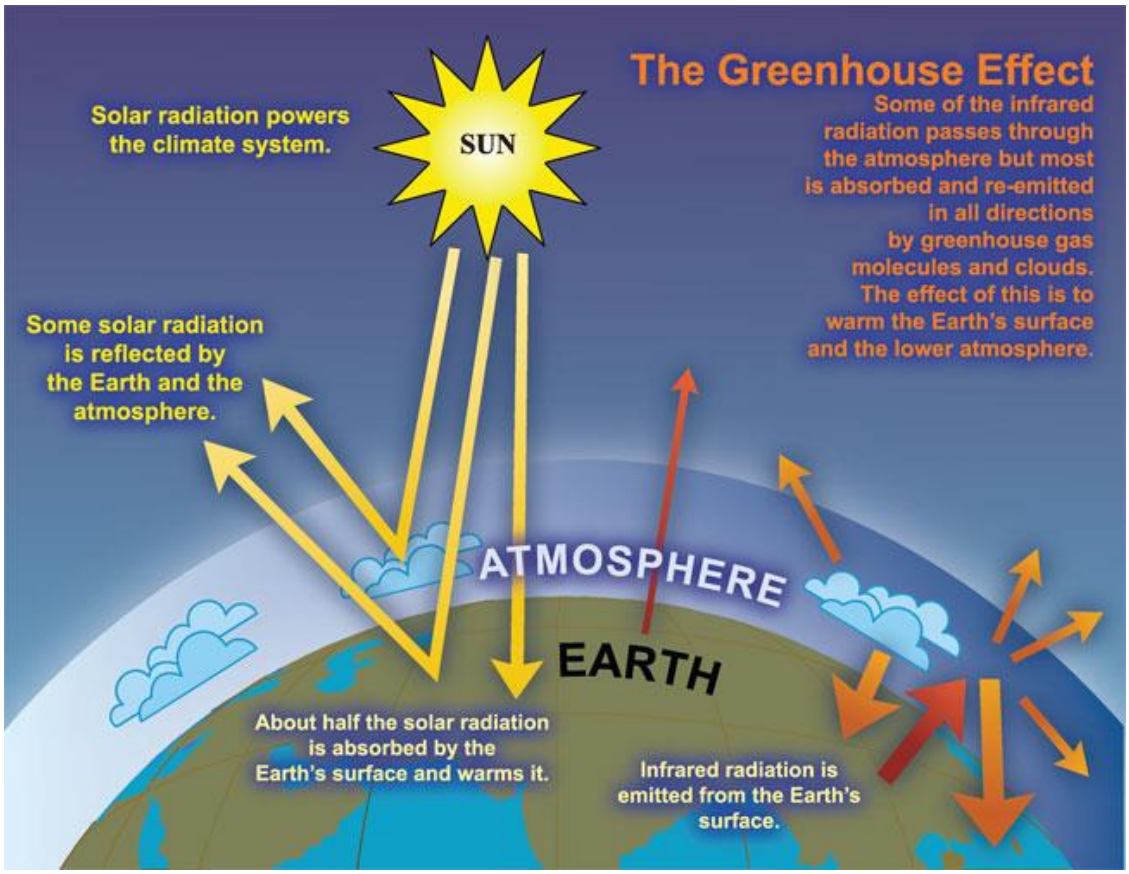
2.1 Greenhouse Effect

The Earth retains outgoing thermal energy and incoming solar energy in the atmosphere, thus maintaining heat temperature levels suitable for biological life. This retention of energy by the atmosphere is known as the greenhouse effect.[2] When solar radiation reaches the Earth, most of the solar radiation is absorbed by the Earth's surface, reflected by the Earth's surface and atmosphere, or — to a lesser degree — absorbed by the Earth's atmosphere. Simultaneously, the Earth radiates its own heat and energy out into the Earth's atmosphere and space. Factors such as the reflectivity of the Earth's surface, the abundance of water vapor, or the extent of cloud cover affects the degree to which solar radiation may be absorbed and reflected. Figure 3 shows the energy flows to and from Earth and the role that the greenhouse effect plays in maintaining heat in the atmosphere.

The composition of gases in the Earth's atmosphere determines the amount of energy absorbed and re-emitted by the atmosphere or simply reflected back into space. The predominant gases in the Earth's atmosphere, nitrogen and oxygen (which together account for nearly 90% of the atmosphere) exert little to no greenhouse effect. Some naturally occurring gases, such as carbon dioxide (CO_2), methane, and nitrous oxide, trap outgoing energy and contribute to the greenhouse effect. Additionally, manufactured pollutants, such as hydrofluorocarbons, can contribute to the greenhouse effect. Unlike most air pollutants (e.g., sulfur dioxide and particulate matter) that have only a local impact on air quality, GHGs affect the atmosphere equally regardless of where they are emitted, and thus they are truly global pollutants. Therefore, a ton of CO_2 emissions in Asia affects the global atmosphere to the same degree as a ton of CO_2 emissions in the United States.

[2] The Intergovernmental Panel on Climate Change (2013) defines the greenhouse effect as follows:
The infrared radiative effect of all infrared-absorbing constituents in the atmosphere. Greenhouse gases (GHGs), clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of GHGs increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a GHG concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing. Surface temperature and troposphere warm in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.

Figure 3. Model of the Natural Greenhouse Effect



Source: Intergovernmental Panel on Climate Change 2007

The extent to which a given GHG traps energy in the atmosphere and contributes to the overall greenhouse effect is characterized by its global warming potential (GWP). Some gases are more effective at trapping heat, while others may be longer-lived in the atmosphere. The reference gas against which others are compared is carbon dioxide, and GWP is thus expressed in terms of carbon dioxide-equivalent (CO_2e). The unit CO_2e represents both a gas's ability to trap heat and the rate at which it breaks down in the atmosphere. Most analyses use 100 years as the period of reference for GWPs, and this technical report conforms to that convention. For example, 1 unit of carbon dioxide has a 100-year GWP of 1, whereas an equivalent amount of methane has a GWP of 25 (Intergovernmental Panel on Climate Change 2007). For this analysis, a 100-year period is used.

Table 2 presents the 100-year GWPs from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) for the GHGs included in the study.[3,4]

Table 2. Global Warming Potentials

Greenhouse Gas	IPCC AR4 100-Year Global Warming Potential
Carbon dioxide	1
Methane	25
Nitrous oxide	298

Source: Intergovernmental Panel on Climate Change 2007

GHG emissions occur from both natural as well as human-made (anthropogenic) sources. Examples of natural sources include decomposition of organic matter and aerobic respiration. Anthropogenic GHG emissions are predominantly from the combustion of fossil fuels, although other sources including industrial processes, land-use change, agriculture, and waste management are also contributors.

The increase of GHGs in the atmosphere has been determined to pose risks to human and natural systems (Intergovernmental Panel on Climate Change 2014). Atmospheric concentrations of GHGs have increased since the Industrial Revolution, but the natural processes that remove those GHGs from the atmosphere have not scaled proportionally. Additionally, concentrations of long-lived manufactured pollutants such as hydrofluorocarbons have increased in recent decades. As the atmospheric concentrations of GHGs increase, the atmosphere's ability to retain heat increases as well. Since the instrumental record began in 1895, the U.S. average temperature has risen by approximately 1.3 to 1.9 degrees Fahrenheit (°F) (U.S. Global Change Research Program 2014). Furthermore, U.S. average temperatures throughout the 21st century are expected to increase at a faster pace, by 2.5°F to 11°F above pre-industrial levels by 2100 (U.S. Global Change Research Program 2014).

The impacts of higher global surface temperatures include widespread changes in the Earth's climate system. This may affect weather patterns, biodiversity, human health, and infrastructure. A discussion of climate impacts as they relate to the Proposed Action is provided in the SEPA Climate Change Technical Report (ICF 2017a)

[3] While additional GHGs (HFCs, PFCs, SF_6) were considered for this analysis as per the Council on Environmental Quality (2016) guidance, carbon dioxide, methane, and nitrous oxide are the greenhouse gases emitted from the fossil fuel combustion and vegetation and wetland activities considered in the analysis.

[4] GWP values for methane have been revised over time from 21 in the IPCC Second Assessment Report (SAR) to 28 in the IPCC Fifth Assessment Report (AR5). GWP values for nitrous oxide have also been revised from 310 in the IPCC SAR report to 265 in the IPCC AR5 report (Intergovernmental Panel on Climate Change 2013; Intergovernmental Panel on Climate Change 1995). This range shows there is uncertainty associated with GWP values. The GWP values used for this report were selected to be consistent with standards developed for the U.S. GHG inventory. The United States and other developed countries of the UNFCCC have agreed to submit annual inventories in 2016, and future years to the UNFCCC using the 100-year GWP values from the IPCC AR4 report. EPA follows this guidance in generating the national greenhouse gas inventory (U.S. Environmental Protection Agency 2016b). Using the AR4 100-year GWPs in the EIS is consistent with the practice of the UNFCCC, and provides greenhouse gas data that are consistent with other corporate, national, and subnational reporting.

2.2 Methods

This section presents the data sources and methods used to estimate project related GHG emissions for the study area. First, the data sources that were used are summarized. Second, the methods used to estimate each source of GHG emissions are described.

2.2.1 Data Sources

The technical reports supporting the SEPA Draft Environmental Impact Statement (EIS) for the Millennium Bulk Terminals—Longview project provided activity data and emissions data to support the GHG analysis. The following sources of information were used to evaluate the GHG emissions from construction and operation of the Proposed Action, the combustion of coal from coal exported from the Proposed Action, domestic and international transport of the coal, and changes in the use of coal and natural gas in response to the operation of the Proposed Action.

- SEPA Air Quality Technical Report (ICF 2017b).
- SEPA Coal Market Assessment Technical Report (ICF 2017c).[5]
- SEPA Energy and Natural Resources Technical Report (ICF 2017d).
- SEPA Rail Transportation Technical Report (ICF and Hellerworx 2017).
- SEPA Vessel Transportation Technical Report (ICF 2017e).
- SEPA Vegetation Technical Report (ICF 2017f).
- SEPA Vehicle Transportation Technical Report (ICF and DKS Associates 2017).

To estimate the GHGs emitted as a result of the processes described in the above reports, ICF used those reports' estimates of fuel consumption and vehicle operation, referred to as activity data, and combined that data with GHG emission factors in order to estimate GHG emissions for the Proposed Action.[6] The GHG emission factors are drawn from the following sources.

- California Air Resources Board. 2011. Appendix D: Emissions Estimation Methodology for Ocean-Going Vessels.
- Clean Cargo Working Group, 2014. Global Maritime Trade Lane Emissions Factors.
- Energy Information Agency 1994. CO_2 Emission Factors for Coal Study for International Coals.
- Hansen 2009. The Viability of Creating Wetlands for the Sale of Carbon Offsets.
- Intergovernmental Panel on Climate Change 2006: Volume 4: Agriculture, Forestry, and Other Land Use.

[5] The SEPA Coal Market Assessment Technical Report (ICF 2017c), hereafter referred to as the coal market assessment, provides estimates on the net changes in international coal extraction and combustion, domestic substitution of natural gas for coal and resulting combustion, extraction of coal at U.S. coal mines, domestic transport of coal to the proposed project, and international transport of the coal to importing countries. The report provides estimates for several scenarios to cover a range of potential changes in net GHG emissions because of the Proposed Action.

[6] An activity is a practice or ensemble of practices that take place on a delineated area over a given period. Activity data are data on the magnitude of a human activity resulting in emissions or removals taking place during a given period of time (e.g., data on energy use, data on equipment used during construction of the Proposed Action) (Intergovernmental Panel on Climate Change 2006).

- Coal Mine Methane Country Profiles (Global Methane Initiative 2015).
- International Energy Statistics (Energy Information Agency 2017).
- IPCC Guidelines for National Greenhouse Gas Inventories (Intergovernmental Panel on Climate Change 2006).
- National Council for Air and Stream Improvement and U.S. Forest Service 2016. Carbon Online Estimator.
- Trettin and Jurgensen 2003. Carbon Cycling in Wetland Forest Soils.
- U.S. Environmental Protection Agency. 1996. AP-42, Section 3.4 Large Stationary Diesel and All Stationary Dual-fuel Engines.
- U.S. Environmental Protection Agency. 2009a. NONROAD Model (Non-road engines, equipment, and vehicles).
- U.S. Environmental Protection Agency. 2009b. Emission Factors for Locomotives.
- U.S. Environmental Protection Agency. 2014a. MOVES (Motor Vehicle Emission Simulator).
- U.S. Environmental Protection Agency. 2015c. U.S. Greenhouse Gas Inventory Report: 1990–2013.
- U.S. Greenhouse Gas Inventory Report: 1990–2014 (U.S. Environmental Protection Agency 2016b).

2.2.2 Impact Analysis

This section describes the methods used to evaluate the potential impacts of the Proposed Action on GHG emissions. The method for estimating the GHG emissions associated with each emission source is described, along with that source's activity data and the calculations used to estimate its associated GHG emissions. The GHG analysis addresses the same set of sources addressed in the SEPA Air Quality Technical Report (ICF 2017b), plus several additional sources (e.g., transportation emissions beyond a 5-mile radius, net emissions from changes in domestic and international coal use).

2.2.2.1 Scope of Analysis

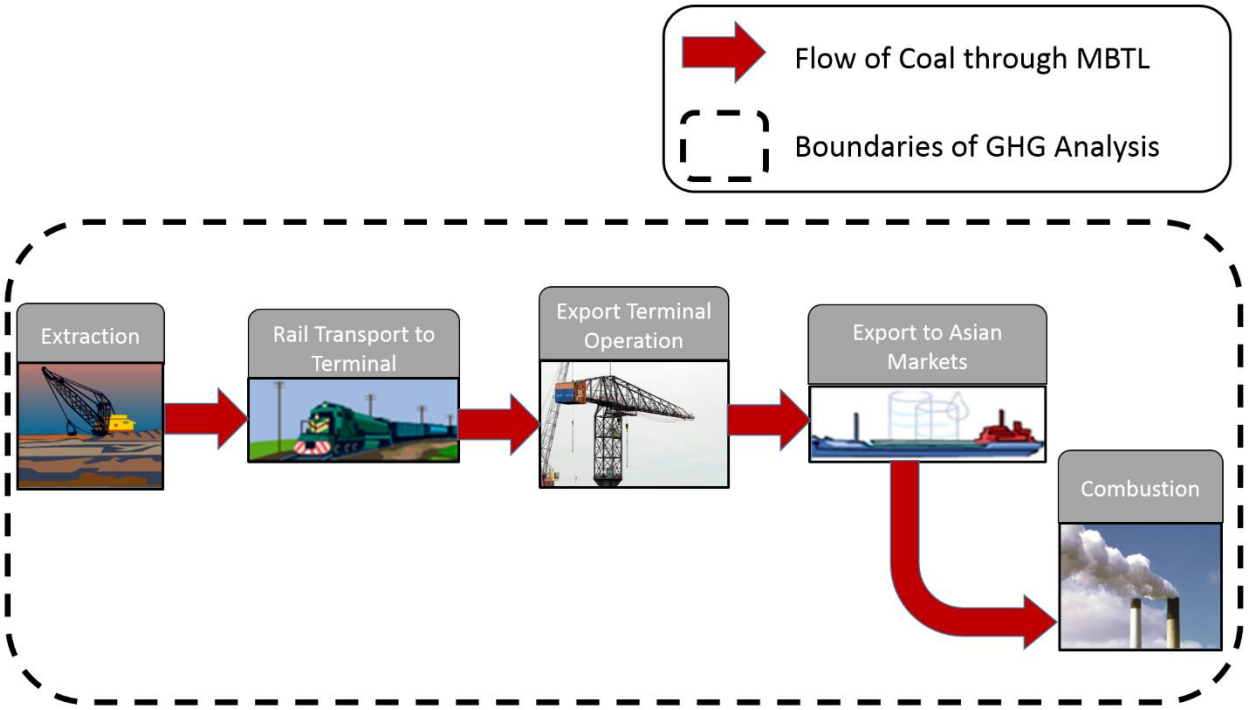
The Proposed Action would emit GHGs during construction and operation, both in the United States and abroad. The emissions would come predominantly from the combustion of fossil fuels for construction and operation, as well as changes in the combustion of coal, both domestically and internationally.

This analysis includes activity data from the technical reports described in Section 2.2.1, *Data Sources.* Additionally, the GHG analysis evaluates emissions scenarios based on the ultimate flow of coal to and through the coal export terminal (ICF 2017c). Figure 4 shows the pathway of coal from extraction to transport to terminal operation to export to its final combustion.

Geographically, the analysis of GHG emissions from the Proposed Action includes the extraction of Powder River Basin and Uinta Basin coals, the rail transport of the coal to Cowlitz County from their points of extraction, coal export terminal operation in Cowlitz County, vessel transport to Asia, and the substitution of coal for end-use combustion in China, Hong Kong, Japan, South Korea, and

Taiwan. Changes in coal combustion elsewhere in Asia (e.g., India) are included in this analysis where coal use would be affected by the import of coal from the coal export terminal (i.e., by induced demand for coal and substitution of international coals for U.S.-based coals). The substitution of natural gas for coal in the United States because of an increase in domestic coal prices is also evaluated.[7]

Figure 4. Coal Export Stages and GHG Analysis Boundaries



The scope of the GHG emissions analysis considers the following elements.

- **Analysis period.** To be consistent with activity data from the other technical reports prepared for the Proposed Action, this analysis considers construction, operation, coal extraction, rail and vessel transport, and fossil fuel combustion emissions from 2018 through 2038.
- **Direct sources of GHG emissions.** Direct emissions refer to GHG emissions from coal export terminal construction, operation, and transportation within Cowlitz County. The following processes are included.
    - Upland and wetland land-cover change
    - Coal export terminal construction
    - Dock dredging during coal export terminal construction and operations and subsequent release of sediment carbon
    - Rail transport of coal in Cowlitz County
    - Vehicle-crossing delay in Cowlitz County

[7] The proposed coal terminal could increase the demand for U.S. coal, resulting in a corresponding increase in coal prices.

- Equipment use during coal export terminal operation
- Vessel idling and tugboat use at the coal export terminal
- Vessel transport of coal in Cowlitz County
- Employee commuting to and from the coal export terminal

- **Indirect sources of GHG emissions.** Indirect emissions refer to GHG emissions that would result from the Proposed Action but are not concurrent with construction or operation on the project area, or that would occur outside of Cowlitz County. The following are indirect sources of GHG emissions.
  - Coal export terminal construction—embedded GHG emissions in materials for coal export terminal construction
  - Extraction of coal at the mining sites
  - Rail transport of coal from extraction sites to Washington State
  - Rail transport of coal within Washington State
  - Consumption of electricity used for coal export terminal operations
  - Helicopter and pilot boat trips for pilot transfers to vessels
  - Vessel transport of coal between the Cowlitz County border and international waters and return of vessels with only ballast water
  - Vessel transport of coal in international waters to markets in China, Hong Kong, Japan, South Korea, and Taiwan and return of vessels with only ballast water
  - Market effects on coal combustion in Asia and the United States
  - Induced natural gas combustion in the United States
- **Geographic scope.** The geographic scope includes GHG emissions that would occur within and outside of the project area. Emissions are evaluated outside of the area because greenhouse gases are a global pollutant as stated in Section 2.1, *Greenhouse Effect*, and there are market impacts from the Proposed Action at multiple geographic scales resulting in GHG emissions. Direct emissions that occur on the project area include those from mobile sources during construction and operation. Additional direct emissions would occur in Cowlitz County from rail and vessel transport of coal. The following indirect emissions would occur.
  - Rail and vessel transport of the coal beyond Cowlitz County and within Washington State
  - Net extraction of the coal in the United States and international coal markets
  - Rail transport of coal from extraction sites to Washington State
  - Transport of coal to Asian markets and the return of vessels with only ballast water in international waters

  GHG emissions are also estimated that would result from shifts in coal combustion and demand in Asian markets and from induced natural gas combustion due to the shift from coal as coal prices increase (relative to the no-action as defined in the coal market assessment) in the United States.

The international coal market is a global commodity market, such that changes in supply or demand in one country can affect coal prices and distribution patterns globally. The global nature of the coal market was demonstrated most recently in the fall of 2016 when China reduced production capacity and international coal prices shot up by 50% over a 2-month period. In addition, coal competes with other fuel sources, such as natural gas, for electric generation. To capture the dynamic changes in the international coal market and the competition among fuel types for electric generation in the United States and Canada, a comprehensive and integrated modeling platform is required. Without this type of modeling, assumptions would be required regarding the ultimate outcome of the exported coal and changes in coal consumption in the United States that would be difficult to make and justify without comprehensive modeling. The importance of modeling is best illustrated by examples.

  - The model established that there are very large existing international coal markets, and there is at most a relatively small increase in coal consumption because of the introduction of a new coal supply.
  - The model established that there are multiple suppliers and that, while U.S. exports are competitive, they are not significantly lower in cost than coal supplied from Australia, China, Indonesia, or Russia. The model showed outcomes where displacement—i.e., sale of U.S. coal rather than sale of competing coal produced in other countries—resulted in small changes in delivered coal price and small to no increases in coal used, except in the Upper Bound Scenario.
  - The model established that the variation in coal emission rates had limited effects on total emissions, although differences in carbon content have somewhat greater effect on net emissions from the Proposed Action. Thus, depending on the scenario, the substitution of coal with different carbon contents in Asia can be one of the key drivers of net emissions compared to other sources such as international vessel transport.
  - The U.S. power and fuel markets are highly integrated, diverse, and competitive, and, consequently, the increase in coal price in the United States results in substitution of gas and other sources for coal.

- **Induced demand for energy.** This analysis addresses coal combustion in Asia that would result from the increased supply of coal due to the operation of the Proposed Action. The addition of 44 million metric tons of coal to the supply of coal in Asia would increase supply and lower international coal prices. Asian coal markets would respond to lower prices by consuming more coal overall. This additional demand for coal that is a result of shifts due to the shift in the price of coal is referred to as induced demand.
- **Offset energy sources.** Operation of the Proposed Action could offset demand for other energy sources, nationally and internationally. Depending on the scenario, operations could affect production of coal from Australia, China, Indonesia, and Russia and its consumption throughout Asia. Additionally, this analysis considers the increased use of U.S. natural gas as a substitute for coal combustion. Consequently, changes in GHG emissions are estimated assuming that coal shipped through the coal export terminal would replace other sources of coal (e.g., coal imported from Australia, China, Indonesia, and Russia) and for the substitution of natural gas for U.S. coal. The GHG emissions associated with replacement of other sources of coal would include differences in the extraction and combustion of these coals compared to U.S. coal from Powder River and Uinta Basins.

- **Coal market assessment scenarios.** Each coal market assessment scenario represents a range of GHG emissions estimates, based on economic and policy projections through 2040. For each scenario, the GHG emissions from Asian coal combustion, U.S. coal combustion, and U.S. natural gas combustion are influenced by factors such as coal prices, transportation costs, demand for thermal coal, status of U.S. and international climate policies, and competing energy sources. Estimates of coal transport, coal consumption, and natural gas substitution are informed by projections in the coal market assessment, which considers four scenarios based on economic and policy projections through 2040.[8] The scenarios represent a range of GHG emissions estimates determined using a multi-dimensional model. Two model runs were conducted for each scenario: a no action model and an action model with the Proposed Action. The resulting net GHG emissions are influenced by the relative differences in coal combustion, distribution, and substitution for each of these model runs.

  The coal market assessment kept the throughput of exported coal constant at 44 million metric tons for the 6 years modeled (2016, 2018, 2020, 2025, 2030, and 2040) for the Proposed Action.[9] However, for the GHG analysis and as described in Section 2.2.2.2, *Method for Assembling an Emissions Time Series,* only years 2025, 2030, and 2040 from the coal market assessment results are used and adjusted to account for changes in quantities of exported coal from 2021 to 2028, the period when the coal export terminal would ramp up operations to reach full capacity in 2028.[10]

  All four scenarios use a common set of base assumptions, many of which were updated between the Draft EIS and Final EIS. Detailed descriptions of these assumptions are included in the coal market assessment. The set of base assumptions include, but are not limited to, the following. Assumptions.

  - Coal supply curves for U.S. and international coal supply regions. In the No Clean Power Plan scenario, the base coal supply curves result in Powder River Basin Wyoming 8800 British thermal units per pound (Btu/lb) of coal being priced at $12.6/ short ton, Uinta Basin 11,280 Btu/lb coal being priced at $39/ short ton, and Australian 10,800 Btu/lb (6,000 kilocalories per kilogram) coal being priced at $62.8/ short ton.[11] All prices are in 2012$ for the year 2018.
  - Coal transportation costs. The base rail transportation costs are $30 to $36 per short ton for coal transported from the Powder River Basin and Uinta Basin to the proposed terminal.
  - Natural gas supply curves
  - Air, waste, and water regulations
  - Renewable energy standards and regulations

[8] In some other studies, scenarios of economic and policy conditions are compared against a common baseline. For this GHG Analysis, the baseline is redefined for each scenario. This approach is used to capture the range of economic and policy conditions that could exist in the future (i.e., 2025, 2030, and 2040).

[9] As described in the coal market assessment, 44 million metric tons of coal is modeled for each year rather than a gradual increase as the coal export terminal reached full capacity.

[10] For purposes of the GHG analysis, the effect of the Proposed Action on net GHG emissions starts in 2021 when the proposed terminal initiates operations, and therefore net GHG emissions from emission sources affected by the coal market assessment are assumed to be 0 $MMTCO_2e$ for 2016, 2018, and 2020. See Section 6.1 of the *SEPA Coal Market Assessment Technical Report* (ICF 2017c) for further information.

[11] British thermal units (Btu) are a standardized measurement of the heat content of coal.

- Reserve margin targets for each U.S. electric demand region
- Firmly planned new generating capacity and retirements
- Electric transmission limits
- Electric demand
- Capital costs for new electric-generating capacity
- International coal demand. The base assumption for international coal demand is the Current Policies scenario from the International Energy Agency's 2015 World Energy Outlook. The Current Policies scenario includes only those GHG reduction policies for which implementing measures have been formally adopted as of mid-2015, and assumes that these policies remain unchanged going forward.
- Elasticity of coal demand for the Asian countries that can receive coal from the proposed terminal. The base elasticity of coal demand for China is -0.44 and is -0.11 for Hong Kong, India, Japan, South Korea, and Taiwan.

The four scenarios incorporate the base assumptions and are differentiated by the following six parameters:

- International coal curves
- International coal demand
- Coal demand elasticity
- Powder River Basin and Uinta Basin coal curves
- U.S. rail transportation costs
- U.S. and international climate policy. The U.S. climate policy is incorporated into the modeling by using an assumed version of the Clean Power Plan, or by not including the Clean Power Plan.[12] The international climate policies are incorporated into the modeling through the international coal demand used in each scenario.

The four scenarios and their key concepts are described below and summarized in Table 3.

- **2015 U.S. and International Energy Policy Scenario.** The 2015 U.S. and International Energy Policy scenario includes U.S. and international climate policies as the defining feature of this scenario. The U.S. climate policy is modeled using a representation of the Clean Power Plan. The international climate policy is modeled by using the international coal demand in the International Energy Agency's 2015 World Energy Outlook New Policies scenario. [13] The 2015 U.S. and International Energy Policy scenario uses the base set of assumptions except for three parameters. First, the international thermal coal demand is taken from the World Energy Outlook demand forecast for the New Policies scenario,

[12] Because implementation of the Clean Power Plan will occur at the state level and states have not determined how they will implement the Clean Power Plan, a version of the Clean Power Plan consistent with one of the alternatives under the EPA's proposed Federal Plan for the Clean Power Plan that features state specific mass standards for existing units is used.

[13] The 2015 World Energy Outlook New Policies Scenario incorporates the policies and measures that affect energy markets that had been adopted by non-U.S. countries as of mid-2015 and other relevant intentions that have been announced, even when the precise implementing measures have not been fully defined.

because it represents coal demand under current and proposed GHG reduction policies. Second, the elasticity of coal demand for China is -0.32. Third, this scenario includes the Clean Power Plan, which reduces coal consumption in the United States (U.S. Environmental Protection Agency 2015b). The final Clean Power Plan was released in August 2015.[14]

- **No Clean Power Plan Scenario.** The No Clean Power Plan scenario represents the state of the energy markets as of 2016. However, it does not include implementation of the Clean Power Plan. The No Clean Power Plan scenario uses the base set of assumptions and assumes that no additional national or international climate policies will be enacted beyond those implemented by mid- 2015.
- **Lower Bound Scenario.** Due to uncertainty over future coal consumption trends, the coal market assessment constructed the Upper and Lower Bound scenarios in a way that they produce illustrative results for a broad range of outcomes. The Lower Bound scenario represents a plausible low estimate of global CO_2 emissions from coal combustion. This scenario is designed to be a plausible and reasonable lower bound of global CO_2 emissions and does not attempt to model an absolute lowest bound of CO_2 emissions. The energy markets under the Lower Bound scenario could reflect a large component of renewable energy resulting in reduced demand for coal combustion. To achieve the low estimate of global CO_2 emissions from coal combustion, the Lower Bound scenario adjusts all six of the parameters used to define the scenarios beyond the base set of assumptions.

  First, the international coal supply curves are decreased by 10% to reduce the likelihood of induced demand. Second, international coal demand is assumed to be as estimated in the International Energy Agency's 2015 World Energy Outlook New Policies scenario, as this scenario includes both existing and proposed GHG reduction policies, which result in less coal consumption. Third, the coal demand elasticity is assumed to be -0.32, which would result in less induced demand than in the other scenarios, except the Energy Policy scenario, which uses the same value. Fourth, Powder River Basin coal supply curves are increased by 25% to reflect higher than expected stripping ratios and that would result in lower coal consumption. Fifth, U.S. rail costs are increased by 20% to reflect higher than expected diesel fuel prices, which would tend to decrease coal consumption in favor of other generation. Sixth, the Lower Bound scenario assumes the Clean Power Plan is implemented in the United States and that proposed international GHG reduction policies are implemented, which are the same assumptions as used in the 2015 U.S. and International Energy Policy scenario.

[14] On August 3, 2015, EPA released the final Clean Power Plan, which regulates CO_2 emissions from existing fossil fuel generation sources under Section 111(d) of the Clean Air Act. "Existing" refers to units that commenced construction before January 8, 2014. EPA estimates that the plan will reduce power sector CO_2 emissions 32% below 2005 levels in 2030. States have flexibility to implement the program as a rate credit trading program or a mass allowance trading program. The plan specified initial state plans due September 2016, updated plans by September 2017, and final state plans by September 2018, with the initial implementation date set for 2022. In February 2016, the Supreme Court granted petitioners a stay of the Clean Power Plan. The stay will not be lifted until all court proceedings, potentially including a hearing by the Supreme Court of the full case, have been settled. The D.C. Circuit heard arguments in the case in September 2016. In March 2017, an Executive Order was issued to review the Clean Power Plan.

- **Upper Bound Scenario.** The Upper Bound scenario represents a reasonable upper bound estimate of global CO_2 emissions from coal combustion and uses assumptions that could maximize the amount of induced demand from the Proposed Action. International coal plant construction and thus coal demand is assumed higher than in all the other scenarios. This higher demand causes both international coal consumption and prices to increase. This scenario does not attempt to model an absolute upper bound of global CO_2 emissions or CO_2 emissions that would result from the Proposed Action.[15] To achieve the high estimate of global CO_2 emissions from coal combustion, the Upper Bound scenario adjusts all six of the parameters used to define the scenarios beyond the base set of assumptions.

  First, the international coal supply curves are increased by 50% to reflect the higher international demand and increase the likelihood of induced demand. Second, international coal demand is assumed to be higher than all the other scenarios due to increased development of coal-fired generating assets. The international coal demand is estimated by assuming the historical coal consumption growth rates for each country during the 2000 to 2012 period, which was a time when coal consumption was increasing rapidly. Third, the coal demand elasticity is assumed to be -0.68, which would result in more induced demand than in the other scenarios. Fourth, Powder River Basin coal supply curves are decreased by 15% to reflect lower than expected stripping ratios and that would result in higher coal consumption. Fifth, U.S. rail costs are decreased by 20% to reflect lower than expected diesel fuel prices, which would tend to increase coal consumption. Sixth, the Upper Bound scenario does not assume the Clean Power Plan is implemented in the United States and assumes that the increased coal consumption does not violate existing international GHG reduction policies.

Table 3 summarizes the scenarios modeled for the coal market assessment, including the cumulative scenario.[16] Many factors would affect the future export and consumption of coal for the Proposed Action. Consequently, the scenarios reflect a range of potential outcomes. For each scenario, the table provides the following information.

- **Purpose:** the phenomena that the scenario is intended to represent.
- **U.S. coal markets:** the domestic coal market reaction to changes in supply and pricing.
- **Asian coal markets:** the international coal market reaction to changes in supply and pricing.
- **Coal prices:** the increases and decreases in coal production and transportation costs relative to the No Clean Power Plan scenario. Coal prices are modeled relative to the No Clean Power Plan scenario rather than the other scenarios because it uses the base set of assumptions without modifications.
- **Climate policy:** Two scenarios (2015 U.S. and International Energy Policy and Lower Bound scenarios) capture the effect of the Proposed Action when the Clean Power Plan and international GHG reduction commitments are implemented.

[15] Due to uncertainty over future coal consumption trends, the coal market assessment constructed the Upper and Lower Bound scenarios to illustrate a broad range of outcomes but not the extreme possibilities.

[16] Additional details on the modeling assumptions for each of the scenarios are provided in the SEPA Coal Market Assessment Technical Report (ICF 2017c).

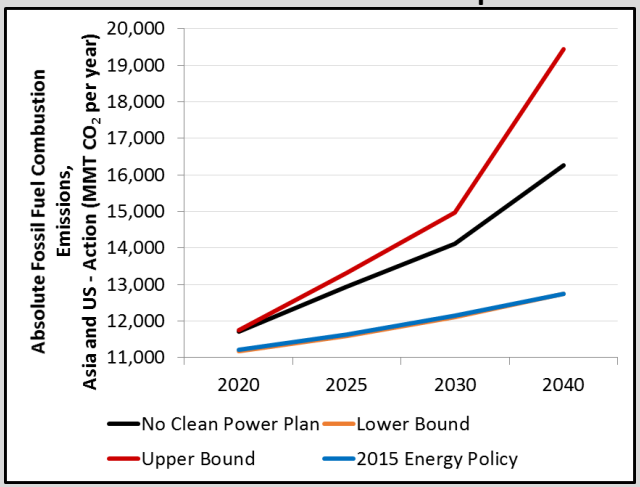
Table 3. Scenarios in the Coal Market Assessment[a]

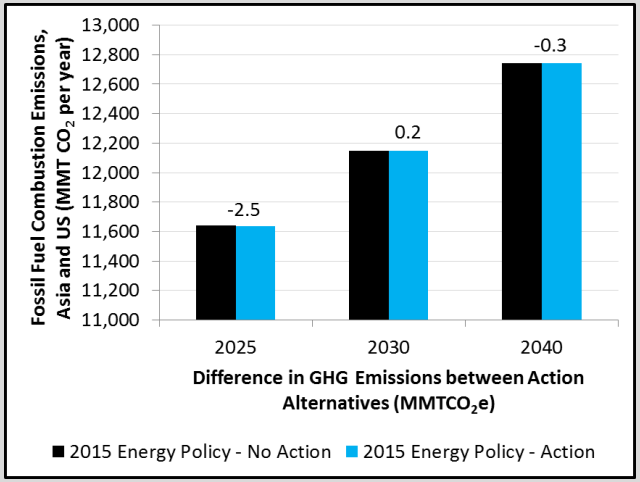
Scenario	Purpose	U.S. Coal Market Conditions (Relative to Base Assumptions)	Asian Coal Market Conditions (Relative to Base Assumptions)	Coal Prices Conditions (Relative to Base Assumptions)	Climate Policy
2015 U.S. and International Energy Policy	Represents impacts of an international climate policy on the coal market as proposed by mid-2015 and the Clean Power Plan	Coal consumption in the United States is lower due to implementation of the Clean Power Plan	Coal consumption is lower due to the implementation of GHG reduction policies	Both domestic and international coal prices are lower due to the lower overall coal demand	Climate policy resembling implementation of the Clean Power Plan and implementation of international GHG reduction policies announced as of mid-2015
No Clean Power Plan	Represents the assumed future state of energy markets in the absence of climate policies	No change from base assumptions	No change from base assumptions	No change from base assumptions	No climate policy implemented in the United States and only those international policies that have been fully implemented by mid-2015
Lower Bound	Represents energy markets where renewable penetration is high and international coal prices and demand are low, making domestic coal exports less attractive to international markets	Coal consumption in the United States is lower due to implementation of the Clean Power Plan and higher assumed Powder River Basin and Uinta Basin coal prices and rail transportation costs	• Lower assumed coal demand due to increased renewables • Lower coal prices due to lower demand	• Higher Powder River Basin and Uinta Basin coal prices due to assumed higher production costs • Lower international coal prices, due to assumed lower production costs	Climate policy resembling implementation of the Clean Power Plan and implementation of international GHG reduction policies proposed as of mid-2015
Upper Bound	Represents energy markets where coal consumption is high, leading to high international demand	Higher coal demand due to lower Powder River Basin and Uinta Basin coal prices	Higher coal demand resulting in higher coal prices	• Lower Powder River Basin and Uinta Basin coal prices due to assumed	No climate policy

Scenario	Purpose	U.S. Coal Market Conditions (Relative to Base Assumptions)	Asian Coal Market Conditions (Relative to Base Assumptions)	Coal Prices Conditions (Relative to Base Assumptions)	Climate Policy
	and prices, making domestic coal exports more attractive to international markets			lower production costs • Higher international coal prices due to increased demand and assumed higher production costs	
Cumulative[b]	Represents the impact of other planned export terminals in the Pacific Northwest	Coal consumption in the United States is lower because the higher amount of exports increases coal prices, which causes a reduction in demand	No change from base assumptions	Domestic coal prices are higher due to increased demand from exports, while international coal prices remain unchanged	No climate policy

Notes:
[a] Scenario conditions are defined relative to the No Clean Power Plan scenario.
[b] Further details on the Cumulative scenario can be found in Section 3.1.15, *Net Greenhouse Gas Emissions.*
GHG = greenhouse gases

Comparison of GHG Emissions Across Coal Market Assessment Scenarios





Each coal market assessment scenario represents a range of GHG emissions estimates, based on economic and policy projections from 2016 to 2040. For each scenario, the GHG emissions from Asian coal combustion, U.S. coal combustion, and U.S. natural gas combustion are influenced by a variety of factors, such as coal prices, transportation costs, and the penetration of competing energy sources.

The first chart on the left shows absolute emissions under each coal market scenario for the Proposed Action (noted as the Action Alternative). The scenarios display a significant variation in GHG emissions for coal and natural gas combustion. There is a difference of about 7,000 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) between the 2040 GHG emissions in the Upper Bound and 2015 U.S. and International Energy Policy scenarios, while the Lower Bound and 2015 U.S. and International Energy Policy Scenarios follow nearly the same trajectory. The difference in emissions between the scenarios indicated in the first chart is almost entirely due to the underlying market conditions rather than the influence of the proposed coal export terminal.

To illustrate the influence of the proposed coal export terminal, the second chart on the left indicates the changes in fossil fuel combustion[a] emissions that would occur in Asia and the United States because of the Proposed Action under 2015 U.S. and International Energy Policy scenario conditions. For example in 2040, the no-action under the 2015 U.S. and International Energy Policy scenario would result in combustion emissions of 12,742.7 $MMTCO_2e$ while the combustion emissions resulting from the Proposed Action under 2015 U.S. and International Energy Policy scenario conditions are 12,742.4 $MMTCO_2e$. The resulting net difference is 0.3 $MMTCO_2e$, or 0.002% of emissions. Likewise, changes in absolute emissions between the no-action and the Proposed Action for the other four coal market assessment scenarios are relatively small.

[a] Fossil fuel combustion emissions refer to coal combustion in Asia and the U.S., as well as U.S. natural gas combustion (ICF 2017c).

2.2.2.2 Method for Assembling an Emissions Time Series

Because GHGs accumulate in the atmosphere, a complete assessment of GHGs associated with the Proposed Action requires a characterization of the GHGs over a full analysis period (2018 through 2038). Construction of the coal export terminal would occur between 2018 and 2020. The coal export terminal would become operational in 2021, and reach full capacity by 2028. The GHG analysis estimates emissions for each year during this analysis period as well as for each scenario.

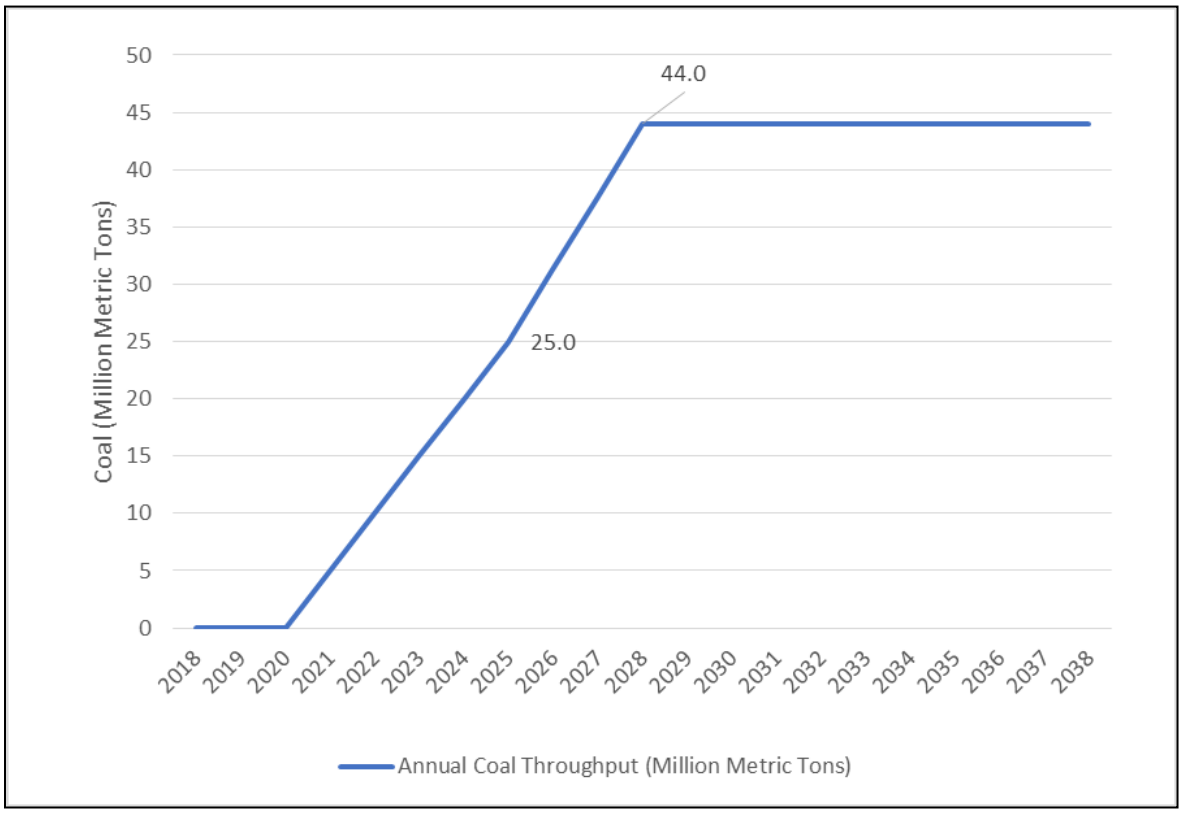
Assembling a complete emissions time series for the GHG analysis requires interpolation of estimates from the other technical reports prepared for the Proposed Action (i.e., coal market, air, and vessel) for the following reasons.

- The coal market assessment provides estimates only for 2025, 2030, and 2040Annual estimates are interpolated from these results.[17]
- The activity data that characterize coal export terminal operations represents conditions in 2028, when the facility is expected to be operational. These data do not reflect coal export terminal start-up, in which the coal throughput increases from zero immediately after construction in 2020 to its full capacity of 44 million metric tons by 2028.

In order to generate estimates of GHG emissions for the full analysis period, the expected coal throughput is increased linearly from zero in 2020 to 25 million metric tons (27.5 million short tons) in 2025. Between 2025 and 2028, the throughput is increased linearly at a slightly faster rate to reach full capacity at 44 million metric tons (48.4 million short tons) by 2028. For this approach, market-influenced emissions are assumed directly proportional to the amount of coal processed by the Proposed Action. The total coal exports for the analysis period add up to 627 million metric tons of coal, including 7 start-up years between 2021 and 2028 and 11 full years of operation from 2028 through 2038 (Figure 5).

[17] This analysis assumes the net impacts from the coal market assessment are 0 in 2020, and thus values are linearly interpolated from 0 in 2020 to the 2025 values in the coal market assessment.

Figure 5. Annual Coal Throughput, 2018-2038



The coal market assessment does not consider a start-up period, so the activity data and emissions estimates for 2025, which assume a full 44 million metric tons of coal throughput, are prorated by 57%; i.e., the ratio of the projected 25 million metric tons of the start-up period and the full 44 million metric ton throughput. This proration factor is applied to all data outputs from the coal market assessment in 2025, including coal extraction, rail transport, coal throughput, fossil fuel combustion emissions,[18] and ocean vessel traffic. Assuming that *net* emissions and activity from operation of the export terminal in the Proposed Action are zero in 2020, the analysis assumes a linear growth to the prorated 2025 data, reaching full operation in 2028, and linear interpolation between the 2030 and 2040 data outputs.

Activity data and emissions estimates are derived and presented in tables in this report only for 2028. Emission estimates for interpolated years from 2021 through 2038 are calculated by interpolating between the emissions values of the closest IPM model run years as well as the calculated value for 2028 (i.e., 2025, 2028, 2030, 2040).

2.2.2.3 Method for Impact Analysis

This section describes the method and approach for each emission source. The methods used for the following emission sources are described: upland and wetland land-cover change; dock dredging during terminal construction and operations—sediment carbon; coal extraction, rail transport, vehicle-crossing delay; coal export terminal construction; coal export terminal operation—equipment operation; coal export terminal operation—electricity consumption; employee

[18] Changes in domestic and international coal combustion are assessed separately.

commuting; vessel idling and tugboat use at coal export terminal; helicopter and pilot boat trips; vessel transport; coal combustion in Asia and the United States; induced natural gas consumption in the United States.

Upland and Wetland Land-Cover Change

The vegetation removal, soil disturbance, and wetland loss associated with construction of the Proposed Action would result in the loss of carbon stocks, the loss of ongoing carbon sequestration, and a reduction in annual emissions in the case of certain wetland vegetation cover types over the analysis period (2018 through 2038).

To estimate the loss of upland carbon stocks from the net change in upland vegetation cover types as a result of construction, estimates of vegetation cover (e.g., aboveground carbon, belowground carbon, understory carbon) and soil carbon stocks (i.e., soil organic carbon) in the project area are based on average carbon stock per area estimates for Cowlitz County taken from the Carbon Online Estimator (National Council for Air and Stream Improvement and U.S. Forest Service 2016). The upland land cover includes forested, scrub-shrub, herbaceous, and managed herbaceous vegetation cover types. The average forested carbon stock per area value may overestimate the actual forested carbon stocks in the project area because the average estimates for Cowlitz County likely include areas with higher carbon stocks (e.g., managed production forests) than the areas within the project area.

These estimates of the carbon stock per area for forested, scrub-shrub, and herbaceous[19] upland vegetation cover types are multiplied by the corresponding changes in area resulting from the construction to estimate the change in carbon stocks associated with construction (e.g., vegetation removal and surface soil disturbance) for the Proposed Action compared to the No Action Alternative. Given the potential high value of the forested carbon stock per area value, these emission estimates likely overestimate the actual construction emissions in the project area but are representative for average areas in Cowlitz County. That said, in the absence of detailed site-level carbon stock surveying, these average values are likely representative and conservative—i.e., they overestimate rather than underestimate emissions.

Loss of ongoing carbon sequestration for the forested, scrub-shrub, and herbaceous[20] upland vegetation cover types are then estimated based on IPCC guidelines (Intergovernmental Panel on Climate Change 2006: Volume 4). These estimates of the lost sequestration per area for forested, scrub-shrub, and herbaceous[21] upland vegetation cover types are multiplied by the corresponding changes in area resulting from construction over the analysis period (2018 through 2038) to estimate the lost sequestration.

Table 4 shows the emission factors (lost carbon stock and lost sequestration values) derived for the upland land cover type.

[19] There is only one carbon stock per area factor available for herbaceous upland vegetation cover type. This carbon stock density is applied for both herbaceous and managed herbaceous vegetation cover types. The carbon in both of these systems predominantly resides in the soil, and is largely independent of management.

[20] The annual carbon sequestration for the forested and scrub-shrub vegetation types is based on the aboveground net biomass growth in natural temperate continental forests in North America. The annual carbon sequestration for the herbaceous vegetation type is assumed zero because the soil carbon gains and losses were assumed to have reached an equilibrium for an established herbaceous system.

[21] The same carbon stock density is applied for both herbaceous and managed herbaceous vegetation cover types since the carbon in both of these systems predominantly resides in the soil.

Table 4. Upland Emission Factors

Land Cover Category	Vegetation Cover Type	One-time Lost Carbon Stock (metric tons CO_2e/acre)[a]	Annual Lost Sequestration (metric tons CO_2e/acre/year)[b]
Upland	Forested	510.5	2.8
	Scrub-shrub	325.6	2.8
	Herbaceous	140.7	0
	Managed herbaceous	140.7	0

Notes:
[a] One-time lost carbon stock values derived from Carbon On-Line Estimator search result in information for Cowlitz County (National Council for Air and Stream Improvement and U.S. Forest Service 2016).
[b] Annual lost sequestration values are from IPCC (2006)
GHG = greenhouse gas; CO_2e = carbon dioxide equivalent

To estimate the loss of wetland carbon stocks, estimates of vegetation cover carbon stocks in the project area are also based on average carbon stock per area estimates for Cowlitz County taken from the Carbon Online Estimator, with the soil carbon stocks taken from a study by the U.S. Department of Agriculture Forest Service (Trettin and Jurgensen 2003). These estimates of the carbon stock per area for forested, scrub-shrub, and herbaceous wetland cover types are multiplied by the corresponding changes in wetland area resulting from construction to estimate the change in carbon stocks associated with construction.

To estimate the loss of ongoing carbon sequestration for the forested, scrub-shrub, and herbaceous wetland vegetation cover types, representative estimates of annual carbon sequestration for wetlands assumed similar to those in the project area are from a study by Hansen (2009). Based on values reported by Trettin and Jurgensen (2003), these annual carbon sequestration estimates are adjusted to include the reduction in annual carbon dioxide and methane emissions for wetlands.

These adjusted estimates of the lost sequestration and reduction in emissions per area for forested, scrub-shrub, and herbaceous wetland vegetation cover types are multiplied by the corresponding changes in area resulting from the construction over the analysis period (2018 through 2038) to estimate the lost sequestration and reduction in emissions.

Table 5 shows the emission factors (i.e., lost carbon stock and lost sequestration and reduction in emission values) derived for the wetland vegetation cover types.

Table 5. Wetland Emission Factors

Land Cover Category	Vegetation Cover Type	One-time Lost Carbon Stock ($MtCO_2e$/acre)[a]	Annual Lost Sequestration ($MtCO_2e$/acre/year)[b]
Wetland	Forested	451.43	–5.51
	Scrub-shrub	266.52	–2.12
	Herbaceous	81.61	1.26

Notes:

[a] One-time lost carbon stock values are derived from Carbon On-Line Estimator search result information for Cowlitz County (National Council for Air and Stream Improvement and U.S. Forest Service 2016), with the soil carbon stocks taken from a study by the Trettin and Jurgensen (2003)

[b] Annual lost sequestration values are from a study by Hansen (2009), adjusted to include the reduction in annual carbon dioxide and methane emissions taken from Trettin and Jurgensen (2003)

GHG = greenhouse gas; CO_2e = carbon dioxide equivalent; $MtCO_2e$ = metric tons of carbon dioxide equivalent

Dock Dredging During Terminal Construction and Operations—Sediment Carbon

To estimate the potential loss of sediment carbon associated with dock dredging during coal export terminal construction and operations, the volume of sediment removed during coal export terminal construction and operations is multiplied by the density of the sediment, the total solids percentage in the sediment, and the total organic carbon percentage in the sediment. The resulting sediment carbon mass is converted to CO_2 equivalents. The density of the sediment is based on engineering density information available online (Engineering ToolBox 2016). The total organic carbon percentage and the total solids percentage in the sediment are based on the chemical analysis results value reported for the existing bulk product terminal (Dredged Material Management Program 2016).

Dredged material disposal would be determined through the Dredged Material Management Program process and options could include flow lane disposal for beneficial use in the Columbia River, or upland use of dredged material for pre-loading stockpile areas (Grette Associates 2014). For these dredge disposal options, how much of the organic carbon contained in the sediment that will actually be exposed to the air, oxidized, and emitted as carbon dioxide is unknown. As a result, the estimates represent the potential loss of sediment carbon, and likely overestimate the actual sediment carbon emissions associated with dock dredging during terminal construction and operations.

Table 6 shows the sediment carbon assumptions.

Table 6. Sediment Carbon Assumptions

Dock Dredging Period	Sediment Removed (cubic yard)	Sediment Density (lbs/ft^3)[a]	Total Solids (%)[b]	Total Organic Carbon (%)[c]
Construction	500,000	80	78.84	0.271
Annual Operations	100,000	80	78.84	0.271

Notes:
1 cubic yard = 27 cubic feet; 1 pound = 0.00454 metric tons; 1 metric ton carbon = 44/12 metric tons CO_2e
[a] Sediment density value is based on engineering density information available online (Engineering ToolBox 2016).
[b] Total solids percentage value is from Dredged Material Management Program Suitability Determination for the existing bulk product terminal (Dredged Material Management Program 2016).
[c] Total organic carbon percentage value is from the Suitability Determination for the existing bulk product terminal (Dredged Material Management Program 2016).

Coal Extraction

The coal market assessment indicates that coal extraction in the United States would increase in all four scenarios under the Proposed Action, as the export of coal through the coal export terminal would cause additional coal to be mined in the United States beyond that which is extracted for domestic consumption under the no-action. While coal production may increase, decrease, or stay the same across the U.S coal regions depending on the year and the scenario, in general the net change in extracted coal would come primarily from the Powder River Basin in Montana and Wyoming and the Uinta Basin in Utah and Colorado. Some change in domestic coal extraction is also expected in other regions outside the Powder River Basin and Uinta Basin due to indirect effects on the domestic coal market by the Proposed Action.

The coal market assessment also indicates that coal extraction outside the United States would decrease in all four scenarios under the Proposed Action, as the export of coal through the terminal would reduce the demand for coal mining in other countries beyond what is currently extracted under the no-action. While coal extraction may increase, decrease, or stay the same across international coal regions depending on the year and the scenario, in general, the avoided extraction of competing coal (i.e., coal extraction in international markets that would no longer occur due to the substitution of U.S.-based coal) would occur primarily in Australia, Indonesia, Russia, India, and China. Some change in international coal extraction is expected in other regions, both within and outside Asia.

Coal extraction from regions assessed in the coal market assessment (i.e., the Powder River Basin, Uinta Basin, other U.S. regions, and non-U.S. regions) would result in GHG emissions from:

- Energy consumption (electricity and diesel fuel) for mining operations, including overburden removal, coal extraction, and reclamation.
- Methane from surface and underground mining.

Under this approach, the indirect coal extraction GHG emissions from the Proposed Action are calculated by applying the GHG emission factors for each source of indirect emissions to the volumes of U.S. coal extraction that would be induced by the Proposed Action, covering the Powder River Basin, the Uinta Basin, and other U.S. coal regions. These GHG estimates are offset by GHG emissions

from competing coal extraction outside the United States, primarily in Australia, Indonesia, Russia, and China. From these annual estimates of net GHG emissions, the total indirect GHG emissions are calculated for coal extraction that would result from the Proposed Action during operations from 2021 through 2038.

The following sections describe the methods for assessing the GHG emissions impacts from coal extraction for each of the coal extraction regions impacted by the Proposed Action.

Coal Extraction from U.S. Mines

For all scenarios under the Proposed Action, surface mining is expected to increase in the United States, with changes in coal extraction occurring primarily in the Powder River Basin and the Uinta Basin during the analysis period. Smaller changes in surface coal extraction occur in other U.S. regions.

Diesel fuel consumption needed for each ton of extracted at the surface mine as part of mine operation is estimated based on a recent life-cycle assessment study of coal exports from the Powder River Basin from the National Energy Technology Laboratory (Skone et al. 2016). The result is 0.351 gallon of diesel fuel per metric ton of coal mined. Based on estimates provided in Skone et al. (2016), the electricity consumption needed for mine operation (e.g., equipment, lighting) is estimated to be 11,500 megawatt-hours per million metric ton of coal mined.

The GHG emissions from diesel fuel combustion are estimated using emission factors from Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model (Argonne National Laboratory 2016). The GHG emissions from electricity production are based on EPA's eGRID annual combustion output emissions rate for states where surface coal extraction is expected to change: Colorado, Illinois, Indiana, Montana, Pennsylvania, Utah, Virginia, West Virginia, Wyoming, Alabama, Arizona, Arkansas, Kansas, Kentucky, Maryland, New Mexico, North Dakota, Oklahoma, Tennessee, Texas, and Mississippi (U.S. Environmental Protection Agency 2017).

Based on estimates provided in Spath et al. (1999), the electricity consumption needed for underground mine operation (e.g., equipment, lighting) is estimated to be 12,755 megawatt-hours per million metric ton of coal mined. The GHG emissions from electricity production use the same EPA eGRID emission factors as the surface mining assessment.

The surface mining methane emissions specific to each U.S. surface mining coal extraction basin are estimated per metric ton of coal mined based on data provided in EPA's 1990–2014 GHG Inventory. Underground mining emissions specific to each basin are unavailable. To estimate underground mining methane emissions, a U.S. average emission factor based on total 2014 U.S. underground mining emissions and production data from the EPA GHG Inventory was used for all underground basins (U.S. Environmental Protection Agency 2016b). For each basin a weighted average methane emission factor was calculated based on the share of basin underground and surface mining production (Mining Safety and Health Administration 2016) and underground and surface mining emission factors. Emission factors for surface and underground mining include both emissions directly from mining and from post-mining activities (e.g., handling, transportation). Table 7 presents a summary of the consumption and emission factors used to assess the GHG emissions from U.S. coal extraction.

Table 7. U.S. Mining Coal Extraction Factors[a]

Material Input/Process	Factor	Unit	Source
Surface Mining Electricity Consumption	11,500	MWh/Million Mt of Coal	Skone et al. 2016
Underground Mining Electricity Consumption	12,755	MWh/Million Mt of Coal	Spath et al. 1999
Electricity emissions – Colorado	0.723	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Illinois	0.452	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Indiana	0.900	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Montana	0.591	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Pennsylvania	0.452	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Utah	0.809	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Virginia	0.401	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – West Virginia	0.903	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Wyoming	0.913	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Alabama	0.481	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Arizona	0.507	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Arkansas	0.587	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Kansas	0.644	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Kentucky	0.946	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Maryland	0.531	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – New Mexico	0.768	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – North Dakota	0.827	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Oklahoma	0.618	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Tennessee	0.487	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Texas	0.540	MtCO2e/MWh	U.S. EPA 2017
Electricity emissions – Mississippi	0.450	MtCO2e/MWh	U.S. EPA 2017
Diesel consumption	0.351	Gallons/Mt of Coal	Skone et al. 2016
Diesel combustion emissions	0.011	MtCO2e/Gallon	Argonne National Laboratory 2016
Surface Mining Methane Emissions – Central Appalachia Basin – Virginia	0.025	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Central Appalachia Basin – West Virginia	0.025	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Central Appalachia Basin – East Kentucky	0.024	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Illinois Basin	0.035	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Northern Great Plains (Powder River Basin) – Wyoming and Montana	0.020	MtCO2e/Mt of Coal	U.S. EPA 2016b

Material Input/Process	Factor	Unit	Source
Surface Mining Methane Emissions – Northern Great Plains (Powder River Basin) – North Dakota	0.005	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Northern Appalachia Basin	0.061	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Rockies (Green River Basin)	0.034	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Rockies (Uinta Basin)	0.016	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Rockies (San Juan Basin)	0.007	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Rockies (Raton Basin)	0.032	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – Warrior Basin	0.029	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – West Interior (Arkoma Basin)	0.071	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – West Interior (Forest City, Cherokee Basins)	0.033	MtCO2e/Mt of Coal	U.S. EPA 2016b
Surface Mining Methane Emissions – West Interior (Gulf Coast Basin)	0.011	MtCO2e/Mt of Coal	U.S. EPA 2016b
Underground Mining Methane Emissions – U.S. Average	0.171	MtCO2e/Mt of Coal	U.S. EPA 2016b

[a] Emission factors for surface and underground mining include both mining and post mining activities.

Sources: Argonne National Laboratory 2016, Skone et al. 2016, U.S. Environmental Protection Agency 2015b, U.S. Environmental Protection Agency 2016b

Mt = metric tons of material; MWh = megawatt-hour; CO_2e = carbon dioxide equivalent

Coal Extraction from International Mines

For all scenarios under the Proposed Action, with the exception of China in the Upper Bound scenario, coal mining is expected to decrease outside the United States, with changes in coal extraction occurring primarily at underground and surface coal mines in Australia, Indonesia, India, Russia, and China across the analysis period. Smaller changes in surface and underground coal extraction are expected to occur in Canada and South Africa.

For each of these international regions, coal extraction emissions were estimated using region-specific emission factors for coal mining methane emissions, electricity use, and diesel fuel use.

Indirect GHG emissions from methane released in coal mining were obtained from the latest United Nations Framework Convention on Climate Change (UNFCCC) GHG inventory data for methane emissions from underground and surface coal mining emissions (United Nations Framework Convention on Climate Change 2015). These emissions estimates include underground and surface mining and post-mining fugitive emissions but exclude abandoned mine emissions, as they are not directly related to ongoing coal extraction.

China, Indonesia, and India did not report coal mining methane emissions to UNFCCC; for these regions this analysis used average Tier 1 underground and surface mining, including mining and

post-mining, from IPCC GHG inventory guidelines (Intergovernmental Panel on Climate Change 2006). These IPCC emission factors were combined with Global Methane Initiative data for shares of surface mining and underground mining of total coal production. According to the Global Methane Initiative data, Indonesia produced coal from 100% surface mines, China produced coal from 10% surface and 90% underground mines, India produced coal from 90% surface and 10% underground mines, and South Africa produced coal from 51% underground and 49% surface mines. For China, the emission factor was adjusted to account for quantities of utilized methane based on Global Methane Initiative data (Global Methane Initiative 2015). Utilized methane represents coal-mining methane that is captured and consumed on site or off site. This method for China's emission factor follows IPCC guidelines (Intergovernmental Panel on Climate Change 2006).

For regions where UNFCCC methane emission data were used, a coal mining methane emission factor was derived by dividing the total methane emissions for the most recent available year (2014) by Energy Information Agency coal production data for the specific region and year (2017).

Electricity and diesel consumption from on-site mining activities came from an Ecoinvent report on environmental impact inventories from international energy systems (Dones et al. 2007 in International Energy Agency 2015). Region-specific electricity emission factors as indicated in the International Energy Agency were applied to calculate indirect CO_2 emission based on the Dones et al. consumption values (International Energy Agency 2015), and used diesel combustion emission factors from the Argonne National Laboratory's GREET model (Argonne National Laboratory 2016).

Table 8 presents a summary of the consumption and emission factors used to assess the GHG emissions from international coal extraction.

Table 8. International Underground and Surface Mining Coal Extraction Factors

Material Input/Process	Factor	Unit	Source
Australia – electricity consumption	17.9	kWh/Mt of Coal	Dones et al. 2007
Canada – electricity consumption	25.1	kWh/Mt of Coal	Dones et al. 2007
China – electricity emissions	12.9	kWh/Mt of Coal	Dones et al. 2007
India – electricity consumption	12.9	kWh/Mt of Coal	Dones et al. 2007
Indonesia – electricity consumption	12.9	kWh/Mt of Coal	Dones et al. 2007
Russia – electricity consumption	93.0	kWh/Mt of Coal	Dones et al. 2007
South Africa – electricity consumption	13.9	kWh/Mt of Coal	Dones et al. 2007
Australia – electricity emissions	798.38	g CO_2/kWh	IEA 2015b
Canada – electricity emissions	158.4	g CO_2/kWh	IEA 2015b
China – electricity emissions	711.9	g CO_2/kWh	IEA 2015b
India – electricity emissions	789.24	g CO_2/kWh	IEA 2015b
Indonesia – electricity emissions	761.21	g CO_2/kWh	IEA 2015b
Russia – electricity emissions	439.37	g CO_2/kWh	IEA 2015b
South Africa – electricity emissions	926.40	g CO_2/kWh	IEA 2015b
Australia – diesel consumption	65.5	MJ/Mt of Coal	Dones et al. 2007
Canada – diesel consumption	33.7	MJ/Mt of Coal	Dones et al. 2007
China – diesel emissions	24.2	MJ/Mt of Coal	Dones et al. 2007
India – diesel consumption	24.2	MJ/Mt of Coal	Dones et al. 2007
Indonesia – diesel consumption	24.2	MJ/Mt of Coal	Dones et al. 2007
Russia – diesel consumption	41.8	MJ/Mt of Coal	Dones et al. 2007
South Africa – diesel consumption	48.3	MJ/Mt of Coal	Dones et al. 2007
Diesel combustion emissions	0.011	MtCO2e/Gallon	Argonne National Laboratory 2016
Australia – Coal Mine Methane	0.04	Mt CO_2e/Mt of Coal	UNFCCC 2017, EIA 2016
Canada – Coal Mine Methane	0.02	Mt CO_2e/Mt of Coal	UNFCCC 2017, EIA 2016
China – Coal Mine Methane	0.30	Mt CO_2e/Mt of Coal	IPCC 2006, GMI 2015, EIA 2016
India – Coal Mine Methane	0.05	Mt CO_2e/Mt of Coal	IPCC 2006, GMI 2015
Indonesia – Coal Mine Methane	0.02	Mt CO_2e/Mt of Coal	IPCC 2006, GMI 2015
Russia – Coal Mine Methane	0.15	Mt CO_2e/Mt of Coal	UNFCCC 2017, EIA 2016
South Africa – Coal Mine Methane	0.19	Mt CO_2e/Mt of Coal	IPCC 2006, GMI 2015

Sources: Argonne National Laboratory 2016, Intergovernmental Panel on Climate Change 2016, Dones et al. 2007, Global Methane Initiative 2015, IEA 2015, UNFCCC 2017

Mt = metric tons of material; kWh = kilowatt-hour; g = grams of material; MJ = megajoule; CO_2 = carbon dioxide; CO_2e = carbon dioxide equivalent; IPCC = Intergovernmental Panel on Climate Change; GMI = Global Methane Initiative

Uncertainty Associated with Methane Emissions from Coal Extraction

Methane emissions during coal extraction represent a major source of GHG emissions in the production of coal. In particular, methane concentrated in coal deposits is released during extraction processes. The amount of methane concentrated in coal deposits varies significantly between regions, but underground deposits have much higher concentrations than surface deposits (Intergovernmental Panel on Climate Change 2006).

Measurements and estimates of methane released during mining can be highly uncertain, even at the mine or basin level. As indicated in the adjacent table, the uncertainty for coal mine methane emissions can be well over 100%.[a] The majority of international emission factors used in the GHG analysis are from UNFCCC sources, where participating countries report both mining and post-mining methane for underground and surface activities.

	Underground Mining		Surface Mining	
Tier Methodology	**Mining**	**Post-Mining**	**Mining**	**Post-Mining**
Tier 3 - Mine Specific Factors	+/-2-30%		N/A	
Tier 2 - Basin Specific Factors	+/-50-75%	+/-50%	+/-200%	+/-50%
Tier 1 - Global Averages	+/-200%	+/-300%	+/-300%	+/-300%

Source: Intergovernmental Panel on Climate Change 2006

However, which Tier each country used and the associated uncertainty are not reported. For countries that do not report coal mining emissions (i.e., China, Indonesia, India, and South Africa for this assessment), IPCC (2006) Tier 1 emission factors are used as shown in the table to the left. These factors have uncertainty ranges from +/- 200 to 300 percent.

	IPCC Tier 1 Methane Emission Factors - Mining and Post-Mining (Mt CO_2e/Mt coal)		
Source Category	**Low**	**Average**	**High**
Underground Mining	0.18	0.34	0.49
Surface Mining	0.01	0.02	0.04

Source: Intergovernmental Panel on Climate Change 2006

In general, the uncertainty associated with the GHG emission estimates from coal mining are an order of magnitude higher than those associated with coal combustion. As an example, the table to the right contrasts the source uncertainties for emission measurements from coal methane and fossil fuel combustion from the latest U.S. Environmental Protection Agency GHG inventory estimates.[b] As indicated, coal mining methane emissions have a relatively higher uncertainty than those from fossil fuel combustion.

	Uncertainty Range for 2014 GHG Inventory	
Source Category	**Low**	**High**
Coal Mining Methane	-12%	15%
Fossil Fuel Combustion	-2%	5%

Source: U.S. EPA 2016b

Coal methane emissions from extraction are key contributors to net GHG emissions in the GHG analysis. Because of this contribution, the net GHG estimates are estimated for both with and without coal extraction emissions for each of the coal market assessment scenarios.

[a]IPCC uncertainties for coal mine methane emissions reflect ranges of percent deviations from the reported emission factors and are based on expert judgement (IPCC 2006).
[b]These values reflect the 95% confidence interval in percent deviations above and below the reported 2014 value for each source category (U.S. EPA 2016b).

Coal methane emissions from extraction are key contributors to net GHG emissions in the GHG analysis. Because of this contribution, the net GHG estimates are estimated both with and without coal extraction emissions. The uncertainties of these estimates are detailed in the text box above.

China, a major driver of this assessment's extraction emissions, currently produces large amounts of coal from methane-intensive underground mines. China has greatly expanded coal mine methane recovery and utilization over the past decade (Global Methane Initiative 2015). Based on its recently developed Intended Nationally Determined Contributions, China plans to continue to enhance vented methane recovery and utilization (United Nations Framework Convention on Climate Change 2015), but this is not reflected in this analysis due to data restrictions. Coal mine methane utilization values were taken into account in the emission factor for China based on data reported as of 2013 (Global Methane Initiative 2015). Increases in coal mine methane utilization in China would result in a decrease in the emission factor for China and an increase in the resulting net GHG estimates for each scenario (i.e., the offsetting of underground mined coal in China would result in offsetting a smaller quantity of methane from the estimate of net GHG emissions).

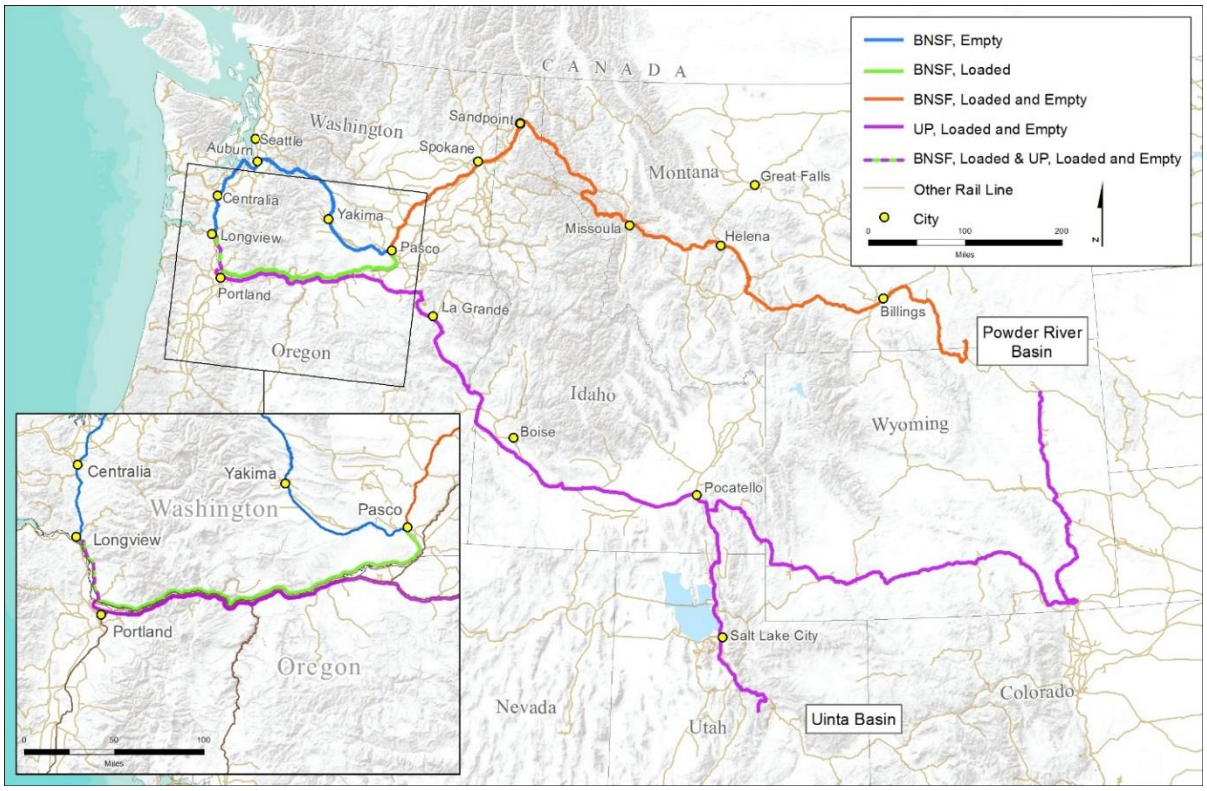
Rail Transport

Rail Transport to Washington State

Indirect sources of GHG emissions from coal transport from the Uinta and Powder River Basins to Washington State include diesel combustion emissions from locomotive operation of empty and loaded Proposed Action-related trains. The Uinta Basin is located in Colorado and Utah, whereas the Powder River Basin is located in Montana and Wyoming. The distances from six coal extraction sites (one each in Colorado and Utah; two in Montana; two in Wyoming) to Washington State range from 627 miles to 946 miles by rail. For this analysis, each train is assumed to consist of four locomotives and 125 rail cars, each loaded with 121 metric tons of coal[22] (ICF and Hellerworx 2017). For the return trip, this analysis assumes that the train would make a return trip to the coal basins with four locomotives and empty rail cars. Figure 6 provides an illustration of coal train routes from the Powder River Basin and the Uinta Basin to the project area.

[22] The approximate amount of coal that would be required to transport 44 million metric tons of coal in 8 loaded unit trains, 125 rail cars per day, 365 days per year.

Figure 6. Rail Transport of Coal to the Project Area



To calculate emissions, the gross mass of the loaded and empty coal trains is derived from BNSF data to determine the gross ton-miles of rail traffic associated with each scenario.[23] Table 9 provides an overview of the mass associated with the locomotives, the loaded coal, and the rail cars.

Table 9. Mass of Coal Train Components

Train Component	Mass (Metric Tons)
Locomotive (one)	196
Rail car (one)	19
Coal per car	121
Gross train mass (full)	18,222
Gross train mass (empty)	3,154

Source: ICF and Hellerworx 2017

The mass of the trains is multiplied by the total distance traveled to bring coal from mines in Colorado, Montana, Utah, and Wyoming to Washington State. The relative amount of train traffic from each extraction site is dependent on the coal market assessment scenario and year. For example, as the coal throughput at the coal export terminal remains constant, the relative shares of coal coming from the Uinta and Powder River Basins shifts. Table 10 provides estimates of rail

[23] Gross-ton miles refer to ton-miles travelled that include the mass of the railcars and locomotives in addition to the mass of the cargo.

distances from coal extraction sites to Washington State for the coal supply regions modeled that could export from the project area.

Table 10. Coal Supply Regions and Distances to Washington State

Coal Type	Rail Distance to Washington State (Miles)
Montana Powder River Basin Coal	797
Montana Signal Peak	760
Wyoming Powder River Basin Coal (8,400 Btu/lb)	946
Wyoming Powder River Basin Coal (8,800 Btu/lb)	946
Colorado Uinta Basin Coal	839
Utah Uinta Basin Coal	1,013

Source: Distances estimated via geographic information system mapping.
Btu/lb = British thermal units per pound

The fuel consumption for transport to Washington State is estimated by multiplying the ton-miles travelled for each data year by a fuel consumption per ton-mile factor for average locomotive diesel consumption.[24] The GHG emissions are estimated by multiplying the total fuel consumption by a rail diesel-specific combustion factor, as shown in Table 11.

Table 11. Emission Factors from Rail Diesel Fuel

Greenhouse Gas	Emission Factor ($MtCO_2e$/1,000 gallons)
Carbon dioxide	10.26
Methane	0.01
Nitrous oxide	0.02
Total	**10.29**

Source: U.S. Environmental Protection Agency 2015a
$MtCO_2e$ = metric tons of carbon dioxide equivalent

Rail Transport in Washington State beyond Cowlitz County

Indirect sources of GHG emissions from rail transport of coal in Washington State include diesel combustion emissions from locomotives. GHG emissions from rail transport of coal within Washington State to the border of Cowlitz County are estimated using the same approach as for transport to Washington State. Powder River and Uinta Basin coal would be transported through Washington State to Cowlitz County via Pasco and through the Columbia River Gorge, entering Cowlitz County near Woodland. Empty trains returning to the Powder River Basin would take a longer northern route (via Stampede Pass) whereas empty trains returning to the Uinta Basin return along the southern route. Therefore, returns to Powder River Basin are longer (Table 12).

[24] An estimate of 833 gross-short ton miles per gallon of diesel is used (BNSF Railway Company 2013).

Table 12. Coal Types and Distances within Washington State beyond Cowlitz County

Coal Type	Loaded Train Distance (Miles)	Empty Train Distance (Miles)
Powder River Basin coal	401	488
Uinta Basin Coal	18	18

Note: Estimate does not include distance travelled within Cowlitz County
Source: ICF and Hellerworx 2017

Rail Transport in Cowlitz County

Direct sources of GHG emissions from rail transport of coal in Cowlitz County include diesel combustion emissions from the operation of locomotives in Cowlitz County. Emissions include round-trip emissions from loaded and empty trains on the BNSF main line as well as the Reynolds Lead and BNSF Spur leading to the project area from the BNSF main line. Loaded trains travel to the project area from near Woodland, whereas empty trains travel along the BNSF main line to near Vader. GHG emissions from rail transport of coal from the border of Cowlitz County to the project area are estimated using the same approach as for the transport outside the county. Emissions are estimated from the project area to the county border; a distance of 25.1 miles for loaded trains entering Cowlitz County and 28.5 miles for empty trains leaving the county (Table 13).

Table 13. Rail Distances Traveled within Cowlitz County

Rail Route	Loaded Train Distance (Miles)	Empty Train Distance (Miles)
Cowlitz County Border to Longview Junction	17.9	-
Longview Junction to project area	7.1	7.1
Longview Junction to Cowlitz County Border	-	21.4
Total	**25.1**	**28.5**

Source: ICF and Hellerworx 2017

Locomotive Operation in the Project Area

Direct GHG emissions at the project area for the Proposed Action include emissions from the movement of coal trains around the 1.65- mile loop, the on-site idling of coal trains, and the operation of a switch locomotive to move cars and assemble trains for departure. The analysis assumes that it takes 1.85 hours to unload a 125-car unit train, each train has a 5-hour idle period prior to departing the facility, and the switch locomotive operates for 8 hours a day. This emission source includes the sum of these three activities. Emission factors for line-haul locomotives are based on projected changes in the locomotive fleet over the next 30 years (U.S. Environmental Protection Agency 2009b). These emission factors are based on engine load and associated fuel consumption during transport to and from the facility, time to unload coal from the train cars, and total annual coal throughput. The power demand is proportional to engine load, which varies in intensity depending on whether the locomotive is hauling freight or idling. The fuel consumption is estimated based on the power demand, which is estimated based on the engine load and duration of the activity. The fuel consumption is then multiplied by fuel combustion emission factors for locomotives as provided in Table 14.

Table 14. Emission Factors for Locomotives

Greenhouse Gas	Emission Factor ($MtCO_2e$/ 1,000 gallons)
Carbon dioxide	10.23
Methane	<0.1
Nitrous oxide	0.1
Total	**10.31**

Source: U.S. Environmental Protection Agency. 2009b. *Emission Factors for Locomotives.*
$MtCO_2e$ = metric tons of carbon dioxide equivalent

Vehicle-Crossing Delay

Direct sources of GHG emissions from vehicle-crossing delay include the incremental fuel emissions caused by vehicle delay at grade crossings in Cowlitz County due to train traffic to the project area. This emission source is based on existing rail infrastructure. GHG emissions are determined by estimating the gate downtime per day at grade crossings along the BNSF Spur and Reynolds Lead (between the BNSF main line and the project area) and at public at-grade crossings along the BNSF main line in Cowlitz County, and then estimating the average delay per vehicle for each crossing. The emission estimate does not consider any track improvements to the Reynolds Lead and BNSF Spur. Emissions are estimated based on the average volume of vehicle traffic for each crossing. The fleet mix, or relative shares of vehicle types delayed at the crossing, is assumed representative of Cowlitz County as a whole, and is derived from the MOtor Vehicle Emission Simulator (MOVES) model (U.S. Environmental Protection Agency 2014a). The MOVES model provides emission factors for each vehicle type in grams per mile travelled, which are converted into vehicle delay emissions by multiplying by the assumed average vehicle speed of 2.5 miles per hour.[25] The mix of vehicles and their contribution to the weighted average Cowlitz County vehicle traffic emission factor is shown in Table 15.

[25] The MOVES emission factor for vehicle idling is based on a slow operation speed of 2.5 miles per hour.

Table 15. Weighted Vehicle Fleet Mix for Cowlitz County, 2028

Vehicle Type	Vehicle Speed (mph)	Emission Factor (g/mi)[a]	Fraction of Each Vehicle (%)[b]	Weighted Emission Factor (g CO_2e/ vehicle-hour)
Combination long-haul truck	2.5	1,866	1.13	52.71
Combination short-haul truck	2.5	1,821	0.82	37.33
Intercity bus	2.5	1,909	0.01	0.48
Light commercial truck	2.5	375	8.07	75.57
Motor home	2.5	1,259	0.88	27.70
Motorcycle	2.5	443	3.22	35.67
Passenger car	2.5	273	48.12	328.01
Passenger truck	2.5	367	33.14	304.23
Refuse truck	2.5	1,839	0.15	6.90
School bus	2.5	1,253	0.36	11.28
Single unit long-haul truck	2.5	1,108	0.16	4.43
Single unit short-haul truck	2.5	1,153	3.92	112.99
Transit bus	2.5	1,648	0.04	1.65
Total			**100.00**	**998.95**

Notes: MOVES assumes a vehicle speed of 2.5 miles per hour to simulate idling emissions.
Sources:
[a] U.S. Environmental Protection Agency 2014a
[b] ICF 2017b

The delay is estimated for each road segment in the county and described as the total minutes of delays (in vehicle-hours) as well as the total vehicles affected. The emissions are estimated by multiplying the above fleet mix by vehicle-specific emission factors (in grams per vehicle-hour of delay) and then by the total amount of delay over the period of a year (Table 16).

Table 16. Activity Data for Vehicle Delay in Cowlitz County, 2028

Street	Daily Trains	Avg. Train Length (feet)	Train Speed (mph)	Avg. Daily Traffic in Both Directions (veh/day)	Number of Lanes in Both Directions	Total Delay (min /day)	Vehicles Delayed per Day (veh/day)
Study Crossings along the Reynolds Lead and BNSF Spur							
Industrial Way (SR 432)	16	5,944	10	12,100	2	4,315	975
Oregon Way (SR 433)	16	5,944	10	18,770	4	6,379	1,513
California Way	16	5,946	8	4,800	2	2,401	477
3rd Avenue (SR 432)	16	5,946	8	20,720	4	10,893	2,060
Dike Road	16	6,301	10	1,100	2	371	94
Project access (opposite 38th Avenue)	16	5,944	5	1,340	2	1,522	209
Weyerhaeuser Access (opposite Washington Way)	16	5,944	8	3,900	4	1,840	388
Weyerhaeuser Norpac Access	16	5,944	10	800	2	240	64
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County							
Taylor Crane Road in Castle Rock	8	5,546	50	50	2	0.4	0.5
Cowlitz Street in Castle Rock	8	5,546	50	1,450	2	13	14
Cowlitz Gardens Road in Kelso	8	5,546	62	850	2	6	7
Mill Street in Kelso	8	5,546	40	3,000	2	39	35
S River Road/ Yew Street in Kelso	8	5,546	40	2,200	2	28	25
Toteff Road/ Port Road in Kalama	8	5,546	62	1,450	2	10	12
W Scott Avenue in Woodland	8	5,546	62	3,100	2	21	26
Davidson Avenue in Woodland	8	5,546	62	2,350	2	16	20
Whalen Road in Woodland	8	5,546	62	1,800	2	12	15

Source: ICF and DKS Associates 2017.

Coal Export Terminal Construction

Direct sources of GHG emissions from construction include operation of the construction equipment itself as well as the vehicles to bring employees and construction materials to the project area. Fossil fuels are combusted for the operation of mobile combustion equipment used for demolition and earthwork to prepare the site. In addition, indirect GHG emissions result from production of the materials required for construction of the Proposed Action, such as conveyors, roadways, docks, and berms. Table 17 summarizes the required equipment and duration of use.

Table 17. Major Construction Activities and Typical Equipment Fleets[a]

Construction Equipment Type	Rail Infrastructure and Rotary Car Dump Station		Conveyors, Transfer Stations and Surge Bins		Shiploader, Dock, and Trestles	
	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)	Max Qty. per Month	Duration (months)
Mobile cranes (25–50 ton)	2	18	2	18	2	18
Mobile cranes (50–150 ton)	2	18	2	18	2	18
Mobile cranes (150–300 ton)	1	18	1	18	1	18
Water trucks	1	12	1	12	0	0
Dump trucks	3	12	1	12	0	0
Dozers	1	5	0	0	0	0
Excavators	1	9	2	12	1	3
Rollers	2	9	2	12	1	3
Graders	2	9	0	0	1	3
Compactors	2	9	2	12	1	3
Track laying machine	1	2	0	0	0	0
Drill rigs	1	2	2	6	0	0
Impact piling rigs	2	6	2	6	2	6
Loaders	1	12	1	12	1	9
River barge	0	0	0	0	2	18
Generator	2	18	2	18	2	18
Air compressor	2	18	2	18	2	18

Notes:
[a] Typical construction fleet may be modified with equivalent items as construction activities demand.
Sources: URS Corporation 2014b, ICF 2017b

Combustion emissions estimates are obtained from the NONROAD emissions model (U.S. Environmental Protection Agency 2009a) for the nonroad equipment. Construction activity is assumed to occur 8 hours per day, 5 days a week, 52 weeks per year, with the exception of the track-laying machine, which operates 4 hours per day. Emission factors are applied to the maximum numbers of equipment operated, duration of use, and horsepower, to obtain annual emissions.

Table 18 provides information on the emission factors for construction equipment.

Table 18. Construction Equipment Activity Data and Emission Factors

Equipment Type	Engine Size	Fuel Type	Number of Equipment Units	Emission Factor ($MtCO_2e$/year per Unit)[c]
Crane, 50-ton	165	Diesel	2	109.3
Crane, 150-ton	280	Diesel	2	183.0
Crane, 300-ton	450	Diesel	1	195.4
Water trucks	350	Diesel	1	98.8
Dump trucks	350	Diesel	4	98.8
Dozers	185	Diesel	0.4	396.5
Excavators	230	Diesel	2	886.6
Rollers	350	Diesel	3.8	100.3
Graders	185	Diesel	1.8	132.7
Compactors	25	Diesel	3.8	0.2
Track laying machine	[a]	Diesel	0.5	416.8
Drill Rigs	(NONROAD Default)[b]	Diesel	1.2	57.1
Impact Piling Rigs	(NONROAD Default)[b]	Diesel	3	57.1
Loaders	140	Diesel	1	416.8
Generator	30	Diesel	6	108.8
Air Compressor	25	Diesel	6	0.3

Notes:

[a] Assumes track-laying machine uses one diesel locomotive and one front end loader engine. Assumes full-time locomotive used 4 hours/day, 5 days/week.

[b] Horsepower and weight estimates are based on capacity ratings and industry specifications, or average ratings per equipment type. Where horsepower could not be assumed, an average horsepower rate in NONROAD for the equipment type is used.

[c] To calculate annual emissions, this emission factor is multiplied by 1.5 years to estimate the emissions for 18 months of construction.

Source: ICF 2017b

$MtCO_2e$ = metric tons of carbon dioxide equivalent

The impact of construction employee commuting is calculated using the MOVES model (U.S. Environmental Protection Agency 2014a), assuming that construction workers would use single-occupant vehicles with a mean round-trip travel time of 48.2 minutes. The analysis assumes that the 200 workers would be commuting during construction. At an estimated speed of 35 miles per hour, this amounts to 1,462,067 miles per year travelled. This distance is multiplied by emission factors for typical commuting vehicles provided by the MOVES model to calculate annual emissions.[26]

For the construction barges (operating under their own power or pushed/towed by another vessel), emissions are calculated using the EPA's AP-42 method for large diesel engines (U.S. Environmental Protection Agency 1996). The analysis assumes that the construction barges would have a positioning time of 1 hour with 1 round trip per day, 5 days per week, 52 weeks per year. Summaries of the barge activity and emission factors are available in Table 19 and Table 20, respectively.

[26] The analysis assumes a 50/50 mix of gasoline and E-85 for construction employee commuting vehicles.

Table 19. Barge Activity and Energy Use for Coal Export Terminal Construction

Barge Activity	Energy Consumption Variables
Barges used	2
Engine size (propulsion)	3,500 hp
Positioning time	1 hour
Total power per trip	7,000 hp
Construction trips	260 trips per year
Annual power	1,820,000 MMBtu per year

Source: ICF 2017b
hp = horsepower; MMBtu= million British thermal units per year

Table 20. Emission Factors for Construction Barges

Greenhouse Gas	$kgCO_2e$ per MMBtu	Emission Factor ($MtCO_2e$/ 1,000 gallons)
Carbon dioxide	74.8	10.23
Methane	0.1	0.1
Nitrous oxide	0.1	0.1
Total	75.0	10.25

Source: U.S. Environmental Protection Agency 1996
$kgCO_2e$ = kilograms of carbon dioxide equivalent; MMBtu = million British thermal units; $MtCO_2e$ = metric tons of carbon dioxide equivalent

The project area does not have an existing barge dock. Therefore, the material from incoming barges would be off-loaded at an existing dock elsewhere on the Columbia River and transported to the project area by truck. Emissions from trucks hauling construction material to the project area are estimated by determining the annual miles traveled by trucks going to and from the construction site and then multiplying those miles traveled by a per-mile emission factor from EPA's MOVES model. The peak annual trips for the Proposed Action are assumed 56,000 round trips (88,000 throughout the entire construction period) (URS Corporation 2015). Short-haul combination tractor-trailer trucks are assumed to move construction material with 47 roundtrip miles of travel in the county. The GHG emission factor is from a MOVES model run for Cowlitz County for the year 2018 (i.e., 1,561 to 1,930 grams of CO_2e per mile, depending on operating conditions).

The GHG emission assessment of the Proposed Action also includes an analysis of the emissions associated with the production of materials used in the initial construction of the coal export terminal. Production of materials, for the purpose of this analysis, includes raw materials extraction and processing, and product manufacturing. Transportation requirements are included for all supply chain elements up to the point of product manufacturing. The transportation of products from the manufacturer to the project area is modeled separately, as described in the previous paragraph.

The GHG emissions associated with construction materials for the Proposed Action are estimated using primary data from coal export terminal facility designs from the Applicant for total estimated material mass. Table 21 presents the estimated material masses for the coal export terminal by general type of material (e.g., concrete, steel, aggregate, and asphalt). The material masses are applied to the most recent and relevant emission factors for manufacturing of each material type. Table 21 summarizes these emission factors, modeling sources, and specific assessment notes or assumptions.

Table 21. Terminal Material Mass and Emission Factors

Facility Material/ Application	Mass (Mt)[a]	Emission Factor Material(s) Assumed	Emission Factor (kg CO_2e/Mt)	Emission Factor Source
Concrete	410,000	Concrete	180.3	UC Berkeley 2016
Berm Import Material	730,000	Primarily aggregates, assumed to be limestone gravel	3.9	Wernet et al. 2016
Transfer towers, galleries, etc.				
Structural Steel	9,500	Low-alloy steel	799.8	Wernet et al. 2016
Steel Piles	6,900	Low-alloy steel	799.8	Wernet et al. 2016
Rebar	9,300	Reinforcing steel	2,361.2	Wernet et al. 2016
Miscellaneous Steel	1,900	Low-alloy steel	799.8	Wernet et al. 2016
Rail System				
Rail	1,600	Steel	3,100.0	Hill et al. 2011
Gravel Ballast	57,600	Aggregate	8.0	Hill et al. 2011
Concrete Ties	9,800	Concrete	180.3	UC Berkeley 2016
Conveyors				
Idlers, belts, drives, take-up, stringers	8,300	Low-alloy steel	799.8	Wernet et al. 2016
Bridge Structures[b]				
Concrete	8,190	Concrete	180.3	UC Berkeley 2016
Rebar	910	Reinforcing steel	2,361.2	Wernet et al. 2016
Roadways[c]				
Asphalt	18,050	Asphalt	91.1	EIO-LCA: 2002 Purchaser (CMU GDI 2008)
Aggregate	11,950	Limestone gravel	3.9	Wernet et al. 2016
Buildings (Administration & Maintenance)	200	Assumed to be made up of low-alloy steel (33.3% of mass) and reinforced concrete (66.6%)	532.2	Wernet et al. 2016 , UC Berkeley 2016
Piping/Utilities	500	Ethylene pipeline	1,509.2	Wernet et al. 2016
Miscellaneous pumps, precast concrete, etc.	250	Assumed to be made up of low-alloy steel (33.3% of mass) and reinforced concrete (66.6%)	532.2	Wernet et al. 2016, UC Berkeley 2016
Electrical				
Substation	100	Low-alloy steel	799.8	Wernet et al. 2016
MCC Buildings	125	Assumed to be made up of steel (33.3% of mass) and reinforced concrete (66.6%)	799.8	Wernet et al. 2016, UC Berkeley 2016
Conduit, cable tray, cable, etc.	700	General cable	4,923.8	Wernet et al. 2016

Facility Material/ Application	Mass (Mt)[a]	Emission Factor Material(s) Assumed	Emission Factor (kg CO_2e/Mt)	Emission Factor Source
Major Equipment				
Tandem Rotary Dumper	500	Low-alloy steel	799.8	Wernet et al. 2016
Stackers	1,875	Low-alloy steel	799.8	Wernet et al. 2016
Reclaimers	3,300	Low-alloy steel	799.8	Wernet et al. 2016
Trestle/Dock/ Shiploaders				
Concrete	36,300	Concrete	180.3	UC Berkeley 2016
Rebar	900	Reinforcing steel	2,361.2	Wernet et al. 2016
Steel Piles	20,000	Low-alloy steel	799.8	Wernet et al. 2016
Shiploaders	3,300	Low-alloy steel	799.8	Wernet et al. 2016
10% Miscellaneous	135,200	Estimated material type, mass, and emission factor based on distribution of known materials	121.8	Emission factor based on distribution of known materials

Notes:

[a] Source: Millennium Bulk Terminals-Longview 2016, Hill et al. 2011, Wernet et al. 2016, UC Berkeley 2016

[b] Structures made of reinforced concrete. Assumed 90% of mass from concrete, 10% steel rebar.

[c] Roadways are designed with 3" of pavement (asphalt), 3" of subgrade (aggregate). Assumed a road width of 32" based on Cowlitz County (2007) standards.

Mt = metric tons of material; kgCO_2e/Mt = kilograms of carbon dioxide equivalent per metric ton of material

Construction of the coal export terminal would require dredging a 48-acre area (an estimated 500,000 cubic yards of sediment) of the river bottom to provide berthing at Docks 2 and 3. Emissions from equipment use for dock dredging were estimated by first determining the equipment necessary for typical dredging operations. Assumptions on the number of tugboats were based on a similar dredging analysis for the Port of Long Beach (Port of Long Beach 2012), while the dredge was assumed to be a diesel clamshell dredge with a capacity of 1,800 cubic yards per hour (Gaines pers. comm.). Horsepower assumptions were used from a similar dredging analysis performed for the Puget Sound Maritime Air Forum (Puget Sound Maritime Air Forum 2012) for tugboat engines, and Ellicott Dredges 2016 for the diesel dredge engines to estimate annual exhaust emissions from dredging equipment use (Table 22). The estimated 500,000 cubic yards of sediment were used to determine the number of tugboat trips required to transport dredged sediment, where 1 hour per round trip was assumed for transporting dredged material for a maximum distance of 3 miles back and forth along the Columbia River (Millennium Bulk Terminal—Longview 2014). The number of trips along the Columbia River was determined by the barge capacity of 2,250 cubic yards (Gaines pers. comm.). Based on these activities and the emission factor for diesel use of 692 g CO_2e/kWh (California Air Resources Board 2011), an annual emission factor for equipment was calculated as provided in Table 22.

Table 22. Coal Export Terminal Equipment and Emission Factors – Dredging Equipment

Equipment Type	Engine Size	Fuel Type	Emission Factor ($MtCO_2e$/year)[a]	Data Sources
Tugboat (Propulsion)	1,506 hp	Diesel	42.8	Puget Sound Maritime Air Forum 2012
Tugboat (Auxiliary)	125 hp	Diesel	3.1	Puget Sound Maritime Air Forum 2012
Tugboat aux at berth	125 hp	Diesel	1.0	Puget Sound Maritime Air Forum 2012
Diesel hydraulic dredge	2,680 hp	Diesel	98.0	Ellicott Dredges 2016, California Air Resources Board 2016
Auxiliary engine for hydraulic dredge	1,410 hp	Diesel	43.5	Ellicott Dredges 2016, California Air Resources Board 2016

$MtCO_2e$ = metric tons of carbon dioxide equivalent; hp = horsepower

[a] Calculated based on duration of 2 years for dredging activities to remove a total of 500,000 cubic yards of sediment, and engine horsepower and load factors as provided in Puget Sound Maritime Air Forum 2012, Ellicott Dredges 2016, California Air Resources Board 2016, and a diesel emission factor from California Air Resources Board 2011.

Coal Export Terminal Operation—Equipment Operation

Direct sources of GHG emissions from equipment operation at the terminal include fossil fuel emissions from mobile equipment on land, mobile equipment for maintenance dock dredging, and emergency equipment. Examples of equipment used for coal export terminal operation include loaders, maintenance vehicles, cranes, and emergency water pump and generator equipment. This equipment uses diesel, gasoline, and propane fuels. Emissions from mobile combustion sources and emergency equipment are estimated by first determining the equipment necessary for typical operation and maintenance and then using the NONROAD model (U.S. Environmental Protection Agency 2009a) to estimate annual exhaust emissions from that mobile and emergency equipment (Table 23). In addition to removing 500,000 cubic yards during construction, annual maintenance dredging of up to 100,000 cubic yards would occur during operation of the coal export terminal. Greenhouse gas emissions are estimated using the same method used during construction and the resulting emission factors are presented in Table 24.

Table 23. Coal Export Terminal Equipment and Emission Factors – Mobile Combustion and Emergency Equipment

Equipment Type	Engine Size	Fuel Type	Number of Equipment Units[a]	Emission Factor ($MtCO_2e$/year per Unit)[b]
Loader	300 hp	Diesel	1	671.7
Bobcat	50 hp	Diesel	2	16.6
10-Ton Truck	300 hp	Diesel	2	98.8
Crane	50 hp	Diesel	1	0.0
Forklift	40 hp	Propane	1	0.1
Maintenance Trucks	300 hp	Gasoline	4	0.2
Fire Water Pump	200 hp	Diesel	1	3.5
Emergency Generators	30 hp	Diesel	2	0.5

Source: U.S. Environmental Protection Agency 2009a, U.S. Environmental Protection Agency 2016c

[a] An equipment unit represents the number of equipment types are that are used in a year for annual operations. Hours of operation are based on those specified in the SEPA Air Quality Technical Report (ICF 2017b).

[b]-Calculated based on horsepower and hours of operation assumptions used in the SEPA Air Quality Technical Report (ICF 2017b).

$MtCO_2e$ = metric tons of carbon dioxide equivalent; hp = horsepower

Table 24. Coal Export Terminal Equipment and Emission Factors – Maintenance Dredging

Equipment Type	Engine Size	Fuel Type	Emission Factor ($MtCO_2e$/year)[b]	Data Source
Tugboat (Propulsion)	1,506 hp	Diesel	17.1	Puget Sound Maritime Air Forum 2012
Tugboat (Auxiliary)	125 hp	Diesel	1.2	Puget Sound Maritime Air Forum 2012
Tugboat aux at berth	125 hp	Diesel	0.4	Puget Sound Maritime Air Forum 2012
Diesel hydraulic dredge	2,680 hp	Diesel	39.2	Ellicott Dredges 2016, California Air Resources Board, 2016
Auxiliary engine for hydraulic dredge	1,410 hp	Diesel	17.4	Ellicott Dredges 2016, California Air Resources Board, 2016

$MtCO_2e$ = metric tons of carbon dioxide equivalent; hp = horsepower

[b] –Calculated based on engine size, emission factor for diesel, and equipment use for one year of operation dredging 100,000 cubic yards of sediment.

Coal Export Terminal Operation—Electricity Consumption

Indirect sources of GHG emissions for electrical consumption include fuel combustion emissions at off-site power plants to produce electricity consumed at the coal export terminal. The local energy grid would provide electricity for operation of coal export terminal facilities. The additional electricity consumption that would be required for the coal export terminal is assumed similar to the annual energy use for the existing bulk product terminal (Chany pers. comm.). To estimate net

annual increase in GHG emissions from electricity consumption, the monthly electricity demand for the existing bulk product terminal is annualized in kilowatt-hours, as shown in Table 25.

Table 25. Monthly and Annual Electricity Demand for Coal Export Terminal

Time Period	Usage
Monthly	552,000 kWh
Annual	6,624 MWh

Notes:
Additional demand is assumed to occur throughout the entire analysis period, including construction.
Source: Chany pers. comm.
kWh = kilowatt hour; MWh = megawatt hour

To derive additional GHG emissions from electricity consumption for coal export terminal operations, the electricity fuel mix for an average water year is obtained from the Cowlitz Public Utility District. Emission factors for each fuel type are then derived from individual plant data for each fuel in the Western Electricity Coordinating Council Northwest subregion as provided in the Emissions & Generation Resource Integrated Database (eGRID). These individual fuel emission factors are combined using the Cowlitz Public Utility District fuel mix to obtain a weighted average emission factor to apply to electricity consumption from the Proposed Action. Table 26 provides the fuel mix and emission factors used to derive GHG emissions from electricity consumption for coal export terminal operations.

Table 26. Average Fuel Mix and Fuel-Specific Emission Factor for the Cowlitz Public Utilities District Region

Fuel Source	Share of Electricity Fuel Mix (%)	Carbon Dioxide (kg CO_2e/MWh)	Methane (kg CO_2e/MWh)	Nitrous Oxide (kg CO_2e/MWh)	Total (kg CO_2e/MWh)
Hydro	84.64%	0	0	0	0
Nuclear	9.70%	0	0	0	0
Wind	2.66%	0	0	0	0
Coal	2.08%	1,095.8	0.3	5.5	1,101.5
Natural Gas	0.79%	436.8	0.2	0.3	437.3
Other[a]	0.13%	302.0	0.1	1.4	303.5
Weighted Average	**100%**	**26.6**	**0.01**	**0.1**	**26.8**

[a] Other is made up of biomass, cogeneration, geothermal, landfill gas, petroleum, solar, and waste incineration.
Source: Cowlitz Public Utility District 2015, U.S. Environmental Protection Agency 2015b

Employee Commuting

Direct sources of GHG emissions from employee commuting include the emissions from fossil fuel combustion associated with the daily commuting traffic for employees to and from the site. The GHG emissions from employees commuting to the project area are calculated using the MOVES model (U.S. Environmental Protection Agency 2014a), assuming that employees would use single-occupant vehicles with a mean round-trip travel time of 48.2 minutes. The analysis assumes that there are 135 employees, with 25 commuting 5 days per week and 110 commuting 7 days per week. At an

estimated speed of 35 miles per hour, this amounts to 1,092,051 miles per year travelled. This distance is multiplied by emission factors for typical commuting vehicles provided by the MOVES model to calculate annual emissions.[27]

Vessel Idling and Tugboat Use at Coal Export Terminal

Direct sources of GHG emissions from vessel idling and tugboat use at the coal export terminal include current vessel operations at the coal export terminal, as vessels use main and auxiliary motors to maneuver in and out of the loading area. Additionally, this source includes fossil fuel combustion emissions from tugboats that are used to assist in vessel maneuvering at the project area.

GHG emissions from vessel idling and tugboat use are calculated by estimating the power consumed by idling vessels, converting the power demand into fuel consumption, and multiplying that fuel consumption by a fuel combustion emission factor. An average of 13 hours would be needed to load each vessel with coal, and during this period, the vessel would be hoteling using auxiliary engines. For each vessel, the typical main and auxiliary engine size is based on Lloyd's Register of Ships Sea-web, which has a database of ship characteristics for ships over 100 gross tons (Sea-web 2015). Each vessel receiving coal is assumed to need three tugs to maneuver the ship. These tugs would operate for 3 hours to assist with docking and departing. The time spent operating the vessels in each mode, multiplied by the estimated engine load and size provided power demand for both the idling vessels and tugboats. The power demand is then multiplied by the emission factors provided in Table 27.

Table 27. Emission Factors for Idling Vessels and Tugboats

Greenhouse Gas	Main Engine Emission Factor (g CO_2e per kWh)	Auxiliary Engine Emission Factor (g CO_2e per kWh)
Carbon dioxide	588	690
Methane	1.75	2.25
Nitrous oxide	0.12	0.12
Total	**590**	**692**

Source: California Air Resources Board 2011. *Appendix D: Emissions Estimation Methodology for Ocean-Going Vessels.*
gCO_2e = grams of carbon dioxide equivalent; kWh = kilowatt-hour

Helicopter and Pilot Boat Trips

Indirect sources of GHG emissions for helicopter and pilot boat transfers include fossil fuels burned to pilot vessels along the Columbia River. GHG emissions from helicopter and pilot boat trips that transfer pilots to vessels are calculated as described in the SEPA Vessel Transportation Technical Report (ICF 2017e). The trips for both vehicle types are multiplied by the distance for each trip to derive the total mileage and fuel consumption for each trip. Assuming that at full capacity, the Proposed Action would service 840 vessels annually and each vessel would require piloting in and out of the Columbia River Bar, this use equates to 1,680 pilot transfers per year. Incoming and outgoing vessels are piloted 15 nautical miles (17 standard miles) from the mouth of the Columbia River, for an average distance of 30 nautical miles (34 standard miles) per trip. The bar pilot to river

[27] The analysis assumes a 50/50 mix of gasoline and E-85 for employee commuting vehicles.

pilot changeover takes place at Tongue Point near Astoria for both outbound and inbound vessels, therefore only one pilot transfer is needed for each incoming and outgoing vessel (Ellenwood pers. comm.). Helicopters are used for offshore transfer of Columbia River Bar pilots 70% of the time, with the remaining 30% of the offshore transfers conducted using a pilot boat due to more challenging weather conditions (Table 28).

Table 28. Annual Helicopter and Pilot Boat Transfers per Vessel, 2028

Project Year	Total Number of Vessels Traveling to the Coal Export Terminal	Number of Pilot Transfers		Total Number of Pilot Transfers
		Helicopter	Pilot Boat	All
2028	840	1,176	504	1,680

Source: ICF 2017e, Ellenwood pers. comm.

The trips are multiplied by the distance to estimate the total nautical miles travelled per mode of transport, as shown in Table 29.

Table 29. Helicopter and Pilot Boat Trips and Nautical Miles Travelled

Project Year	Helicopter		Pilot Boat	
	Trips	Total Miles	Trips	Total Miles
2028	1,176	40,600	504	17,400

Source: ICF 2017e

GHG emissions from each mode of transport are based on the time of travel from shore to the vessels. The average trip time for helicopters is assumed 18 minutes (Ellenwood pers. comm.). For pilot boats, an average speed of 14 miles per hour is assumed (Columbia River Bar Pilots 2015), resulting in a roundtrip travel time of 2.5 hours. For helicopters, the fuel consumption rate of 1 gallon per minute was obtained directly from Brim Aviation (Ellenwood pers. comm.). Fuel consumption and aviation gasoline emission factors are presented in Table 30 and Table 31, respectively. The emissions are calculated by first estimating the amount of fuel consumed per helicopter trip, multiplying that by the emission factor for aviation gasoline, and then by the number of helicopter trips.

Table 30. Helicopter Fuel Consumption

Aircraft	Average Fuel Consumption Rate (Gallons per Minute)	Average Trip Time (Minutes)
Sikorsky S-76 "Seahawk"	1	18

Source: Ellenwood pers. comm.

Table 31. Combustion Emissions for Aviation Gasoline

Greenhouse Gas	Emission Factor ($MTCO_2e$/1,000 gallons)
Carbon dioxide	8.31
Methane	0.18
Nitrous oxide	0.03
Total	**8.52**

Source: U.S. Environmental Protection Agency 2015a
$MTCO_2e$ = metric tons of carbon dioxide equivalent

GHG emissions from pilot boats are based on the energy required for the pilot boat to make one trip based on the estimated round-trip duration of 2.5 hours. Energy is converted into gallons of residual fuel and multiplied by an emission factor for residual fuel combustion in order to calculate the GHG emissions for a single pilot boat trip. This value is then multiplied by the total number of annual pilot boat trips to estimate the total annual GHG emissions. The factors used to estimate the energy consumption and the emissions for pilot boats are shown in Table 32 and Table 33, respectively.

Table 32. Factors for Pilot Boat Fuel Consumption

Factor	Magnitude
Trip duration	2.5 hours
Horsepower of engines[a]	1,800 hp
Average engine load over trip[b]	45%
Energy consumed, kWh	1,511 kWh
Energy consumed, MMBtu[c]	5.2 MMBtu
Energy in residual fuel[d]	0.15 MMBtu per gallon
Gallons of residual fuel consumed	34.4 gallons per trip

Notes:
[a] Brusco Tug and Barge Undated
[b] California Air Resources Board 2011
[c] Estimated by converting kWh to MMBtu
[d] U.S. Environmental Protection Agency 2015a
hp = horsepower; MMBtu = million British thermal units

Table 33. Combustion Emissions for Residual Fuel

Greenhouse Gas	Emission Factor ($MtCO_2e$/1,000 gallons)
Carbon dioxide	11.24
Methane	0.003
Nitrous oxide	0.17
Total	**11.41**

Source: U.S. Environmental Protection Agency 2015a
$MTCO_2e$ = metric tons of carbon dioxide equivalent

Vessel Transport

Vessel transport is calculated in three phases: the transport of coal between the project area and the border of Cowlitz County, the transport of coal down the Columbia River through Washington State, and lastly, the transport of coal to markets in Asia. Both incoming and outgoing vessel traffic are accounted for within Cowlitz County and Washington State, while only a share of the returning vessels from Asia are accounted for since only a share of these vessels return with ballast water only.

Vessel Transport in Cowlitz County

Direct sources of GHG emissions from vessel transport in Cowlitz County include fossil fuel combustion associated with current vessel transport from the coal export terminal down the Columbia River to the border of Cowlitz County, a 9.87 nautical mile (11.35 mile) distance. This distance is repeated to account for empty vessels returning to the coal export terminal. GHG emissions from vessel transport are calculated using the same method as for air emissions and summarized in the SEPA Air Quality Technical Report (2017b). This analysis assumes that the coal export terminal would be serviced by a mix of Panamax (80%) and Handymax (20%) vessels. To incorporate this assumption, the engine size is considered a weighted average of Panamax and Handymax vessels. For each vessel, the typical main and auxiliary engine size is based on Lloyd's Register of Ships Sea-web, which has a database of ship characteristics for ships over 100 gross tons (Sea-web 2015).

GHG emissions from vessel idling and tugboat use are calculated by estimating the energy consumed by vessels exiting Cowlitz County, which is a factor of the duration to enter or exit the county, the engine size, and engine load for loaded ships in transit. The annual energy demand is multiplied by an emission factor for main engine vessel use for loaded transit. The one-way transit time within Cowlitz County is assumed 0.9 hour. The annual energy demand is then multiplied by the emission factors provided in Table 34.

Table 34. Emission Factors for Vessels in Transit

Greenhouse Gas	Main Engine Emission Factor (g CO_2e per kWh)	Auxiliary Engine Emission Factor (g CO_2e per kWh)
Carbon dioxide	588	690
Methane	1.75	2.25
Nitrous oxide	0.12	0.12
Total	**590**	**692**

Source: California Air Resources Board 2011. *Appendix D: Emissions Estimation Methodology for Ocean-Going Vessels.*
$kgCO_2e$ = kilograms of carbon dioxide equivalent; kWh = kilowatt-hours

Vessel Transport in Washington State beyond Cowlitz County

As previously mentioned, the coal export terminal would be serviced by a mix of Panamax (80%) and Handymax (20%) bulk carrier vessels. To incorporate this assumption for vessel transport outside of Cowlitz County through Washington State and overseas to Asian markets, IHS Sea-Web data (Sea-web 2015), a database of ship characteristics for ships over 100 gross tons, is used to determine average service speed and total propulsion power for the two vessels. Four vessels for each size are used with the same approximate deadweight tons of the two vessels to determine the averages. Ship characteristics for the two vessels are shown in Table 35.

Table 35. Average Vessel Characteristics

Vessel Size	Main Engine Propulsion Power (kW)	Average Vessel Service Speed (knots)
HandyMax	7,789	14.40
PanaMax	9,473	14.39

Source: Sea-web 2015

Emissions are estimated depending upon operating mode. Three operating modes are defined here, namely, open-ocean, transit down the Columbia and hoteling at berth. Movement in the open-ocean between the mouth of the Columbia River and Asia occurs at service speed. Transit down the Columbia River occurs at 8.4 knots (average between 6.5 knots up and 12 knots down the Columbia River due to currents) (Breen pers. comm.).

Propulsion engine load factors are determined using the propeller law, which is the cube of the actual vessel speed divided by the maximum vessel speed. Service speed is typically 93.5% of maximum speed (ICF 2009). Auxiliary engine and boiler loads are from the 2014 Port of Los Angeles Emissions Inventory Document and are listed in Table 36 (Starcrest Consulting Group 2015). When the propulsion engines are operating at 20% load or more, exhaust economizers supply steam so boilers are shut off.

Table 36. Auxiliary Engine and Boiler loads

	Loads (kW)	
Operation	**Auxiliary**	**Boiler**
Moving	225	132

Source: Starcrest Consulting Group 2015
kW = kilowatt

Emission factors in grams per kilowatt-hour from the California Air Resources Board are used to develop overall ship emission factors in terms of kilograms per nautical mile. Table 37 presents emission factors in grams per kilowatt-hour for each greenhouse gas.

Table 38 presents the overall ship emission factors in kg per nautical mile based on the various speed and load assumptions for the two ships.

Table 37. Vessel Emission Factors by Equipment Type

Greenhouse Gas	Main Engine Emission Factor (g CO_2e per kWh)	Auxiliary Engine Emission Factor (g CO_2e per kWh)	Boiler Emission Factor (g CO_2e per kWh)
Carbon dioxide	588	690	970
Methane	1.75	2.25	0.75
Nitrous oxide	0.12	0.12	0.12
Total	590	692	971

Source: California Air Resources Board 2011. *Appendix D: Emissions Estimation Methodology for Ocean-Going Vessels.*
kgCO_2e = kilograms of carbon dioxide equivalent; kWh = kilowatt-hours

Table 38. Emission Factors by Vessel Type

	CO_2e emission factors (kg/nm)	
Ship	**At Sea**	**Columbia**
HandyMax	277.69	124.28
PanaMax	335.59	144.14

Source: Calculated.
kg/nm = kilograms per nautical mile

Indirect sources of GHG emissions from vessel transport outside of Cowlitz County but within Washington State include fossil fuel combustion. This analysis assumes a distance of 47.78 nautical miles (54.94 miles), which takes the vessels from the border of Cowlitz County to 3 nautical miles past the mouth of the Columbia River. This distance is repeated for vessels returning to the state to pick up coal. Emissions are calculated by multiplying this distance by the Columbia River emission factor.

Vessel Transport to Asian Markets

Indirect sources of GHG emissions from vessel transport to Asian markets include fossil fuel combustion. GHG emissions are based on nautical miles of shipping from the coal market assessment, which provides yearly total nautical miles of coal shipped throughout the Pacific Basin

for both the action and no-action models for each scenario. The difference in ship traffic between these scenarios is used to estimate the change in nautical miles attributable to the Proposed Action. Table 39 summarizes the distances to Asian markets from the United States.

For changes in coal shipments within the Pacific Basin, GHG emissions are based on an estimate in the coal market assessment of the total net change in nautical miles traveled within the Pacific Basin. This estimate considers the total change in Pacific Basin coal traffic because of the Proposed Action, including the new coal coming from the United States, and shifts in coal shipments from producers primarily in Indonesia, Australia, Russia, and China.

Table 39. Net Change in Nautical Miles Traveled by Proposed Action-Related Vessels

Scenario	2020	2025	2030	2040
2015 U.S. and International Energy Policy	0	2,722,792	2,525,104	3,145,596
Lower Bound	0	3,459,178	2,524,928	3,176,780
Upper Bound	0	3,324,926	2,555,506	3,721,348
No Clean Power Plan	0	2,086,181	2,591,077	2,311,512
Cumulative	0	5,805,597	7,365,846	8,235,972

Notes: 1 nautical mile is equivalent to 1.15078 miles. The net change in nautical miles includes vessels departing from the terminal, and vessels that would be substituted by vessels departing from the terminal. The distances provided in this table are one-way distances.
Source: ICF 2017c

The total change in nautical miles traveled in the Pacific Basin from the Proposed Action is multiplied by the At Sea emission factor as provided in Table 38. The net impact of this emission source is the sum of the new emissions (delivery of coal from the Proposed Action) to Asian markets and the emissions offset from changes in Pacific Basin coal transport. In addition to the five Asian markets importing coal as identified in the coal market assessment, the effect of the Proposed Action on coal markets could cause shifts in additional Asian markets as Australian and Indonesian coals find new markets. The additional countries include India and other smaller consumers in the Pacific Basin that are grouped into the "Asia Other" demand region.[28] For example, for some scenarios, the coal market analysis indicates that Hong Kong substitutes some of its consumption of Indonesian coal with coal exported from the Proposed Action; however, the Asia Other demand region increases its purchases of the Indonesian coal displaced from Japan.

With few exceptions, dry bulk vessels "do not travel repetitive routes" and "dry bulk carriers seldom operate on round-trip voyages; the norm is multi-leg or triangular service to avoid excessive ballasting (traveling without paying cargo)" (Coal Age 2015). To estimate the share of trips that return empty and filled with ballast water, an analysis of data from the Automatic Identified System (AIS) from 2016 was performed.[29] The dataset was filtered to account for vessels that had the vessel type description of Handymax/Panamax. The percent of similar vessels that leave Asia in ballast is based on an evaluation of Automatic Identified System data to determine vessels of a similar size and class that transit near the mouth of the Columbia River and travel to/from Asia, and to conduct comparative data analysis of scantling and design draft of the individual vessels with the actual reported draft for each voyage. Based on this method, a conservative estimate of 40% of trips returning from Asia empty filled with ballast water was used. The same 40% is added onto

[28] This category includes Malaysia, the Philippines, Thailand, and Vietnam, as well as smaller importers of coal.

[29] An overview of the Automated Identified System is available from U.S. Department of Homeland Security, 2014.

international vessel transport from non-U.S. coal exports (e.g., Australia, Indonesia, Russia, and China) being substituted by the Proposed Action.

Coal Combustion in Asia and the United States

Indirect sources of GHG emissions from coal combustion include the change in both U.S. and Asia coal consumption that would result from a new coal export terminal. The coal market assessment estimates net coal combustion in Asia and the United States. These estimates are presented in the GHG analysis for each scenario relative to the no-action model results.

GHG emissions from coal combustion include those associated with market effects, which dictate the total amount of coal produced and combusted in the United States and Asia in response to coal supply and price. Emissions also reflect coal substitution, which is driven by the difference in carbon content between Powder River Basin coal, Uinta Basin coal, and coals produced in Asia. Table 40 summarizes the differences in carbon and heat contents among some of the coals assessed in the coal market assessment. [30]

Table 40. Heat Content and Carbon Coefficients for U.S. and Asian Reference Coals

Source	Coal Type	Heat Content (MMBtu per ton)[a]	CO_2 Emission Factor (pounds per MMBtu)
Powder River Basin—WY	Subbituminous	17.6	209.4
Powder River Basin—MT	Subbituminous	18.64 / 17.08	213.8
Uinta—CO	Bituminous	22.22	208.4
Uinta—UT	Bituminous	22.56 / 24.06	205.6
Australia	Bituminous	21.6	206.0
Indonesia	Bituminous	23.43 / 20.33	203.7
Indonesia	Subbituminous	18.05 / 17.19 / 15.12	214.8
China	Bituminous	23.85	212.2
China	Lignite	14.04	218.5

[a] For some coal types, more than one heat content value is indicated, because multiple coal types are modeled that have the same CO_2 emissions factor.
Source: ICF 2017c
MMBtu = million metric British thermal units; CO_2 = carbon dioxide

Induced Natural Gas Consumption in the United States

Indirect sources of GHG emissions from induced natural gas consumption would result from changes in consumption as a function of changes in the coal market. As coal prices increase due to the increased demand by the project for coal to export, the United States' natural gas consumption is expected to increase.

The Proposed Action could result in supply and price shifts in the coal markets, which affect the consumption of natural gas in the United States. The coal market assessment describes the substitution of natural gas for coal and estimates the GHG emissions from induced natural gas

[30] See the SEPA Coal Market Assessment Technical Report, Section 4.2.13 for the carbon and heat content of all of the coal types modeled.

consumption in the United States. Depending on the scenario, natural gas consumption changes based on coal prices and U.S. coal consumption.

2.3 Existing Conditions

The existing environmental conditions related to GHG emissions in the study area are described in the sections that follow.

2.3.1 Applicant's Leased Area

The existing bulk product terminal in the Applicant's leased area draws electricity from the regional electricity grid, amounting to 552,000 kilowatt hours of electricity demand per month, or 6,624 megawatt hours of electricity annually (Chany pers. comm.). The emissions from this source are already occurring and would continue whether or not the coal export terminal is constructed. Electricity usage results in indirect emissions of approximately 177 metric tons of CO_2e annually, as estimated in Section 3.1.8, *Coal Export Terminal Operation—Electricity Consumption.*

The current vessel traffic at Dock 1 is six ships per year. Using the method described in Section 2.2.2.3, *Method for Impact Analysis,* under *Vessel Transport in Cowlitz County,* and assuming that the vessels are docking for approximately 13 hours per trip, maneuvering for 1 hour, and transiting within Cowlitz County for 0.9 hour each way, their operation emissions total 95 metric tons of CO_2e annually. Table 41 describes the current vessel transport activity at the project area. The current emissions from the project area for the Proposed Action are relatively small compared to the scale of emissions from the Proposed Action and are thus not taken into account when estimating the net emissions associated with the Proposed Action.

Table 41. Current Vessel Transport Activities in the Project Area

Transport Type	Transport Activity	Facility Activity
Handymax Class Vessel	6 ships per year	Ships currently deliver alumina over Dock 1; the cargo is temporarily stored and then shipped to Chelan County by train

Source: ICF and Hellerworx 2017, and ICF 2017e

2.3.2 Cowlitz County

Approximately 7 trains per day consisting of approximately 78 cars typically pass between the BNSF Spur and main line (ICF and Hellerworx 2017). Using the method described in Section 2.2.2.3, *Method for Impact Analysis,* under *Rail Transport of Coal in Cowlitz County,* and assuming that the trains haul 122.1 metric tons of material per rail car, use two locomotives, and travel 20.0 miles through Cowlitz County to and from the north on the main line and BNSF Spur, the annual emissions from those trains are currently 2,206 metric tons of CO_2e. Baseline traffic on the Reynolds Lead at the project area in Cowlitz County is about two trains per day. Assuming that the trains traveling on the Reynolds Lead also haul 122.1 metric tons of material per rail car, use one locomotive, and travel the approximately 5-mile length of the Reynolds Lead, the annual emissions from those trains are currently 79 metric tons of CO_2e. These totals include trains delivering grain as well as trains connecting to other port facilities.

2.3.3 Washington State

Washington State's total GHG emissions were 92.0 $MMTCO_2e$ in 2012, the most recent year for which a GHG Inventory was conducted. Of that total, 42.5 $MMTCO_2e$ (46.2%) are attributable to the transportation sector, and 12.1 $MMTCO_2e$ (13.2%) are attributable to coal combustion in the electricity sector (Washington State Department of Ecology 2016).

Rail traffic in Washington is busy in areas, with some route segments seeing as many as 70 trains per day (ICF and Hellerworx 2017). Existing rail capacity provides passenger service as well as transport for a variety of goods. The rail network accommodates empty and full coal trains as well as intermodal, grain, and general manifest trains from both BNSF and UP. Similarly, existing vessel traffic along the Columbia River is heavy due to the amount of bulk cargo transported in the region. The gross tonnage of vessel traffic in a 1-year period (averaged from 2010 to 2014) is approximately 91 million gross short tons (ICF 2017e).

Chapter 3
Impacts

This chapter describes the potential GHG emissions that would result from construction and operation of the Proposed Action relative to the No-Action Alternative.

3.1 Proposed Action

The GHG emissions are presented in terms of the 2028 emissions and total net emissions over the 2018 through 2038 analysis period. The total net emissions are the sum of emissions for the entire analysis period, including construction beginning in 2018 and operation through 2038.

The results are presented by emission sources, which are described in Section 2.2.2.3, *Method for Impact Analysis*. The source emissions are then combined into an estimate of total net GHG emissions.

3.1.1 Upland and Wetland Land-Cover Change

The vegetation removal, soil disturbance, and wetland loss associated with construction of the coal export terminal would result in the loss of accumulated carbon stocks during construction, as well as the loss of ongoing carbon sequestration from the removed vegetation (resulting in net increases in emissions) and a reduction in carbon dioxide and methane emissions from permanently filled wetlands over the analysis period (2018 through 2038). Table 42 presents the estimated emissions associated with construction of the coal export terminal.

Table 42. Vegetation Removal, Soil Disturbance, and Wetland Loss Emissions ($MtCO_2e$)

Emission Source	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Emissions During 12-Months of Construction Period ($MtCO_2e$)	11,771	11,771	11,771	11,771
Annual Emissions, 2028 ($MtCO_2e$)	17	17	17	17
Total Emissions, 2018–2038 ($MtCO_2e$)	12,121	12,121	12,121	12,121

Notes:
Vegetation Removal, Soil Disturbance, and Wetland Loss emissions represent the total emissions resulting from the proposed project emission sources, including: (1) loss of accumulated carbon stocks during construction; (2) lost sequestration from removed vegetation that results in net increases in emissions; and (3) reduction in carbon dioxide and methane emissions from permanently filled wetlands.
$MtCO_2e$ = metric tons of carbon dioxide equivalent

For construction of the Proposed Action, carbon stock losses are estimated to be 11,771 metric tons of CO_2e and total (2018 through 2038) emissions are estimated to be 12,121 metric tons of CO_2e (which includes GHG emissions of 350 metric tons of CO_2e from lost sequestration/wetland emission reductions).

3.1.2 Dock Dredging During Terminal Construction and Operations—Sediment Carbon

Dock dredging during terminal construction and operations associated with the Proposed Action would result in the potential loss of sediment carbon. Table 43 presents the estimated emissions associated with the potential loss of sediment carbon from dock dredging during coal export terminal construction and operations associated with the Proposed Action.

Table 43. Potential Loss of Sediment Carbon from Dock Dredging ($MtCO_2e$)

Emission Source	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Emissions During 12-Months of Construction Period[a] ($MtCO_2e$)	1,919	1,919	1,919	1,919
Annual Emissions, 2028 ($MtCO_2e$)	768	768	768	768
Total Emissions, 2018–2038 ($MtCO_2e$)	17,654	17,654	17,654	17,654

Notes:

[a] Dredging during the construction period is expected to occur over two annual approved work periods to coincide with fish protection during the construction phase (Millennium Bulk Terminal—Longview 2014). One of the approved work periods is assumed to coincide with the first 12 months of construction period, while the second dredging event is assumed to occur within the following year. Therefore, emissions during the 12 months of construction period shown above are assumed to be half of the total emissions of 3,838 $MMTCO_2e$ during the entire construction period from 2018-2020.

$MtCO_2e$ = metric tons of carbon dioxide equivalent

For dock dredging during terminal construction associated with the Proposed Action from 2018 through 2020, the potential loss of sediment carbon is estimated to be 3,838 metric tons of CO_2e and total (2018 through 2038) potential losses are estimated to be 17,654 metric tons of CO_2e. The 768 metric tons of CO_2e in 2028 is the potential loss of sediment carbon during annual maintenance dredging.

3.1.3 Coal Extraction

Coal extraction emissions are assumed to occur throughout the analysis period based on the coal extraction scenarios described in the coal market assessment. Under the approach described in Section 2.2.2.3, *Method for Impact Analysis,* the net indirect coal extraction GHG emissions from the Proposed Action are calculated by applying the GHG emission factors for each source of indirect emissions to the mass of U.S. coal extraction that would be induced by the Proposed Action, covering the Powder River Basin, the Uinta Basin, and other U.S. coal regions. These GHG estimates are offset by changes in GHG emissions from competing coal extraction outside the United States, primarily in Australia, China, and Russia. From these annual estimates of net GHG emissions, the net indirect GHG emissions are calculated for coal extraction that would result from the Proposed Action from 2018 through 2038.

The net emissions from coal extraction vary across the four scenarios depending on the magnitude of the increase in coal extraction in the United States, the different U.S. extraction regions impacted by the Proposed Action, the magnitude of the decrease in international coal extraction, and the different international extraction regions impacted by the Proposed Action throughout the analysis period. Coal extraction emissions vary for coal extracted in regions within the United States and regions outside the United States due to differences in the energy needed for coal extraction by

region and mine type, grid electricity emission factors, grid electricity production mix, and methane emitted from different mining basins and mine types (i.e., underground or surface mining). Table 44 below presents estimates based on the coal extraction results provided in the coal market assessment.

Table 44. Emissions from Coal Extraction ($MMTCO_2e$)

	Scenario			
Emission Source	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Powder River Basin ($MMTCO_2e$)				
Annual Emissions, 2028	1.37	1.22	1.46	1.31
Total Emissions, 2018-2038	17.97	17.60	21.91	18.65
Uinta Basin ($MMTCO_2e$)				
Annual Emissions, 2028	-0.04	0.02	0.22	<0.005
Total Emissions, 2018-2038	3.40	0.59	9.94	<0.005
Other U.S. Coals ($MMTCO_2e$)				
Annual Emissions, 2028	0.09	0.27	<0.005	<0.005
Total Emissions, 2018-2038	2.27	3.67	0.78	<0.005
Australia ($MMTCO_2e$)				
Annual Emissions, 2028	-0.39	-0.40	0	-1.22
Total Emissions, 2018-2038	-4.86	-4.89	0	-15.26
Canada ($MMTCO_2e$)				
Annual Emissions, 2028	0	<0.005	0	0
Total Emissions, 2018-2038	0	-0.01	0	0
China ($MMTCO_2e$)				
Annual Emissions, 2028	-2.56	-2.17	1.87	-2.74
Total Emissions, 2018-2038	-69.38	-60.63	23.09	-44.85
India ($MMTCO_2e$)				
Annual Emissions, 2028	0	-0.50	0	-0.28
Total Emissions, 2018-2038	0	-4.09	-4.64	-2.31
Indonesia ($MMTCO_2e$)				
Annual Emissions, 2028	-0.28	-0.04	-0.41	-0.27
Total Emissions, 2018-2038	-2.27	-0.31	-4.53	-3.17
Russia ($MMTCO_2e$)				
Annual Emissions, 2028	-3.15	-3.08	-1.65	<0.005
Total Emissions, 2018-2038	-33.33	-32.66	-20.39	-9.56
South Africa ($MMTCO_2e$)				
Annual Emissions, 2028	0.04	0	-0.41	<0.005
Total Emissions, 2018-2038	0.30	0	-5.09	<0.005
Net Emissions ($MMTCO_2e$)				
Annual Emissions, 2028	-4.91	-4.68	1.08	-3.21
Total Emissions, 2018-2038	-85.90	-80.74	21.07	-56.50

Notes: "Other U.S. Coals" includes the following basins: Central Appalachia (VA, WV, East KY), Illinois, Northern Appalachia, Rockies (Green River, San Juan, Raton), Warrior, North Great Plains (Non-Powder River Basin – WY, MT, ND), West Interior (Arkoma, Gulf Coast, Forest City, Cherokee)$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Figure 7 presents the net GHG emissions from changes in coal extraction in each country between 2021-2038 for the 2015 U.S. and International Energy Policy scenario. Reduced GHG emissions in China have the largest impact on the net GHG emissions, as production is increasingly offset by greater PRB and Uinta coal production. The black bars in the Figure 7 indicate the resulting net GHG emissions from coal extraction. Figure 8 details net GHG emissions by country over time for each of the four scenarios.

Figure 7. Net GHG Emissions from Coal Extraction by Country and U.S. Coal Basin for 2015 U.S. and International Energy Policy Scenario

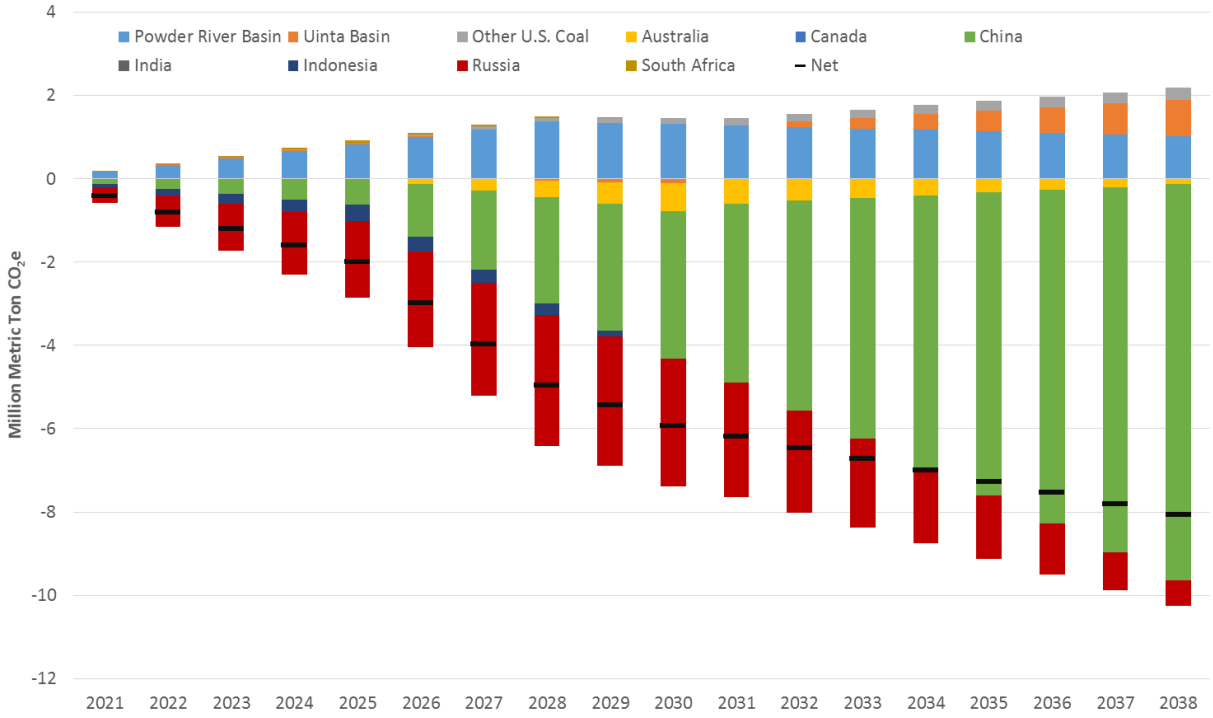
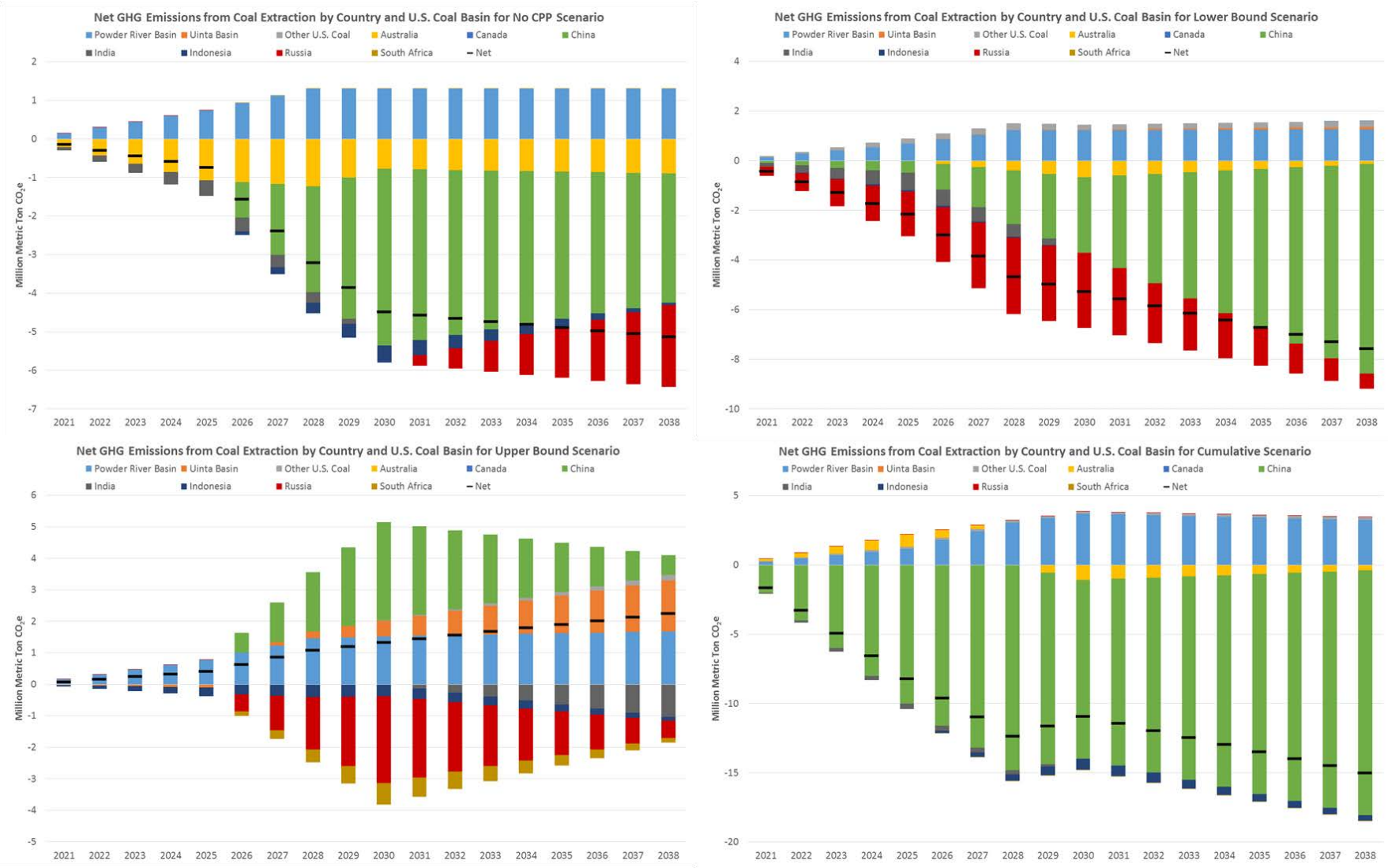


Figure 8. Net GHG Emissions from Coal Extraction by Country and U.S. Coal Basin for No Clean Power Plan, Lower Bound, Upper Bound, and Cumulative Scenarios



As previously mentioned in Section 2.2.2.3, *Method for Impact Analysis,* the uncertainty of the estimates for coal extraction is relatively high. To illustrate this uncertainty, the methane emissions from coal extraction are estimated for a range of emission factors for non-U.S. countries to reflect the -/+ uncertainty of 200% for underground mining and -/+300% for surface mining emission factors. However, use of these uncertainty values resulted in emission factors that are outside the range provided by IPCC for Tier 1 default values, except for in the case of Canadian underground mining. Consequently, the emission factor range for non-U.S. countries is the lower and upper bound as provided by IPCC.[31] The proportion of underground and surface mining relative to total production are from GMI (2015) and were applied to the high and low Tier 1 emission factors following the same method described in Section 2.2.2.3 for countries that did not report to UNFCCC. As part of this uncertainty, a range of emission factors is used for U.S. coal mines based on the uncertainty values provided in the U.S. GHG Inventory (U.S. Environmental Protection Agency 2016b). The uncertainty values for the U.S. estimates are approximately 10% (e.g., an order of magnitude less than the uncertainty estimates used for other countries). Table 45 shows the emission factors used for U.S. basins and non-U.S. countries evaluating the range of net GHG emissions from coal extraction.

Table 45. Range of Coal Mine Methane Emission Factors for Coal Extraction

	Emission Factors (MT CO_2e/MT Coal)		
Coal Basin	**Low**	**Modeled**	**High**
All U.S. Coal - Underground	0.15	0.17	0.20
PRB - Surface	0.02	0.02	0.02
Uinta - Surface	0.01	0.02	0.02
Other U.S. - Surface	0.03	0.03	0.03
Australia	0.04	0.04	0.13
Canada	0.01	0.02	0.04
China	0.16	0.30	0.44
India	0.02	0.05	0.08
Indonesia	0.01	0.02	0.04
Russia	0.05	0.15	0.16
South Africa	0.1	0.19	0.27

Figure 9 and Figure 10 reflect the resulting net GHG emissions for coal extraction. The upper range is based on using the high estimate for the emission factor for countries and basins where coal extraction is increasing, and using the low estimate for the emission factor for countries where coal is being displaced. Alternatively, the lower range is based on using the low estimate for the emission factor for countries and basins where coal extraction is increasing, and using the high estimate for the emission factor for countries where coal is being displaced.

[31] The Canadian upper bound underground emission factor was derived using IPCC's +200% uncertainty value for underground mining.

Figure 9. Range of Net GHG Emissions from Coal Extraction for the 2015 Energy Policy Scenario

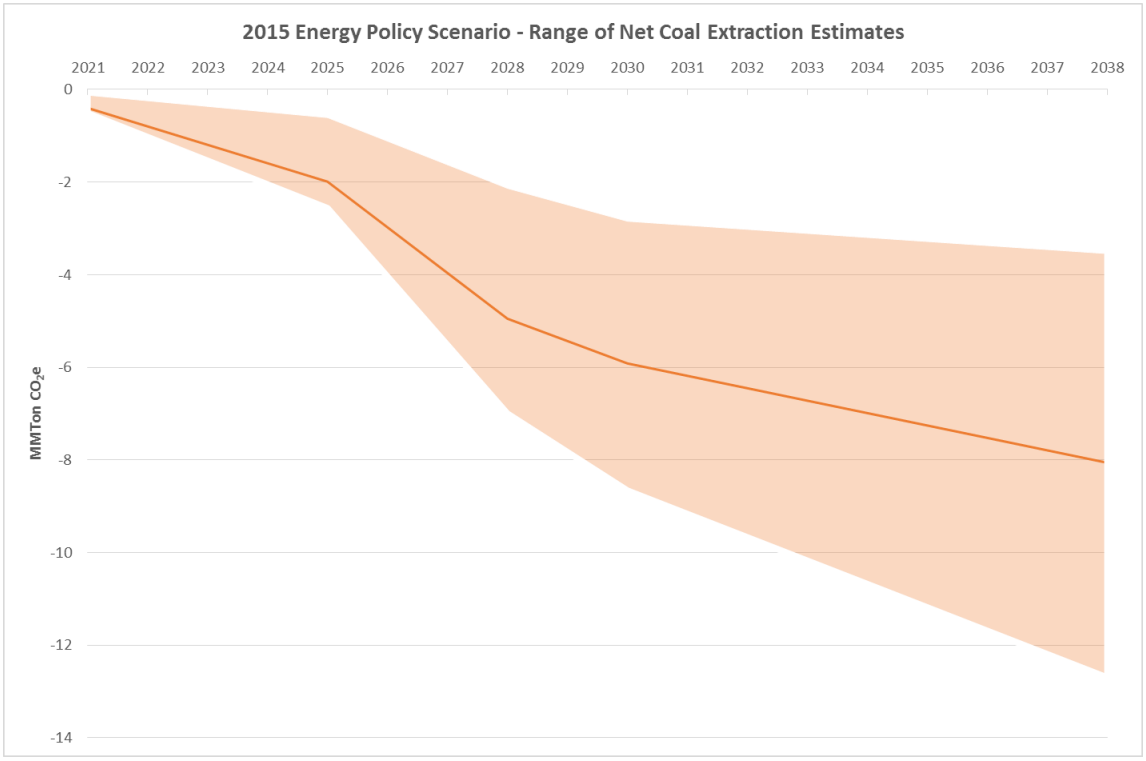


Figure 10. Range of Net GHG Emissions from Coal Extraction for the No CPP, Lower Bound, Upper Bound, and Cumulative Scenarios



3.1.4 Rail Transport

Model results indicate that rail transport across the four scenarios is relatively constant, with slight fluctuations occurring depending on the share of Uinta Basin coal exported via the Proposed Action relative to the Powder River Basin coal. Although the distance from the Uinta Basin to Washington State is shorter than the distance from the Powder River Basin, the majority of the transport emissions occur from the transport of Powder River Basin coal, as its lower price results in higher demand despite the longer distances. The largest source of rail transport emissions is from transport to Washington State. The second largest source of emissions from rail transport is from transport within Washington, which is approximately half the distance as the distance outside Washington State. Once the return trip is taken into account, the difference in emissions between the two routes taken from the different coal basins increases, as empty and loaded Uinta Basin trains return along the same route. Empty Powder River Basin coal trains, however, travel a longer northern route to the Powder River Basin (ICF and Hellerworx 2017).

Emissions from transport of coal within Cowlitz County also vary slightly for Powder River Basin and Uinta Basin coal due to the different directions travelled for empty Powder River Basin and Uinta Basin coal trains. However, due to the small distances involved, this difference does not have a large impact on emissions. The coal market assessment captures changes in the transportation routes from extraction sites to the project area due to shifts in coal demand and prices. Consequently, the emissions change across the scenarios. In Table 47 and Table 48, the Lower Bound scenario has slightly higher total emissions than the No Clean Power Plan and the Upper Bound scenarios because less coal from the Uinta Basin is transported under this scenario. In the Lower Bound scenario, less coal is transported from the Uinta Basin because the higher coal prices assumed under this scenario make the Powder River Basin coal more economical to export than the Uinta Basin coal. Thus, total emissions are higher under the Lower Bound scenario because the total ton-miles of coal transported is greater than in the No Clean Power Plan or Upper Bound scenarios, as the distance from the Powder River Basin is greater than from the Uinta Basin. The on-site emissions are equal across all scenarios, as those emissions are proportional solely to coal throughput for the Proposed Action. Table 46, Table 47, and Table 48 summarize rail emissions for each scenario.

Table 46. Locomotive Emissions from Extraction Sites to Washington State ($MMTCO_2e$)

Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MMTCO_2e$)	0.67	0.74	0.63	0.63
Total Emissions, 2018–2038 ($MMTCO_2e$)	9.50	10.63	9.29	8.96

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table 47. Locomotive Emissions within Washington State (Excluding Cowlitz County) ($MMTCO_2e$)[32]

Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MMTCO_2e$)	0.32	0.32	0.31	0.32
Total Emissions, 2018–2038 ($MMTCO_2e$)	4.42	4.62	4.12	4.62

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table 48. Locomotive Operation Emissions within Cowlitz County ($MMTCO_2e$)

Emission Source	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Locomotive Operation, BNSF Main Line & Spur ($MMTCO_2e$)				
Annual Emissions, 2028	0.02	0.02	0.02	0.02
Total Emissions, 2018–2038	0.29	0.29	0.29	0.29
Locomotive Operation, at Terminal Loop ($MMTCO_2e$)				
Annual Emissions, 2028	<0.005	<0.005	<0.005	<0.005
Total Emissions, 2018–2038	0.03	0.03	0.03	0.03
Subtotal ($MMTCO_2e$)				
Annual Emissions, 2028	0.02	0.02	0.02	0.02
Total Emissions, 2018–2038	0.31	0.31	0.31	0.31

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

3.1.5 Vehicle-Crossing Delay

The GHG emissions from vehicle-crossing delays are consistent across all four scenarios, as they are directly proportional to the throughput of the Proposed Action. After the start-up period, emissions from this source remain constant throughout the analysis period (Table 49).

[32] Locomotive operation within Cowlitz County is not included in this table, thus results from Table 46, Table 47, and Table 48 are additive.

Table 49. Vehicle-Crossing Delay Emissions from Fossil Fuel Combustion from Vehicles Idling within Cowlitz County ($MtCO_2e$)

Track Section/Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Study Crossings along the Reynolds Lead and BNSF Spur ($MtCO_2e$)				
Annual Emissions, 2028	170	170	170	170
Total Emissions, 2018–2038	2,427	2,427	2,427	2,427
Public At-Grade Crossings along the BNSF Main Line in Cowlitz County ($MtCO_2e$)				
Annual Emissions, 2028	1	1	1	1
Total Emissions, 2018–2038	13	13	13	13
All Vehicle Crossings ($MtCO_2e$)				
Annual Emissions, 2028	171	171	171	171
Total Emissions, 2018–2038	2,439	2,439	2,439	2,439

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.6 Coal Export Terminal Construction

Coal export terminal construction emissions are assumed to occur in an 18-month period prior to the operation of the Proposed Action. Because construction dates are unknown, the GHG analysis assumes that the 18-month construction period would occur at some point between the years 2018 and 2020. For the purposes of estimating emissions associated with coal export terminal operation, the GHG analysis assumes that construction would be completed before the end of 2020. As the construction would be structurally similar across the four scenarios, construction GHG emissions are equal across all four scenarios (Table 50). The emissions from the operation of construction equipment would exceed those of the barges used for bringing construction materials to the project area.

Table 50. Coal Export Terminal Construction Emissions ($MtCO_2e$)

Emission Source	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Construction Equipment ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	5,349	5,349	5,349	5,349
Total Emissions, 2018–2038[a]	8,024	8,024	8,024	8,024
Employee Commuting ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	465	465	465	465
Total Emissions, 2018–2038[a]	698	698	698	698
Construction Trucks Carrying Materials to Project Area ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	1,081	1,081	1,081	1,081
Total Emissions, 2018–2038 [a]	1,621	1,621	1,621	1,621
Construction Barges Carrying Materials to Project Area ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	955	955	955	955
Total Emissions, 2018–2038 [a]	1,433	1,433	1,433	1,433
Subtotal ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	7,851	7,851	7,851	7,851
Total Emissions, 2018–2038	11,776	11,776	11,776	11,776

Notes:

[a] Construction emissions occur over an 18-month period prior to the operation of the coal export terminal; therefore, emissions from 2021 through 2038 are zero. Given the 18-month period for construction, total construction emissions are those for the 12-month period multiplied by 1.5.

$MtCO_2e$ = metric tons of carbon dioxide equivalent

The GHG emissions resulting from the production of materials used to construct the coal export terminal occur upstream of the project area. Table 51 summarizes the GHG emissions by general material type. The "Other" category includes plastics and cable wiring, but is mostly composed of the "10% Miscellaneous" materials expected to be used in the construction process. These emissions are assumed to occur once, and have been prorated over the 18-month construction period.

While aggregates compose the majority of total materials mass from berms and roadways (material masses can be found in Table 21, the associated emissions are a minimal portion of the total estimated emissions. In contrast to this distribution of materials, steel materials represent less than 5% of total material mass, but almost 30% of total GHG emissions. This distribution of emission occurs because steel manufacturing emission factors are an order of magnitude higher than any other material due to the energy-intensive nature of the production process.

Table 51. Embedded Emissions in Construction Materials ($MtCO_2e$)

Emission Sources	Scenario: 2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Concrete Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	55,818	55,818	55,818	55,818
Total 2018-2038[a]	83,727	83,727	83,727	83,727
Rebar Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	17,489	17,489	17,489	17,489
Total 2018-2038[a]	26,233	26,233	26,233	26,233
Steel Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	33,059	33,059	33,059	33,059
Total 2018-2038[a]	49,588	49,588	49,588	49,588
Aggregates Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	2,225	2,225	2,225	2,225
Total 2018-2038[a]	3,338	3,338	3,338	3,338
Asphalt Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	1,096	1,096	1,096	1,096
Total 2018-2038[a]	1,644	1,644	1,644	1,644
Reinforced Concrete Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	160	160	160	160
Total 2018-2038[a]	239	239	239	239
Other Materials Production and Supply ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	13,781	13,781	13,781	13,781
Total 2018-2038[a]	20,672	20,672	20,672	20,672
Subtotal ($MtCO_2e$)				
Emissions During 12 Months of Construction Period	123,627	123,627	123,627	123,627
Total Emissions, 2018–2038[a]	185,441	185,441	185,441	185,441

Notes:

[a] Construction emissions occur over an 18-month period prior to the operation of the coal export terminal; therefore, embedded emissions in construction materials from 2021 through 2038 are zero. Given the 18-month period for construction, total construction emissions are those for the 12-month period multiplied by 1.5.

$MtCO_2e$ = metric tons of carbon dioxide equivalent

GHG emissions from fuel use occur from initial dock dredging of 500,000 cubic yards of sediment during the construction period. These emissions result from the operation of tugboats and dredging equipment (Table 52).

Table 52. Emissions from Dredging during Construction – Fuel Use ($MtCO_2e$)

	Scenario			
Emission Source	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Emissions from Dredging Operations ($MtCO_2e$)				
Emissions During 12 Months of Construction Period[a]	188	188	188	188
Total Emissions, 2018–2038[a]	377	377	377	377

Notes:

[a] Construction emissions occur over an 18-month period prior to the operation of the coal export terminal; therefore, emissions from 2021 through 2038 are zero. Emissions from maintenance dredging occur during the operational phase; however, these are presented in Section 3.1.7, *Coal Export Terminal Operation—Equipment Operation*. Dredging is expected to occur over two annual approved work periods to coincide with fish protection during the construction phase (Millennium Bulk Terminal—Longview 2014). One of the approved work periods is assumed to coincide with the 12 months of construction period, while the second dredging event is assumed to occur within the following year. Therefore, emissions during the 12 months of construction period shown above are assumed to be half of the total emissions during the entire construction period from 2018-2020.

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.7 Coal Export Terminal Operation—Equipment Operation

GHG emissions from mobile equipment used for routine operation of the coal export terminal are consistent across all four scenarios, as they are directly proportional to the throughput of the Proposed Action (Table 53). After the start-up period, emissions from this source would remain constant throughout the analysis period.

Table 53. Coal Export Terminal Operation Emissions from Mobile Combustion ($MtCO_2e$)

	Scenario			
Period	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Annual Emissions, 2028 ($MtCO_2e$)	908	908	908	908
Total Emissions, 2018–2038 ($MtCO_2e$)	12,977	12,977	12,977	12,977

$MtCO_2e$ = metric tons of carbon dioxide equivalent

GHG emissions from fuel use occur from maintenance dock dredging of an estimated 100,000 cubic yards per year of sediment during the operations period. These emissions result from the operation of tugboats and dredging equipment (Table 54).

Table 54. Dredging Emissions during Operations – Fuel Use ($MtCO_2e$)

Period	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MtCO_2e$)	75	75	75	75
Total Emissions, 2018–2038 ($MtCO_2e$)	1,355	1,355	1,355	1,355

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.8 Coal Export Terminal Operation—Electricity Consumption

Electricity consumption emissions for operation of the new coal export terminal are assumed constant across all years of the analysis period and for all scenarios (Table 55).

Table 55. Coal Export Terminal Operation—Indirect Emissions from Electricity Consumption ($MtCO_2e$)

Period	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MtCO_2e$)	177	177	177	177
Total Emissions, 2018–2038 ($MtCO_2e$)	3,191	3,191	3,191	3,191

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.9 Employee Commuting

GHG emissions from employee commuting are consistent across all four scenarios, as they are directly proportional to the throughput of the Proposed Action (Table 56). After the start-up period, emissions from this source would remain constant throughout the analysis period.

Table 56. Employee Commuting ($MtCO_2e$)

Period	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MtCO_2e$)	275	275	275	275
Total Emissions, 2018–2038 ($MtCO_2e$)	3,922	3,922	3,922	3,922

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.10 Vessel Idling and Tugboat Use at Coal Export Terminal

GHG emissions from idling vessels and tugboats are consistent across all four scenarios, as they are directly proportional to the throughput of the Proposed Action (Table 57). Tugboats emit approximately twice as many emissions as idling vessels. After the start-up period, emissions from this source remain constant throughout the analysis period.

Table 57. Emissions from Vessel Idling and Tugboat Use at Coal Export Terminal ($MtCO_2e$)

	Scenario			
Emission Source	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Vessel Idling at Terminal ($MtCO_2e$)				
Annual Emissions, 2028	2,498	2,498	2,498	2,498
Total Emissions, 2018–2038	35,660	35,660	35,660	35,660
Tugboat Operation ($MtCO_2e$)				
Annual Emissions, 2028	4,840	4,840	4,840	4,840
Total Emissions, 2018–2038	69,081	69,081	69,081	69,081
Subtotal ($MtCO_2e$)				
Annual Emissions, 2028	7,338	7,338	7,338	7,338
Total Emissions, 2018–2038	104,740	104,740	104,740	104,740

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.11 Helicopter and Pilot Boat Trips

GHG emissions from pilot transfers are consistent across all four scenarios, as they are directly proportional to the throughput of the Proposed Action (Table 58). Helicopters emit about the same GHGs as pilot boats and are assumed responsible for 70% of the pilot transfers. After the start-up period, emissions from this source would remain constant throughout the analysis period.

Table 58. Emissions from Helicopter and Pilot Boat Trips for Pilot Transfers to Vessels ($MtCO_2e$)

	Scenario			
Emission Source	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Helicopter Operation ($MtCO_2e$)				
Annual Emissions, 2028	180	180	180	180
Total Emissions, 2018–2038	2,575	2,575	2,575	2,575
Pilot Boat Operation ($MtCO_2e$)				
Annual Emissions, 2028	198	198	198	198
Total Emissions, 2018–2038	2,827	2,827	2,827	2,827
Subtotal ($MtCO_2e$)				
Annual Emissions, 2028	378	378	378	378
Total Emissions, 2018–2038	5,402	5,402	5,402	5,402

$MtCO_2e$ = metric tons of carbon dioxide equivalent

3.1.12 Vessel Transport

Vessel transport GHG emissions are equivalent across all scenarios within Cowlitz County and Washington State but diverge for international transport (Table 59 and Table 60). The differences in international transport emissions result from different destinations for the exported coal and the extent to which demand for existing sources of Asian coal is substituted, primarily by coal from Indonesia, China, Russia, Australia, and India Consequently, the net emissions from international transport of coal include both transport to the Asian market and the adjustment for the substituted vessel transport from other international coal production sources to the Asian market (Table 61). In all of the scenarios, the addition of 44 million metric tons of coal would displace less than 44 million metric tons of coal traffic within the Pacific Basin because of differences in the heat content of the coals. In the Upper Bound scenario, displacement of international coal is less than in other scenarios because coal demand increases due to induced demand, and thus the amount of coal displaced by the proposed coal export terminal is even less than in other scenarios.

Table 59. Emissions from Vessel Transport within Cowlitz County ($MMTCO_2e$)

	Scenario			
Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MMTCO_2e$)	0.01	0.01	0.01	0.01
Total Emissions, 2018–2038 ($MMTCO_2e$)	0.12	0.12	0.12	0.12

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Table 60. Emissions from Vessel Transport within Washington State (Excluding Transport within Cowlitz County) ($MMTCO_2e$)[33]

	Scenario			
Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MMTCO_2e$)	0.01	0.01	0.01	0.01
Total Emissions, 2018-2038 ($MMTCO_2e$)	0.15	0.15	0.15	0.15

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

[33] This table does not include emissions generated from vessel transport within Cowlitz County so that the results in Table 59, Table 60, and Table 61 are additive.

Table 61. Net Emissions from Changes in International Vessel Transport to Asian Markets ($MMTCO_2e$)[a]

Period	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Net Annual Emissions, 2028 ($MMTCO_2e$)	1.01	1.13	1.12	0.93
Net Total Emissions, 2018–2038 ($MMTCO_2e$)	15.16	16.17	16.87	13.32

[a] Net GHG emissions represent the difference between the Proposed Action and the no-action.
$MMTCO_2e$ = metric tons of carbon dioxide equivalent

3.1.13 Coal Combustion

Coal combustion in the United States and Asia is one of the largest and most variable sources of GHG emissions associated with the Proposed Action. Model results indicate that this source of emissions varies significantly throughout the analysis period and between scenarios, indicating that it is sensitive to policy and market factors. For most scenarios, the coal combustion emissions in the United States decrease while coal combustion emissions in Asia increase, to varying degrees. The key factor behind this shift is U.S. and Asian markets' reactions to price and supply shifts for coal. As the Proposed Action exports U.S. coal, prices in the United States go up in response to supply decreasing, thus reducing coal combustion. Likewise, the increased supply of coal in Asia decreases prices and facilitates additional coal combustion.

Coal combustion emissions in Asia are separated in Table 62 into two subcategories: emissions from induced coal demand and emissions from coal substitution. Induced demand emissions would occur because of lowered coal prices in response to an increase in coal supply caused by the Proposed Action. Coal substitution emissions are a result of one of two processes. In the first process, lower-heat-content coal displaces higher-heat-content coal, which results in a net increase in emissions to generate the same amount of energy. In the second process, coal with a higher CO_2 emissions rate displaces coal with a lower CO_2 emissions rate, which also results in a net increase in emissions. Both of these processes may occur in reverse as well, which would result in lower net emissions.

The differences between scenarios are driven by the following factors.

- Coal combustion emissions in the United States are less than the no-action for all scenarios, except for the Upper Bound scenario. Thus the net emissions from coal combustion are negative in the United States except for the Upper Bound scenario. Domestic coal prices increase in every scenario in response to the export of Powder River Basin and Uinta Basin coal. The higher prices then reduce the U.S. demand for coal, except in the Upper Bound scenario. In the Upper Bound scenario, changes in solar and combined cycle builds in the North and South Carolina electric demand region result in increases in coal consumption by an average of 0.40 million metric tons per year over the 2025 through 2040 period. [34]
- In the Upper Bound scenario, the additional coal exported to Asia from the Proposed Action reduces the delivered Asia coal prices, inducing demand. This increases overall coal

[34] A solar build of 29 megawatts is delayed in the Proposed Action from coming online in 2020 to coming online in 2030. Also, there is 4 megawatts less combined cycle builds. Both actions result in greater coal consumption.

consumption even as some Asian coals from Indonesia and Australia are substituted by Powder River Basin and Uinta Basin coals.

- There is a secondary driver of emissions in Asia, as lower-heat-content coal from the United States is a substitute for higher-heat-content coal, or higher-CO_2-content coal is a substitute for lower-CO_2-content coal. This substitution of higher-heat-content coal results in additional low-heat-content coal being combusted in order to meet electricity demands (i.e., Btu demands), therefore raising emissions in Asia.[35] There is an increase in CO_2 combustion emissions due to this driver in all but the Lower Bound scenario.
- In the 2015, U.S. and International Energy Policy scenario, the increase in Asian CO_2 emission is driven by the mix of coal consumed. U.S. coal consumption decreases slightly relative to the no-action because U.S. coal prices are already low due to a decrease in consumption from the enactment of EPA's Clean Power Plan in 2022, as modeled.

The coal market assessment provides a thorough discussion of the market.

Table 62. Net Emissions from Coal Combustion ($MMTCO_2e$)[a]

	Scenario			
Emission Source	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Coal Combustion, United States ($MMTCO_2e$)				
Net Annual Emissions, 2028	-1.25	-7.94	0.03	<0.005
Net Total Emissions, 2018–2038	-14.02	-93.59	0.77	-0.04
Coal Combustion from Induced Demand, Asia ($MMTCO_2e$)				
Net Annual Emissions, 2028	0	<0.005	52.48	0
Net Total Emissions, 2018–2038	0	<0.005	747.07	0
Coal Combustion from Coal Substitution, Asia ($MMTCO_2e$)				
Net Annual Emissions, 2028	0.32	-0.54	0.41	1.84
Net Total Emissions, 2018–2038	5.47	-7.86	1.62	23.95
Subtotal ($MMTCO_2e$)				
Net Annual Emissions, 2028	-0.93	-8.48	52.92	1.83
Net Total Emissions, 2018–2038	-8.55	-101.44	749.46	23.91

Notes:
[a] Net GHG emissions represent the difference between the Proposed Action and the no-action.
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

3.1.14 Induced Natural Gas Consumption

Natural gas consumption in the United States is a large and highly variable source of emissions. Higher coal prices or lower natural gas prices in the United States induce electricity generators to switch to natural gas. Relative to the no-action, natural gas emissions increase for all scenarios except for the Upper Bound scenario, although the results display significant variation depending on

[35] For example, for the No Clean Power Plan scenario, coal consumption in Taiwan increases by 1.7 million metric tons in 2025 over the no-action; however, there is no induced demand in this scenario. Thus the full 1.7 million metric tons of the increase in coal consumption in Taiwan in 2025 is due to changes in the mix of coal consumed.

the extent to which coal is displaced (Table 63). The differences among scenarios are driven by the following two factors.

- The inclusion of the Clean Power Plan, which generally reduces coal consumption and prices and increases natural gas consumption and prices. One of the components of compliance with the Clean Power Plan is increased energy efficiency. Thus in the scenarios without the Clean Power Plan the increased energy efficiency is removed, which results in overall electric demand being higher. This results in higher coal and natural gas consumption in the scenarios without the Clean Power Plan in 2025 and later when the Clean Power Plan implementation is ramped up.
- The assumed Powder River Basin coal production costs. Higher Powder River Basin coal production costs, as in the Lower Bound scenario, result in a greater increase in natural gas consumption under the Proposed Action, because there is a greater increase in coal prices. The greater increase in coal prices results in a larger decrease in coal consumption and a subsequent larger increase in natural gas consumption.

Table 63. Net Emissions from Natural Gas Substitution in the United States ($MMTCO_2e$)[a]

	Scenario			
Period	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**
Net Annual Emissions, 2028 ($MMTCO_2e$)	0.07	2.42	-0.02	<0.005
Net Total Emissions, 2018–2038 ($MMTCO_2e$)	0.89	27.78	-0.24	<0.005

Notes:
[a] Net GHG emissions represent the difference between the Proposed Action and the no-action.
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

3.1.15 Net Greenhouse Gas Emissions

This section presents the aggregated results of each of the emission sources described previously.

Model results indicate that the direct GHG emissions from the Proposed Action (Table 64) are the same for each of the four scenarios, as they are emitted in proportion to the throughput of the Proposed Action and are not influenced by outside economic factors. The largest contributors to the direct emissions are transportation-related emissions, including locomotive operation and vessel transport within Cowlitz County. Together, these two sources contribute about 72% of direct emissions. For the 2015 U.S. and International Energy Policy scenario, the total direct emissions contributed an increase of approximately 0.60 $MMTCO_2e$ (0.9%) (Table 64). This value is compared to a total net increase in emissions of 22.36 $MMTCO_2e$ excluding coal extraction (Table 66) and a net decrease in emissions of 63.54 $MMTCO_2e$ including coal extraction (Table 67) throughout the 2018 through 2038 analysis period once market-influenced and indirect sources of emissions are considered.

Table 64. Direct Emissions (Generated in Cowlitz County) for the Proposed Action ($MMTCO_2e$)[36]

Period	Scenario			
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan
Annual Emissions, 2028 ($MMTCO_2e$)	0.04	0.04	0.04	0.04
Total Emissions, 2018–2038 ($MMTCO_2e$)	0.60	0.60	0.60	0.60

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Statewide, emissions are about 9 times as high as the county emissions, largely driven by the greater distances traveled by locomotives and vessels outside of Cowlitz County. Locomotive transport constitutes about 97% of emissions generated within Washington State and outside of Cowlitz County (Table 65).

Table 65. Emissions Generated within Washington State, Excluding Cowlitz County ($MMTCO_2e$)

Period	Scenario				
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan	Cumulative
Annual Emissions, 2028 ($MMTCO_2e$)	0.33	0.33	0.32	0.33	0.33
Total Emissions, 2018–2038 ($MMTCO_2e$)	4.57	4.77	4.27	4.77	4.77

Notes:
The Cumulative scenario is provided here for comparison and is addressed in Section 3.1.15, *Net Greenhouse Gas Emissions*, under *Cumulative Scenario*.
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

The total net indirect emissions from activities outside the project area and Cowlitz County attributed to the operation of the Proposed Action come from a variety of sources, including:

- Extraction of coal at the mining sites
- Rail Transport
- Coal export terminal construction—embedded GHG emissions in materials for coal export terminal construction
- Coal Export Terminal Operation—Electricity Consumption
- Helicopter and Pilot Boat Trips
- Vessel Transport
- Coal Combustion in Asia and the United States
- Induced Natural Gas Consumption in the United States

Net indirect emissions over the 2018 through 2038 analysis period excluding coal extraction vary depending on the scenario, from a decrease of 41.904 $MMTCO_2e$ in the Lower Bound scenario to an increase of 779.83 $MMTCO_2e$ in the Upper Bound scenario (Table 66). The total net impacts (i.e., direct and indirect emissions) excluding coal extraction range from a decrease in emissions of 41.31 $MMTCO_2e$ in the Lower Bound scenario relative to the no-action to an increase in emissions of 780.42 $MMTCO_2e$ in the Upper Bound scenario relative to the no-action. The No Clean Power Plan

[36] By definition, direct emissions are equivalent to emissions generated in Cowlitz County.

scenario, which depicts a "business as usual" projection of market conditions in the absence of climate policy, indicates a net increase of 51.75 $MMTCO_2e$ across the entire analysis period studied. Table 66 summarizes direct emissions, indirect emissions, and total net emissions excluding coal extraction.

Table 66. Net (Direct and Indirect) Emissions for the Proposed Action Excluding Coal Extraction ($MMTCO_2e$)

	Scenario				
Period	**2015 Energy Policy**	**Lower Bound**	**Upper Bound**	**No Clean Power Plan**	**Cumulative**
Direct emissions (generated in Cowlitz County) excluding coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	0.04	0.04	0.04	0.04	0.04
Total Emissions, 2018–2038	0.60	0.60	0.60	0.60	0.60
Net indirect emissions excluding coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	1.15	-3.84	54.97	3.72	19.45
Total Emissions, 2018–2038	21.76	-41.90	779.83	51.16	350.64
Net emissions (direct + indirect) excluding coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	1.19	-3.80	55.01	3.76	19.49
Total Emissions, 2018–2038	22.36	-41.31	780.42	51.75	351.24

Notes:
The Cumulative scenario is provided here for comparison and is addressed in Section 3.1.15, *Net Greenhouse Gas Emissions*, under *Cumulative Scenario*
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Net indirect emissions over the 2018 through 2038 analysis period including coal extraction vary depending on the scenario, from a decrease of 122.64 $MMTCO_2e$ in the Lower Bound scenario to an increase of 800.90 $MMTCO_2e$ in the Upper Bound scenario (Table 67). The total net impacts (i.e., direct and indirect emissions) including coal extraction range from a decrease in emissions of 122.04 $MMTCO_2e$ in the Lower Bound scenario relative to the no-action to an increase in emissions of 801.49 $MMTCO_2e$ in the Upper Bound scenario relative to the no-action. The No Clean Power Plan scenario, which depicts a "business as usual" projection of market conditions in the absence of climate policy, indicates a net decrease of 4.75 $MMTCO_2e$ across the entire analysis period studied. Table 67 summarizes direct emissions, indirect emissions, and total net emissions including coal extraction.

Table 67. Net Emissions (Direct + Indirect) for the Proposed Action Including Coal Extraction ($MMTCO_2e$)[a]

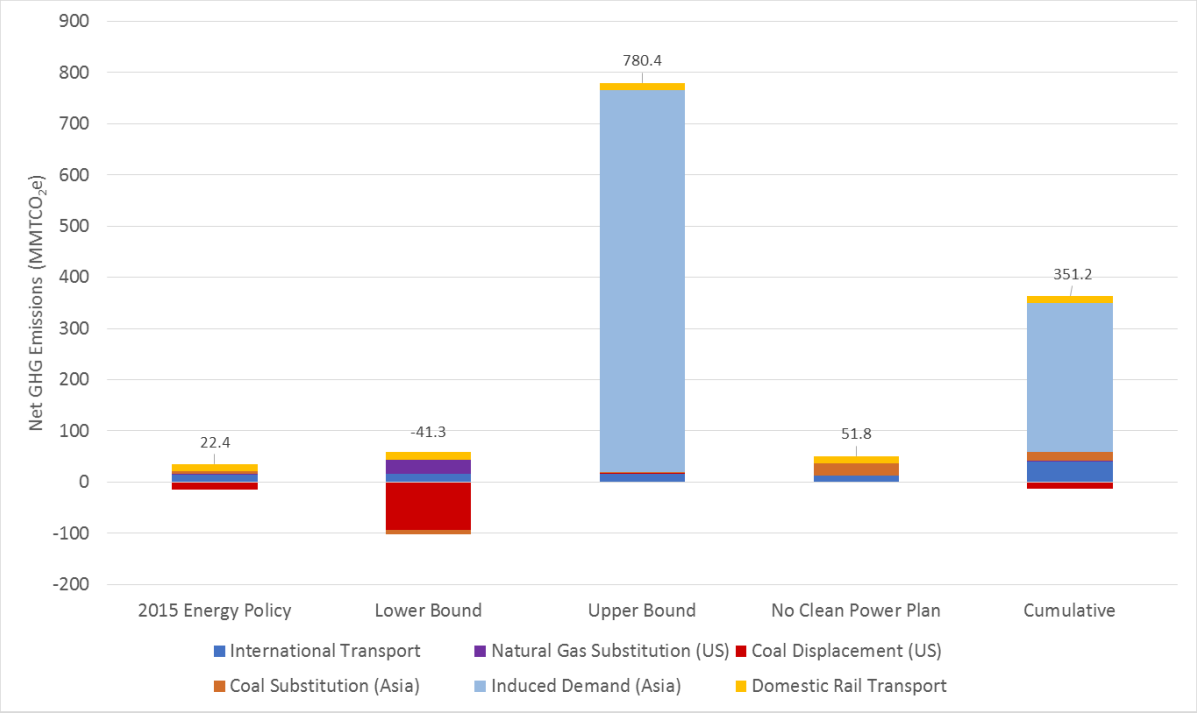
Period	Scenario				
	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan	Cumulative
Direct emissions (generated in Cowlitz County) including coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	0.04	0.04	0.04	0.04	0.04
Total Emissions, 2018–2038	0.60	0.60	0.60	0.60	0.60
Net indirect emissions including coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	-3.77	-8.52	56.05	0.51	7.11
Total Emissions, 2018–2038	-64.14	-122.64	800.90	-5.34	164.83
Net emissions (direct + indirect) including coal extraction ($MMTCO_2e$)					
Annual Emissions, 2028	-3.73	-8.48	56.09	0.55	7.15
Total Emissions, 2018–2038	-63.54	-122.04	801.49	-4.75	165.43

Notes:
[a] Net GHG emissions represent the difference between the Proposed Action and the no-action.
$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

Figure 11 depicts the range of net total emissions from the operation of the Proposed Action excluding coal extraction across the different scenarios studied.[37] This figure, which identifies the major sources of emissions, shows that the largest contributors to net emissions vary across scenarios. In the 2015 U.S. and International Energy Policy scenario, international vessel transportation is the largest contributor to net emissions. In the Lower Bound scenario, coal displacement in the United States is the largest contributor to net emissions. In the No Clean Power Plan scenario, coal substitution in Asia is the largest contributor to net emissions, while in the Upper Bound and Cumulative scenarios, induced demand in Asia is the largest contributor to net emissions.

[37] The bars in this figure do not include some of the smaller sources of emissions (for instance on-site emissions are not included). However, the number for each bar denotes the total net emissions for each scenario modeled and includes all emission sources.

Figure 11. Total Net Emissions for Each Scenario, Excluding Coal Extraction 2018-2038 ($MMTCO_2e$)[a]



Notes: [a] Net GHG emissions represent the difference between the proposed action and the no-action. The bars in this figure do not include some of the smaller sources of emissions (for instance on-site emissions are not included). However, the number for each bar denotes the total net emissions for each scenario modeled and includes all emission sources apart from coal extraction. The Cumulative scenario is provided here for comparison and is addressed in Section 3.1.15, *Net Greenhouse Gas Emissions*, under *Cumulative Scenario*

Figure 12 depicts the range of net total emissions from the operation of the Proposed Action, including coal extraction across the different scenarios studied.[38] Similar to Figure 11, this figure also shows that the largest contributors to net emissions vary across scenarios. In the 2015 U.S. and International Energy Policy and No Clean Power Plan scenarios, coal extraction is the largest contributor to net emissions, In the Lower Bound scenario, coal displacement in the United States is the largest contributor to net emissions, while in the Upper Bound and Cumulative scenario, induced demand in Asia is the largest contributor to net emissions.

[38] The bars in this figure do not include some of the smaller sources of emissions (for instance on-site emissions are not included). However, the number for each bar denotes the total net emissions for each scenario modeled and includes all emission sources.

Figure 12. Total Net Emissions for Each Scenario, Including Coal Extraction 2018-2038 ($MMTCO_2e$)[a]

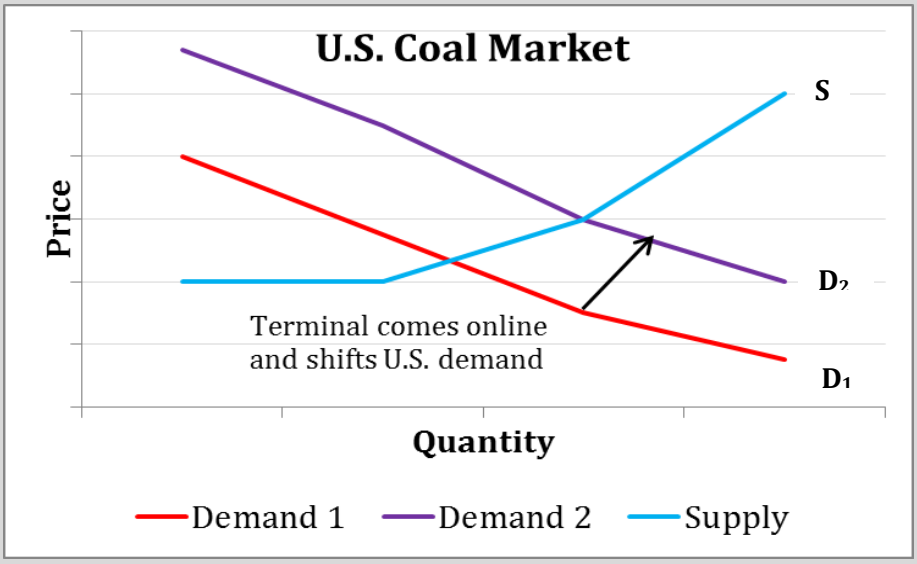


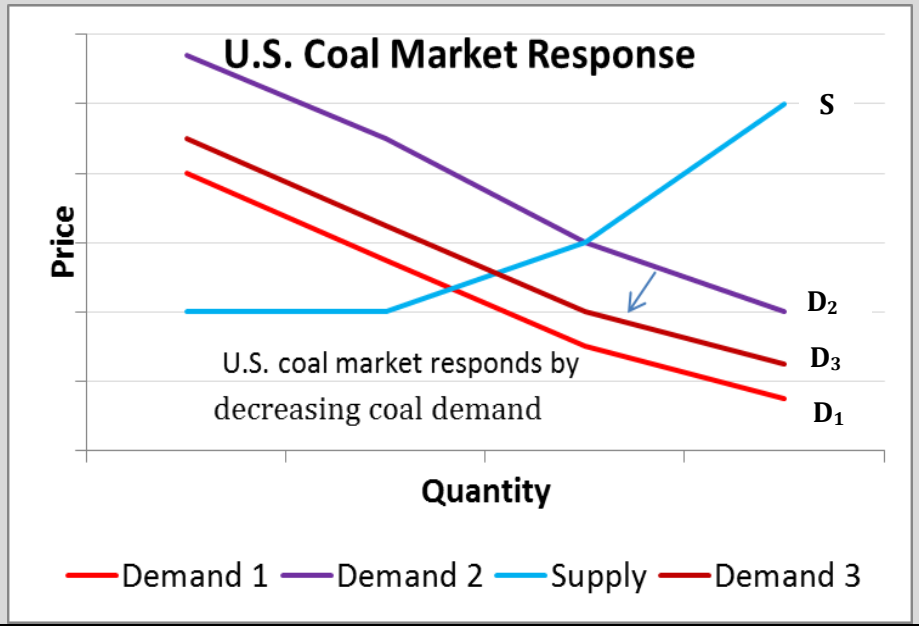
Notes: [a] Net GHG emissions represent the difference between the Proposed Action and the no-action. The bars in this figure do not include some of the smaller sources of emissions (for instance on-site emissions are not included). However, the number for each bar denotes the total net emissions for each scenario modeled and includes all emission sources. The Cumulative scenario is provided here for comparison and is addressed in Section 3.1.15, *Net Greenhouse Gas Emissions*, under *Cumulative Scenario*

The shift in coal prices both domestically and internationally have a major impact on the resulting net GHG emissions for each scenario compared to the no-action. The textboxes that follow illustrate key concepts on the shift in coal prices. These shifts are mentioned as they influence the net change in GHG emissions as described below. For additional details, see the SEPA Coal Market Assessment Technical Report (ICF 2017c).

Impact of the Proposed Action on Domestic Coal Supply and Demand, Assuming Coal Export Terminal Operates at Full Capacity

The operation of the Proposed Action would have the effect of improving integration of the U.S. and Asian coal markets. However, to the extent that Asian coal prices are higher than U.S. coal prices, operation of the Proposed Action would cause Asian coal prices to decline, while U.S. coal prices would increase. These changes in price would cause Asian coal demand to increase and U.S. coal demand to decrease. Increase in demand for U.S. coal as coal is exported from the Proposed Action (D_1 shifts to D_2) would result in higher U.S. coal prices and a subsequent decrease in domestic coal demand compared to the no-action. The international "demand" from the coal export terminal is inelastic (i.e., for a 1% change in coal price, there is no change in demand for coal from the export terminal) while the domestic demand from coal plants is elastic and decreases with an increase in coal prices (e.g., for a 1% increase in coal price, the demand for coal will decrease 0.3%).





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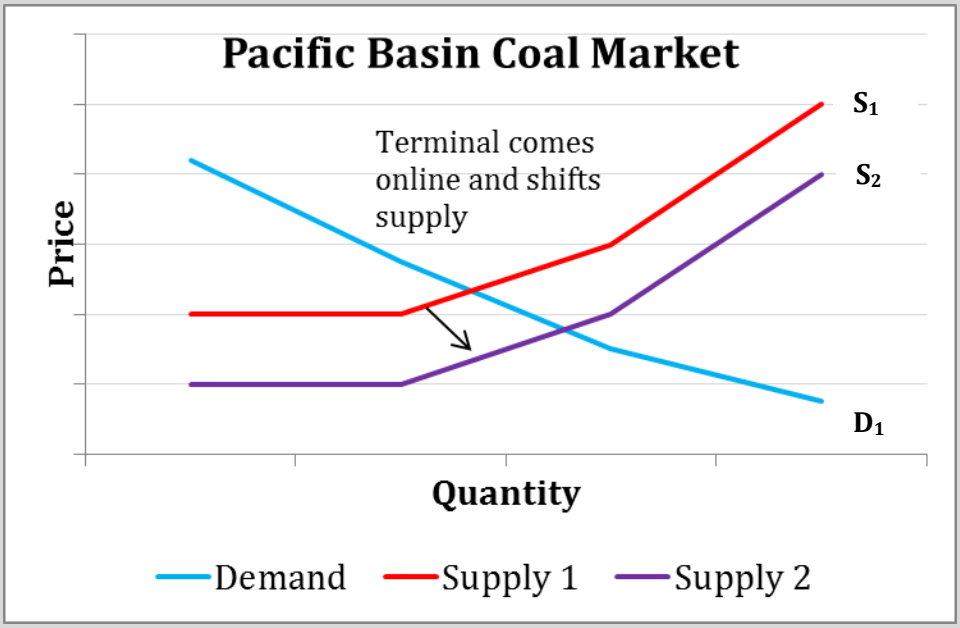
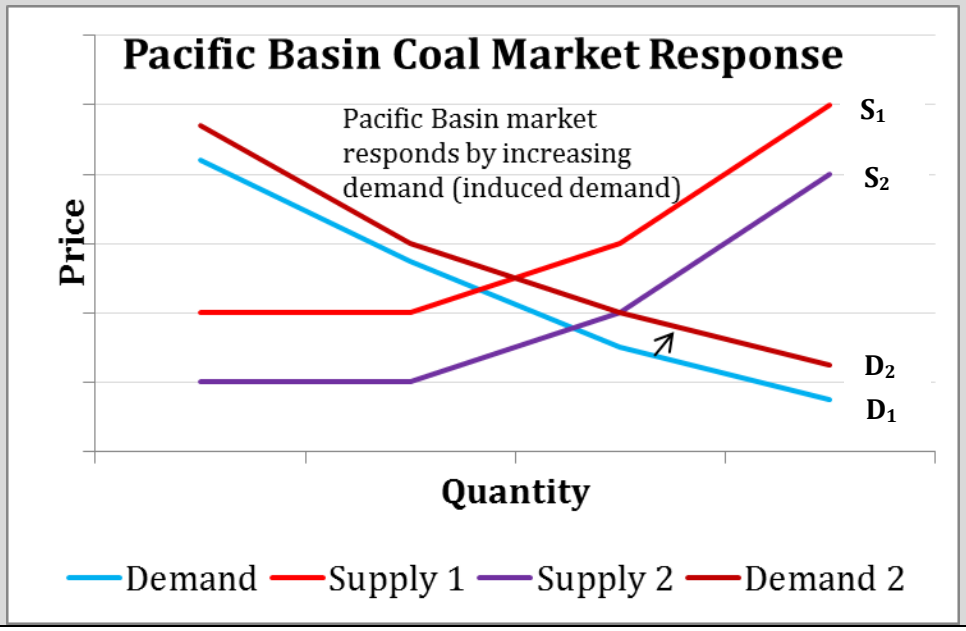
Impact of the Proposed Action on International Coal Supply and Demand, Assuming Coal Export Terminal Operates at Full Capacity

1. Increase in coal supplied to international market from the Proposed Action.
2. This increase in the coal supply in Asia would result in lower international coal prices and a subsequent increase in international coal demand compared to the no-action.





The diagrams above explain the general impact of the Proposed Action on coal markets regardless of the scenario. What makes each scenario different, however, is that the supply and demand curves for coal each have different slopes. The slopes of the supply and demand curves vary based on economic and policy conditions dictated by each scenario. For example, the Lower Bound scenario has a lower slope for coal demand than the No Clean Power Plan scenario, indicating a lower elasticity of demand in response to supply changes. Likewise, the slope of the demand curves in the Upper Bound Scenario is higher than the No Clean Power Plan Scenario, which results in greater elasticity of demand and thus greater induced demand. In effect, the differences in supply and demand curves differentiate the emissions between each scenario.

3.1.15.1 No Clean Power Plan Scenario

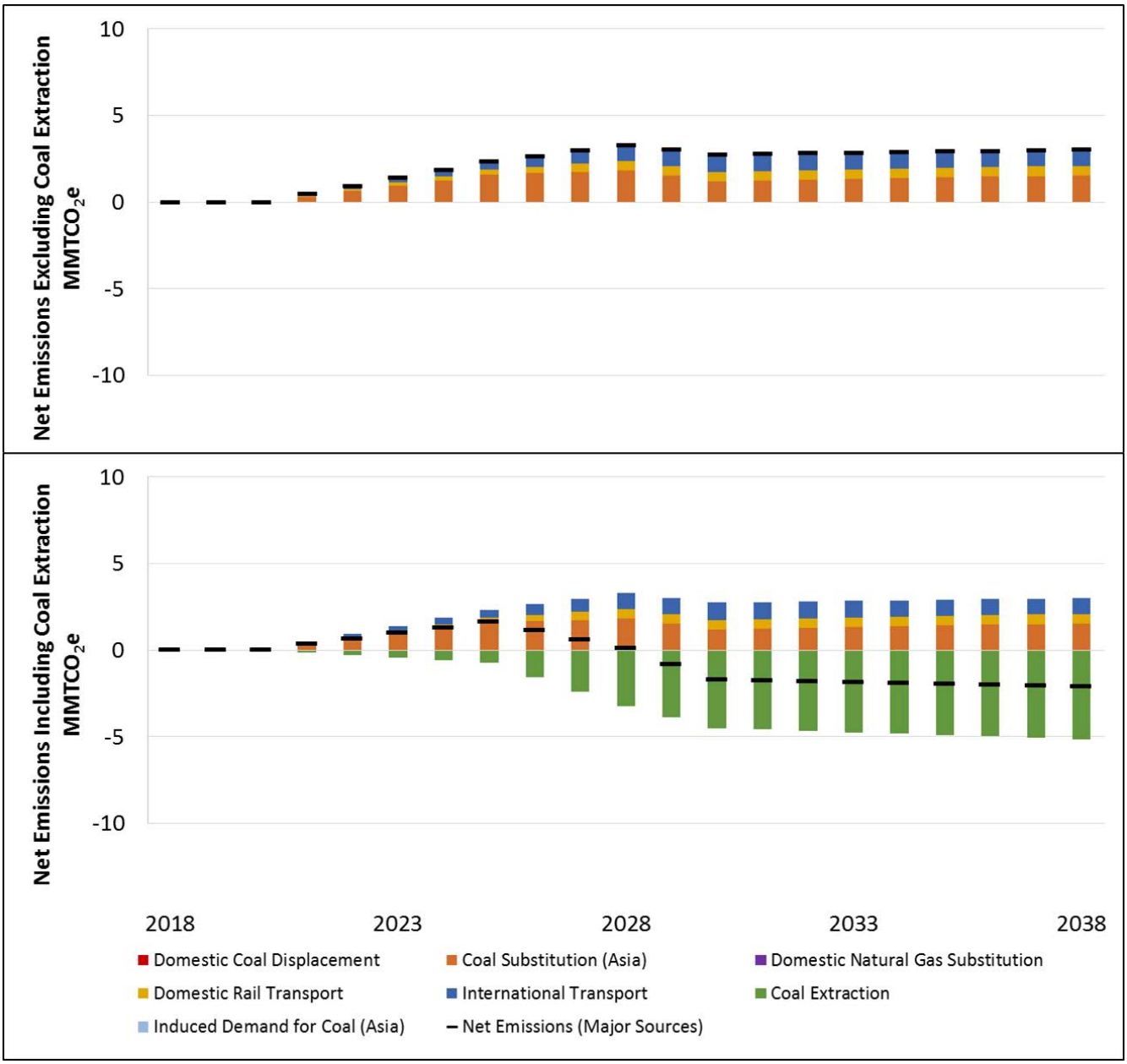
Emissions estimated in the coal market assessment are assumed zero from 2018 through 2020 because the proposed terminal is not operating yet. Emissions start to ramp up when the coal export terminal would begin operating in 2021 and continue through 2038. As shown in Figure 13, there is significant variation from year to year, as well as a ramp-up period where the coal export terminal would increase exports from zero to 44 million metric tons of coal per year. In the No Clean Power Plan Scenario, U.S. coal consumption and thus emissions do not change under the Proposed Action because domestic coal prices do not increase enough to cause a change in demand. The coal exported through the proposed terminal replaces coal produced primarily from Indonesia, China, Russia, Australia, and India, resulting in a net decrease in annual GHG emissions of 3.21 million metric tons from coal extraction when the terminal reaches full capacity in 2028 (Table 44).

Impacts on Coal and Natural Gas Combustion Relative to the No Clean Power Plan Scenario

The table below compares how coal and natural gas combustion change in response to market and policy conditions. The No Clean Power Plan scenario row compares the emissions relative to the no-action, whereas the other rows indicate whether emissions have increased or decreased relative to the no-action and then indicate whether the magnitude of this increase or decrease is greater than or less than the increase or decrease from the No Clean Power Plan scenario.

Scenario	U.S. Coal Combustion	Asian Coal Combustion	U.S. Natural Gas Combustion
No Clean Power Plan	Decrease in domestic coal emissions compared to the no-action due to slight decrease in coal consumption.	Increase in Asian coal emissions compared to the no-action due to the change in the mix of coal consumed.	Increase in domestic natural gas emissions compared to the no-action due to the slight decrease in coal consumption.
2015 U.S. and International Energy Policy	Decrease in domestic coal emissions compared to the no-action.	Increase in Asian coal emissions compared to the no-action.	Increase in domestic natural gas emissions compared to the no-action.
	Magnitude of decrease is greater than of the No Clean Power Plan due to greater sensitivity to coal price changes due to overall lower electric demand.	Magnitude of increase is less than that of the No Clean Power Plan due to a different mix of coals consumed.	Magnitude of increase is greater than that of the No Clean Power Plan due to the greater decrease in coal consumption.
Lower Bound	Decrease in domestic coal emissions compared to the no-action.	Decrease in Asian coal emissions compared to the no-action.	Increase in domestic natural gas emissions compared to the no-action.
	Magnitude of the decrease is greater than that of the No Clean Power Plan due to the higher assumed production costs in the Powder River Basin that result in higher coal prices in the Proposed Action that results in greater reduction of domestic coal consumption.	Magnitude of the decrease is less than in the No Clean Power Plan. In both scenarios the changes in Asian coal combustion emissions are due only to changes in the mix of coal consumed.	Magnitude of the increase in natural gas emissions is greater than in the No Clean Power Plan due to the greater reduction in coal consumption.
Upper Bound	Increase in domestic coal emissions compared to the no-action.	Increase in Asian coal emissions compared to the no-action.	Decrease in domestic natural gas emissions compared to the no-action.
	Magnitude of the decrease is greater than in the No Clean Power Plan scenario due to the higher overall demand for coal	Magnitude of the increase is greater than in the No Clean Power Plan scenario because the higher assumed production costs of international coal producers results in greater induced demand.	Magnitude of decrease is greater than in the No Clean Power Plan scenario because of the greater change in domestic coal consumption.

Figure 13. No Clean Power Plan—Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038



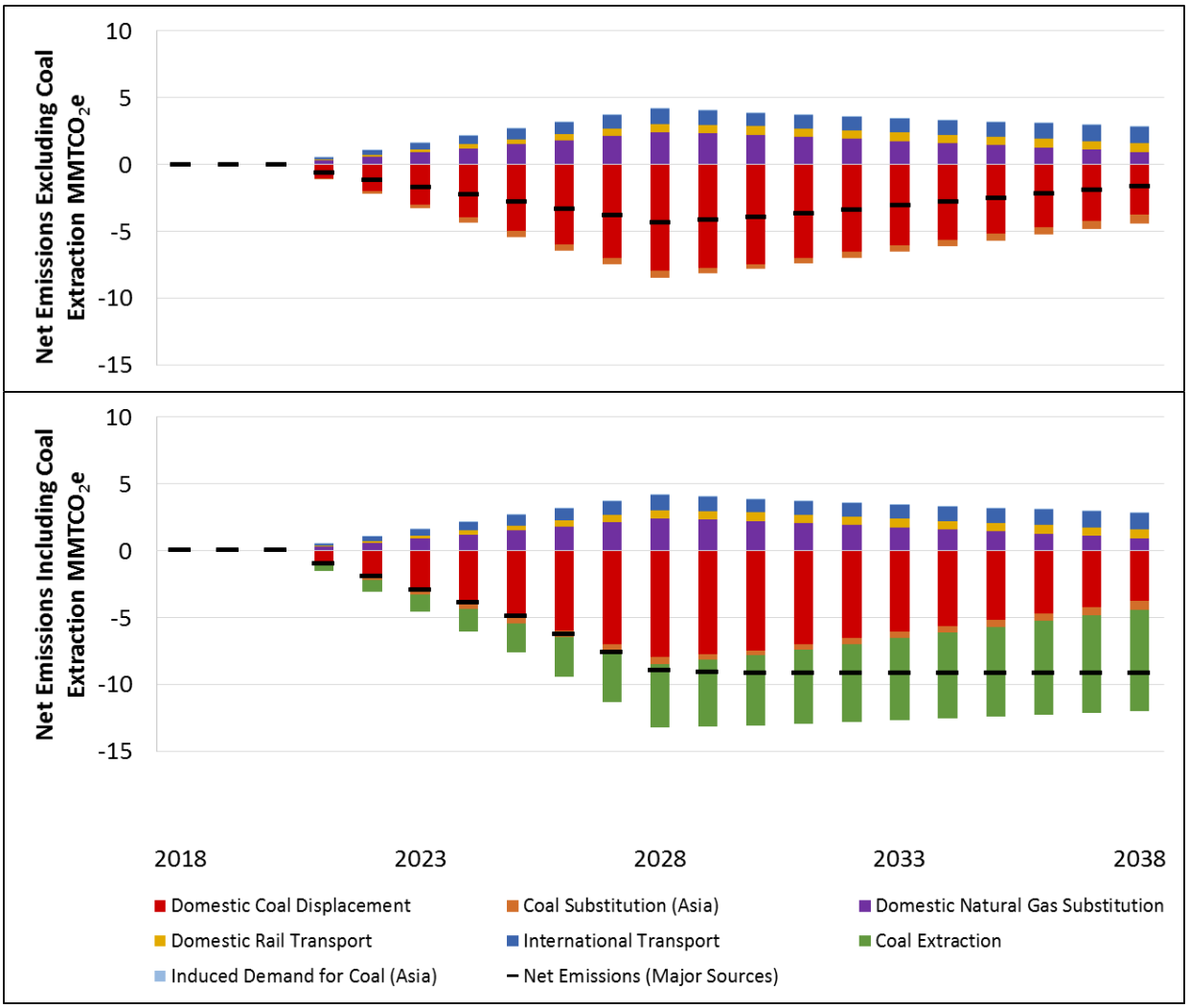
Note: Net GHG emissions represent the difference between the Proposed Action and the no-action.

3.1.15.3 Lower Bound Scenario

In the Lower Bound scenario (Figure 14), coal displacement in the United States results in a reduction of GHG emissions. The displacement of U.S. coal is highest in the Lower Bound Scenario because the PRB and Uinta Basin coal supply curves are assumed higher than the base assumption coal curves, which results in higher coal prices in both the No Action and Proposed Action alternatives. Thus the domestic coal demand is more sensitive to the coal price increase that occurs in the Proposed Action (i.e., for a percent increase in price, coal demand would decrease by 1.6 million metric tons on average). Induced demand in Asia increases Asian coal GHG emissions. In the Lower Bound Scenario, there is a decrease in emissions due to the mix of coal consumed in Asia as more coal with a lower carbon emissions rate is consumed and less coal with a higher carbon emissions rate is consumed. Thus the overall net emissions in Asia are less than in the 2015 U.S. and International Energy Policy Scenario. Compared to the No Clean Power Plan scenario, the Lower Bound Scenario results in higher natural gas emissions in the United States due to the deeper reduction of coal use domestically and the replacement of some of that coal energy with natural gas. In summary, the Lower Bound scenario results in the following emissions conditions.

- Overall net emissions are lower than in the No Clean Power Plan scenario.
- Coal emissions in Asia would be lower than in the No Clean Power Plan scenario because of the mix of coals consumed.
- Natural gas substitution is higher because domestic coal prices are more sensitive to changes in demand in the Lower Bound than the No Clean Power Plan scenario.
- Coal extraction emissions are lower than in the No Clean Power Plan scenario, driven by coal production reductions in Russia and China.

Figure 14. Lower Bound – Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038



Note: Net GHG emissions represent the difference between the Proposed Action and the no-action.

3.1.15.4 Upper Bound Scenario

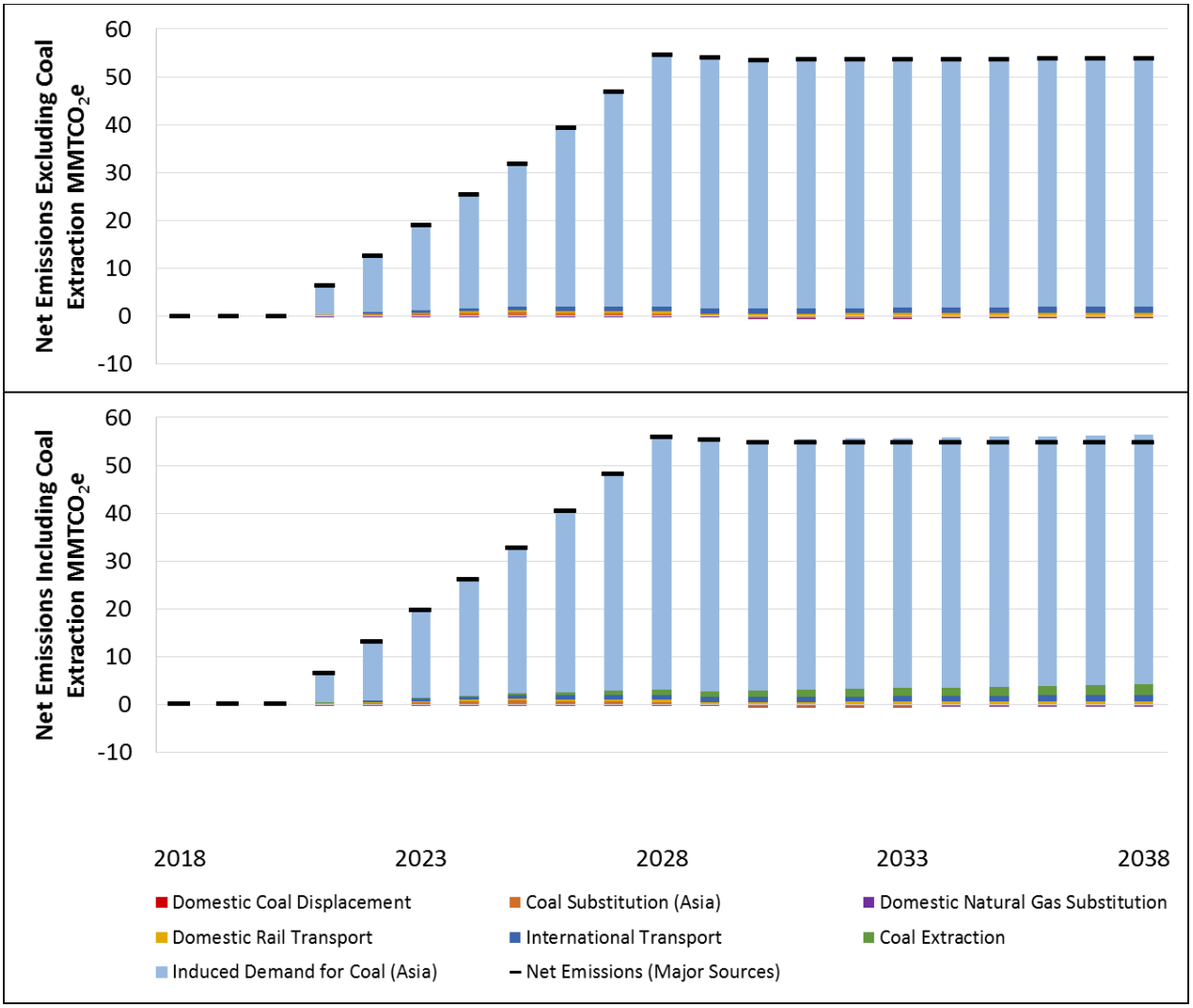
The Upper Bound scenario (Figure 15), which has a higher sensitivity to coal price changes, exhibits stronger induced demand from Asia, resulting in higher Asian coal emissions than the No Clean Power Plan scenario. There is a higher sensitivity to coal price changes due to the overall higher global coal demand, which in turn stresses the coal supply chain more than the other scenarios.[39] In summary, the Upper Bound scenario results in the following emissions conditions.

- Overall net emissions are higher than in the No Clean Power Plan scenario.
- Coal emissions in Asia rise more than in the No Clean Power Plan scenario because more demand is induced in the Upper Bound Scenario than in the No Clean Power Plan Scenario.

[39] The Upper Bound Scenario international coal demand is 33% higher than the No Clean Power Plan Scenario and 71% higher than the Lower Bound and 2015 U.S. and International Energy Policy Scenarios demand in 2040.

- Coal extraction emissions are higher than in the No Clean Power Plan scenario, driven by coal production increases in the Powder River and Uinta Basins, and China.

Figure 15. Upper Bound – Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038



Note: Net GHG emissions represent the difference between the Proposed Action and the no-action.

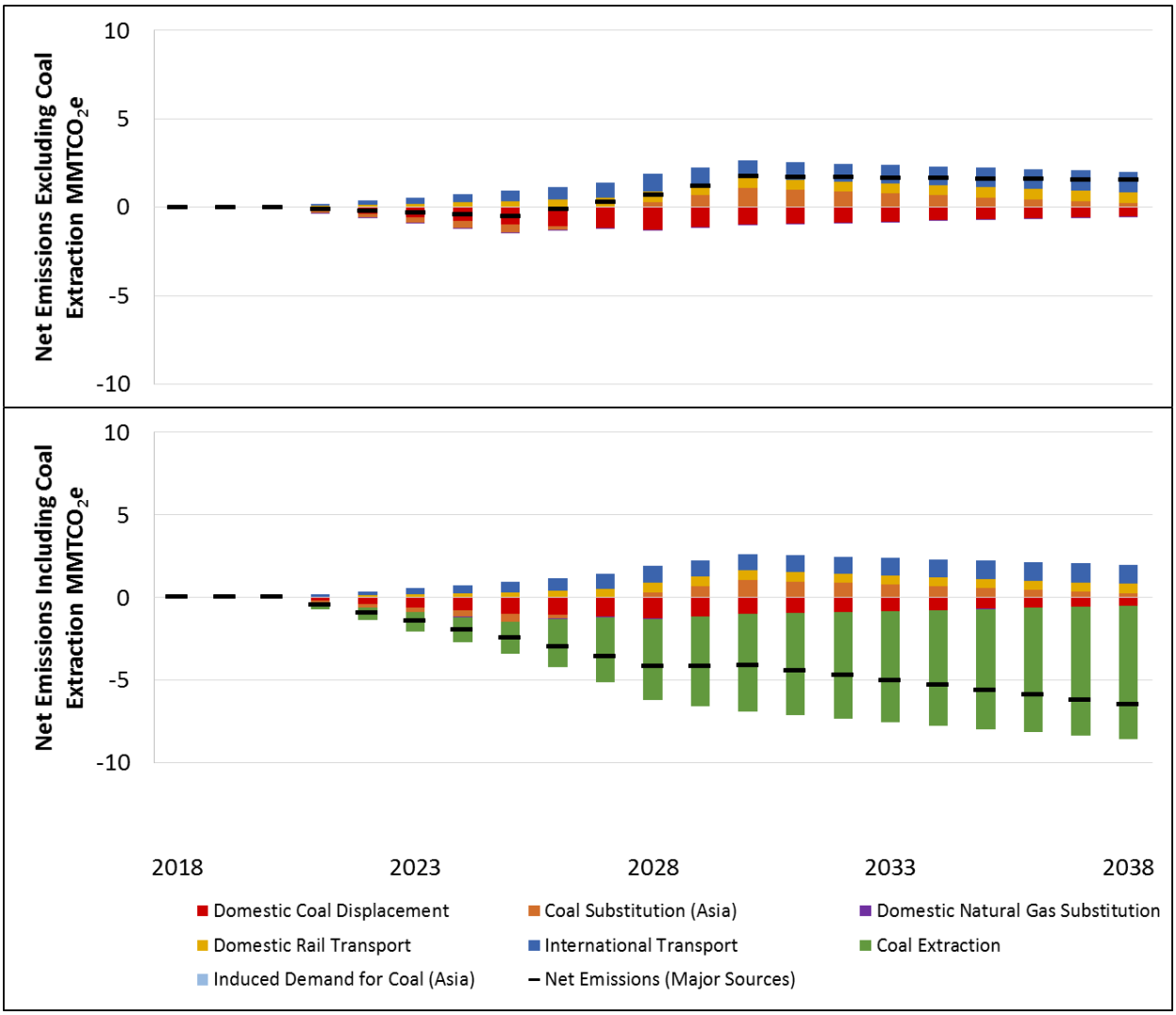
3.1.15.5 2015 U.S. and International Energy Policy Scenario

The 2015 U.S. and International Energy Policy scenario (Figure 16) has U.S. coal displacement that is lower than the No Clean Power Plan Scenario and higher than the Lower Bound scenario. This shift in coal displacement occurs because the climate policy in the United States depresses coal demand and prices and reduces coal combustion. Therefore, in this scenario, domestic coal emissions and natural gas emissions stay relatively flat throughout the analysis period. Net emissions in Asia are lower than in the No Clean Power Plan scenario and are driven by the change in the mix of coals. (One important note is that, although state climate emissions goals drive up the use of renewables relative to the No Clean Power Plan scenario, use of coal is permissible). Natural gas substitution is low in the 2015 U.S. and International Energy Policy Scenario because the Proposed Action does not cause coal prices to increase enough to result in a large decrease in coal consumption.

- The decrease in net emissions[40] from domestic coal combustion is greater than in the No Clean Power Plan scenario because coal consumption in the 2015 U.S. and International Energy Policy scenario is more sensitive to changes in coal prices due to lower overall electric demand (the coal elasticity of demand results in a decrease in coal demand of 0.5 million metric tons for every 1% increase in price).
- Net emissions from coal combustion in Asia increase less than in the No Clean Power Plan scenario because of changes in the mix of coal consumed.
- Net GHG emissions in Asia from coal combustion in the 2015 U.S. and International Energy Policy scenario are driven by changes in coal types consumed (i.e., low CO_2-content versus high CO_2-content coal).
- Net emissions from domestic natural gas combustion are greater than in the No Clean Power Plan scenario because of the larger decrease in domestic coal consumption in the 2015 U.S. and International Energy Policy scenario.
- Net emissions in coal extraction are lower than in the No Clean Power Plan scenario, driven by coal production reductions in Russia and China.

[40] Net GHG emissions represent the difference between the Proposed Action and the No-Action.

Figure 16. 2015 U.S. and International Energy Policy—Net Annual Emissions Excluding and Including Coal Extraction, 2018–2038



Note: Net GHG emissions represent the difference between the Proposed Action and the no-action.

To highlight the differences between net emissions during construction, net emissions during initial operation of the terminal, and net emissions during full operation of the terminal, Table 68 presents total net emissions for each phase as well as average net emissions if coal extraction is excluded. Table 69 shows net emissions if coal extraction is included.

Table 68. Net Emissions (Direct and Indirect) Excluding Coal Extraction by Phase ($MMTCO_2e$)

Phase	Years	2015 Energy Policy		Lower Bound		Upper Bound		No Clean Power Plan	
		GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions
Net Emissions Excluding Coal Extraction ($MMTCO_2e$)									
Construction Emissions	2018–2020	0.21	0.07	0.21	0.07	0.21	0.07	0.21	0.07
Total Net Emissions for Initial Operation	2021–2027	0.30	0.04	-13.66	-1.95	183.41	26.20	14.19	2.03
Total Net Emissions for Full Operations	2028–2038	21.85	1.99	-27.86	-2.53	596.80	54.25	37.35	3.40
Total Emissions	2018–2038	22.36		-41.31		780.42		51.75	

Table 69. Net Emissions (Direct and Indirect) Including Coal Extraction by Phase ($MMTCO_2e$)

Phase	Years	2015 Energy Policy		Lower Bound		Upper Bound		No Clean Power Plan	
		GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions	GHG Emissions	Avg. Annual Emissions
Net Emissions Including Coal Extraction ($MMTCO_2e$)									
Construction Emissions	2018–2020	0.21	0.07	0.21	0.07	0.21	0.07	0.21	0.07
Total Net Emissions for Initial Operation	2021–2027	-12.37	-1.77	-26.92	-3.85	186.11	26.59	8.04	1.15
Total Net Emissions for Full Operations	2028–2038	-51.38	-4.67	-95.34	-8.67	615.17	55.92	-13.00	-1.18
Total Emissions	2018–2038	-63.54		-122.04		801.49		-4.75	

3.1.15.6 Cumulative Scenario

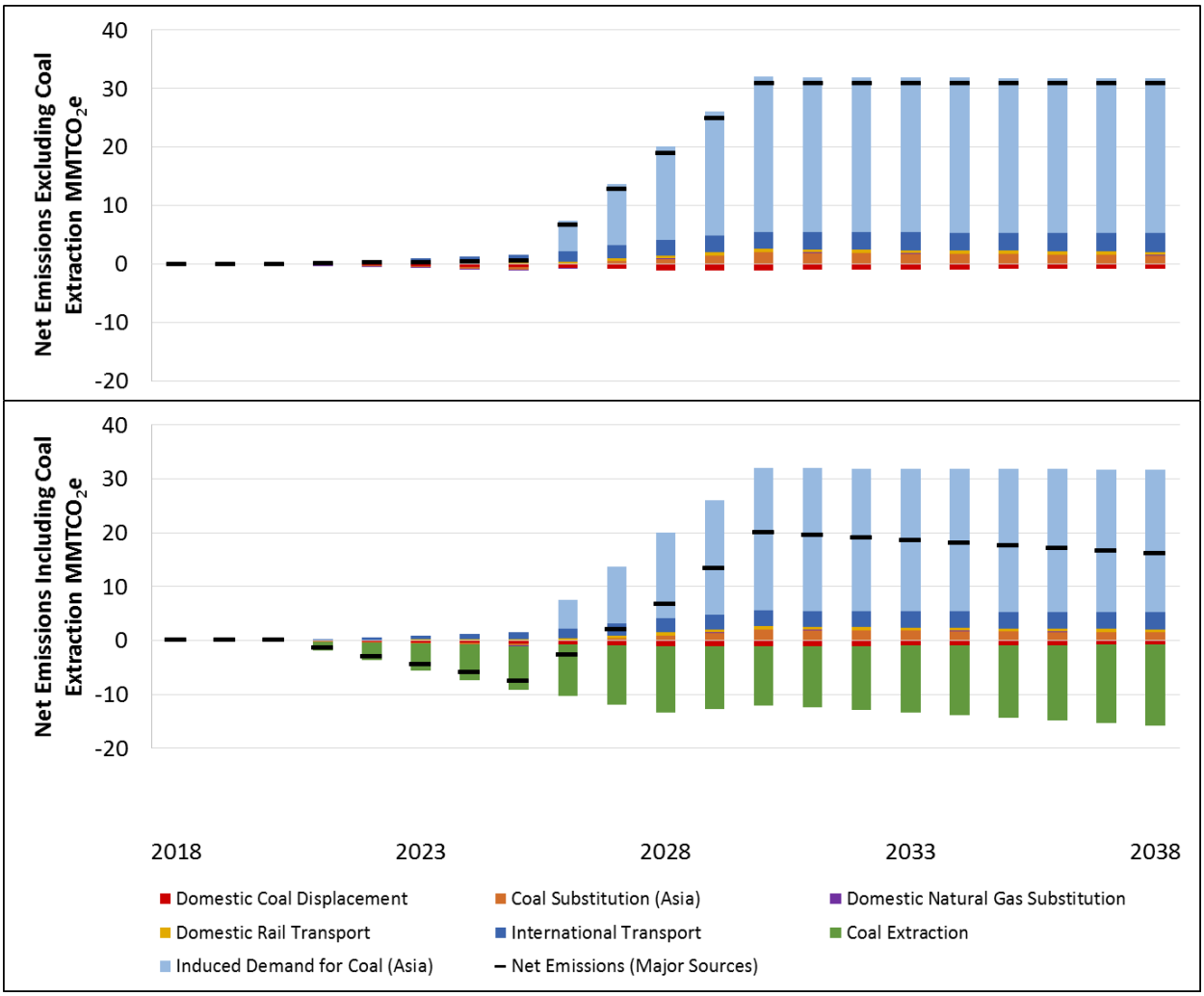
The Cumulative scenario includes other planned export coal terminals in the Pacific Northwest. Each terminal would operate at full capacity, except for the Ridley terminal due to its long distance from the Powder River Basin, for a total export tonnage of 175 million metric tons, which includes both thermal and metallurgical coal.[41] The emissions from the operation of the other coal export terminals are not included in the cumulative emissions analysis. Their impact is solely limited to their ability to influence coal supplies and prices. All other assumptions are the same as the No Clean Power Plan scenario. The Cumulative scenario compares the no-action without the additional coal export terminals against the Proposed Action that includes the other coal export terminals.

The Cumulative scenario emissions are dominated by changes in Asian coal emissions (Figure 17.). The operation of multiple coal export terminals changes the mix of coal types consumed in Asia with only a small decline in domestic coal consumption. The additional export capacity beyond the Proposed Action causes a decrease in coal prices in 2030, which results in induced demand equivalent to about 12.5 million metric tons. In summary, the Cumulative scenario results in the following emissions conditions.

- Net emissions relative to the no-action are higher than the No Clean Power Plan scenario (351.24 $MMTCO_2e$ versus -51.75 from 2018 through 2038 excluding coal extraction, and 165.43 $MMTCO_2e$ versus -4.75 from 2018 through 2038 including coal extraction).
- The change in Asian coal combustion emissions is due to a mix of induced demand and a change in the mix of coals consumed.
- Coal use in the United States declines more relative to the No Clean Power Plan scenario due to the increased demand from multiple coal export terminals that is a greater stimulus to the domestic supply system and, as such, causes coal prices to rise higher and coal demand to fall farther. The change in coal use in the United States is less than 0.9 million metric tons in both the Cumulative and No Clean Power Plan Scenarios.
- Natural gas substitution follows the same pattern as in the No Clean Power Plan scenario as natural gas consumption moves in the opposite direction of coal consumption changes in each scenario.
- Coal extraction emissions show a similar trend as the No Clean Power Plan scenario; however, emissions are almost exclusively driven by a reduction in coal production in China.

[41] The analysis for the EIS only models thermal coal as only thermal coal would be exported through the proposed terminal. The total export capacity for thermal coal is 157 million metric tons.

Figure 17. Cumulative Scenario—Net Annual Emissions, 2018–2038



Note: Net GHG emissions represent the difference between the Proposed Action and the no-action.

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal and GHG emissions would not be affected by construction or operation. However, the Applicant has indicated that the operation of the current bulk product terminal would continue and increase within the project area. The Applicant would not construct Docks 2 and 3. Dock 1 would continue to be used for bulk cargo, primarily alumina, and might be used for general cargo.

Alternative uses of the project area would be expected to result in minimal increases in GHG emissions relative to current conditions in Cowlitz County. Under the No-Action Alternative, the Applicant anticipates importing from Asia up to 600,000 short tons of calcined pet coke a year. This material would arrive by vessel and be stored in a building at the facility. Approximately 200,000 short tons of coal tar pitch per year could also be imported by vessel, as well as an undetermined amount of cement. Future operations would result in two additional daily trains arriving and departing the facility with an average rail car length of 30 cars carrying bulk product. Each train is

composed of two locomotives. In addition, an average of 26 Panamax-sized vessels would arrive and depart each year, an increase of 20 vessels compared to the 6 vessels that currently arrive and depart. Truck haul emissions associated with the transport of coal to the nearby Weyerhaeuser facility would increase and are included in estimate of GHG emissions. Emissions from the consumption of electricity at the bulk product terminal would increase due to the planned terminal expansion; however, the extent of this increase is uncertain. The estimated emissions are shown in Table 70.

Table 70. No-Action Alternative Annual Average Emissions from Rail, Vessel, and Haul Trucks Operating within Cowlitz County ($MMTCO_2e$)

Source	Maximum Annual Average Emissions ($MMTCO_2e$)
Locomotive combustion	0.0005
Vessel combustion	0.0004
Haul trucks	0.0002
Total	**0.0012**

$MMTCO_2e$ = million metric tons of carbon dioxide equivalent

The no-action in coal market assessment contains different boundaries than the emission sources above (i.e., the coal market assessment examines effects on the international coal market, while the No-Action Alternative examines alternative uses of the project area). While the no-action for the coal market assessment examines the implications of not building the coal export terminal, net emissions between a given coal market scenario and the no-action consider changes in emissions from coal combustion in Asia and the U.S. for instance, but do not consider changes in emissions from emission sources described in Table 70. In particular, the no-action as it relates to the coal market assessment does not evaluate net impacts associated with existing vessel, rail, and vehicle traffic.

Chapter 4
Supplementary Data

4.1 Interpolated Results from Coal Market Assessment

The GHG analysis used coal market assessment estimates on changes in domestic and international coal demand for 2025, 2030, and 2040. For the GHG analysis, the years 2025, 2028, and 2038 are extracted from the full, interpolated time series and presented below. As mentioned in Section 2.2.2.2, *Method for Assembling an Emissions Time Series,* the coal market assessment values were adjusted to capture the gradual increase in coal exports from 2020 to 2025 (from zero to 25 million metric tons) and 2028 (full capacity of 44 million metric tons). This chapter presents the interpolated results based on the coal market assessment results. The following tables are presented.

- Table 71. Interpolated Coal Market Assessment Results, 2015 U.S. and International Energy Policy
- Table 72. Interpolated Coal Market Assessment Results, Lower Bound
- Table 73. Interpolated Coal Market Assessment Results, Upper Bound
- Table 74. Interpolated Coal Market Assessment Results, No Clean Power Plan
- Table 75. Interpolated Coal Market Assessment Results, Cumulative

In addition, Table 76 provides the net change in coal extraction volumes for the year 2028 and the entire 2018 through 2038 analysis period.

Table 71. Interpolated Coal Market Assessment Results, 2015 U.S. and International Energy Policy

	2025	2028	2038
Coal Exported Through the Proposed Action (million metric tons)	**25.0**	**44.0**	**44.0**
Coal by Origin exported Through the Proposed Action (million metric tons)			
Powder River Basin - Total	25.0	44.0	37.5
MT Powder River Basin	9.9	29.0	36.1
MT Signal Peak	0.0	0.0	0.0
Powder River Basin WY 8400	0.0	0.0	0.0
Powder River Basin WY 8800	15.1	15.0	1.4
Uinta Basin - Total	0.0	0.0	6.5
Colorado	0.0	0.0	3.2
Utah	0.0	0.0	3.3
Total U.S. CO_2 Emissions - Coal (thousand metric tons)	**-953.2**	**-1,251.4**	**-498.8**
Total Asian CO_2 Emissions - Coal (thousand metric tons)	**-482.5**	**317.1**	**252.9**
Asia - Other	-1,179.9	-830.7	0.0
Australia	0.0	0.0	0.0
China	-66.8	1.6	16.2
Hong Kong	472.4	416.5	149.0
India	0.0	0.0	0.0
Indonesia	0.0	0.0	0.0
Japan	-95.1	-165.9	35.7
Korea	-151.8	-6.3	118.5
Taiwan	538.8	901.8	-66.5
Total U.S. Natural Gas Consumption (TBtu)	**0.0**	**1.2**	**0.8**
Total U.S. CO_2 emissions - Natural Gas (thousand metric tons)	**0.0**	**65.2**	**41.6**
Net Change in Shipping GHG Emissions from all Asian Sources, Excluding Transport from coal export terminal to WA State Border – Thousand $MTCO_2e$	**602.6**	**1,013.2**	**1,179.9**

Table 72. Interpolated Coal Market Assessment Results, Lower Bound

	2025	2028	2038
Coal Exported Through the Proposed Action (million metric tons)	**25.0**	**44.0**	**44.0**
Coal by Origin exported Through the Proposed Action (million metric tons)			
Powder River Basin - Total	25.0	44.0	44.0
MT Powder River Basin	0.0	0.0	0.0
MT Signal Peak	0.0	0.0	0.0
Powder River Basin WY 8400	0.0	0.0	11.4
Powder River Basin WY 8800	25.0	44.0	32.6
Uinta Basin - Total	0.0	0.0	0.0
Colorado	0.0	0.0	0.0
Utah	0.0	0.0	0.0
Total U.S. CO_2 Emissions - Coal (thousand metric tons)	**-4,928.4**	**-7,940.6**	**-3,725.4**
Total Asian CO_2 Emissions - Coal (thousand metric tons)	**-473.8**	**-535.5**	**-652.1**
Asia - Other	-161.2	-113.5	0.0
Australia	0.0	0.0	0.0
China	-52.4	-89.8	-122.2
Hong Kong	269.2	45.4	-256.0
India	-632.9	-445.5	0.0
Indonesia	0.0	0.0	0.0
Japan	-95.1	-165.9	-41.6
Korea	-151.8	-252.2	-59.1
Taiwan	350.4	486.1	-173.3
Total U.S. Natural Gas Consumption (TBtu)	**28.8**	**45.6**	**18.3**
Total U.S. CO_2 emissions - Natural Gas (thousand metric tons)	**1,531.1**	**2,424.0**	**972.4**
Net Change in Shipping GHG Emissions from all Asian Sources, Excluding Transport from coal export terminal to WA State Border – Thousand $MTCO_2e$	**769.8**	**1,130.8**	**1,189.9**

Table 73. Interpolated Coal Market Assessment Results, Upper Bound

	2025	2028	2038
Coal Exported Through the Proposed Action (million metric tons)	**25.0**	**44.0**	**44.0**
Coal by Origin exported Through the Proposed Action (million metric tons)			
Powder River Basin - Total	25.0	42.4	32.1
MT Powder River Basin	25.0	42.4	32.1
MT Signal Peak	0.0	0.0	0.0
Powder River Basin WY 8400	0.0	0.0	0.0
Powder River Basin WY 8800	0.0	0.0	0.0
Uinta Basin - Total	0.0	1.6	11.9
Colorado	0.0	0.0	2.9
Utah	0.0	1.6	9.0
Total U.S. CO_2 Emissions - Coal (thousand metric tons)	**17.4**	**26.0**	**115.3**
Total Asian CO_2 Emissions - Coal (thousand metric tons)	**30,790.8**	**52,895.8**	**51,805.7**
Asia - Other	0.0	-440.4	-160.0
Australia	0.0	0.0	0.0
China	28,225.5	49,371.7	49,168.2
Hong Kong	23.4	149.7	278.0
India	1,429.7	2,289.3	1,525.4
Indonesia	0.0	0.0	0.0
Japan	477.4	618.8	350.6
Korea	130.9	292.4	251.1
Taiwan	503.9	614.3	392.4
Total U.S. Natural Gas Consumption (TBtu)	**-0.4**	**-0.5**	**-0.1**
Total U.S. CO_2 emissions - Natural Gas (thousand metric tons)	**-18.9**	**-24.1**	**-3.6**
Net Change in Shipping GHG Emissions from all Asian Sources, Excluding Transport from coal export terminal to WA State Border – Thousand $MTCO_2e$	**739.3**	**1,116.7**	**1,366.4**

Table 74. Interpolated Coal Market Assessment Results, No Clean Power Plan

	2025	2028	2038
Coal Exported Through the Proposed Action (million metric tons)	**25.0**	**44.0**	**44.0**
Coal by Origin exported Through the Proposed Action (million metric tons)			
Powder River Basin - Total	25.0	44.0	44.0
MT Powder River Basin	25.0	44.0	44.0
MT Signal Peak	0.0	0.0	0.0
Powder River Basin WY 8400	0.0	0.0	0.0
Powder River Basin WY 8800	0.0	0.0	0.0
Uinta Basin - Total	0.0	0.0	0.0
Colorado	0.0	0.0	0.0
Utah	0.0	0.0	0.0
Total U.S. CO_2 Emissions - Coal (thousand metric tons)	**-2.6**	**-2.1**	**-4.0**
Total Asian CO_2 Emissions - Coal (thousand metric tons)	**1,579.4**	**1,835.5**	**1558.8**
Asia - Other	0.0	-672.2	-224.1
Australia	0.0	0.0	0.0
China	183.3	300.0	57.0
Hong Kong	522.6	979.5	356.1
India	-357.0	-251.3	0.0
Indonesia	0.0	0.0	0.0
Japan	710.1	499.9	102.9
Korea	0.0	0.0	92.5
Taiwan	520.5	979.5	1,174.4
Total U.S. Natural Gas Consumption (TBtu)	**0.0**	**0.0**	**0.0**
Total U.S. CO_2 emissions - Natural Gas (thousand metric tons)	**0.8**	**0.2**	**-0.1**
Net Change in Shipping GHG Emissions from all Asian Sources, Excluding Transport from coal export terminal to WA State Border – Thousand $MTCO_2e$	**458.0**	**927.2**	**918.5**

Table 75. Interpolated Coal Market Assessment Results, Cumulative

	2025	2028	2038
Coal Exported Through the Proposed Action (million metric tons)	**25.0**	**44.0**	**44.0**
Coal by Origin exported Through the Proposed Action (million metric tons)			
Powder River Basin - Total	25.0	44.0	44.0
MT Powder River Basin	25.0	44.0	44.0
MT Signal Peak	0.0	0.0	0.0
Powder River Basin WY 8400	0.0	0.0	0.0
Powder River Basin WY 8800	0.0	0.0	0.0
Uinta Basin - Total	0.0	0.0	0.0
Colorado	0.0	0.0	0.0
Utah	0.0	0.0	0.0
Total U.S. CO_2 Emissions - Coal (thousand metric tons)	**-556.0**	**-1,028.3**	**-734.3**
Total Asian CO_2 Emissions - Coal (thousand metric tons)	**-394.0**	**16,801.8**	**27,986.3**
Asia - Other	0.0	-678.4	-300.7
Australia	0.0	0.0	0.0
China	247.9	16,306.7	26,876.6
Hong Kong	522.6	953.6	-163.6
India	-357.0	-251.3	0.0
Indonesia	0.0	0.0	0.0
Japan	-1,327.9	-796.7	230.3
Korea	0.0	89.3	148.8
Taiwan	520.5	1,178.7	1,194.9
Total U.S. Natural Gas Consumption (TBtu)	**-0.4**	**0.8**	**0.4**
Total U.S. CO_2 emissions - Natural Gas (thousand metric tons)	**-23.7**	**43.1**	**20.2**
Net Change in Shipping GHG Emissions from all Asian Sources, Excluding Transport from coal export terminal to WA State Border – Thousand $MTCO_2e$	**1,302.6**	**2,666.8**	**3,194.4**

Table 76. Coal Extraction by Region (Million Metric Tons)

	Scenario				
Extraction Source / Period	2015 Energy Policy	Lower Bound	Upper Bound	No Clean Power Plan	Cumulative
Powder River Basin					
Annual Extraction, 2028	43.46	36.09	40.07	44.00	83.08
Total Extraction, 2018-2038	582.64	524.93	522.80	628.00	1,309.33
Uinta Basin					
Annual Extraction, 2028	-0.24	0.09	1.15	<0.005	-0.03
Total Extraction, 2018-2038	21.10	3.98	56.15	<0.005	-0.22
Other U.S. Coals					
Annual Extraction, 2028	0.45	2.26	<0.005	<0.005	1.37
Total Extraction, 2018-2038	14.92	26.47	10.22	-0.01	19.04
Australia					
Annual Extraction, 2028	-6.15	-6.19	0.00	-19.09	-0.44
Total Extraction, 2018-2038	-75.80	-76.39	0.00	-238.25	-58.72
Canada					
Annual Extraction, 2028	0.00	-0.02	0.00	0.00	0.00
Total Extraction, 2018-2038	0.00	-0.22	0.00	0.00	0.00
China					
Annual Extraction, 2028	-8.36	-7.09	6.11	-8.96	-48.25
Total Extraction, 2018-2038	-226.57	-197.99	75.40	-146.45	-721.00
India					
Annual Extraction, 2028	0.00	-7.59	0.00	-4.28	-4.28
Total Extraction, 2018-2038	0.00	-62.12	-70.45	-35.04	-35.04
Indonesia					
Annual Extraction, 2028	-8.29	-1.13	-12.32	-8.01	-14.44
Total Extraction, 2018-2038	-67.83	-9.27	-135.61	-94.96	-209.24
Russia					
Annual Extraction, 2028	-16.08	-15.72	-8.45	0.00	0.01
Total Extraction, 2018-2038	-170.44	-167.01	-104.25	-48.86	0.17
South Africa					
Annual Extraction, 2028	0.18	0.00	-2.04	<0.005	0.00
Total Extraction, 2018-2038	1.49	0.00	-25.15	<0.005	-0.05
Net Extraction					
Annual Extraction, 2028	4.78	0.67	26.57	3.65	17.01
Total Extraction, 2018-2038	78.03	42.38	354.27	64.43	304.33

Chapter 5
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MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA CLIMATE CHANGE TECHNICAL REPORT

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Contents

List of Tables ii
List of Figures ii
List of Acronyms and Abbreviations iii

Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.1.2 No-Action Alternative 1-5
1.2 Regulatory Setting 1-5
1.3 Study Area 1-6
Chapter 2 **Climate Change and Projected Changes to Climate** **2-1**
2.1 Greenhouse Effect 2-1
2.2 Climate Change Projections 2-3
2.3 Existing and Future Conditions 2-5
2.3.1 Historical and Projected Changes in Temperature 2-5
2.3.2 Historical and Projected Changes in Precipitation 2-6
2.3.3 Historical and Projected Changes in Snowpack 2-8
Chapter 3 **Impacts** **3-1**
3.1 Proposed Action 3-1
3.1.1 Impacts of Climate Change on the Proposed Action 3-1
3.1.2 Impacts of Climate Change on Other Resource Areas 3-1
3.2 No-Action Alternative 3-6
Chapter 4 **References** **4-1**

Tables

Table 1. Regulations, Statutes, and Guidelines for Climate Change 1-5

Table 2. Historical and Projected Changes in Temperature in Cowlitz County, WA 2-6

Table 3. Historical and Projected Changes in Precipitation in the Lower Columbia River Basin 2-8

Table 4. Historical and Projected Changes in Snow in the Lower Columbia River Basin 2-9

Figures

Figure 1. Project Vicinity 1-3

Figure 2. Proposed Action 1-4

Figure 3. An Idealized Model of the Natural Greenhouse Effect 2-2

Acronyms and Abbreviations

°F	degrees Fahrenheit
Applicant	Millennium Bulk Terminals—Longview
BNSF	BNSF Railway Company
CCC	Cowlitz County Code
CDID	Consolidated Diking and Improvement District
CFR	Code of Federal Regulations
CMIP5	Fifth Coupled Model Intercomparison Project
GHG	greenhouse gas
LVSW	Longview Switching Company
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
PUD	Public Utility District
RCP	Representative Concentration Pathway
RCW	Revised Code of Washington
SEPA	State Environmental Policy Act
UP	Union Pacific Railroad
USC	United States Code
VOC	volatile organic compound
WAC	Washington Administrative Code

Chapter 1
Introduction

This technical report discusses the potential impacts of climate change in relation to the proposed Millennium Bulk Terminals—Longview project (Proposed Action). The impacts are evaluated in two categories. First, the potential impacts of climate change on the Proposed Action and the No-Action Alternative (e.g., impact of increased precipitation on the Proposed Action and No Action Alternative) are summarized. Second, the impacts of climate change on other resource areas to determine if it may exacerbate or relieve the impacts of the Proposed Action (e.g., droughts exacerbating the impact of the Proposed Action on water quality in the Columbia River).

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming, and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and Union Pacific Railroad (UP) and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would

occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70 vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1. Project Vicinity

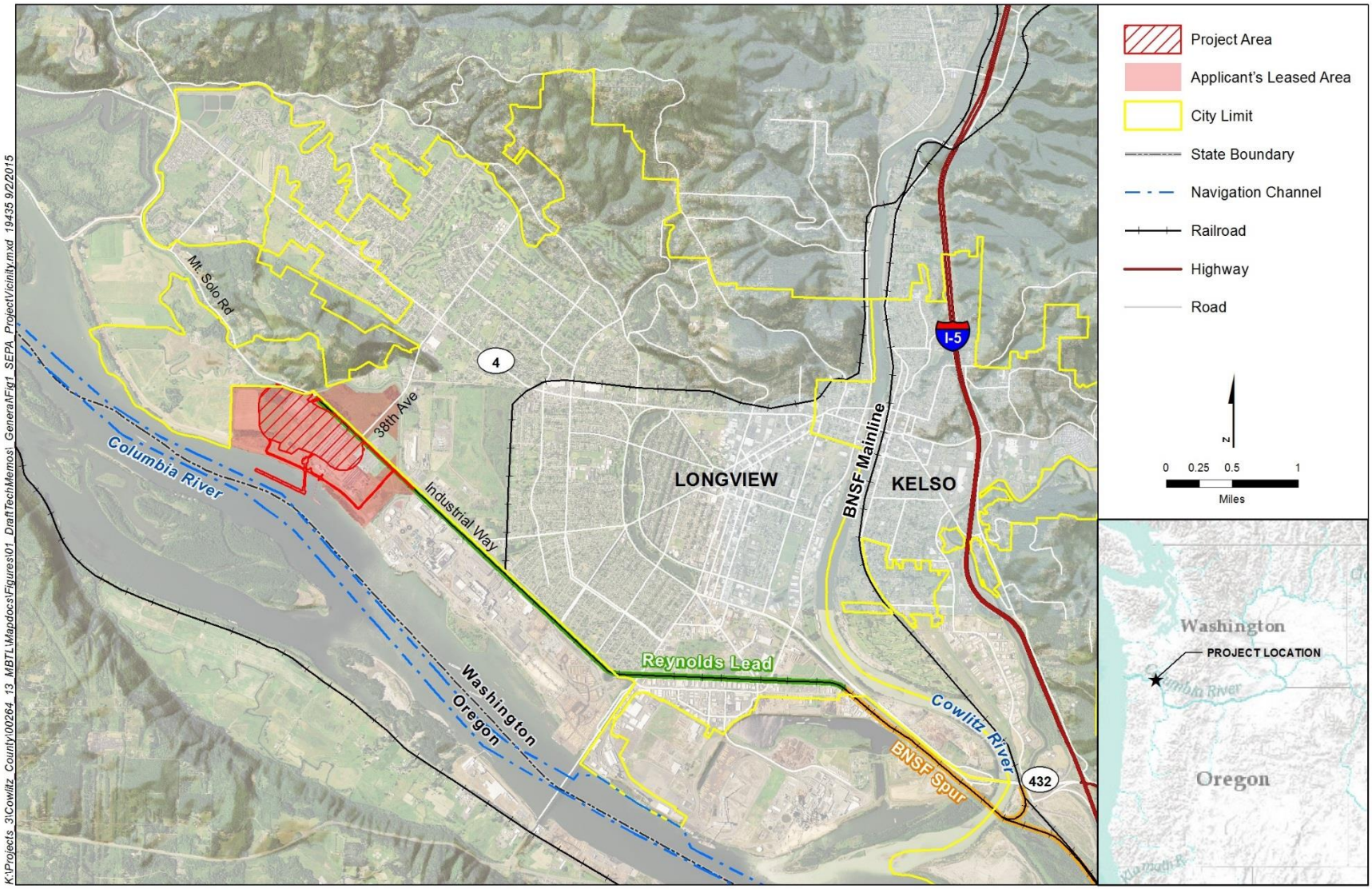
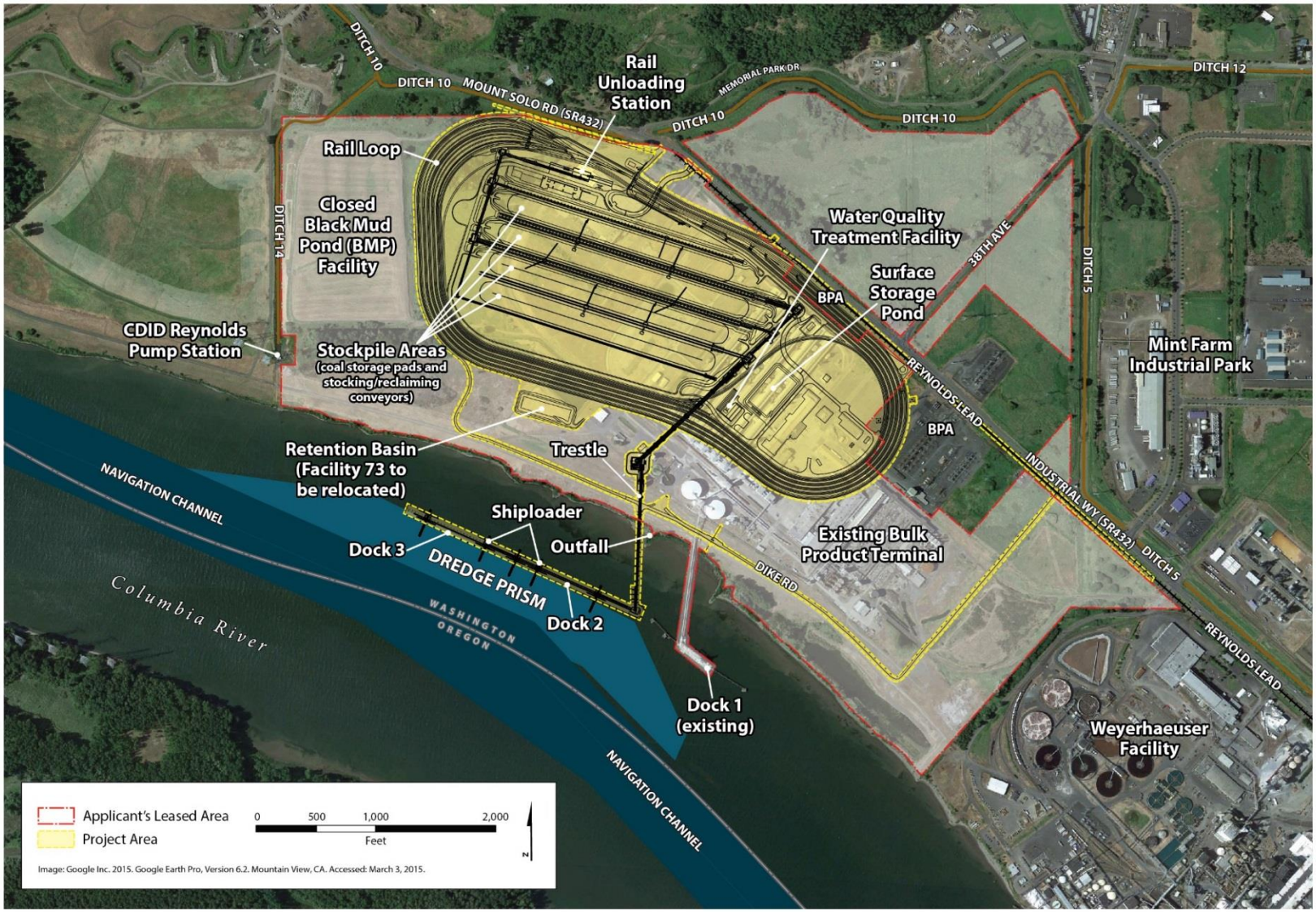


Figure 2. Proposed Action



1.1.2 No-Action Alternative

The Applicant plans to continue operating its existing bulk product terminal located adjacent to the project area. Ongoing operations would include storing and transporting alumina and small quantities of coal, and continued use of Dock 1. Maintenance of the existing bulk product terminal would continue, including maintenance dredging at the existing dock every 2 to 3 years. The Applicant plans to expand operations at the existing bulk product terminal, which could include increased storage and upland transfer of bulk products utilizing new and existing buildings. The Applicant would likely need to undertake demolition, construction, and other related activities to develop expanded bulk product terminal facilities.

If the coal export terminal is not constructed, the Applicant would likely propose expansion of the bulk product terminal onto areas that would have been subject to construction and operation of the proposed coal export terminal. Additional bulk product transfer activities could involve products such as a calcined pet coke, coal tar pitch, cement, fly ash, and sand or gravel. Any new operations would be evaluated under applicable regulations. Upland areas of the project area are zoned Heavy Industrial and it is assumed future proposed industrial uses in these upland areas could be permitted. Any new construction would be limited to uses allowed under existing Cowlitz County development regulations.

1.2 Regulatory Setting

The jurisdictional authorities and corresponding regulations, statutes, and guidance for determining potential climate change impacts are summarized in Table 1.

Table 1. Regulations, Statutes, and Guidelines for Climate Change

Regulation, Statute, Guideline	Description
Federal	
National Environmental Policy Act (42 USC 4321 *et seq*.)	Requires the consideration of potential environmental effects. NEPA implementation procedures are set forth in the President's Council on Environmental Quality's Regulations for Implementing NEPA (49 CFR 1105).
Clean Air Act of 1963 (42 USC 7401)	Directs the control of air pollutants nationally. The U.S. Supreme Court in 2007 established that greenhouse gases are air pollutants, and are therefore covered under this Act.
State	
Washington State Environmental Policy Act (WAC 197-11, RCW 43.21C)	Requires state and local agencies in Washington to identify potential environmental impacts that could result from governmental decisions.

Regulation, Statute, Guideline	Description
Requirements of Strategy—Initial Climate Change Response Strategy (RCW 43.21M.020)	Directs state agencies to develop an integrated climate change response strategy to enable state, tribal, and local governments and public and private organizations to prepare for and adapt to the impacts of changing climate conditions. *Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy* outlines strategies for protecting human health, safeguarding infrastructure and transportation systems, improving water management, reducing losses to agriculture and forestry, protecting sensitive and vulnerable species, and supporting communities by involving the public.
Washington State's Growth Management Act (WAC 365-195-920)	Requires counties and cities to include the "best available science" when developing policies and development regulations. Suggests the use of adaptive management as an interim approach for managing scientific uncertainty.
Local	
Cowlitz County SEPA Regulations (CCC 19.11)	Provide for the implementation of SEPA in Cowlitz County.

USC = United States Code; NEPA = National Environmental Policy Act; RCW = Revised Code of Washington; WAC = Washington Administrative Code; CCC = Cowlitz County Code; SEPA = Washington State Environmental Policy Act

1.3 Study Area

The study area for potential impacts from climate change on the Proposed Action and No-Action Alternative is defined as the project area for the Proposed Action and the access roads and rail leading to the project area.

The study area for the potential for climate change effects to exacerbate or alleviate the impacts of the project on other resource areas is equivalent to the study areas set for those specific resource areas.[1]

[1] For example, the analysis of the ability of climate change to exacerbate or alleviate the impacts of the project on geology and soils is the same as the study area defined in the SEPA Geology and Soils Technical Report (ICF 2017a).

Chapter 2
Climate Change and Projected Changes to Climate

This section summarizes the recent and projected future climate conditions in the study area. Trends and projections in temperature, precipitation, and snowfall are provided for current and historical conditions (generally from 1950 to 2005), the near-term future (2025 to 2049), and the midterm future (2050 to 2075)[2]. Midterm future conditions are typically considered in climate change analyses and are consistent with the likely operation of the Proposed Action. Future changes in climate will depend on the concentration of greenhouse gases (GHG) released to the atmosphere by human activities in the coming decades. As a result, climate projections are provided for both moderate and high GHG concentration scenarios.[3]

2.1 Greenhouse Effect

The Earth retains outgoing thermal energy and incoming solar energy in the atmosphere, thus maintaining heat temperature levels suitable for biological life. This retention of energy by the atmosphere is known as the greenhouse effect.[4] When solar radiation reaches the Earth, most of the solar radiation is absorbed by the Earth's surface, reflected by the Earth's surface and atmosphere, or to a lesser degree, absorbed by the Earth's atmosphere. Simultaneously, the Earth radiates its own heat and energy out into the Earth's atmosphere and space. Factors such as the reflectivity of the Earth's surface, the abundance of water vapor, or the extent of cloud cover affects the degree to which solar radiation may be absorbed and reflected. Figure 3 shows the energy flows to and from Earth and the role that the greenhouse effect plays in maintaining heat in the atmosphere.

The composition of gases in the Earth's atmosphere determines the amount of energy absorbed and re-emitted by the atmosphere or simply reflected back into space. The predominant gases in the Earth's atmosphere, nitrogen and oxygen (which together account for nearly 90% of the atmosphere) exert little to no greenhouse effect. Gases such as carbon dioxide, methane, and nitrous

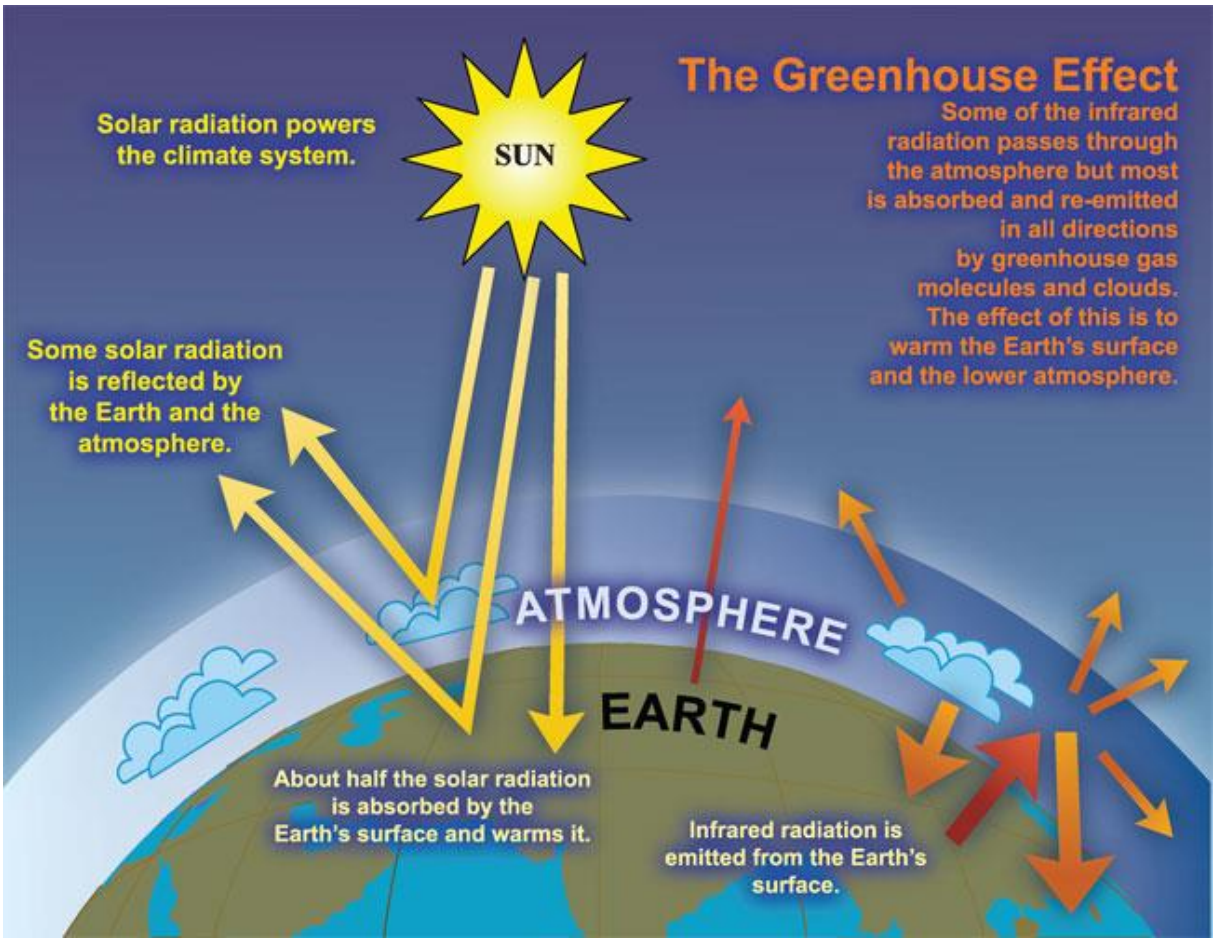
[2] The very near term 2006–2024 is not addressed here. This term is typically covered by existing procedures and examination of current conditions are adequate for planning purposes. Further, the very near term does not allow future climatic changes to be realized and assessed. Hence, this period is excluded from consideration in this report.

[3] Unless otherwise noted, the moderate concentration scenario corresponds to Representative Concentration Pathway (RCP) 4.5; the high concentration scenario corresponds to RCP 8.5. RCPs project increases in atmospheric concentrations of GHGs between now and 2100. They are used in international climate modeling to develop consistent future scenarios of climate change and have been adopted by the Intergovernmental Panel on Climate Change in its Fifth Assessment Report.

[4] The Intergovernmental Panel on Climate Change (2014) defines the greenhouse effect as follows:
The infrared radiative effect of all infrared-absorbing constituents in the atmosphere. Greenhouse gases, clouds, and (to a small extent) aerosols absorb terrestrial radiation emitted by the Earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the troposphere and the consequent weakening of emission. An increase in the concentration of greenhouse gases increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a greenhouse gas concentration because of anthropogenic emissions contributes to an instantaneous radiative forcing. Surface temperature and troposphere warm in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.

oxide, trap outgoing energy and contribute to the greenhouse effect. These greenhouse gases are pollutants under the federal Clean Air Act. Additionally, manufactured pollutants, such as hydrofluorocarbons, can contribute to the greenhouse effect. Unlike most air pollutants (e.g., particulate matter) that have only a local impact on air quality, GHGs affect the atmosphere equally, regardless of where they are emitted, and thus are global pollutants. A ton of methane emissions in Asia affects the global atmosphere to the same degree as a ton of methane emissions in the United States.

Figure 3. An Idealized Model of the Natural Greenhouse Effect



Source: Intergovernmental Panel on Climate Change 2007

As the atmospheric concentrations of GHGs increase, the atmosphere's ability to retain heat increases as well. Since the instrumental record began in 1895, the U.S. average temperature has risen by approximately 1.3 to 1.9 degrees Fahrenheit (°F) (U.S. Global Change Research Program 2014). Furthermore, U.S. average temperatures throughout the 21st century are expected to increase at a faster pace, by 3°F to 10°F by 2100 above a 1970 to 1999 baseline (U.S. Global Change Research Program 2014).

The impacts of higher global surface temperatures include widespread changes in the Earth's climate system. Increased surface temperatures is causing sea level to rise both from thermal expansion of seawater as well as increased melting of ice sheets in the most northerly and southerly reaches. It is also changing weather patterns, including the frequency, severity, and duration of heat

waves, drought, and extreme precipitation events. Incidences of drought are expected to become more frequent.

Climate change also affects the natural environment and virtually all aspects of society, including biodiversity, invasive species, human health, cultural resources, infrastructure, and other sectors. The impacts will vary by location and depend on the nature of the hazards experienced. Coastal areas are particularly at risk because of their exposure to sea level rise.

2.2 Climate Change Projections

This section describes the data and methods used to identify projected changes in climate and to evaluate the impacts of climate change on the Proposed Action and No-Action Alternative.

This report assesses available information on historical climate and projected changes in climate change for southwestern Washington State using[5] the U.S. Geological Survey National Climate Change Viewer (2014) and the 2014 National Climate Assessment (Melillo et al. 2014).

- **National Climate Change Viewer.** The National Climate Change Viewer contains historical and future climate projections at watershed, state, and county levels for the continental United States. The viewer contains *multimodel ensemble data* (*mean model*), combining the results from 30 independent climate models developed by researchers around the world under the coordination of the Fifth Coupled Model Intercomparison Project (CMIP5).[6] Multimodel data increases the robustness of projections and provides information on the level of uncertainty in the direction and magnitude of future climate trends. Climate information in the viewer has been *downscaled*, or processed using statistical analysis to provide projections with higher geographic resolution of temperature, precipitation, and snowfall. Historical values and future projections of temperature were examined for Cowlitz County where the Proposed Action would be located. Historical values and future projections of precipitation and snowfall were examined for the Lower Columbia River Basin.
- **2014 National Climate Assessment.** The 2014 National Climate Assessment was conducted by the U.S. Global Change Research Program (Melillo et al. 2014). This assessment summarizes the current and future impacts of climate change on the United States. Its findings, which have undergone extensive public and expert peer review, were compiled by a team of more than 300 experts guided by the 60-member Federal Advisory Committee of the National Academy of Sciences. The report uses multimodel ensemble projections developed under CMIP5, supplemented by information from an earlier phase of the project, CMIP3, where necessary. This report relies heavily on the chapters devoted to impacts in the Pacific Northwest whose convening lead authors were Phillip Mote, Oregon State University and Amy Snover, Climate Impacts Group, University of Washington.

[5] Both information sources rely on climate information developed by CMIP5. CMIP5 is the fifth phase of the World Climate Research Programme's Coupled Model Intercomparison Project, which has established a standard set of simulations for coordinated climate experiments among international climate modeling groups. CMIP5 data is accessible over the internet and has been used in the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report, an internationally vetted and authoritative report on global climate change.

[6] A list of the climate models can be found in Appendix 5 of the National Climate Change Viewer Tutorial (U.S. Geological Survey 2014b).

This section provides an overview of the likely climate impacts affecting the Pacific Northwest. The following sections focus more directly on the anticipated impacts at the project's location.

Temperatures have already increased across the Pacific Northwest by 1.3°F since 1895. Precipitation has, as well, but to date these increases are small and vary with location within the region. Under the changing climate, temperatures could rise by as much as 9.7 °F by the end of the century. Future trends in average precipitation are very uncertain and may increase or decrease, but summer precipitation is projected to decrease by as much as 30% by 2100.

Snow pack averaged over the Cascade Mountains has declined by about 20% since 1950 (Mote et al. 2014). In the future, snowpack is expected to continue its downward trend, causing declines in snowmelt. According to Eisner, et al., The snow water equivalent on April 1 could decline by almost half (46%) by the 2040s and virtually disappear by the 2080s, greatly reducing streamflow in some areas. The incidence of extreme precipitation, which causes important impacts on infrastructure in the region, may have increased over time, but it has not yet been demonstrated to be statistically significant. It varies with location within the region. Under the changing climate in the Pacific Northwest, the number of days with daily rainfall greater than one inch could increase by 13% in the 2041–2070 period (Mote et al. 2014).

Sea levels are rising but uplift of the land in parts of the Pacific Northwest mitigates possible impacts from sea-level rise. By contrast, areas around Puget Sound are subsiding and causing larger than average increases in sea levels. For the Pacific Northwest, sea level rise is expected to be as little as five inches or less to greater than four feet by the end of the century. The impacts of the El Nino South Oscillation phenomenon on climate variability can be significant. During El Nino years regional sea levels can increase by 4 to 12 inches and last for many months (Mote et al. 2014).

Climatic changes in precipitation could have far-reaching effects for the Pacific Northwest. Reduced summer rainfall and reductions in snowmelt – demonstrated under all emission scenarios and with near 100% likelihood -- will probably result in reduced streamflow. This trend could cause trade-offs among the many water uses, including transport, agriculture, recreation, and others, and a possible reduction in hydropower. Human activities have extracted so much water that conflicts have already occurred in dry years. Despite these summertime reductions, increases in extreme precipitation could lead to increased flooding, especially in basins that derive their water from both rain- and snowfall. Rising sea levels could also lead to flooding of public and private property including ferry terminals, and roads and railways in coastal areas. Increasing temperatures and reduced precipitation could lead to an increase in wildfires, which are driven in part by water deficits. By the 2080s, the median area burned annually in the Pacific Northwest could quadruple compared to the 1916 to 2007 period (Mote et al. 2014).

Information on the potential impacts of climate change on resource areas was drawn from a diverse set of scientific literature, with reliance on two primary information sources:

- **2014 National Climate Assessment.** In addition to providing information on climate change projections, the National Climate Assessment also provides a summary of the potential impacts of climate change on a wide range of resource areas.
- **Climate Change Impacts and Adaptation in Washington State.** In 2013, the University of Washington produced a summary State of the Knowledge report on the likely effects of climate change on Washington State (University of Washington 2013). The report provides technical summaries detailing observed and projected changes for Washington's climate, water resources, forests, species and ecosystems, coasts and ocean, infrastructure, agriculture, and human health.

The report draws from major international, United States, and Pacific Northwest assessment reports.

2.3 Existing and Future Conditions

This section presents the historical and projected changes in temperature, precipitation, and the snowfall for the study area. Ocean acidification is not addressed here since its impacts on the Proposed Action are anticipated to be minimal.

2.3.1 Historical and Projected Changes in Temperature

Washington State has a varied climate with significant differences in temperature and precipitation on the east and west sides of the Cascade Mountains. Temperatures across the Pacific Northwest have increased from 1895 to 2011 by 1.3°F (Mote et al. 2014). West of the Cascades, where the study area is located, the climate is characterized by mild temperatures, and heavy annual rain and snow. From 1950 to 2005, the highest monthly average temperatures[7] in Cowlitz County were more than 75°F, cooler than Washington State as a whole (77.5°F) but warmer than the lower Columbia River Basin of which it is part (73.4°F). The highest monthly average temperature in Cowlitz County over this period was 77.2°F (August) (U.S. Geological Survey 2014). In general, the lowest monthly average temperatures in Cowlitz County during winter[8] were below 31.6°F from 1950 to 2005. The area has experienced a warming trend in the past five decades; the annual average maximum temperatures have increased by 0.9°F (U.S. Geological Survey 2014).

In the near-term future, seasonal temperatures in the study area are projected to increase. In Cowlitz County, hot summer temperatures could rise by as much as 4.3°F in the high GHG concentration scenario from 2025 to 2049, compared to baseline (U.S. Geological Survey 2014)[9]. Cold winter temperatures are projected to increase by 2.4 to 3.0°F in moderate and high GHG concentration scenarios over this period (U.S. Geological Survey 2014). This warming trend continues into the midterm future (2050 and 2075), where hot summer temperatures in Cowlitz County are projected to increase by 5.4 to 7.2°F. Coldest temperatures are expected to increase by as much as 5.2°F (U.S. Geological Survey 2014). These increases will likely bring the coldest temperatures near to or above the freezing point[10]. While some models project higher or lower increases in temperature, all 30 models agree that temperatures will increase in Cowlitz County. Table 2 summarizes these historical and projected changes in temperature.

[7] The highest temperatures and precipitation are taken as the top 10% (i.e., 90th percentile) of temperature and precipitation readings or projections. The lowest temperatures and precipitation values are the bottom 10% (i.e., 10th percentile) of all readings or projections.

[8] For seasonal results, winter averages December, January, and February; spring averages March, April, and May; summer averages June, July, and August; and fall averages September, October, and November.

[9] The baseline is defined as 1950 to 2005, which is thought to represent a period during which relatively few changes had occurred because of climate change.

[10] Note that while the average monthly temperatures during winter will likely rise above 32°F, cold temperatures on any given day could still be below freezing.

Table 2. Historical and Projected Changes in Temperature in Cowlitz County, WA

Historical climate and observed changes (1950–2005)	Near-term projected changes (2025–2049 compared to 1950–2005)	Midterm projected changes (2050–2075 compared to 1950–2005)	Level of certainty in projections
The average monthly summer and winter temperatures (approximately 75°F and 32°F, respectively) reflect the moderate climate of the area.	Summer and winter temperature extremes are projected to increase.	Summer and winter temperature extremes are projected to increase.	There is excellent agreement across models on the direction of change.
Highest average monthly summer temperatures (top 10%, or 90th percentile) were above 75.0°F. Max monthly average temperature for August was 77.2°F.	90th percentile temperature is projected to increase by 3.8 to 4.3°F under moderate and high emissions scenarios.	90th percentile temperature is projected to increase by 5.4 to 7.2°F under moderate and high emissions scenarios.	Monthly average temperature is projected to increase in all months across all models compared to 1950–2005.
Lowest monthly average winter temperatures (10th percentile) were below 31.6°F.	10th percentile temperature is projected to increase by 2.4 to 3.0°F under moderate and high emissions scenarios.	10th percentile temperature is projected to increase by 4.0 to 5.2°F under moderate and high emissions.	

2.3.2 Historical and Projected Changes in Precipitation

Extreme precipitation especially during the winter months has frequently led to flooding events in the Pacific Northwest. These storms have caused billions of dollars of loss and have been responsible for about two-thirds of the presidential disaster declarations since 1955. Major flooding in January 2009 closed Interstate 5, heavily damaged the Howard Hanson Dam and put tens of thousands of people at risk (Warner et al. 2012). A key driver of these precipitation events is the phenomenon of atmospheric rivers that form in the Pacific Ocean and move eastward toward the Pacific Northwest. In December 2105, an atmospheric river formed and made landfall along the Washington coast, resulting in almost 16 inches of precipitation over three days across Oregon, Washington, and British Columbia, Canada.

The Columbia River is the fourth largest river in North America. It is influenced by multiple river basins from multiple states and British Columbia. The geographic and hydrologic characteristics of the river, which drains a 259,000 square mile basin, are suited to beneficial multiple-purpose storage development. Since the 1930s, numerous dams, both Federal and private, have been built to store water for flood control, to generate hydroelectric power, and for other purposes. Total storage capacity of these dams is about 25 percent of the 156 million acre foot average annual runoff volume for the Columbia River at its mouth. Federal projects in the basin have 19,900 megawatts of existing hydroelectric capacity, and non-federal projects add 10,700 megawatts (U.S. Army Corps of Engineers 2015).

According to the National Climate Assessment (Mote et al. 2014), the anticipated change in annual precipitation in the Pacific Northwest ranges from decreases (-11%) to increases (+12%) from 2030

to 2059 for the B1, A1B, and A2 scenarios.[11] This variability makes the analysis of potential impacts problematic. Typically, average monthly precipitation is greatest in winter (December through February) and least in summer (June through August) (U.S. Geological Survey 2014). From 1950 to 2005, precipitation in the lower Columbia River Basin averaged 0.40 inch per day in winter (U.S. Geological Survey 2014) and about half that in spring (0.22) and fall (0.25). By contrast, only 0.07 inch per day fell during the summer months.

In the near-term future, the mean model indicates slight increases in the winter, spring, and fall compared to the 1950 to 2005 average. The largest increase in precipitation is projected to occur in fall (4.1 to 2.1%)[12] and winter (2.3 to 4.8%). Very little increase is projected for the spring (0 to 1%) (U.S. Geological Survey 2014). By contrast, summers in the near-term future are projected to become drier by 10 to 12%, although some climate models disagree and instead project that summer precipitation will remain the same or increase (U.S. Geological Survey 2014). Overall, model agreement on precipitation is not strong. For example, in some cases just 19 models project decreases in June precipitation (and 11 indicate increases) for the near-term future. Agreement for the month of August, however, was closer, with 26 models showing decreases and only four demonstrating increases.

Similar changes are projected to continue in the midterm future: the winter, spring, and fall seasons could become wetter, while summers could become drier. In the lower Columbia River Basin, winter and fall precipitation levels are projected to increase by 4.9 to 7.1% and 3.6 to 1.5%, respectively, while spring levels remain relatively constant (0 to 1.8% increase) in moderate and high scenarios compared to the 1950 to 2005 average. Extreme precipitation[13] could increase as the highest events could increase by 5.0 to 6.1% in the near-term future and 6.1 to 8.0% in the midterm future (U.S. Geological Survey 2014), but studies of past trends in observed changes in extreme precipitation have yielded ambiguous results (Mote et al. 2014). Model discrepancies are similar with most models showing increases and others showing decreases. Table 3 summarizes these historical and projected changes in precipitation.

[11] The B1, A1B, and A2 scenarios refer to emissions scenarios from the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios (2000). These scenarios have been superseded in the international climate modeling by Representative Concentration Pathway scenarios. The B1 and A2 scenarios are generally considered low and high emissions scenarios, respectively. The A1B scenario falls between them. Since not all projections have been updated with the latest GHG concentration scenarios, these scenarios have been retained where new information is not yet available.

[12] By convention, the value from the moderate emissions scenario is presented first even though the value from the high emissions scenario is lower.

[13] Extreme precipitation is determined as the magnitude of rain events in the 90th percentile (i.e., top 10% of all rain events for precipitation in a given period).

Table 3. Historical and Projected Changes in Precipitation in the Lower Columbia River Basin

Historical climate and observed changes (1950–2005)	Near-term projected changes (2025–2049 compared to 1950–2005)	Mid-term projected changes (2050–2075 compared to 1950–2005)	Level of certainty in projections
Average annual precipitation was 0.24 inch/day.	Wetter winter, spring, and fall seasons; possible drier summers.	Wetter winter, spring, and fall seasons; possible drier summers.	Some models show increases in precipitation while others show decreases. Incidence of extreme precipitation is more likely to increase.
The highest (90th percentile) monthly average precipitation was 0.43 inch/day.	Change in average precipitation by season under moderate and high emission scenarios. • Winter: +2 to 5% • Spring: 0 to +1% • Summer: -10 to -12% • Fall: +4 to +2%	Change in average precipitation by under moderate and high emission scenarios • Winter: +5 to +7% • Spring: +0 to +2% • Summer: -10 to -16% • Fall: +4 to +2%	A majority of models (18 to 26 of 30, depending on the scenario and timeframe) project that precipitation will decrease in the summer.
The lowest (10th percentile) monthly average precipitation was 0.06 inch/day.	Intensity of extreme precipitation could increase. • 90th percentile precipitation is projected to increase by 5 to 6% under moderate and high emissions scenarios.	Intensity of extreme precipitation could increase. • 90th percentile precipitation is projected to increase by 6 to 8% under moderate and high emissions scenarios.	Most models (20 of 30) project an increase in extreme precipitation.

2.3.3 Historical and Projected Changes in Snowpack

Melting snowpack in the Canadian Rockies and the Cascade Mountains provides much of the water flowing in the Columbia River. In contrast to the variable projections in overall precipitation, the anticipated changes in snowfall and snowpack are large and model agreement is very high.

Average annual snowfall was 5.6 inches per month from 1950 to 2005. Average winter and spring snowfall, when virtually all snowfall occurs, was about 29.7 and 33.3 inches, respectively. These levels are expected to decline by 39 to 45% in the near-term future for the moderate and high GHG emissions scenarios. This substantial decrease is projected to occur within relatively narrow bands (winter: 33 to 40%; spring: 41 to 47%). All models indicate decreases in annual, winter, and spring snowfall (U.S. Geological Survey 2014).

In the midterm future, these trends are expected to intensify. Winter snowfall could decline by as much as 62% (ranging from 49 to 62% under the moderate and high emissions scenarios); spring snowfall could decrease by as much as 75% under the moderate emissions scenario and 68% under

the high emissions scenario.[14] Again, all models agree that snowfall will decline over time. Table 4 summarizes these historical and projected changes in snowfall.

Table 4. Historical and Projected Changes in Snow in the Lower Columbia River Basin

Historical climate and observed changes (1950–2005)	Near-term projected changes (2025–2049 compared to 1950–2005)	Mid-term projected changes (2050–2075 compared to 1950–2005)	Level of certainty in projections
Heaviest snowfall occurs in the winter and spring leading to high average annual snowfall totals.	Average annual, winter and spring snowfall will likely decline under the moderate and high emission scenarios in the near term.	Average annual, winter and spring snowfall will likely decline under the moderate and high emission scenarios in the mid-term.	There is excellent agreement on the direction of change.
Average annual snowfall was 5.6 inches/month.	Change in average monthly snowfall could decline by 39 to 45%.	Change in average monthly snowfall could decline by 54 to 66%.	All models agree on the direction of the impact.
Average winter and spring snowfall was 29.7 and 33.3 inches, respectively.	Change in average winter and spring snowfall under moderate and high emission scenarios. • Winter: -33 to -40% • Spring: -41 to -47%	Change in average winter and spring snowfall under moderate and high emission scenarios. • Winter: -49 to -62% • Spring: -75 to -68%	All models agree that snowfall will decline in the winter and spring in near- and mid-terms.

[14] Higher emissions do not necessarily equate to increases in precipitation. Note that under the higher emissions scenario, average precipitation declines can be either more or less than under the moderate emissions scenario. Existing models must take other variables such as weather patterns and topography into account when projecting future precipitation levels.

Chapter 3
Impacts

This chapter describes the potential impacts of climate change on the Proposed Action and the No-Action Alternative.

3.1 Proposed Action

This section describes the potential impacts of climate change on the construction and operation of the Proposed Action that could occur within the study area.

3.1.1 Impacts of Climate Change on the Proposed Action

Changes in current and historical patterns of temperature and precipitation may affect the infrastructure, operation, and service of the coal export terminal.

Impacts on the coal export terminal and to transportation routes could be caused by the following climate change impacts

Low water levels. Decreased snowfall in the lower Columbia River Basin, especially in the winter and spring, coupled with potential declines in rainfall in the summer could lead to abnormally low levels of water in the Columbia River, which could impede the passage of large ships to and from the docks at the project area. With the coal export terminal located some 50 miles inland from the Columbia River estuary, the main impact of sea level rise at the project area is expected to be minimal in and of itself, but may reduce the potential for service disruptions from low water and exacerbate the potential for flooding at discrete project locations.

Flooding. Potential precipitation increases and intense downpours could cause the Cowlitz or Columbia Rivers to flood, affecting the rail lines and docks that access the project area or the project area itself.

Wildfire. Higher temperatures could increase the likelihood of wildfire, although wetter summers with reduced wildfire likelihood cannot be ruled out.

3.1.1.1 Service Disruptions from Low Water

Decreased snowfall, especially in the winter and spring, coupled with potential declines in summer rainfall in the Lower Columbia River Basin, could lead to abnormally low levels of water in the Columbia River. Low water levels could impede the passage of large ships to and from the docks of the project area. Low water levels could raise costs for electricity or otherwise force difficult choices on competing water usage. Operational changes to the water management of the Columbia River system may be sufficient to address these potential impacts.

Snowfall is expected to decline substantially in the near and midterm futures (Section 2.3.3, *Historical and Projected Changes in Snowpack*). In the lower basin of the Columbia River, the amount of snow could be reduced by almost half and two-thirds by 2075 (U.S. Geological Survey 2014). In

addition, while not all models agree, spring and summer precipitation levels could remain flat or decline over the same periods.

Drought is already of concern. Washington State defines drought as 75% of normal water conditions (Revised Code of Washington 43.83B.400). In the past century, drought occurred from 1928 to 1932, 1992 to 1994, and1996 to 1997, and most recently in 2015. Drought has caused shipping costs to rise, sometimes requiring wheat growers to move their product by rail or truck instead of barge transport. Washington State estimates that it will experience severe or extreme drought 5% of the time in the future and more frequently east of the Cascade Mountains (Washington State Emergency Management Division 2012). This year's drought emergency includes all of Washington State (Washington State Department of Ecology 2015).

The Proposed Action would require ships of the Panamax class to berth at existing and newly installed docks to receive coal shipments. Panamax ships are midsized cargo ships, the largest that could fit through the Panama Canal prior to expansion. They have a capacity of 60,000 to 100,000 deadweight tonnage and require a draft of 42 to 49 feet. The depth of the Columbia River at Longview varies by season. Periodic dredging, as needed, part of the Proposed Action. If precipitation from snow and rain is reduced and low water levels occur on the Columbia River, shipping may be restricted or more dredging may be required.

At the project area, the Columbia River experiences tidal fluctuation, although less than at the mouth of the river. Tidal forces could replace some or all of the water needed for ship passage in the event of low runoff from reduced snowmelt and rainfall. Nonetheless, the impact of low tides on ship passage should be considered. The potential for low water disruptions may also be reduced by future sea level rise. However, because the project area is approximately 50 miles inland from the Columbia River estuary, the impact of sea level rise at the project area is expected to minimal. The Columbia River is also highly managed to provide water for multiple competing uses. For example, low water levels upstream of the project area have constrained recreational boating at times.

3.1.1.2 Damage and Service Disruptions from Flooding

The project area is directly on the Columbia River about 5 miles from the confluence of the Columbia and Cowlitz Rivers (ICF 2017a). The study area, including Longview, is protected from flooding by a levee maintained by the Consolidated Diking Improvement District, which is 34 feet above the Columbia River Datum.[15] It is also protected by a system of sloughs, ditches, and drains. The Federal Emergency Management Agency classifies the project area as Zone B in its Flood Insurance Rate Map, meaning the area is expected to flood every 100 to 500 years.

Water levels in the Columbia River vary by season and year, depending on the snow mass in the upper watershed. Historic crests on the Columbia River range from 13 to 24 feet with flood stage at 13.5 feet. Historic crests on the Cowlitz River range from 21 to 29.5 feet and have been recorded well above flood stage (21 feet). Above 28.5 feet, major flooding at Kelso (across the river from Longview) is expected. This flood stage could overtop the levee and increase erosion rates (ICF 2017b).

[15] The Columbia River Datum is the lowest level recorded on the river, which occurred on October 6, 1886. It is about 2.5 feet above the North American Vertical Datum 1988, which is the national standard geodetic reference for heights.

Under current conditions, flooding is expected to be minimal at the project area for the Proposed Action (ICF 2017a). In the future, flooding could be of concern, particularly from the Cowlitz River. In August 2014, the U.S. Army Corps of Engineers found that sediment buildup on the Cowlitz River was increasing the potential for flooding, Without further action, the flood risk level on the river (0.6%) would be exceeded by 2018 (U.S. Army Corps of Engineers 2014). While future precipitation is somewhat uncertain, the mean model indicates increases in fall and winter precipitation for both the near and midterm futures, which could increase flood risk. Future flood risk could be exacerbated by sea level rise in the Pacific Northwest. Seas are expected to rise by as little as five inches to as much as four feet depending on vertical land movements (either uplift or subsidence).

Additionally, wetlands provide an important buffer for absorbing increased runoff and river overflow during severe precipitation events. The project area currently includes almost 27 acres of natural wetland habitat. Under the Proposed Action, 24.10 acres would be permanently filled. The loss of these wetlands would cause a reduction in flood mitigation and stormwater treatment capacity.

The BNSF Spur and Reynolds Lead that would carry Proposed Action-related trains to the project area could be subjected to flooding. The rail line crosses the Cowlitz River near the confluence with the Columbia River and runs near the rivers for the 5 miles to the project area. Because historical and recent crests have been reported on the Cowlitz River, flood risk from sedimentation is increasing, and future precipitation could increase, flooding of the Reynolds Lead is possible. Cowlitz River flooding at this location would likely disrupt rail and terminal operations, and ballast supporting the rail line could be dislodged. Therefore, Proposed Action-related trains could be affected by a Cowlitz River flood.

3.1.1.3 Service Disruptions from Wildfires

Wildfire is a threat in Washington State. Cowlitz County is considered a high-risk area (Washington State Emergency Planning Division 2012c). Wildfires in Cowlitz County numbered more than 350 from 2004 to 2013, burning more than 561 acres. In late summer and early fall, dry easterly winds can produce extreme fire conditions. This threat has increased over time because of four factors: earlier snowmelt, higher summer temperatures, longer fire season, and an expanded vulnerable area of high-elevation forests. These factors are caused by increases in summer temperatures and past increases can be attributed to climate change (Washington State Emergency Planning Division 2012c). Increasing temperatures, extreme heat events, and drought could have an effect on fire regimes in Washington State by influencing the length of the fire season and contributing to drier conditions and the availability of readily combustible fuel for fires (Mote et al. 2014). Maximum temperatures are predicted to increase while summer precipitation is predicted to decrease in the study area, although there is some disagreement among the models, and some indicate that summers could become slightly wetter (Section 2.3.1, *Historical and Projected Changes in Temperature;* Section 2.3.2, *Historical and Projected Changes in Precipitation*). Hotter and drier summers will increase the likelihood of wildfires. The Proposed Action would be similarly affected by the risk of wildfire.

3.1.2 Impacts of Climate Change on Other Resource Areas

The impacts from construction and operations of the Proposed Action could be compounded by climate change. The following subsections qualitatively examine climate change effects on other resource areas to determine where the environment could be modified by the effects of climate change.

The effect of climate change on the impacts of the Proposed Action on resource areas are summarized as follows. More detail on each of these topic areas follows later in this section.

- **Social and Community Resources.** The combination of projected increases in wildfire risks due to climate change and the additional strain placed on the fire service by the Proposed Action (lCF and BergerABAM 2017) has the potential to increase impacts on community resources. However, fire risk in the project area would be addressed because fire and life safety systems in the project area would be installed according to fire code standards.
- **Cultural Resources.** The combination of projected increases in heavy precipitation events due to climate change and the expansion of impervious surfaces due to the Proposed Action has the potential to increase the risk of flooding events potentially damaging the Consolidated Diking Improvement District (CDID) #1 levee. Permit conditions would reduce the risk of impacts from climate change affecting the proposed export terminal, the Columbia River, and the CDID #1 levee.
- **Geology and Soils.** The projected increase in flooding from more frequent heavy precipitation events due to climate change is not expected to increase erosion or landslide potential in the study area because more than 90% of the project area would be impervious after construction. However, there is a nearby active landslide. The extent to which heavier and more frequent precipitation events due to climate change would result in the toe of the slide extending towards the project area is unknown.
- **Water Quality.** The combination of increased frequency of heavy precipitation events due to climate change, reduced wetlands, and pollutants from Proposed Action construction and operations could create risks of greater runoff pollution into local water bodies and absorption into groundwater. However, all stormwater runoff would be collected for treatment before reuse or discharge to the Columbia River.
- **Vegetation.** Climate change will alter local conditions (e.g., temperature, precipitation), and when coupled with greater land-use disturbances from the Proposed Action, could propagate the growth of noxious weeds that have a greater capacity to adapt than native vegetation species. However, noxious weeds on disturbed lands would be monitored.
- **Fish.** Climate change induced water quality threats, from downstream ocean acidification, warming water temperatures, greater runoff flows, and streamflow variations from climate change coupled with potential changes resulting from the Proposed Action could threaten native fish populations.
- **Wildlife.** Combined habitat disruption effects from climate change (i.e., warming temperatures, longer dry periods, increased heavy precipitation) and the Proposed Action (i.e., physical alteration or removal of habitat) could threaten native wildlife populations and potentially promote the proliferation of invasive wildlife species with a greater capacity for adaptation.

- **Energy and Natural Resources.** Climate change will generate longer and more intense summer droughts and could increase energy and groundwater consumption. However, if climate change were to affect groundwater supply in the project area, the water rights adjudication process would likely address this issue.
- **Air Quality**. Climate change-induced warming temperatures will drive secondary aerosol formation and create greater risks of wildfire, which when coupled with increased fossil fuel combustion from Proposed Action equipment use, could create greater air pollutant concentrations.

3.1.2.1 Built Environment

The following subsections summarize the effect that climate change may have on the impacts of the Proposed Action to the built environment resource areas.

Social and Community Resources

As detailed in the SEPA Social and Community Resources Technical Report (ICF and BergerABAM 2017), construction and operation of the Proposed Action would place new demand on Cowlitz Fire & Rescue protection services. This demand could be compounded by the increasing risk of wildfires from warmer, drier conditions induced by climate change (University of Washington 2013). These conditions are specifically due to projected increases in global and regional average temperatures and reductions in summer precipitation volumes. However, fire risk in the project area would be addressed because the Applicant would be required to install fire and life safety systems in the project area according to fire code standards. These systems would be regularly inspected and maintained. The Applicant would also maintain a surface water storage pond with a reserve of 0.36 million gallons for fire suppression.

Cultural Resources

Potential climate change impacts associated with construction and operations of the Proposed Action could affect the CDID #1 levee. Climate change is expected to increase the frequency of heavy rainfall events throughout the Pacific Northwest, where days with precipitation greater than 1 inch is expected to increase 13% by 2050 (University of Washington, 2013). The Proposed Action would fill existing wetlands with impervious surfaces, reducing the area's natural capacity to control stormwater. The combination of projected increases in heavy precipitation events and the expansion of impervious surfaces has the potential to increase the risk of flooding events, potentially damaging the historic CDID #1 levee. The Proposed Action would construct a new on-site stormwater capture and treatment system to manage the stormwater flood risks. The Applicant would operate the terminal under a National Pollutant Discharge Elimination System (NPDES) Industrial Stormwater Permit that would need to be issued for the Proposed Action. The NPDES permit would outline specific terms and conditions and would be required to adhere to the terms and conditions of that permit, which would reduce the risk of impacts from climate change affecting the proposed export terminal, the Columbia River, and the CDID #1 levee.

3.1.2.2 Natural Environment

The following subsections summarize the effect that climate change may have on the impacts of the Proposed Action to natural environment resource areas.

Geology and Soils

Climate change could affect geology and soils. For example, increases in the frequency of heavy precipitation events could result in high river flows and flooding and generate greater risks for riverside erosion and landslides. Sea-level rise could also increase the likelihood for flooding and erosion in the project area since the location is a tidally influenced segment of the river. However, the project area is within a federally designated diking district. Warming temperatures that create greater rainfall in place of typical snowfall upstream could alter the timing of seasonal flow conditions, such as the timing of spring high-flow events or summer low-flow periods (University of Washington 2013). Decreased rainfall in the spring and summer may increase the likelihood of wind-driven erosion of soils, due to changes in soil moisture content (U.S. Global Change Research Program 2014).

As described in the SEPA Geology and Soils Technical Report (ICF 2017b), the topography in the project area is relatively flat, minimizing the risk of landslides. While soils along the river have a high to moderate capacity for erosion, there is a slight risk for erosion on-site due to protective shoreline armoring, and the combination of a levee with a flat gradient. After construction is complete, the project area would be approximately 90% impervious surfaces, essentially eliminating any risk of erosion within the project area. The project area is near an active deep-seated landslide on the south flank of Mount Solo, but is more than 50 feet from its edge, which is the minimum distance required by the Cowlitz County Critical Areas Ordinance for landslide hazards. While periods of prolonged and intense rainfall (including multiyear periods) could activate this landslide, the extent to which climate change could potentially affect any shift in the landslide in terms of distances traveled or shifts in the leading edge of the landslide toward the project area cannot be predicted.

Water Quality

Climate change-induced impacts on local water quality from the Proposed Action would be associated with increased precipitation, combined with a decrease in local wetlands. Surface and groundwater resources could be affected by intense and sustained precipitation events that could overwhelm the stormwater facilities and inadvertently discharge untreated stormwater that could carry pollutants and debris, including coal dust, from the project area. Pollution that entered these local resources could degrade local water quality, which could affect aquatic and terrestrial species and aquatic habitats.

With reduced wetlands to capture and filter stormwater flows and coal terminal operations producing potential contaminants, surface and groundwater resources could be vulnerable to greater pollution during flood events or periods of sustained precipitation. If not treated, polluted stormwater runoff could seep into the groundwater or discharge to surface waters and degrade water quality. However, the local soils have low permeability for both shallow and deep aquifers, which reduces the risk of polluted water reaching the groundwater table, as described in the SEPA Groundwater Technical Report (ICF 2017e). Further, stormwater generated within the project area would be collected, treated, and either stored on-site for re-use or discharged to the Columbia River. Stormwater discharged to the Columbia River would be treated to meet the NPDES permit requirements. The Applicant would be required to update the NPDES discharge permit every 5 years, which would address future changes in stormwater and discharges.

Vegetation

As described in the SEPA Vegetation Technical Report (ICF 2017c), construction of the Proposed Action would remove over 26 acres of non-wetland vegetation. Operations of the Proposed Action could result in the introduction of invasive or noxious weeds from trains or vessels calling to the project area, which could increase the risk of impacts on native vegetation in and directly adjacent to the project area. Further, climate change could result in conditions favorable to the growth of unwanted invasive or noxious weeds, which are adapted to the changing climate and may be well suited to colonizing highly disturbed areas.

Climate change can support the colonization of invasive species or noxious weeds, where changes in local conditions, such as variations in precipitation events and/or temperature, are more suitable to nonnative plants, which may have a greater adaptive capacity (Bradley et al. 2010). This combination of climate change and Proposed Action impacts could threaten native vegetation populations in and near the project area. However, even if climate change compounds the colonization of invasive species or noxious weeds, the Applicant would monitor for noxious weeds on disturbed land during construction and operations, which would limit the potential for noxious weeds to colonize the project area and disturbed areas adjacent to the project area. In addition, the Applicant would be required to prevent the potential establishment and spread of noxious weeds per Washington State noxious weed regulations (Revised Code of Washington [RCW] 17.10).

Fish

Local fish populations are dependent on a sustained level of water quality, specific temperatures, specific habitat, and other environmental conditions, which may be at risk as climate change impacts are coupled with changes resulting from the Proposed Action. Tribal resources are also centered on local fish populations and the habitats that sustain them.

Stress from the Proposed Action to fish populations, particularly salmonids, could be compounded by warming freshwater temperatures. Downstream ocean acidification could reduce salmonid prey and hinder growth and survival of native fish populations (University of Washington 2015).

Wildlife

As described in the SEPA Wildlife Technical Report (ICF 2017g), the Proposed Action could disrupt local wildlife habitats during operations, which could compound stressors to wildlife populations from climate change. Wildlife species include common species of birds, rodents, mammals, amphibians, reptiles, and invertebrates. Climate change could promote the proliferation of invasive wildlife species that have a higher adaptive capacity in Washington State and the Columbia River (University of Washington 2013).

Construction activities would alter or permanently remove 59 acres of aquatic habitat and permanently remove 24.10 acres of wetland and 26.26 acres of upland terrestrial habitats. These impacts could disrupt normal wildlife behavior patterns. Climate change could further alter habitat conditions and wildlife species' life-cycle events through changes in seasonal weather patterns (i.e., changes in seasonal air and water temperatures, seasonal precipitation patterns) (U.S. Global Change Research Program 2014). Combined Proposed Action and potential climate change impacts may threaten native wildlife populations while promoting climatic shifts in weather and subsequent changes in habitat conditions that provide conditions more suitable to the proliferation of invasive species, which could have a greater capacity for adapting to these changed and variable conditions.

Energy and Natural Resources

As described in SEPA Energy and Natural Resources Technical Report (ICF 2017h), the coal export terminal would consume 6,624,000 kilowatt hours annually during operations, which represents an average of 4% of Cowlitz Public Utility District's (PUD's) electricity demand. Cowlitz PUD currently sources 82.5% of electricity from hydropower sources (Cowlitz Public Utility District 2016). Climate change is projected to intensify summer droughts in the Northwest through longer dry periods and increasing temperatures (U.S. Global Change Research Program 2014), which will reduce summer streamflows and limit the output of hydropower facilities (Seattle City Light 2015). Climate change will also reduce snowpack upstream of hydropower facilities and the project area due to higher average temperatures, creating greater risks for surface water shortages and reduced summer flows (University of Washington 2013).

Washington State is heavily dependent on hydropower for electricity. Approximately 75% of its electricity comes from hydropower generated by its systems of rivers and dams. The rivers also supply water for irrigation, municipalities, and industry. Drought-induced loss of hydropower could raise costs. As the supply of locally generated hydropower is reduced, utilities must seek additional sources of electricity, which could drive up electricity prices for construction and operation of the Proposed Action (Washington State Emergency Management Division 2012). As described in the SEPA Surface Water and Floodplains Technical Report (ICF 2017a) and the SEPA Groundwater Technical Report (ICF 2017e), the Proposed Action would increase on-site water demands. Total annual consumption of water is estimated at 3,387 acre-feet, where 89% would be sourced from existing groundwater wells and 11% from stormwater reuse facilities on-site; there would be no need for new wells. The existing groundwater wells draw from a deep aquifer with low permeability, reducing the capacity for natural recharge.

Climate change could induce longer, drier summers, which, coupled with a decreasing snowpack, could reduce river water levels during droughts, forcing local services to rely more on groundwater resources. Historically, the low permeability of the local aquifers and unaffected recharge from the Columbia River would make any groundwater recharge impacts from the Proposed Action negligible; however, the projected increase in the frequency and severity of droughts due to climate change could affect groundwater recharge. If groundwater recharge were to diminish due to an increase in the frequency and severity of droughts, any subsequent increased reliance on groundwater during times of drought could create greater risks for overdraft conditions, where groundwater is being withdrawn faster than it can be recharged. However, Proposed Action operations would withdraw groundwater under a state-approved water right, which would avoid or limit such an impact from occurring. If climate change were to affect groundwater supply in the project area, the water rights adjudication process would likely address this issue. The adjudication process is key to resolving and preventing water conflicts of increasing water demands and water supply impacts of climate change.

3.1.2.3 Operations

The following subsection summarizes the effect that climate change may have on the impacts of the Proposed Action on operations resource area.

Air Quality

As described in the SEPA Air Quality Technical Report (ICF 2017i), air quality impacts reflect air pollutant emissions from the Proposed Action. Recent research has shown secondary aerosols are primarily driven by increasing temperatures and humidity (Hessberg et al. 2009). With rising average temperatures due to climate change, secondary organic aerosol formation could be accelerated. Secondary aerosols generate particulate matter concentrations from volatile organic compounds (VOCs).

During Proposed Action operations, increased VOC emissions will come from fossil fuel combustion due to equipment and vehicle use on site. Warming temperatures from climate change could drive secondary aerosol formation, and when combined with greater local VOC emissions, could increase air quality risks within and near the project area. Higher temperatures can also lead to increased ground level ozone formation, where VOCs and nitrous oxide emissions from equipment and vehicle use are precursors to this reaction (Union of Concerned Scientists 2011).

Prolonged summer droughts from climate change could create risks for wind erosion, which are a source of particulate matter. These droughts can also create greater risks of regional wildfires, which can affect air quality in the surrounding area through spiked particulate matter emissions. Drought effects may compound the air quality impacts associated with greater fossil fuel combustion from operations.

3.2 No-Action Alternative

Under the No-Action Alternative, the Applicant would not construct the coal export terminal and potential climate change impacts related to construction and operation of the Proposed Action would not occur. The Applicant would continue with current and future increased operations in the project area. The project area could be developed for other industrial uses, including an expanded bulk product terminal or other industrial uses. The Applicant has indicated that, over the long term, it would expand the existing bulk product terminal and develop new facilities to handle more products such as calcine petroleum coke, coal tar pitch, and cement.

Ongoing and expanded operations in the project area would be affected by climate change as described for the Proposed Action. These impacts could include possible service disruptions from low water levels, flooding, and wildfires, as well as impacts on local resource areas.

Chapter 4
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MILLENNIUM BULK TERMINALS—LONGVIEW SEPA ENVIRONMENTAL IMPACT STATEMENT

SEPA COAL MARKET ASSESSMENT TECHNICAL REPORT

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Contents

List of Tables iv
List of Figures x
List of Acronyms and Abbreviations xi
Chapter 1 **Introduction** **1-1**
1.1 Project Description 1-1
1.1.1 Proposed Action 1-1
1.2 Overview of Coal Market Analysis 1-5
1.2.1 Report Organization and Chapter Summary 1-6
Chapter 2 **U.S. Coal Market and Pacific Northwest Export Terminals** **2-1**
2.1 General U.S. Coal Market 2-1
2.1.1 Total Production 2-1
2.1.2 Types of Coal 2-1
2.1.3 Exports 2-2
2.2 Powder River Basin 2-2
2.3 Uinta Basin 2-6
2.4 Coal Distribution 2-9
2.4.1 Powder River Basin 2-9
2.4.2 Uinta Basin 2-11
2.5 Pacific Northwest Export Terminals 2-12
2.5.1 Existing Pacific Northwest Terminals 2-12
2.5.2 Planned Pacific Northwest Export Terminals 2-13
2.5.3 Export Routing 2-15
Chapter 3 **International Coal Markets** **3-1**
3.1 International Coal Demand 3-1
3.1.1 Major Importing and Exporting Countries 3-1
3.1.2 Asian Focus 3-3
3.1.3 Coal Prices 3-7
Chapter 4 **Model Framework, Methods, and Key Assumptions** **4-1**
4.1 IPM® Overview and Model Framework 4-1
4.1.1 IPM® Users and Documentation 4-3
4.2 Key Assumptions 4-4
4.2.1 Assumptions from Millennium Bulk Terminals—Longview 4-4
4.2.2 Fuel 4-5
4.2.3 Air, Waste, and Water Regulations 4-10
4.2.4 Renewable Energy Regulations 4-11
4.2.5 Electric Demand 4-11
4.2.6 Reserve Margin Targets 4-15

4.2.7 Planned New Capacity and Retirements 4-15
4.2.8 Mothballing and Retirement 4-17
4.2.9 Capital Costs for New Generating Capacity 4-18
4.2.10 Transmission 4-19
4.2.11 International Coal Demand 4-20
4.2.12 Coal Demand Elasticity 4-30
4.2.13 Coal Heat and CO_2 Content 4-31
4.2.14 Coal Distribution Limitations 4-36
4.2.15 Coal Reserves 4-37
4.2.16 Federal Coal Lease Review 4-39
4.3 Methods 4-39
4.3.1 Model Run Years 4-40
4.3.2 Coal 4-41
4.3.3 Environmental Compliance 4-44
4.3.4 Natural Gas 4-46
Chapter 5 **Scenarios 5-1**
5.1 Scenarios Analyzed 5-2
5.1.1 No Clean Power Plan Scenario 5-3
5.1.2 Lower Bound Scenario 5-4
5.1.3 Upper Bound Scenario 5-5
5.1.4 2015 U.S. and International Energy Policy Scenario 5-6
5.1.5 Cumulative Scenario 5-7
Chapter 6 **Modeling Results 6-1**
6.1 Overview of Results 6-1
6.1.1 No Clean Power Plan Scenario Results 6-2
6.1.2 Scenario Results 6-4
6.2 No Clean Power Plan Scenario 6-9
6.2.1 Coal Production 6-10
6.2.2 Coal Consumption 6-12
6.2.3 Coal Distribution 6-16
6.2.4 CO_2 Emissions 6-21
6.3 Lower Bound Scenario 6-24
6.3.1 Coal Production 6-24
6.3.2 Coal Consumption 6-27
6.3.3 Coal Distribution 6-31
6.3.4 CO_2 Emissions 6-35
6.4 Upper Bound Scenario 6-38
6.4.1 Coal Production 6-38
6.4.2 Coal Consumption 6-41
6.4.3 Coal Distribution 6-45

6.4.4 CO_2 Emissions 6-49
6.5 2015 U.S. and International Energy Policy Scenario 6-52
6.5.1 Coal Production 6-52
6.5.2 Coal Consumption 6-54
6.5.3 Coal Distribution 6-58
6.5.4 CO_2 Emissions 6-63
6.6 Cumulative Scenario 6-66
6.6.1 Coal Production 6-66
6.6.2 Coal Consumption 6-68
6.6.3 Coal Distribution 6-73
6.6.4 CO_2 Emissions 6-76
Chapter 7 **Conclusions 7-1**
7.1 Summary of Key Results 7-1
7.1.1 Coal Production 7-1
7.1.2 Coal Consumption 7-2
7.1.3 Coal Distribution 7-2
7.1.4 CO_2 Emissions from Coal Consumption 7-2
Chapter 8 **References 1**
8.1 Written References 1
8.2 Personal Communications 4

Appendix A Planned New Generating Capacity and Planned Retirements

Tables

Table 2-1. Powder River Basin Coal Production by State (million short tons) 2-5
Table 2-2. Uinta Basin Coal Production by State (million short tons) 2-8
Table 2-3. Average Annual Deliveries of Powder River Basin Coal by Region[a] 2-9
Table 2-4. Historical Powder River Basin Coal Production by Source State and Destination (million short tons)[a] 2-10
Table 2-5. Powder River Basin Coal Exports by Terminal of Departure (2012) 2-11
Table 2-6. Average Annual Deliveries of Uinta Basin Coal by Region[a] 2-11
Table 2-7. Estimated Powder River Basin Rail and Ship Export Costs—Pacific Northwest Exports 2-16
Table 2-8. Estimated Powder River Basin Delivered Coal Costs—Pacific Northwest Exports 2-17
Table 3-1. Top International Coal Importers in Million Short Tons (2014) 3-1
Table 3-2. Top International Coal Exporters in Million Short Tons (2014) 3-2
Table 4-1. Private and Public Sector Entities Using IPM® 4-3
Table 4-2. Coal Prices in the 2015 U.S. and International Energy Policy Scenario—No-Action Alternative (2012$/short ton) 4-6
Table 4-3. Coal Prices in the 2015 U.S. and International Energy Policy Scenario—Proposed-Action Alternative (2012$/short ton) 4-6
Table 4-4. Coal Prices in the Lower Bound Scenario—No-Action Alternative (2012$/short ton) 4-7
Table 4-5. Coal Prices in the Lower Bound Scenario—Proposed-Action Alternative (2012$/short ton) 4-7
Table 4-6. Coal Prices in the Upper Bound Scenario—No-Action Alternative (2012$/short ton) 4-8
Table 4-7. Coal Prices in the Upper Bound Scenario—Proposed-Action Alternative (2012$/short ton) 4-8
Table 4-8. Coal Prices in the No Clean Power Plan and Cumulative Scenarios—No-Action Alternative (2012$/short ton) 4-9
Table 4-9. Coal Prices in the No Clean Power Plan Scenario—Proposed-Action Alternative (2012$/short ton) 4-9
Table 4-10. Coal Prices in the Cumulative Scenario—Proposed-Action Alternative (2012$/short ton) 4-10
Table 4-11. Natural Gas Prices in the No Clean Power Plan Scenario (2012$/MMBtu) 4-10
Table 4-12. IPM Region Groups 4-12
Table 4-13. Net Energy for Load (GWh), 2016–2040 4-14
Table 4-14. Coincident Peak Demand (MW), 2016–2040 4-14
Table 4-15. Planned New Capacity by Region, 2016 to 2020 (MW) 4-16
Table 4-16. Planned New Capacity by Capacity Type, 2016 to 2020 (MW) 4-16
Table 4-17. Planned Retirements by Region, 2016 to 2020 (MW) 4-17
Table 4-18. Planned Retirements by Capacity Type, 2016 to 2020 (MW) 4-17
Table 4-19. Capital Costs for New Generating Capacity, 2011$/kW 4-18
Table 4-20. Total Primary Energy Demand – Coal – No Clean Power Plan and Cumulative Scenarios (Trillion Btu) 4-22

Table 4-21. Total Primary Energy Demand – Coal – Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu) 4-23
Table 4-22. 2014 Coal Consumption by Country, Total Primary Energy Demand (Trillion Btu) 4-24
Table 4-23. Global Metallurgical Coal Demand 4-24
Table 4-24. Metallurgical Coal Demand Forecast - No Clean Power Plan, Cumulative, and Upper Bound Scenarios (Trillion Btu) 4-25
Table 4-25. Metallurgical Coal Demand Forecast - Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu) 4-26
Table 4-26. International Thermal Coal Demand Forecast — No Clean Power Plan and Cumulative Scenarios (Trillion Btu) 4-28
Table 4-27. International Thermal Coal Demand Forecast — Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu) 4-29
Table 4-28. International Thermal Coal Demand Forecast — Upper Bound Scenario (Trillion Btu) 4-30
Table 4-29. CO_2 and Heat Content in Coal by Type and Source Region: Domestic Coal Types for Appalachia and the Illinois Basin 4-33
Table 4-30. CO_2 and Heat Content in Coal by Type and Source Region: Domestic Coal Types for Interior and Western Regions 4-34
Table 4-31. CO_2 and Heat Content in Coal by Type and Source Region: International Coal Types for the Americas and Europe 4-35
Table 4-32. CO_2 and Heat Content in Coal by Type and Source Region: International Coal Types for the Rest of the World 4-36
Table 4-33. Subbituminous Coal Consumption Limits 4-37
Table 4-34. Recoverable Coal Reserves by Mine Type and State, 2014 (million short tons) 4-38
Table 4-35. Mapping of Calendar Years and Model Run Years 4-40
Table 4-36. Coal Rank Heat Content Ranges 4-41
Table 4-37. Coal Grade SO_2 Content Ranges 4-41
Table 4-38. U.S. Electric Energy Demand Forecast 4-43
Table 5-1. Scenario Definitions 5-3
Table 5-2. Planned and Existing Pacific Northwest Export Terminals 5-8
Table 6-1. No Clean Power Plan Scenario Coal Production—No-Action Alternative (million metric tons) 6-10
Table 6-2. No Clean Power Plan Scenario Coal Production—Proposed Action (million metric tons) 6-11
Table 6-3. No Clean Power Plan Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons) 6-11
Table 6-4. No Clean Power Plan Scenario Coal Consumption—No-Action Alternative (million metric tons) 6-13
Table 6-5. No Clean Power Plan Scenario Coal Consumption—No-Action Alternative (TBtu per year) 6-13
Table 6-6. No Clean Power Plan Scenario Coal Consumption—Proposed Action (million metric tons) 6-14
Table 6-7. No Clean Power Plan Scenario Coal Consumption—Proposed Action (TBtu per year) 6-15
Table 6-8. No Clean Power Plan Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons) 6-16

Table 6-9. No Clean Power Plan Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year) 6-16
Table 6-10. No Clean Power Plan Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons) 6-17
Table 6-11. No Clean Power Plan Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles) 6-18
Table 6-12. No Clean Power Plan Scenario Distribution of Coal Exported through Coal Export Terminal—Proposed Action (million metric tons) 6-18
Table 6-13. No Clean Power Plan Scenario Seaborne Coal Imports in Asian —Proposed Action (million metric tons) 6-19
Table 6-14. No Clean Power Plan Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles) 6-19
Table 6-15. No Clean Power Plan Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons) 6-20
Table 6-16. No Clean Power Plan Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles) 6-20
Table 6-17. No Clean Power Plan Scenario CO_2 Emissions—No-Action Alternative (million metric tons) 6-21
Table 6-18. No Clean Power Plan Scenario CO_2 Emissions—Proposed Action (million metric tons) 6-22
Table 6-19. No Clean Power Plan Scenario Change in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons) 6-23
Table 6-20. Lower Bound Scenario Coal Production—No-Action Alternative (million metric tons) 6-25
Table 6-21. Lower Bound Scenario Coal Production—Proposed Action (million metric tons) 6-25
Table 6-22. Lower Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons) 6-26
Table 6-23. Lower Bound Scenario Coal Consumption—No-Action Alternative (million metric tons) 6-27
Table 6-24. Lower Bound Scenario Coal Consumption—No-Action Alternative (TBtu per year) 6-28
Table 6-25. Lower Bound Scenario Coal Consumption—Proposed Action (million metric tons) 6-29
Table 6-26. Lower Bound Scenario Coal Consumption—Proposed Action (TBtu per year) 6-29
Table 6-27. Lower Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons) 6-30
Table 6-28. Lower Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year) 6-30
Table 6-29. Lower Bound Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons) 6-31
Table 6-30. Lower Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles) 6-32
Table 6-31. Lower Bound Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons) 6-32
Table 6-32. Lower Bound Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons) 6-33

Table 6-33. Lower Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles) 6-33
Table 6-34. Lower Bound Scenario Change in Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million metric tons) 6-34
Table 6-35. Lower Bound Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles) 6-34
Table 6-36. Lower Bound Scenario CO_2 Emissions—No-Action Alternative (million metric tons) 6-35
Table 6-37. Lower Bound Scenario CO_2 Emissions—Proposed Action (million metric tons) 6-36
Table 6-38. Lower Bound Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons) 6-37
Table 6-39. Upper Bound Coal Production—No-Action Alternative (million metric tons) 6-39
Table 6-40. Upper Bound Scenario Coal Production—Proposed Action (million metric tons) 6-40
Table 6-41. Upper Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons) 6-40
Table 6-42. Upper Bound Scenario Coal Consumption—No-Action Alternative (million metric tons) 6-42
Table 6-43. Upper Bound Scenario Coal Consumption—No-Action Alternative (TBtu per year) 6-42
Table 6-44. Upper Bound Scenario Coal Consumption—Proposed Action (million metric tons) 6-43
Table 6-45. Upper Bound Scenario Coal Consumption—Proposed Action (TBtu per year) 6-43
Table 6-46. Upper Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons) 6-44
Table 6-47. Upper Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year) 6-45
Table 6-48. Upper Bound Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons) 6-46
Table 6-49. Upper Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles) 6-46
Table 6-50. Upper Bound Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons) 6-47
Table 6-51. Upper Bound Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons) 6-47
Table 6-52. Upper Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles) 6-48
Table 6-53. Upper Bound Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons) 6-48
Table 6-54. Upper Bound Scenario Change in Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million nautical miles) 6-49
Table 6-55. Upper Bound Scenario CO_2 Emissions—No-Action Alternative (million metric tons) 6-50
Table 6-56. Upper Bound Scenario CO_2 Emissions—Proposed Action (million metric tons) 6-50
Table 6-57. Upper Bound Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons) 6-51

Table 6-58. 2015 U.S. and International Energy Policy Scenario Coal Production—No-Action Alternative (million metric tons) 6-53
Table 6-59. 2015 U.S. and International Energy Policy Scenario Coal Production—Proposed Action (million metric tons) 6-53
Table 6-60. 2015 U.S. and International Energy Policy Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons) 6-54
Table 6-61. 2015 U.S. and International Energy Policy Scenario Coal Consumption—No-Action Alternative (million metric tons) 6-55
Table 6-62. 2015 U.S. and International Energy Policy Scenario Coal Consumption—No-Action Alternative (TBtu per year) 6-55
Table 6-63. 2015 U.S. and International Energy Policy Scenario Coal Consumption—Proposed Action (million metric tons) 6-56
Table 6-64. 2015 U.S. and International Energy Policy Scenario Coal Consumption—Proposed Action (TBtu per year) 6-57
Table 6-65. 2015 U.S. and International Energy Policy Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons) 6-58
Table 6-66. 2015 U.S. and International Energy Policy Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year) 6-58
Table 6-67. 2015 U.S. and International Energy Policy Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons) 6-59
Table 6-68. 2015 U.S. and International Energy Policy Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles) 6-60
Table 6-69. 2015 U.S. and International Energy Policy Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons) 6-60
Table 6-70. 2015 U.S. and International Energy Policy Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons) 6-61
Table 6-71. 2015 U.S. and International Energy Policy Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles) 6-61
Table 6-72. 2015 U.S. and International Energy Policy Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons) 6-62
Table 6-73. 2015 U.S. and International Energy Policy Scenario Change in Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million nautical miles) 6-62
Table 6-74. 2015 U.S. and International Energy Policy Scenario CO_2 Emissions—No-Action Alternative (million metric tons) 6-63
Table 6-75. 2015 U.S. and International Energy Policy Scenario CO_2 Emissions—Proposed Action (million metric tons) 6-64
Table 6-76. 2015 U.S. and International Energy Policy Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons) 6-65
Table 6-77. Cumulative Scenario Coal Production—No-Action Alternative (million metric tons) 6-67
Table 6-78. Cumulative Scenario Coal Production—Proposed Action (million metric tons) 6-67

Table 6-79. Cumulative Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons) 6-68
Table 6-80. Cumulative Scenario Coal Consumption—No-Action Alternative (million metric tons) 6-69
Table 6-81. Cumulative Scenario Coal Consumption—No-Action Alternative (TBtu per year) 6-69
Table 6-82. Cumulative Scenario Coal Consumption—Proposed Action (million metric tons) 6-70
Table 6-83. Cumulative Scenario Coal Consumption—Proposed Action (TBtu per year) 6-71
Table 6-84. Cumulative Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons) 6-72
Table 6-85. Cumulative Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year) 6-72
Table 6-86. Cumulative Scenario Seaborne Coal Distribution in Asia—No-Action Alternative (million metric tons) 6-73
Table 6-87. Cumulative Scenario Shipping Distance for Seaborne Coal Distribution in Asia—No-Action Alternative (million nautical miles) 6-74
Table 6-88. Cumulative Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons) 6-74
Table 6-89. Cumulative Scenario Seaborne Coal Distribution in Asia—Proposed Action (million metric tons) 6-75
Table 6-90. Cumulative Scenario Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action (million nautical miles) 6-75
Table 6-91. Cumulative Scenario Change in Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million metric tons) 6-76
Table 6-92. Cumulative Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles) 6-76
Table 6-93. Cumulative Scenario CO_2 Emissions—No-Action Alternative (million metric tons) 6-77
Table 6-94. Cumulative Scenario CO_2 Emissions—Proposed Action (million metric tons) 6-78
Table 6-95. Cumulative Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons) 6-79
Table 7-1. Average Change in CO_2 Emissions by Scenario and Region—Proposed Action minus No-Action Alternative (million metric tons) 7-3

Figures

Figure 1-1.Project Vicinity....1-3
Figure 1-2. Proposed Action....1-4
Figure 2-1. Powder River Basin (Montana and Wyoming)....2-3
Figure 2-2. Historical Powder River Basin Coal Production (Montana and Wyoming)....2-4
Figure 2-3. Powder River Basin 2015 Production by Mine (million short tons)....2-5
Figure 2-4. Uinta Basin (Colorado and Utah)....2-7
Figure 2-5. Historical Uinta Basin Coal Production (Colorado and Utah)....2-7
Figure 2-6. Uinta Basin 2015 Production by Mine (million short tons)....2-8
Figure 2-7. Existing and Planned Coal Export Terminals....2-14
Figure 3-1. Indonesia and Australia Dominate Asian Coal Markets....3-2
Figure 3-2. China's Coal Imports and Exports, 2000–2014 (million short tons)....3-4
Figure 3-3. Delivered Coal versus Natural Gas Prices to Japan ($/MMBtu)....3-6
Figure 3-4. Historical Asian Free On Board Steam Coal Prices....3-7
Figure 3-5. Asian Steam Coal Prices—Japan....3-8
Figure 4-1. Integrated Planning Model (IPM®)....4-2
Figure 4-2. Map of IPM Model Regions....4-12
Figure 4-3. Domestic Coal Supply Regions....4-42
Figure 4-4. International Coal Supply Regions....4-42
Figure 4-5. Renewable Portfolio Standards....4-45
Figure 6-1. Change in Annual Average Production for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons per year)....6-5
Figure 6-2. Change in Annual Average Consumption for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons and trillion Btu (TBtu) per year)....6-7
Figure 6-3. Change in Annual Average Imports of Coal in Asia via Ship for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons per year)....6-8
Figure 6-4. Change in Annual Average Imports of Coal in Asia via Ship for 2025 to 2040—Proposed Action minus No-Action Alternative (million nautical miles per year)....6-8
Figure 6-5. Change in Annual Average CO2 Emissions from the Consumption of Coal for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons CO2 per year)....6-9
Figure 6-6. No Clean Power Plan Scenario Change in Coal Production—Proposed Action minus No-Action Alternative....6-12
Figure 6-7. No Clean Power Plan Scenario Changes in CO2 Emissions—Proposed Action minus No-Action Alternative....6-24
Figure 6-8. Lower Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative....6-26

Figure 6-9. Lower Bound Scenario Changes in CO2 Emissions by Region—Proposed Action minus No-Action Alternative 6-38
Figure 6-10. Upper Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative....6-41
Figure 6-11. Upper Bound Scenario Changes in CO2 Emissions by Region—Proposed Action minus No-Action Alternative 6-52
Figure 6-12. 2015 U.S. and International Energy Policy Scenario Change in Coal Production—Proposed Action minus No-Action Alternative....6-54
Figure 6-13. 2015 U.S. and International Energy Policy Scenario Changes in CO2 Emissions by Region—Proposed Action minus No-Action Alternative....6-66
Figure 6-14. Cumulative Scenario Change in Coal Production—Proposed Action minus No-Action Alternative....6-68
Figure 6-15. Cumulative Scenario Changes in CO2 Emissions by Region—Proposed Action minus No-Action Alternative 6-79
Figure 7-1. Change in Annual Average CO2 Emissions from the Consumption of Coal and Natural Gas in the United States for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons CO2 per year) 7-3

Acronyms and Abbreviations

$/MMBtu	dollars per million British thermal unit
Applicant	Millennium Bulk Terminals—Longview, LLC
BNSF	BNSF Railway Company
Btu/lb	British thermal units per pound
CFR	Code of Federal Regulations
CN	Canadian National
CO_2	carbon dioxide
CP	Canadian Pacific
EIA	U.S. Energy Information Administration
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FOB	free on board
GHG	greenhouse gas
IEA	International Energy Agency
IPM®	Integrated Planning Model
MMBtu	million British thermal unit
NO_X	nitrogen oxides
SEPA	Washington State Environmental Policy Act
SO_2	sulfur dioxide
TBtu	trillion British thermal unit
WEO	World Energy Outlook

Chapter 1
Introduction

This chapter provides an overview of the coal export terminal proposed for development in Cowlitz County, Washington, and its potential impact on the coal market.

1.1 Project Description

Millennium Bulk Terminals—Longview, LLC (Applicant) is proposing to construct and operate a coal export terminal (Proposed Action) in Cowlitz County, Washington, along the Columbia River (Figure 1). The coal export terminal would receive coal from the Powder River Basin in Montana and Wyoming and the Uinta Basin in Utah and Colorado via rail shipment. The coal export terminal would receive, stockpile, and load coal onto vessels and transport the coal via the Columbia River and Pacific Ocean to overseas markets in Asia.

1.1.1 Proposed Action

Under the Proposed Action, the Applicant would develop the coal export terminal on 190 acres (project area) primarily within an existing 540-acre site that is currently leased by the Applicant (Applicant's leased area). The project area is adjacent to the Columbia River in unincorporated Cowlitz County, Washington near Longview, Washington (Figure 2). The Applicant currently operates and would continue to operate a bulk product terminal within the Applicant's leased area.

BNSF Railway Company (BNSF) or Union Pacific Railroad (UP) trains would transport coal on BNSF main line routes in Washington State, and the BNSF Spur and Reynolds Lead in Cowlitz County to the project area. Coal would be unloaded from rail cars, stockpiled, and loaded by conveyor onto ocean-going vessels for export at two new docks (Docks 2 and 3) located in the Columbia River.

Once construction is complete, the Proposed Action could have a maximum annual throughput capacity of up to 44 million metric tons of coal per year. The coal export terminal would consist of one operating rail track, eight rail tracks for storing up to eight unit trains, rail car unloading facilities, a stockpile area for coal storage, conveyor and reclaiming facilities, two new docks in the Columbia River (Docks 2 and 3), and shiploading facilities on the two docks. Dredging of the Columbia River would be required to provide access to and from the Columbia River navigation channel and for berthing at the two new docks.

Vehicles would access the project area from Industrial Way (State Route 432), and vessels would access the project area via the Columbia River. The Reynolds Lead and BNSF Spur track—both jointly owned by BNSF and UP and operated by Longview Switching Company (LVSW)—provide rail access to the project area from a point on the BNSF main line (Longview Junction) located to the east in Kelso, Washington. Coal export terminal operations would occur 24 hours per day, 7 days per week. The coal export terminal would be designed for a minimum 30-year period of operation.

At full terminal operations, approximately 8 loaded unit trains each day would carry coal to the export terminal, 8 empty unit trains each day would leave the export terminal, and an average of 70

vessels per month or 840 vessels per year would be loaded, which would equate to 1,680 vessel transits in the Columbia River annually.

Figure 1-1. Project Vicinity

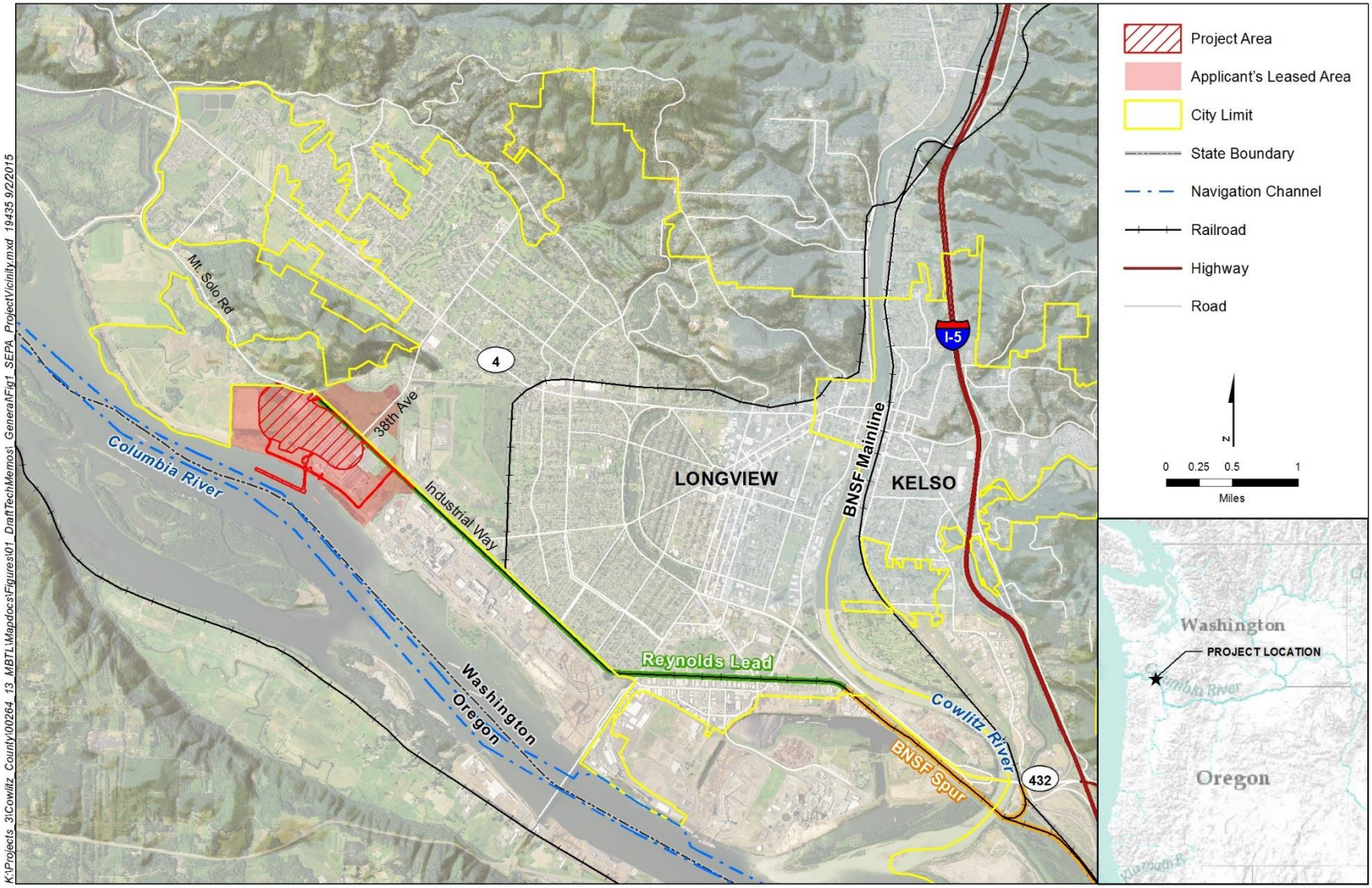
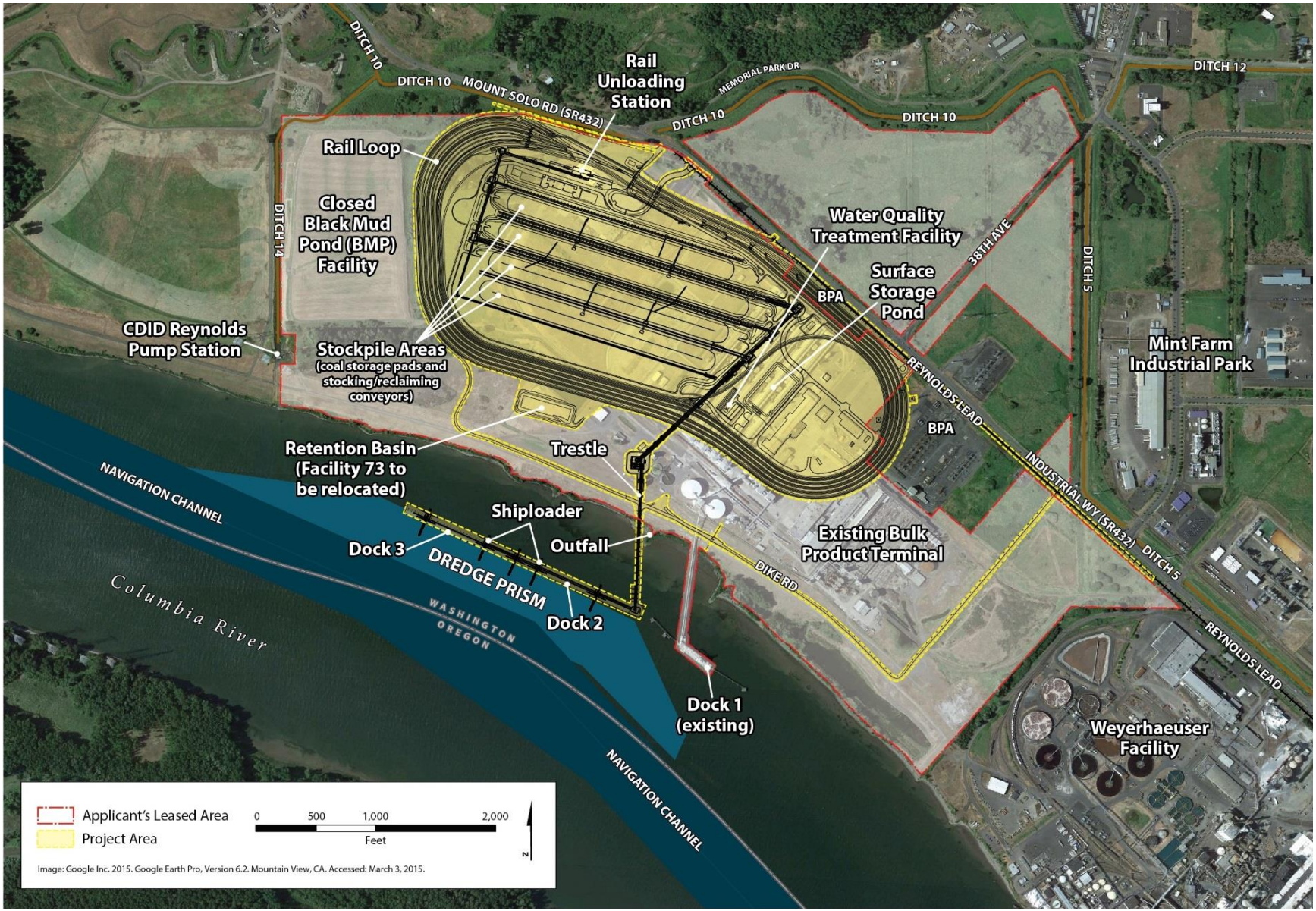


Figure 1-2. Proposed Action



1.2 Overview of Coal Market Analysis

This report presents the analysis of coal production, consumption, distribution, and CO_2 emissions from combustion of coal in relation to the U.S. and Asian markets.[1] The analysis examines the Proposed Action and No-Action Alternative and documents the methods and data used to develop the results and conclusions.

This analysis examines the movement of coal from the Powder River Basin in Montana and Wyoming, and coal from the Uinta Basin in Colorado and Utah, through the proposed coal export terminal to China, Japan, South Korea, and Taiwan. Only coal from these coal basins were examined for export through the proposed coal export terminal based on information provided by the Applicant. To examine the potential impact of the proposed coal export terminal on domestic and Asian coal markets, a least-cost, linear programming model was used to capture the dynamic interactions between the supply and demand regions within these markets.

The international coal market is a global commodity market such that changes in supply or demand in one country can affect coal prices and distribution patterns globally. The global nature of the coal market was demonstrated most recently in the fall of 2016, when China reduced production capacity and international coal prices shot up by 50% over a 2-month period. In addition, coal competes with other fuel sources, such as natural gas, for electric generation. To capture the dynamic changes in the international coal market and the competition among fuel types for electric generation in the United States and Canada, a comprehensive and integrated modeling platform is required. Without this type of modeling, assumptions would be required regarding the ultimate outcome of the exported coal and changes in coal consumption in the United States that would be difficult to make and justify without comprehensive modeling.

The importance of modeling is best illustrated by examples. The modeling for the Draft Environmental Impact Statement (Draft EIS) established that rather than the new coal resource resulting in an increase in coal consumption equal to the amount of coal exported, the increase is close to zero in all but the Upper Bound Scenario. Additionally, the modeling established that there are multiple suppliers and that U.S. exports, while competitive, are not significantly lower-cost than coal supplied from Australia, China, Indonesia, or Russia. The model showed outcomes where displacement (i.e., sale of U.S. coal rather than sale of competing coal produced in other countries), resulted in small changes in delivered coal price, and small to no increases in coal used, except in the Upper Bound Scenario. The modeling established that the differences in carbon content have a somewhat greater effect on net emissions from the Proposed Action than some of the other sources of emissions. Thus, the net emissions from the substitution of coal with different carbon contents in Asia has more of an impact on the net emissions than other emission sources such as international vessel transport. Fourth, if the U.S. power and fuel markets were not highly integrated, diverse, and competitive, the increase in coal price in the United States would not result in substitution of gas and other sources for coal. In some model scenarios, small substitution effects were identified because of the high degree of competition, diversity, and integration.

[1] The Asian market refers to the following countries: Australia, China, India, Indonesia, Japan, Korea, Russia, Taiwan, Thailand, and Vietnam.

Historically, approximately 2% of Powder River Basin coal has been exported.[2] There are four primary reasons that Powder River Basin coal has not been exported in larger quantities in the past.

- The Powder River Basin is far from large U.S. coal export facilities along the Atlantic coast and in the Gulf Coast.
- Canadian coal export facilities in the Pacific Northwest have had limited capacity for Powder River Basin coal or are too far to be economic.
- Powder River Basin coal has a lower heat content than eastern bituminous coals. Lower heat content increases transportation cost per unit of energy delivered.[3]
- Powder River Basin coal is subbituminous coal that is suitable for use in electric power plants, but is not suitable for coking coal, which limits the marketability of the coal.

The Proposed Action would address the first two reasons Powder River Basin coal has not been exported, and thus would reduce the distance to Asian markets and make Powder River Basin coal more competitive with other coal delivered to Asia. Currently, the largest suppliers of coal in Asia are Australia, China, India, and Indonesia. This analysis examines the U.S. and Asian coal market changes that would take place under the Proposed Action, under five different scenarios. The scenarios examine a wide range of possible future market states that would have an influence on how the proposed coal export terminal would affect these markets

1.2.1 Report Organization and Chapter Summary

The following sections describe the remaining chapters of this report.

1.2.1.1 Chapter 2, U.S. Coal Market and Pacific Northwest Export Terminals

This chapter provides a brief overview of the U.S. coal market and more in-depth information about the Powder River Basin and the Uinta Basin. Information on the type of coal mined in these coal basins is included, as well as the historical distribution of the coal. This chapter also discusses the existing and planned Pacific Northwest coal export terminals.

1.2.1.2 Chapter 3, International Coal Markets

Chapter 3 describes the international coal markets into which the coal exported from the proposed coal export terminal would enter. This chapter provides information on the major coal importing and exporting countries and provides a summary of each country that is a possible destination for coal exported from the proposed terminal. Finally, this chapter provides a brief discussion on international coal prices.

[2] Based on EIA U.S. Domestic and Foreign Coal Distribution by State of Origin.

[3] The cost per unit of energy delivered is proportional to the tons of coal transported and the heat content of the coal. If the energy or heat content per ton is low, then the transportation cost per unit of energy is higher.

1.2.1.3 Chapter 4, Model Framework, Methods, and Key Assumptions

Chapter 4 provides a summary of the model, methods, and assumptions used in this analysis to estimate coal production, consumption, distribution, and CO_2 emissions. This analysis uses ICF's Integrated Planning Model (IPM®) to assess coal production, consumption, and distribution patterns that would be affected by the Proposed Action. This computer modeling platform is also used by the U.S. Environmental Protection Agency (EPA), other government entities, electric utilities, independent power producers, coal companies, and environmental groups. The assumptions used in this analysis are largely from publicly available sources.

Chapter 4 provides a base set of assumptions that are used by all the scenarios and describes some of the scenario-specific assumptions that require detailed information. The full scenario descriptions are included in Chapter 5.

1.2.1.4 Chapter 5, Scenarios

Chapter 5 describes the five scenarios analyzed in this report and how the assumptions defining each scenario differ from the base set of assumptions. Under each scenario, both a No-Action Alternative and a Proposed Action are examined to determine the effect of the Proposed Action on the U.S. and Asian coal markets. The five scenarios analyzed in this report are as follows.

- No Clean Power Plan Scenario, which represents the business as usual case in 2016 but does not include the Clean Power Plan.
- Lower Bound Scenario, which is designed to result in a reasonable lower bound of global CO_2 emissions from the power sector. The energy markets under the Lower Bound Scenario could be described as a high renewable energy penetration scenario, where international coal demand and prices are lower than in the base assumptions.
- Upper Bound Scenario, which is designed to result in a reasonable upper bound of global CO_2 emissions from the power sector. The energy markets under the Upper Bound Scenario could be described as a high international coal demand scenario, where international coal demand and prices are higher than in the base assumptions.
- 2015 U.S. and International Energy Policy Scenario, which differs from the base assumptions in that it includes implementation of EPA's Clean Power Plan and assumes greenhouse gas (GHG) reduction policies are implemented in other countries that have made commitments under the Paris Accord of 2015.
- Cumulative Scenario, which differs from the base assumptions only in that it includes the capacity of other proposed Pacific Northwest coal export facilities. The Cumulative Scenario also does not include the Clean Power Plan.

1.2.1.5 Chapter 6, Modeling Results

Chapter 6 presents the modeling results of the five scenarios analyzed. The results are presented for the No-Action Alternative and Proposed Action and for the difference as calculated by subtracting the No-Action Alternative results from the Proposed Action results. Results are presented for coal production from the U.S. and non-U.S. producing regions; coal consumption in the United States and Asia; the distribution of coal in Asia; and CO_2 emissions from the combustion of coal. In addition,

natural gas usage at electric power plants in the United States and the CO_2 emissions from natural gas combustion are reported as natural gas is a substitute fuel when coal consumption decreases.

1.2.1.6 Chapter 7, Conclusions

Chapter 7 provides a summary of the conclusions from the analysis.

Chapter 2

U.S. Coal Market and Pacific Northwest Export Terminals

2.1 General U.S. Coal Market

The United States is the world's second largest coal producer and consumer, with total coal production of 897 million short tons in 2015 (Mine Safety and Health Administration 2016 Part 50 data). The largest coal producer and consumer is China, with total coal production of 4.2 billion short tons (International Energy Agency 2016). This chapter discusses the U.S. coal market to provide context for the focus of this analysis, which is coal produced from the Powder River Basin and the Uinta Basin to be exported through the proposed coal export terminal. The goal of this chapter is to provide a basic understanding of the U.S. coal markets, and Chapter 3, *International Coal Markets*, provides an overview of the international coal markets, both of which will help the reader to understand and interpret the modeling results

2.1.1 Total Production

Between 1990 and 2015, total U.S. coal production has been more than 1 billion tons, except for only six years (Mine Safety and Health Administration 2016). In this period, coal production has averaged 1.06 billion tons and peaked at 1.17 billion tons in 2008 (Mine Safety and Health Administration 2016). However, since 2011, coal production has been declining due to competition from natural gas as an energy source for electric generation. Historically, about 90% of U.S. coal has been used domestically for power generation, with the remainder being used for industrial processes, steel production, or export. The Powder River Basin is the leading source of U.S. coal, at more than 40% of U.S. total coal production (Mine Safety and Health Administration 2016). The majority of Powder River Basin coal is used in domestic power plants, with only 1% to 2% being exported, primarily to Asia. Coal exports from all the United States coal-producing regions have been primarily to Europe.

Coal production and consumption have both decreased since 2011, when natural gas prices first fell below $3.5 per million British thermal unit (MMBtu). Natural gas is a competing fuel for electric generation and thus when natural gas prices are below $3.5/MMBtu the cost of generating electricity from natural gas is below the cost of generating electricity from some types of coal.

Coal is produced in four major coal basins within the United States, along with several smaller coal basins. The four major coal basins are the Powder River Basin, Rocky Mountains, Illinois Basin, and Appalachia. The Appalachian coal basin is further divided into a Northern, Central, and Southern section. The Rocky Mountain area includes the Uinta Basin, which includes Utah and the western part of Colorado, the Wyoming Green River area, and parts of Colorado not in the Uinta Basin.

2.1.2 Types of Coal

Coal has two primary uses: metallurgical and thermal. Coal used to produce coke (a hard porous residue used in steel manufacturing) is called metallurgical coal. Non-metallurgical coal is referred to as thermal or steam coal, because it is used to generate electricity through steam turbines.

Metallurgical coal in the United States is found in the Appalachian basin. Thermal coal is produced in all regions.

Coal is also categorized by rank, with three ranks used in the United States. The coal ranks are, from hardest and highest heat content to softest and lowest heat content, bituminous, subbituminous, and lignite. Bituminous coal is mined in the Appalachian and Illinois Basins as well as in the Rocky Mountains.[4] Subbituminous coal is primarily mined in the Powder River Basin. Lignite coal is primarily found in Texas and the Great Plains area of North Dakota and Montana.

Within each rank, coal is graded by the heat content as well as the trace elements found in the coal, such as sulfur, mercury, and chlorine. Generally, higher heat content coal sells at a higher price, and coal with lower concentrations of trace elements sells for a higher price, all else being equal.

2.1.3 Exports

The United States imports small amounts of thermal coal and exports both metallurgical and thermal coal. Appalachia is the focal point of U.S. coal exports. This is due to high coal quality, nearby infrastructure (i.e., ports), and locational proximity to Atlantic Basin markets. In the past, Appalachian coal demand has increased when international markets strengthened. However, there is large and growing energy demand and coal industry demand in Asia. Delivered Asian coal prices were 2.1 times higher between 2010 and 2013 versus 2000 and 2006. Since coal prices peaked in 2011 Asian coal prices have declined by more than 50%, as of mid-2016. The coal trade in Asia is seaborne.

2.2 Powder River Basin

The Powder River Basin, located in Montana and Wyoming, is the largest source of coal production in the United States, accounting for more than 40% of national coal production (Figure 2-1). Powder River Basin coal is all subbituminous coal that is mined from large surface mines. Since 1970, Powder River Basin coal production has increased at an average annual rate of 10% per year (Figure 2-2). Between 1993 and 2008, production more than doubled, from 228 million short tons per year to a record high of 496 million short tons per year. Coal production in the Powder River Basin was able to expand so quickly because the coal seams are thick compared to all other coal-producing regions in the United States and because the coal is close to the surface and can be mined using surface mining techniques. The largest Powder River Basin coal seams are 100 feet thick, while seams in other coal basins in the United States are typically less than 8 feet thick.

Between 2009 and 2011, coal production averaged 464 million short tons per year, and ranged from 452 million short tons in 2009 to 473 million short tons in 2010 (Mine Safety and Health Administration 2016). In 2012, production decreased to 425 million short tons, driven down by the lowest natural gas prices in 15 years and lower electric power demand (Mine Safety and Health Administration 2016). This trend has continued with 2015 production at 405 million short tons. The U.S. Energy Information Administration (EIA) expects total U.S. coal production in 2016 and 2017 to continue to fall to about 850 million short tons, as compared to 896 million short tons in 2015 (U.S. Energy Information Administration 2016a).

[4] The Uinta Basin is part of the Rocky Mountain coal production area.

Figure 2-1. Powder River Basin (Montana and Wyoming)

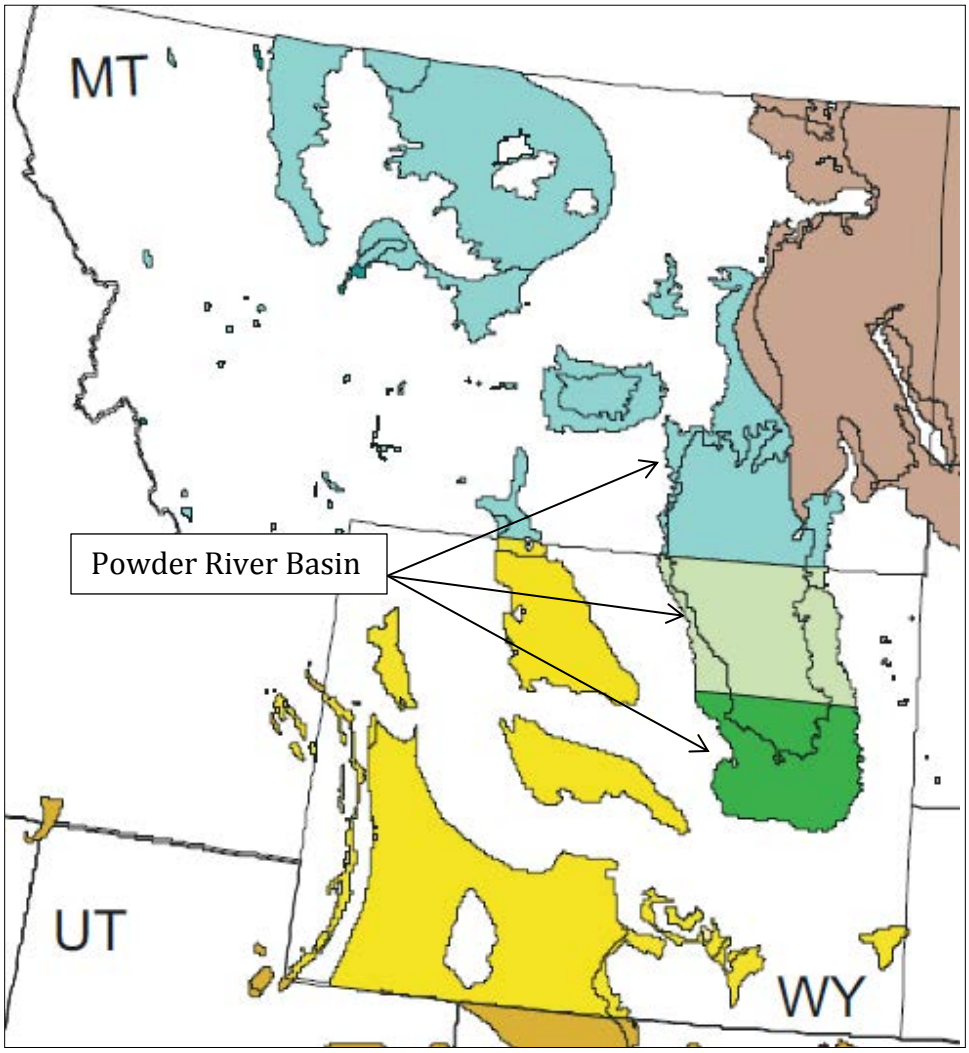
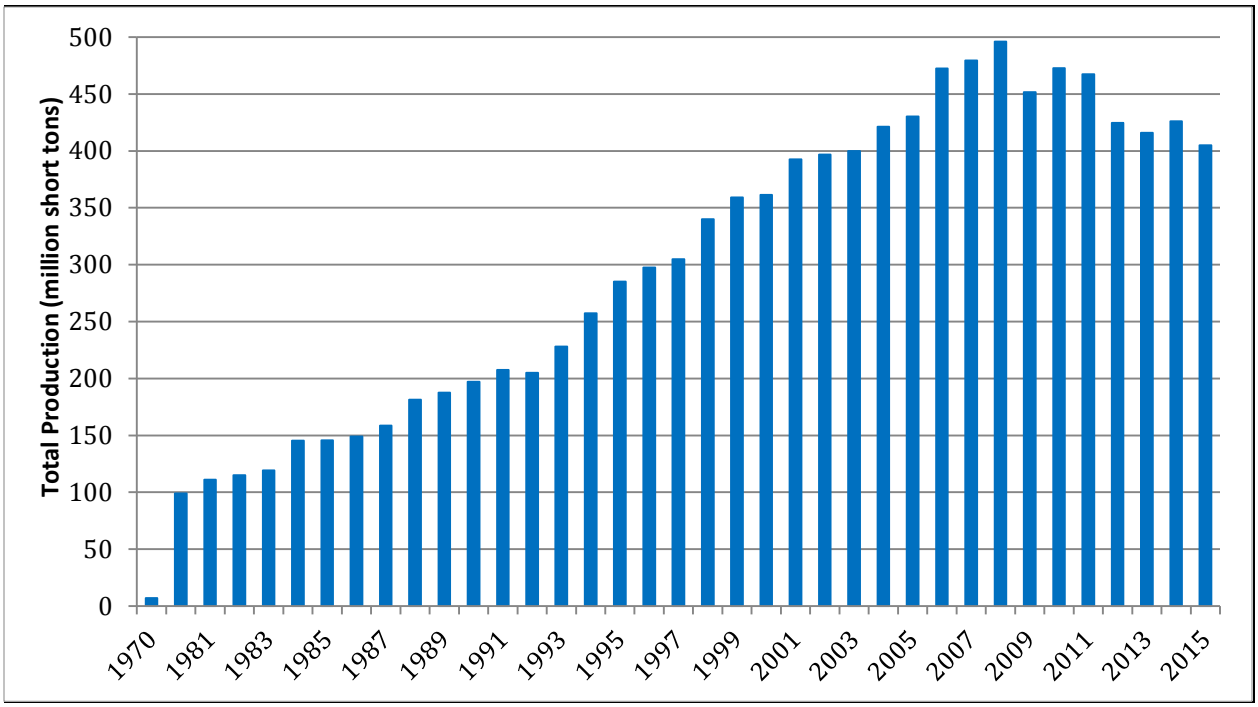


Figure 2-2. Historical Powder River Basin Coal Production (Montana and Wyoming)



Source: BXG Publications 1993 (1970–1982 data); Mine Safety and Health Administration 2016 (1983–2015 data).

This analysis considers the following three sources of Powder River Basin coal.

Montana coal: Coal produced in Montana with a heat content of 9,300 British thermal units per pound (Btu/lb).

Wyoming 8400 coal: Coal produced in Wyoming with a heat content of 8,400 Btu/lb.

Wyoming 8800 coal: Coal produced in Wyoming with a heat content of 8,800 Btu/lb.

Since 2008, Wyoming coalfields have produced about 91% of Powder River Basin coal, with the remaining 9% produced in Montana (Table 2-1). However, because Montana coal has a higher heat content, it is more likely to be exported. Higher heat content coals are more likely to be exported because they contain more heating potential per ton of coal, thus, users have to transport fewer tons of high heat content coal than they would have to import lower heat content coal. For example, a coal consumer would have to import 5.7% more Wyoming 8,800 coal than they would the higher heat content Montana coal.

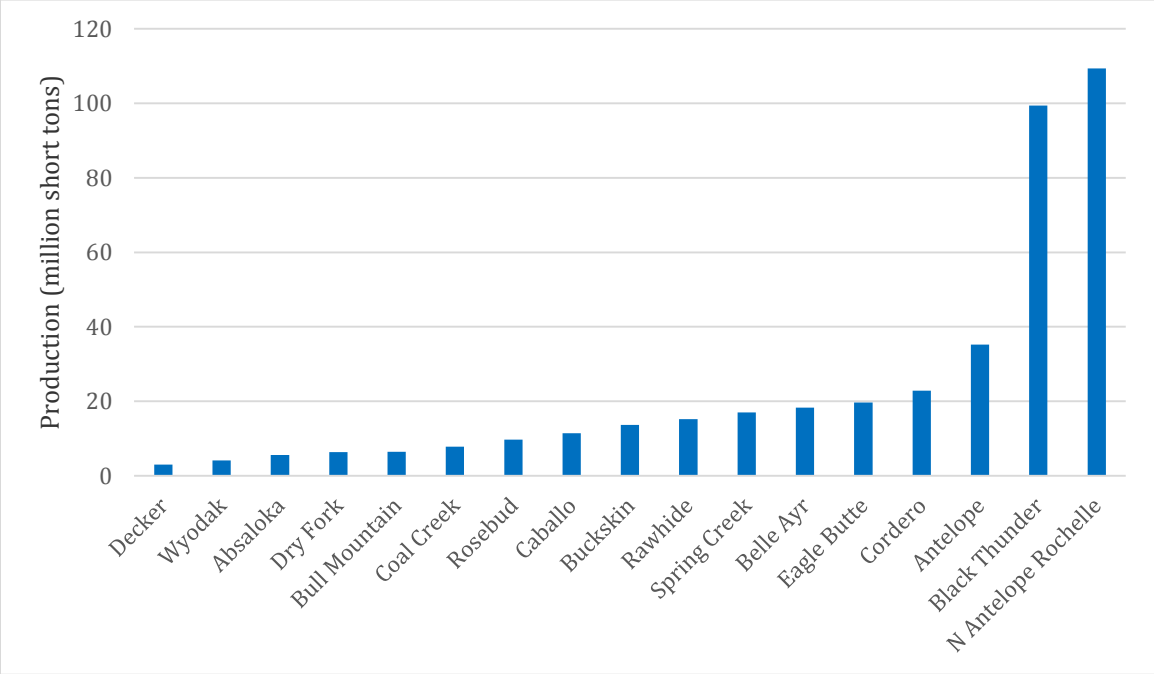
Table 2-1. Powder River Basin Coal Production by State (million short tons)

State	2008	2009	2010	2011	2012	2013	2014	2015	2008–2015 Average
Montana	44	38	44	41	36	42	44	42	41
Wyoming	452	414	428	426	388	374	381	363	403
Total	496	452	473	467	425	416	425	405	445

Source: Mine Safety and Health Administration 2016

Figure 2-3 shows that only 17 mines contribute to coal production in the Powder River Basin, and all except one (Bull Mountain) are surface mines. Two mines (Black Thunder and North Antelope Rochelle) dominate production, accounting for approximately half of the region's coal production.

Figure 2-3. Powder River Basin 2015 Production by Mine (million short tons)



Source: Mine Safety and Health Administration 2016.

Powder River Basin coal mines are large compared to other U.S. coal mines. Most Powder River Basin mines produce at least 10 million short tons per year, and two (the Black Thunder and the North Antelope Rochelle Mines in Wyoming) each produce 100 million short tons per year. For comparison, mines in the eastern United States produce, on average, less than 1 million short tons of coal per year, with very few mines producing more than 4 million short tons per year.

Mining conditions change over time. Initially coal reserves are mined that are the easiest to access and have the least amount of overburden.[5] However, as a mine ages, more overburden must be removed to access the coal, thus increasing the cost of production. Productivity gains have counteracted some of the increased cost of overburden removal. For example, the size of the shovels and trucks has increased, which allows more material to be moved in the same amount of time. The most significant contributor to the cost of surface mining coal production, however, remains the overburden ratio.[6]

2.3 Uinta Basin

The Uinta Basin coalfield is located in the western portion of Colorado and in Utah (Figure 2-4). Coal production in the Uinta Basin is from both underground and surface mines; however, more than 80% of the coal is from underground mines (Mine Safety and Health Administration 2016). The coal produced from the Uinta Basin is both bituminous and subbituminous coal, with bituminous coal the predominant kind at 85% of annual production. The Uinta Basin bituminous coal has an average heat content of 11,315 Btu/lb and the subbituminous coal has an average heat content of 10,000 Btu/lb.[7]

Between 1983 and 2015, coal production in the Uinta Basin has ranged between 26.9 and 62.1 million short tons, with an average of 45.9 million short tons (Figure 2-5) (Mine Safety and Health Administration 2016). Uinta Basin coal production peaked in 2005 with 62.1 million short tons (Mine Safety and Health Administration 2016). Since 2005, Uinta Basin coal production steadily declined through 2010, and then picked up slightly in 2011 before declining again. Since 2011, Uinta Basin coal production has decreased from 45.6 million short tons to 32.5 million short tons in 2015.

This analysis considers two sources of Uinta Basin coal: coal produced in Colorado with a heat content of 11,110 Btu/lb, and coal produced in Utah. Two bituminous coal types are modeled in Utah, one with a heat content of 11,280 Btu/lb and low sulfur content and the second with a heat content of 12,000 Btu/lb and medium sulfur content.

[5] Overburden is the layers of soil and rock covering a coal seam. It is removed prior to surface mining and replaced after the coal has been taken from the seam.

[6] The overburden ratio refers to the ratio of the thickness of soil and rock that lies above a coal seam and the thickness of the coal seam itself. In surface mining, which is the predominant mining method in the Powder River Basin, the soil and rock above a coal seam must be removed before the coal can be mined. For example, a coal seam that is 30 feet thick and overlain by 120 feet of rock and soil would have an overburden ratio of 4.0 (=120/30)

[7] EIA 923 data, using a weighted average over 2010 through 2015 (U.S. Energy Information Administration 2016b).

Figure 2-4. Uinta Basin (Colorado and Utah)

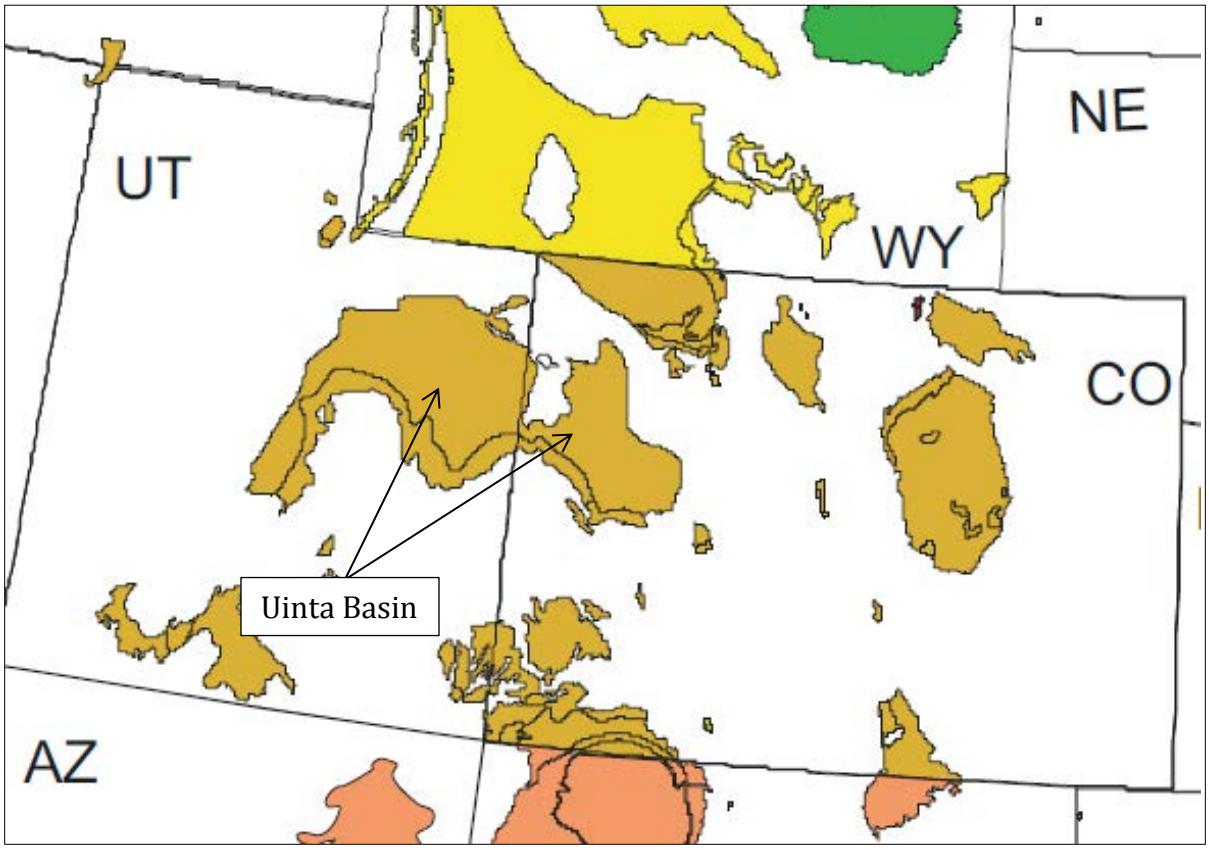
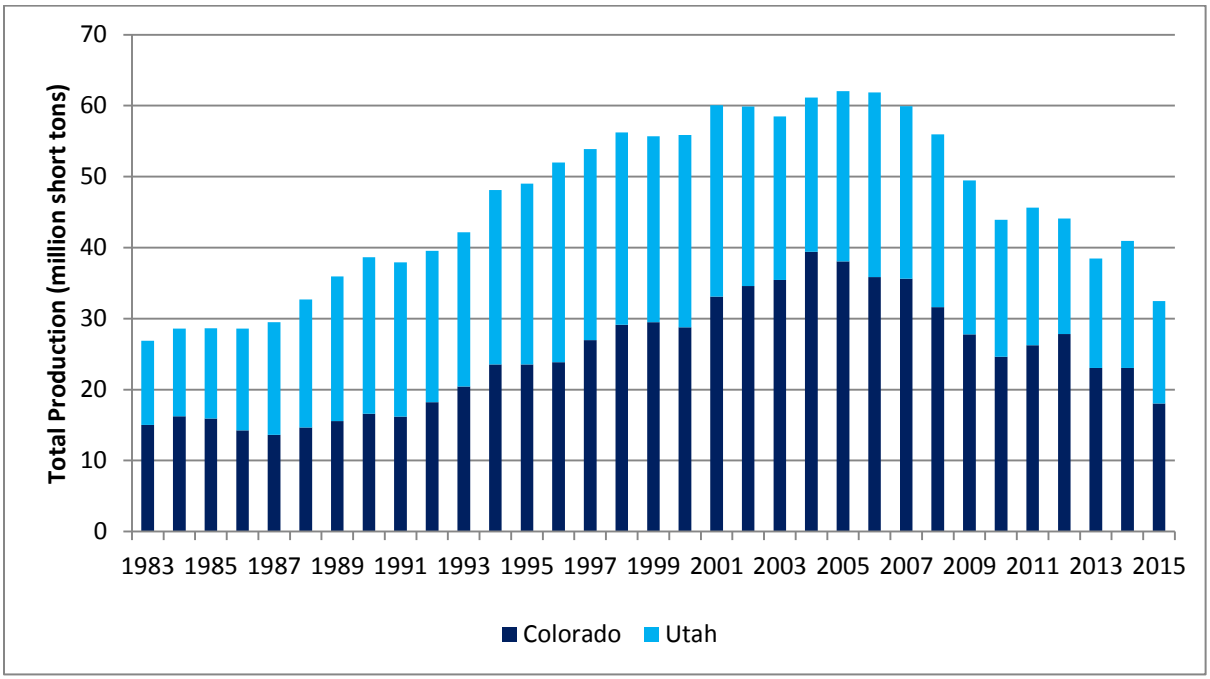


Figure 2-5. Historical Uinta Basin Coal Production (Colorado and Utah)



Source: Mine Safety and Health Administration 2016 (1983–2015 data).

Since 2008, Colorado coalfields have produced about 57% of Uinta Basin coal, with the remaining 43% produced in Utah (Table 2-2). The coal from both regions has a similar heat content; however, the Utah coal is closer to the proposed export terminals, and thus, may be more likely to be exported.

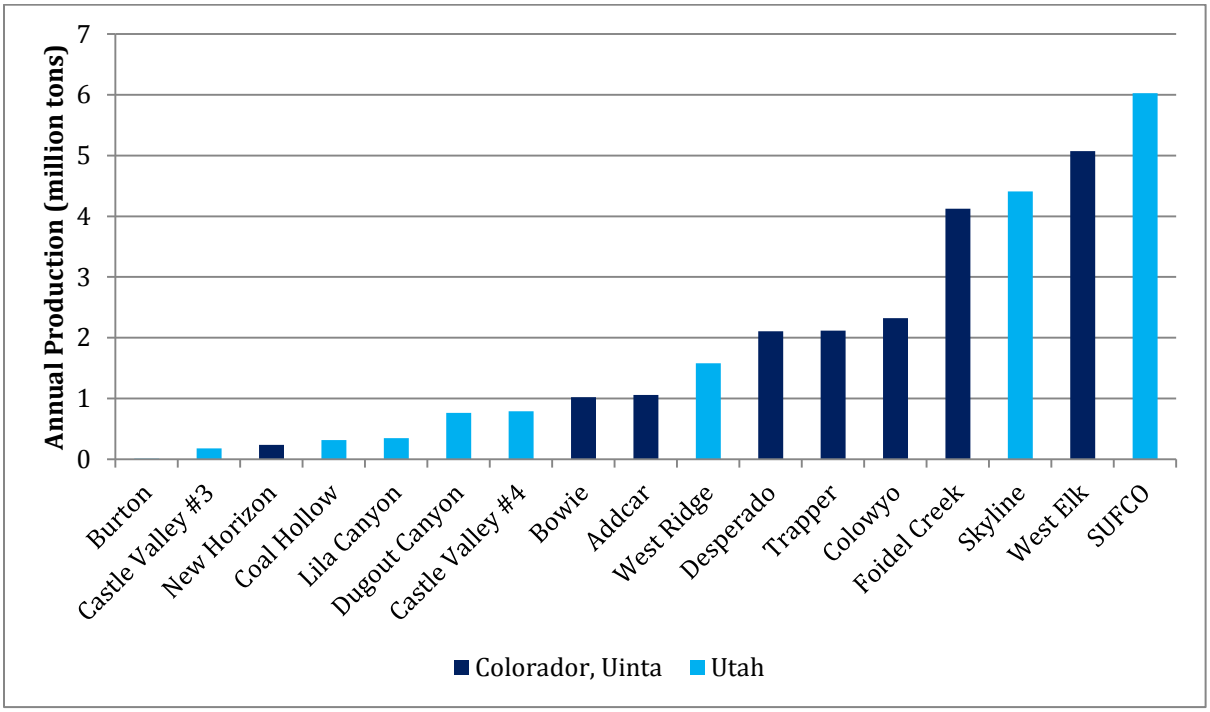
Table 2-2. Uinta Basin Coal Production by State (million short tons)

State	2008	2009	2010	2011	2012	2013	2014	2015	2008–2014 Average
Colorado, Uinta	31.6	27.8	24.6	26.2	27.8	23.5	23.0	18.1	25.3
Utah	24.4	21.7	19.3	19.4	16.3	16.4	17.9	14.4	18.7
Total	56.0	49.5	43.9	45.6	44.1	39.9	41.0	32.5	44.1

Source: Mine Safety and Health Administration 2016

Figure 2-6 shows that only 17 mines contribute to coal production in the Uinta Basin in 2015. Four mines (Foidel Creek Mine, Skyline, Sufco, and West Elk Mine) produce more than 4 million short tons per year and account for approximately half of the region's coal production.

Figure 2-6. Uinta Basin 2015 Production by Mine (million short tons)



Source: Mine Safety and Health Administration 2016

2.4 Coal Distribution

2.4.1 Powder River Basin

Powder River Basin coal is subbituminous and has a lower heat content than the bituminous coal mined in the eastern United States. The lower heat content increases the transportation cost per unit of energy, and has effectively limited the historical distribution of Powder River Basin coal to domestic markets, although in recent years exports of Powder River Basin coal have been increasing.

Historically, 98% of Powder River Basin coal has been distributed to the domestic market. Powder River Basin coal generally reaches large markets in the Midwest, Texas, the southeast, and within the basin itself (U.S. Energy Information Administration 2013a). On average, from 2010 through 2014, Iowa, Illinois, Kansas, Michigan, Missouri, Oklahoma, and Wisconsin, consumed more than 48% (201 million short tons per year) of Powder River Basin coal, while Texas consumed 14% (58 million short tons per year) (Tables 2-3 and 2-4).

Table 2-3. Average Annual Deliveries of Powder River Basin Coal by Region[a]

Region	Montana Coal (million short tons per year)	Wyoming Coal (million short tons per year)	Total (million short tons per year)	Montana Coal (%)	Wyoming Coal (%)
Central United States	15.1	269.7	284.8	41	68
Mid-Atlantic	0.2	1.0	1.1	0	0
Northeast		1.5	1.5	0	0
Powder River Basin	8.9	15.3	24.1	24	4
Rockies		9.8	9.8	0	2
Southeast		24.3	24.3	0	6
Southwest	0.6	6.1	6.8	2	2
Texas	0.0	58.4	58.4	0	15
West	2.6	4.2	6.8	7	1
Exports	9.4	4.2	13.6	26	1
Total	**36.8**	**394.5**	**431.2**	**100**	**100**

Notes:

[a] Domestic deliveries average 2010-2014 data from U.S. Energy Information Administration 923; International deliveries (exports) average 2009-2011 data from U.S. Energy Information Administration *Annual Coal Distribution Report* as 2012 data is not yet available.

Source: U.S. Energy Information Administration 2013a

Table 2-4. Historical Powder River Basin Coal Production by Source State and Destination (million short tons)[a]

State	Historical Distribution	2009	2010	2011	2012	2013	2014	2015
Montana	Domestic Consumption[b]	36	38	33	25	30	44	42
	Exports[c,d]	2	6	8	11	12	0	0
	Total Production[e]	38	44	41	36	42	44	42
Wyoming	Domestic Consumption[b]	411	423	422	384	370	381	363
	Exports[c,d]	3	5	4	4	4	1	0.1
	Total Production[e]	414	428	426	388	374	382	363
Total	Domestic Consumption[b]	447	462	455	409	400	425	405
	Exports[c,d]	5	11	12	15	16	1	0.1
	Total Production[e]	452	473	467	425	416	426	405

Notes:

[a] Estimated exports from Montana have grown six-fold between 2009 and 2013, causing total Powder River Basin exports to more than triple. However, exports of Powder River Basin coal remain less than 4% of total Powder River Basin coal production.

[b] Total production less exports. Includes consumption at electric generating stations and industrial facilities.

[c] U.S. Energy Information Administration 2013a. Export values estimated for 2012 and 2013. U.S. Energy Information Administration 2016c. U.S. Energy Information Administration 2016d. Export values for 2014 and 2015 are only for exports directly from mines. Additional exports may have been made by brokers.

[d] Thapa pers. comm.

[e] Mine Safety and Health Administration 2016

The following factors have historically limited the economic viability of exporting Powder River Basin coal compared to higher heat content thermal coal.

- Long distances to export terminals
- Abundant international coal supply
- Relatively low international coal prices
- Relatively high shipping costs compared to international coal sources

Powder River Basin coal is exported primarily through the Pacific Northwest to Asia, with a small amount exported to Europe (Table 2-5).

Table 2-5. Powder River Basin Coal Exports by Terminal of Departure (2012)

Terminal	Destination	Coal Exports (million short tons per year)
Westshore (Vancouver, BC)[a]	Asia	4.5
Ridley (Prince Rupert, BC)[b]	Asia	2.2
New Orleans and Texas Gulf Coast[c,d]	Asia	2.0
Duluth (Superior, WI)[c,d]	Europe	1.5
Total		**10.2**

Notes:
[a] Westshore Terminals Investment Corporation 2012
[b] IHS McCloskey 2013a
[c] U.S. Securities and Exchange Commission 2012a
[d] U.S. Securities and Exchange Commission 2012b

2.4.2 Uinta Basin

The Uinta Basin consists of coal deposits in Utah and northwestern Colorado, and is part of the broader Rocky Mountain coal production area. In total, the basin covers 14,450 square miles. Over the last 20 years (1996 to 2015), Utah has produced an average of 22.8 million short tons of coal, although production in the last 3 years has fallen to between 17.9 and 14.4 million short tons. The Colorado portion of the Uinta Basin has had average production over the last 20 years of 29.6 million short tons, with production in the last 3 years ranging between 23.5 and 18.1 million short tons (Mine Safety and Health Administration 2016).[8] The coal from this region is bituminous and ideal for energy production, and stays primarily within Colorado and Utah. On average between 2010 and 2015, 72% of Uinta basin coal has been consumed in Colorado and Utah. However, Uinta Basin Coal is also consumed in states to the east, including Alabama, Illinois, Kentucky, Mississippi, and Tennessee[9]. Table 2-6 shows the average annual deliveries of Uinta Basin coal by region.

Table 2-6. Average Annual Deliveries of Uinta Basin Coal by Region[a]

Region	Colorado Uinta Coal (million short tons per year)	Utah Coal (million short tons per year)	Total (million short tons per year)	Colorado Uinta Coal (%)	Utah Coal (%)
Central United States	5.70	0.21	5.91	32	1
Mid-Atlantic	0.07	0	0.07	0	0
Rockies	9.96	12.37	22.34	56	84
Southeast	1.45	0.13	1.58	8	1
Southwest	0.13	0	0.13	1	0
West	0.41	2.06	2.47	2	14
Total	**17.73**	**14.77**	**32.50**	**100**	**100**

Notes:
[a] Domestic deliveries average 2010–2014 data from U.S. Energy Information Administration 923
Source: U.S. Energy Information Administration 2016b

[8] MSHA Part 50 data.
[9] EIA 923 data 2010 through 2015.

2.5 Pacific Northwest Export Terminals

The main operating coal export terminals on the west coast are in Vancouver and Prince Rupert (British Columbia, Canada). These terminals have limited capacity for additional overseas export of U.S. coal in spite of recently completed and proposed capacity expansions. Existing coal traffic from Canadian mines already consumes most of the Canadian terminal capacity (Westshore Terminals 2013). Increased coal terminal capacity in the United States or Canada is foreseeable because several companies in addition to the Applicant, such as Teck Coal and SSA Marine, have recently proposed several new terminals for construction on the west coast and have begun environmental reviews or permitting processes.

2.5.1 Existing Pacific Northwest Terminals

There are three existing terminals and three proposed terminals in the Pacific Northwest through which U.S. coal could be exported. The existing coal export terminals are in British Columbia, Canada, and include Westshore Terminal, Neptune Terminal, and Ridley Terminal. The Westshore and Neptune Terminals are located near Vancouver, while the Ridley Terminal is located at Prince Rupert, which is approximately 1,400 rail miles north of Vancouver.

2.5.1.1 Westshore Terminal

The Westshore Terminal is located at Roberts Bank, British Columbia, less than 1 mile north of the U.S. border. The BNSF Railway Company (BNSF), Canadian Pacific (CP), and Canadian National (CN) railroads serve this terminal. Westshore is one of the largest coal export terminals in North America and serves both Canadian and U.S. coal producers with a capacity of 36.3 million short tons per year.

2.5.1.2 Neptune Terminal

The Neptune Terminal is owned by Canadian coal company Teck Coal and is served by the BNSF, CP, and CN railroads. Neptune's export capacity is 13.2 million short tons per year. Teck Coal plans to expand the Neptune Terminal capacity by an additional 6.6 million short tons per year, with an expected online date of 2020 (Teck Resources Limited 2016). Historically, Neptune Terminal has only shipped metallurgical coal.

2.5.1.3 Ridley Terminal

The Ridley Terminal, located in Prince Rupert, British Columbia, is served by the CN railroad, and has a capacity of 19.8 million short tons per year. Ridley Terminal primarily handles coal from mines in northern British Columbia, although a few million short tons of coal from the Powder River Basin have shipped through this terminal since 2008. Several Powder River Basin coal producers, such as Arch Coal and Cloud Peak Energy, signed 5-year contracts to ship coal through Ridley Terminal. The contracts expired in 2015 and the government-owned terminal is expected to handle only Canadian coal from 2016 onward (Arch Coal 2011, de Place and MacRae 2012).[10] It is also significantly more expensive to ship Powder River Basin or other U.S. coal through Ridley Terminal compared to current or proposed terminals in Washington, Oregon, or Vancouver, British Columbia. Despite having 10% shorter shipping distance to Asia, Ridley Terminal has a rail distance that is about 100%

[10] Arch Coal's agreement with Ridley Terminal to export up to 2.5 million metric tons per year through 2015.

longer than other terminals.[11] At current rail and shipping costs, the overall transportation cost from the Powder River Basin to Asia is higher through Ridley Terminal than through the Westshore Terminal. Due to the current unfavorable market conditions, the planned expansion at Ridley Terminal is modeled as coming online in 2020.

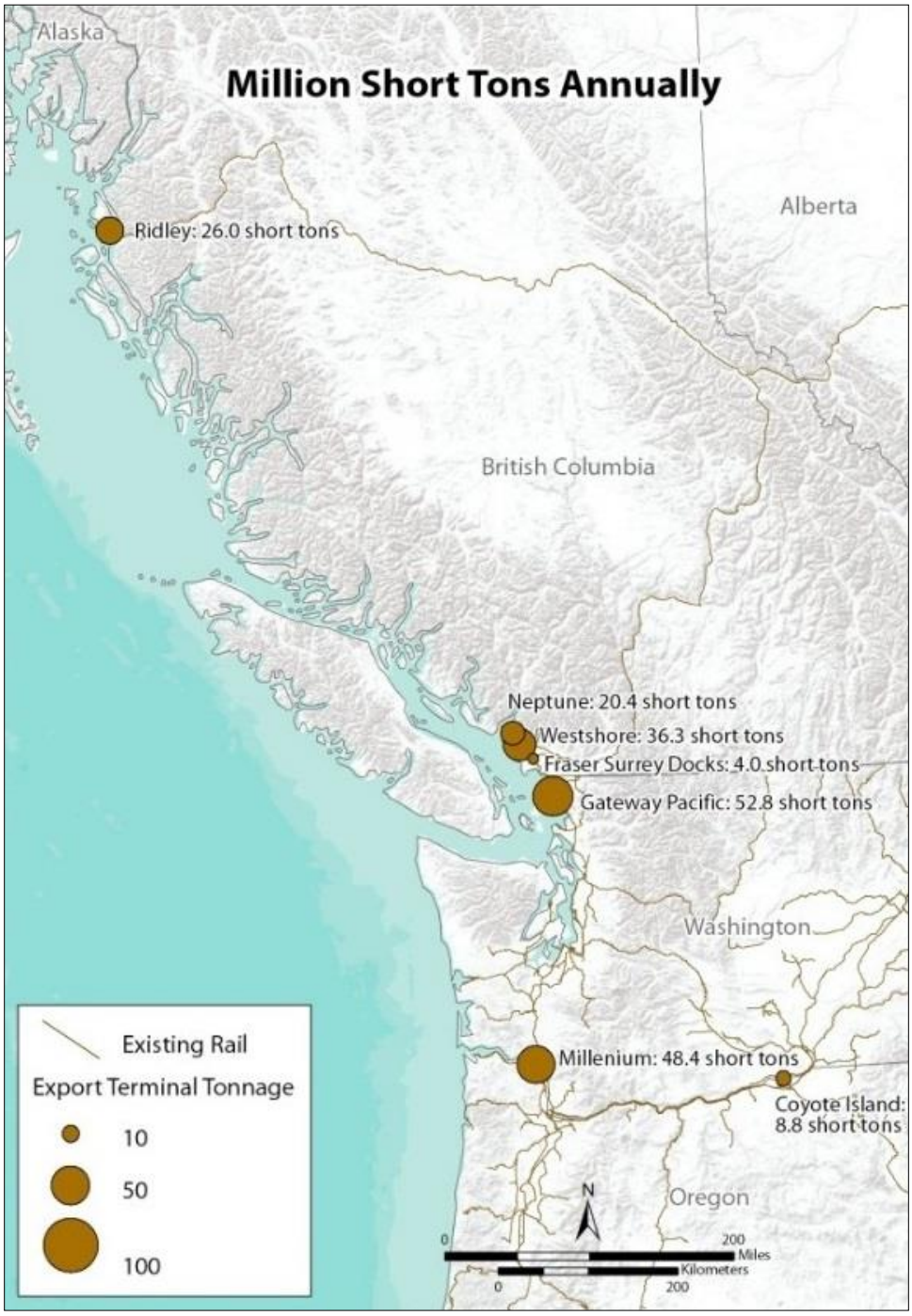
2.5.2 Planned Pacific Northwest Export Terminals

Three new coal export terminals are proposed in Washington and British Columbia that could provide additional capacity for Powder River Basin and other U.S. coal exports.[12] Figure 2-7 shows the export capacities of these terminals. Two of the proposed terminal projects are in Washington State.

[11] Cloud Peak states that the rail distance from their Powder River Basin mines to Ridley is over 2,600 miles and can require up to three different rail carriers (Cloud Peak Energy 2013).

[12] On October 16, 2016, Lighthouse Resources, Inc. announced as a result of the capability to ship coal through Westshore Terminals in Canada, they will exit the Coyote Island Project and will no longer pursue its appeal of the Oregon Department of State Lands permit opinion in 2014.

Figure 2-7. Existing and Planned Coal Export Terminals



2.5.2.1 Gateway Pacific Terminal

The proposed Gateway Pacific Terminal at Cherry Point, Washington, would handle bulk commodities such as coal. The proposed terminal is served by BNSF and has a planned capacity of

52.8 million short tons of coal per year. One advantage of this proposed terminal would be that it could load capesize vessels, which provide a cost advantage over smaller Panamax vessels.[13]

2.5.2.2 Millennium Bulk Terminals—Longview

This is the Proposed Action discussed in this technical report and described in Chapter 1, *Introduction*. The Applicant operates an existing bulk product terminal on the Columbia River in Cowlitz County. Plans include adding infrastructure to unload coal from trains and move it to storage and then to ships. The terminal is served by the BNSF and UP railroads. The terminal can load up to Panamax size vessels, with no plans to modify the port to handle larger vessels.

2.5.2.3 Fraser Surrey Docks

Fraser Surrey Docks, at Vancouver, British Columbia, has applied for a permit to construct a coal transfer facility of 4.4 million short tons per year of capacity. The BNSF railroad would serve this facility. On August 21, 2014, Port Metro Vancouver granted a Project Permit for the terminal's Direct Coal Transfer Project (Port Metro Vancouver 2014). The terminal was scheduled to begin operations in late 2015; however, the project has been delayed and the new online date is uncertain. For purposes of this analysis the terminal is assumed to come online in 2020.

2.5.3 Export Routing

The coal that would most likely be exported out of the proposed Pacific Northwest terminals is from the Powder River Basin, as most other coal basins are farther away or have other export options, such as terminals on the Atlantic or Gulf coast. The one exception is the Uinta Basin that might be competitive through the proposed coal export terminal. The transportation costs were estimated for coal exports through the proposed terminal and the other existing and planned Pacific Northwest terminals.

Tables 2-7 and 2-8 show the details of the cost calculations for transporting coal to Japan from the Powder River Basin through the two most economically viable options, which would be the Proposed Action and the Vancouver, British Columbia, area terminals. This analysis focuses on Asia because it is the fastest growing market for steam coals, and Japan is an example of an Asian movement. Japan was selected for the model to illustrate the total transportation costs, because it has historically imported more coal than any other Asian country, and is one possible destination for coal exports through the proposed terminal. Powder River Basin coal exports to other countries, such as China, South Korea, or Taiwan, would be similar, except that the shipping distances would be longer by 140 to 1,100 miles.

[13] *Capesize* vessels are cargo ships capable of carrying approximately 150,000 metric tons. *Panamax* vessels are smaller and can carry approximately 75,000 metric tons. The Gateway Pacific Terminal would be able to load the larger, capesize vessels because of its deeper waters.

Table 2-7. Estimated Powder River Basin Rail and Ship Export Costs—Pacific Northwest Exports

Powder River Basin Export Routes	Rail Distance (miles)	Rail Rate with fuel surcharge ($/ton-mile)	Total Rail Cost (2012$/ton)[a]	Ship Distance (nautical miles)	Ship Rate ($/ton-nautical mile)	Total Ship Cost via Panamax ($/ton)[b]	Port Fee ($/ton)	Total Transportation Cost ($/ton)
Montana to Japan via Proposed Coal Export Terminal	1,231	$0.0249	$30.65	4,402	$0.0027	$11.88	$11.00	$53.53
Montana to Japan via Vancouver	1,357	$0.0249	$33.79	4,328	$0.0027	$11.69	$11.00	$56.48
Wyoming 8800 Btu/lb to Japan via Proposed Coal Export Terminal	1,360	$0.0249	$33.86	4,402	$0.0027	$11.88	$11.00	$56.74
Wyoming 8800 Btu/lb to Japan via Vancouver	1,483	$0.0249	$36.93	4,328	$0.0027	$11.69	$11.00	$59.62

Notes:

[a] Includes fixed rail cost of $1.50/short ton.

[b] Includes transfer cost of $1.50/short ton.

PNW = Pacific Northwest; Btu/lb = British thermal units per pound

Source: ICF estimates and calculations. Rail distances obtained from BNSF website (http://www.bnsf.com/bnsf.was6/RailMiles/RMCentralController). Shipping distances obtained from SeaRates.com.

Table 2-8. Estimated Powder River Basin Delivered Coal Costs—Pacific Northwest Exports

Powder River Basin Export Routes	Total Transportation Cost ($/ton)[a]	Illustrative Minemouth Price ($/ton)[b]	Total Delivered Cost ($/ton)	Heat Content (MMBtu /ton)	Delivered Cost to Japan ($/MMBtu)
Montana to Japan via Proposed Coal Export Terminal	$53.53	$16.00	$69.53	18.6[c]	$3.74
Montana to Japan via Vancouver	$56.48	$167.00	$72.48	18.6[c]	$3.90
Wyoming 8800 Btu/lb to Japan via Proposed Coal Export Terminal	$56.74	$12.00	$68.74	17.6	$3.91
Wyoming 8800 Btu/lb to Japan via Vancouver	$59.62	$12.00	$71.62	17.6	$4.07

Notes:

[a] Transportation costs are derived in Table 2-7.

[b] Actual minemouth prices will differ by year for the various Powder River Basin coals; $16/ton approximates the Montana Powder River Basin 9,300 Btu/lb coal prices expected in 2016, and $13/ton approximates Powder River Basin Wyoming 8,800 Btu/lb coal prices expected in 2016.

[c] Spring Creek heat content is 9,300 Btu/lb; this is taken as the illustrative existing Montana coal's heat content.

MMBtu = million British thermal units; Btu = British thermal units

Source: ICF estimates.

The existing and proposed Pacific Northwest terminals, not including Ridley Terminal, have the following advantages and characteristics.

- **Shortest export route to Asia.** Shipping distances to Japan from the Pacific Northwest are approximately half the distance from the U.S. Gulf Coast.
- **Lowest-cost export.** There is an ocean freight cost advantage to Asia via the Pacific Northwest as compared to Gulf Coast or California originating exports.
- **Historically used for Powder River Basin shipments**. Historically, Powder River Basin exports have been shipped primarily via Pacific Northwest terminals, supporting the conclusion that this export route is most economical for Powder River Basin coal.

Lastly, as Table 2-8 shows, the delivered costs to Japan via the existing and proposed Pacific Northwest terminals are similar for all Powder River Basin coals. Relatively small changes in production costs or parts of the transportation cost could affect the export prospects of any of the Powder River Basin coals. It may be more economical to export certain Powder River Basin coals to Asia and transport others to domestic locations, as determined by the variables of location, markets, transportation facilities, and heat content of the coal.

Chapter 3
International Coal Markets

3.1 International Coal Demand

As described in Chapter 2, Section 2.3, *Coal Distribution*, only about 2% of Powder River Basin coal is exported to international markets. This chapter discusses this market.

3.1.1 Major Importing and Exporting Countries

The top five global coal-importing countries (Japan, China, South Korea, India, and Taiwan) are located in Asia and together they accounted for 63% of total coal imports globally in 2014. In Europe, while total coal imports have not bounced back to pre-recession levels last seen in 2007, they grew by about 8% from 2009 to 2012. A greater percentage of European coal imports came from the United States over this period, with U.S. coal exports to Europe approximately doubling in just four years. Table 3-1 provides the top coal countries for coal imports in 2014.

Some of the top importers rely heavily on coal imports to meet their consumption. For example, Japan, South Korea, and Taiwan import all of their coal, whereas China and India have significant domestic production and could reduce imports if coal prices increase.

Table 3-1. Top International Coal Importers in Million Short Tons (2014)

Rank	Country	Total Coal Import	Total Coal Consumption	Import (%) of Consumption
1	China	321.0	4,539.7	7.1%
2	Japan	206.9	210.6	98.2%
3	India	203.8	880.2	23.2%
4	Korea, South	144.3	144.4	99.9%
5	Taiwan	74.0	71.8	103.1%
6	Germany	62.9	264.6	23.8%
7	United Kingdom	46.0	53.5	86.0%
8	Turkey	29.6	100.4	29.5%
9	Russia	27.9	242.9	11.5%
10	Brazil	23.9	30.1	79.4%
11	Malaysia	23.5	29.3	80.2%
12	Thailand	23.0	39.7	57.9%
Total Coal Imports		**1,186.8**		

Source: U.S. Energy Information Administration 2016g

The top coal exporters are Indonesia and Australia, together accounting for nearly 54% of the total coal exports in 2012 (Table 3-2). In Australia, companies and port owners propose to construct and expand export terminals, which would triple export capacity from 490 to 1,420 million metric tons per year (Yang and Cui 2012).

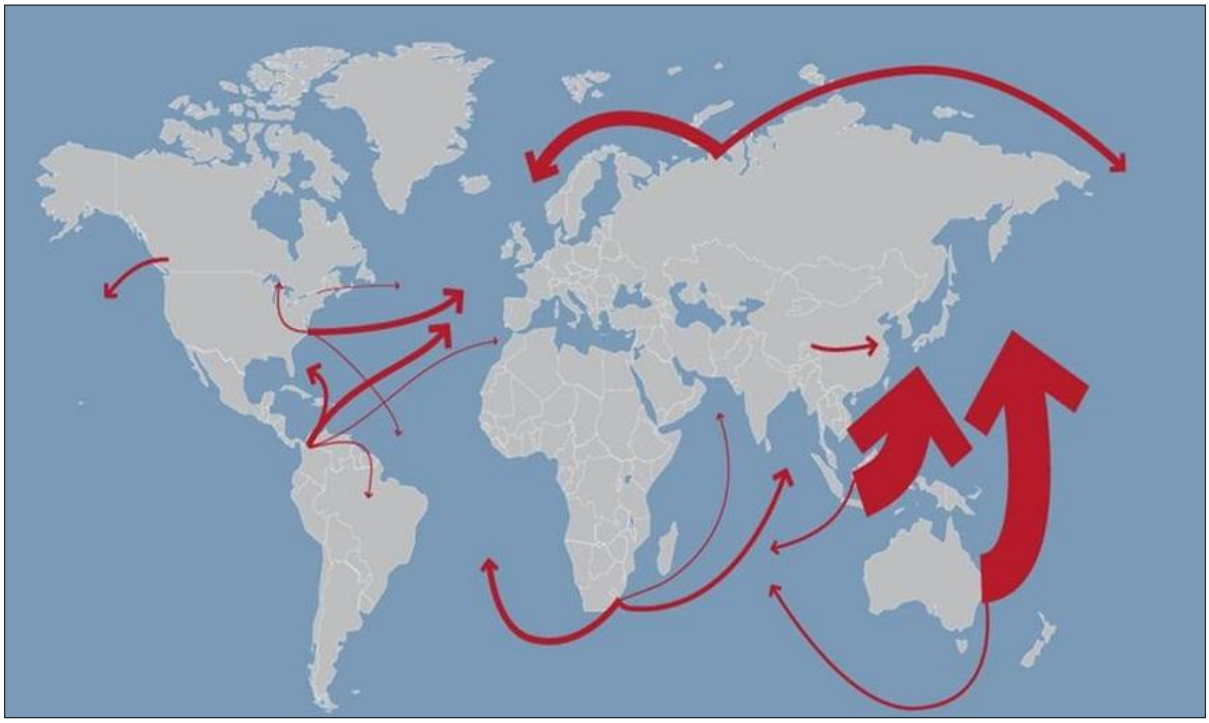
Table 3-2. Top International Coal Exporters in Million Short Tons (2014)

Rank	Country	Total Coal Export	Total Coal Production	Export (%) of Production
1	Indonesia	449.9	518.7	86.7%
2	Australia	387.3	553.3	70.0%
3	Russia	171.4	393.8	43.5%
4	United States	97.3	1,000.0	9.7%
5	Colombia	96.0	97.6	98.3%
6	South Africa	86.1	288.1	29.9%
7	Canada	38.0	74.6	50.9%
8	Kazakhstan	33.0	127.3	25.9%
9	Mongolia	20.7	34.0	61.0%
10	Korea, North	17.2	45.2	38.0%
11	Poland	10.1	150.4	6.7%
12	Vietnam	8.0	39.4	20.3%
Total Coal Exports		**1,414.9**		

Source: U.S. Energy Information Administration 2016g

In summary, the largest markets in Asia are served primarily by the largest exporters in Asia, Australia, and Indonesia (Figure 3-1). Recent Asian coal trade is comparable to the flows presented for 2009. While the Asian market is expected to grow, so is the competition between a few large suppliers.

Figure 3-1. Indonesia and Australia Dominate Asian Coal Markets



Source: Alpha Natural Resources 2010.

While Japan has historically been the largest importer of coal worldwide, India and China surpassed Japan in 2013. The economies in India and China are projected to continue to grow, adding to the demand for energy resources in the Indo-Pacific region. Coal continues to be the fuel of choice to meet burgeoning demand in these growing countries; however, planned coal additions and construction have slowed significantly since 2012. In 2015, India and China had plans to increase coal capacity by nearly 800 gigawatts, down from 1,100 gigawatts in 2012 (Shearer et al. 2015). China's 13th 5-year plan, released in November 2016, shows that China plans to limit coal plant additions such that the total coal-fired capacity remains less than 1,100 gigawatts by 2020. In 2015 China had about 900 gigawatts of coal-fired capacity. Japan, South Korea, and Taiwan lack significant domestic thermal coal reserves and have been key importers in the Asian steam coal import market. Both India and China will likely continue or increase their consumption of coal going forward.

The following sections address market conditions in the top two coal-importing nations, which are expected to remain the top importing countries for the next 10 years: Japan and China. The next three top importers—South Korea, India, and Taiwan—are expected to have flat to increasing imports, with South Korea generally flat and Taiwan increasing slowly, while coal imports to India are expected to grow more rapidly as large amounts of new electrical generating capacity comes online.

3.1.2 Asian Focus

China, Japan, South Korea, and Taiwan have historically been the world's primary importers of coal. The following provides an overview of their coal consumption and recent import level trends.

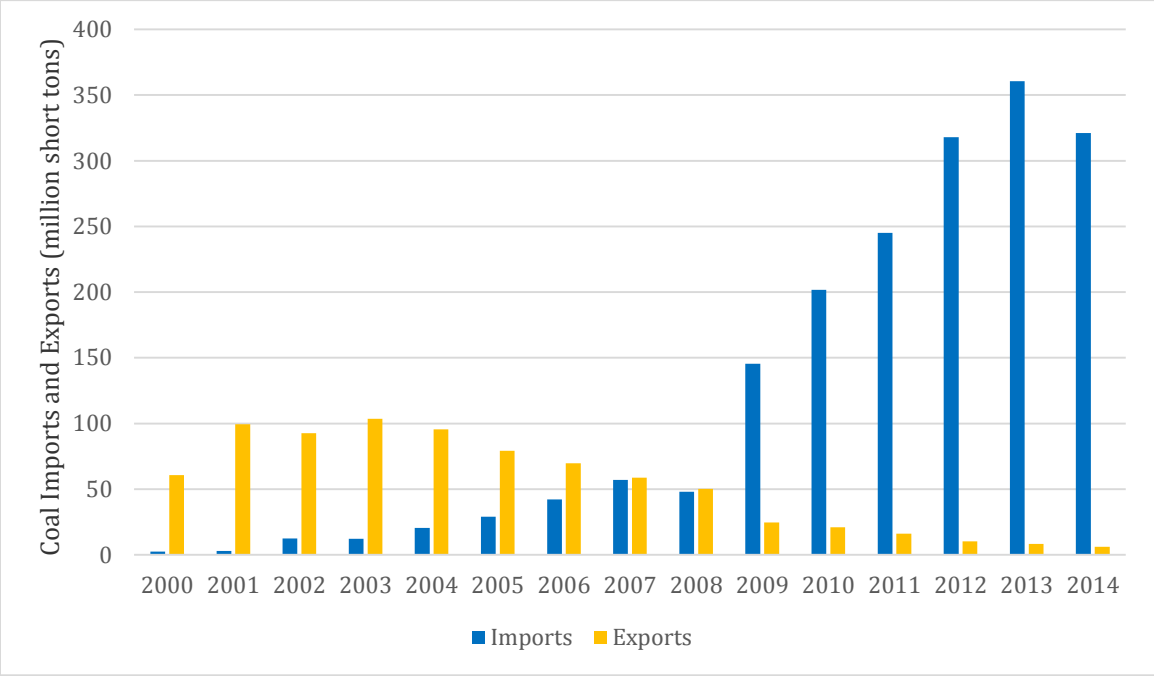
3.1.2.1 China

China is the world's largest coal producer and consumer. China's coal demand, driven by power generation and industrial uses, increased by an average of 8.44% annually from 2001 to 2012. For comparison, coal demand outside of China increased at an average of 3.8% per year (U.S. Energy Information Administration 2013a). However, coal consumption in China and across the globe actually slipped in 2012 by about 1.7% and 1.2%, respectively. As of 2012, China's coal consumption accounted for 47% of global coal consumption at about 3.9 billion tons annually—almost as much as the entire rest of the world combined (U.S. Energy Information Administration 2013b). China's demand for coal is expected to grow in the future. Although current policy changes in China will reduce the growth rate of coal consumption and the share of coal used for generating electricity, the absolute amount of coal consumed is expected to continue to increase at least through 2030, and possibly through 2040, depending on the policy alternatives (International Energy Agency World Energy Outlook 2015). To meet growing electric demand, China is planning for new installed coal capacity to peak at 1,100 gigawatts by 2020 (China's 13th 5 Year Plan). To meet growing electric demand, China is considering proposals for new installed coal capacity of 496 gigawatts (Shearer et al. 2015). For comparison, as of the end of 2015, the total capacity for all coal-fired power plants in the United States was 280 gigawatts, with nearly 18 additional gigawatts of retirements expected by the end of 2016 (SNL Energy 2015). With its vast domestic coal resources, China has historically been a coal exporter. However, China's coal imports exceeded exports for the first time in 2009 (Figure 3-2). In 2012, China imported 318 million short tons of coal, or approximately 8% of total Chinese coal consumption.[14] Chinese coal imports peaked in 2013 and fell in 2014, illustrating the

[14] For reference, 200 million tons is about 45% of recent annual coal production from the Powder River Basin, and about 10 times the permitted annual production of 20 million tons from the Otter Creek Mine.

dynamic nature of the global coal market. Climate policy developments and China's commitments at the Conference of the Parties meeting in Paris in December 2015 will likely result in Chinese coal consumption for power generation growing at 5.8% per year over the next 20 years before starting a slow decline, as projected in the International Energy Agency (IEA) 2015 World Energy Outlook (WEO) New Policies Scenario for China.

Figure 3-2. China's Coal Imports and Exports, 2000–2014 (million short tons)



Source: U.S. Energy Information Administration 2016g.

While analysts expected China's reliance on imports to increase through 2015, Chinese coal imports have actually fallen since peaking in 2013. Weaker economic growth has led to lower coal consumption, while a governmental emphasis on reducing the energy intensity of their economy and lowering air pollution are both compounding factors as well. In response, the government has protected domestic industry and prioritized domestic coal consumption. These measures resulted in a Chinese import tariff of 6% for thermal coal as of October 2014 (The Guardian 2015; Sustainable Enterprises Media 2014).

China has made progress in addressing a number of issues that might have required it to import more coal, and will allow China greater flexibility in sourcing the lowest cost coal in the future (Hook 2011).

- **Transportation bottlenecks.** Mining activity in China has shifted farther north and west, away from the south and eastern coastal cities where many coal-fired power plants are located and the demand for electricity is greatest. The coal must be transported from remote northwest locations, where there is limited demand for electricity, to the northeast ports, where it is shipped to the southern ports for domestic consumption. China has made extensive progress in addressing transportation bottlenecks over the last 5 years, which has reduced the reliance on imported coal.

- **Mine safety.** China produces coal primarily from underground coal mines. The methane concentrations in China's underground mines are responsible for a high number of fatalities, relative to fatalities in U.S. underground mines on a per ton basis. In 2012, the overall death rate in China's coal mines was 0.374 deaths per million short tons of coal production. In contrast, the death rate in the United States was around 0.035 deaths per million short tons of coal production. By closing smaller poorly run mines and through consolidation, China expects to lower overall mining fatalities per ton of coal produced (China Labour Bulletin 2013; Mine Safety and Health Administration 2016).

- **Mine consolidation.** The Chinese government has been consolidating small, private mines into a few large state-owned mines. Initially, consolidation causes coal production to fall dramatically as mines are closed temporarily to retrofit them with additional safety measures (Hook 2011). This consolidation process is well under way and most mines are back to full production.

3.1.2.2 Japan

Japan was the world's largest coal importer through 2010; however, after 2010, China became the world's largest coal importer. Japan imported an average of 193.5 million short tons of coal per year between 2000 and 2012 (U.S. Energy Information Administration 2011). Without domestic steam coal resources, Japan relies heavily on imports to satisfy domestic coal demands. Several factors may drive an increase in Japan's coal consumption and imports in the future.

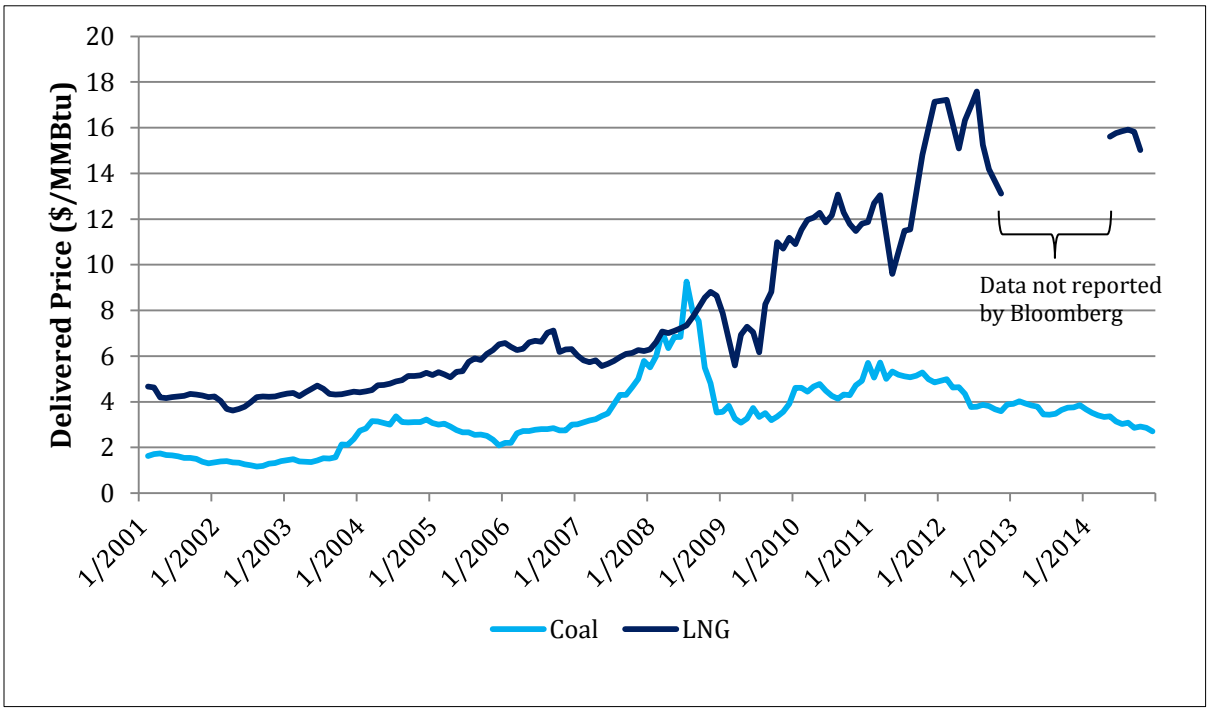
- **Uncertain future for nuclear energy.** The earthquake and tidal wave of March 2011 caused cataclysmic damage at the Fukushima nuclear power plant, precipitating the shutdown of 48 of Japan's 50 nuclear reactors, leaving only two reactors at the Oi nuclear plant in operation (Westlake 2012). Oi Units 3 and 4 ran through 2013, when they were shut down for maintenance and then ordered not to restart (World Nuclear Association 2016). Nuclear energy had previously supplied about 30% of the country's electricity needs, a percentage that, prior to the damage, had been expected to increase to 40% by 2017 and 50% by 2030 (World Nuclear Association 2016). Now the government of Japan is hoping for nuclear to supply 20-22 % of the country's electricity needs by 2030 (The Economist 2016). Since the shutdown of Japan's nuclear reactors, five nuclear reactors have been approved by Japan's Nuclear Regulation Authority to restart operations (Slater-Thompson 2016). Sendai Units 1 and 2 have restarted in August and October 2015, and Ikata Unit 3 in August 2016 (Slater-Thompson 2016). Takahama Units 3 and 4 were restarted in February and March 2016, but forced to shut down after a court injunction (World Nuclear Association 2016). Japan's Institute of Energy Economics has estimated that seven nuclear reactors could restart by March 2017, with 12 more restarting by March 2018 (World Nuclear Association 2016).

- **Relative expense of liquefied natural gas.** Coal has historically been significantly cheaper than liquefied natural gas at generally about half price per unit of energy (Figure 3-3). Much of the recent rush to build U.S. liquefied natural gas export terminals is targeted at exporting gas to Asian countries such as Japan (the world's largest liquefied natural gas importer) to take advantage of the significantly higher natural gas prices in Asia.

- **Renewed government commitment to coal energy.** After withholding approval of all but two proposed coal-fired power plants since 2006, Japan's Ministry of Environment recently lifted a virtual ban on the construction of new coal plants, provided they are equipped with the cleanest

and best technologies. This development is motivated by the economic need to diversify energy resources rather than by environmental or safety considerations (Iwata 2013).

Figure 3-3. Delivered Coal versus Natural Gas Prices to Japan ($/MMBtu)



Source: McCloskey and LNG Japan Corporation data from Bloomberg 2015

3.1.2.3 South Korea

South Korea is one of the top energy importers in the world, relying on fuel imports for about 97% of its energy demand due to lack of domestic fuel resources. In 2013 and 2014, the country was the fourth-largest importer of coal (U.S. Energy Information Administration 2016g). Australia and Indonesia account for the majority of South Korea's coal imports, followed by Russia, Canada, the United States, and China (UN Comtrade 2017). Between 2005 and 2014 coal consumption in South Korea increased by 54.5%. This rise was driven primarily by growing demand from the electric power sector. The electric power sector accounts for 62% of the country's coal consumption, while the industrial sector accounts for most of the remaining amount (U.S Energy Information Administration 2016g).

3.1.2.4 Taiwan

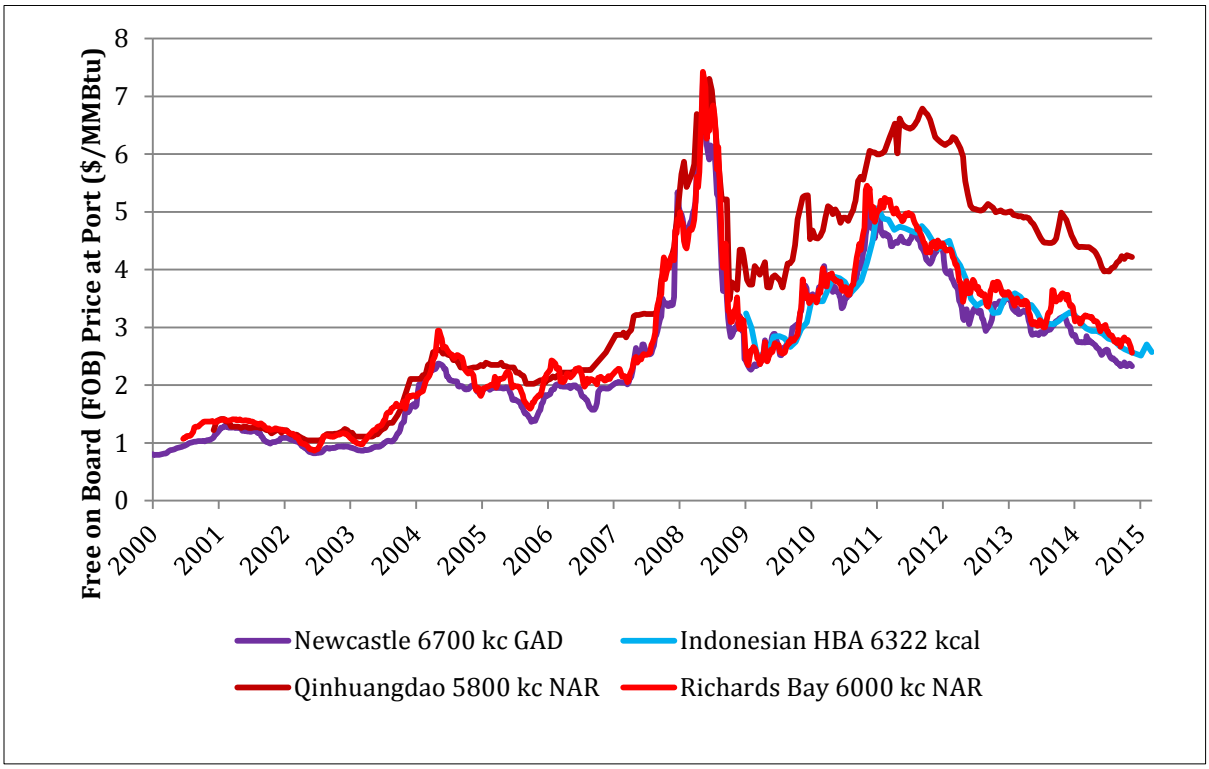
Oil and coal made up 41% and 34% of Taiwan's total primary energy consumption in 2013, respectively, while the remainder was mostly natural gas, nuclear, and smaller amounts of various renewable energy sources. Due to its very limited domestic energy resources, Taiwan imports a large percentage of coal and oil. Taiwan consumed about 72 million short tons of coal in 2014, all of which was imported (U.S. Energy Information Agency 2016g). Coal consumption steadily increased overall since the 1990s and slowed after 2008 because of natural gas and renewables substituting some coal supply in the power sector.

3.1.3 Coal Prices

3.1.3.1 Free On Board Prices

Free on board (FOB) terminal prices refer to the aggregate price of the coal, insurance, loading, transportation to the terminal, and documentation costs, typically paid by the seller. Figure 3-4 shows FOB prices at the supply country's terminal, expressed as price per energy unit ($/MMBtu) to account for coals with different heat content. Key players in the Asian steam coal export market shown in Figure 3-5 include Australia (Newcastle), Indonesia (HBA), China (Qinhuangdao), and South Africa (Richards Bay). The coal prices in Figure 3-5 are not adjusted for the coal moisture content because coals are reported as gross air-dried, gross as received, and net as received.[15]

Figure 3-4. Historical Asian Free On Board Steam Coal Prices



Source: McCloskey, Platts, Indonesia Coal Index, and Newcastle Export Index data from Bloomberg 2015

Trends in FOB costs are relatively consistent across supply ports, with the exception of China's Qinhuangdao prices, which were noticeably higher from late 2008 to 2015. This gap in prices further illustrates demand for lower-cost coal imports in China, although there are non-market effects affecting Chinese prices as well. The most recent peak in prices was in early 2011 at about $5/MMBtu. Since then international coal prices have dropped by 50% to around $2.5/MMBtu. Powder River Basin coal shipped through Vancouver, British Columbia or other Pacific Northwest

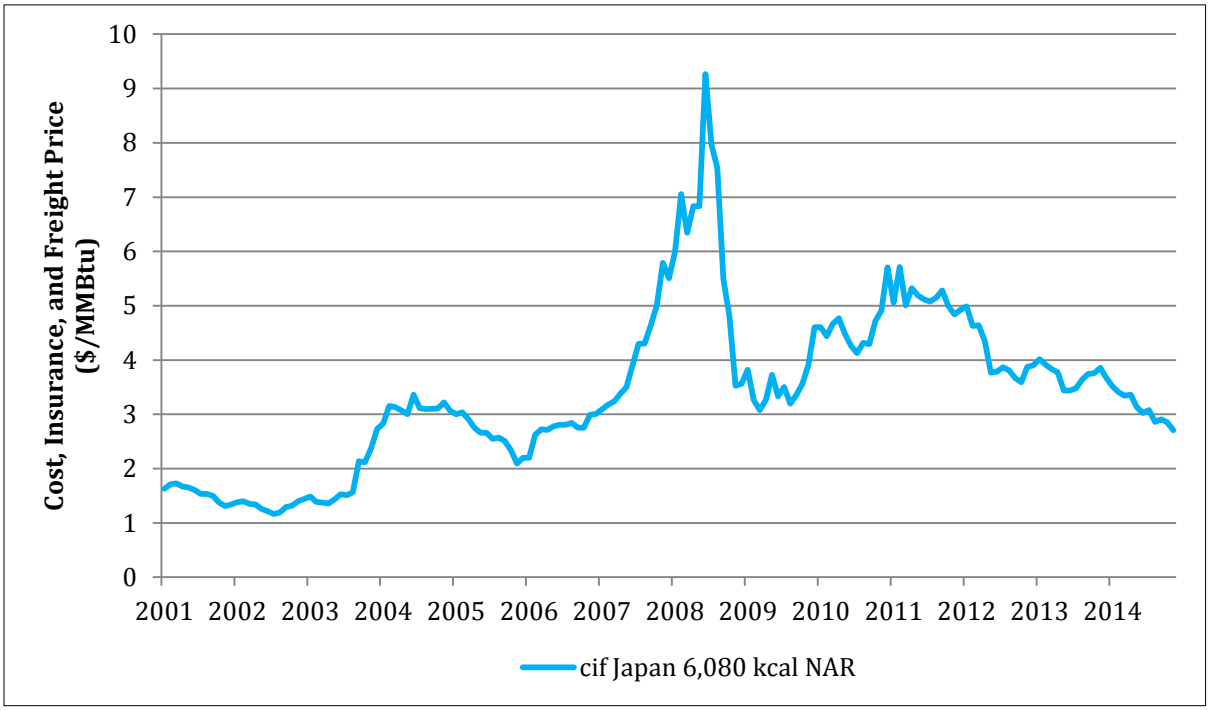
[15] Definitions and conversions can be found at World Coal Association, Coal Conversion Statistics (http://www.worldcoal.org/resources/coal-statistics/coal-conversion-statistics).

ports would have an FOB cost of close to $2.9/MMBtu in 2015, making it somewhat higher than the Asian 2015 coal prices.

3.1.3.2 Delivered Coal Prices to Japan

Delivered coal prices to Japan include the costs of coal, freight, and insurance. These prices are summarized using IHS McCloskey's Japan index benchmarks (IHS McCloskey 2013b), which show delivered prices at the terminal of delivery.[16] Prices ranged from $2.7 to $5.7/MMBtu from their peak in early 2011 through 2014 (Figure 3-5). Delivered prices to Japan in the range of $3.0/MMBtu suggest that Powder River Basin coal would have a difficult time being cost-competitive, if shipped through the Pacific Northwest to Japan or other Asian countries, until international coal prices increase.

Figure 3-5. Asian Steam Coal Prices—Japan



Source: McCloskey data from Bloomberg 2015

[16] IHS McCloskey is a company that provides benchmark coal prices that can be accessed through Bloomberg.

Chapter 4
Model Framework, Methods, and Key Assumptions

IPM® was used to assess likely coal production, consumption, and distribution patterns resulting from development of the proposed coal export terminal. The impacts of economic and regulatory uncertainties on these outcomes were also examined, through the analysis of three scenarios.

This chapter provides an overview of the IPM® framework, the key assumptions for running the model, and the specific methods used in its analysis.

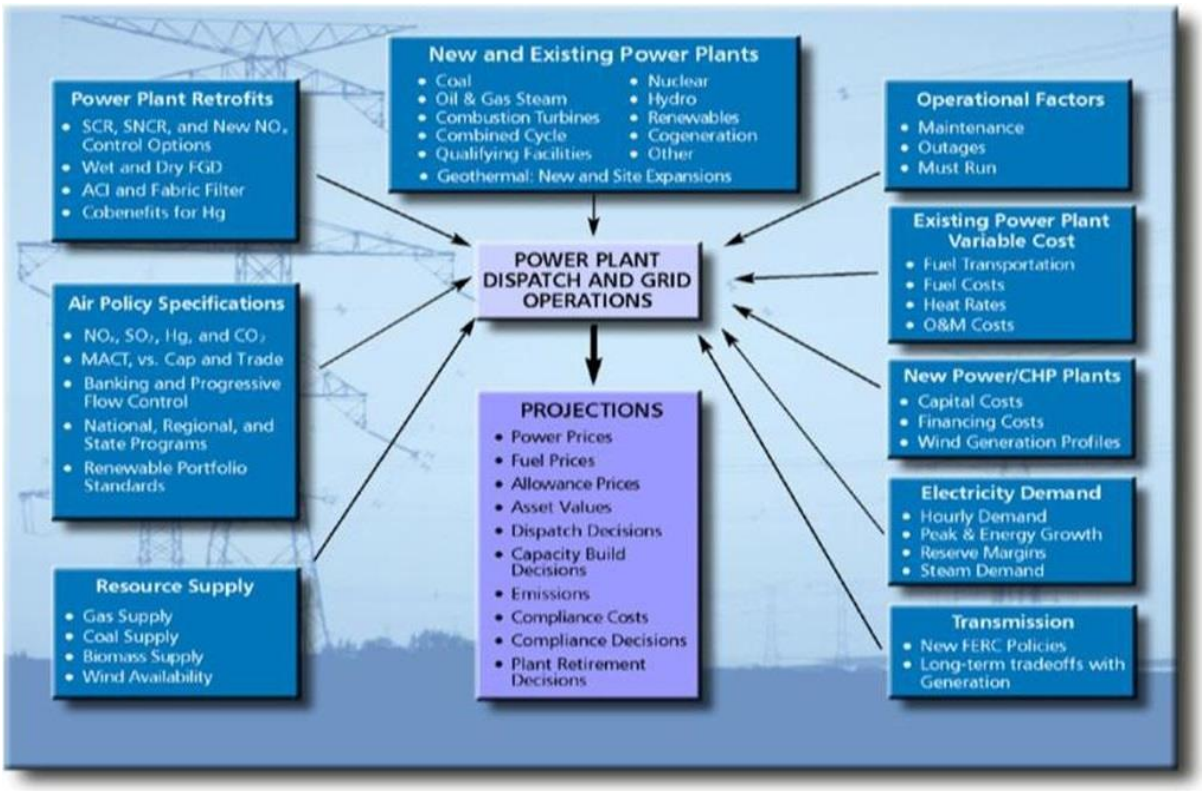
4.1 IPM® Overview and Model Framework

IPM® is an engineering and economic model of the coal and power sectors, supported by an extensive database of coal and power parameters. The model has the ability to add new electricity-generating capacity in response to demand growth and policies, such as renewable portfolio standards. It is widely used to assess domestic and international coal production, transportation, and consumption, and the operations and economics of the U.S. electric power industry. The model also characterizes the U.S. natural gas industry. IPM® is a multiregional model in terms of electricity demand regions, fuel demand regions, and coal supply regions that provides detailed results on a plant, regional, or national level. ICF has maintained IPM® since the mid-1970s.

IPM® simultaneously analyzes the following energy sectors and the important interactions between them (Figure 4-1).

- The coal mining industry, including regional coal mine type and coal quality distinctions.
- Coal transportation sectors, such as rail, barge, and ship.
- The electric power generation sector, including regional and power-plant-type distinctions, and very detailed treatment of existing power plants, especially coal-fired units.
- The electricity consumption portion of the business, including hourly and seasonal variations in demand.
- The electricity transmission sectors and the alternatives available to local power production.
- Environmental regulations (national and state) affecting the power sector including CO_2 emissions limitations and renewable portfolio standards. The model also calculates emissions for each individual plant.
- Investment and long-term operational decisions such as coal power plant retirement, power plant mothballing, new power plant construction, existing coal mine operation, and new coal mine additions.
- Domestic and international coal deliveries and consumption.
- Interactions with the natural gas industry.

Figure 4-1. Integrated Planning Model (IPM®)



IPM® analyzes these markets and calculates competitive market prices based on supply and demand fundamentals. It forecasts the following wide range of parameters.

- Wholesale market power prices for each electricity demand region.
- Power plant dispatch.
- Fuel consumption and both delivered and coal minemouth or gas hub prices.
- Interregional transmission flows.
- Environmental emissions and associated costs.
- Capacity expansion and retirements.
- Retrofits based on an analysis of the engineering economic fundamentals.

The model does not extrapolate from historical conditions. Rather, it provides a least-cost forecast for a given set of current and future conditions that determine how the industry will function. The optimization routine that IPM® uses has dynamic effects—it looks ahead at future years and simultaneously evaluates decisions over an entire specified time horizon, typically 20 to 40 years.

IPM® uses a dynamic linear programming structure to model how electricity demand is met through a mix of generation and transmission in each region, as well as the transmission between

regions. The North American version[17] of IPM® is divided into 73 power demand regions that include nine Canadian provinces. The North American version of the model also includes international coal demand and coal supply regions to forecast global coal production and movement. Regions outside of the United States and Canada in the model are limited to coal supply and demand regions only. Thus, while the North American version of IPM® explicitly includes coal power plants that can have varying coal demand depending on other inputs, such as natural gas prices and environmental regulations, regions outside of the United States and Canada have coal demand represented by a static forecast.

4.1.1 IPM® Users and Documentation

IPM® is widely used, both in the United States and globally, by private sector companies such as electric utilities, coal power plant owners, coal companies, independent power producers, and financial institutions, and public sector entities, such as environmental groups and state public service commissions (Table 4-1).

Table 4-1. Private and Public Sector Entities Using IPM®

Private Sector Entities	Public Sector Entities
PEPCO	U.S. Environmental Protection Agency
Entergy	State public service commissions
Exelon	Environment Canada
Tucson Electric Power	European Union
Florida Power and Light	Environmental groups (e.g., Natural Resources Defense Council)
Dominion	
NRG Energy	
Delmarva Power	
Southwestern Electric Power Company	
Calpine	
APS	
Duke Energy	
American Electric Power	
Otter Tail Power Company	
Xcel Energy	
Dogwood Energy	
Peabody Energy	
Dynegy	

IPM® has been used in support of the following types of analyses.

- Coal price forecasts, including forecasts supporting litigation.
- Other coal industry forecasts, including production, transportation, and consumption.

[17] ICF has completed IPM® systems for Europe, Australia, Japan, China, Korea and India, among other nations.

- Air emissions compliance strategies for coal power plants and emissions allowance price forecasting.
- Impact assessments of alternate environmental regulatory standards including coal sector impacts.
- Assessments of power plant retirement decisions, such as for existing coal power plants.
- Valuation studies for generation and transmission assets, including coal power plant valuations.
- Forecasting of regional forward energy and capacity prices.
- Forecasting of state and regional renewable energy credits.
- Impact assessments of changes in fuel pricing.
- Integrated Resource Planning analyses.
- Economic or electricity demand growth analyses.
- Pricing impacts of demand responsiveness.

EPA uses IPM® to analyze the impact of air emissions policies on the U.S. electric power sector. As part of this analysis, EPA publishes its assumptions and other information regarding its use of IPM® on its website (U.S. Environmental Protection Agency 2013 and 2015). This documentation provides insight into EPA's assumptions, and as many EPA assumptions as possible were used by ICF in this analysis as described in more detail in Section 4.2.

4.2 Key Assumptions

In this use of IPM®, key assumptions were made regarding fuel; air, waste, and water regulations; renewable energy regulations; reserve margin targets; mothballing and retirement of existing power plants; and transmission. To the extent possible, assumptions from publicly available sources, such as the EIA, IEA, and EPA were used. The majority of assumptions were obtained from EPA's v5.15 IPM Base Case (U.S. Environmental Protection Agency 2015). The following subsections discuss the major assumptions used in this analysis.

4.2.1 Assumptions from Millennium Bulk Terminals—Longview

The following project-specific assumptions were provided by the Applicant.

- The proposed coal export terminal would export 44 million metric tons of coal per year.
- The proposed coal export terminal would begin operating in 2021 and ramp up to exporting 44 million metric tons of coal by 2028; however, the IPM analysis models the terminal exporting 44 million metric tons starting in 2025.

- Only Powder River Basin or Uinta Basin coal would be exported through the proposed coal export terminal.
- Destinations for the exported coal would include China, Hong Kong, Japan, South Korea, and Taiwan.

4.2.2 Fuel

Fuel-related assumptions include those concerning coal and natural gas production and demand are presented in this section.

4.2.2.1 Coal Supply Curves and Coal Prices

The coal supply curves are pairs of quantity and price data that are used to determine the coal production and price for each coal supply region and coal type in each model solution. Thus, similar to U.S. and Canadian coal demand, the amount of coal supplied by each coal supply region is a model output and not a model input. Thus in different scenarios, the amount of coal produced from each supply region may be different. While international coal demand is an input to the model, the source of the coal consumed in each international coal demand region is a model output that is based on the coal supply curves and transportation costs to deliver the coal to each coal demand region.

The coal supply curves are built using data primarily from the Mine Safety and Health Administration's (MSHA) Part 50 database, EIA data and company financial reports. The domestic coal curves are developed by determining characteristics of U.S. mines -- including coal types produced, mine productivity, annual production capacity and available reserves – as well as developing assumptions for potential new mines, such as: mining technology type, types of coal produced, coal mine productivity, annual production capacity and reserves available. Production costs are then calculated using ICF's CoalDOM Cost Model. Finally, coal supply curves are generated for each supply region and coal type for each year based on assumptions regarding changes in productivity over time.

The domestic and international coal supply curves go through somewhat different processes to develop the supply curves, due to the lack of adequate data from many countries. The process for developing international coal supply curves entails determining the coal types produced in each supply region, their annual production capacity, available reserves, production growth rates, and costs. The coal supply curves are generated for each supply region and coal type for each year based on assumptions regarding changes in productivity over time.

The coal prices that the coal supply curves (ICF 2017a) produce in each scenario are shown in Tables 4-2 through 4-10 for both domestic and international coal prices that are most directly affected by the proposed coal export terminal. The domestic coal prices in the following tables include Wyoming, Montana, Colorado, and Utah, which are regions from which coal might be exported through the proposed terminal. The international coal prices in the following tables include Australia and Indonesia, which are the two supply regions most likely to have coal displaced by the coal exported through the proposed coal export terminal, and which have the most price visibility in the market. The coal prices presented in Tables 4-2 to 4-10 represent the prices solved by the IPM® using the assumptions defining the No-Action or Proposed Action for each scenario.

Table 4-2. Coal Prices in the 2015 U.S. and International Energy Policy Scenario—No-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	62.5	62.8	63.1	63.9	64.7	66.3
Bull Mountain	BB	33.2	33.4	33.6	28.6	29.9	29.9
CO Uinta	BB	30.7	31.2	31.9	33.3	35.4	39.1
Indonesia	BA	70.9	72.0	73.0	71.5	74.1	79.8
Indonesia	BB	58.9	59.6	60.7	59.9	62.3	67.2
Indonesia	SA	50.3	50.8	51.9	51.3	52.0	53.3
Indonesia	SB	47.5	47.9	49.0	48.4	49.1	50.3
Indonesia	SD	42.1	42.3	43.1	43.1	43.6	44.7
MT Powder River Basin	SA	15.1	15.3	15.5	15.9	17.1	17.7
MT Powder River Basin	SD	13.8	14.0	14.1	14.5	14.7	15.3
WY 8400	SB	9.0	9.1	9.3	9.6	10.0	10.8
WY 8800	SA	10.7	10.9	11.1	11.5	11.9	12.8
Utah	BA	33.6	34.5	35.7	38.5	40.7	44.1
Utah	BE	34.0	34.8	36.2	38.9	42.7	47.4

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-3. Coal Prices in the 2015 U.S. and International Energy Policy Scenario—Proposed-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	62.5	62.8	63.1	63.9	64.7	66.3
Bull Mountain	BB	33.2	33.4	33.6	28.6	29.9	29.9
CO Uinta	BB	30.9	31.4	32.1	33.6	35.8	39.6
Indonesia	BA	70.9	72.0	73.0	71.5	74.1	79.8
Indonesia	BB	58.9	59.6	60.7	59.9	62.3	67.2
Indonesia	SA	50.3	50.8	51.9	51.3	52.0	53.3
Indonesia	SB	47.5	47.9	49.0	48.4	49.1	50.3
Indonesia	SD	42.1	42.3	43.1	43.1	43.6	44.7
MT Powder River Basin	SA	15.2	15.4	15.6	16.9	17.3	17.7
MT Powder River Basin	SD	13.9	14.1	14.3	14.7	15.0	15.6
WY 8400	SB	9.1	9.2	9.4	9.8	10.2	11.1
WY 8800	SA	10.8	11.0	11.2	11.6	12.1	13.2
Utah	BA	33.9	34.8	36.1	39.0	41.4	45.3
Utah	BE	34.3	35.1	36.6	39.4	43.5	48.5

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-4. Coal Prices in the Lower Bound Scenario—No-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	56.2	56.5	56.8	57.5	58.2	59.7
Bull Mountain	BB	32.7	28.9	29.2	30.2	31.2	31.1
CO Uinta	BB	35.6	36.2	36.6	37.7	39.2	42.4
Indonesia	BA	64.1	64.5	65.3	64.9	66.5	71.8
Indonesia	BB	53.0	53.3	54.1	54.1	60.7	62.3
Indonesia	SA	45.2	45.4	46.2	46.2	46.8	47.9
Indonesia	SB	42.6	42.8	43.6	43.6	44.1	45.3
Indonesia	SD	37.1	37.4	38.3	38.1	38.7	39.6
MT Powder River Basin	SA	18.2	17.3	17.8	18.7	19.6	22.2
MT Powder River Basin	SD	16.8	17.0	17.1	17.5	17.9	18.4
WY 8400	SB	10.6	10.7	10.9	11.2	11.5	12.0
WY 8800	SA	12.4	12.0	12.5	12.9	13.3	14.5
Utah	BA	38.3	39.2	40.3	42.7	44.0	45.9
Utah	BE	42.5	42.9	43.1	43.5	46.1	48.1

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-5. Coal Prices in the Lower Bound Scenario—Proposed-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	56.2	56.5	56.8	57.5	58.2	59.7
Bull Mountain	BB	32.7	29.4	29.8	30.9	32.1	32.1
CO Uinta	BB	35.8	36.3	36.8	37.9	39.5	42.9
Indonesia	BA	64.1	64.5	65.3	64.8	66.5	71.8
Indonesia	BB	53.0	53.3	54.1	54.0	60.7	62.3
Indonesia	SA	45.2	45.4	46.2	46.2	46.8	47.9
Indonesia	SB	42.6	42.8	43.6	43.6	44.1	45.3
Indonesia	SD	37.1	37.4	38.3	38.2	38.7	39.6
MT Powder River Basin	SA	18.4	17.8	18.3	19.6	20.0	22.2
MT Powder River Basin	SD	16.8	17.0	17.1	17.5	18.3	18.9
WY 8400	SB	10.9	11.1	11.3	11.7	12.1	12.9
WY 8800	SA	12.7	12.6	12.9	13.9	14.3	15.5
Utah	BA	38.6	39.4	40.6	43.0	44.4	46.2
Utah	BE	42.4	43.1	43.4	43.8	46.6	48.4

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-6. Coal Prices in the Upper Bound Scenario—No-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	93.7	95.5	103.3	96.9	98.8	106.0
Bull Mountain	BB	29.1	27.4	27.5	30.2	32.4	35.7
CO Uinta	BB	28.6	29.3	30.2	32.1	34.5	37.8
Indonesia	BA	104.8	109.2	117.4	111.1	116.7	124.4
Indonesia	BB	88.8	92.6	99.3	94.2	99.0	105.6
Indonesia	SA	78.6	80.4	86.0	81.8	86.0	91.9
Indonesia	SB	70.7	76.0	81.3	81.3	81.3	86.8
Indonesia	SD	63.2	67.0	71.6	71.6	71.7	76.5
MT Powder River Basin	SA	17.0	17.0	14.2	14.5	14.7	15.1
MT Powder River Basin	SD	14.1	14.1	12.4	12.7	13.1	13.8
WY 8400	SB	11.2	11.5	12.1	13.4	15.2	19.3
WY 8800	SA	12.8	13.2	13.9	15.2	17.1	21.6
Utah	BA	32.6	33.6	35.2	37.5	39.8	40.6
Utah	BE	34.5	35.4	37.0	39.4	41.9	42.6

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-7. Coal Prices in the Upper Bound Scenario—Proposed-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	93.7	95.3	103.3	96.7	98.4	106.0
Bull Mountain	BB	29.1	27.4	27.5	30.5	33.2	36.4
CO Uinta	BB	29.0	29.7	30.7	32.7	35.3	39.0
Indonesia	BA	104.8	109.0	117.4	110.8	116.3	124.4
Indonesia	BB	88.8	92.5	99.3	94.2	98.7	105.6
Indonesia	SA	78.6	80.3	86.0	81.6	85.8	91.9
Indonesia	SB	70.7	75.9	81.3	81.0	81.0	86.8
Indonesia	SD	63.2	66.8	71.6	71.3	71.4	76.5
MT Powder River Basin	SA	17.0	17.0	14.2	14.5	14.7	15.1
MT Powder River Basin	SD	14.1	14.1	12.4	12.7	13.1	13.8
WY 8400	SB	11.2	11.5	12.1	13.4	15.2	19.3
WY 8800	SA	12.8	13.2	13.9	15.2	17.1	21.6
Utah	BA	33.1	33.8	35.4	37.7	40.0	43.7
Utah	BE	35.0	35.6	37.2	39.6	46.5	51.2

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-8. Coal Prices in the No Clean Power Plan and Cumulative Scenarios—No-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	62.5	62.8	63.1	63.9	64.7	66.3
Bull Mountain	BB	33.2	33.4	33.6	33.9	30.2	30.6
CO Uinta	BB	31.1	31.7	32.4	34.0	36.3	40.3
Indonesia	BA	70.9	72.7	73.8	73.8	76.3	79.2
Indonesia	BB	59.1	60.6	61.4	61.8	63.7	65.1
Indonesia	SA	51.5	51.9	52.7	53.3	54.9	57.2
Indonesia	SB	48.7	49.0	49.8	50.4	51.8	54.0
Indonesia	SD	42.1	42.3	43.8	44.1	45.6	46.7
MT Powder River Basin	SA	16.0	16.3	16.7	17.1	17.3	17.7
MT Powder River Basin	SD	14.1	14.3	14.5	14.9	15.3	16.2
WY 8400	SB	10.5	10.8	11.2	11.9	12.9	15.3
WY 8800	SA	12.3	12.6	13.0	13.9	15.0	17.5
Utah	BA	37.8	39.0	40.8	44.0	46.8	47.8
Utah	BE	39.9	41.2	42.7	46.2	49.3	50.1

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-9. Coal Prices in the No Clean Power Plan Scenario—Proposed-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	62.5	62.8	63.1	63.9	64.7	66.3
Bull Mountain	BB	33.2	33.4	33.6	33.9	30.0	30.6
CO Uinta	BB	31.1	31.7	32.4	34.0	36.3	40.3
Indonesia	BA	70.9	72.7	73.8	73.8	76.1	79.1
Indonesia	BB	59.1	60.6	61.4	61.8	63.7	65.1
Indonesia	SA	51.5	51.9	52.7	53.3	54.8	57.2
Indonesia	SB	48.7	49.0	49.8	50.4	51.7	54.0
Indonesia	SD	42.1	42.3	43.8	44.0	45.5	47.5
MT Powder River Basin	SA	16.0	16.3	16.7	17.1	17.3	17.7
MT Powder River Basin	SD	14.1	14.3	14.5	14.9	15.3	16.2
WY 8400	SB	10.5	10.8	11.2	11.9	12.9	15.3
WY 8800	SA	12.3	12.6	13.0	13.9	15.0	17.5
Utah	BA	37.8	39.0	40.8	44.0	46.8	47.8
Utah	BE	39.9	41.2	42.7	46.2	49.3	50.1

[a] Coal Types are defined in Tables 4-36 and 4-37

Table 4-10. Coal Prices in the Cumulative Scenario—Proposed-Action Alternative (2012$/short ton)

Supply Region	Coal Type[a]	2016	2018	2020	2025	2030	2040
Australia	BA	62.5	62.8	63.1	63.9	64.7	66.3
Bull Mountain	BB	35.8	34.8	34.9	38.5	41.8	45.1
CO Uinta	BB	31.1	31.7	32.4	34.0	36.3	40.3
Indonesia	BA	70.9	72.7	73.8	73.8	75.8	78.9
Indonesia	BB	59.1	60.6	61.4	61.8	63.7	65.1
Indonesia	SA	51.5	51.9	52.7	53.3	54.5	57.2
Indonesia	SB	48.6	49.0	49.8	50.3	51.5	54.0
Indonesia	SD	42.1	42.3	43.8	44.0	45.5	47.5
MT Powder River Basin	SA	16.3	16.7	17.0	17.4	17.8	18.4
MT Powder River Basin	SD	14.3	14.5	14.8	15.3	15.8	16.8
WY 8400	SB	10.6	10.8	11.2	12.0	13.0	15.4
WY 8800	SA	12.4	12.6	13.1	13.9	15.0	17.6
Utah	BA	37.8	39.0	40.8	44.0	46.8	47.8
Utah	BE	39.9	41.2	42.7	46.2	49.3	50.1

[a] Coal Types are defined in Tables 4-36 and 4-37

4.2.2.2 Natural Gas

The analysis conducted for the Draft EIS used gas price data from EPA IPM v5.13. Due to significant changes in the natural gas market over the last year, the natural gas data used in this analysis incorporates data from the EIA Annual Energy Outlook 2016, since the EPA IPM v5.15 natural gas projections are out of date (U.S. Energy Information Administration 2016a). Table 4-11 shows the natural gas prices at Henry Hub, which is a major natural gas pricing point in Louisiana, for the Draft EIS and Final EIS analysis.

Table 4-11. Natural Gas Prices in the No Clean Power Plan Scenario (2012$/MMBtu)

Year	Draft EIS Henry Hub (2012$/MMBtu)	Final EIS Henry Hub (2012$/MMBtu)
2016	4.73	3.22
2018	5.39	3.74
2020	4.86	4.44
2025	5.34	4.76
2030	5.52	4.47
2040	6.12	5.14

Note: These natural gas prices represent the prices solved by IPM® using the assumptions defining the No-Action Alternative in the No Clean Power Plan Scenario for this analysis.

4.2.3 Air, Waste, and Water Regulations

The regulatory assumptions used in this analysis reflect the assumptions used by EPA in its IPM® v5.15 Base Case. Since the non-U.S. and non-Canadian regions are only represented by coal supply and demand regions and a coal demand forecast, the impacts of environmental regulations for each

country are embedded in the coal demand forecast as described in section 4.2.8. The following regulations for the United States are included in the analysis as per the EPA IPM v5.15 Base Case.

- The provisions of the Cross State Air Pollution Rule are used in the analysis for sulfur dioxide (SO_2) and nitrogen oxides (NO_x) regulations. The rule uses a cap and trade system with allowances to reduce SO_2 and NO_x for 23 eastern states. Phase I of the rule begins in 2015, with a stepdown in available allowances in Phase II in 2017. For the Annual NO_x trading program, the total Annual NO_x allowances issued for 2015 is 1.27 million before dropping to 1.2 million allowances in 2017. For the Ozone Season NO_x trading program, the total seasonal NO_x allowances issued for 2015 is 0.63 million before dropping to 0.59 million short tons in 2017. For the Annual SO_2 trading program, the total allowances issued for 2015 is 3.47 million short tons, dropping to 2.26 million short tons in 2017.

- The EPA's Mercury and Air Toxics Standards final rule is used in the analysis and requires that all coal-fired generating units be controlled for air toxics, or be within 1 year of being controlled, by 2016, or the units must be retired (40 Code of Federal Regulations [CFR] Parts 60 and 63).

- EPA included the CO_2 cap in the Regional Greenhouse Gas Initiative for this analysis. The Regional Greenhouse Gas Initiative is a market-based regulatory program to reduce CO_2 emissions by setting a cap on emissions that decreases each year. Nine states in the northeast are part of the initiative (Regional Greenhouse Gas Initiative 2014).

- EPA also included the California Assembly Bill 32 cap-and-trade program in the v5.15 Base Case, which is expected to be more stringent than any likely federal CO_2 standards. The bill affects both in-state generation and power imported into California (Assembly Bill No. 32 Chapter 488).

- Other state SO_2 and NO_X regulations are included where final regulations exist.

4.2.4 Renewable Energy Regulations

The renewable energy standards used in this analysis reflect EPA's assumptions and regional structure regarding state specific renewable portfolio standards and solar carve-outs. These standards are provided in Table 3-17 of EPA's documentation of its IPM® v5.15 Base Case Updates, and a description of the EPA's approach is presented in Section 3.9.8 of Chapter 3 of EPA's documentation of its IPM® v5.13 Base Case. Since the non-U.S. and non-Canadian regions are only represented by coal supply and demand regions and a coal demand forecast, the impacts of renewable energy regulations for each country are embedded in the coal demand forecast as described in section 4.2.8.

4.2.5 Electric Demand

The analysis models net energy and peak demand using the assumptions in EPA's IPM v.5.15 documentation. EPA divides the 48 contiguous states and the District of Columbia into 64 model regions based on the characterization of operations. IPM also covers the electric power sector in Canada, and Canada is divided into 11 model regions. Figure 4-2 shows the electric demand regions used in the analysis for the EIS.

Figure 4-2. Map of IPM Model Regions

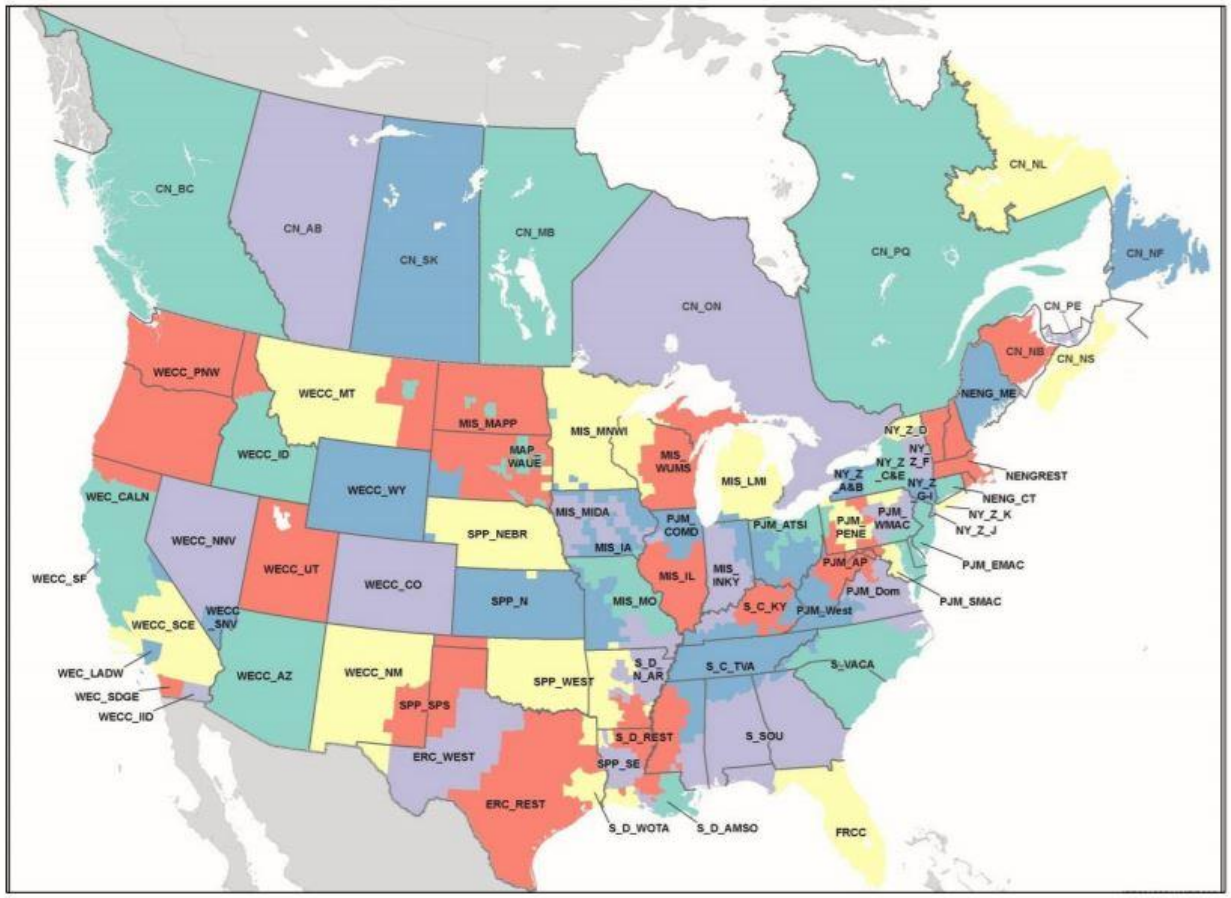


Table 4-12 shows the 64 electric demand regions assembled into eight regional groups that are defined by independent system operator (ISO) or North American Electric Reliability Council (NERC) boundaries. The net energy for load and coincident peak load values assumed in this analysis, are shown in Tables 4-13 and 4-14 by these eight regional groups.

Table 4-12. IPM Region Groups

Model Region Name	General Region Name	General Region Acronym
ERCOT_Tenaska Frontier Generating Station	Electric Reliability Council of Texas	ERCOT
ERCOT_Tenaska Gateway Generating Station	Electric Reliability Council of Texas	ERCOT
ERCOT_Rest	Electric Reliability Council of Texas	ERCOT
ERCOT_West	Electric Reliability Council of Texas	ERCOT
FRCC	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
MAPP_WAUE	Midwest Reliability Organization	MRO
MISO_Iowa	Midwest Reliability Organization	MRO
MISO_Illinois	Midwest Reliability Organization	MRO
MISO_Indiana (including parts of Kentucky)	Midwest Reliability Organization	MRO
MISO_Lower Michigan	Midwest Reliability Organization	MRO
MISO_MT, SD, ND	Midwest Reliability Organization	MRO
MISO_Iowa-MidAmerican	Midwest Reliability Organization	MRO
MISO_Minnesota and Western Wisconsin	Midwest Reliability Organization	MRO
MISO_Missouri	Midwest Reliability Organization	MRO

Model Region Name	General Region Name	General Region Acronym
MISO_Wisconsin- Upper Michigan (WUMS)	Midwest Reliability Organization	MRO
ISONE_Connecticut	ISO New England	ISONE
ISONE_Maine	ISO New England	ISONE
ISONE_MA, VT, NH, RI (Rest of ISO New England)	ISO New England	ISONE
NY_Zones A&B	New York ISO	NYISO
NY_Zone C&E	New York ISO	NYISO
NY_Zones D	New York ISO	NYISO
NY_Zone F (Capital)	New York ISO	NYISO
NY_Zone G-I (Downstate NY)	New York ISO	NYISO
NY_Zone J(NYC)	New York ISO	NYISO
NY_Zone K(LI)	New York ISO	NYISO
PJM_AP	PJM Interconnection	PJM
PJM_ATSI	PJM Interconnection	PJM
PJM_ComEd	PJM Interconnection	PJM
PJM_Dominion	PJM Interconnection	PJM
PJM_EMAAC	PJM Interconnection	PJM
PJM_PENELEC	PJM Interconnection	PJM
PJM_SWMAAC	PJM Interconnection	PJM
PJM West	PJM Interconnection	PJM
PJM_Western MAAC	PJM Interconnection	PJM
SERC_Central_Kentucky	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Central_TVA	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Delta_Amite South (including DSG)	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Delta_Northern Arkansas (including AECI)	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Delta_Rest of Delta (Central Arkansas)	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Delta_WOTAB (including Western)	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_Southeastern	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SERC_VACAR	SERC Reliability Corporation + Florida Reliability Coordinating Council	SERC + FRCC
SPP_Kiamichi Energy Facility	Southwest Power Pool	SPP
SPP North- (Kansas, Missouri)	Southwest Power Pool	SPP
SPP Nebraska	Southwest Power Pool	SPP
SPP Southeast- (Louisiana)	Southwest Power Pool	SPP
SPP SPS (Texas Panhandle)	Southwest Power Pool	SPP
SPP West (Oklahoma, Arkansas, Louisiana)	Southwest Power Pool	SPP
WECC_Northern California (including SMUD)	Western Electricity Coordinating Council	WECC
WECC_LADWP	Western Electricity Coordinating Council	WECC
WECC_San Diego Gas and Electric	Western Electricity Coordinating Council	WECC
WECC_Arizona	Western Electricity Coordinating Council	WECC
WECC_Colorado	Western Electricity Coordinating Council	WECC
WECC_Idaho	Western Electricity Coordinating Council	WECC
WECC_Imperial Irrigation District (IID)	Western Electricity Coordinating Council	WECC
WECC_Montana	Western Electricity Coordinating Council	WECC
WECC_New Mexico	Western Electricity Coordinating Council	WECC
WECC_Northern Nevada	Western Electricity Coordinating Council	WECC
WECC_Pacific Northwest	Western Electricity Coordinating Council	WECC
WECC_Southern California Edison	Western Electricity Coordinating Council	WECC
WECC_San Francisco	Western Electricity Coordinating Council	WECC
WECC_Southern Nevada	Western Electricity Coordinating Council	WECC
WECC_Utah	Western Electricity Coordinating Council	WECC
WECC_Wyoming	Western Electricity Coordinating Council	WECC

Table 4-13. Net Energy for Load (GWh), 2016–2040

Year	ERCOT	ISONE	MRO	NYISO	PJM	SERC + FRCC	SPP	WECC	Total
2016	336,781	135,562	523,629	154,648	791,098	1,058,519	265,877	726,464	3,992,578
2017	335,378	137,602	529,019	154,133	796,575	1,067,427	265,681	730,228	4,016,043
2018	339,396	137,741	531,748	153,329	799,977	1,078,305	268,215	735,360	4,044,071
2019	344,623	137,300	535,104	152,941	804,735	1,091,911	271,474	743,130	4,081,218
2020	346,838	135,738	535,239	151,010	802,854	1,096,599	272,832	745,085	4,086,195
2021	349,809	135,046	537,082	149,882	803,749	1,104,174	274,826	750,824	4,105,392
2022	353,286	134,675	540,125	149,152	806,620	1,113,545	277,235	756,705	4,131,343
2023	357,387	134,755	544,524	149,168	812,315	1,126,847	280,255	765,045	4,170,296
2024	361,419	134,812	548,372	149,123	817,361	1,138,496	283,011	772,731	4,205,325
2025	364,711	134,684	551,154	148,866	820,954	1,148,364	285,244	779,232	4,233,209
2026	368,660	134,833	553,938	148,864	824,941	1,158,932	287,754	785,717	4,263,639
2027	371,928	135,059	556,513	148,960	828,709	1,168,639	289,868	792,410	4,292,086
2028	375,271	135,100	558,019	148,929	831,408	1,177,867	291,800	798,702	4,317,096
2029	378,904	135,234	559,371	149,040	834,105	1,186,624	293,777	804,964	4,342,019
2030	381,943	135,117	560,078	148,877	835,612	1,193,392	295,349	809,455	4,359,823
2031	385,342	135,268	561,275	148,993	837,917	1,200,995	297,191	814,606	4,381,587
2032	389,039	135,550	563,542	149,333	841,639	1,210,294	299,354	821,394	4,410,145
2033	393,036	135,925	566,307	149,718	846,035	1,220,957	301,836	829,594	4,443,408
2034	397,367	136,367	569,568	150,090	851,053	1,232,585	304,594	838,089	4,479,713
2035	401,882	136,929	573,401	150,712	856,892	1,245,282	307,559	847,306	4,519,963
2036	406,543	137,454	577,216	151,234	862,814	1,258,074	310,560	856,723	4,560,618
2037	411,608	138,091	581,037	151,769	868,982	1,271,971	313,761	866,580	4,603,799
2038	417,023	138,651	585,140	152,282	875,440	1,286,667	317,218	877,170	4,649,591
2039	422,121	139,116	589,757	152,783	882,045	1,300,014	320,585	887,429	4,693,850
2040	427,127	139,718	594,765	153,407	889,038	1,313,687	324,076	898,730	4,740,548

Source: EPA IPM v.5.15

Table 4-14. Coincident Peak Demand (MW), 2016–2040

Year	ERCOT	ISONE	MRO	NYISO	PJM	SERC + FRCC	SPP	WECC
2016	69,984	25,350	92,566	29,772	144,532	190,958	51,667	127,597
2017	69,854	25,831	93,098	29,761	145,262	192,170	51,723	128,320
2018	70,499	25,941	93,386	29,656	145,687	193,632	52,066	129,279
2019	71,486	25,939	93,963	29,646	146,587	195,846	52,650	130,846
2020	72,157	25,834	94,341	29,471	146,906	197,343	53,091	131,809
2021	72,821	25,820	94,833	29,363	147,401	198,959	53,532	133,140
2022	73,516	25,839	95,414	29,321	148,089	200,664	53,991	134,486
2023	74,307	25,939	96,278	29,404	149,337	203,166	54,566	136,376
2024	75,140	26,036	97,017	29,470	150,464	205,395	55,112	138,027

2025	75,911	26,118	97,649	29,540	151,460	207,456	55,624	139,494
2026	76,861	26,290	98,315	29,650	152,555	209,731	56,225	141,080
2027	77,659	26,452	98,929	29,787	153,624	211,915	56,752	142,686
2028	78,505	26,556	99,434	29,871	154,544	214,054	57,271	144,242
2029	79,492	26,682	99,951	29,992	155,532	216,210	57,853	145,819
2030	80,508	26,785	100,440	30,121	156,487	218,251	58,439	147,206
2031	81,605	26,940	101,029	30,300	157,592	220,469	59,085	148,699
2032	82,756	27,120	101,772	30,510	158,907	222,965	59,800	150,525
2033	83,892	27,299	102,555	30,724	160,281	225,587	60,517	152,515
2034	85,094	27,486	103,423	30,904	161,723	228,343	61,292	154,607
2035	86,305	27,700	104,392	31,123	163,336	231,282	62,089	156,833
2036	87,542	27,908	105,367	31,372	164,999	234,193	62,892	159,067
2037	88,822	28,146	106,359	31,595	166,676	237,265	63,716	161,408
2038	90,170	28,350	107,391	31,798	168,362	240,438	64,588	163,851
2039	91,462	28,528	108,456	31,998	170,022	243,388	65,443	166,310
2040	92,698	28,726	109,573	32,243	171,764	246,338	66,291	168,925

Source: EPA IPM v.5.15

4.2.6 Reserve Margin Targets

IPM's reliability-related assumptions reflect planning reserve margin requirements. These requirements are targets for generating capacity that are used to ensure sufficient generating capacity is available at all times, such as when some plants are out of service for maintenance or equipment problems occur during peak demand periods. The reserve margin assumptions used in IPM® for this analysis are the planning reserve margins used by EPA in its IPM® v5.13 Base Case, as described in Section 3.6 of Chapter 3 of its v5.13 documentation. These assumptions were not updated for v5.15.

Since the non-U.S. and non-Canadian regions are only represented by coal supply and demand regions and a coal demand forecast, the electric power system is not modeled explicitly and thus reserve margin target assumptions are not necessary for these regions.

4.2.7 Planned New Capacity and Retirements

The installation of new generating capacity and retirement of existing capacity is typically planned several years in advance of the capacity coming online or being retired. The analysis for the EIS includes new planned generating capacity and retirements that have been announced and meet threshold criteria. New generating capacity is included in the analysis if the plant has either started construction or meets two of the three criteria:

- All environmental permits have been obtained.
- Financing has been secured.
- At least 50% of the output is under a power purchase agreement.

Announced retirements are included if they have been approved by the relevant utility commission or independent system operator, or are part of a court settlement. Planned new capacity and retirements are important to energy market analyses, as they incorporate known changes to the existing capacity mix. The changes in capacity mix impact the fuels consumed and thus the demand for and prices of fuels within the forecast horizon. Tables 4-15 and 4-16 show the planned new capacity from 2016 through 2020 that are included in the analysis. Table 4-15 shows new capacity by the eight regions described in Section 4.2.5, *Electric Demand,* and shown in Table 4-12. Table 4-16 shows new generating capacity by capacity type. Tables 4-17 and 4-18 show the planned retirements from 2016 through 2020 by region and by capacity type, respectively. A full list of plant and unit names for the planned new capacity and planned retirements can be found in Appendix A, *Planned New Generating Capacity and Planned Retirements.*

Table 4-15. Planned New Capacity by Region, 2016 to 2020 (MW)

Region Name	2016	2017	2018	2019	2020	Total
ERCOT	1,855	5,370	24	400	0	7,649
ISONE	152	923	0	2	0	1,077
MRO	2,158	2,208	386	170	0	4,922
NYISO	694	0	1,154	6	0	1,854
PJM	4,857	4,695	525	48	0	10,125
SERC + FRCC	3,233	1,188	2,425	2,200	1,100	10,146
SPP	1,853	495	400	0	0	2,748
WECC	4,919	565	1,409	1,215	628	8,736
Total	19,721	15,444	6,323	4,041	1,728	47,257

Source: SNL

Table 4-16. Planned New Capacity by Capacity Type, 2016 to 2020 (MW)

Capacity Type	2016	2017	2018	2019	2020	Total
Biomass	437	180	0	0	0	617
Coal	99	134	850	400	0	1,483
Combined Cycle	7,610	11,354	3,265	460	487	23,176
Combustion Turbine	822	1,584	280	0	0	2,686
Geothermal	11	28	165	45	90	339
Hydro	29	8	64	24	0	125
Landfill	10	2	0	0	0	12
Nuclear	1,122	0	1,100	2,200	1,100	5,522
Oil/Gas	8	0	0	0	0	8
Other	282	1,058	0	0	0	1,340
Solar	4,578	239	49	500	51	5,417
Wind	4,713	857	550	412	0	6,532
Total	19,721	15,444	6,323	4,041	1,728	47,257

Source: SNL

Table 4-17. Planned Retirements by Region, 2016 to 2020 (MW)

Region Name	2016	2017	2018	2019	2020	Total
ISONE	0	1,678	0	0	0	1,678
MRO	3,044	51	322	0	176	3,593
NYISO	78	0	0	0	0	78
PJM	4,377	339	1,215	615	0	6,546
SERC + FRCC	3,410	2,299	1,730	664	0	8,103
SPP	810	0	0	1,383	103	2,296
WECC	65	1,214	928	2,070	1,288	5,565
Total	11,784	5,581	4,195	4,732	1,567	27,859

Source: SNL

Table 4-18. Planned Retirements by Capacity Type, 2016 to 2020 (MW)

Capacity Type	2016	2017	2018	2019	2020	Total
Coal	10,713	3,862	3,939	2,388	1,464	22,366
Combustion Turbine	846	704	14	6	0	1,570
Hydro	0	5	0	0	0	5
Nuclear	0	0	0	615	0	615
Oil/Gas	225	1,010	242	1,723	103	3,303
Total	11,784	5,581	4,195	4,732	1,567	27,859

Source: SNL

4.2.8 Mothballing and Retirement

ICF's assumptions reflect the ability of electricity generating plants to mothball and return to service later, or to retire. The capability to model plants entering a mothball state or retiring more realistically represents the actual energy market than a model that does not include this capability.

- To capture market exit behavior, IPM® included mothballing and retirement capabilities. Generating units with high fixed operations and maintenance costs become candidates for mothballing and retirement as more efficient generation capacity is constructed.
- The mothballing option is provided for all oil/natural gas steam facilities and is exercised if short-term annual fixed costs exceed annual revenues in a market with excess supply. The decision to mothball takes into consideration fixed costs, reserve requirements, and the costs of mothballing a unit and returning it to service later.
- Retirement options are available to all existing coal, nuclear, and oil/natural gas steam units in IPM®. The modeling assumes that the retirement option would be exercised if projected discounted cash flows do not exceed projected costs (fixed, variable, and capital). Again, this decision takes long-term reserve requirements and revenues into consideration.

- The analysis assesses higher fixed operations and maintenance costs to uncontrolled coal units after 60 years in service to account for life-extension costs, potentially increasing the amount of coal retirements as the model chooses to retire units rather than pay the life-extension costs.

Since the non-U.S. and non-Canadian regions are only represented by coal supply and demand regions and a coal demand forecast, individual power plants are not modeled in these regions and thus assumptions regarding mothballing and retirement are not needed.

4.2.9 Capital Costs for New Generating Capacity

Table 4-19 shows the "main street" capital costs of new generating capacity for the IPM run years. The "main street" costs are for a representative location, and then adjusted for each electric demand region based on region specific cost multipliers. Costs for all capacity types, except for solar photovoltaic, solar thermal, onshore wind, and offshore wind remain the same in the forecast horizon. Solar and wind capital costs change over the years due to technological development as well as available tax incentives. Costs for capacity types other than solar and wind new generating capacity are based on the assumptions from EPA's power sector modeling platform IPM v.5.15. For solar and wind builds, capital costs are based on EPA's power sector modeling platform IPM v5.15 as well, but with additional adjustments based on the latest production tax credit and investment tax credit structures.

Table 4-19. Capital Costs for New Generating Capacity, 2011$/kW

Capacity Type	Class	Step	2016	2018	2020	2025	2030	2040
Advanced Combined Cycle	N/A	N/A	1,006	1,006	1,006	1,006	1,006	1,006
Advanced Combustion Turbine	N/A	N/A	664	664	664	664	664	664
Nuclear	N/A	N/A	5,429	5,429	5,429	5,429	5,429	5,429
IGCC	N/A	N/A	2,969	2,969	2,969	2,969	2,969	2,969
IGCC with Carbon Sequestration	N/A	N/A	4,086	4,086	4,086	4,086	4,086	4,086
Supercritical Pulverized Coal	N/A	N/A	2,883	2,883	2,883	2,883	2,883	2,883
Biomass-Bubbling Fluidized Bed (BFB)	N/A	N/A	4,041	4,041	4,041	4,041	4,041	4,041
Geothemal	N/A	N/A	1,187 - 15,752	1,187 - 15,752	1,187 - 15,752	1,187 - 15,752	1,187 - 15,752	1,187 - 15,752
Landfill - LGHI	N/A	N/A	8,408	8,408	8,408	8,408	8,408	8,408
Landfill - LGLo	N/A	N/A	10,594	10,594	10,594	10,594	10,594	10,594
Landfill - LGVLo	N/A	N/A	16,312	16,312	16,312	16,312	16,312	16,312
Hydro	N/A	N/A	1,170 - 6,541	1,170 - 6,541	1,170 - 6,541	1,170 - 6,541	1,170 - 6,541	1,170 - 6,541
Fuel Cells	N/A	N/A	7,117	7,117	7,117	7,117	7,117	7,117
Solar PV	N/A	N/A	1,575	1,581	1,583	2,056	1,668	2,134
Solar Thermal	N/A	N/A	3,705	3,713	3,718	4,805	4,849	4,914
Onshore Wind	1	1	1,044	1,043	1,289	1,664	1,675	1,691
Onshore Wind	1	2	945	943	1,228	1,664	1,675	1,691
Onshore Wind	1	3	846	844	1,168	1,664	1,675	1,691
Onshore Wind	1	5	813	810	1,148	1,664	1,675	1,691

Onshore Wind	2	1	730	727	1,098	1,664	1,675	1,691
Onshore Wind	2	2	1,099	1,098	1,322	1,664	1,675	1,691
Onshore Wind	2	3	1,009	1,008	1,267	1,664	1,675	1,691
Onshore Wind	2	5	920	917	1,213	1,664	1,675	1,691
Onshore Wind	3	1	889	894	1,213	1,711	1,731	1,751
Onshore Wind	3	2	814	818	1,167	1,711	1,731	1,751
Onshore Wind	3	3	1,167	1,175	1,382	1,711	1,731	1,751
Onshore Wind	3	5	1,087	1,095	1,333	1,711	1,731	1,751
Onshore Wind	4	1	1,008	1,018	1,294	1,732	1,757	1,779
Onshore Wind	4	2	981	991	1,277	1,732	1,757	1,779
Onshore Wind	4	3	915	924	1,236	1,732	1,757	1,779
Onshore Wind	4	5	1,349	1,364	1,506	1,732	1,757	1,779
Onshore Wind	5	1	1,119	1,131	1,269	1,491	1,512	1,531
Onshore Wind	5	2	945	954	1,091	1,309	1,327	1,345
Onshore Wind	5	3	895	905	1,040	1,258	1,275	1,292
Onshore Wind	5	5	788	796	931	1,145	1,161	1,176
Offshore Wind - Deep	1		4,467	4,444	4,666	5,064	5,094	5,140
Offshore Wind - Deep	2		4,327	4,295	4,571	5,064	5,094	5,140
Offshore Wind - Deep	3		4,266	4,231	4,526	5,064	5,094	5,140
Offshore Wind - Deep	4		4,231	4,194	4,509	5,064	5,094	5,140
Offshore Wind - Deep	5		4,186	4,146	4,475	5,064	5,094	5,140
Offshore Wind - Shallow	1		4,588	4,571	4,745	5,064	5,094	5,140
Offshore Wind - Shallow	2		4,483	4,460	4,672	5,064	5,094	5,140
Offshore Wind - Shallow	3		4,432	4,407	4,644	5,064	5,094	5,140
Offshore Wind - Shallow	4		4,407	4,380	4,627	5,064	5,094	5,140
Offshore Wind - Shallow	5		4,372	4,343	4,599	5,064	5,094	5,140

Source: EPA IPM v.5.15

4.2.10 Transmission

IPM's assumptions took into account the capabilities of transmission lines. These assumptions are based on a thorough analysis of the transmission structure and constraints, and represent the most probable outlook at the time of the forecast.

- Joint capacity constraints were included to reflect limitations across groups of transmission links.
- Total transmission capability assumptions from public sources such as the North American Electric Reliability Corporation and regional reliability councils were used, as well as interface limits published by the International Organization for Standardization, where available.
- In regions where data were unavailable, the analysis used estimates derived from industry contacts and proprietary modeling exercises.

- The model assumed that power transported across power pools would incur a cost of $3.09 per megawatt hour (2011 U.S. dollars) to reflect charges assessed by one power pool to another.
- IPM® did not include regional through-and-out rates for any transactions terminating in the combined PJM-MISO footprint. Regional through-and-out rates are transmission rates for transactions where electricity originated in one transmission control area was transmitted to a point outside that control area.
- Transmission losses vary with line loading and line length, but estimating the exact loss factors for each interconnecting transmission path for the entire country would be impracticable. ICF's analysis, therefore, assumed transmission losses between 2% and 3%, based on industry practices. Note that these losses were intended to capture only bulk power transmission losses; distribution losses were not included.
- Because the non-U.S. and non-Canadian regions are only represented by coal supply and demand regions and a coal demand forecast, the transmission network for these regions is not explicitly modeled and thus assumptions regarding transmission for these regions are not needed.

4.2.11 International Coal Demand

International coal demand in the model is represented by a forecast of a region's or country's total thermal coal demand, which is modeled as a fixed input. The rest of the world, outside of the United States and Canada, is divided into 26 coal demand regions that are comprised of 15 countries and 11 regions. The thermal coal demand for the rest of the world is modeled as the total heating value of the coal in trillion British thermal units (TBtu).[18] The coal demand in these 26 regions is met by delivering coal from one or more of the 58 coal supply regions modeled in the IPM. The coal is "transported" from the supply regions to the demand regions along transportation links that have a cost for moving the coal that is based on the mode of transportation as well as the distance traveled. Thus the fixed coal demand in the 26 international coal demand regions is met by determining the least cost method of meeting the coal demand over the whole planning horizon given the transportation costs and coal supply curves for each of the 58 coal supply regions.

[18] Only thermal coal demand is modeled in the analysis for the EIS, because only thermal coal would be exported through the proposed terminal.

2015 WEO Scenario Definitions
The **New Policies Scenario** incorporates policies and measures that affect energy markets and that have been adopted as of mid-2015. This scenario also includes other relevant "intentions" that have been announced, but may not be fully defined or implemented.
The **Current Policies Scenario** takes into consideration only those policies for which implementing measures have been formally adopted as of mid-2015, and assumes that these policies do not change over time.
(International Energy Agency 2015)

Two sources were used as starting points for the international demand forecast. The first source is the IEA 2015 WEO, which provides an estimate for the demand for coal and other energy sources under three scenarios and for 11 regions and 7 individual countries.[19] Two scenarios in the IEA 2015 WEO were used for the analysis, the New Policies Scenario and the Current Policies Scenario. The analysis for the Final EIS uses the New Policies Scenario and the Current Policies Scenario data for the international coal demand. The coal demand in the Current Policies Scenario is used in the No Clean Power Plan and Cumulative Scenarios, while the coal demand in the New Policies Scenario is used in the Lower Bound and 2015 U.S. and International Energy Policy Scenarios. The New Policies Scenario differs from the Current Policies Scenario in that it includes both implemented policies as well as policies that have been announced, but may not be fully defined. These policies include the energy related aspects of the Intended Nationally Determined Contributions that had been submitted as of October 1, 2015 in preparation for the United Nations Framework Convention on Climate Change Conference of the Parties. While the New Policies Scenario includes policies that have been announced, but have not been implemented, it takes a conservative view on the extent and timing of the implementation of those policies.

Tables 4-20 and 4-21 contain these coal consumption estimates for the Current Policies Scenario and for the New Policies Scenario, respectively. The second source is EIA, which has historical data on coal consumption by country. The EIA data was used to disaggregate the regional coal demand from the IEA 2015 WEO into individual country demands. The regional coal demand from the WEO was allocated to each member country according to the percent of 2014 consumption for the same group of countries. The individual country coal demand was then recombined into the regions used in the model. Table 4-22 shows the 2014 coal consumption by country from the EIA data.

The IEA 2015 WEO incorporates environmental and renewable regulations and policies, among many other inputs, into their energy demand projections. The IEA's Current Policies Scenario includes "…only those policies for which implementing measures had been formally adopted as of mid-2015 and makes the assumption that these policies persist unchanged."[20] The New Policies Scenario includes not only the policies in the Current Policies Scenario, but other announced intentions that may not be fully defined. For example, the New Policies Scenario includes "…the energy-related components of the Intended Nationally Determined Contributions submitted by national governments by 1 October as pledges in the run-up to the United Nations Framework Convention on Climate Change Conference of the Parties."[21]

Coking coal demand was then subtracted from the IEA 2015 WEO data for total primary energy demand for coal to obtain the demand for thermal coal. The global demand for metallurgical coal is

[19] The international coal demand in the Draft EIS was based on the IEA 2014 WEO.

[20] International Energy Agency, 2015 World Energy Outlook, page 34.

[21] Ibid

based on the IEA 2015 WEO projections of metallurgical coal demand under the Current Policies and New Policies Scenarios. Table 4-23 shows the global metallurgical coal demand from the IEA 2015 WEO. The global demand for metallurgical coal was allocated to the demand regions used in the IPM based on historical consumption. Tables 4-24 and 4-25 contain the metallurgical coal forecast for the 21 IPM demand regions that consume metallurgical coal. The metallurgical coal forecast was developed by starting with historical consumption and applying a growth rate based on the developmental stage of the country, its place in global coking coal production, and expected gross domestic product growth, to get within 2% of the IEA 2015 WEO metallurgical coal forecast. One simplifying assumption in the IPM is that metallurgical coal and thermal coal are modeled separately, without the ability of one to cross over into the other type. Since this analysis involves Powder River Basin and Uinta Basin coal, neither of which have metallurgical quality coal, this simplifying assumption will not affect the results.

Table 4-20. Total Primary Energy Demand – Coal – No Clean Power Plan and Cumulative Scenarios (Trillion Btu)

	Current Policies Scenario Consumption (TBtu)				
Country or Region	**1999**	**2013**	**2020**	**2030**	**2040**
OECD	42,871	40,838	39,252	37,835	35,801
OECD Americas	19,463	18,597	18,173	18,575	17,978
OECD Europe	17,920	12,469	11,551	10,048	8,800
European Union	18,077	11,365	10,155	8,298	6,652
OECD Asia Oceania	5,488	9,772	9,528	9,211	9,024
Japan	3,040	4,812	4,519	4,331	4,043
Non-OECD	45,245	115,081	128,507	158,205	187,137
Eastern Europe/Eurasia	14,570	8,706	8,665	9,123	9,955
Russia	7,582	4,297	4,386	4,763	5,068
Non-OECD Asia	27,136	101,190	113,966	141,672	166,910
China	21,153	81,446	85,083	94,690	99,144
India	3,714	13,546	19,804	31,650	45,062
Middle East	28	124	141	163	176
Africa	2,935	4,123	4,529	5,623	7,993
South Africa	2,640	3,783	3,805	3,923	4,147
Latin America	576	938	1,205	1,622	2,104
Brazil	384	653	815	964	1,135

Source: International Energy Agency, 2015 World Energy Outlook, Current Policies Scenario

Table 4-21. Total Primary Energy Demand – Coal – Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu)

Country or Region	New Policies Scenario Consumption (TBtu)						
	1999	2013	2020	2025	2030	2035	2040
OECD	42,871	40,838	36,312	32,830	29,141	26,092	24,389
OECD Americas	19,463	18,597	16,013	14,843	13,312	12,249	12,102
OECD Europe	17,920	12,469	11,046	9,360	7,628	6,205	5,333
European Union	18,077	11,365	9,720	7,923	6,163	4,821	4,025
OECD Asia Oceania	5,488	9,772	9,253	8,627	8,201	7,637	6,954
Japan	3,040	4,812	4,407	4,091	3,916	3,615	3,274
Non-OECD	45,245	115,081	123,727	130,329	138,265	145,413	150,762
Eastern Europe/Eurasia	14,570	8,706	8,377	8,477	8,493	8,791	8,863
Russia	7,582	4,297	4,239	4,556	4,521	4,614	4,490
Non-OECD Asia	27,136	101,190	109,561	115,539	122,835	128,719	132,716
China	21,153	81,446	81,751	81,725	81,627	80,226	76,932
India	3,714	13,546	18,907	22,544	27,399	32,300	37,045
Middle East	28	124	140	150	156	161	163
Africa	2,935	4,123	4,480	4,854	5,292	6,103	7,200
South Africa	2,640	3,783	3,735	3,687	3,556	3,469	3,388
Latin America	576	938	1,168	1,309	1,489	1,639	1,820
Brazil	384	653	808	866	929	966	1,025

Source: International Energy Agency, 2015 World Energy Outlook, New Policies Scenario

Table 4-22. 2014 Coal Consumption by Country, Total Primary Energy Demand (Trillion Btu)

Country	2014 Consumption	Country	2014 Consumption	Country	2014 Consumption
Australia	1,615	Hungary	111	Poland	2,021
Austria	81	India	12,560	Portugal	93
Belgium	110	Indonesia	2,076	Romania	187
Bosnia and Herzegovina	131	Israel	201	Russia	4,118
Brazil	633	Italy	457	Serbia	326
Bulgaria	304	Japan	4,169	Slovakia	125
Canada	692	Kazakhstan	1,489	South Africa	3,789
Chile	267	Korea, North	461	Spain	442
China	72,269	Korea, South	2,859	Sweden	66
Colombia	178	Malaysia	546	Taiwan	1,417
Czech Republic	579	Mexico	351	Thailand	583
Denmark	87	Mongolia	152	Ukraine	1,262
Finland	105	Morocco	147	United Arab Emirates	48
France	307	Netherlands	325	United Kingdom	1,060
Germany	2,884	New Zealand	54	United States	15,872
Greece	229	Pakistan	139	Uzbekistan	52
Hong Kong	290	Philippines	421	Vietnam	586

Source: Energy Information Administration website, International Coal data explorer. Accessed October 12, 2016

Table 4-23. Global Metallurgical Coal Demand

Metallurgical Coal Demand	Historical		Current Policies Scenario		New Policies Scenario	
	2000	2013	2020	2040	2020	2040
Demand in Mtce	452	940	941	851	929	785
Demand in TBtu	12,555	26,109	26,137	23,637	25,804	21,804

Source: International Energy Agency 2015 World Energy Outlook
Mtce = Million tons coal equivalent

Table 4-24. Metallurgical Coal Demand Forecast - No Clean Power Plan, Cumulative, and Upper Bound Scenarios (Trillion Btu)

Country	2016	2018	2020	2025	2030	2035	2040
Australia	134.4	134.9	135.4	136.8	138.2	139.6	141.0
Britain	213.6	211.1	207.7	197.0	187.0	179.2	171.6
China	14,478.5	14,155.8	13,840.2	13,081.6	12,364.6	11,687.0	11,046.4
Colombia	17.0	18.1	19.1	21.2	23.5	24.6	25.7
Europe-East	795.8	799.0	802.2	810.2	818.4	826.6	834.9
Europe-North	105.1	103.8	102.1	96.9	92.0	88.1	84.4
Europe-South	175.8	173.7	170.9	162.1	153.9	147.4	141.2
Europe-West	425.6	420.6	413.7	392.5	372.6	357.0	342.0
Germany	634.0	626.6	616.3	584.6	555.1	531.8	509.5
India	2,378.7	2,450.6	2,524.7	2,719.8	2,930.0	3,156.4	3,400.4
Japan	1,636.6	1,572.4	1,510.8	1,367.0	1,237.0	1,119.2	1,012.7
Kazakhstan	520.6	522.7	524.8	530.1	535.4	540.8	546.2
South Korea	1,005.8	1,015.9	1,026.1	1,052.0	1,078.5	1,105.8	1,133.7
Mexico	31.3	31.9	32.6	34.2	36.0	37.8	39.7
Poland	404.0	399.3	392.8	372.6	353.8	338.9	324.7
Russia	1,562.4	1,599.5	1,637.5	1,736.4	1,841.3	1,952.5	2,070.4
South Africa	81.5	84.6	87.1	91.6	96.1	98.6	101.2
South America	284.7	303.2	319.8	356.0	394.0	411.6	430.0
Spain	108.1	106.9	105.1	99.7	94.7	90.7	86.9
Taiwan	197.8	201.8	205.8	216.3	227.4	239.0	251.2
Ukraine	819.6	822.9	826.2	834.4	842.8	851.3	859.8

Source: Historical data was extrapolated based on IEA 2015 WEO projections for 2020 and 2040 demand.

Table 4-25. Metallurgical Coal Demand Forecast - Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu)

Country	2016	2018	2020	2025	2030	2035	2040
Australia	134.4	134.9	135.4	136.8	138.2	139.6	141.0
Britain	213.6	211.1	207.7	197.0	187.0	179.2	171.6
China	14,478.5	13,873.8	13,294.3	11,949.2	10,740.3	9,653.6	8,676.9
Colombia	17.0	18.1	19.1	21.2	23.5	24.6	25.7
Europe-East	795.8	799.0	802.2	810.2	818.4	826.6	834.9
Europe-North	105.1	103.8	102.1	96.9	92.0	88.1	84.4
Europe-South	175.8	173.7	170.9	162.1	153.9	147.4	141.2
Europe-West	425.6	420.6	413.7	392.5	372.6	357.0	342.0
Germany	634.0	626.6	616.3	584.6	555.1	531.8	509.5
India	2,378.7	2,450.6	2,524.7	2,719.8	2,930.0	3,156.4	3,400.4
Japan	1,636.6	1,570.8	1,507.6	1,360.5	1,227.8	1,108.0	999.9
Kazakhstan	520.6	522.7	524.8	530.1	535.4	540.8	546.2
South Korea	1,005.8	1,015.9	1,026.1	1,052.0	1,078.5	1,105.8	1,133.7
Mexico	31.3	31.9	32.6	34.2	36.0	37.8	39.7
Poland	404.0	399.3	392.8	372.6	353.8	338.9	324.7
Russia	1,562.4	1,604.6	1,648.0	1,761.5	1,882.9	2,012.7	2,151.4
South Africa	81.5	84.6	87.1	91.6	96.1	98.6	101.2
South America	284.7	303.2	319.8	356.0	394.0	411.6	430.0
Spain	108.1	106.9	105.1	99.7	94.7	90.7	86.9
Taiwan	197.8	201.8	205.8	216.3	227.4	239.0	251.2
Ukraine	819.6	822.9	826.2	834.4	842.8	851.3	859.8

Source: Historical data was extrapolated based on IEA 2015 WEO projections for 2020 and 2040 demand.

Tables 4-26 and 4-27 show the final thermal coal demand from IEA 2015 WEO Current Policies Scenario and the New Policies Scenario. The coal demand in the Current Policies Scenario is used in the No Clean Power Plan and Cumulative Scenarios, while the coal demand in the New Policies Scenario is used in the Lower Bound and 2015 U.S. and International Energy Policy Scenarios. The coal demand for the Upper Bound Scenario uses a different methodology, as explained below.

The international coal demand in Tables 4-26 and 4-27 may not exactly match with the IEA 2015 WEO data due to several adjustments that were required to convert the IEA data from the region groups contained in the WEO to the region groups used in IPM. These adjustments include separating out the individual countries in the WEO region groups using historical coal consumption data from IEA 2015 WEO, and combining the individual countries into the region groups used in IPM. For example, the coal demand for India is included as a separate country in the IEA data; however, in IPM both India and Pakistan are included together as one coal demand region, so the coal demand for Pakistan was added to the coal demand for India to obtain the "India" coal demand shown in Tables 4-26 and 4-27.

Table 4-28 shows the thermal coal demand for the Upper Bound Scenario. The coal demand in the Upper Bound Scenario is based on the assumption that the higher coal demand growth of the period of 2000 through 2012 is achieved going forward. This methodology starts with the EIA historical total coal consumption for 2000 through 2012 (U.S. Energy Information Administration 2016e). The

coal demand in subsequent years is determined by using the average growth rate of the 3-year rolling average growth rates for each region. For regions where the 2040 coal demand was more than 100% of the IEA 2015 WEO Current Scenario demand, the growth rate was adjusted down to yield a lower and more reasonable forecast. As with the Current Policies Scenario and the New Policies Scenario, the metallurgical coal forecast is subtracted from the total coal forecast. In this case the metallurgical coal forecast for the Current Policies Scenario was used.

Table 4-26. International Thermal Coal Demand Forecast — No Clean Power Plan and Cumulative Scenarios (Trillion Btu)

Country	2016	2018	2020	2025	2030	2035	2040
Africa, North	182.7	2,355.7	4,528.7	5,076.0	5,623.3	6,808.1	7,992.9
Asia Other	2,602.9	2,968.3	3,333.8	3,739.0	4,144.3	4,513.4	4,882.5
Australia	1,268.3	1,480.6	1,693.0	1,661.2	1,629.4	1,610.1	1,590.8
Britain	752.1	835.0	918.7	826.4	733.4	650.0	566.2
China	57,998.5	64,719.0	71,432.3	77,017.0	82,560.1	85,485.9	88,374.6
Colombia	161.5	179.4	197.5	232.7	267.9	310.1	352.2
Europe-East	597.8	708.4	819.0	773.9	728.7	710.8	692.8
Europe-North	50.9	75.1	99.8	86.6	73.0	60.5	47.8
Europe-South	1,413.8	1,484.0	1,555.0	1,445.1	1,334.6	1,241.2	1,147.6
Europe-West	1,527.6	1,667.5	1,809.3	1,627.3	1,443.9	1,279.4	1,114.3
Germany	2,134.4	2,289.9	2,448.3	2,199.8	1,949.2	1,724.1	1,498.1
Hong Kong	303.4	332.1	360.9	404.7	448.6	488.6	528.5
India	10,213.2	13,833.7	17,452.1	23,201.3	28,935.4	35,433.8	41,914.7
Indonesia	2,485.7	2,534.6	2,583.4	2,897.4	3,211.5	3,497.5	3,783.5
Japan	2,337.0	2,674.0	3,008.5	3,058.3	3,094.5	3,068.1	3,030.4
Kazakhstan	977.4	1,063.3	1,149.1	1,188.1	1,227.0	1,301.9	1,376.8
South Korea	1,716.2	1,911.1	2,106.0	2,028.0	1,949.3	1,891.4	1,832.8
Mexico	313.9	326.3	338.7	341.1	343.5	335.6	327.5
Middle East	221.1	180.9	140.7	151.9	163.2	169.7	176.1
Poland	1,469.4	1,611.2	1,754.8	1,578.6	1,401.2	1,242.0	1,082.2
Russia	2,452.6	2,600.9	2,748.4	2,838.2	2,922.0	2,963.1	2,997.4
South Africa	3,597.5	3,657.4	3,717.8	3,772.5	3,827.1	3,936.4	4,045.6
South America	921.8	935.8	951.5	1,089.4	1,225.5	1,400.7	1,575.1
Spain	400.3	382.2	364.6	327.0	289.1	255.1	220.8
Taiwan	1,091.0	1,324.3	1,557.5	1,761.4	1,964.7	2,148.3	2,331.3
Ukraine	345.8	469.2	592.6	621.8	650.9	710.5	770.0
Total	97,871.4	113,030.4	128,188.2	140,463.6	152,651.2	163,715.5	174,700.2

Source: U.S. Energy Information Administration 2016e; International Energy Agency 2015; ICF calculations

Table 4-27. International Thermal Coal Demand Forecast — Lower Bound and 2015 U.S. and International Energy Policy Scenarios (Trillion Btu)

Country	2016	2018	2020	2025	2030	2035	2040
Africa, North	182.7	2,331.5	4,480.3	4,854.0	5,291.9	6,103.0	7,199.6
Asia Other	2,602.9	2,903.9	3,204.9	3,379.8	3,593.2	3,765.3	3,882.3
Australia	1,268.3	1,454.3	1,640.2	1,518.8	1,435.6	1,326.1	1,193.5
Britain	752.1	810.8	870.5	681.8	496.6	355.6	274.8
China	57,998.5	63,331.4	68,638.9	69,967.3	71,090.3	70,786.2	68,475.5
Colombia	161.5	176.1	190.7	213.9	244.0	270.0	301.2
Europe-East	597.8	678.2	758.5	641.5	517.5	452.2	398.6
Europe-North	50.9	70.8	91.1	60.6	30.5	7.7	0.0
Europe-South	1,413.8	1,446.3	1,479.7	1,229.1	972.8	764.5	639.7
Europe-West	1,527.6	1,619.9	1,714.1	1,341.9	976.5	698.4	539.2
Germany	2,134.4	2,224.3	2,317.1	1,806.4	1,304.7	923.1	705.3
Hong Kong	303.4	325.2	346.9	365.9	389.0	407.6	420.3
India	10,213.2	13,382.2	16,549.1	19,999.2	24,655.4	29,338.7	33,846.4
Indonesia	2,485.7	2,484.7	2,483.6	2,619.1	2,784.5	2,917.8	3,008.4
Japan	2,337.0	2,619.8	2,899.9	2,730.7	2,688.7	2,506.9	2,273.8
Kazakhstan	977.4	1,035.4	1,093.4	1,107.6	1,105.2	1,157.5	1,166.0
South Korea	1,716.2	1,866.0	2,015.7	1,784.0	1,617.4	1,404.9	1,152.2
Mexico	313.9	304.2	294.6	269.0	236.0	212.4	207.5
Middle East	221.1	180.8	140.5	150.1	156.1	160.5	163.1
Poland	1,469.4	1,565.2	1,662.8	1,303.0	949.5	680.6	526.6
Russia	2,452.6	2,522.6	2,591.4	2,794.0	2,637.9	2,601.5	2,338.9
South Africa	3,597.5	3,622.2	3,647.6	3,595.4	3,459.9	3,370.4	3,286.4
South America	921.8	903.6	887.1	948.4	1,034.3	1,123.7	1,250.7
Spain	400.3	372.2	344.5	266.7	190.4	132.3	99.3
Taiwan	1,091.0	1,290.2	1,489.4	1,571.3	1,673.2	1,752.6	1,802.3
Ukraine	345.8	445.6	545.3	553.5	547.7	588.1	591.3
Total	97,871.4	110,354.2	122,817.3	126,129.4	130,376.4	134,044.2	135,953.6

Source: U.S. Energy Information Administration 2016e; International Energy Agency 2015; ICF calculations

Table 4-28. International Thermal Coal Demand Forecast — Upper Bound Scenario (Trillion Btu)

Country	2016	2018	2020	2025	2030	2035	2040
Africa, North	182.7	2,355.7	4,528.7	5,076.0	5,623.3	6,808.1	7,992.9
Asia Other	2,602.9	2,968.3	3,333.8	4,254.9	5,430.4	7,138.0	8,845.6
Australia	1,268.3	1,480.6	1,693.0	1,661.2	1,629.4	1,610.1	1,590.8
Britain	752.1	835.0	918.7	874.7	832.7	792.3	751.5
China	57,998.5	64,719.0	71,432.3	78,781.0	86,597.5	95,218.9	103,803.1
Colombia	161.5	179.4	197.5	232.8	270.9	320.5	370.0
Europe-East	597.8	708.4	819.0	893.6	972.4	1,057.8	1,143.2
Europe-North	50.9	75.1	99.8	86.5	74.4	63.5	52.4
Europe-South	1,413.8	1,484.0	1,555.0	1,651.8	1,752.6	1,858.8	1,964.7
Europe-West	1,527.6	1,667.5	1,809.3	1,658.3	1,519.5	1,394.3	1,268.4
Germany	2,134.4	2,289.9	2,448.3	2,348.5	2,252.7	2,158.4	2,063.1
Hong Kong	303.4	332.1	360.9	425.1	500.8	598.0	695.1
India	10,213.2	13,833.7	17,452.1	23,201.3	30,308.8	40,790.6	51,254.8
Indonesia	2,485.7	2,637.1	2,797.7	3,243.3	3,759.9	4,406.5	5,053.0
Japan	2,337.0	2,674.0	3,008.5	3,283.4	3,548.4	3,807.0	4,054.4
Kazakhstan	977.4	1,063.3	1,149.1	1,229.2	1,313.6	1,405.0	1,496.3
South Korea	1,716.2	1,911.1	2,106.0	2,322.1	2,556.3	2,820.9	3,084.7
Mexico	313.9	326.3	338.7	365.8	395.1	428.1	460.9
Middle East	221.1	225.5	230.1	241.8	254.2	267.4	280.7
Poland	1,469.4	1,611.2	1,754.8	1,706.5	1,659.4	1,611.2	1,562.4
Russia	2,452.6	2,600.9	2,748.4	2,873.2	3,003.4	3,145.6	3,281.1
South Africa	3,597.5	3,677.3	3,759.6	3,975.6	4,204.0	4,454.9	4,705.8
South America	921.8	1,020.0	1,131.3	1,473.0	1,908.5	2,566.3	3,223.2
Spain	400.3	386.5	373.5	344.1	316.8	291.9	266.9
Taiwan	1,091.0	1,324.3	1,557.5	1,761.4	1,964.7	2,148.3	2,331.3
Ukraine	345.8	469.2	592.6	621.8	650.9	710.5	770.0
Total	97,536.7	112,855.4	128,196.0	144,586.8	163,300.8	187,872.9	212,366.7

Source: U.S. Energy Information Administration 2016e; International Energy Agency 2015; ICF calculations

4.2.12 Coal Demand Elasticity

Because the international coal demand is a forecast that is an input to the model, coal demand elasticity was used to adjust the demand based on the change in delivered coal prices. The change in coal demand is referred to as "induced demand" in the following report chapters. The demand elasticity is a measure of how much coal demand will change with a given change in the delivered coal price. As delivered coal prices change, the demand for coal changes in the opposite direction. A

literature search was done to identify an energy-specific demand elasticity for this analysis. Five sources were reviewed that provided information on long-term coal demand elasticity.[22]

Coal plays a crucial role in China, Japan, India, South Korea, and Taiwan, with coal consumption levels forecasted to either peak in the future or continue to grow. China is currently the world's largest coal consumer and producer by a wide margin. Although peak coal demand in China has been forecast in the next decade, the amount of coal needed in China to satisfy its energy needs is significant within international coal markets. Given these trends and the fact that at least half of the coal consumed in these Asian countries is for power generation, coal demand is relatively inelastic, meaning a 1% increase in coal prices would lead to a less than 1% decrease in coal demand. The one exception is China, which has a large sector with direct use of coal for space heating, leading to lower elasticities. Based on a literature review, the price elasticity of coal demand in the United States is -0.11 (consequently, a 1% increase in coal prices results in a 0.11% decrease in coal demand). India, Japan, South Korea, and Taiwan continue to rely on imported coal as intermediate goods in power production and to a lesser degree steel production; therefore, this analysis assumes a -0.11 price elasticity of coal demand in these countries.

The price elasticities of coal demand for India, Japan, South Korea, and Taiwan are held constant in all scenarios, as they exhibit inelastic demand of coal. However, for China, compared to the No Clean Power Plan Scenario, coal demand in the 2015 U.S. and International Energy Policy Scenario and the Lower Bound Scenario is more inelastic, while coal demand in the Upper Bound Scenario is more elastic (i.e., change in price has more of an effect on the quantity of coal demanded than in the 2015 U.S. and International Energy Policy Scenario). To reflect these variations, a price elasticity of -0.32 is assumed in the Lower Bound and 2015 U.S. and International Energy Policy Scenario, while -0.68 is assumed for the Upper Bound in China.

To reflect the change in demand (induced demand) due to a change in delivered coal prices, the analysis assumes that new demand is only induced in one period and is then constant throughout the remainder of the forecast period. This assumption is made because the analysis is examining the impact of the terminal coming online, and it is not reasonable to attribute changes in coal prices 10 or 20 years later to the proposed coal export terminal. The induced demand could be realized in one of two ways; either by existing coal plants operating more, or through the construction of new coal plants. This analysis assumes that existing coal plants would be operated more throughout the forecast period.

Domestic coal demand changes as coal and natural gas prices change within the model. Thus an externally applied demand elasticity for domestic coal demand does not need to be specified or applied, because domestic coal demand will change automatically as other inputs change.

4.2.13 Coal Heat and CO_2 Content

In the IPM for this analysis, coal supply is modeled through 58 coal supply regions. Typically within each region there are between one and six coal types modeled. The coal types within and across coal supply basins differ based on the heat, CO_2, sulfur, mercury, hydrogen chloride, and ash content. For this analysis, the most important coal characteristics are the heat content and CO_2 emission rates. The coal types used in this analysis are identified by a two-letter code. The first letter represents the

[22] The five sources used are: Burke 2015, Jiao 2009, Ma 2016, Parry 2014, and U.S. Energy Information Administration 2012.

rank of the coal and the second letter represents the sulfur content of the coal. The first letter is either "B" for bituminous, "L" for lignite, or "S" for subbituminous. The second letter ranges from "A" to "G" with "A" being low sulfur and "G" being high sulfur. The EPA IPM documentation for v5.13 includes a "Coal" chapter that provides the specific sulfur grade definitions.

To estimate the CO_2 emissions from coal combustion, two main inputs are required. These inputs are (1) the amount of coal consumed in trillion Btu (TBtu), and (2) the carbon content, in pounds per million Btu, of the coal being consumed. The carbon content varies by coal rank (i.e., bituminous, subbituminous, and lignite) and by the source region of the coal. Since IPM® includes all U.S. coal plants, the model calculates the CO_2 emissions in the United States. However, IPM® does not calculate the CO_2 emissions for international coal consumption, as coal plants are not modeled explicitly. The model solution does determine the amount of coal consumed and the type of coal consumed, which covers the two inputs required for calculating CO_2 emissions from international coal demand regions. IPM® assumes that no international coal plants have carbon capture and sequestration technology installed and that it will not be installed on new or existing international coal plants during the timeframe of this analysis.

Tables 4-29 through 4-32 show the CO_2 emission rate and heat content of both domestic and international coal types. These tables include those coal types assumed to be exported through the proposed coal export terminal and that might be displaced by the exported coal. The coal that may be exported through the proposed terminal is from Colorado, Utah, Montana, and Wyoming. The international coals that the coal exported through the proposed terminal might displace includes coal from Australia, Canada, China, Colombia, India, Indonesia, Russia, South Africa, South Korea, Thailand, and Vietnam.

Five data sources were used to compile the coal heat content and CO_2 emission rate values. The first source is the EPA IPM modeling documentation, which has data for domestic and Canadian coal heat content and CO_2 emission rates (U.S. Environmental Protection Agency 2013).[23] The second source is the EIA Form 923 submissions, which contain information on deliveries of coal to power plants that includes the heat content of the coal (U.S. Energy Information Administration 2016b). The third source is the USGS World Coal Quality Inventory, which contains both heat content and carbon content data for some international coal supply regions (Tewalt et al 2010). The fourth source is the EIA 1994 study authored by B.D. Hong and E.R. Slatick. This study provides state specific CO_2 emission rates, which were used for most domestic coals, except for the regions that could export through the proposed coal export terminal. Finally, the fifth source used was the USGS CoalQual database that contains coal samples from within the United States, and was used to update the Wyoming and Montana Powder River Basin CO_2 emission rates, along with the Colorado and Utah Uinta Basin emission rates (Palmer et al 2015).

[23] EPA IPM documentation for IPM version 5.13, Chapter 9, Coal. The Coal chapter of the EPA documentation and the coal assumptions were not updated in either EPA IPM versions 5.14 or 5.15. Thus the use of EPA IPM v5.13 coal data.

Table 4-29. CO_2 and Heat Content in Coal by Type and Source Region: Domestic Coal Types for Appalachia and the Illinois Basin

Supply Region	Rank	Coal Type	Heat Content (MMBtu/ton)[a]	CO_2 Emissions Rate (lb CO_2/MMBtu)[b]
Central Appalachia				
Kentucky, East	Bituminous	BB	25.00	206.4
Kentucky, East	Bituminous	BD	24.80	206.4
Kentucky, East	Bituminous	BE	24.64	206.4
Tennessee	Bituminous	BB	26.20	206.4
Tennessee	Bituminous	BE	25.23	206.4
Virginia	Bituminous	BB	25.90	206.4
Virginia	Bituminous	BD	25.20	206.4
Virginia	Bituminous	BE	25.00	206.4
West Virginia, South	Bituminous	BB	24.40	206.4
West Virginia, South	Bituminous	BD	24.50	206.4
West Virginia, South	Bituminous	BE	23.83	206.4
Northern Appalachia				
Maryland	Bituminous	BD	23.00	204.7
Maryland	Bituminous	BE	23.20	204.7
Ohio	Bituminous	BE	24.20	204.7
Ohio	Bituminous	BG	24.10	204.7
Pennsylvania, Central	Bituminous	BG	24.40	204.7
Pennsylvania, West	Bituminous	BE	26.00	204.7
Pennsylvania, West	Bituminous	BG	25.40	204.7
West Virginia, North	Bituminous	BE	25.35	204.7
West Virginia, North	Bituminous	BG	25.00	204.7
Southern Appalachia				
Alabama	Bituminous	BB	25.50	204.7
Alabama	Bituminous	BE	24.00	204.7
Illinois Basin				
Illinois	Bituminous	BE	23.75	203.1
Illinois	Bituminous	BG	23.50	203.1
Indiana	Bituminous	BB	22.00	203.1
Indiana	Bituminous	BE	22.70	203.1
Indiana	Bituminous	BG	22.40	203.1
Kentucky, West	Bituminous	BD	23.80	203.1
Kentucky, West	Bituminous	BG	23.80	203.1

[a] Heat content data sourced from EPA v5.13 documentation, Chapter 9, Coal, Table 9-5 Coal Quality Characteristics by Supply Region and Coal Grade.

[b] CO_2 emission rate data sourced from Hong and Slatick, 1994, and from the USGS CoalQual database.

Table 4-30. CO_2 and Heat Content in Coal by Type and Source Region: Domestic Coal Types for Interior and Western Regions

Supply Region	Rank	Coal Type	Heat Content (MMBtu/ton)[a]	CO_2 Emissions Rate (lb CO_2/MMBtu)[b]
Interior				
Arkansas, North	Bituminous	BG	22.00	202.8
Kansas	Bituminous	BG	22.00	202.8
Louisiana	Lignite	LE	13.80	212.6
Missouri	Bituminous	BG	22.00	202.8
Oklahoma	Bituminous	BG	22.00	202.8
Great Plains, Montana, and Northwest				
Montana, East	Lignite	LE	12.97	219.3
North Dakota	Lignite	LE	13.10	219.3
Montana, Bull Mountains	Bituminous	BB	20.40	212.5
Alaska	Bituminous	BA	24.40	205.5
Alaska	Subbituminous	SA	15.30	214.0
Powder River Basin				
Montana, Powder River	Subbituminous	SA	18.64	213.8
Montana, Powder River	Subbituminous	SD	17.08	213.8
WY, Powder River Basin (8400)	Subbituminous	SB	16.79	212.0
WY, Powder River Basin (8800)	Subbituminous	SA	17.60	209.4
Rockies				
Colorado, Green River	Bituminous	BB	22.74	209.6
Colorado, Green River	Subbituminous	SB	20.00	209.6
Colorado, Raton	Bituminous	BB	23.36	209.6
Colorado, Uinta	Bituminous	BB	22.22	208.4
Utah	Bituminous	BA	22.56	205.6
Utah	Bituminous	BE	24.06	205.6
Wyoming, Green River	Bituminous	BB	22.00	214.3
Wyoming, Green River	Subbituminous	SD	18.80	214.3
Southwest				
Arizona	Bituminous	BB	21.50	207.1
New Mexico, San Juan	Subbituminous	SB	19.60	209.2
New Mexico, San Juan	Subbituminous	SE	18.40	209.2
Texas				
Texas	Lignite	LE	13.47	212.6
Texas	Lignite	LF	12.47	212.6
Texas	Lignite	LG	10.68	212.6

[a] Heat content data sourced from EPA v5.13 documentation, Chapter 9, Coal, Table 9-5 Coal Quality Characteristics by Supply Region and Coal Grade, except for Colorado, Uinta; Montana, Bull Mountains; Montana, Powder River; and Utah, which were sourced from EIA 923 data for 2011 to April 2016.

[b] CO_2 emission rate data sourced from Hong and Slatick, 1994, and from the USGS CoalQual database.

Table 4-31. CO_2 and Heat Content in Coal by Type and Source Region: International Coal Types for the Americas and Europe

Supply Region	Rank	Coal Type	Heat Content (MMBtu/ton)[a]	CO_2 Emissions Rate (lb CO_2/MMBtu)[c]
Alberta, Canada	Subbituminous	SA	16.12	214.9
Alberta, Canada	Subbituminous	SB	15.55	211.0
Alberta, Canada	Subbituminous	SD	14.94	214.9
British Columbia, Canada - North	Bituminous	BD	21.40	205.4
British Columbia, Canada - South	Bituminous	BD	21.40	205.4
Colombia[b]	Bituminous	BA	21.60	205.9
Europe - East	Bituminous	BA	21.61	206.0
Europe - East	Lignite	LD	7.69	217.2
Europe - North	Lignite	LD	7.56	217.2
Germany	Bituminous	BA	26.64	208.4
Germany	Lignite	LD	11.93	212.7
Greece/Turkey	Bituminous	BA	20.26	206.0
Greece/Turkey	Lignite	LD	12.53	214.7
Mexico	Subbituminous	SB	17.52	206.3
Other South America	Lignite	LD	11.05	217.2
Other South America	Subbituminous	SB	16.00	212.0
Poland	Lignite	LD	6.75	212.7
Poland	Subbituminous	SB	19.00	206.3
Saskatchewan, Canada	Lignite	LD	13.82	219.3
Saskatchewan, Canada	Lignite	LE	10.58	215.3
Spain	Bituminous	BA	19.44	206.0
Spain	Lignite	LD	13.29	217.2
United Kingdom	Bituminous	BA	25.06	205.7
Venezuela	Bituminous	BA	26.37	199.6

[a] The source for heat content is the USGS World Coal Inventory, unless otherwise identified in these notes.

[b] Source for Colombia and Australia coal heat content is Argus Coal Daily Methodology and IHS Thermal Coal and Petcoke Marker Price Methodology and Specifications.

[c] The source for CO_2 emission rates are from the USGS World Coal Inventory for the following countries: Colombia, Germany, Greece/Turkey, Mexico, Spain, United Kingdom, and Venezuela. The CO_2 emission rate for the following countries was estimated based on the coal type and location: Europe-East, Europe-North, Other South America, Poland, and Spain. The CO_2 emission rate for the Canadian provinces is from EPA v5.13 documentation, Chapter 9, Coal, Table 9-5 Coal Quality Characteristics by Supply Region and Coal Grade.

Table 4-32. CO_2 and Heat Content in Coal by Type and Source Region: International Coal Types for the Rest of the World

Supply Region	Rank	Coal Type	Heat Content (MMBtu/ton)[a]	CO_2 Emissions Rate (lb CO_2/MMBtu)[d]
Australia[b]	Bituminous	BA	21.60	206.0
Australia[b]	Lignite	LD	8.44	205.8
China	Bituminous	BA	23.85	212.2
China	Lignite	LD	14.04	218.5
India/Pakistan	Bituminous	BA	22.26	210.9
India/Pakistan	Lignite	LD	11.10	198.7
India/Pakistan	Subbituminous	SB	17.01	210.6
Indonesia[c]	Bituminous	BA	23.43	203.7
Indonesia[c]	Bituminous	BB	20.33	203.7
Indonesia[c]	Lignite	LD	12.95	205.8
Indonesia[c]	Subbituminous	SA	18.05	214.8
Indonesia[c]	Subbituminous	SB	17.09	214.8
Indonesia[c]	Subbituminous	SD	15.12	214.8
Kazakhstan	Bituminous	BA	23.08	212.5
Kazakhstan	Subbituminous	SB	18.92	214.6
Korea, South	Bituminous	BA	21.72	211.3
Korea, South	Lignite	LD	12.53	217.8
Russia	Lignite	LD	12.82	214.7
Russia	Subbituminous	SB	20.00	212.0
South Africa	Bituminous	BA	20.28	206.0
Thailand/Vietnam	Bituminous	BA	22.82	209.4
Thailand/Vietnam	Lignite	LD	12.30	211.8
Ukraine	Lignite	LD	6.00	214.7
Ukraine	Subbituminous	SB	18.19	212.0

[a] The source for heat content is the USGS World Coal Inventory, unless otherwise identified in these notes.

[b] Source for Australia coal heat content is Argus Coal Daily Methodology and IHS Thermal Coal and Petcoke Marker Price Methodology and Specifications

[c] Source of Indonesian coal heat content is the weighted average of mine specific data from nine Indonesian coal mining companies that produced more than 60% of Indonesia's coal in 2013 and 2014.

The nine Indonesian coal companies used are Adaro Energy, Arutmin, Bayan Resources, Berau Coal, Harum Energy, Indo Tambangraya Megah, Kaltim Prima Coal, Kideco, and Sakari Resources.

[d] The source for CO_2 emission rates are from the USGS World Coal Inventory for the following countries: China, India/Pakistan, Indonesia, South Korea, Kazakhstan, and Thailand/Vietnam. The CO_2 emission rate for the following countries was estimated based on the coal type and location: Australia, Russia, South Africa, and Ukraine.

4.2.14 Coal Distribution Limitations

Two limitations were placed on coal distribution and consumption. The first was placed on imports to China to limit the total amount of coal China could import. The limit of coal imports to China were included to ensure that the model did not import an unreasonable amount of coal into China, since China has only recently become a net importer of coal. The limits also were included because it is

unlikely that Chinese energy policy would allow for large amounts of coal to be imported for energy security reasons. The total coal import limits imposed on China restrict imports to less than 227 million metric tons through 2020, 318 million metric tons for 2025 to 2030, and 726 million metric tons in 2040.

The second limitation was placed on subbituminous coal imports into Hong Kong, Japan, South Korea, and Taiwan. Based on import and export data sourced from the United Nations Comtrade database – and assuming that each country already maximizes the amount of subbituminous coal that they can consume – the percentages for subbituminous coal consumption in Table 4-33 were set as the maximum that can be consumed. These percentages result in these four countries being able to consume between 39 and 44 million metric tons of subbituminous coal. Since the capacity of the proposed coal export terminal is 44 million metric tons, some of the exported coal may be shipped to and consumed in China or India.

Table 4-33. Subbituminous Coal Consumption Limits

Region	Weight Based Limit	Heat Content Based Limit[24]
Japan	6.8%	5.2%
Hong Kong	56.7%	49.6%
South Korea	16.3%	12.7%
Taiwan	18.7%	14.7%

Source: UN Comtrade 2017

4.2.15 Coal Reserves

Coal reserves both domestically and internationally are an important companion input to annual coal production capacity in the coal supply curves. Over time as the reserves on a step on the coal supply curve are exhausted, the solved equilibrium price must solve higher on the coal supply curve, thus generally pushing prices higher over time, all else equal.

International reserve data is generally of lower quality and can be inconsistent between sources. If multiple sources of reserve estimates were available, the analysis used the higher estimates, as technological improvements tend to make resources available that might have been uneconomic previously.

The estimates of reserves at existing U.S. mines is based on information contained in company financial reports and EIA data of state level reserves by mine type (surface or underground). For public mining companies the reserves are obtained from the financial reports. These reserves are then subtracted from the EIA reserve estimates for each state. The remaining reserves in the EIA data are allocated to all the other U.S. mines in each state for which data are not available through company financial reports. The reserves are allocated proportionally based on the annual production capacity. Table 4-34 shows the recoverable reserves at producing mines and the

[24] The Heat Content Based Percentage is calculated by assuming a subbituminous coal heat content of 18 MMBtu/ton and a bituminous coal heat content of 24 MMBtu/ton and taking the weighted average using the quantities for the year with the highest percentage of subbituminous coal in 2012 to 2014, which is the period for which data was available. For example, for Japan the calculation is: (13.8 mst x 18 MMBtu/ton) / (188.7 mst x 24 MMBtu/ton + 13.8 mst x 18 MMBtu/ton) = 0.052 or 5.2%. Where "mst" is million short tons.

estimated recoverable reserves. Recoverable reserves are coal deposits which are considered economically recoverable at the time the estimate is made.

Table 4-34. Recoverable Coal Reserves by Mine Type and State, 2014 (million short tons)

Coal-Resource State	Underground - Minable Coal		Surface - Minable Coal	
	Reserves at Producing Mines	Estimated Reserves	Reserves at Producing Mines	Estimated Reserves
Alabama	213	399	16	2,222
Alaska	-	2,335	53	483
Arizona	-	-	216	-
Arkansas	25	126	-	101
Colorado	207	5,766	126	3,742
Georgia	-	1	-	1
Idaho	-	2	-	-
Illinois	2,426	27,729	37	10,035
Indiana	295	3,515	351	286
Iowa	-	807	-	320
Kansas	-	-	<0.5	679
Kentucky Total	767	6,845	122	7,230
Kentucky (East)	293	317	66	5,003
Kentucky (West)	474	6,528	55	2,227
Louisiana	-	-	92	283
Maryland	8	307	14	31
Michigan	-	55	-	3
Mississippi	-	-	698	-
Missouri	-	689	1	3,154
Montana	240	35,889	618	38,666
New Mexico	16	2,749	169	4,048
North Carolina	-	5	-	-
North Dakota	-	-	1,003	6,657
Ohio	332	7,585	47	3,705
Oklahoma	8	570	1	220
Oregon	-	6	-	2
Pennsylvania Total	1,088	10,232	167	973
Pennsylvania (Anthracite)	1	340	121	418
Pennsylvania (Bituminous)	1,087	9,892	46	555
South Dakota	-	-	-	277
Tennessee	1	273	<0.5	171
Texas	-	-	703	9,169
Utah	95	2,332	2	210
Virginia	230	491	23	306
Washington	-	674	-	6
West Virginia Total	1,554	14,778	475	2,013

Coal-Resource State	Underground - Minable Coal		Surface - Minable Coal	
	Reserves at Producing Mines	Estimated Reserves	Reserves at Producing Mines	Estimated Reserves
West Virginia (Northern)	937	NA	7	NA
West Virginia (Southern)	617	NA	468	NA
Wyoming	35	22,918	6,878	13,683
U.S. Total	7,542	147,079	11,810	108,676

- = No data reported; NA = Not Available.
Source: U.S. Energy Information Administration 2016f

4.2.16 Federal Coal Lease Review

In January 2016, the U.S. Department of Interior Secretary, Sally Jewell, announced that the Interior Department would conduct a comprehensive review of the federal coal lease program and the royalty structure, and imposed a moratorium on new federal leases. The proposed review was to take the form of a Programmatic Environmental Impact Statement to address concerns raised by the public and other government agencies. Approximately 90% of coal on federal lands is in the Powder River Basin, and changes in the federal coal leasing program could affect this analysis. However, there are several factors that will reduce the chance that the change in the federal coal leasing program would affect the results of this analysis.

- First, existing leases have coal resources that will provide enough coal for extraction for the next 20 years, as of 2016 (U.S. Department of the Interior 2016). The existing leases will allow production to continue at 2016 levels through 2036, which is close to the end of the analytical period for this EIS. Therefore, any change to the coal leasing program would only affect the final 4 years of this coal market analysis. To the extent that production levels are lower or higher than in 2016, the 20-year timeframe would expand or decrease.

- Second, potential changes to the federal coal leasing program are highly speculative as of early 2017, and will likely not be known for 2 to 4 years. There is insufficient information available to make judgements on how the federal coal leasing program might change and thus how it should be modeled for this EIS.

- Third, the November 2016 presidential and congressional elections have resulted in an administration and Congress that show a greater interest in sustaining the coal industry and are less likely to overhaul the federal coal lease program in a way that will significantly increase the cost to mine operators.

Thus, while the review of the federal coal leasing program could result in significant changes to the program and thus to coal production costs in the Powder River Basin, there is too much uncertainty to include such possibilities in this analysis.

4.3 Methods

This section provides an overview of the methods used in the analysis.

4.3.1 Model Run Years

Table 4-35 presents a map of calendar years and run years. Run years aggregate calendar years to limit model complexity. In other words, a run year is a calendar year chosen to represent a single year or a group of years in which prevailing electricity and fuel market conditions and environmental policies are expected to be most similar. The number of IPM® run years is limited to decrease model complexity and run time. The analysis period of 2018 to 2038 reflects the 20-year period of reasonably foreseeable construction and coal export by the proposed coal export terminal. The coal market analysis models the proposed coal export terminal as fully online in the 2025 run year, and not operating in the 2020 run year.

Table 4-35. Mapping of Calendar Years and Model Run Years

Calendar Year	Run Year
2016	2016
2017	
2018	2018
2019	2020
2020	
2021	
2022	
2023	2025
2024	
2025	
2026	
2027	
2028	2030
2029	
2030	
2031	
2032	
2033	
2034	2040
2035	
2036	
2037	
2038	
2039	
2040	
2041	
2042	
2043	
2044	
2045	

4.3.2 Coal

4.3.2.1 Modeling U.S. Coal Production

IPM® optimizes coal production, transportation, and consumption. For this purpose, the model uses coal supply curves developed for EPA, which provide supply curves for 34 different domestic coal supply basins. The international coal supply curves for 25 international supply basins were developed by ICF and added to the domestic supply curves to allow for global coal modeling. Coal supply curves are developed for 15 coal types distinguished by rank and sulfur content. There are multiple coal supply curves for each supply basin corresponding to the major coal quality types in that region. The supply curves consist of a series of supply "steps" that consist of a production cost, annual production capacity, and a coal resource limit. These supply curves are then incorporated into IPM®. Each coal power plant in IPM® is assigned to its own coal demand region in the model.

Coal varies by heat content, SO_2 content, hydrogen chloride content, and mercury content among other characteristics. To capture differences in the sulfur and heat content of coal, a two letter "coal grade" nomenclature is used. The first letter indicates the "coal rank" (bituminous, subbituminous, or lignite) with their associated heat content ranges (as shown in Table 4-36). The second letter indicates their "sulfur grade," i.e., the SO_2 ranges associated with a given type of coal. (The sulfur grades and associated SO_2 ranges are shown in Table 4-37).

Table 4-36. Coal Rank Heat Content Ranges

Coal Type	Heat Content (Btu/lb)	Classification
Bituminous	>10,260–13,000	B
Subbituminous	>7,500–10,260	S
Lignite	Less than 7,500	L

Notes:
Btu/lb = British thermal units per pound

Table 4-37. Coal Grade SO_2 Content Ranges

SO_2 Grade	SO_2 Content Range (lbs/MMBtu)
A	0.00–0.80
B	0.81–1.20
D	1.21–1.66
E	1.67–3.34
G	3.35–5.00
H	> 5.00

Notes:
SO_2 = sulfur dioxide; lbs/MMBtu = pounds per million British thermal unit

IPM® includes integrated U.S. and international coal market modeling. Figures 4-3 and 4-4 show the domestic and international coal supply regions. The modeling platform captures terminal capacity limits, international shipping costs, steam coal supply, and demand from both electricity and non-electricity sectors.

Figure 4-3. Domestic Coal Supply Regions

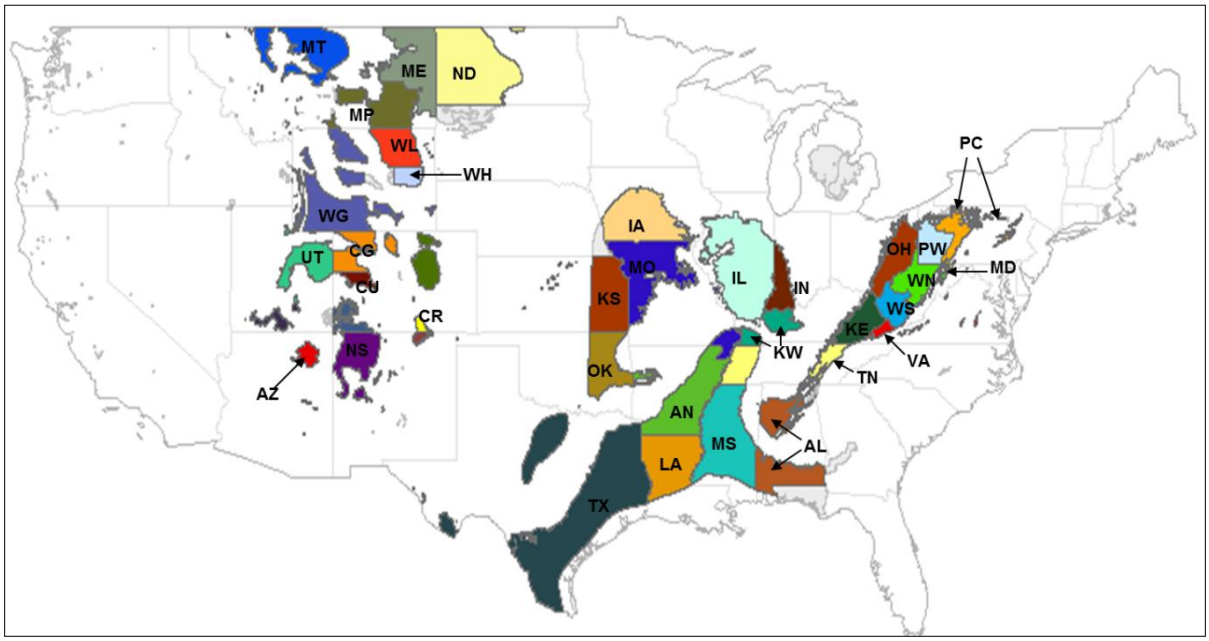
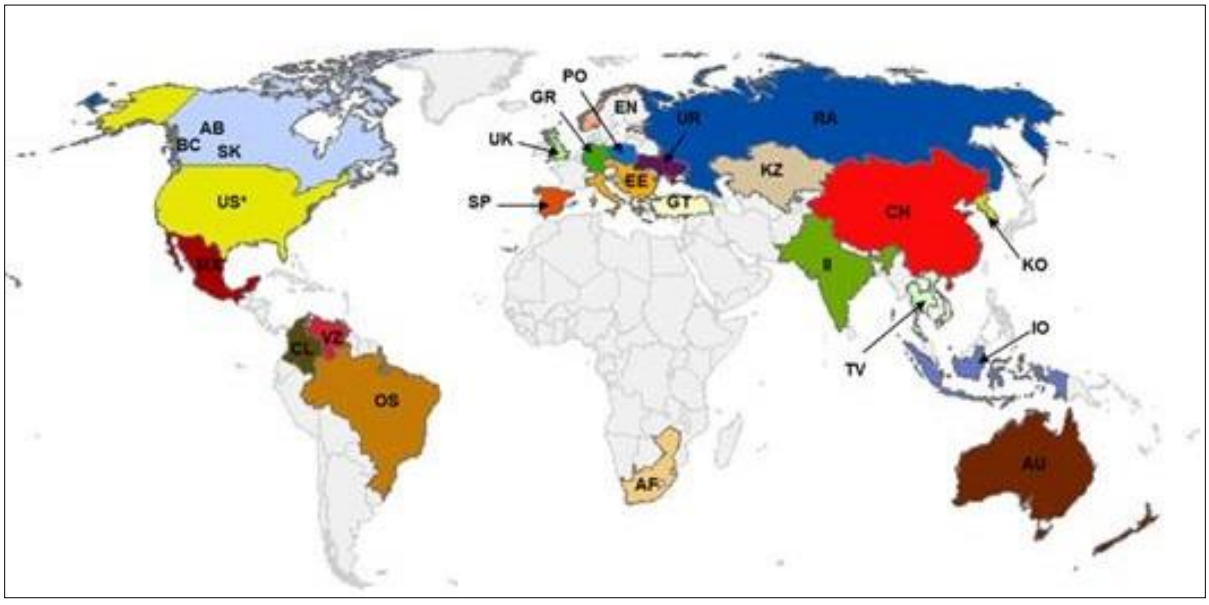


Figure 4-4. International Coal Supply Regions



4.3.2.2 Coal Demand

Using IPM®, coal demand is determined in the United States and Canada by the operation of existing coal-fired power plants, and elsewhere by projections of coal demand by country. Within a model run, IPM® calculates thermal coal consumption for each coal-fired electricity generation plant in the United States and Canada. Thermal coal consumption and coal prices are determined by the supply and demand economics of meeting the electricity demand. Thus if coal prices increase, there will be a reduction in coal demand in response to the higher coal prices. The plant specific coal

consumption and coal supply region price projections result in an integrated and consistent analysis in IPM® of the electricity demand; natural gas supply and prices; air emissions regulations for NO_X, SO_2, hydrogen chloride, and mercury; CO_2 policy alternatives, and renewable portfolio standards and explicit modeling of renewable generation options.

If the future electricity demand cannot be met by existing power plants, IPM® will determine the type and amount of new generating capacity required to meet the electricity demand on a least cost basis. The different types of capacity that can be added consist of combustion turbines, combined cycles, nuclear units, wind plants, coal-fired units, solar PV and thermal, geothermal, biomass, landfill gas, and hydro. Thus, if IPM® determines that new generating capacity in the United States and Canada are necessary and economic, IPM® will "build" new capacity from the types listed above. If the most economical new capacity is a coal plant, then coal demand would increase, resulting in higher coal prices, all else equal. IPM® can also determine that it is most economical to retire existing coal plants, which would decrease coal demand, and result in lower coal prices. This is only applicable in the United States and Canada, as coal plants are modeled explicitly in only these countries. Using this structure, IPM® is able to model explicitly the shifts in coal demand related to environmental mandates, natural gas prices, and coal production and transportation costs. For example, if natural gas prices are low, more electricity will be generated by natural gas-fired combined cycles, and coal consumption will be lower than in a case with higher natural gas prices.

In terms of non-electricity sector demand for thermal coal, IPM® includes domestic and international forecasts that serve as the demand for this coal. IPM® has an international coal supply and demand representation that enables it to project coal exports out of and imports into the United States and other countries. In the United States, coal demand is determined by the dispatch of coal-fired power plants and other generating resources to meet the electric demand. Table 4-38 summarizes the overall U.S. electricity demand forecast used in this analysis.

Table 4-38. U.S. Electric Energy Demand Forecast

Year	Energy Demand (TWh)
2016	4,050.9
2018	4,134.1
2025	4,327.7
2030	4,465.3
2040	4,740.5

Source: EPA IPM V5.15 documentation
TWh = terawatt hours

4.3.2.3 Coal Transportation

The model also connects the 34 U.S. coal supply regions and the 25 international supply regions with the plant specific coal demand regions in the United States and Canada, and 26 international coal demand regions. The transportation costs between supply and demand regions are based on the transportation mode, such as rail, barge, and truck, and the mileage between each region by mode. Each coal demand region has on average 9 supply regions connected to it, using one or more transportation modes. For international shipments, shipping rates are estimated based on published shipping cost data and are adjusted going forward based on projections of the global shipping index, the Baltic Dry Index.

Asian coal demand regions are linked to more than 20 supply regions including U.S. supply regions in Appalachia, the Uinta Basin, and the Powder River Basin and international supply regions such as Australia, Canada, China, Colombia, Indonesia, Korea, Kazakhstan, Russia, South Africa, and Venezuela.

During each run, IPM® determines the least cost means to meet power sector demand for coal as part of an integrated optimal solution for power, fuel, and emissions markets. Thus, IPM® is able to determine the optimal sourcing of coal for each power plant based on the estimated coal prices and transportation costs. Additional information on the coal transportation inputs and methodology used can be found in Chapter 9 of EPA's documentation on the IPM v5.13 Base Case.

4.3.3 Environmental Compliance

4.3.3.1 Plant-by-Plant Compliance Overview

For explicitly modeled coal plants in the United States and Canada, IPM® incorporates constraints on emissions of NO_X, SO_2, hydrogen chloride, mercury, CO_2, and potentially other pollutants into its optimization process. Since coal demand in other countries is done through a forecast and not explicitly modeling coal plants, this is only applicable to U.S. and Canadian coal plants. Constraints are specified based on target emissions rates, cap-and-trade policies, dollars per ton emitted tariffs, or command-and-control policies, and applied to individual generating units or groups of units. Power-generating units subject to environmental regulations have the following compliance options, with any combination or individual use of the first four options as a viable compliance mechanism.

- **Reduce running regime**. To comply with non-command-and-control policies, such as target emissions rates or an emissions cap, a unit can reduce the number of hours in a year it operates and shift when it operates to hours that are more lucrative, which would be during peak demand periods of a day or year. For example, a plant might run only during the peak hours of 6:00 a.m. and 10:00 p.m., or only during the peak summer season.

- **Fuel switch**. Coal-fired units can choose from a variety of coals of different sulfur and mercury contents to minimize emissions and allowance cost impacts. The demand for these lower content coals results in premiums for those coals, over coals with higher pollutant contents. This premium may shrink if, for example, control becomes the dominant compliance option and higher pollutant content coals can be burned by controlled units. Oil units are generally offered fuels with different sulfur contents as well. The system may also fuel switch, from new coal builds to new natural gas builds, for example, to address CO_2 emissions requirements.

- **Retrofit**. For the four pollutants NO_X, SO_2, hydrogen chloride, and mercury, a variety of retrofit technologies is available to reduce emissions. In the case of CO_2, IPM® includes potential carbon capture-and-sequestration technology retrofits that can be applied to both new and existing units.

- **Purchase allowances**. By calculating an allowance price, IPM® is implicitly assuming that some units are sellers of allowances and others are buyers.

- **Retire.** A unit can be forced to retire or be given the economic option to retire if it cannot cover its operating costs going forward.

4.3.3.2 CO_2 Emissions

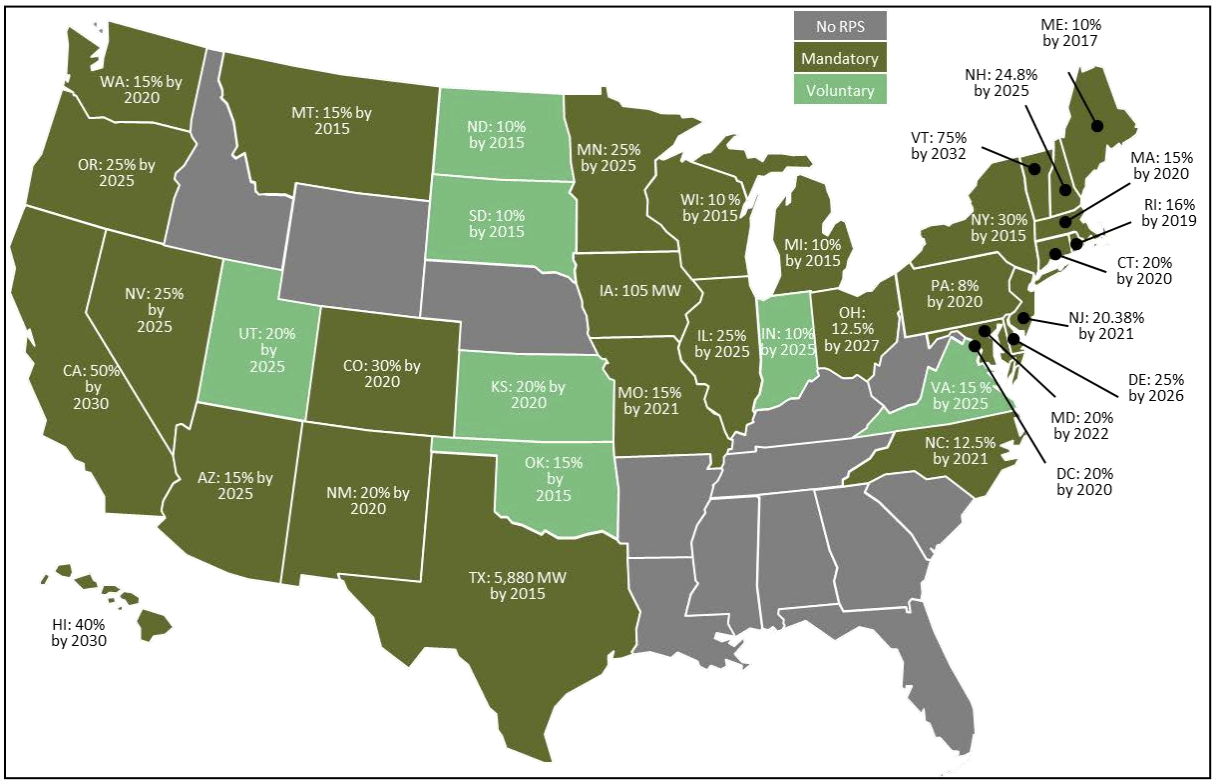
IPM® has the capability to model carbon policies as a cap-and-trade program or as a strict limit on CO_2 emissions from the power sector or the economy as a whole. In the 2015 U.S. and International Energy Policy Scenario, consistent with one of the alternatives under the EPA's proposed Federal Plan for the Clean Power Plan, IPM models EPA's final Clean Power Plan through state specific mass-based new and existing emissions constraints. The New Source Performance Standards for CO_2 for new and modified sources are reflected in the model by requirements that any new coal units, other than those named by EPA as exceptions, would have to be constructed with carbon capture and sequestration.

4.3.3.3 Renewable Portfolio Standards

IPM® treats renewable portfolio standards as follows.

- Twenty-eight states and the District of Columbia have passed mandatory renewable energy requirements; eight more have enacted voluntary standards or goals (Figure 4-5).
- The design of each renewable portfolio standard varies by target and timing, the types of renewable generation allowed, the geographic scope within which a generator might be eligible to meet the standard, and the types of enforcement mechanisms and escape clauses included.

Figure 4-5. Renewable Portfolio Standards



Renewable generation capacity tends to have a higher-leveled cost than fossil-fuel generation. To encourage the development of renewable capacity, many states allow generators to commoditize the

green attributes of renewable power in renewable energy credits.[25] The sale of such credits can provide supplemental revenue. IPM models wholesale power markets for a given set of future conditions (energy demand, new power plant costs, fuel market conditions, environmental regulations, renewable energy standards, etc.), using a least-cost optimization approach. IPM models REC pricing as the value needed to make renewable generators whole, given the gap between generator costs and revenue sources. Revenue sources include energy prices, capacity prices, and other nonrenewable energy certificate subsidies, such as the federal production and investment tax credits and modified accelerated cost recovery system.

4.3.3.4 Other State and Regional Requirements

The modeling also addresses the following state and regional programs.

- IPM® included the CO_2 cap currently specified in the Regional Greenhouse Gas Initiative.
- IPM® includes California Assembly Bill 32 cap-and-trade program, which affects both in-state generation, as well as power imported into California.
- IPM® includes other state SO_2 and NO_X regulations where final regulations exist.

4.3.4 Natural Gas

This analysis uses the natural gas mode from EPA's IPM v5.15 Base Case. A thorough description of the natural gas modeling and assumption is contained in Chapter 10 of EPA's documentation for v5.13, and thus, is not duplicated here.

[25] Alternative terms used for such instruments include *green tags* and *renewable energy certificates*.

Chapter 5
Scenarios

Four main scenarios and a cumulative scenario were modeled using IPM®. The four main scenarios are the No Clean Power Plan Scenario, Lower Bound Scenario, Upper Bound Scenario, and 2015 U.S. and International Energy Policy Scenario. The Cumulative Scenario takes into account the addition of other reasonably foreseeable planned export terminals in the Pacific Northwest. The Lower and Upper Bound Scenarios are designed to provide reasonable bounds on GHG emissions from implementing the Proposed Action. The four main scenarios differ regarding the following six parameters.

- International coal supply curves
- International thermal coal demand
- Coal demand elasticity
- Powder River Basin and Uinta Basin coal supply curves
- U.S. rail transportation costs
- U.S. and International Climate Policy. The U.S. climate policy is incorporated into the modeling by using an assumed version of the Clean Power Plan or by not including the Clean Power Plan.[26] The international climate policies are incorporated into the modeling through the international coal demand used in each scenario.

All five scenarios use a common set of base assumptions, many of which were updated between the Draft EIS and Final EIS. Detailed descriptions of these assumptions are included in Chapter 4. The set of base assumptions include, but are not limited to, the following:

- Coal supply curves for U.S. and international coal supply regions. In the No Clean Power Plan Scenario, the base coal supply curves result in Powder River Basin Wyoming 8800 Btu/lb coal being priced at $12.6/ short ton, Uinta Basin 11,280 Btu/lb coal being priced at $39.0/short ton, and Australian 10,800 Btu/lb coal being priced at $62.8/ short ton.[27] All prices are in 2012$ for the year 2018.
- Coal transportation costs. The base rail transportation costs are $30 to $36 per short ton for coal transported from the Powder River Basin and Uinta Basin to the proposed coal export terminal.
- Natural gas supply curves.
- Air, waste, and water regulations

[26] Since implementation of the Clean Power Plan will occur at the state level and states have not determined how they will implement the Clean Power Plan, a version of the Clean Power Plan consistent with one of the alternatives under the EPA's proposed Federal Plan for the Clean Power Plan that features state specific mass standards for existing units was used.

[27] British thermal units (Btu) are a standardized measurement of the heat content of coal.

- Renewable energy standards and regulations
- Reserve margin targets for each U.S. electric demand region
- Planned new generating capacity and retirements
- Electric transmission limits
- Electric demand
- Capital costs for new electric generating capacity
- International coal demand. The base assumption for international coal demand is the Current Policies Scenario from the IEA 2015 WEO. The Current Policies Scenario includes only those GHG reduction policies for which implementing measures have been formally adopted as of mid-2015, and assumes that these policies remain unchanged going forward.
- Elasticity of coal demand for the Asian countries that can receive coal from the proposed coal export terminal. The base elasticity of coal demand for China is -0.44 and is -0.11 for India, Japan, South Korea, and Taiwan.

5.1 Scenarios Analyzed

A No-Action Alternative and a Proposed Action case were created for each scenario analyzed, except for the Cumulative Scenario, where the Proposed Action is compared to the No Clean Power Plan Scenario No-Action Alternative. This was done to isolate the Proposed Action as the only change between the No-Action Alternative and Proposed Action in each scenario. Table 5-1 summarizes the No Clean Power Plan, Lower Bound, Upper Bound, and 2015 U.S. and International Energy Policy Scenarios and the following sections provide additional details on the differences between each scenario.

Table 5-1. Scenario Definitions

Parameter	Scenario			
	No Clean Power Plan	**Lower Bound**	**Upper Bound**	**2015 U.S. and International Energy Policy**
International Coal curves	No change from base assumptions	Base supply curves decreased by 10%	Base supply curves increase by 50%, based on prices observed between 2012 and 2014	No change from base assumptions
International thermal coal demand	No change from base assumptions	IEA 2015 WEO demand forecast from the New Policies Scenario	Increase coal demand by using historical growth rates from the period 2000 to 2012, when coal demand was rapidly increasing	IEA 2015 WEO demand forecast from the New Policies Scenario
Coal demand elasticity	No change from base assumptions	1.0% change in delivered coal cost results in 0.32% change in demand in opposite direction in China and 0.11% elsewhere	1.0% change in delivered coal cost results in 0.68% change in demand in opposite direction in China and 0.11% elsewhere	1.0% change in delivered coal cost results in 0.32% change in demand in opposite direction in China and 0.11% elsewhere
Powder River Basin and Uinta Basin coal curves	No change from base assumptions	Increase Powder River Basin curves by 25%, based on coal prices between 2012 and 2014	Decrease Powder River Basin and Uinta Basin coal curves by 15%, based on low coal prices between 2012 and 2016	No change from base assumptions
U.S. Rail transportation costs	No change from base assumptions	Increase costs by 20%	Decrease costs by 20%	No change from base assumptions
U.S. and International Climate Policy	No U.S. or international Climate Policies	Clean Power Plan and International GHG reduction commitments	No U.S. or international Climate Policies	Clean Power Plan and International GHG reduction commitments

IEA 2015 WEO = International Energy Agency 2015 World Energy Outlook

5.1.1 No Clean Power Plan Scenario

The No Clean Power Plan Scenario is defined by a set of assumptions that are intended to represent the state of the energy markets as of 2016, but without EPA's Clean Power Plan. The No Clean Power Plan Scenario uses the base set of assumptions and assumes no additional national or international climate policies will be enacted beyond those implemented by mid-2015. For the six parameters that are changed to define the four main scenarios, the No Clean Power Plan Scenario is defined as described in the following bullets.

- International coal curves: no change from base assumptions. Australian bituminous 10,800 Btu/lb (6,000 kilocalorie per kilogram) coal is $62.8 per short ton in 2018 (2012$).
- International thermal coal demand: no change from base assumption, which uses the IEA 2015 WEO coal demand forecast from the Current Policies Scenario.
- Coal demand elasticity: no change from base assumption, which is every 1.0% change in delivered coal cost would result in 0.44% change in demand in opposite direction in China and 0.11% for Hong Kong, India, Japan, South Korea, and Taiwan.
- Powder River Basin and Uinta Basin coal curves: no change from base assumption. The Powder River Basin Wyoming 8800 Btu/lb coal would be $12.6/short ton, and Uinta Basin prices would be $39.0/ton for 11,280 Btu/lb coal in 2018 (2012$).
- Rail transportation costs: no change from base assumptions, which are $30 to $36 per short ton for coal transported from the Powder River Basin and Uinta Basin to the proposed coal export terminal (2012$).
- U.S. and international climate policies: This scenario does not include implementation of the Clean Power Plan or international climate policies that were implemented after mid-2015.

5.1.2 Lower Bound Scenario

The Lower Bound Scenario is designed to result in a reasonable lower bound estimate of global CO_2 emissions from the power sector and to evaluate the likelihood of a smaller CO_2 emissions impact with the construction and operation of the proposed coal export terminal. This scenario is designed to be a plausible and reasonable lower bound, and does not attempt to model an absolute lowest bound of CO_2 emissions or CO_2 emissions due to the Proposed Action. The energy market under the Lower Bound Scenario could be described as a high renewable energy penetration scenario. If renewable energy penetration is higher than expected, international coal consumption and prices would both decline. For the six parameters that are changed to define the four main scenarios, the Lower Bound Scenario for both the No-Action Alternative and Proposed Action is defined as described in the following bullets.

- International coal curves were decreased from the base assumptions by 10%. This change might cause a smaller amount of induced demand because it would reduce the differential in prices between international coal and the coal exported through the proposed terminal. Australian bituminous 10,800 Btu/lb (6,000 kilocalorie per kilogram) coal is $56.5 per short ton in 2018 (2012$).
- International thermal coal demand was obtained from the IEA 2015 WEO coal demand forecast from the New Policies Scenario, as this Scenario includes both existing and proposed GHG reduction policies. Thus the international thermal coal demand in the Lower Bound Scenario is lower than the base assumptions.
- Coal demand elasticity would be less elastic than the base assumptions. In the Lower Bound Scenario a 1.0% change in delivered coal cost would result in a 0.32% change in demand in opposite direction in China and 0.11% elsewhere. To the extent that there would be a decrease

in delivered coal costs, this assumption would cause the amount of induced demand to be less than it would be under the base assumptions.

- The Powder River Basin coal curves are increased by 25% to reflect higher than expected stripping ratios. The Powder River Basin Wyoming 8800 Btu/lb coal would be $12.0/short ton, and Uinta Basin prices would be $39.2/ton for 11,280 Btu/lb coal in 2018 (2012$).

- Rail transportation costs were increased by 20% to reflect higher than expected fuel costs compared to the base assumptions.

- U.S. and international climate policies: The Lower Bound Scenario assumes the Clean Power Plan is implemented in the United States and the international GHG reduction commitments that are included in the IEA 2015 WEO New Policies Scenario.

5.1.3 Upper Bound Scenario

The Upper Bound Scenario is designed to result in a reasonable upper bound estimate of global CO_2 emissions from the combustion of coal and to evaluate the possibility of greater CO_2 emissions due to the construction and operation of the proposed terminal. This scenario is designed to be a plausible and reasonable upper bound on global CO_2 emissions from coal combustion, but does not attempt to model an absolute highest amount of global CO_2 emissions or CO_2 emissions due to the Proposed Action.[28] The world energy outlook under the Upper Bound Scenario could be described as a high coal demand scenario, where coal plant construction, and thus, coal demand, is higher than in the base assumptions. Thus, both international coal consumption and prices would increase. The coal prices would increase because the higher demand would drive the prices higher. For the six parameters that change to define the four main scenarios, the Upper Bound Scenario for both the No-Action Alternative and Proposed Action is described in the following bullets.

- International coal curves were increased from the base assumptions by 50%. This change causes a larger amount of induced demand because it would increase the differential between the international coal prices and the coal exported though the proposed terminal. Australian bituminous 10,800 Btu/lb (6,000 kilocalorie per kilogram) coal is $95.5 per short ton in 2018 (2012$).

- International thermal coal demand was obtained from using historical coal consumption growth rates from the period 2000 to 2012 and applying those growth rates to current consumption. Thus, the international thermal coal demand in the Upper Bound Scenario is higher than the base assumptions.

- Coal demand elasticity would be more elastic than the base assumptions. In the Upper Bound Scenario, a 1.0% change in delivered coal cost would result in a 0.68% change in demand in opposite direction in China and 0.11% elsewhere. To the extent that there would be a change in delivered coal costs, this assumption would cause the amount of induced demand to be greater than it would be under the base assumptions.

- Powder River Basin and Uinta Basin coal curves: the Powder River Basin and Uinta Basin coal curves were decreased by 15% to reflect lower than expected stripping ratios. The Powder

[28] There is no specific confidence interval or probability associated with this scenario.

River Basin Wyoming 8800 Btu/lb coal would be $13.2/short ton, and Uinta Basin prices would be $33.6/ton for 11,280 Btu/lb coal in 2018 (2012$).

- Rail transportation costs were decreased by 20% to reflect lower than expected fuel costs compared to the base assumptions.
- U.S. and international climate policies: The Upper Bound Scenario does not include implementation of the Clean Power Plan or international climate policies that were implemented after mid-2015.

5.1.4 2015 U.S. and International Energy Policy Scenario

The 2015 U.S. and International Energy Policy Scenario was created to evaluate how recent international climate negotiations and perspectives on future climate policies might affect GHG emissions under the Proposed Action. In particular, this scenario includes the November 2014 U.S.-China announcement on climate change action goals, other international GHG reduction commitments made by mid-2015, and implementation of the U.S. EPA Clean Power Plan. This scenario represents the energy market as of late 2015.

The 2015 U.S. and International Energy Policy Scenario uses the base assumptions except for three changes. First, the international thermal coal demand was taken from the IEA 2015 WEO, New Policies Scenario demand forecast. The New Policies Scenario takes into account the policies and implementing measures affecting energy markets that have been adopted as of mid-2015, together with relevant policy proposals, even if specific measures needed to put them into effect have yet to be fully developed. The New Policies Scenario assumed only cautious implementation of these proposed commitments and plans.

Second, this scenario includes EPA's final Clean Power Plan, which is intended to reduce CO_2 emissions in the United States that are a start to achieving the November 2014 commitments. The Clean Power Plan would also likely reduce the amount of coal consumed in the United States. Consistent with one of the alternatives under the EPA's proposed Federal Plan for the Clean Power Plan, the 2015 U.S. and International Energy Policy Scenario features state specific mass standards for existing sources. Allowances are assumed fully tradable between covered fossil units within a state, and can be traded across states. The trading is modeled such that all affected sources in all states can trade allowances with each other except for those in California and the member states of the Regional Greenhouse Gas Initiative, which are limited to trading within California or the Regional Greenhouse Gas Initiative, respectively. EPA's leakage requirement for mass based standards over existing sources is met by including allocations for existing gas and new renewable units, consistent with EPA's proposed Federal Plan and modeling for the Regulatory Impact Analysis for the final rule.

For the six parameters that are changed to define the four main scenarios, the 2015 U.S. and International Energy Policy Scenario is defined as described as follows.

- International coal curves: no change from base assumptions. Australian bituminous 10,800 Btu/lb (6,000 kilocalorie per kilogram) coal is $62.8 per short ton in 2018 (2012$).
- International thermal coal demand was obtained from the IEA 2015 WEO coal demand forecast from the New Policies Scenario, as this scenario includes both existing and proposed GHG

reduction policies. Thus the international thermal coal demand in the 2015 U.S. and International Energy Policy Scenario is lower than the base assumptions.

- Coal demand elasticity would be less elastic than the base assumptions. In the 2015 U.S. and International Energy Policy Scenario a 1.0% change in delivered coal cost would result in a 0.32% change in demand in opposite direction in China and 0.11% elsewhere. To the extent that there would be a decrease in delivered coal costs, this assumption would cause the amount of induced demand to be less than it would be under the base assumptions.
- Powder River Basin and Uinta Basin coal curves: no change from base assumption. The Powder River Basin Wyoming 8800 Btu/lb coal would be $10.9/short ton, and Uinta Basin prices would be $34.5/ton for 11,280 Btu/lb coal in 2018 (2012$).
- Rail transportation costs: no change from base assumptions, which are $30 to $36 per short ton for coal transported from the Powder River Basin and Uinta Basin to the proposed coal export terminal (2012$).
- U.S. and international climate policies: This scenario assumes the Clean Power Plan is implemented in the United States and the international GHG reduction commitments that are included in the IEA 2015 WEO New Policies Scenario.

5.1.5 Cumulative Scenario

The Cumulative Scenario includes the addition of other planned export terminals in the Pacific Northwest in both the United States and Canada. The planned export terminals, and their capacities included in this scenario, are shown in Table 5-2. Each terminal is assumed to operate at full capacity, except for the Ridley terminal due to the long rail distance of this terminal from the Powder River Basin. Thus there is a total export capacity of 183 million metric tons, which would include both thermal and metallurgical coal. Because the Canadian export terminals primarily export Canadian coal and are expected to continue this practice, only a portion of these terminals are available to export U.S. coal, as shown in the last column of Table 5-2. All other assumptions are the same as the base assumptions. The Cumulative Scenario does not include implementation of the Clean Power Plan.

Table 5-2. Planned and Existing Pacific Northwest Export Terminals

Terminal	State/Province	Online Year	Capacity (MMTons/year)	Capacity Available for U.S. Coal (MMTons/year)
Planned				
Millennium Bulk Terminal—Longview	Washington	2025	44	44
Gateway Pacific Terminal	Washington	2030	48	48
Fraser Surrey Docks	British Columbia	2018	4	4
Westshore Expansion	British Columbia	2017	3	3
Ridley Expansion	British Columbia	2016	13	9
Neptune Expansion	British Columbia	2018	6	0
Total Planned			118	108
Existing				
Westshore	British Columbia	N/A	33	8
Neptune (metallurgical coal only)	British Columbia	N/A	12	0
Ridley	British Columbia	N/A	12	5
Total Existing			57	13
Total Planned and Existing			**175**	**121**

MMTons/year = million metric tons per year

Chapter 6
Modeling Results

6.1 Overview of Results

This chapter presents the coal production, consumption, distribution, and emissions modeling results. Coal production results are presented for both U.S. and non-U.S. production, with a focus on Powder River Basin and Uinta Basin coal production. Emissions of CO_2 are presented for the consumption of coal only in Asia, and for coal and natural gas in the United States. Emissions from other sources, such as the transportation of coal, are presented in the air quality and greenhouse gas sections of the EIS. Emissions of CO_2 from natural gas are included in this chapter, because natural gas generation is a replacement for coal-fired electric generation that will have CO_2 emissions; however, emissions from natural gas are included only for U.S. and not international natural gas consumption.[29]. Results are presented for the full modeling time horizon of 2016 through 2040 to provide additional context for the changes that would occur under the Proposed Action. However, the averages presented in the tables are only for the period 2025 to 2040, to focus the changes in results on the period when the proposed coal export terminal is fully operational in the model. Construction of the proposed coal export terminal is expected to begin in 2018 and continue through 2020, with initial operation of the proposed coal export terminal beginning in 2021and ramping up capacity over time. Due to the run year structure, as described in Section 4.3.1, in the IPM the proposed coal export terminal is fully online in the 2025 run year and not online in the 2020 run year.

The proposed coal export terminal may cause changes in coal production at the following scales of production.

- Powder River Basin or Uinta Basin coal production
- U.S. coal production
- Non-U.S. coal production, such as in Australia, China, Indonesia or Russia

This section provides an overview of the No Clean Power Plan Scenario, No-Action Alternative and Proposed Action results, as well as results from the four scenarios analyzed.

- Lower Bound Scenario
- Upper Bound Scenario
- 2015 U.S. and International Energy Policy Scenario
- Cumulative Scenario

All coal production and consumption results in this analysis are presented in million metric tons.

[29] As discussed in Chapter 4, the international representation in the model only includes the consumption of coal.

6.1.1 No Clean Power Plan Scenario Results

Under the No Clean Power Plan Scenario total U.S. coal production for the No-Action Alternative would have an average of 813 million metric tons per year from 2025 to 2040. Coal production in the United States would increase steadily over this period, because of three factors.

- First, natural gas prices increase by $0.38/MMBtu, which keeps coal competitive.
- Second, there are no environmental policies making coal less competitive than other fuels.
- Third, electric demand continues to increase over this period.

Total non-U.S. coal production in this period would have an average of 7,098 million metric tons per year and would increase during the period analyzed to meet the expected growth in coal demand, which is primarily in China and India. For the Proposed Action, the U.S. average coal production over 2025 to 2040 would be 857 million metric tons, an increase of 44 million metric tons over the No-Action Alternative. The non-U.S. average coal production would decrease by 39 million metric tons per year in the Proposed Action.

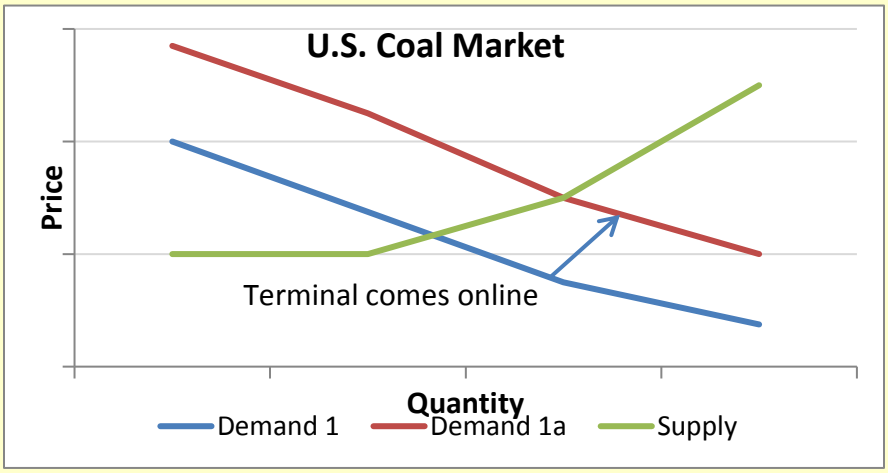
The total average U.S. thermal coal consumption for 2025 to 2040 under the No-Action Alternative would be 671 million metric tons per year, while the average thermal coal consumption in Asia would be 5,855 million metric tons per year. Average annual coal consumption in Asia for the period 2025 to 2040 under the Proposed Action would be within 5 million metric tons of consumption under the No-Action Alternative. The change would be due to the increased consumption of lower heat content coal that replaces some higher heat content coal. Under the Proposed Action, U.S. coal consumption would remain at 671 million metric tons because there is no decrease in U.S. coal consumption when the proposed coal export terminal comes online.

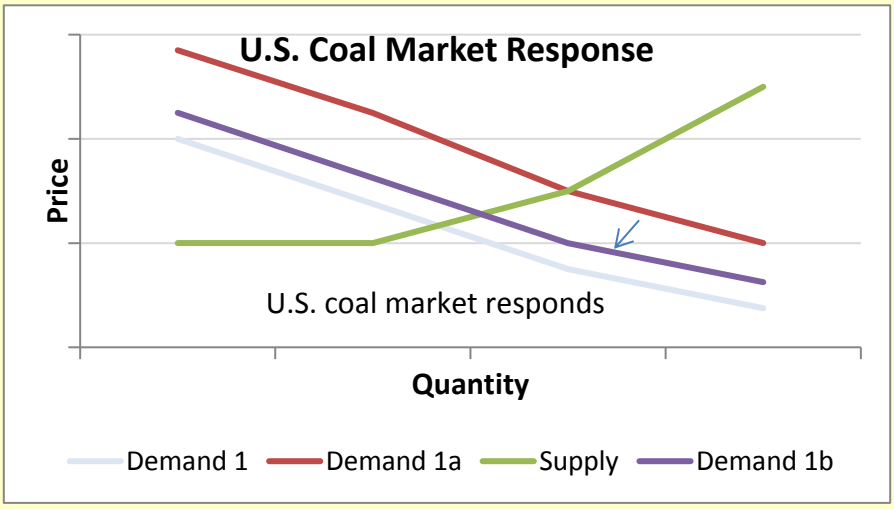
Seaborne thermal coal distribution in Asia would average 511 million metric tons per year during 2025 to 2040 under the No-Action Alternative, and would change by 18 million metric tons under the Proposed Action because the exported coal would replace coal produced in Asia. Under the Proposed Action, coal from the Montana portion of the Powder River Basin would be exported to China, Hong Kong, Japan, South Korea, and Taiwan. The distance that the coal travels would be greater under the Proposed Action than under the No-Action Alternative. Under the Proposed Action, the change in the distance coal would be transported would average 232 nautical miles per shipment more than under the No-Action Alternative.

CO_2 emissions in the United States under the No-Action Alternative from the combustion of coal would average 1,320 million metric tons per year over 2025 to 2040, while emissions from natural gas consumption would average 588 million metric tons per year. In Asia, CO_2 emissions under the No-Action Alternative from the combustion of coal would average 12,715 million metric tons per year over 2025 to 2040. Under the Proposed Action, CO_2 emissions would increase by 1.815 million metric tons per year in Asia to 12,717 million metric tons Coal emissions in the United States would fall slightly, while natural gas emissions would not change. Thus, the total net change in CO_2 emissions under the Proposed Action would be an increase of 1.811 million metric tons per year on average over 2025 to 2040.

Operation of the Proposed Action would further integrate the U.S. and Asian coal markets. However, to the extent that Asian coal prices would be higher than U.S. prices, operation of the Proposed Action would cause Asian coal prices to decline, while U.S. prices would increase. These changes in prices would cause Asian coal demand to increase and U.S. demand to decrease. The reason U.S. coal prices would increase is because the Applicant would act as a "buyer" of coal, and thus, would shift the demand curve (Demand 1) to the right (Demand 1a), setting a new, higher equilibrium coal price. In response, utilities would choose to use less coal and more natural gas, so the coal demand curve shifts back to the left (Demand 1b), but still to the right of the original curve (Demand 1).

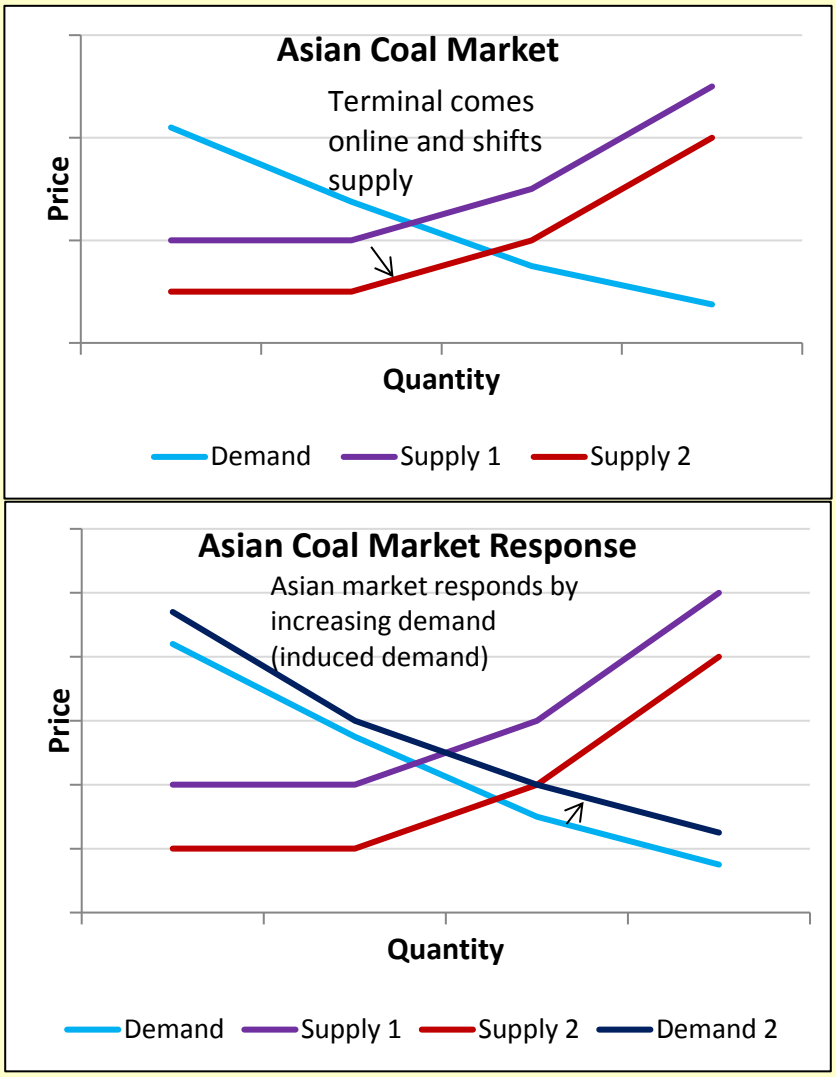
Impact of Proposed Action on Domestic Coal Supply and Demand at Full Capacity





The Proposed Action would cause Asian coal demand to increase because the coal export terminal would act as a new source of coal, and thus, would shift the supply curve (Supply 1) to the right (Supply 2), setting a new, lower equilibrium coal price. In response, Asian countries would choose to use more coal, so the coal demand curve would shift to the right (Demand 2).

Impact of Proposed Action on International Coal Supply and Demand at Full Capacity



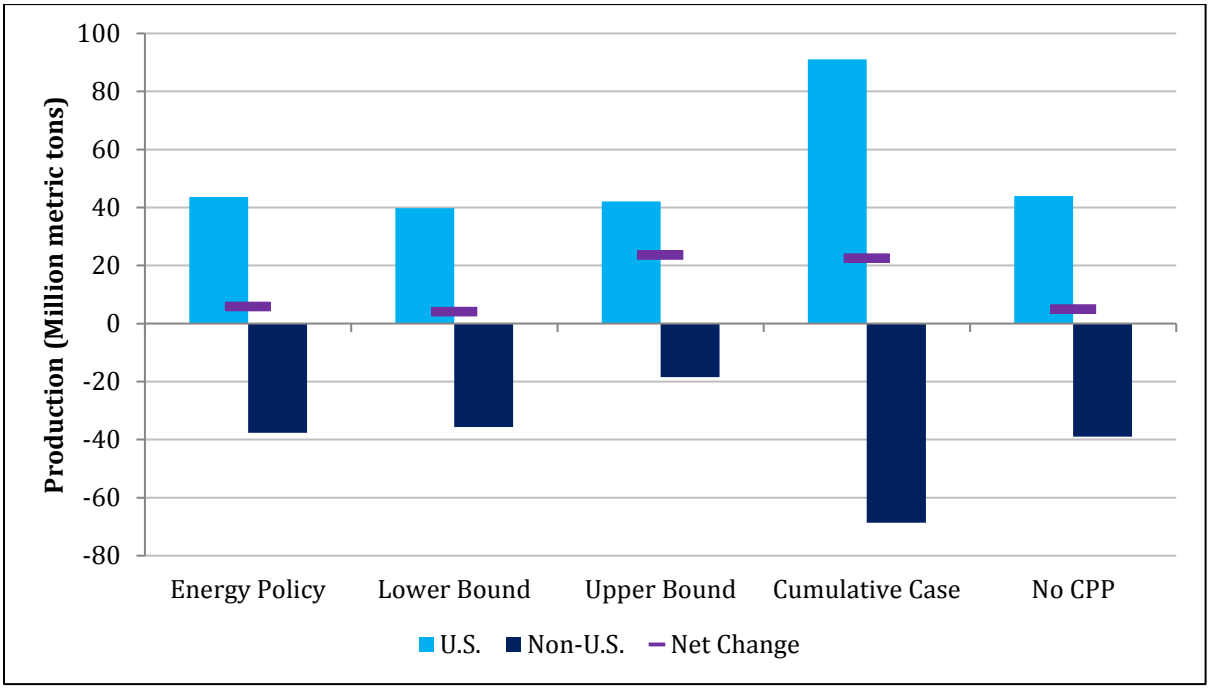
6.1.2 Scenario Results

The five scenarios that were analyzed are used to explore how CO_2 emissions from the Proposed Action would change under different sets of assumptions. Figure 6-1 shows the change in average production under each scenario for 2025 to 2040, where the change is calculated by subtracting the No-Action Alternative production from Proposed Action production. Except for the Cumulative Case,

in which other coal export terminal capacity comes online, the change in the average U.S. thermal coal production is within 5 million metric tons of the capacity of the proposed coal export terminal.

In the Cumulative Scenario, average U.S. coal production over 2025 to 2040 increases under the Proposed Action by 91 million metric tons, which is less than the full 99 million metric tons of new thermal coal export capacity, excluding Ridley Terminal.[30] This increase in U.S. production is less than the full new terminal capacity because there is a decrease in U.S. coal demand and because exports of non-Powder River Basin coal decrease in some years. The decrease in U.S. demand for Powder River Basin coal in the Cumulative Scenario is an average 2.7 million metric tons while the demand for all coal in the United States declines by 0.9 million metric tons.

Figure 6-1. Change in Annual Average Production for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons per year)



Non-U.S. coal production declines in each scenario in equal proportion to the increase in U.S. production, with the exception of the Upper Bound scenario. However, the increase in U.S. production is generally slightly higher because the exported Powder River Basin coal would have a lower heat content than some of the coal that it would displace; thus, less total tons would be displaced than exported, while the same amount of total heating value would be replaced. For example, if 10 million metric tons of a 9,000 Btu/lb coal is exported and displaces a 12,000 Btu/lb coal, then the total heat content exported would be 198.4 TBtu (*=10,000,000 metric tons x 1.1023-short tons/metric ton x 2,000 lbs/ short ton x 9,000 Btu/lb x 1 TBtu/10^12 Btu*). The equivalent tons of the 12,000 Btu/lb coal is then 7.5 million metric tons (*=198.4 TBtu x 10^12 Btu/1 TBtu x 1/12,000 Btu/lb x 1 short ton/2000 lbsx 1 metric ton/1.1023 short ton x 1 million metric ton/10^6 metric tons*). Thus, for every 10 million metric tons of 9,000 Btu/lb coal exported, only 7.5 million metric tons of

[30] Results are averaged over the period 2025 to 2040, because in the coal market analysis the proposed terminal comes online at full capacity in 2025. This is due to the years that are explicity run in the model, as explained in Section 4.3.1.

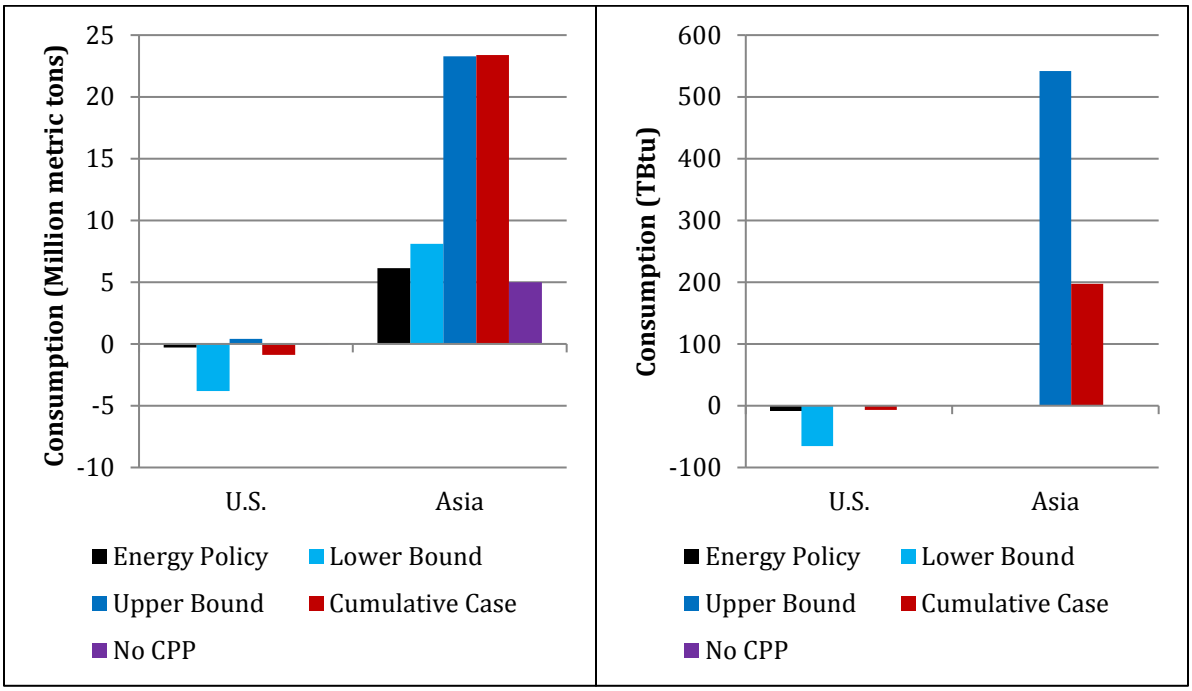
12,000 Btu/lb coal would be displaced. In the Upper Bound Scenario, the reason that the non-U.S. coal production does not decrease as much as the increase in U.S. production is because there is some induced coal demand.

Average coal consumption in the United States would be lower under the Proposed Action because higher Powder River Basin coal prices would depress the U.S. demand for Powder River Basin coal (Figure 6-2). The Powder River Basin coal prices would be higher due to the export of Powder River Basin coal through the proposed coal export terminal, which causes a shift in the demand curve. In all but the Upper Bound Scenario, coal consumption, as measured in tons and TBtu, in the United States is lower under the Proposed Action. In the Upper Bound Scenario, average annual domestic coal consumption from 2025 to 2040 is 0.4 million metric tons higher under the Proposed Action. While the United States consumes less Powder River Basin coal as export increases, domestic coal consumption shifts to coal produced in Northern Appalachia and the Illinois Basin. Without the Clean Power Plan and the higher energy efficiency assumed under the Clean Power Plan, domestic coal demand is higher than the scenarios including the Clean Power Plan and energy efficiency, because overall electric demand is higher without the additional energy efficiency assumed under the Clean Power Plan. Under the Proposed Action, Powder River Basin prices are pushed higher due to increased export via the proposed coal export terminal, but other types of domestic coal remain available economically. In the Cumulative Case where Clean Power Plan and energy efficiency are also excluded, when new export capacity is added, a larger amount of U.S. coal has higher prices due to the larger export increase, thus having a greater effect on decreasing domestic coal consumption in total than the No Clean Power Plan Scenario.

The depressive effect on total U.S. coal consumption would be the largest in the Lower Bound Scenario at an average of 3.8 million metric tons per year (Figure 6-2, left-hand chart), because in addition to the Clean Power Plan and international GHG reduction commitments, Powder River Basin and Uinta basin coal prices have been increased by 25% in the Lower Bound Scenario compared to the Energy Policy, No Clean Power Plan, and Cumulative Scenarios. Moreover, U.S. rail transportation costs have been increased by 20% in the Lower Bound Scenario. Higher domestic minemouth coal prices and transportation costs lead to lower coal consumption domestically.

Coal consumption in Asia on a per ton basis would be higher under the Proposed Action for two reasons. First, lower heat content coal would displace some higher heat content coal. Therefore, to maintain the same level of electric generation, more tons of the lower heat content coal must be consumed than the amount of the higher heat content coal that was displaced. Second, Asian coal consumption is higher because of induced demand in the Upper Bound and Cumulative Scenarios. The change in coal consumption due to the mix of coals is evident by comparing the two charts in Figure 6-2. The left hand chart shows the change in tons of coal consumed and includes changes due to both induced demand and a change in the mix of coal consumed, while the right hand chart shows the change in total heating value of the coal consumed, and thus just the amount of induced demand. Asian consumption in the right hand chart reflects the amount in TBtu of induced demand in each scenario, while the left hand chart shows the combined effects of the induced demand and changes in the mix of coals consumed in tons. In the right hand chart, only the Upper Bound and Cumulative Scenarios have significant non-zero values in Asia because there is induced demand in these scenarios. The largest increase in total coal consumption in tons is in the Cumulative Scenario, where there is a shift in China, Hong Kong, and Taiwan to consuming more Powder River Basin subbituminous coal and less Australian, Chinese, and Indonesian bituminous coal.

Figure 6-2. Change in Annual Average Consumption for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons and trillion Btu (TBtu) per year)



The change in the average amount of coal imported in Asia would be positive in all scenarios and would be highest in the Cumulative Scenario (Figure 6-3). The Cumulative Scenario has the largest increase in coal exported from the United States to Asia, because of multiple coal export terminals coming online. Exports from the new coal terminals drive the increase in imported coal, especially for China, since the imported coal displaces some domestic coal production. Also, the exported coal would be displacing the delivery of coal from other countries, and since the coal exported through the proposed terminal would be displacing higher heat content coal on average there would be a net increase in the tons of coal imported and consumed, since the coal demand is assumed to remain constant or increase due to induced demand from lower delivered coal prices.

Because CO_2 emissions from the transportation of coal depend on how far the coal is shipped, Figure 6-4 shows the change in the total distance the coal is shipped as measured by the change in total distance that the ships would travel. For the Lower Bound, Upper Bound, Cumulative, and the No Clean Power Plan Scenarios, the shipping distances track closely to the overall change in tons shipped. However, the 2015 U.S. and International Energy Policy Scenario incurs a slightly larger difference in the distance due to shifts in the sources of coal that would be displaced by coal from the proposed export terminal. Specifically, more coal would be displaced from China and Russia, than from Australia and Indonesia, which have longer shipping distances. The Cumulative Scenario has the highest increase in the distance of shipped coal since the additional export terminal capacity displaces more coal produced and consumed in Asia.

Figure 6-3. Change in Annual Average Imports of Coal in Asia via Ship for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons per year)

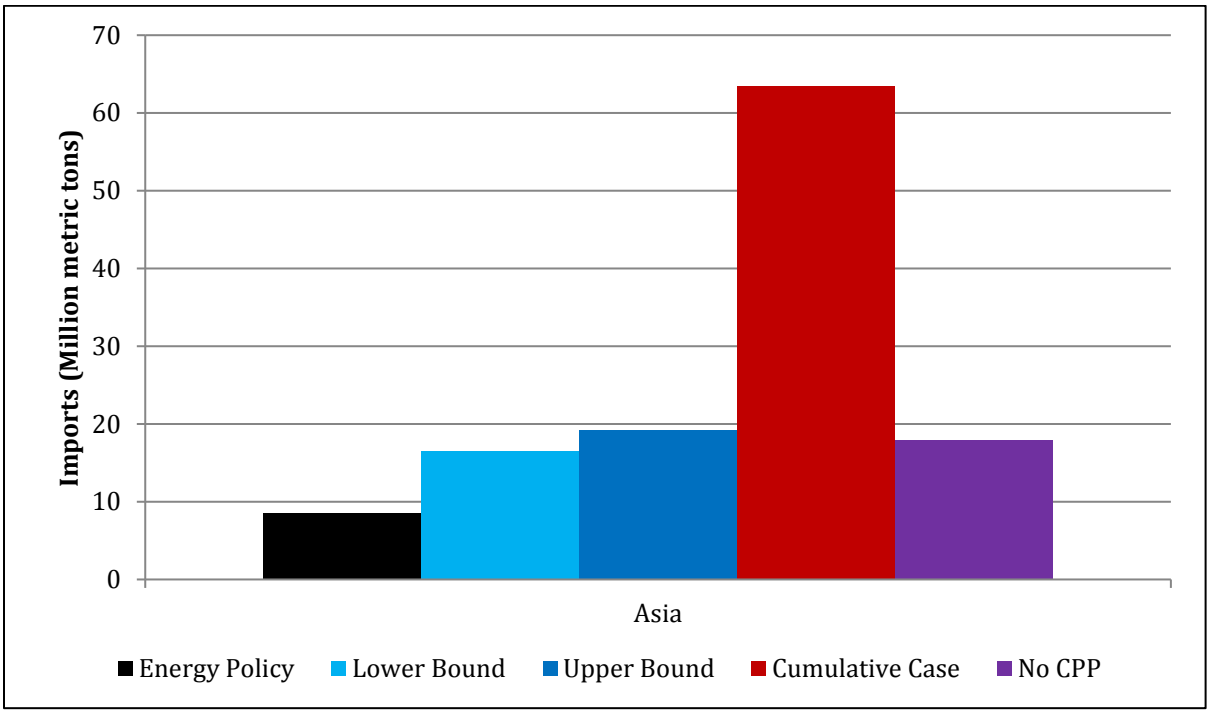
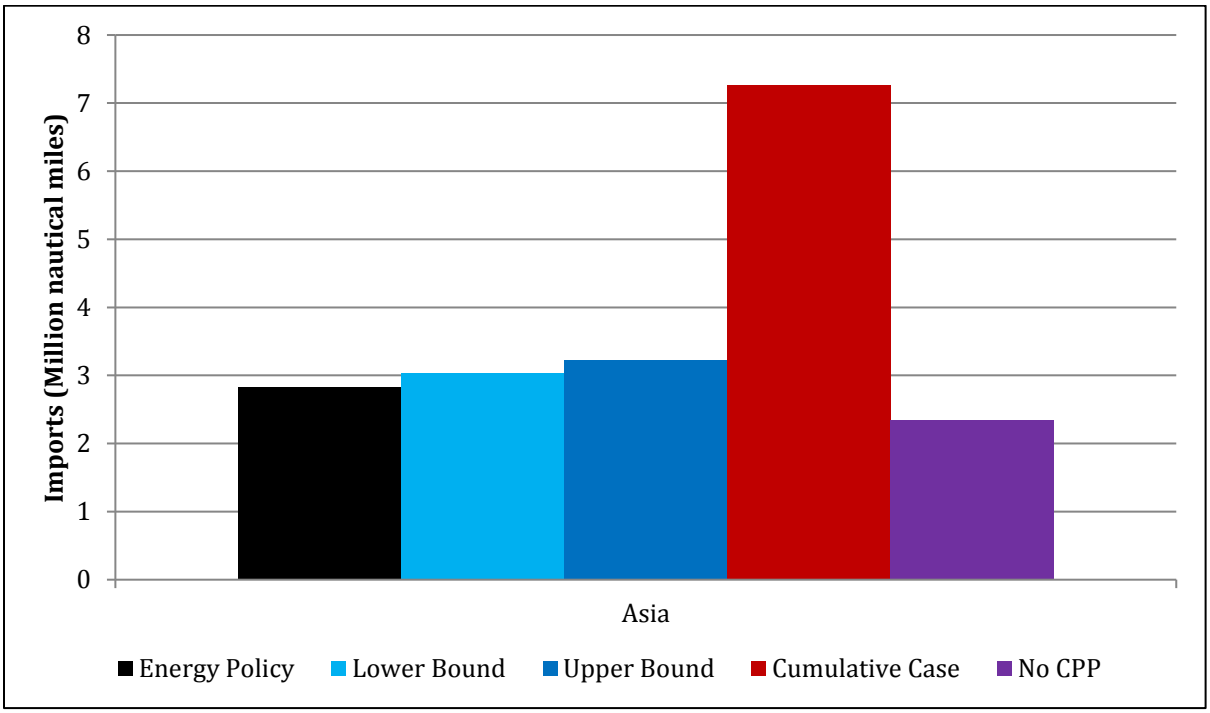
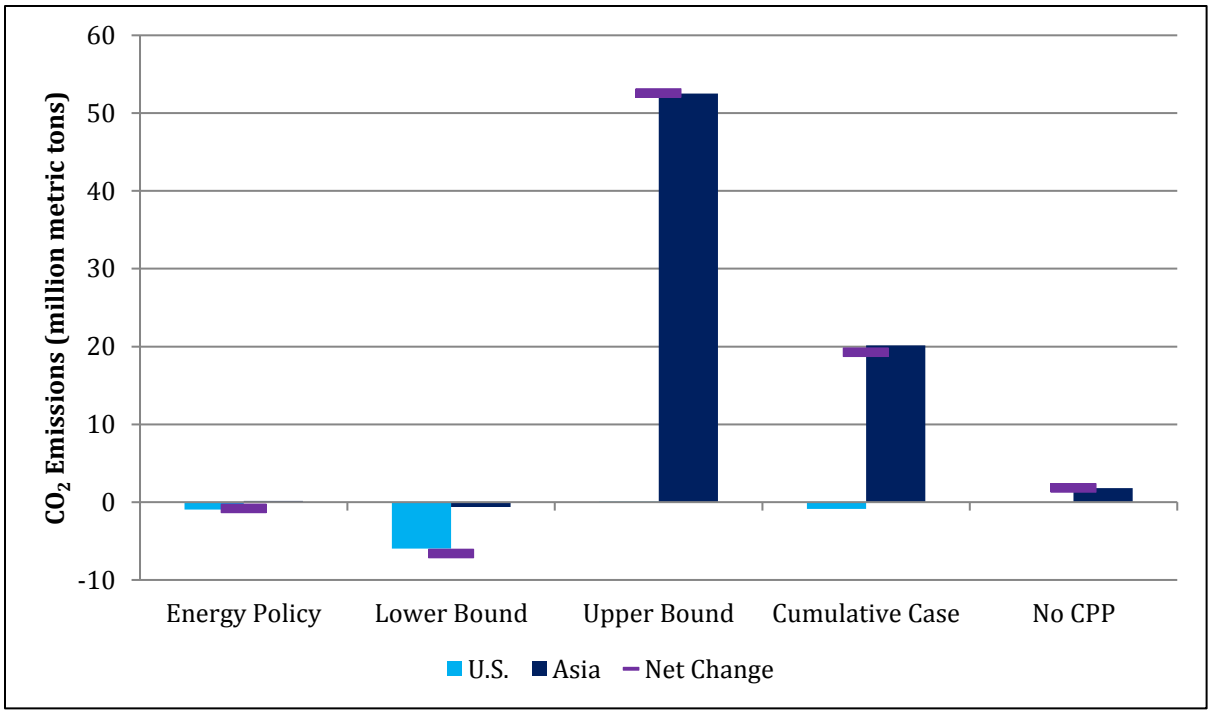


Figure 6-4. Change in Annual Average Imports of Coal in Asia via Ship for 2025 to 2040—Proposed Action minus No-Action Alternative (million nautical miles per year)



CO_2 emissions from the combustion of coal in the United States and Asia are estimated for all five scenarios. Figure 6-5 shows the average change in CO_2 emissions from the combustion of coal for 2025 to 2040. The CO_2 emissions reflect the changes in consumption with U.S. emissions declining in all scenarios except for the Upper Bound Scenario. Demand for Powder River Basin coal is higher under the Proposed Action in the Upper Bound Scenario, because of the lower assumed production costs in the Powder River Basin in this scenario. Asian emissions are increasing in all scenarios, except for the Lower Bound Scenario, due to changes in the mix of coals consumed and the induced demand. The Lower Bound Scenario has lower emissions from the combustion of coal in Asia due to a shift to using coals with lower CO_2 emissions rates. Due to the mix of coals consumed and their respective CO_2 emissions rates, the emissions do not exactly reflect the change in consumption seen in Figure 6-2.

Figure 6-5. Change in Annual Average CO_2 Emissions from the Consumption of Coal for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons CO_2 per year)



6.2 No Clean Power Plan Scenario

The No Clean Power Plan Scenario uses the assumptions presented in Chapter 4, *Model Framework, Methods, and Key Assumptions*, and represents the energy market outcome assuming the EPA's Clean Power Plan is not implemented. This section presents the modeling results for the No Clean Power Plan Scenario No-Action Alternative and Proposed Action for coal production, consumption, distribution, and CO_2 emissions.

6.2.1 Coal Production

Under the No-Action Alternative, U.S. thermal coal production would average 813 million metric tons per year for the 2025 to 2040 period.[31] U.S. coal production steadily increases primarily because coal exports increase over time, but also because electric demand and natural gas prices increase, and nuclear units begin to retire between 2030 and 2040. Over the 2016 to 2040 period, non-U.S. coal production would grow at an average annual rate of 2.4% per year from 4,510 to 7,887 million metric tons. Over the same period, U.S. coal production would grow at an average annual rate of 1.3%. Powder River Basin coal production under the No-Action Alternative would average 311 million metric tons per year over 2025 to 2040. Uinta Basin coal production under the No-Action Alternative would average 13.6 million metric tons per year, with production gradually increasing. Table 6-1 shows the No-Action Alternative coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-1. No Clean Power Plan Scenario Coal Production—No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,510	5,115	5,806	6,304	6,839	7,887	7,098
Total U.S. Thermal Coal	628	673	752	773	790	861	813
Powder River Basin Coal	310	286	324	329	292	313	311
Uinta Basin Coal	7.0	7.9	8.5	10.6	14.4	15.0	13.6

Under the Proposed Action, U.S. thermal coal production would average 857 million metric tons per year for the 2025 to 2040 period. As with the No-Action Alternative, U.S. coal production would increase over the full time horizon, although at the slightly higher rate of 1.5%. Non-U.S. coal production would grow at an average annual rate of 2.3%, similar to the growth rate in the No-Action Alternative. Coal production would be slightly lower under the Proposed Action than the No-Action Alternative starting in 2025 when the full capacity of the terminal comes on line. The non-U.S. production would decline in the Proposed Action because the coal exported through the proposed terminal would displace some of the coal that was produced in other countries in the No-Action Alternative.

Powder River Basin coal production under the Proposed Action would average 355 million metric tons per year, with production fluctuating around this average with no clear upward or downward trend. Uinta Basin coal production would average 13.6 million metric tons per year for 2025 to 2040, the same as under the No-Action Alternative. Table 6-2 shows the Proposed Action coal

[31] Throughout the documentation of trends in coal production and coal prices, the period from 2025 to 2040 is evaluated as this period covers years in which the coal terminal is at full capacity and GHG emission are estimated through 2038 in the SEPA Greenhouse Gas Emissions Technical Report (ICF 2017b). Trends over the full 2016 to 2040 modeling period are included for context only, as the modeling results before 2025 are not used for estimating GHG emissions. The SEPA Greenhouse Gas Emissions Technical Report linearly extrapolates from the start of the proposed terminal exports in 2021 to the projected GHG emissions in 2025 assuming that the emissions prior to operation are zero.

production values for each model run year.[32] The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.[33]

Table 6-2. No Clean Power Plan Scenario Coal Production—Proposed Action (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,510	5,115	5,806	6,264	6,798	7,850	7,059
Total U.S. Thermal Coal	628	673	752	817	834	905	857
Powder River Basin Coal	310	286	324	373	336	357	355
Uinta Basin Coal	7.0	7.9	8.5	10.6	14.4	15.0	13.6

Table 6-3 shows the estimated change in coal production between the Proposed Action and the No-Action Alternative by model run year to be close to zero in the years before 2025 when the proposed terminal was assumed fully online. Once the proposed terminal is online and exporting coal, total modeled U.S. coal production would be higher under the Proposed Action, primarily due to an increase in Powder River Basin coal production. The decrease in non-U.S. coal production is due to coal shipped through the proposed coal export terminal displacing coal from other countries.

There are small changes in coal production prior to the proposed terminal coming online because the IPM model is forward-looking and makes adjustments in the near term to optimize the whole period being analyzed.[34] This is referred to as perfect foresight. As described in Chapter Two of the EPA's *Documentation for EPA Base Case v.5.13 Using the Integrated Planning Model*, perfect foresight in IPM® means that agents know the precise timing and essence of future events that may affect decisions and the overall deployment of resources.

Table 6-3. No Clean Power Plan Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	0	0	0.1	-40.2	-40.4	-36.9	-39.0
Total U.S. Thermal Coal	0	0	0	44.0	44.0	44.0	44.0
Powder River Basin Coal	0	0	0	44.0	44.0	44.0	44.0
Uinta Basin Coal	0	0	0	0	0	0	0

Figure 6-6 shows that total non-U.S. thermal coal production would decrease in similar amounts to the increase in U.S. coal production under the Proposed Action. This trend indicates that U.S. thermal coal exports would mostly replace internationally produced coal, instead of the full exported amount

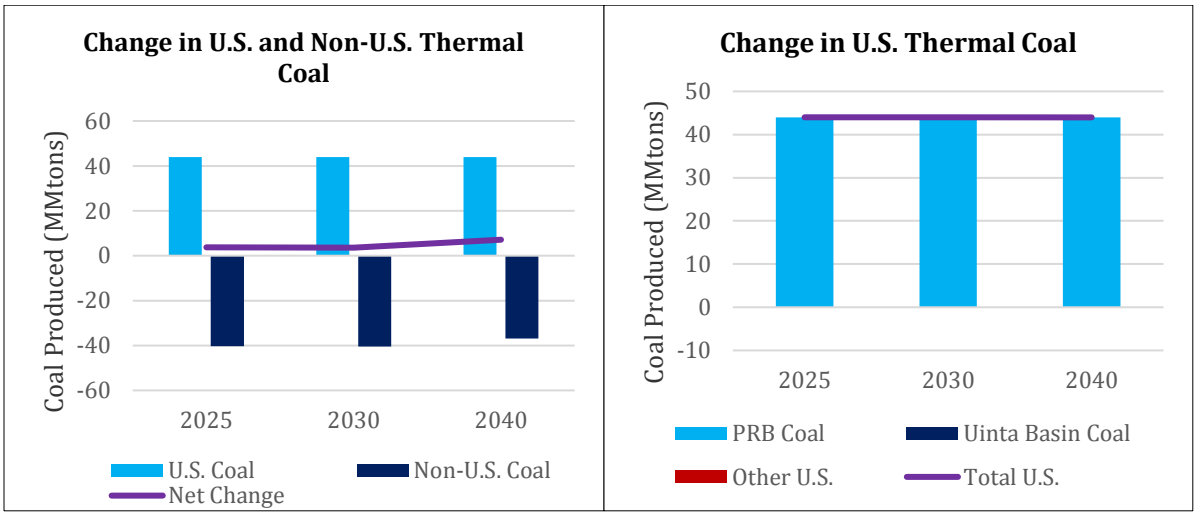
[32] The model run years include 2016, 2018, 2020, 2025, 2030, and 2040.

[33] Five calendar years are mapped to 2025, six years are mapped to 2030, and seven years are mapped to 2040.

[34] As a linear programming model, IPM seeks a solution that minimizes the overall system costs of meeting electric demand. The costs include, but are not limited to, fuel costs, costs for transporting fuel, variable and fixed operating costs of the various generating resources, costs for new generating resources, and the costs for retrofitting existing generating resources with additional environmental controls.

adding to overall global coal demand. The right hand graph in Figure 6-6 shows that the increase in U.S. thermal coal production is due entirely to the increase in Powder River Basin coal production. The export of Powder River Basin coal through the proposed coal export terminal displaces coal produced in Australia, China, Indonesia, and Russia.

Figure 6-6. No Clean Power Plan Scenario Change in Coal Production—Proposed Action minus No-Action Alternative



6.2.2 Coal Consumption

Under the No-Action Alternative U.S. thermal coal consumption would average 671 million metric tons per year for the 2025 to 2040 period. U.S. coal consumption would trend upwards from 2016 to 2040, but fluctuate around the average from 2025 to 2040 because electric demand growth would be primarily met with natural gas and renewable generation. Total U.S. consumption would grow at a fairly flat rate of 0.4% from 2016 to 2040.

Over the 2016 to 2040 period, Asian coal consumption would grow at an average rate of 2.9% per year from 3,395 to 6,679 million metric tons. The growth in consumption is driven by increasing coal consumption in China and India. Table 6-4 shows the No-Action Alternative coal consumption values for each model run year. Table 6-5 shows the coal consumption values in TBtu per year. The average values in the last column of the tables were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

China is responsible for the largest share of global thermal coal consumption, burning 2,269 million metric tons of coal in 2016. This amount is projected to grow under the No-Action Alternative to 3,489 million metric tons by 2040 and average 3,274 million metric tons over the 2025 to 2040 period. India has the highest average annual growth rate at 6.2%, with coal consumption rising from 543 million metric tons in 2016 to 2,287 million metric tons in 2040.

Table 6-4. No Clean Power Plan Scenario Coal Consumption—No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	118	138	166	161	210	252	213
Australia	104	114	123	124	124	125	124
China	2,269	2,534	2,797	3,015	3,239	3,489	3,274
Hong Kong	13	15	16	16	17	20	18
India	543	723	935	1,233	1,558	2,287	1,751
Indonesia	138	142	152	165	188	220	194
Japan	96	113	127	126	119	116	120
South Korea	68	81	89	79	76	71	75
Taiwan	46	56	65	74	83	98	86
Total Asian Coal Consumption	3,395	3,915	4,472	4,993	5,613	6,679	5,855
Total U.S. Coal Consumption	613	606	672	686	651	679	671
Rest of World Coal Consumption	1,131	1,269	1,418	1,401	1,368	1,395	1,388

Table 6-5. No Clean Power Plan Scenario Coal Consumption—No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,968	3,334	3,739	4,144	4,883	4,319
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	77,017	82,560	88,375	83,282
Hong Kong	303	332	361	405	449	529	467
India	10,213	13,834	17,452	23,201	28,935	41,915	32,390
Indonesia	2,486	2,535	2,583	2,897	3,212	3,784	3,347
Japan	2,337	2,674	3,009	3,058	3,095	3,030	3,060
South Korea	1,716	1,911	2,106	2,028	1,949	1,833	1,926
Taiwan	1,091	1,324	1,558	1,761	1,965	2,331	2,051
Total Asian Coal Consumption	80,016	91,778	103,528	115,768	127,938	148,269	132,464
Total U.S. Coal Consumption	12,675	12,682	14,022	14,278	13,651	14,201	14,039
Rest of World Coal Consumption	18,366	21,747	25,172	25,128	24,978	26,592	25,647

Coal consumption under the Proposed Action follows similar patterns as the No-Action Alternative, with U.S. thermal coal consumption averaging 671 million metric tons per year for the 2025 to 2040

period. As it would be under the No-Action Alternative, U.S. coal consumption would be fairly flat between 2020 and 2040 as electric demand growth is primarily met with natural gas and renewable generation.

Over the 2016 to 2040 period, Asian coal consumption follows the same pattern as it would under the No-Action Alternative, growing from 3,395 to 6,686 million metric tons.

Table 6-6 shows the Proposed Action coal consumption values for each model run year and Table 6-7 shows those values in TBtu per year. The average values in the last column of the tables were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-6. No Clean Power Plan Scenario Coal Consumption—Proposed Action (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	118	138	166	161	208	252	212
Australia	104	114	123	124	124	125	124
China	2,269	2,534	2,797	3,020	3,243	3,489	3,277
Hong Kong	13	15	16	18	20	23	20
India	543	723	935	1,230	1,558	2,287	1,750
Indonesia	138	142	152	165	186	221	194
Japan	96	113	127	124	119	117	120
South Korea	68	81	89	79	76	72	75
Taiwan	46	56	65	76	84	100	88
Total Asian Coal Consumption	3,395	3,915	4,472	4,997	5,617	6,686	5,860
Total U.S. Coal Consumption	613	606	672	686	651	679	671
Rest of World Coal Consumption	1,131	1,269	1,418	1,401	1,368	1,395	1,388

Table 6-7. No Clean Power Plan Scenario Coal Consumption—Proposed Action (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,968	3,334	3,739	4,144	4,883	4,319
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	77,017	82,560	88,375	83,282
Hong Kong	303	332	361	405	449	529	467
India	10,213	13,834	17,452	23,201	28,935	41,915	32,390
Indonesia	2,486	2,535	2,583	2,897	3,212	3,784	3,347
Japan	2,337	2,674	3,009	3,058	3,095	3,030	3,060
South Korea	1,716	1,911	2,106	2,028	1,949	1,833	1,926
Taiwan	1,091	1,324	1,558	1,761	1,965	2,331	2,051
Total Asian Coal Consumption	80,016	91,778	103,528	115,768	127,938	148,269	132,464
Total U.S. Coal Consumption	12,675	12,682	14,022	14,278	13,651	14,201	14,039
Rest of World Coal Consumption	18,366	21,747	25,172	25,128	24,978	26,592	25,647

Table 6-8 shows the estimated change in coal consumption between the Proposed Action and the No-Action Alternative by model run year to be zero in the years before 2025 when the proposed coal export terminal is assumed fully online, except for Indonesia in 2020. Table 6-9 shows the same values in TBtu per year. Once the terminal is online and exporting coal, there is no change in United States and Rest of World coal consumption on a tonnage basis, and only a decrease of 0.1 TBtu in the United States in 2040. The decrease of 0.1 TBtu is equivalent to about 0.005 million metric tons. In Asia, there is no change in the total heating value of the coal consumed; however, there are shifts in the tons of coal consumed.

In Asia, coal consumption in the Proposed Action is higher on average by 5.0 million metric tons per year for 2025 to 2040, which is 0.09% higher than the average Asian coal consumption in the No-Action Alternative shown in Table 6-6. The reason that Asian coal consumption increases is that a larger quantity of lower heat content subbituminous coal is being consumed, while the total heating value of coal demand remains the same. For example, in Hong Kong under the Proposed Action, coal consumption increases by 2.0 million metric tons in 2025 over the No-Action Alternative (Table 6-8); however, the total heat content of the coal consumed remains the same (Table 6-9). This is possible because Indonesia reduces the bituminous coal exported to Hong Kong by 7.78 million metric tons and the United States exports 9.77 million metric tons more of Montana Powder River Basin coal, which has a lower heat content.

Table 6-8. No Clean Power Plan Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	0	0	0	0	-2.6	0	-0.9
Australia	0	0	0	0	0	0	0
China	0	0	0	4.7	4.2	0	2.7
Hong Kong	0	0	0	2.0	2.2	2.8	2.4
India	0	0	0	-2.9	0	0	-0.8
Indonesia	0	0	0.1	0	-2.2	1.1	-0.3
Japan	0	0	0	-1.8	0	0.5	-0.3
South Korea	0	0	0	0	0	0.5	0.2
Taiwan	0	0	0	1.7	1.9	2.3	2.0
Total Asian Coal Consumption	0	0	0.1	3.8	3.6	7.1	5.0
Total U.S. Coal Consumption	0	0	0	0	0	0	0
Rest of World Coal Consumption	0	0	0	0	0	0	0

Table 6-9. No Clean Power Plan Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0
Hong Kong	0	0	0	0	0	0	0
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0
South Korea	0	0	0	0	0	0	0
Taiwan	0	0	0	0	0	0	0
Total Asian Coal Consumption	0	0	0	0	0	0	0
Total U.S. Coal Consumption	0	0	0	0	0	0	0
Rest of World Coal Consumption	0	0	0	0	0	0	0

6.2.3 Coal Distribution

Coal from the Powder River Basin and the Uinta Basin are distributed primarily in the United States. These distribution patterns are expected to remain largely unchanged under the Proposed Action. Thus, this section focuses on the distribution of coal in Asia and how that distribution would be expected to change with the construction of the proposed terminal. Under the No-Action Alternative,

no coal would be exported through the proposed terminal; however, 313 million metric tons of thermal coal would be distributed in Asia by ship in the seaborne coal market in 2016. Table 6-10 shows the tons of coal that are imported by each country in Asia under the No-Action Alternative. In 2040, a total of 550 million metric tons of thermal coal are expected to be distributed in the Asian seaborne coal market.

Table 6-10. No Clean Power Plan Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	80	98	124	142	203	244	202
Australia	0	0	0	0	0	0	0
China	0	65	144	0	0	0	0
Hong Kong	13	15	16	16	17	20	18
India	10	47	0	35	0	0	10
Indonesia	0	0	0	0	0	0	0
Japan	96	113	127	126	119	116	120
South Korea	68	81	89	79	76	71	75
Taiwan	46	56	65	74	83	98	86
Total Asian Coal sent via ship	313	475	567	471	498	550	511

To understand how coal distribution is changing in more detail than the tons of coal imported by each country, the tons of coal shipped to each country were multiplied by the distance in nautical miles that the coal is shipped and then divided by an average ship size. This is important because the change in tons imported might not change significantly; however, where the coal is sourced might change, which has a significant impact on the emissions associated with shipping. Table 6-11 shows the result of multiplying the tons of coal by the nautical miles that the coal was shipped and dividing by the average ship size for coal shipped to each country for the No-Action Alternative.[35] Thus the values in Table 6-11 are in units of million nautical miles.

[35] The average ship size is 66,000 metric tons, which is the weighted average of a Panamax and a Handymax ship, where the weights are 80% for the Panamax and 20% for the Handymax ship.

Table 6-11. No Clean Power Plan Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.44	0.76	2.13	2.65	3.95	4.84	3.93
Australia	0	0	0	0	0	0	0
China	0	1.68	4.51	0	0	0	0
Hong Kong	0.39	0.44	0.47	0.46	0.55	0.24	0.41
India	0.45	2.20	0	1.64	0	0	0.46
Indonesia	0	0	0	0	0	0	0
Japan	5.12	7.17	8.07	6.11	1.59	1.55	2.83
South Korea	1.81	5.23	5.77	0.75	0.72	0.67	0.71
Taiwan	2.89	3.51	4.13	4.67	5.20	6.20	5.44
Total Asian Coal sent via ship	11.10	20.99	25.07	16.27	12.01	13.51	13.78

Under the Proposed Action, coal would be exported through the proposed terminal to destinations in Asia. Table 6-12 shows how the coal exported from the proposed coal export terminal is distributed by the model.

Table 6-12. No Clean Power Plan Scenario Distribution of Coal Exported through Coal Export Terminal—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040
China	0	0	0	21.6	19.1	0
Hong Kong	0	0	0	9.8	10.8	12.8
Japan	0	0	0	0	0	7.7
South Korea	0	0	0	0	0	6.9
Taiwan	0	0	0	12.6	14.1	16.7
Total Asian Coal sent via ship through Proposed Coal Export Terminal	0	0	0	44.0	44.0	44.0

Under the Proposed Action, a similar number of tons is distributed in the Asian seaborne coal market as the No-Action Alternative, as can be seen in Table 6-13, which shows the tons of coal that would be imported by each country in Asia under the Proposed Action. Meanwhile, Table 6-14 shows the shipping mile values for coal distributed in the Asian seaborne coal market under the Proposed Action.

Table 6-13. No Clean Power Plan Scenario Seaborne Coal Imports in Asian —Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	80	98	124	142	201	244	201
Australia	0	0	0	0	0	0	0
China	0	65	144	22	19	0	12
Hong Kong	13	15	16	18	20	23	20
India	10	47	0	43	0	0	12
Indonesia	0	0	0	0	0	0	0
Japan	96	113	127	124	119	117	120
South Korea	68	81	89	79	76	72	75
Taiwan	46	56	65	76	84	100	88
Total Asian Coal sent via ship	313	475	567	503	519	556	529

Table 6-14. No Clean Power Plan Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.44	0.76	2.13	2.65	3.89	4.84	3.92
Australia	0	0	0	0	0	0	0
China	0	1.68	4.50	1.75	1.55	0	1.00
Hong Kong	0.39	0.44	0.47	1.08	1.24	1.23	1.19
India	0.45	2.20	0	2.00	0	0	0.56
Indonesia	0	0	0	0	0	0	0
Japan	5.12	7.17	8.07	5.09	1.59	1.97	2.71
South Korea	1.81	5.23	5.77	0.75	0.72	1.10	0.87
Taiwan	2.89	3.51	4.13	5.03	5.61	6.68	5.87
Total Asian Coal sent via ship	11.10	20.99	25.06	18.36	14.60	15.82	16.12

As can be seen in Table 6-15, which shows the estimated change in tons of coal imported by each of the regions, the largest change in coal imports between the No-Action Alternative and the Proposed Action is in coal exported to China in 2025 with an increase of 21.6 million metric tons. However, the change is only about 0.7% of coal consumption in China.

Table 6-15. No Clean Power Plan Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	0	-2.6	0	-0.9
Australia	0	0	0	0	0	0	0
China	0	0	0	21.6	19.1	0	12.4
Hong Kong	0	0	0	2.0	2.2	2.8	2.4
India	0	0	0	7.8	0	0	2.2
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	-1.8	0	0.5	-0.3
South Korea	0	0	0	0	0	0.5	0.2
Taiwan	0	0	0	1.7	1.9	2.3	2.0
Total Asian Coal sent via ship	0	0	0.1	31.4	20.7	6.1	18.0

While the changes in the total tons of coal imported to each region are relatively small on a percentage basis, there are some relatively large changes in the shipping mile values, as shown in Table 6-16. The overall distance coal would be shipped in Asia increases by 17% over the No-Action Alternative. For example, in Taiwan in 2025, coal imports increase by 2.3% (1.7 million metric tons) while the shipping miles increase by 7.9% (0.37 million nautical miles). This change is due to Taiwan importing Powder River Basin coal through the proposed coal export terminal, which displaces some coal from Australia, which is closer than the proposed coal export terminal.

Table 6-16. No Clean Power Plan Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	Annual Average
Asia - Other	0	0	0	0	-0.05	0	-0.02
Australia	0	0	0	0	0	0	0
China	0	0	-0.01	1.75	1.55	0	1.00
Hong Kong	0	0	0	0.62	0.69	0.99	0.78
India	0	0	0	0.36	0	0	0.10
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	-1.02	0	0.41	-0.12
South Korea	0	0	0	0	0	0.43	0.17
Taiwan	0	0	0	0.37	0.41	0.49	0.43
Total Asian Coal sent via ship	0	0	-0.01	2.09	2.59	2.31	2.34

6.2.4 CO_2 Emissions

This section presents the CO_2 estimated emissions from coal combusted in the United States and Asia under the No Clean Power Plan Scenario No-Action Alternative and Proposed Action. In addition, CO_2 emissions from natural gas consumption in the United States are included because decreases in coal consumption may be offset by increases in natural gas consumption. No other emissions of GHGs are included in this section.

Table 6-17 presents the CO_2 emissions under the No-Action Alternative. Total U.S. CO_2 emissions from coal remain fairly flat at an average of 1,319.78 million metric tons for 2025 to 2040, which reflects the flat coal consumption in the United States. Asian CO_2 emissions from coal average 12,714.98 million metric tons per year between 2025 and 2040, which is 9.6 times the total coal CO_2 emissions from the United States.

Table 6-18 presents the CO_2 emissions under the Proposed Action. Total CO_2 emissions from coal in Asia under the Proposed Action are within 2.8 million metric tons of the No-Action Alternative.

Table 6-17. No Clean Power Plan Scenario CO_2 Emissions—No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	247.26	285.00	322.40	347.92	401.48	475.60	415.43
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,230.49	6,869.91	7,422.30	7,957.21	8,519.96	8,027.47
Hong Kong	28.03	30.69	33.34	37.40	41.52	50.87	44.01
India	971.98	1,314.34	1,663.26	2,208.16	2,757.05	3,991.99	3,084.83
Indonesia	239.90	244.43	248.95	278.94	308.90	363.15	321.67
Japan	218.18	250.63	281.95	288.97	297.84	291.67	292.98
South Korea	161.27	179.24	197.51	195.18	187.61	176.39	185.35
Taiwan	101.94	123.74	145.53	164.58	183.58	217.90	191.65
Asia - Coal	7,676.27	8,796.83	9,920.98	11,098.59	12,287.35	14,236.09	12,714.98
U.S. - Coal	1,192.66	1,191.89	1,318.40	1,342.64	1,283.18	1,334.84	1,319.78
U.S. - Natural Gas	562.33	520.06	472.01	500.29	540.37	692.55	588.42
Rest of World	1,755.77	2,072.97	2,397.94	2,391.95	2,375.45	2,529.00	2,439.75

Table 6-18. No Clean Power Plan Scenario CO_2 Emissions—Proposed Action (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	247.26	285.00	322.43	347.92	400.36	475.60	415.05
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,230.49	6,869.90	7,422.63	7,957.49	8,519.96	8,027.66
Hong Kong	28.03	30.69	33.34	38.32	42.54	51.06	44.68
India	971.98	1,314.34	1,663.26	2,207.53	2,757.05	3,991.99	3,084.66
Indonesia	239.90	244.43	248.95	278.94	308.90	363.15	321.67
Japan	218.18	250.63	281.95	290.22	297.84	291.80	293.37
South Korea	161.27	179.24	197.51	195.18	187.61	176.50	185.39
Taiwan	101.94	123.74	145.53	165.50	184.60	219.11	192.71
Asia - Coal	7,676.27	8,796.83	9,921.00	11,101.37	12,288.56	14,237.73	12,716.80
U.S. - Coal	1,192.66	1,191.89	1,318.40	1,342.63	1,283.17	1,334.83	1,319.78
U.S.- Natural Gas	562.33	520.06	472.01	500.29	540.37	692.55	588.42
Rest of World	1,755.77	2,072.97	2,397.94	2,391.95	2,375.45	2,529.00	2,439.75

Table 6-19 shows the estimated change in CO_2 emissions for each region, as well as the total net change across all regions. Total Asian CO_2 emissions from coal consumption increase by an average of 1,81 million metric tons per year for 2025 to 2040. The change in CO_2 emissions from individual countries would be between a decrease of 1.12 million metric tons to an increase of 1.25 million metric tons.

Table 6-19. No Clean Power Plan Scenario Change in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons)

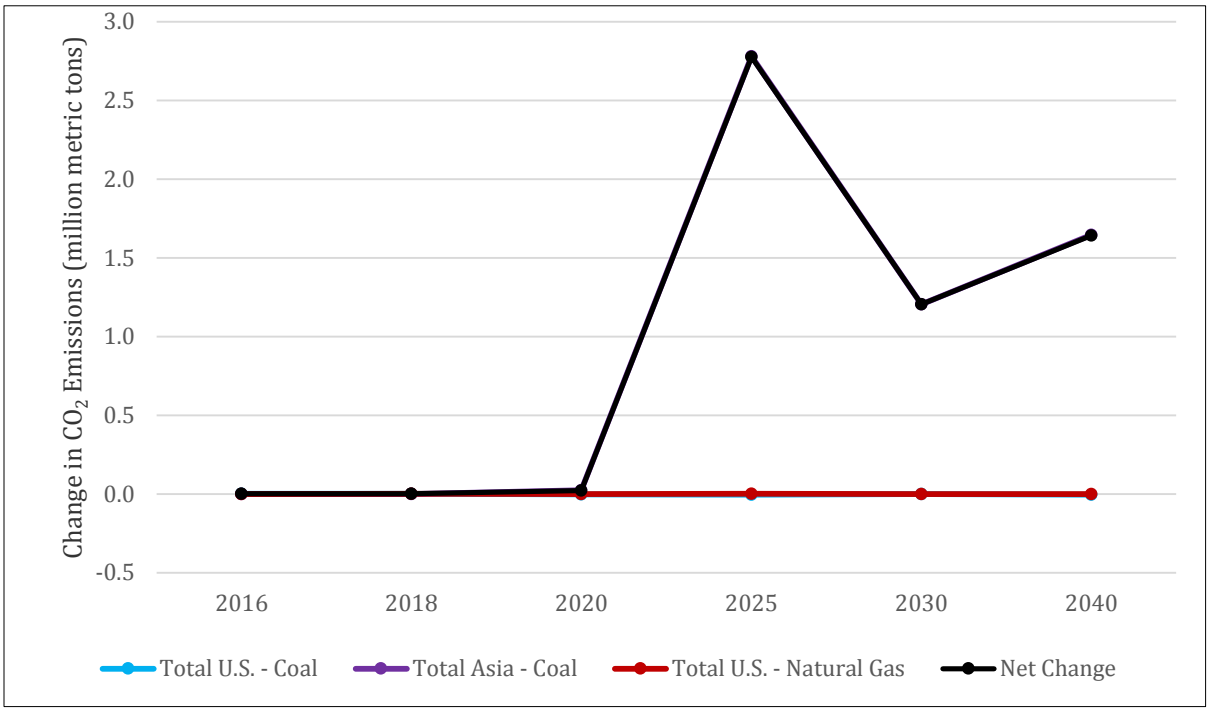
Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0.03	0	-1.12	0	-0.37
Australia	0	0	0	0	0	0	0
China	0	0	-0.01	0.32	0.29	0	0.18
Hong Kong	0	0	0	0.92	1.02	0.19	0.67
India	0	0	0	-0.63	0	0	-0.17
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	1.25	0	0.13	0.40
South Korea	0	0	0	0	0	0.12	0.04
Taiwan	0	0	0	0.92	1.02	1.21	1.07
Asia[a]- Coal	0	0	0.02	2.78	1.21	1.65	1.81
U.S. - Coal	0	0	0	0	0	0	0
U.S. - Natural Gas	0	0	0	0	0	0	0
Rest of World	0	0	0	0	0	0	0
Total Change	0	0	0.02	2.78	1.20	1.64	1.81

[a] Asia row is sum of Asia-Other through Taiwan rows.

U.S. coal CO_2 emissions would decrease in every year due to a slight decrease in the amount of coal consumed. The total net change in CO_2 emissions, including both coal and natural gas emissions, would increase by an average of 1,81 million metric tons per year for 2025 to 2040, which is primarily due to the increase in Asian emissions from coal consumption.

Figure 6-7 shows the net change in CO_2 emissions between the No-Action Alternative and Proposed Action. The increase in Asian coal emissions would drive the net change to be a net increase in CO_2 emissions under the Proposed Action.

Figure 6-7. No Clean Power Plan Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative[a,b,c]



[a] The total change in U.S. CO_2 emissions from the combustion of coal would be zero because coal consumption does not change under the Proposed Action.

[b] Asian CO_2 emissions from the combustion of coal would increase because more tons of lower heat content coal would be consumed, and because of a shift in the types of coal with different CO_2 emission rates.

[c] Total U.S. natural gas combustion CO_2 emissions would be zero because natural gas consumption would not change under the Proposed Action.

6.3 Lower Bound Scenario

The Lower Bound Scenario uses the assumptions presented in Chapter 5, *Scenarios*, and represents the lower bound of global GHG emissions that could be reasonably expected if the assumptions are realized. This scenario is designed to model the lowest potential GHG emissions under the Proposed Action, and to provide a low GHG emissions world into which the proposed terminal is constructed and operated. This section presents the modeling results for the Lower Bound Scenario No-Action Alternative and Proposed Action for coal production, consumption, distribution, and CO_2 emissions.

6.3.1 Coal Production

The Lower Bound Scenario is designed to reduce coal consumption and, thus, coal production. Therefore, coal production in the Lower Bound Scenario would be less than the No Clean Power Plan Scenario. Under the No-Action Alternative, U.S. thermal coal production would average 610 million metric tons per year for the 2025 to 2040 period, and would fluctuate around that average with no clear upward or downward trend. Over the 2016 to 2040 period, non-U.S. coal production would grow at an average annual rate of 1.4% per year from 4,467 to 6,172 million metric tons. Powder River Basin coal production under the No-Action Alternative would average 184 million metric tons per year over 2025 to 2040, and would decrease by 45 million metric tons over that period. The

Powder River Basin coal production decreases over time due to the higher assumed production costs in the Lower Bound Scenario. Uinta Basin coal production under the No-Action Alternative would average 4.6 million metric tons per year over 2025 to 2040. Table 6-20 shows the No-Action Alternative coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-20. Lower Bound Scenario Coal Production—No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,467	5,022	5,588	5,673	5,896	6,172	5,941
Total U.S. Thermal Coal	583	589	630	632	589	613	610
Powder River Basin Coal	232	198	217	216	172	171	184
Uinta Basin Coal	6.8	5.6	5.6	5.0	3.5	5.3	4.6

Under the Proposed Action, U.S. thermal coal production would average 650 million metric tons per year for the 2025 to 2040 period. When the proposed terminal comes fully online in 2025, total U.S. coal production would increase by 39.7 million metric tons on average from 2025 to 2040.

Non-U.S. coal production would follow a similar growth rate under the Proposed Action, at 1.3%, as it would under the No-Action Alternative. Powder River Basin coal production under the Proposed Action would average 221 million metric tons per year for 2025 to 2040, with production declining by 42 million metric tons between 2025 and 2030 and then remains flat through 2040. Uinta Basin coal production would average 5.0 million metric tons per year for 2025 to 2040, with production following the same fluctuating trends as it would under the No-Action Alternative, decreasing in 2030 and then increasing in 2040 to 6.1 million metric tons due to changes in coal consumption in the United States.

Table 6-21 shows the Proposed Action coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-21. Lower Bound Scenario Coal Production—Proposed Action (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,467	5,022	5,588	5,633	5,860	6,140	5,906
Total U.S. Thermal Coal	581	584	626	671	628	654	650
Powder River Basin Coal	229	190	211	251	209	209	221
Uinta Basin Coal	6.8	5.6	5.6	5.0	3.6	6.1	5.0

For the United States, Table 6-22 shows the estimated change in coal production between the Proposed Action and the No-Action Alternative by model run year to be a decrease of 8.3 million metric tons or less in the years before 2025 when the proposed terminal would come online. There are changes in coal production prior to the proposed terminal coming online because IPM® is forward-looking and makes adjustments in the near term to optimize the whole period being analyzed. In the Proposed Action, IPM® "knows" that the terminal comes fully online in 2025—and thus it makes adjustments throughout the analysis period to minimize overall costs. Once the

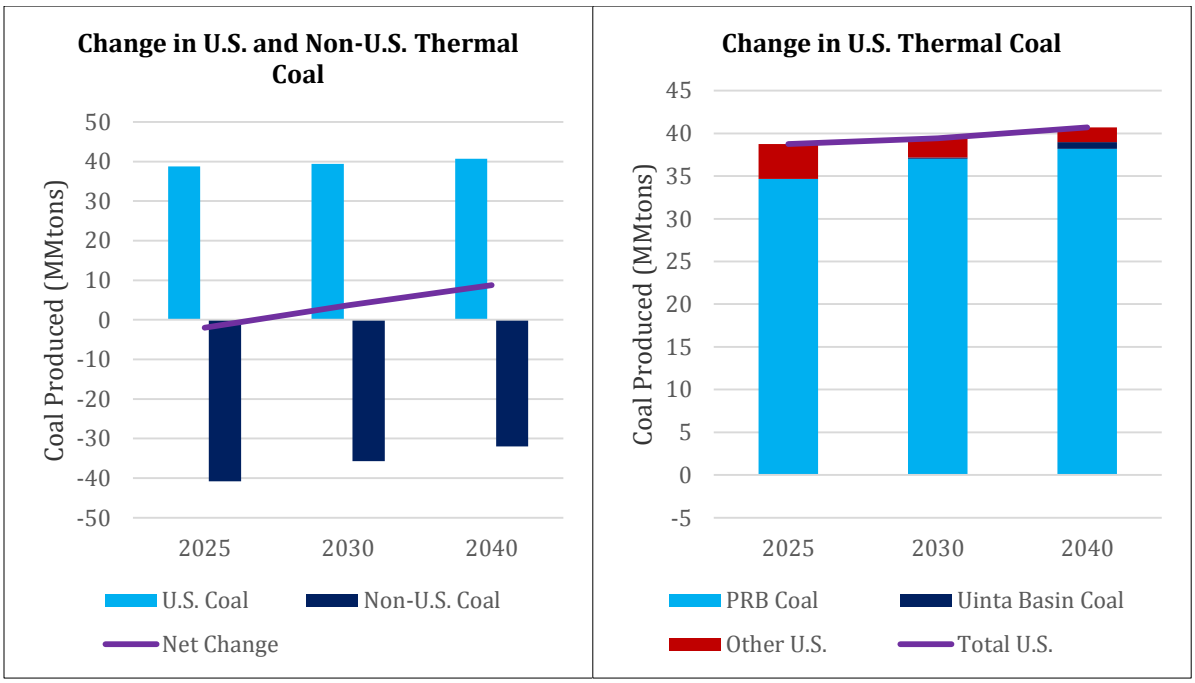
proposed terminal is online and exporting coal, total modeled U.S. coal production would be higher by an average of 39.7 million metric tons under the Proposed Action, primarily due to increases in Powder River Basin production.

Table 6-22. Lower Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	0	0	0.3	-40.8	-35.7	-32.0	-35.7
Total U.S. Thermal Coal	-2.2	-4.8	-3.7	38.7	39.4	40.7	39.7
Powder River Basin Coal	-3.4	-8.3	-5.8	34.7	37.0	38.2	36.8
Uinta Basin Coal	0	0	0	0	0.1	0.8	0.4

The left-hand chart in Figure 6-8 shows that total non-U.S. thermal coal production would decrease in similar amounts to the increase in U.S. coal production when comparing the Proposed Action to the No-Action Alternative. This similarity is indicative of U.S. thermal coal exports taking the place of some internationally produced coal, instead of adding to overall global coal demand. The right-hand chart in Figure 6-8 shows that the changes in Powder River Basin coal production would make up most of the changes in overall U.S. coal production.

Figure 6-8. Lower Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative



In the Lower Bound Scenario, the average increase in U.S. coal production (39.7 million metric tons) under the Proposed Action would be close to the 44 million metric tons of coal being exported through the proposed terminal. The No Clean Power Plan Scenario increase would average 44

million metric tons. The difference is due primarily to decreases in coal exports through Canadian export terminals in the No Clean Power Plan Scenario.

6.3.2 Coal Consumption

Under the No-Action Alternative, U.S. thermal coal consumption would average 519 million metric tons per year for the 2025 to 2040 period. U.S. coal consumption declines over the 2016 and 2040 period due to the higher assumed Powder River Basin coal prices and the implementation of the Clean Power Plan. Over the 2016 to 2040 period, Asian coal consumption would grow at an average rate of 1.9% per year from 3,402 to 5,294 million metric tons. The growth in consumption would be driven by increasing coal consumption in China and India. Table 6-23 shows the No-Action Alternative coal consumption values for each model run year. Table 6-24 shows the same values in TBtu per year.

China is responsible for the largest share of global thermal coal consumption, burning 2,269 million metric tons of coal in 2016. This amount is projected to grow in the Lower Bound Scenario under the No-Action Alternative to 2,732 million metric tons by 2040. Total U.S. coal consumption would remain relatively stable through 2025 at an average of 573 million metric tons before declining at an annual rate of -1.3% from 2025 to 2040, finally dropping below 500 million metric tons by 2040.

Table 6-23. Lower Bound Scenario Coal Consumption—No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	121	135	157	148	188	202	182
Australia	104	113	121	118	116	108	113
China	2,269	2,478	2,685	2,747	2,803	2,732	2,760
Hong Kong	14	15	15	14	15	16	15
India	547	717	887	1,075	1,329	1,857	1,464
Indonesia	138	139	141	151	163	181	167
Japan	94	107	122	105	103	86	97
South Korea	70	75	80	70	63	44	57
Taiwan	46	54	63	62	68	69	66
Total Asian Coal Consumption[a]	3,402	3,833	4,271	4,490	4,847	5,294	4,922
Total U.S. Coal Consumption	583	554	580	577	519	477	519
Rest of World Coal Consumption	1,066	1,226	1,370	1,243	1,121	1,015	1,114

[a] Asia row is sum of Asia-Other through Taiwan rows.

Table 6-24. Lower Bound Scenario Coal Consumption—No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,904	3,205	3,380	3,593	3,882	3,646
Australia	1,268	1,454	1,640	1,519	1,436	1,194	1,365
China	57,999	63,331	68,639	69,967	71,090	68,476	69,761
Hong Kong	303	325	347	366	389	420	395
India	10,213	13,382	16,549	19,999	24,655	33,846	26,936
Indonesia	2,486	2,485	2,484	2,619	2,785	3,008	2,826
Japan	2,337	2,620	2,900	2,731	2,689	2,274	2,539
South Korea	1,716	1,866	2,016	1,784	1,617	1,152	1,483
Taiwan	1,091	1,290	1,489	1,571	1,673	1,802	1,695
Total Asian Coal[a] Consumption	80,016	89,658	99,269	103,936	109,927	116,055	110,646
Total U.S. Coal Consumption	12,329	11,843	12,369	12,180	10,980	9,948	10,912
Rest of World Coal Consumption	18,440	21,234	24,086	22,670	20,799	20,071	21,036

[a] Asia row is total of Asia-Other through Taiwan rows.

Coal consumption under the Proposed Action would follow similar patterns as the No-Action Alternative, with U.S. thermal coal consumption averaging 515 million metric tons per year for the 2025 to 2040 period. As with the No-Action Alternative, U.S. coal consumption would be fairly flat until 2025, before decreasing in 2030 and 2040, as electric demand growth would be met primarily with natural gas and renewable generation.

Over the 2016 to 2040 period, Asian coal consumption would follow the same pattern as it grows from 3,402 to 5,306 million metric tons. Tables 6-25 and 6-26 show the Proposed Action coal consumption values for each model run year in million metric tons and in TBtu, respectively. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-25. Lower Bound Scenario Coal Consumption—Proposed Action (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	121	135	157	148	188	202	182
Australia	104	113	121	118	116	108	113
China	2,269	2,478	2,685	2,748	2,804	2,733	2,761
Hong Kong	14	15	15	16	17	19	18
India	547	717	887	1,070	1,329	1,857	1,462
Indonesia	138	139	141	151	163	181	167
Japan	94	107	122	106	104	88	98
South Korea	70	75	80	71	64	46	59
Taiwan	46	54	63	65	70	72	69
Total Asian Coal Consumption	3,402	3,833	4,271	4,492	4,855	5,306	4,930
Total U.S. Coal Consumption	581	549	577	572	515	475	515
Rest of World Coal Consumption	1,066	1,226	1,370	1,243	1,121	1,015	1,114

Table 6-26. Lower Bound Scenario Coal Consumption—Proposed Action (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,904	3,205	3,380	3,593	3,882	3,646
Australia	1,268	1,454	1,640	1,519	1,436	1,194	1,365
China	57,999	63,331	68,639	69,967	71,090	68,476	69,761
Hong Kong	303	325	347	366	389	420	395
India	10,213	13,382	16,549	19,999	24,655	33,846	26,936
Indonesia	2,486	2,485	2,484	2,619	2,785	3,008	2,826
Japan	2,337	2,620	2,900	2,731	2,689	2,274	2,539
South Korea	1,716	1,866	2,016	1,784	1,617	1,152	1,483
Taiwan	1,091	1,290	1,489	1,572	1,673	1,803	1,695
Total Asian Coal Consumption	80,016	89,658	99,269	103,936	109,928	116,055	110,646
Total U.S. Coal Consumption	12,297	11,761	12,321	12,083	10,896	9,920	10,846
Rest of World Coal Consumption	18,440	21,234	24,086	22,670	20,798	20,068	21,034

Tables 6-27 and 6-28 show the estimated change in coal consumption, in million metric tons and TBtu, between the Proposed Action and the No-Action Alternative by model run year to be nearly zero in Asia before 2025 when the proposed terminal was assumed to be fully online. There are small changes in coal consumption prior to the proposed terminal coming online because the IPM model is forward-looking and makes adjustments in the near term to optimize the whole period being analyzed. In the Proposed Action the IPM® model ”knows” that the terminal comes fully online in 2025 and thus it makes adjustments throughout the analytical period to minimize overall costs. Once the proposed terminal is exporting coal at full capacity (i.e., 44 million metric tons), total Asian

coal consumption would increase by an average of 8.1 million metric tons between 2025 and 2040. The increase in consumption between 2025 and 2040 would be due to the consumption of a greater quantity of lower heat content coal. U.S. coal consumption would have an average decline of 3.8 million metric tons per year over the 2025 to 2040 period under the Proposed Action due to a decrease in the demand for Powder River Basin coal. Powder River Basin coal demand in the United States would decrease due to higher coal prices caused by higher production when the Powder River Basin coal is exported through the proposed terminal.

Table 6-27. Lower Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	-0.6	0	0	-0.2
Australia	0	0	0	0	0	0	0
China	0	0	0	1.0	0.9	1.4	1.1
Hong Kong	0	0	0	2.3	2.6	2.8	2.6
India	0	0	0	-5.2	0	0	-1.4
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.9	0.9	1.9	1.3
South Korea	0	0	0	1.4	1.3	2.3	1.7
Taiwan	0	0	0	3.0	2.4	3.6	3.0
Total Asian Coal Consumption	0	0	0	2.7	8.0	12.0	8.1
Total U.S. Coal Consumption	-2.2	-4.8	-3.4	-4.8	-4.1	-2.8	-3.8
Rest of World Coal Consumption	0	0	0.1	0.1	0	-0.1	<0.05

Table 6-28. Lower Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0
Hong Kong	0	0	0	<0.1	<0.1	<0.1	<0.1
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0
South Korea	0	0	0	0	0	0	0
Taiwan	0	0	0	0.2	0.2	0.2	0.2
Total Asian Coal Consumption	0	0	0	0.3	0.3	0.3	0.3
Total U.S. Coal Consumption	-31.8	-82.0	-48.6	-96.9	-83.8	-27.3	-65.4
Rest of World Coal Consumption	0	0	0	0	-0.8	-3.0	-1.4

6.3.3 Coal Distribution

Similar to the No Clean Power Plan Scenario, the Lower Bound Scenario distribution patterns for Powder River Basin and Uinta Basin coal are expected to remain largely unchanged under the Proposed Action. Thus, this section focuses on the distribution of coal in Asia and how that distribution would be expected to change with the construction of the terminal. Under the No-Action Alternative, there is no coal exported through the proposed terminal; however, there would be 306 million metric tons of coal distributed in Asia by ship in the seaborne coal market in 2016. Table 6-29 shows the tons of coal that would be imported by each country in Asia under the No-Action Alternative. By 2040, a total of 409 million metric tons of thermal coal are expected to be imported in the seaborne coal market in Asia.

Table 6-29. Lower Bound Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	83	95	115	129	180	194	171
Australia	0	0	0	0	0	0	0
China	0	10	32	0	0	0	0
Hong Kong	14	15	15	14	15	16	15
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	94	107	122	105	103	86	97
South Korea	70	75	80	70	63	44	57
Taiwan	46	54	63	62	68	69	66
Total Asian Coal sent via ship	306	356	428	379	430	409	408

To understand how coal distribution is changing in more detail than the tons of coal imported by each country, the tons of coal shipped to each country were multiplied by the distance in nautical miles that the coal would be shipped and then divided by an average ship size. The change in tons imported might not change significantly; however, where the coal is sourced might change, which can have a significant impact on the emissions associated with shipping. Table 6-30 shows the shipping miles for coal shipped to each country under the No-Action Alternative.

Table 6-30. Lower Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.50	0.69	1.94	2.37	3.47	3.78	3.29
Australia	0	0	0	0	0	0	0
China	0	0.25	0.84	0	0	0	0
Hong Kong	0.40	0.43	0.46	0.42	0.18	0.19	0.25
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	4.39	5.71	7.76	1.40	1.38	1.15	1.30
South Korea	1.91	2.65	2.79	0.66	0.59	0.43	0.55
Taiwan	2.89	3.42	3.95	1.91	3.36	0.57	1.87
Total Asian Coal sent via ship	10.08	13.15	17.73	6.75	8.98	6.13	7.25

Under the Proposed Action coal would be exported through the terminal to destinations in Asia. Table 6-31 shows the distribution of coal exported from the proposed terminal, which would be similar to the distribution in the other scenarios as the coal is delivered to all of the possible destinations.

Table 6-31. Lower Bound Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040
China	0	0	0	3.7	3.6	5.3
Hong Kong	0	0	0	9.4	9.9	10.7
Japan	0	0	0	7.3	7.2	6.4
South Korea	0	0	0	11.7	10.6	7.9
Taiwan	0	0	0	11.9	12.7	13.7
Total Asian Coal sent via ship through Proposed Terminal	0	0	0	44.0	44.0	44.0

Under the Proposed Action, a similar number of tons would be distributed in the seaborne coal market as for the No-Action Alternative, as can be seen in Table 6-32, which shows the tons of coal that would be imported by each country in Asia under the Proposed Action. The shipping distance for the coal distribution in Asia is presented in Table 6-33 for the Proposed Action.

Table 6-32. Lower Bound Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	83	95	115	128	180	194	171
Australia	0	0	0	0	0	0	0
China	0	10	32	4	4	5	4
Hong Kong	14	15	15	16	17	19	18
India	0	0	0	14	0	0	4
Indonesia	0	0	0	0	0	0	0
Japan	94	107	122	106	104	88	98
South Korea	70	75	80	71	64	46	59
Taiwan	46	54	63	65	70	72	69
Total Asian Coal sent via ship	306	356	428	403	440	425	424

Table 6-33. Lower Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.50	0.69	1.94	2.35	3.47	3.78	3.28
Australia	0	0	0	0	0	0	0
China	0	0.25	0.84	0.30	0.29	0.43	0.35
Hong Kong	0.40	0.43	0.46	1.02	0.95	1.03	1.00
India	0	0	0	0.65	0	0	0.18
Indonesia	0	0	0	0	0	0	0
Japan	4.39	5.71	7.76	1.80	1.77	1.52	1.68
South Korea	1.91	2.65	2.79	1.38	1.25	0.92	1.16
Taiwan	2.89	3.42	3.95	2.71	3.77	1.62	2.64
Total Asian Coal sent via ship	10.08	13.15	17.73	10.21	11.51	9.31	10.29

As can be seen in Table 6-34, which shows the estimated change in tons of coal imported by each of the regions, the changes in coal imports between the No-Action Alternative and the Proposed Action mirror the changes in consumption. As mentioned in the previous section, the changes in consumption are due to changes in the mix of coal being consumed and not a change in overall coal demand.

Table 6-34. Lower Bound Scenario Change in Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	-0.6	0	0	-0.2
Australia	0	0	0	0	0	0	0
China	0	0	0	3.7	3.6	5.3	4.3
Hong Kong	0	0	0	2.3	2.6	2.8	2.6
India	0	0	0	13.8	0	0	3.8
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.9	0.9	1.9	1.3
South Korea	0	0	0	1.4	1.3	2.3	1.7
Taiwan	0	0	0	3.0	2.4	3.6	3.0
Total Asian Coal sent via ship	0	0	0	24.5	10.7	15.9	16.6

The changes in the total tons of coal imported to each region would be magnified or diminished depending on how the sources of the coal shifted. There would be some relatively large changes in the ton-mile values, as shown in Table 6-35.

Table 6-35. Lower Bound Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	Annual Average
Asia - Other	0	0	0	-0.01	0	0	<0.005
Australia	0	0	0	0	0	0	0
China	0	0	0	0.30	0.29	0.43	0.35
Hong Kong	0	0	0	0.61	0.77	0.84	0.75
India	0	0	0	0.65	0	0	0.18
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.40	0.39	0.37	0.38
South Korea	0	0	0	0.73	0.66	0.49	0.61
Taiwan	0	0	0	0.79	0.41	1.06	0.77
Total Asian Coal sent via ship	0	0	0	3.46	2.52	3.18	3.04

6.3.4 CO_2 Emissions

This section presents the estimated CO_2 emissions from coal combusted in the United States and Asia in the Lower Bound Scenario. In addition, CO_2 emissions from natural gas consumption in the United States are included because decreases in coal consumption may be offset by increases in natural gas consumption. Table 6-36 presents the CO_2 emissions under the No-Action Alternative. Total U.S. CO_2 emissions from coal would gradually decline and average 1,022.71 million metric tons between 2025 and 2040. Asian CO_2 emissions would average 10,624.68 million metric tons per year between 2025 and 2040, which is 10.4 times the total CO_2 emissions from the U.S. coal combustion emissions. Natural gas CO_2 emissions would average 567.27 million metric tons per year between 2025 and 2040, which is 21.15 million metric tons lower than the No Clean Power Plan Scenario. The lower natural gas emissions under the Lower Bound Scenario, in spite of higher assumed coal prices in this scenario, are due to the inclusion of the Clean Power Plan, along with additional energy efficiency, which would decrease generation, including gas-fired generation. However, within the Lower Bound Scenario, between 2030 and 2040, CO_2 emissions from natural gas would increase by 152.18 million metric tons. This increase would be due to nuclear units retiring in this period and natural gas-fired generation replacing the retired nuclear generation.

Table 6-37 presents the CO_2 emissions under the Proposed Action. Total CO_2 emissions under the Proposed Action would follow the same trends as under the No-Action Alternative.

Table 6-36. Lower Bound Scenario CO_2 Emissions—No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	249.64	278.72	307.81	315.01	349.95	378.15	351.21
Australia	118.44	135.82	153.19	141.84	134.07	111.44	127.43
China	5,589.28	6,102.28	6,611.34	6,743.76	6,853.22	6,604.62	6,726.13
Hong Kong	28.03	30.04	32.06	33.80	37.44	40.45	37.60
India	972.75	1,275.00	1,577.00	1,905.11	2,348.19	3,221.25	2,564.63
Indonesia	239.90	239.57	239.23	251.81	267.30	287.63	270.90
Japan	217.19	244.08	271.31	262.82	258.78	218.86	244.38
South Korea	161.27	173.30	187.21	171.69	155.66	110.91	142.71
Taiwan	101.94	120.56	139.17	145.35	155.55	173.47	159.69
Asia- Coal	7,678.43	8,599.37	9,518.31	9,971.20	10,560.15	11,146.77	10,624.68
U.S. - Coal	1,157.94	1,110.06	1,160.04	1,142.49	1,028.90	931.85	1,022.71
U.S. - Natural Gas	574.39	551.71	510.16	495.88	517.59	660.85	567.27
Rest of World	1,757.68	2,022.82	2,294.97	2,156.06	1,976.51	1,904.87	1,998.52

Table 6-37. Lower Bound Scenario CO_2 Emissions—Proposed Action (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	249.64	278.72	307.81	314.73	349.95	378.15	351.13
Australia	118.44	135.82	153.19	141.84	134.07	111.44	127.43
China	5,589.28	6,102.28	6,611.34	6,743.66	6,853.13	6,604.49	6,726.03
Hong Kong	28.03	30.04	32.06	34.28	37.20	40.19	37.55
India	972.75	1,275.00	1,577.00	1,903.99	2,348.19	3,221.25	2,564.33
Indonesia	239.90	239.57	239.23	251.81	267.30	287.63	270.90
Japan	217.19	244.08	271.31	262.65	258.62	218.85	244.27
South Korea	161.27	173.30	187.21	171.43	155.42	110.89	142.55
Taiwan	101.94	120.56	139.17	145.97	155.95	173.16	159.87
Asia- Coal	7,678.43	8,599.37	9,518.31	9,970.36	10,559.81	11,146.04	10,624.06
U.S. - Coal	1,154.79	1,102.20	1,155.19	1,133.82	1,021.45	929.05	1,016.73
U.S.- Natural Gas	575.66	554.39	510.85	498.58	519.83	661.50	569.02
Rest of World	1,757.68	2,022.82	2,294.99	2,156.09	1,976.44	1,904.58	1,998.40

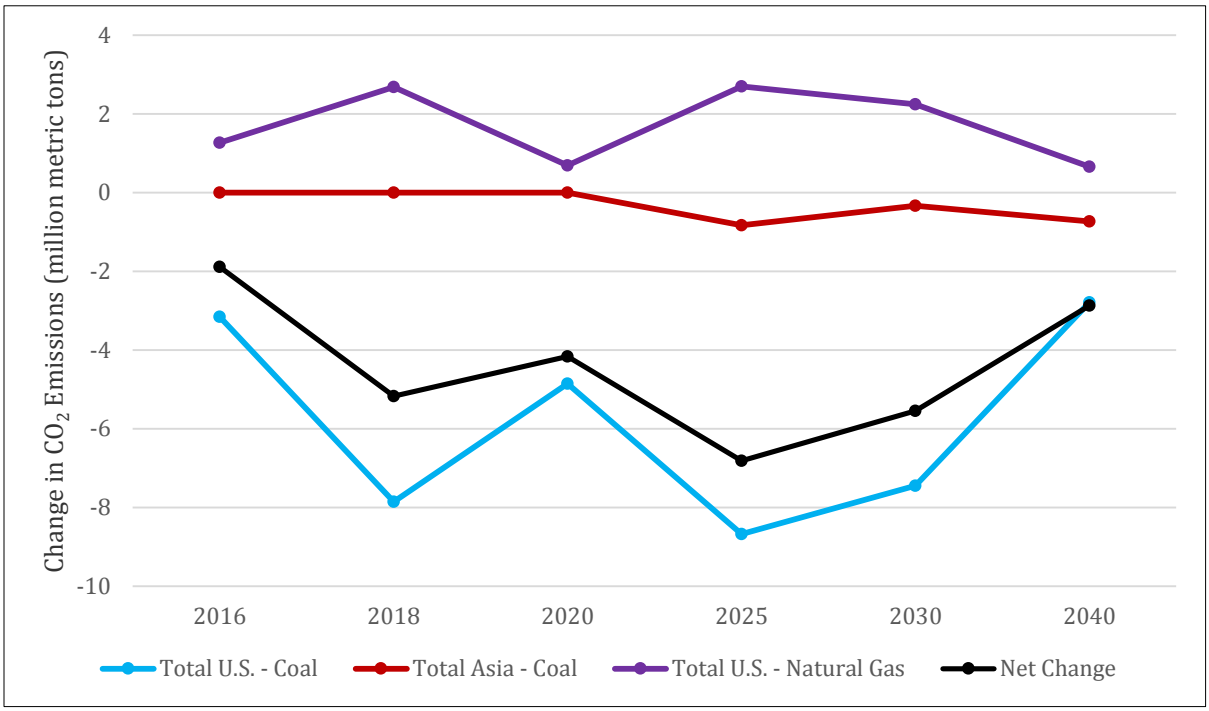
Table 6-38 shows the estimated change in CO_2 emissions for each region and the total net change across all regions. Total Asian CO_2 emissions from coal consumption would decrease by 0.63 million metric tons on average from 2025 to 2040. U.S. coal CO_2 emissions would also decrease in every year due to higher coal prices that would depress U.S. coal demand. The higher coal prices would result from the fact that an additional 44 million metric tons of coal would be exported under the Proposed Action, which would shift the demand curve up and yield higher coal prices in the United States. The decrease in coal consumption would be offset by an increase in natural gas consumption, as is seen by the increase in CO_2 emissions from natural gas, which would average 1.75 million metric tons per year between 2025 and 2040. The total net change in CO_2 emissions would be a decrease of an average of 4.86 million metric tons per year between 2025 and 2040.

Table 6-38. Lower Bound Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0	-0.28	0	0	-0.08
Australia	0	0	0	0	0	0	0
China	0	0	0	-0.09	-0.09	-0.13	-0.11
Hong Kong	0	0	0	0.47	-0.24	-0.26	-0.05
India	0	0	0	-1.11	0	0	-0.31
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	-0.17	-0.16	-0.01	-0.11
South Korea	0	0	0	-0.27	-0.24	-0.01	-0.16
Taiwan	0	0	0	0.62	0.40	-0.32	0.18
Asia- Coal	0	0	0	-0.83	-0.34	-0.73	-0.63
U.S. - Coal	-3.15	-7.85	-4.85	-8.67	-7.45	-2.79	-5.98
U.S. - Natural Gas	1.26	2.68	0.69	2.69	2.24	0.65	1.75
Rest of World	0	0.01	0.02	0.03	-0.06	-0.29	-0.12
Total Change	-1.89	-5.17	-4.17	-6.81	-5.54	-2.87	-4.86

In the Lower Bound Scenario, coal combustion emissions of CO_2 would be lower under the Proposed Action in Asia than under the No-Action Alternative. U.S. emissions would generally decline, with the decline from coal offsetting the increase in emissions from natural gas. Figure 6-9 shows the net change in CO_2 emissions between the No-Action Alternative and Proposed Action. The decrease in U.S. and Asian coal emissions would override the increase in U.S. natural gas emissions and would drive the net change to be a net decrease in CO_2 emissions under the Proposed Action through 2040.

Figure 6-9. Lower Bound Scenario Changes in CO_2 Emissions by Region—Proposed Action minus No-Action Alternative



a. Total U.S. CO_2 emissions from the combustion of coal decrease because the proposed coal export terminal would be a new demand sink for U.S. coal, and thus, would cause coal prices to rise, and U.S. coal consumption to decrease in response to the higher prices.

b. Asian CO_2 emissions from the combustion of coal decrease due to a general shift toward consuming more coal with a lower CO_2 emission rate and away from coals with a higher CO_2 emissions rate.

c. Total U.S. natural gas combustion CO_2 emissions increase because when coal consumption for electric generation declines, natural gas usage for electric generation increases to fill some of the gap.

6.4 Upper Bound Scenario

The Upper Bound Scenario uses the assumptions presented in Chapter 5, *Scenarios*, and represents the upper bound of global GHG emissions that could be reasonably expected if the scenario assumptions are realized. This scenario is designed to model the highest potential GHG emissions under the Proposed Action, and to provide a high GHG emissions environment into which the terminal is constructed and operated. This section presents the modeling results for the Upper Bound Scenario No-Action Alternative and Proposed Action for coal production, consumption, distribution, and CO_2 emissions.

6.4.1 Coal Production

The Upper Bound Scenario is designed to model high levels of coal consumption, and thus, increased CO_2 emissions. Therefore, coal production in the Upper Bound Scenario would be greater than the No Clean Power Plan Scenario. Under the No-Action Alternative U.S. thermal coal production would average 876 million metric tons per year for the 2025 to 2040 period. In contrast, the average U.S. coal production over 2025 to 2040 under the No Clean Power Plan Scenario would be lower by 63 million metric tons at 813 million metric tons. The higher production under the Upper Bound

Scenario would be due to the following factors. International coal prices are 50% higher than the base assumptions, due to higher demand, and Powder River Basin and Uinta Basin coal prices are assumed 15% lower in the Upper Bound Scenario than the base assumptions, while domestic coal transportation costs are decreased. Additionally, international coal demand is higher in the Upper Bound Scenario than in the base assumptions. The increase in demand for U.S. coal exports along with lower costs lead to the increase in U.S. coal production. U.S. coal production would fluctuate over the 2016 to 2040 period in response to both domestic demand and exports, and would end up being 153 million metric tons higher in 2040 than in 2016. Over the 2016 to 2040 period, non-U.S. coal production would grow at an average annual rate of 3.2% per year from 4,417 to 9,470 million metric tons.

Powder River Basin coal production under the No-Action Alternative would average 379 million metric tons per year over 2025 to 2040. The modeled Powder River Basin average production in the Upper Bound Scenario, No-Action Alternative, would be 19.9% below the 2006 to 2011 historical production average of 473 million metric tons (i.e., 379 million metric tons relative to 473 million metric tons). After 2011, natural gas prices dropped to below $3/MMBtu, which significantly reduced coal demand and drove Powder River Basin production to around 435 million metric tons. Uinta Basin coal production under the No-Action Alternative would average 17.2 million metric tons per year over 2025 to 2040, with production remaining flat through 2030 and increasing in 2040. Table 6-39 shows the No-Action Alternative coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-39. Upper Bound Coal Production—No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,417	5,014	5,694	6,371	7,197	9,470	7,852
Total U.S. Thermal Coal	731	790	866	884	859	884	876
Powder River Basin Coal	412	381	428	407	364	372	379
Uinta Basin Coal	15.0	14.9	15.0	14.9	14.9	20.9	17.2

Under the Proposed Action, U.S. thermal coal production would average 918 million metric tons per year for the 2025 to 2040 period. Similar to the No-Action Alternative, under the Proposed Action, U.S. coal production would fluctuate and by 2040 would end at 196 million metric tons higher than production in 2016 at 927 million metric tons. The higher production by 2040 is due to the additional exports through the proposed terminal. Non-U.S. coal production would follow the same growth rate under the Proposed Action as it would under the No-Action Alternative. Powder River Basin coal production under the Proposed Action would average 415 million metric tons per year between 2025 and 2040 with production generally increasing over time. Uinta Basin coal production would average 22.1 million metric tons per year between 2025 and 2040, with production remaining flat through 2025 and then increasing in 2030 and 2040. Table 6-40 shows the Proposed Action coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-40. Upper Bound Scenario Coal Production—Proposed Action (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,418	5,014	5,694	6,357	7,179	9,448	7,833
Total U.S. Thermal Coal	731	790	866	928	898	927	918
Powder River Basin Coal	412	381	428	452	400	401	415
Uinta Basin Coal	14.4	14.9	15.0	13.6	17.7	31.9	22.1

Table 6-41 shows the estimated change in coal production between the Proposed Action and the No-Action Alternative by model run year. Upon the export of 44 million metric tons of coal, total modeled U.S. coal production would be higher under the Proposed Action, primarily due to increases in the Powder River Basin and the Uinta Basin. In response to the increase in exports from the proposed terminal, non-U.S. coal production would decrease by an average of 18.4 million metric tons per year from 2025 to 2040.

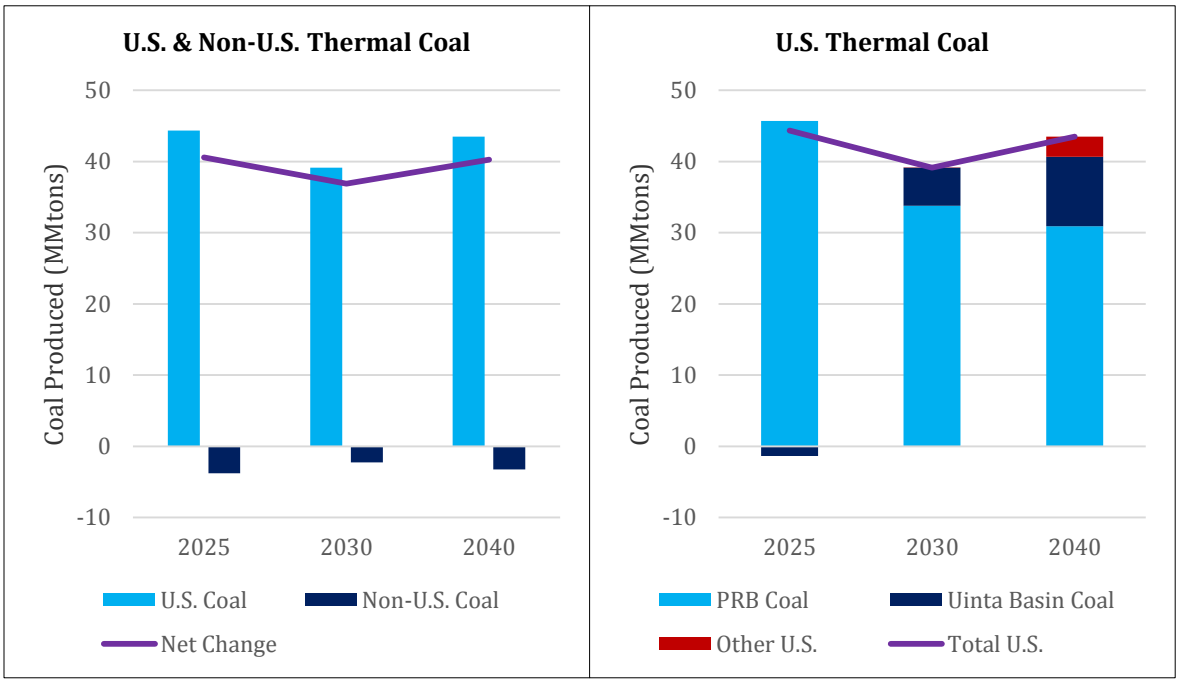
Table 6-41. Upper Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	1.7	0	0	-14.0	-18.5	-21.5	-18.4
Total U.S. Thermal Coal	-0.4	0	0	44.3	39.1	42.9	42.0
Powder River Basin Coal	0.1	0.1	0	45.7	36.3	29.0	36.1
Uinta Basin Coal	-0.6	0	0	-1.4	2.8	11.0	4.9

Figure 6-10 shows that total non-U.S. thermal coal production would decrease under the Proposed Action. The decrease in non-U.S. coal production is smaller than the increase in U.S. coal production because of induced demand in this scenario of between 23 and 33 million metric tons.[36] The positive net change in production that is greater than the amount of induced demand indicates that U.S. thermal coal exports of lower heat content coal would displace some internationally produced higher heat content coal.

[36] The amount of induced demand is determined by the increase in total heating value of coal, which in the Upper Bound Scenario is 542 TBtu. Depending on the mix of coal types consumed between lignite, subbituminous, and bituminous coal, the amount of induced demand on a tonnage basis is expected to be between 23 and 33 million metric tons.

Figure 6-10. Upper Bound Scenario Change in Coal Production—Proposed Action minus No-Action Alternative



6.4.2 Coal Consumption

In the Upper Bound Scenario, under the No-Action Alternative U.S. thermal coal consumption would average 698 million metric tons per year for the 2025 to 2040 period. U.S. coal consumption would be fairly flat over the whole period because of two factors. First, consumption is not driven down by the Clean Power Plan implementation. Second, low natural gas prices and relatively low renewable capital costs result in demand growth being met with natural gas combined cycles and renewable resources.

Over the 2016 to 2040 period, Asian coal consumption would grow at an average rate of 3.6% per year from 3,388 to 7,974 million metric tons. The growth in consumption would be driven by increasing coal consumption in China and India. Tables 6-42 and 6-43 show the No-Action Alternative coal consumption values for each model run year in units of million metric tons and TBtu, respectively.

China is responsible for the largest share of global thermal coal consumption, burning 2,269 million metric tons of coal in 2016. This amount is projected to grow in the Upper Bound Scenario, No-Action Alternative to 4,076 million metric tons by 2040.

Table 6-42. Upper Bound Scenario Coal Consumption—No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	115	142	158	185	262	440	310
Australia	104	114	123	124	124	125	124
China	2,269	2,533	2,804	3,083	3,393	4,076	3,572
Hong Kong	13	14	17	19	19	26	22
India	543	701	888	1,194	1,541	2,637	1,871
Indonesia	136	147	163	179	217	303	240
Japan	96	113	127	137	136	154	143
South Korea	67	81	89	90	100	117	104
Taiwan	47	56	65	74	84	95	86
Total Asian Coal Consumption	3,388	3,900	4,435	5,085	5,875	7,974	6,472
Total U.S. Coal Consumption	659	645	711	715	682	700	698
Rest of World Coal Consumption	1,102	1,260	1,416	1,457	1,501	1,684	1,560

Table 6-43. Upper Bound Scenario Coal Consumption—No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	2,603	2,968	3,334	4,255	5,430	8,846	6,432
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	78,781	86,598	103,803	91,117
Hong Kong	303	332	361	425	501	695	555
India	10,213	13,834	17,452	23,201	30,309	51,255	36,480
Indonesia	2,486	2,637	2,798	3,243	3,760	5,053	4,119
Japan	2,337	2,674	3,009	3,283	3,548	4,054	3,671
South Korea	1,716	1,911	2,106	2,322	2,556	3,085	2,697
Taiwan	1,091	1,324	1,558	1,761	1,965	2,331	2,051
Total Asian Coal Consumption	80,016	91,880	103,742	118,934	136,296	180,713	148,747
Total U.S. Coal Consumption	13,129	12,933	14,282	14,573	14,043	14,513	14,373
Rest of World Coal Consumption	18,316	21,846	25,426	26,538	27,740	32,263	29,165

Over the 2016 to 2040 period, Asian coal consumption under the Proposed Action grows from 3,390 to 7,994 million metric tons, similar to the No-Action Alternative. Due to lower delivered coal prices causing induced demand, the demand in Asian countries increases by 542 TBtu annually from 2025.

Tables 6-44 and 6-45 show the Proposed Action coal consumption values for each model run year in units of million metric tons and TBtu, respectively. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-44. Upper Bound Scenario Coal Consumption—Proposed Action (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	118	142	158	185	259	440	309
Australia	104	114	123	124	124	125	124
China	2,269	2,533	2,804	3,109	3,412	4,095	3,594
Hong Kong	13	14	17	19	22	30	24
India	543	701	888	1,196	1,542	2,634	1,870
Indonesia	136	147	163	179	216	303	240
Japan	94	113	127	136	137	154	144
South Korea	67	81	89	91	100	117	104
Taiwan	47	56	65	76	84	96	86
Total Asian Coal Consumption	3,390	3,900	4,435	5,115	5,896	7,994	6,495
Total U.S. Coal Consumption	659	645	711	715	682	700	698
Rest of World Coal Consumption	1,102	1,260	1,416	1,457	1,500	1,684	1,560

Table 6-45. Upper Bound Scenario Coal Consumption—Proposed Action (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,968	3,334	4,255	5,430	8,846	6,432
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	79,292	87,108	104,314	91,628
Hong Kong	303	332	361	426	501	696	556
India	10,213	13,834	17,452	23,224	30,332	51,278	36,503
Indonesia	2,486	2,637	2,798	3,243	3,760	5,053	4,119
Japan	2,337	2,674	3,009	3,287	3,552	4,058	3,675
South Korea	1,716	1,911	2,106	2,325	2,559	3,087	2,699
Taiwan	1,091	1,324	1,558	1,763	1,966	2,333	2,052
Total Asian Coal Consumption	80,016	91,880	103,742	119,476	136,837	181,256	149,289
Total U.S. Coal Consumption	13,118	12,933	14,281	14,573	14,043	14,513	14,373
Rest of World Coal Consumption	18,316	21,846	25,426	26,538	27,740	32,263	29,165

Tables 6-46 and 6-47 show the estimated change in coal consumption between the Proposed Action and the No-Action Alternative by model run year in units of million metric tons and TBtu, respectively. Once the proposed terminal is online and exporting coal in 2025, total Asian coal consumption is higher by an average of 23.3 million metric tons between 2025 and 2040. China's consumption has the largest increase, with an average of 21.5 million metric tons per year between 2025 and 2040. U.S. coal consumption increases slightly by an average of 0.4 million metric tons per year over the 2025 to 2040 period under the Proposed Action. In 2040, the tons of coal consumed in India decreases, while the total heat content of coal consumption increases. This occurs because India increases its use of higher-heat-content Australian bituminous coal and decreases its use of lower heat content domestic subbituminous coal.

Table 6-46. Upper Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	3.8	0	0	0	-2.9	-0.1	-1.0
Australia	0	0	0	0	0	0	0
China	0	0	0	26.9	19.4	19.4	21.5
Hong Kong	0	0	0	0	2.7	3.7	2.3
India	0	0	0	2.1	1.0	-3.2	-0.3
Indonesia	0	0	0	0	-0.7	-0.1	-0.3
Japan	-2.1	0	0	-0.6	0.7	0.1	0.1
South Korea	0	0	0	0.1	0.5	0.1	0.2
Taiwan	0	0	0	1.4	0.1	0.7	0.7
Total Asian Coal Consumption	1.7	0	0	30.0	20.7	20.7	23.3
Total U.S. Coal Consumption	-0.4	0	0	0.3	0.1	0.7	0.4
Rest of World Coal Consumption	0	0	0	0	0	0	0

Table 6-47. Upper Bound Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
China	0	0	0	510.8	510.8	510.8	510.8
Hong Kong	0	0	0	0.4	0.4	0.4	0.4
India	0	0	0	22.9	22.9	22.9	22.9
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	3.3	3.3	3.3	3.3
South Korea	0	0	0	2.4	2.4	2.4	2.4
Taiwan	0	0	0	2.1	2.1	2.1	2.1
Total Asian Coal Consumption	0	0	0	541.9	541.9	541.9	541.9
Total U.S. Coal Consumption	-11.4	-0.1	-0.2	0.2	0.2	0.1	0.1
Rest of World Coal Consumption	0	0	0	0	0	0	0

6.4.3 Coal Distribution

As with the No Clean Power Plan Scenario, distribution patterns for Powder River Basin and Uinta Basin coal are expected to remain largely unchanged under the Proposed Action. This section focuses on the distribution of coal in Asia and how that distribution would be expected to change with the construction of the terminal. Under the No-Action Alternative, there would be no coal exported through the proposed terminal; however, there would be 308 million metric tons of coal distributed in Asia by ship in the seaborne coal market in 2016. Table 6-48 shows the tons of coal that would be imported by each country in Asia under the No-Action Alternative. By 2040, 1,373 million metric tons of coal are expected to be distributed in the seaborne coal market in Asia.

Table 6-48. Upper Bound Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	76	102	116	165	255	432	299
Australia	0	0	0	0	0	0	0
China	0	17	101	0	0	0	0
Hong Kong	13	14	17	19	19	26	22
India	9	112	131	183	334	548	375
Indonesia	0	0	0	0	0	0	0
Japan	96	113	127	137	136	154	143
South Korea	67	81	89	90	100	117	104
Taiwan	47	56	65	74	84	95	86
Total Asian Coal sent via ship	308	495	647	669	927	1,373	1,029

To understand how coal distribution is changing in more detail than the tons of coal imported by each country, the tons of coal shipped to each country were multiplied by the distance in nautical miles that the coal is shipped. The change in tons imported might not change significantly; however, where the coal is sourced might change, which would have a significant impact on the emissions associated with shipping. Table 6-49 shows the shipping miles for coal shipped to each country under the No-Action Alternative.

Table 6-49. Upper Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	1.23	1.79	1.30	3.14	5.49	8.79	6.12
Australia	0	0	0	0	0	0	0
China	0	1.30	4.33	0	0	0	0
Hong Kong	0.67	0.87	0.50	1.43	0.23	0.32	0.60
India	0.61	6.32	6.31	14.24	27.80	45.69	30.99
Indonesia	0	0	0	0	0	0	0
Japan	7.26	7.15	8.05	7.76	1.82	2.05	3.56
South Korea	0.63	5.23	5.77	0.85	0.94	1.16	1.00
Taiwan	3.08	3.51	4.13	4.73	5.54	3.66	4.58
Total Asian Coal sent via ship	13.48	26.16	30.37	32.14	41.82	61.67	46.85

Under the Proposed Action, coal would be exported through the terminal to destinations in Asia. Table 6-50 shows that the coal exported from the proposed terminal would be distributed by the model to China, Hong Kong, Japan, South Korea, and Taiwan. The distribution of coal in the Upper

Bound Scenario is varied over time and across destinations, as the model strives to minimize overall system costs.

Table 6-50. Upper Bound Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040
China	0	0	0	33.7	0	0
Hong Kong	0	0	0	10.3	12.1	16.8
Japan	0	0	0	0	9.0	0
South Korea	0	0	0	0	6.2	0
Taiwan	0	0	0	0	16.8	27.2
Total Asian Coal sent via ship through proposed Coal Export Terminal	0	0	0	44.0	44.0	44.0

Under the Proposed Action, a similar number of tons would be distributed in the seaborne coal market as the No-Action Alternative, except for an increase in imports to China, Hong Kong, India Japan, South Korea, and Taiwan (Table 6-51). Table 6-51 shows the tons of coal that would be imported by each country in Asia under the Proposed Action. The distance weighted coal distribution in Asia is presented in Table 6-52 for the Proposed Action.

Table 6-51. Upper Bound Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	80	102	116	165	252	432	298
Australia	0	0	0	0	0	0	0
China	0	17	101	34	0	0	9
Hong Kong	13	14	17	19	22	30	24
India	9	112	131	185	335	565	383
Indonesia	0	0	0	0	0	0	0
Japan	94	113	127	136	137	154	144
South Korea	67	81	89	91	100	117	104
Taiwan	47	56	65	76	84	96	86
Total Asian Coal sent via ship	310	495	647	707	930	1,394	1,048

Table 6-52. Upper Bound Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	1.31	1.79	1.30	3.14	5.98	8.94	6.34
Australia	0	0	0	0	0	0	0
China	0	1.30	4.33	2.76	0	0	0.77
Hong Kong	0.67	0.87	0.50	1.45	1.17	1.62	1.42
India	0.61	6.32	6.31	14.93	27.88	47.05	31.74
Indonesia	0	0	0	0	0	0	0
Japan	6.42	7.15	8.05	7.33	2.31	2.06	3.61
South Korea	0.63	5.23	5.77	0.85	1.32	1.16	1.13
Taiwan	3.08	3.51	4.13	5.00	5.72	4.57	5.07
Total Asian Coal sent via ship	12.71	26.16	30.37	35.47	44.38	65.39	50.07

Table 6-53 shows the estimated change in tons of coal imported by each of the regions. The changes in coal imports between the No-Action Alternative and the Proposed Action generally mirror the changes in consumption, except for China and India. In China, the increase in consumption has a corresponding increase in imports only in 2025, because there is an increase in domestic production and a decrease in exports in 2030 and 2040. In India in 2040, coal consumption decreases by 3.2 million metric tons, while imports increase by 16.4 million metric tons. The increase in imports occurs because domestic production declines by 19.6 million metric tons.

Table 6-53. Upper Bound Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	3.8	0	0	0	-2.9	-0.1	-1.0
Australia	0	0	0	0	0	0	0
China	0	0	0	34.1	0	0	9.5
Hong Kong	0	0	0	0	2.7	3.7	2.3
India	0	0	0	2.1	1.0	16.4	7.3
Indonesia	0	0	0	0	0	0	0
Japan	-2.1	0	0	-0.6	0.7	0.1	0.1
South Korea	0	0	0	0.1	0.5	0.1	0.2
Taiwan	0	0	0	1.4	0.1	0.7	0.7
Total Asian Coal sent via ship	1.7	0	0	37.2	2.0	21.0	19.2

The changes in the total tons of coal imported to each region are magnified or diminished depending on how the sources of the coal are shifting. There are some relatively large changes in the ton-mile values, as shown in Table 6-54.

Table 6-54. Upper Bound Scenario Change in Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	Annual Average
Asia - Other	0.08	0	0	0	0.49	0.15	0.22
Australia	0	0	0	0	0	0	0
China	0	0	0	2.76	0	0	0.77
Hong Kong	0	0	0	0.02	0.94	1.30	0.82
India	0	0	0	0.69	0.08	1.36	0.75
Indonesia	0	0	0	0	0	0	0
Japan	-0.85	0	0	-0.42	0.49	0	0.05
South Korea	0	0	0	0	0.38	0	0.13
Taiwan	0	0	0	0.27	0.18	0.90	0.49
Total Asian Coal sent via ship	-0.77	0	0	3.32	2.56	3.72	3.22

6.4.4 CO_2 Emissions

This section presents the CO_2 estimated emissions from coal combusted in the United States and Asia in the Upper Bound Scenario. In addition, CO_2 emissions from natural gas consumption in the United States are included because decreases in coal consumption may be offset by increases in natural gas consumption. Table 6-55 presents the CO_2 emissions under the No-Action Alternative. Total U.S. CO_2 emissions from coal are relatively flat and average 1,354.72 million metric tons between 2025 and 2040. Asian CO_2 emissions average 14,261.98 million metric tons per year between 2025 and 2040, which is 10.5 times the total coal CO_2 emissions from the United States. Natural gas CO_2 emissions average 580.17 million metric tons per year 2025-2040, or about 43% of U.S. coal CO_2 emissions. Between 2030 and 2040, CO_2 emissions from natural gas increase by 156 million metric tons, which is due to nuclear units retiring in this period and natural gas-fired generation replacing some of the retired nuclear generation.

Table 6-56 presents the CO_2 emissions under the Proposed Action. Total CO_2 emissions under the Proposed Action follow the same trends as under the No-Action Alternative, and are within 1% of the coal CO_2 emissions under the No-Action Alternative.

Table 6-55. Upper Bound Scenario CO_2 Emissions—No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	244.58	282.33	320.98	399.25	518.61	855.45	616.45
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,236.58	6,877.93	7,592.10	8,345.82	10,004.99	8,781.68
Hong Kong	28.52	31.03	34.25	40.47	48.21	66.90	53.33
India	972.05	1,309.81	1,653.09	2,201.02	2,871.67	4,856.98	3,457.45
Indonesia	239.49	254.42	269.84	312.64	362.34	486.83	396.95
Japan	218.36	250.15	281.46	308.43	341.53	390.25	351.28
South Korea	165.17	179.24	197.51	223.48	246.02	296.91	259.55
Taiwan	102.51	123.74	145.53	164.78	184.52	222.22	193.70
Asia - Coal	7,678.39	8,805.59	9,938.71	11,397.32	13,070.90	17,329.09	14,261.98
U.S. - Coal	1,238.76	1,219.12	1,347.26	1,373.73	1,323.74	1,367.69	1,354.72
U.S. - Natural Gas	547.39	512.32	465.88	493.60	529.59	685.36	580.17
Rest of World	1,748.36	2,079.77	2,418.77	2,522.91	2,635.50	3,066.29	2,771.75

Table 6-56. Upper Bound Scenario CO_2 Emissions—Proposed Action (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	244.58	282.33	320.98	399.25	517.88	855.43	616.20
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,236.58	6,877.93	7,641.77	8,394.99	10,054.15	8,830.99
Hong Kong	28.52	31.03	34.25	40.51	48.43	67.19	53.53
India	972.05	1,309.81	1,653.09	2,203.54	2,873.81	4,858.35	3,459.39
Indonesia	239.49	254.42	269.84	312.64	362.34	486.83	396.95
Japan	217.69	250.15	281.46	309.27	342.00	390.57	351.80
South Korea	165.17	179.24	197.51	223.71	246.36	297.14	259.82
Taiwan	102.51	123.74	145.53	165.67	184.96	222.60	194.24
Asia - Coal	7,677.72	8,805.59	9,938.71	11,451.51	13,122.93	17,380.84	14,314.50
U.S. - Coal	1,237.69	1,219.11	1,347.24	1,373.76	1,323.76	1,367.83	1,354.79
U.S.- Natural Gas	547.79	512.32	465.88	493.56	529.57	685.36	580.15
Rest of World	1,748.36	2,079.77	2,418.77	2,522.91	2,635.50	3,066.29	2,771.75

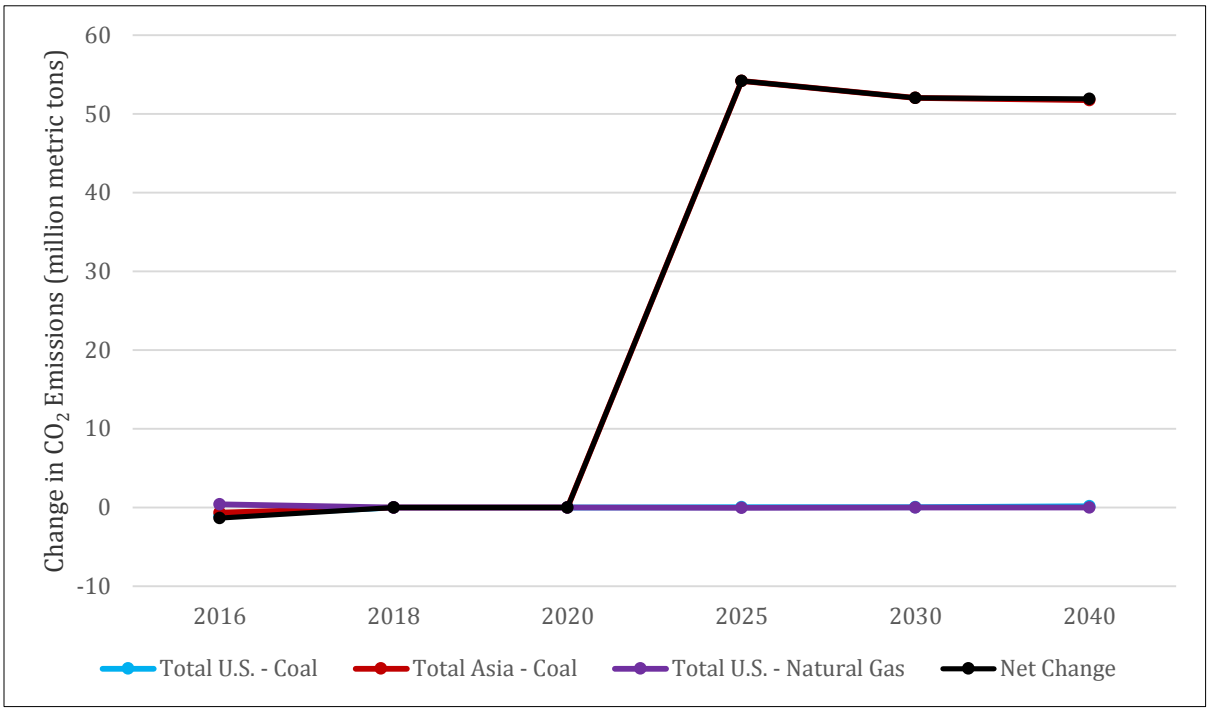
Table 6-57 shows the estimated change in CO_2 emissions for each region, as well as the total net change across all regions. Total Asian CO_2 emissions from coal consumption would increase an average of 52.52 million metric tons per year between 2025 and 2040, , due to induced demand from the reduction in delivered coal prices under the Proposed Action and because of shifts in the type of coal consumed.

Table 6-57. Upper Bound Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0	0	-0.73	-0.02	-0.25
Australia	0	0	0	0	0	0	0
China	0	0	0	49.68	49.17	49.17	49.31
Hong Kong	0	0	0	0.04	0.22	0.29	0.20
India	0	0	0	2.52	2.14	1.37	1.95
Indonesia	0	0	0	0	0	0	0
Japan	-0.67	0	0	0.84	0.47	0.32	0.52
South Korea	0	0	0	0.23	0.33	0.23	0.26
Taiwan	0	0	0	0.89	0.43	0.38	0.54
Asia - Coal	-0.67	0	0	54.19	52.03	51.75	52.52
U.S. - Coal	-1.07	-0.01	-0.02	0.03	0.02	0.14	0.07
U.S. - Natural Gas	0.39	0	0	-0.03	-0.02	0	-0.02
Rest of World	0	0	0	0	0	0	0
Total Change	-1.35	-0.01	-0.02	54.19	52.04	51.89	52.58

In the Upper Bound Scenario the change in coal combustion emissions between the No-Action Alternative and Proposed Action would fluctuate for both Asia and the United States. Figure 6-11 shows the net change in CO_2 emissions between the No-Action Alternative and Proposed Action. The increase in Asian coal emissions would be the main driver of the net positive change to CO_2 emissions under the Proposed Action.

Figure 6-11. Upper Bound Scenario Changes in CO_2 Emissions by Region—Proposed Action minus No-Action Alternative[a,b,c]



[a] Total U.S. CO_2 emissions from the combustion of coal are close to zero because the proposed coal export terminal would not affect coal prices enough to cause a change in coal consumption.

[b] Asian CO_2 emissions from the combustion of coal increase primarily due to induced demand from the lower delivered coal prices when the proposed terminal fully comes online in 2025, and also due to a larger quantity of lower heat content coal being consumed.

[c] Total U.S. natural gas combustion CO_2 emissions are near zero because coal consumption in the United States only changes slightly.

6.5 2015 U.S. and International Energy Policy Scenario

The 2015 U.S. and International Energy Policy Scenario uses the assumptions presented in Chapter 5, *Scenarios*, and is intended to represent a scenario in which the United States and other countries have implemented policies to reduce GHG emissions. These policies would also reduce coal consumption, and thus production, especially in the long term. This section presents the modeling results for the 2015 U.S. and International Energy Policy Scenario No-Action Alternative and Proposed Action for coal production, consumption, distribution, and CO_2 emissions.

6.5.1 Coal Production

Under the No-Action Alternative U.S. thermal coal production would average 672 million metric tons per year from 2025 to 2040. Annual U.S. coal production would initially increases through 2020 and then decline by 53 million metric tons by 2040 because the climate policies would drive down coal demand. Coal production would increase to support increasing exports. Over the 2016 to 2040 period, non-U.S. coal production would grow at an average annual rate of 1.3% per year from 4,513 to 6,148 million metric tons. Powder River Basin coal production under the No-Action Alternative

would average 250 million metric tons per year over 2025 to 2040. Uinta Basin coal production under the No-Action Alternative would average7.6 million metric tons per year. Table 6-58 shows the No-Action Alternative coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-58. 2015 U.S. and International Energy Policy Scenario Coal Production—No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,513	4,981	5,534	5,674	5,865	6,148	5,922
Total U.S. Thermal Coal	638	662	700	700	677	647	672
Powder River Basin Coal	318	293	309	290	250	222	250
Uinta Basin Coal	7.6	6.8	6.8	5.8	9.0	7.6	7.6

Under the Proposed Action, U.S. thermal coal production would average 715 million metric tons per year for the 2025 to 2040 period. As with the No-Action Alternative, U.S. coal production would decline between 2025 and 2040. Non-U.S. coal production would follow the same growth rate under the Proposed Action as it would under the No-Action Alternative, except production would decline by 36 to 41 million metric tons per year once the proposed terminal is fully online in 2025. Thus, the coal exported from the proposed terminal would displace some coal production in other countries. Powder River Basin coal production under the Proposed Action would average 290 million metric tons per year for the 2025 to 2040 period. Uinta Basin coal production would average 10.2 million metric tons per year. Table 6-59 shows the Proposed Action coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-59. 2015 U.S. and International Energy Policy Scenario Coal Production—Proposed Action (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,513	4,981	5,535	5,633	5,827	6,113	5,884
Total U.S. Thermal Coal	638	660	698	745	720	690	715
Powder River Basin Coal	318	290	307	334	293	256	290
Uinta Basin Coal	7.3	6.8	6.8	6.4	8.2	14.6	10.2

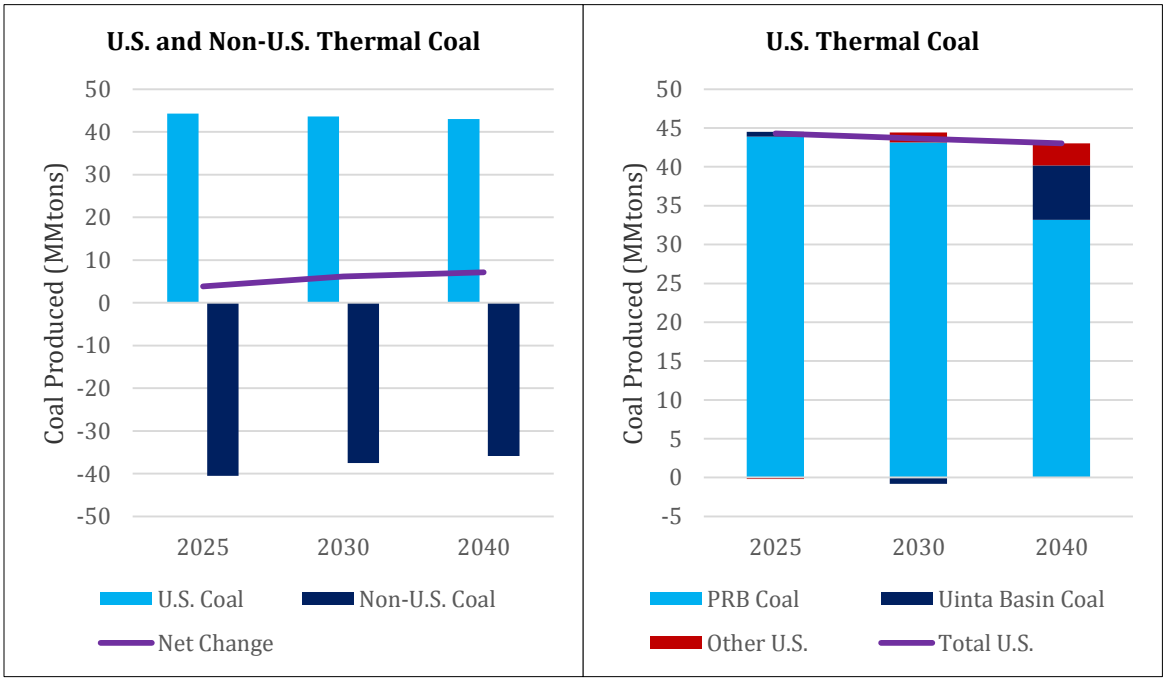
Table 6-60 shows the estimated change in coal production between the Proposed Action and the No-Action Alternative by model run year. Assuming the proposed terminal is online and exporting coal, total modeled U.S. coal production would be higher under the Proposed Action, primarily due to increases in Powder River Basin and the Uinta Basin.

Table 6-60. 2015 U.S. and International Energy Policy Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	0.4	0	1.2	-40.5	-37.5	-35.9	-37.7
Total U.S. Thermal Coal	-0.6	-2.3	-2.1	44.3	43.6	43.0	43.6
Powder River Basin Coal	-0.3	-2.7	-2.3	43.9	43.2	33.2	39.5
Uinta Basin Coal	-0.3	0	0	0.6	-0.8	7.0	2.6

Figure 6-12 shows that total non-U.S. thermal coal production would decrease in proportion to the increase in U.S. coal production under the Proposed Action. The difference in the changes of U.S. and non-U.S. coal production are because the increase in U.S. coal production would be lower heat content subbituminous coal and the decrease in non-U.S. coal production would be higher heat content bituminous coal.

Figure 6-12. 2015 U.S. and International Energy Policy Scenario Change in Coal Production—Proposed Action minus No-Action Alternative



6.5.2 Coal Consumption

In the 2015 U.S. and International Energy Policy Scenario, under the No-Action Alternative U.S. thermal coal consumption would average 548 million metric tons per year for the 2025 to 2040 period. U.S. coal consumption would fluctuate around 610 million metric tons between 2016 and 2025 before it would decline steeply through 2040, as electric demand growth is primarily met with natural gas and renewable generation. Over the 2016 to 2040 period, Asian coal consumption would grow at an average rate of 1.9% per year from 3,399 to 5,294 million metric tons. The growth in consumption is driven by increasing coal consumption in China and India. Tables 6-61 and 6-62 show the No-Action Alternative coal consumption values for each model run year.

Table 6-61. 2015 U.S. and International Energy Policy Scenario Coal Consumption—No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	121	135	160	161	188	202	186
Australia	104	113	121	118	116	108	113
China	2,269	2,479	2,689	2,747	2,803	2,732	2,760
Hong Kong	14	15	16	14	15	16	15
India	543	682	849	1,058	1,317	1,857	1,455
Indonesia	138	139	147	151	163	181	167
Japan	94	111	123	105	103	86	97
South Korea	70	80	86	70	63	44	57
Taiwan	46	54	63	62	71	69	67
Total Asian Coal Consumption	3,399	3,809	4,253	4,485	4,837	5,294	4,917
Total U.S. Coal Consumption	623	594	617	612	561	492	548
Rest of World Coal Consumption	1,130	1,243	1,367	1,280	1,145	1,010	1,130

Table 6-62. 2015 U.S. and International Energy Policy Scenario Coal Consumption—No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025-2040 Average
Asia - Other	2,603	2,904	3,205	3,380	3,593	3,882	3,646
Australia	1,268	1,454	1,640	1,519	1,436	1,194	1,365
China	57,999	63,331	68,639	69,967	71,090	68,476	69,761
Hong Kong	303	325	347	366	389	420	395
India	10,213	13,382	16,549	19,999	24,655	33,846	26,936
Indonesia	2,486	2,485	2,484	2,619	2,785	3,008	2,826
Japan	2,337	2,620	2,900	2,731	2,689	2,274	2,539
South Korea	1,716	1,866	2,016	1,784	1,617	1,152	1,483
Taiwan	1,091	1,290	1,489	1,571	1,673	1,802	1,695
Total Asian Coal Consumption	80,016	89,658	99,269	103,936	109,927	116,055	110,646
Total U.S. Coal Consumption	12,830	12,230	12,704	12,486	11,534	10,003	11,203
Rest of World Coal Consumption	18,358	21,217	24,081	22,656	20,740	20,060	21,008

China is responsible for the largest share of global thermal coal consumption, burning 2,269 million metric tons of coal in 2016. This amount is projected to grow in the 2015 U.S. and International Energy Policy Scenario No-Action Alternative to 2,732 million metric tons by 2040. Under the 2015 U.S. and International Energy Policy Scenario, the growth in coal demand in countries in Asia would be the same as the No-Action Alternative.

Coal consumption under the Proposed Action would follow similar patterns as the No-Action Alternative, with U.S. thermal coal consumption averaging 548 million metric tons per year for the 2025 to 2040 period.

Over the 2016 to 2040 period, Asian coal consumption would follow the same pattern as the No-Action Alternative, growing from 3,399 to 5,303 million metric tons. Tables 6-63 and 6-64 show the Proposed Action coal consumption values for each model run year, in units of million metric tons and TBtu, respectively. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-63. 2015 U.S. and International Energy Policy Scenario Coal Consumption—Proposed Action (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	121	135	160	156	188	202	184
Australia	104	113	121	118	116	108	113
China	2,269	2,479	2,689	2,749	2,804	2,732	2,761
Hong Kong	14	15	16	16	17	18	17
India	543	682	849	1,058	1,317	1,857	1,455
Indonesia	138	139	147	151	163	181	167
Japan	94	111	123	106	104	88	98
South Korea	70	80	86	71	64	45	59
Taiwan	46	54	63	65	72	72	70
Total Asian Coal Consumption	3,399	3,809	4,253	4,488	4,844	5,303	4,923
Total U.S. Coal Consumption	623	592	616	613	561	491	548
Rest of World Coal Consumption	1,130	1,243	1,367	1,280	1,145	1,010	1,130

Table 6-64. 2015 U.S. and International Energy Policy Scenario Coal Consumption—Proposed Action (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	2,603	2,904	3,205	3,380	3,593	3,882	3,646
Australia	1,268	1,454	1,640	1,519	1,436	1,194	1,365
China	57,999	63,331	68,639	69,967	71,090	68,476	69,761
Hong Kong	303	325	347	366	389	420	395
India	10,213	13,382	16,549	19,999	24,655	33,846	26,936
Indonesia	2,486	2,485	2,484	2,619	2,785	3,008	2,826
Japan	2,337	2,620	2,900	2,731	2,689	2,274	2,539
South Korea	1,716	1,866	2,016	1,784	1,617	1,152	1,483
Taiwan	1,091	1,290	1,489	1,571	1,673	1,802	1,695
Total Asian Coal Consumption	80,016	89,658	99,269	103,936	109,927	116,055	110,646
Total U.S. Coal Consumption	12,823	12,198	12,690	12,471	11,524	9,999	11,194
Rest of World Coal Consumption	18,363	21,217	24,081	22,656	20,742	20,060	21,009

Tables 6-65 and 6-66 show the estimated change in coal consumption between the Proposed Action and the No-Action Alternative by model run year in units of million metric tons and TBtu, respectively. Assuming the proposed terminal is online and exporting coal, total Asian coal consumption would be higher with an average of 6.1 million metric tons between 2025 and 2040. The changes in consumption would be due to changes in the mix of coal consumed and the differences in heat content of the coal being consumed. In contrast, U.S. coal consumption would be slightly down at an average of 0.3 million metric tons per year over the 2025 to 2040 period under the Proposed Action. The reduction in U.S. coal consumption is due to both changes in the mix of coal consumed as well as a 0.08% decline in overall coal consumption.

In general, the change in the mix of coals consumed increases the tons of coal consumed in Asia. One exception is in 2025 for the Asia – Other coal demand region, which has a decrease in the tons of coal consumed by 4.8 million metric tons. The tons of coal consumed in the Asia – Other demand coal region decrease because it is switching from Indonesian subbituminous coal to Indonesian bituminous coal, which has a higher heat content and thus fewer tons are needed to achieve the same heating value. The switch to Indonesian bituminous coal is economic: both Hong Kong and Taiwan consume less Indonesian bituminous coal because they are both importing Montana Powder River Basin coal through the proposed coal export terminal.

Table 6-65. 2015 U.S. and International Energy Policy Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	0	0	0	-4.8	0	0	-1.3
Australia	0	0	0	0	0	0	0
China	0	0	-0.2	1.3	1.2	0	0.7
Hong Kong	0	0	0	1.8	2.1	2.2	2.0
India	0	0	0.2	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.9	0.9	1.3	1.0
South Korea	0	0	0	1.4	0.7	1.6	1.2
Taiwan	0	0	0	2.5	1.6	3.1	2.4
Total Asian Coal Consumption	0	0	0	3.0	6.4	8.1	6.1
Total U.S. Coal Consumption	-0.4	-1.8	-1.0	0.7	-0.3	-0.9	-0.3
Rest of World Coal Consumption	0	0	0	0	0	0	0

Table 6-66. 2015 U.S. and International Energy Policy Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia – Other	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
China	0	0	0	0	0	0	0
Hong Kong	0	0	0	0	0	0	0
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0
South Korea	0	0	0	0	0	0	0
Taiwan	0	0	0	0	0	0	0
Total Asian Coal Consumption	0	0	0	0	0	0	0
Total U.S. Coal Consumption	-7	-31	-14	-14	-10	-5	-9
Rest of World Coal Consumption	5	0	0	0	2	0	1

6.5.3 Coal Distribution

In the 2015 U.S. and International Energy Policy Scenario, as with the No Clean Power Plan Scenario, distribution patterns for Powder River Basin and Uinta Basin coal are expected to remain largely unchanged under the Proposed Action. Thus, this section focuses on the distribution of coal in Asia and how that distribution would be expected to change with the construction of the proposed

terminal. Under the No-Action Alternative, no coal would be exported through the proposed terminal; however, there would be 317 million metric tons of coal distributed in Asia by ship in the seaborne coal market in 2016. Table 6-67 shows the tons of coal that would be imported by each country in Asia under the No-Action Alternative. By 2040, 409 million metric tons of coal are estimated to be distributed in the seaborne coal market in Asia.

Table 6-67. 2015 U.S. and International Energy Policy Scenario Seaborne Coal Imports in Asia—No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	83	95	118	141	180	194	175
Australia	0	0	0	0	0	0	0
China	0	10	36	0	0	0	0
Hong Kong	14	15	16	14	15	16	15
India	10	94	101	47	33	0	24
Indonesia	0	0	0	0	0	0	0
Japan	94	111	123	105	103	86	97
South Korea	70	80	86	70	63	44	57
Taiwan	46	54	63	62	71	69	67
Total Asian Coal sent via ship	317	460	542	439	465	409	436

To understand how coal distribution is changing in more detail than the tons of coal imported by each country, the tons of coal shipped to each country were multiplied by the distance in nautical miles that the coal is shipped and then divided by an average ship size. The change in tons imported might not change significantly; however, where the coal is sourced might change, which can have a significant impact on the emissions associated with shipping. Table 6-68 shows the shipping miles for coal shipped to each country for the No-Action Alternative.

Table 6-68. 2015 U.S. and International Energy Policy Scenario Shipping Distance for Seaborne Coal Imports in Asia—No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.50	0.69	2.00	2.63	3.47	3.78	3.36
Australia	0	0	0	0	0	0	0
China	0	0.26	0.99	0	0	0	0
Hong Kong	0.41	0.45	0.48	0.42	0.18	0.19	0.25
India	0.45	4.39	4.72	2.20	1.56	0	1.13
Indonesia	0	0	0	0	0	0	0
Japan	4.41	7.02	7.77	1.40	1.38	1.15	1.30
South Korea	1.92	4.51	5.52	0.66	0.59	0.43	0.55
Taiwan	2.89	3.42	3.95	2.25	4.76	0.57	2.43
Total Asian Coal sent via ship	10.57	20.75	25.42	9.55	11.94	6.13	9.02

Under the Proposed Action, coal would be exported through the terminal to destinations in Asia. Table 6-69 shows the distribution of the coal exported from the proposed terminal. The distribution of the exported coal is similar to the distribution under the No Clean Power Plan Scenario.

Table 6-69. 2015 U.S. and International Energy Policy Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040
China	0	0	0	4.8	5.4	0
Hong Kong	0	0	0	8.8	9.4	10.1
Japan	0	0	0	7.3	7.2	5.8
South Korea	0	0	0	11.7	10.0	7.1
Taiwan	0	0	0	11.4	12.0	21.0
Total Asian Coal sent via ship through the proposed Terminal	0	0	0	44.0	44.0	44.0

Under the Proposed Action, a similar number of tons would be distributed in the seaborne coal market as it would under the No-Action Alternative. Table 6-70 shows the tons of coal that would be imported by each country in Asia under the Proposed Action. The distance weighted coal distribution in Asia is presented in Table 6-71 for the Proposed Action.

Table 6-70. 2015 U.S. and International Energy Policy Scenario Seaborne Coal Imports in Asia—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	83	95	118	137	180	194	174
Australia	0	0	0	0	0	0	0
China	0	10	36	5	5	0	3
Hong Kong	14	15	16	16	17	18	17
India	10	94	100	47	33	0	24
Indonesia	0	0	0	0	0	0	0
Japan	94	111	123	106	104	88	98
South Korea	70	80	86	71	64	45	59
Taiwan	46	54	63	65	72	72	70
Total Asian Coal sent via ship	317	460	542	446	476	417	445

Table 6-71. 2015 U.S. and International Energy Policy Scenario Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Avg.
Asia - Other	0.50	0.69	2.00	2.53	3.47	3.78	3.33
Australia	0	0	0	0	0	0	0
China	0	0.26	0.93	0.39	0.44	0	0.25
Hong Kong	0.41	0.45	0.48	0.98	0.91	0.98	0.95
India	0.45	4.39	4.69	2.20	1.56	0	1.13
Indonesia	0	0	0	0	0	0	0
Japan	4.41	7.02	7.77	1.80	1.77	1.48	1.66
South Korea	1.92	4.51	5.52	1.38	1.21	0.86	1.12
Taiwan	2.89	3.42	3.95	3.00	5.11	2.17	3.38
Total Asian Coal sent via ship	10.57	20.75	25.34	12.27	14.47	9.27	11.84

As seen in Table 6-72, which shows the estimated change in tons of coal imported by each of the regions, the changes in coal imports between the No-Action Alternative and the Proposed Action would mirror the changes in consumption, except for China. The change in imports of coal to China would be due to the coal imported from the United States displacing coal produced in China that has a different heat content. So the amount of coal consumed on a tonnage basis changes slightly, while the amount of coal consumed on a heating value basis does not change.

Table 6-72. 2015 U.S. and International Energy Policy Scenario Change in Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	-4.8	0	0	-1.3
Australia	0	0	0	0	0	0	0
China	0	0	-0.2	4.8	5.4	0	3.1
Hong Kong	0	0	0	1.8	2.1	2.2	2.0
India	0	0	-0.6	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.9	0.9	1.3	1.0
South Korea	0	0	0	1.4	0.7	1.6	1.2
Taiwan	0	0	0	2.5	1.6	3.1	2.4
Total Asian Coal sent via ship	0	0	-0.9	6.6	10.7	8.1	8.5

The changes in the total tons of coal imported to each region would be magnified or diminished depending on how the sources of the coal shift. Table 6-73 shows the change in the total shipping distance traveled to deliver coal imported in Asia. The change in the distance coal is shipped to the Asia – Other coal demand region decreases because of the switch from Indonesian subbituminous coal to Indonesian bituminous coal, which has a higher heat content. The shipping distance in 2040 to Taiwan increases over earlier years because less coal is shipped from nearby China and more coal is shipped from the proposed coal export terminal.

Table 6-73. 2015 U.S. and International Energy Policy Scenario Change in Shipping Distance for Seaborne Coal Imports in Asia—Proposed Action minus No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	Annual Average
Asia - Other	0	0	0	-0.10	0	0	-0.03
Australia	0	0	0	0	0	0	0
China	0	0	-0.05	0.39	0.44	0	0.25
Hong Kong	0	0	0	0.56	0.73	0.78	0.70
India	0	0	-0.03	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0.40	0.39	0.32	0.37
South Korea	0	0	0	0.73	0.62	0.43	0.58
Taiwan	0	0	0	0.75	0.35	1.60	0.95
Total Asian Coal sent via ship	0	0	-0.08	2.72	2.53	3.15	2.82

6.5.4 CO_2 Emissions

This section presents the CO_2 estimated emissions from coal combusted in the United States and Asia in the 2015 U.S. and International Energy Policy Scenario. In addition, CO_2 emissions from natural gas consumption in the United States are included because decreases in coal consumption may be offset by increases in natural gas consumption.

Table 6-74 presents the CO_2 emissions under the No-Action Alternative. Total U.S. CO_2 emissions from coal would increase through 2020 and then decline gradually as the Clean Power Plan implementation ramps up, and would average 1,053.02 million metric tons per year between 2025 and 2040. Asian CO_2 emissions would average 10,624.60 million metric tons per year between 2025 and 2040, which would be 10.1 times the total coal CO_2 emissions from the U.S. Natural gas CO_2 emissions average 559.85 million metric tons per year, or about one-half of coal CO_2 emissions. Between 2030 and 2040, CO_2 emissions from natural gas would increase by 152.81 million metric tons. This increase would be due to nuclear units retiring in this period and natural gas-fired generation replacing some of the retired nuclear generation.

Table 6-75 presents the CO_2 emissions under the Proposed Action. Total CO_2 emissions under the Proposed Action would follow the same trends as under the No-Action Alternative.

Table 6-74. 2015 U.S. and International Energy Policy Scenario CO_2 Emissions—No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	249.64	278.72	310.38	320.48	349.95	378.15	352.73
Australia	118.44	135.82	153.19	141.84	134.07	111.44	127.43
China	5,589.28	6,102.76	6,611.38	6,743.76	6,853.22	6,604.62	6,726.13
Hong Kong	28.25	30.85	32.70	33.80	37.44	40.45	37.60
India	971.98	1,267.46	1,568.87	1,901.31	2,345.49	3,221.25	2,562.68
Indonesia	239.90	239.57	239.23	251.81	267.30	287.63	270.90
Japan	217.62	245.55	271.77	262.82	258.78	218.86	244.38
South Korea	161.27	174.53	189.04	171.69	155.66	110.91	142.71
Taiwan	101.94	120.56	139.17	145.46	156.51	173.47	160.04
Asia- Coal	7,678.31	8,595.82	9,515.72	9,972.97	10,558.42	11,146.77	10,624.60
U.S. - Coal	1,207.73	1,150.40	1,195.32	1,174.92	1,084.13	939.28	1,053.02
U.S. - Natural Gas	555.31	538.48	504.98	491.49	503.86	656.67	559.85
Rest of World	1,755.17	2,022.91	2,293.97	2,156.41	1,973.24	1,902.58	1,996.64

Table 6-75. 2015 U.S. and International Energy Policy Scenario CO_2 Emissions—Proposed Action (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	249.64	278.72	310.38	318.40	349.95	378.15	352.15
Australia	118.44	135.82	153.19	141.84	134.07	111.44	127.43
China	5,589.28	6,102.76	6,611.34	6,743.64	6,853.30	6,604.62	6,726.13
Hong Kong	28.25	30.85	32.70	34.64	37.58	40.60	37.94
India	971.98	1,267.46	1,568.92	1,901.31	2,345.49	3,221.25	2,562.68
Indonesia	239.90	239.57	239.23	251.81	267.30	287.63	270.90
Japan	217.62	245.55	271.77	262.65	258.62	218.95	244.31
South Korea	161.27	174.53	189.04	171.43	155.83	111.01	142.73
Taiwan	101.94	120.56	139.17	146.41	157.38	173.17	160.47
Asia- Coal	7,678.31	8,595.82	9,515.73	9,972.12	10,559.51	11,146.82	10,624.74
U.S. - Coal	1,207.05	1,147.60	1,193.91	1,173.24	1,083.16	938.90	1,052.08
U.S.- Natural Gas	555.51	539.62	505.18	491.49	503.97	656.69	559.89
Rest of World	1,755.61	2,022.92	2,293.97	2,156.41	1,973.45	1,902.58	1,996.71

Table 6-76 shows the estimated change in CO_2 emissions for each region, as well as the total net change across all regions between the No-Action Alternative and Proposed Action. Total Asian CO_2 emissions from coal consumption would increase on average 0.15 million metric tons per year from 2025 to 2040, due to shifts in the type of coal consumed, where the different coal types have different CO_2 emissions rates. In contrast, U.S. coal CO_2 emissions would decrease in every year and average 0.94 million metric tons per year over 2025 to 2040. The decrease in coal consumption would be somewhat offset by an increase in natural gas consumption, as is seen by the increase in CO_2 emissions from natural gas, which would average 0.05 million metric tons per year between 2025 and 2040. The total net change in CO_2 emissions would be a decrease of an average of 0.75 million metric tons per year between 2025 and 2040.

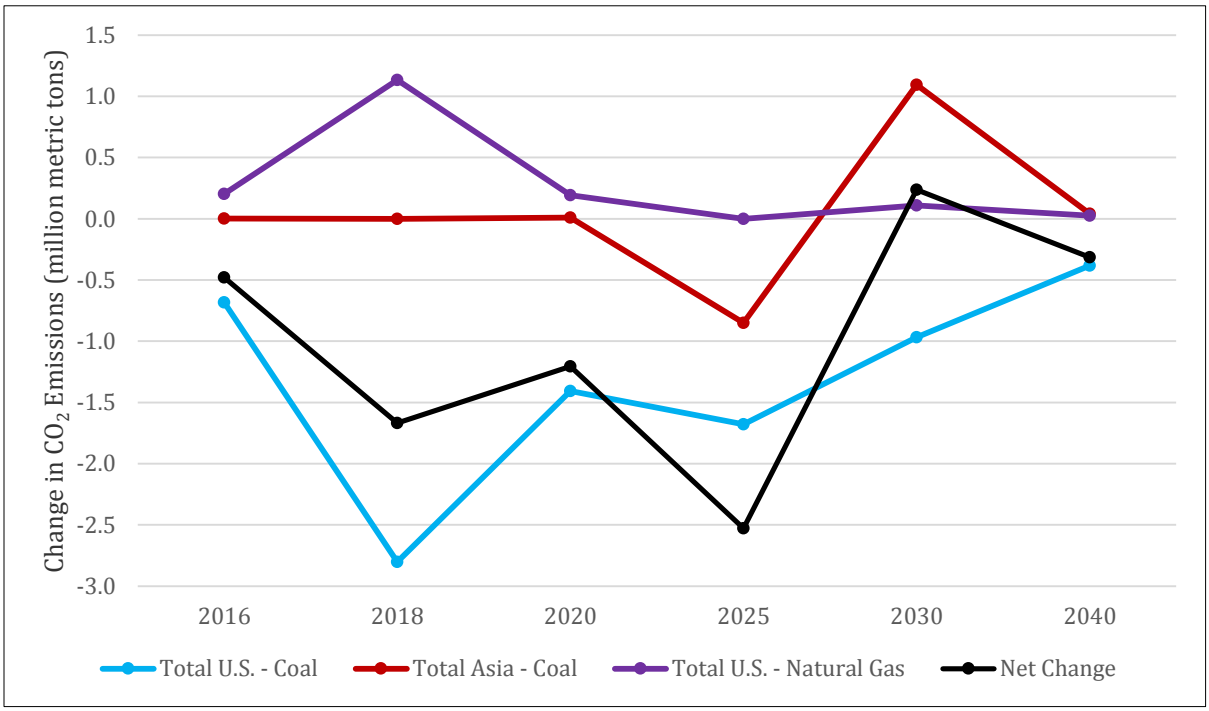
The CO_2 emissions from the Asia – Other coal demand region decrease because fewer tons of coal are consumed due to a switch from subbituminous to bituminous coal and because the bituminous coal has a lower CO_2 emissions rate. For all other regions, coal consumption increases on a tonnage basis; however, CO_2 emissions decrease in some years for China, Japan, South Korea, and Taiwan. A decrease in CO_2 emissions is possible when more coal is consumed if the coal has a lower CO_2 emissions rate in those years.

Table 6-76. 2015 U.S. and International Energy Policy Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0	-2.08	0	0	-0.58
Australia	0	0	0	0	0	0	0
China	0	0	-0.04	-0.12	0.08	0	-0.01
Hong Kong	0	0	0	0.83	0.14	0.15	0.34
India	0	0	0.05	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	-0.17	-0.16	0.09	-0.07
South Korea	0	0	0	-0.27	0.17	0.11	0.02
Taiwan	0	0	0	0.95	0.87	-0.30	0.44
Asia- Coal	0	0	0.01	-0.85	1.09	0.04	0.15
U.S. - Coal	-0.68	-2.80	-1.41	-1.68	-0.97	-0.38	-0.94
U.S. - Natural Gas	0.20	1.13	0.19	0	0.11	0.02	0.05
Rest of World	0.45	0.01	0	0	0.21	0	0.07
Total Change	-0.48	-1.67	-1.21	-2.53	0.24	-0.31	-0.75

Emissions of CO_2 from coal combustion in the United States would decline in general throughout the forecast horizon. U.S. emissions from natural gas tend to move in the opposite direction as emissions from coal. Figure 6-13 shows the net change in CO_2 emissions between the No-Action Alternative and Proposed Action. In the long term, the decrease in U.S. coal emissions would drive a net decrease in CO_2 emissions under the Proposed Action.

Figure 6-13. 2015 U.S. and International Energy Policy Scenario Changes in CO_2 Emissions by Region—Proposed Action minus No-Action Alternative



[a] Total U.S. CO_2 emissions from the combustion of coal decrease through 2040 because the proposed coal export terminal would be a new demand sink for U.S. coal, and thus, would cause coal prices to rise and U.S. coal consumption to decrease in response to the higher prices.

[b] Asian CO_2 emissions from the combustion of coal would increase due to a larger quantity of lower heat content coal being consumed.

[c] Total U.S. natural gas combustion CO_2 emissions generally would increase and decrease in response to the changes in coal consumption.

6.6 Cumulative Scenario

The Cumulative Scenario is the same as the No Clean Power Plan Scenario, except that all of the proposed export terminals in the Pacific Northwest would be constructed and online by 2030 at the latest, and operating at full capacity. This section presents the modeling results for the Cumulative Scenario No-Action Alternative and Proposed Action for coal production, consumption, distribution, and CO_2 emissions. Note that the Cumulative Scenario No-Action Alternative is the same as the No Clean Power Plan Scenario No-Action Alternative.

6.6.1 Coal Production

Under the No-Action Alternative U.S. thermal coal production would average 813 million metric tons per year for the 2025 to 2040 period. Over the 2016 to 2040 period, non-U.S. coal production would grow at an average annual rate of 2.4% per year from 4,510 to 7,887 million metric tons. Powder River Basin coal production under the No-Action Alternative would average 311 million metric tons per year over 2016 to 2040, with production remaining relatively flat. Uinta Basin coal production under the No-Action Alternative would average 13.6 million metric tons per year, with production gradually increasing over the 2016 to 2040 period.

Table 6-77 shows the No-Action Alternative coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-77. Cumulative Scenario Coal Production—No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,510	5,115	5,806	6,304	6,839	7,887	7,098
Total U.S. Thermal Coal	628	673	752	773	790	861	813
Powder River Basin Coal	310	286	324	329	292	313	311
Uinta Basin Coal	7.0	7.9	8.5	10.6	14.4	15.0	13.6

Under the Proposed Action, U.S. thermal coal production would average 904 million metric tons per year for the 2025 to 2040 period. U.S. coal production would have an upward trend as production increases to meet the increased exports. Non-U.S. coal production would have a slightly lower annual growth rate of 2.3% under the Proposed Action than the No-Action Alternative, because some of the exported coal displaces some international coal production. Powder River Basin coal production under the Proposed Action would average 400 million metric tons per year with production generally increasing over time. Uinta Basin coal production would average 13.6 million metric tons per year. Table 6-78 shows the Proposed Action coal production values for each model run year. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-78. Cumulative Scenario Coal Production—Proposed Action (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	4,512	5,114	5,799	6,260	6,756	7,814	7,029
Total U.S. Thermal Coal	628	674	759	827	895	966	904
Powder River Basin Coal	309	286	330	382	396	416	400
Uinta Basin Coal	7.0	7.9	8.5	10.6	14.4	15.0	13.6

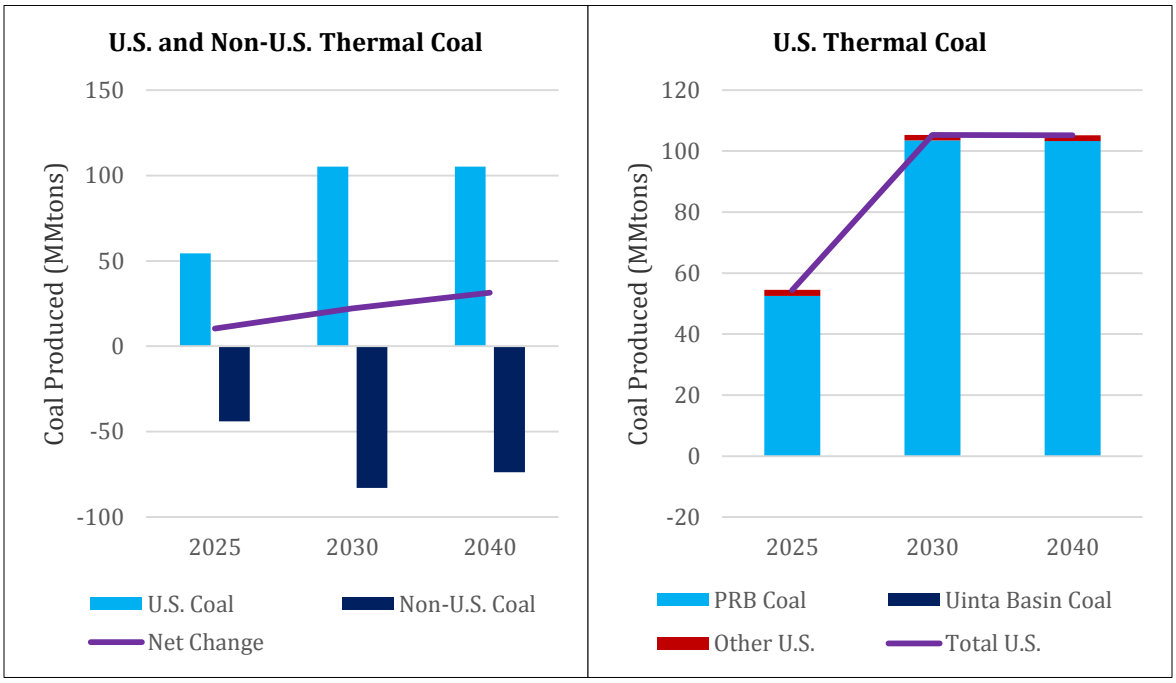
Table 6-79 shows the estimated change in coal production between the Proposed Action and the No-Action Alternative by model run year. Since IPM® is forward–looking and solves all years simultaneously, the model shows that there would be changes to production under the Proposed Action before the terminal is modeled to fully come online in 2025. The changes in coal production prior to 2025 reflect the model optimizing the overall solution based on what it calculates will be happening in the future. Once the proposed terminal is fully online and exporting coal, total average modeled U.S. coal production would be higher under the Proposed Action by 91.1 million metric tons per year, primarily due to increases in Powder River Basin coal production.

Table 6-79. Cumulative Scenario Change in Coal Production—Proposed Action minus No-Action Alternative (million metric tons)

Producing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Total Non-U.S. Thermal Coal	2.0	-1.0	-6.1	-44.0	-83.0	-73.8	-68.6
Total U.S. Thermal Coal	0.6	0.9	7.0	54.4	105.2	105.1	91.1
Powder River Basin Coal	-0.2	0.1	6.5	52.5	103.5	103.3	89.2
Uinta Basin Coal	0	0	0	<-0.05	<-0.05	<0.05	<-0.05

Figure 6-14 shows that total non-U.S. thermal coal production would decrease as U.S. coal production increases under the Proposed Action. This indicates that U.S. thermal coal exports would displace of some internationally produced coal, instead of just adding to overall global coal demand.

Figure 6-14. Cumulative Scenario Change in Coal Production—Proposed Action minus No-Action Alternative



6.6.2 Coal Consumption

Under the No-Action Alternative U.S. thermal coal consumption would average 671 million metric tons per year for the 2025 to 2040 period. U.S. coal consumption would increase through 2020 and then be fairly flat through 2040, as electric demand growth would be primarily met with natural gas and renewable generation. Over the 2016 to 2040 period, Asian coal consumption would grow at an average rate of 2.9% per year from 3,395 to 6,679 million metric tons. The growth in consumption would be driven primarily by increasing coal consumption in China and India. Tables 6-80 and 6-81 show the No-Action Alternative coal consumption values for each model run year in units of million metric tons and TBtu, respectively.

China is responsible for the largest share of global thermal coal consumption, burning 2,269 million metric tons of coal in 2016. This amount is projected to increase in the Cumulative Scenario No-Action Alternative to 3,489 million metric tons by 2040. Total U.S. coal consumption would remain relatively stable, hovering in the mid to upper 600 million metric ton range.

Table 6-80. Cumulative Scenario Coal Consumption—No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	118	138	166	161	210	252	213
Australia	104	114	123	124	124	125	124
China	2,269	2,534	2,797	3,015	3,239	3,489	3,274
Hong Kong	13	15	16	16	17	20	18
India	543	723	935	1,233	1,558	2,287	1,751
Indonesia	138	142	152	165	188	220	194
Japan	96	113	127	126	119	116	120
South Korea	68	81	89	79	76	71	75
Taiwan	46	56	65	74	83	98	86
Total Asian Coal Consumption	3,395	3,915	4,472	4,993	5,613	6,679	5,855
Total U.S. Coal Consumption	613	606	672	686	651	679	671
Rest of World Coal Consumption	1,131	1,269	1,418	1,401	1,368	1,395	1,388

Table 6-81. Cumulative Scenario Coal Consumption—No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	2,603	2,968	3,334	3,739	4,144	4,883	4,319
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	77,017	82,560	88,375	83,282
Hong Kong	303	332	361	405	449	529	467
India	10,213	13,834	17,452	23,201	28,935	41,915	32,390
Indonesia	2,486	2,535	2,583	2,897	3,212	3,784	3,347
Japan	2,337	2,674	3,009	3,058	3,095	3,030	3,060
South Korea	1,716	1,911	2,106	2,028	1,949	1,833	1,926
Taiwan	1,091	1,324	1,558	1,761	1,965	2,331	2,051
Total Asian Coal Consumption	80,016	91,778	103,528	115,768	127,938	148,269	132,464
Total U.S. Coal Consumption	12,675	12,682	14,022	14,278	13,651	14,201	14,039
Rest of World Coal Consumption	18,366	21,747	25,172	25,128	24,978	26,592	25,647

Coal consumption under the Proposed Action would follow similar patterns as the No-Action Alternative, with the U.S. thermal coal consumption averaging 671 million metric tons per year for the 2025 to 2040 period. As under the No-Action Alternative, U.S. coal consumption would be fairly flat, as electric demand growth would be primarily met with natural gas and renewable generation.

Over the 2016 to 2040 period, Asian coal consumption would follow the same pattern as it grows from 3,398 to 6,711million metric tons, a 2.9% average annual increase.

Tables 6-82 and 6-83 show the Proposed Action coal consumption values for each model run year in units of million metric tons and TBtu, respectively. The average values in the last column of the table were derived by weighting the modeled values based on the number of calendar years mapped to each model run year.

Table 6-82. Cumulative Scenario Coal Consumption—Proposed Action (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	118	138	166	161	208	252	212
Australia	104	114	123	124	124	125	124
China	2,269	2,534	2,799	3,022	3,264	3,514	3,294
Hong Kong	13	15	16	18	20	24	21
India	543	723	935	1,230	1,558	2,287	1,750
Indonesia	138	142	152	165	184	221	193
Japan	97	113	127	129	119	117	121
South Korea	68	81	89	79	76	71	75
Taiwan	47	56	65	76	85	100	88
Total Asian Coal Consumption	3,398	3,915	4,473	5,004	5,637	6,711	5,879
Total U.S. Coal Consumption	613	606	671	685	650	678	671
Rest of World Coal Consumption	1,131	1,269	1,418	1,401	1,368	1,395	1,388

Table 6-83. Cumulative Scenario Coal Consumption—Proposed Action (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	2,603	2,968	3,334	3,739	4,144	4,883	4,319
Australia	1,268	1,481	1,693	1,661	1,629	1,591	1,623
China	57,999	64,719	71,432	77,017	82,829	88,644	83,476
Hong Kong	303	332	361	405	449	529	468
India	10,213	13,834	17,452	23,201	28,935	41,915	32,390
Indonesia	2,486	2,535	2,583	2,897	3,212	3,784	3,347
Japan	2,337	2,674	3,009	3,058	3,097	3,033	3,061
South Korea	1,716	1,911	2,106	2,028	1,951	1,834	1,927
Taiwan	1,091	1,324	1,558	1,761	1,965	2,331	2,051
Total Asian Coal Consumption	80,016	91,778	103,528	115,768	128,211	148,542	132,661
Total U.S. Coal Consumption	12,673	12,684	14,009	14,271	13,642	14,196	14,032
Rest of World Coal Consumption	18,366	21,747	25,172	25,128	24,978	26,592	25,647

Tables 6-84 and 6-85 show the estimated change in coal consumption between the Proposed Action and the No-Action Alternative by model run year in units of million metric tons and TBtu, respectively. The change is coal consumption is zero, or near zero, in Asia before 2025 when the terminal was assumed fully online. Once the proposed terminal is exporting 44 million metric tons of coal at full capacity in 2025, total Asian coal consumption would be higher with an average change of 23.4 million metric tons per year between 2025 and 2040, with China having the largest average increase in coal consumption at 19.7 million metric tons. Coal consumption in the United States would decrease by an average of 0.9 million metric tons per year under the Proposed Action. The increase of 19.7 million metric tons of coal consumption in China is due to induced demand and to changes in the mix of coal consumed. As shown in Table 6-85, China's coal demand increases by an average of 194.2 TBtu from 2025 to 2040, which is about 9 million metric tons. Thus, about 45% of the increase in China's coal consumption of 19.7 million metric tons is due to induced demand and 55% is due to changes in the coal mix.

Table 6-84. Cumulative Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (million metric tons)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	0	-2.7	-0.3	-1.0
Australia	0	0	0	0	0	0	0
China	0	0.4	2.0	6.4	24.9	24.7	19.7
Hong Kong	0	0	0	2.0	2.1	3.9	2.8
India	0	-0.5	0	-2.9	0	0	-0.8
Indonesia	0	0	0.1	0	-3.4	1.7	-0.5
Japan	1.2	0	-0.4	3.8	0.1	0.1	1.1
South Korea	0.3	0	0	0	0.1	0.1	<0.05
Taiwan	1.4	0	0	1.7	2.2	2.2	2.1
Total Asian Coal Consumption	3.0	-0.2	1.8	11.0	23.3	32.4	23.4
Total U.S. Coal Consumption	-0.3	0	-0.9	-0.6	-1.0	-1.0	-0.9
Rest of World Coal Consumption	0	0	0	0	0	0	0

Table 6-85. Cumulative Scenario Change in Coal Consumption—Proposed Action minus No-Action Alternative (TBtu per year)

Consuming Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	0	0	0	0
Australia	0	0	0	0	0	0	0
China	0	0	0	0	268.9	268.9	194.2
Hong Kong	0	0	0	0	0.2	0.2	0.2
India	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	0	0	2.4	2.4	1.7
South Korea	0	0	0	0	1.6	1.6	1.1
Taiwan	0	0	0	0	0	0	0
Total Asian Coal Consumption	0	0	0	0	273.1	273.1	197.2
Total U.S. Coal Consumption	-2.0	1.7	-13.3	-7.0	-9.3	-5.0	-7.0
Rest of World Coal Consumption	-0.1	0	0	0	0	0	0

6.6.3 Coal Distribution

As with the No Clean Power Plan Scenario, distribution patterns for Powder River Basin and Uinta Basin coal are expected to remain largely unchanged under the Proposed Action in the Cumulative Scenario. Thus, this section focuses on the distribution of coal in Asia and how that distribution would be expected to change with the construction of the proposed terminal. Under the No-Action Alternative, there would be no coal exported through the proposed terminal; however, there would be 313 million metric tons of coal distributed in Asia by ship in the seaborne coal market in 2016. Table 6-86 shows the tons of coal that would be imported by each country in Asia under the No-Action Alternative. By 2040, a total of 550 million metric tons of coal are expected to be distributed in the seaborne coal market in Asia.

Table 6-86. Cumulative Scenario Seaborne Coal Distribution in Asia—No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	80	98	124	142	203	244	202
Australia	0	0	0	0	0	0	0
China	0	65	144	0	0	0	0
Hong Kong	13	15	16	16	17	20	18
India	10	47	0	35	0	0	10
Indonesia	0	0	0	0	0	0	0
Japan	96	113	127	126	119	116	120
South Korea	68	81	89	79	76	71	75
Taiwan	46	56	65	74	83	98	86
Total Asian Coal sent via ship	313	475	567	471	498	550	511

To understand how coal distribution is changing in more detail than the tons of coal imported by each country, ICF multiplied the tons of coal shipped to each country by the distance in nautical miles that the coal is shipped and then divided by an average ship size. The change in tons imported might not change significantly; however, where the coal is sourced might change, which can have a significant impact on the emissions associated with shipping. Table 6-87 shows the shipping miles for coal shipped to each country for the No-Action Alternative.

Table 6-87. Cumulative Scenario Shipping Distance for Seaborne Coal Distribution in Asia—No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0.44	0.76	2.13	2.65	3.95	4.84	3.93
Australia	0	0	0	0	0	0	0
China	0	1.68	4.51	0	0	0	0
Hong Kong	0.39	0.44	0.47	0.46	0.55	0.24	0.41
India	0.45	2.20	0	1.64	0	0	0.46
Indonesia	0	0	0	0	0	0	0
Japan	5.12	7.17	8.07	6.11	1.59	1.55	2.83
South Korea	1.81	5.23	5.77	0.75	0.72	0.67	0.71
Taiwan	2.89	3.51	4.13	4.67	5.20	6.20	5.44
Total Asian Coal sent via ship	11.10	20.99	25.07	16.27	12.01	13.51	13.78

Under the Proposed Action, coal would be exported through the terminal to destinations in Asia. Table 6-88 shows the distribution of the coal exported from the proposed terminal. In the Cumulative Scenario, a larger portion of the coal exported through the proposed coal export terminal in 2030 and 2040 is delivered to China than in the other scenarios. The Gateway Pacific Terminal is modeled to come online in 2030 and it would cause coal distribution patterns to shift, which is why more coal from the proposed coal export terminal is delivered to China in 2030 and 2040 in the Cumulative Scenario.

Table 6-88. Cumulative Scenario Distribution of Coal Exported through the Coal Export Terminal—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040
China	0	0	0	29.3	44.0	44.0
Hong Kong	0	0	0	9.8	0	0
Japan	0	0	0	0	0	0
South Korea	0	0	0	0	0	0
Taiwan	0	0	0	5.0	0	0
Total Asian Coal sent via ship through proposed Coal Export Terminal	0	0	0	44.0	44.0	44.0

Under the Proposed Action, a similar number of tons would be distributed in the seaborne coal market as it would under the No-Action Alternative, as seen in Table 6-89, which shows the tons of coal that would be imported by each country in Asia under the Proposed Action. The total shipping distance for coal distribution in Asia is presented in Table 6-90 for the Proposed Action.

Table 6-89. Cumulative Scenario Seaborne Coal Distribution in Asia—Proposed Action (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	80	98	124	142	200	244	201
Australia	0	0	0	0	0	0	0
China	0	65	146	29	67	66	56
Hong Kong	13	15	16	18	20	24	21
India	10	48	0	43	0	0	12
Indonesia	0	0	0	0	0	0	0
Japan	97	113	127	129	119	117	121
South Korea	68	81	89	79	76	71	75
Taiwan	47	56	65	76	85	100	88
Total Asian Coal sent via ship	316	477	568	516	567	623	574

Table 6-90. Cumulative Scenario Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0.44	0.76	2.13	2.65	4.75	5.69	4.53
Australia	0	0	0	0	0	0	0
China	0	1.78	4.84	2.37	5.42	5.35	4.55
Hong Kong	0.39	0.44	0.47	1.08	1.19	1.83	1.41
India	0.45	2.26	0	2.00	0	0	0.56
Indonesia	0	0	0	0	0	0	0
Japan	5.75	7.17	8.05	8.20	1.59	1.56	3.41
South Korea	2.37	5.23	5.77	0.75	0.72	0.67	0.71
Taiwan	3.13	3.51	4.13	5.02	5.71	6.64	5.88
Total Asian Coal sent via ship	12.54	21.15	25.38	22.07	19.38	21.74	21.05

As seen in Table 6-91, which shows the estimated change in tons of coal imported by each of the regions, the changes in coal imports between the No-Action Alternative and the Proposed Action would mirror the changes in consumption, except for China. The average increase in imports of coal into China is 56.3 million metric tons per year for 2025 to 2040, while the increase in consumption averages 19.7 million metric tons per year. The change in consumption is entirely due to changes in the mix of coal consumed. The increase in imports is because coal exported from the proposed coal export terminal is displacing coal produced in China, thus causing the larger increase in imports compared to the increase in consumption.

Table 6-91. Cumulative Scenario Change in Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million metric tons)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia – Other	0	0	0	0	-2.7	-0.3	-1.0
Australia	0	0	0	0	0	0	0
China	0	0.4	2.0	29.3	67.1	66.2	56.3
Hong Kong	0	0	0	2.0	2.1	3.9	2.8
India	0	1.3	0	7.8	0	0	2.2
Indonesia	0	0	0	0	0	0	0
Japan	1.2	0	-0.4	3.8	0.1	0.1	1.1
South Korea	0.3	0	0	0	0.1	0.1	<0.05
Taiwan	1.4	0	0	1.7	2.2	2.2	2.1
Total Asian Coal sent via ship	3.0	1.7	1.7	44.5	68.9	72.2	63.4

The changes in the total tons of coal imported to each region would be magnified or diminished depending on how the sources of the coal shift, and there would be some relatively large changes in the total shipping mile values, as shown in Table 6-92. The largest change in shipping distance is in China, because there is an increase in imported coal that displaces domestic Chinese coal production.

Table 6-92. Cumulative Scenario Change in Shipping Distance for Seaborne Coal Distribution in Asia—Proposed Action minus No-Action Alternative (million nautical miles)

Importing Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0	0	0.80	0.85	0.60
Australia	0	0	0	0	0	0	0
China	0	0.10	0.33	2.37	5.42	5.35	4.55
Hong Kong	0	0	0	0.62	0.63	1.59	1.00
India	0	0.06	0	0.36	0	0	0.10
Indonesia	0	0	0	0	0	0	0
Japan	0.63	0	-0.02	2.09	0	0	0.58
South Korea	0.57	0	0	0	0	0	0
Taiwan	0.24	0	0	0.36	0.51	0.45	0.44
Total Asian Coal sent via ship	1.44	0.16	0.31	5.81	7.37	8.24	7.27

6.6.4 CO_2 Emissions

This section presents the CO_2 estimated emissions from coal combusted in the United States and Asia in the Cumulative Scenario. In addition, CO_2 emissions from natural gas consumption in the United States are included because decreases in coal consumption may be offset by increases in natural gas consumption. Table 6-93 presents the CO_2 emissions under the No-Action Alternative.

Total U.S. CO_2 emissions from coal would slightly increase and average 1,319.78 million metric tons per year over 2025 to 2040. Asian CO_2 emissions would average 12,714.98 million metric tons per year between 2025 and 2040, which would be 9.6 times the total coal CO_2 emissions from the U.S. Natural gas CO_2 emissions average 588.42 million metric tons per year, or about 45% of U.S. coal CO_2 emissions. Between 2030 and 2040, CO_2 emissions from natural gas would increase by 152 million metric tons. This increase would be due to nuclear units retiring in this period and natural gas-fired generation replacing some of the retired nuclear generation.

Table 6-94 presents the CO_2 emissions under the Proposed Action. Total CO_2 emissions under the Proposed Action for this scenario would follow the same trends as the No-Action Alternative, and would be within 2.5% of the coal CO_2 emissions under the No-Action Alternative.

Table 6-93. Cumulative Scenario CO_2 Emissions—No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	247.26	285.00	322.40	347.92	401.48	475.60	415.43
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,230.49	6,869.91	7,422.30	7,957.21	8,519.96	8,027.47
Hong Kong	28.03	30.69	33.34	37.40	41.52	50.87	44.01
India	971.98	1,314.34	1,663.26	2,208.16	2,757.05	3,991.99	3,084.83
Indonesia	239.90	244.43	248.95	278.94	308.90	363.15	321.67
Japan	218.18	250.63	281.95	288.97	297.84	291.67	292.98
South Korea	161.27	179.24	197.51	195.18	187.61	176.39	185.35
Taiwan	101.94	123.74	145.53	164.58	183.58	217.90	191.65
Asia- Coal	7,676.27	8,796.83	9,920.98	11,098.59	12,287.35	14,236.09	12,714.98
U.S. - Coal	1,192.66	1,191.89	1,318.40	1,342.64	1,283.18	1,334.84	1,319.78
U.S. - Natural Gas	562.33	520.06	472.01	500.29	540.37	692.55	588.42
Rest of World	1,755.77	2,072.97	2,397.94	2,391.95	2,375.45	2,529.00	2,439.75

Table 6-94. Cumulative Scenario CO_2 Emissions—Proposed Action (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	247.26	285.00	322.43	347.92	400.35	475.51	415.01
Australia	118.44	138.28	158.12	155.15	152.18	148.56	151.60
China	5,589.28	6,230.61	6,870.98	7,422.74	7,984.10	8,546.83	8,047.01
Hong Kong	28.03	30.69	33.34	38.32	42.49	50.42	44.42
India	971.98	1,314.23	1,663.26	2,207.53	2,757.05	3,991.99	3,084.66
Indonesia	239.90	244.43	248.95	278.94	308.90	363.15	321.67
Japan	218.23	250.58	281.49	286.63	298.07	291.90	292.49
South Korea	159.39	179.24	197.51	195.18	187.76	176.54	185.45
Taiwan	102.20	123.74	145.53	165.50	184.93	219.05	192.80
Asia- Coal	7,674.70	8,796.79	9,921.62	11,097.90	12,315.82	14,263.95	12,735.11
U.S. - Coal	1,192.38	1,192.02	1,317.06	1,341.66	1,282.11	1,334.19	1,318.90
U.S. - Natural Gas	562.33	519.96	472.01	500.25	540.47	692.55	588.44
Rest of World	1,755.76	2,072.97	2,397.94	2,391.95	2,375.45	2,529.00	2,439.75

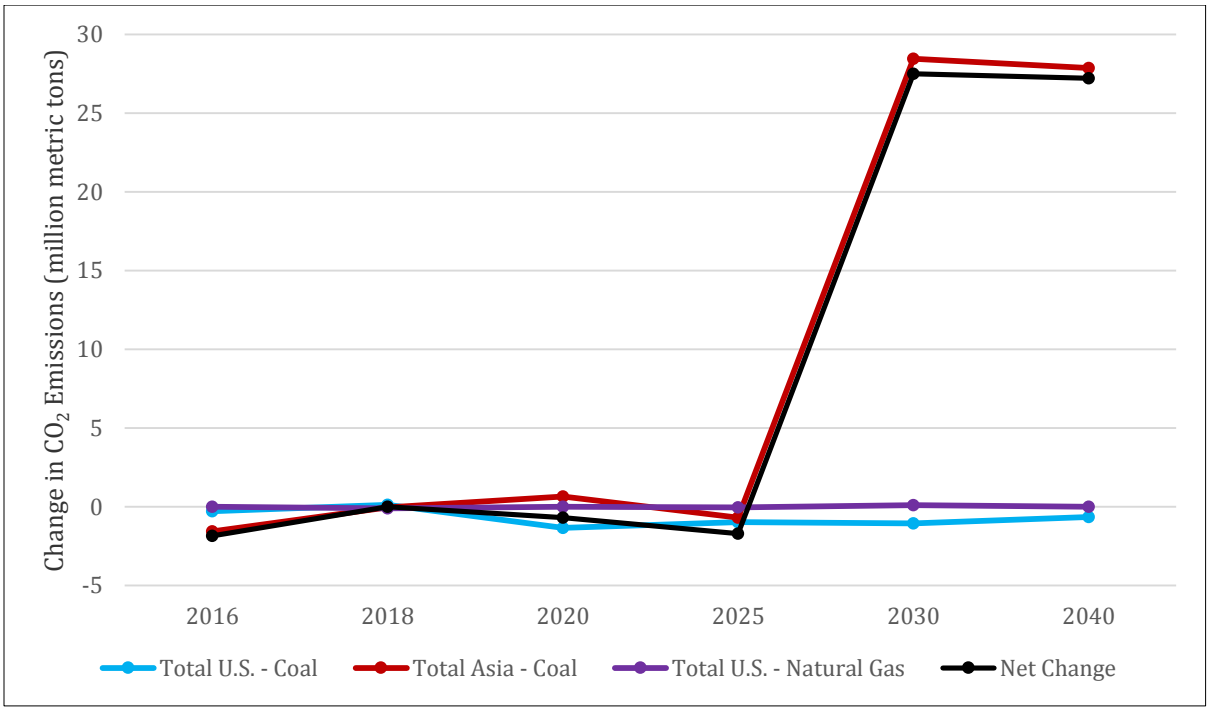
Table 6-95 shows the estimated change in CO_2 emissions for each region, as well as the total net change across all regions. Total Asian CO_2 emissions from coal consumption would increase an average of 20.13 million metric tons per year from 2025 to 2040 because of shifts in the type of coal consumed and due to induced demand. In contrast, U.S. coal CO_2 emissions would decrease 0.88 million metric tons over 2025 to 2040 due to higher coal prices that depress domestic coal demand. The higher coal prices result from the fact that an additional 44 million metric tons of coal is exported starting in 2025, and another 48 million metric tons of coal is exported starting in 2030 from the Gateway Pacific Terminal, under the Proposed Action, which shifts the demand curve up and yields higher coal prices in the United States. The decrease in coal consumption is offset by an increase in natural gas consumption, as is seen by the increase in CO_2 emissions from natural gas, which would average 0.02 million metric tons per year over 2025 to 2040. Natural gas consumption does not increase in proportion to the decrease in coal consumption because there is an increase in renewable generation. The total net change in CO_2 emissions would be an increase of an average of 19.28 million metric tons per year over 2025 to 2040.

Table 6-95. Cumulative Scenario Changes in CO_2 Emissions—Proposed Action minus No-Action Alternative (million metric tons)

Region	2016	2018	2020	2025	2030	2040	2025–2040 Average
Asia - Other	0	0	0.03	0	-1.13	-0.09	-0.41
Australia	0	0	0	0	0	0	0
China	0	0.12	1.07	0.44	26.89	26.87	19.53
Hong Kong	0	0	0	0.92	0.98	-0.45	0.41
India	0	-0.11	0	-0.63	0	0	-0.17
Indonesia	0	0	0	0	0	0	0
Japan	0.05	-0.06	-0.46	-2.34	0.23	0.23	-0.48
South Korea	-1.88	0	0	0	0.15	0.15	0.11
Taiwan	0.26	0	0	0.92	1.35	1.16	1.15
Asia- Coal	-1.57	-0.04	0.64	-0.69	28.47	27.87	20.13
U.S. - Coal	-0.28	0.13	-1.34	-0.98	-1.06	-0.65	-0.88
U.S. - Natural Gas	0	-0.09	0.01	-0.04	0.10	0	0.02
Rest of World	-0.01	0	0	0	0	0	0
Net Change	-1.85	-0.01	-0.69	-1.71	27.50	27.21	19.28

Figure 6-15 shows the net change in CO_2 emissions between the No-Action Alternative and Proposed Action. In the long term, the increase in Asian coal emissions would drive the net change to be a net increase in CO_2 emissions under the Proposed Action.

Figure 6-15. Cumulative Scenario Changes in CO_2 Emissions by Region—Proposed Action minus No-Action Alternative



[a] Total U.S. CO_2 emissions from the combustion of coal would decrease because the proposed coal export terminal would be a new demand sink for U.S. coal, and thus, would cause coal prices to rise and U.S. coal consumption to decrease in response to the higher prices.

[b] Asian CO_2 emissions from the combustion of coal would increase due to a larger quantity of lower heat content coal being consumed and due to induced demand from the lower delivered coal prices when the proposed coal export terminal fully comes online in 2025, and when the Gateway Pacific Terminal comes online in 2030.

[c] Total U.S. natural gas combustion CO_2 emissions would increase slightly because when coal consumption for electric generation declines, natural gas usage for electric generation increases to fill some of the gap.

Chapter 7
Conclusions

This analysis examined the coal production, consumption, distribution, and CO_2 emissions associated with the operation of the coal export terminal under five scenarios. The results of the analysis show that the operation of the terminal would likely cause changes in the production, consumption, and distribution of coal in the United States and Asia. These changes would cause a change in CO_2 emissions as well, with the net average annual emissions ranging from a decrease of 6.61 million metric tons CO_2 in the Lower Bound Scenario to an increase of 52.59 million metric tons CO_2 in the Upper Bound Scenario, when averaged over 2025 to 2040.

7.1 Summary of Key Results

The Co-Lead Agencies defined the study area for the coal market analysis as the United States and Asian coal markets. Within the United States, results for the CO_2 emissions from the combustion of coal and natural gas are the primary results from this analysis that are used in the GHG analysis report. Additionally, the GHG analysis uses the change in the distribution of coal in Asia to estimate the CO_2 emissions from the change in the transportation of coal.

7.1.1 Coal Production

This analysis shows that coal production in the United States would increase in all five scenarios under the Proposed Action, as the export of coal through the terminal would cause additional coal to be mined in the United States, beyond that which is produced for domestic consumption under the No-Action Alternative. If production did not increase under each scenario, it would imply either that there is a decrease in the consumption of Powder River Basin and Uinta Basin coal in the United States, or that exports of other coal are decreasing. The results also show that coal production in Asia would decrease in all five scenarios, as the exported coal displaces some coal production from Asian coal producing countries.

The amount of increase in production varies by scenario and by year in each scenario. The Lower Bound Scenario has the lowest change in U.S. coal production at an average of 39.74 million metric tons, because this scenario has the largest decrease in domestic coal consumption once the terminal comes online. Thus, the increase in the U.S. coal production due to the Proposed Action is reduced by the amount of coal no longer consumed domestically. However, all scenarios besides the Cumulative Scenario have increases in U.S. production between 39.74 and 44.00 million metric tons.

The 2015 U.S. and International Energy Policy Scenario is similar to the other scenarios in that U.S. coal production increases, but not as much as the full terminal capacity. The reason that coal production in the United States increases an average 43.6 million metric tons per year under the 2015 U.S. and International Energy Policy Scenario, and not the full 44 million metric tons of the proposed coal export terminal's capacity, is that there is a decline in U.S. demand for Powder River Basin and Uinta Basin coal. The increase is slightly lower than under the No Clean Power Plan Scenario because there is a larger decrease in domestic coal consumption in this scenario.

Finally, the Cumulative Scenario has an average annual increase in U.S. coal production of 91.09 million metric tons. In this scenario, Powder River Basin coal demand in the United States declines by 2.7 million metric tons in the long term as the higher export demand on Powder River Basin coal increases the prices, which in turn, suppresses domestic demand for Powder River Basin coal. The other reason that U.S. production increases by less than the total amount of new export capacity is that exports from Appalachian coal regions are lower under the Proposed Action.

7.1.2 Coal Consumption

This analysis shows that coal consumption in the United States would decrease in all but the Upper Bound Scenario under the Proposed Action. U.S. coal consumption decreases because the export of coal through the proposed coal export terminal would cause additional demand for U.S. coal, which causes coal prices to rise. In response to the higher coal prices, U.S. coal plants consume between 0.01 and 3.8 million metric tons per year less coal. If flatter coal supply curves were used in this analysis, then the decrease in U.S. coal consumption would be less. Similarly, if steeper coal supply curves were used in this analysis, then the decrease in U.S. coal consumption would be greater.

Coal consumption in the Upper Bound Scenario increases slightly in the United States because of changes in the electric demand region containing North and South Carolina.

The results also show that the tons of coal consumed in Asia would increase in all scenarios. The tons of coal consumed increases because a larger quantity of lower heat content coal is consumed and because of induced demand in the Upper Bound and Cumulative Scenarios. The exported coal has a lower heat content than the coal that it displaces and more coal must be consumed to achieve the same electric power output. The induced demand is another factor causing higher coal consumption in Asia. In all scenarios with induced demand, the amount of induced demand is less than about 33 million metric tons per year.

7.1.3 Coal Distribution

Coal distribution in Asia changes when the proposed terminal comes online because the coal exported through the terminal displaces coal from other sources. Primarily the exported coal displaces coal from Australia, China, Indonesia, and Russia. The average change in coal distribution under the Proposed Action, as measured by the change in the total amount of Asian coal imports, is less than 19.2 million metric tons over 2025 to 2040, for all but the Cumulative Scenario, and ranges from 8.5 to 19.2 million metric tons. The change in coal distribution is used to estimate the change in the distance that the coal imported by the Asian countries must be shipped. This is done by multiplying the tons of coal imported by the distance traveled between supply and demand region, and then dividing by the average capacity of a shipping vessel. The average annual change in shipping distances for the five scenarios ranges from 2.3 to 7.3 million nautical miles.

7.1.4 CO_2 Emissions from Coal Consumption

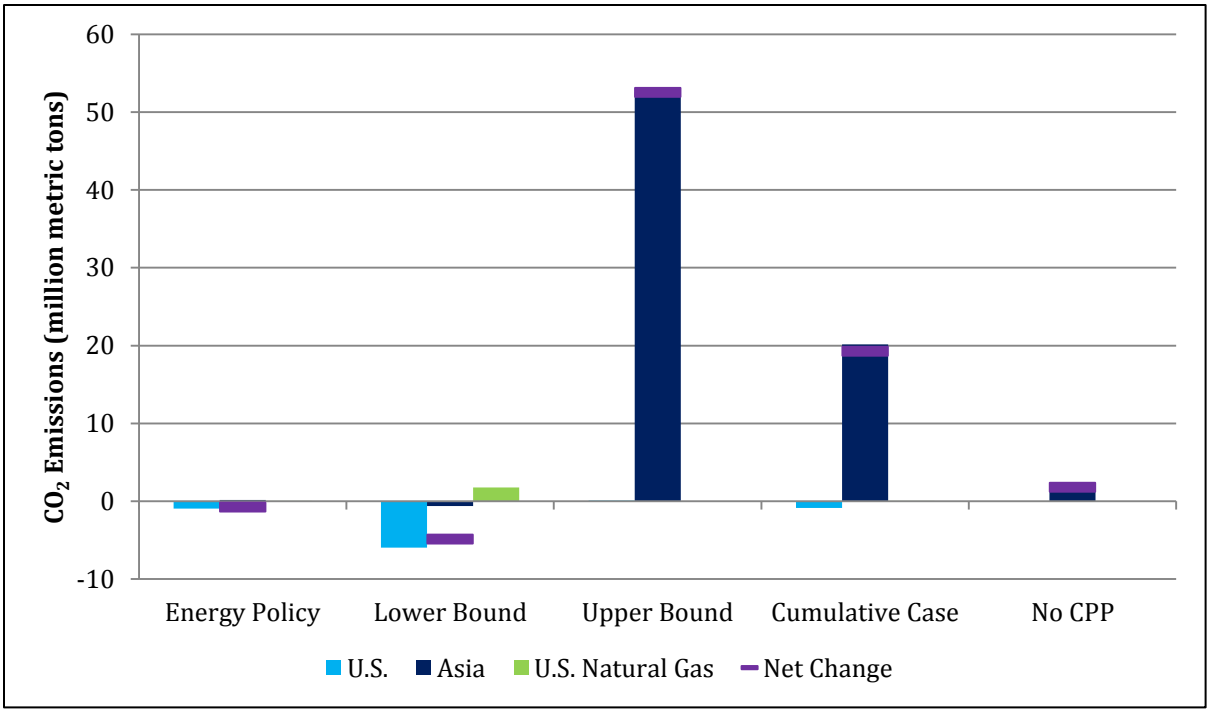
The CO_2 emissions from the combustion of coal follow a similar pattern as the changes in consumption under the Proposed Action, especially in the United States but somewhat less so in Asia. Thus, in the United States, CO_2 emissions from coal consumption would decrease in all but the Upper Bound Scenario, while CO_2 emissions from Asia would increase in all but the Lower Bound Scenario. Under the Proposed Action, the No Clean Power Plan Scenario would result in a net average increase in U.S. CO_2 emissions from the combustion of coal of 1.81 million metric tons, the

Cumulative Scenario would result in an increase of 19.25 million metric tons, and the Upper Bound Scenario would result in an increase of 52.59 million metric tons, while the other two scenarios would show a decrease. The largest change would be in the Upper Bound Scenario, where U.S. CO_2 emissions from the combustion of coal would increase under the Proposed Action by 52.59 million metric tons. The Lower Bound scenario would have the largest decrease in U.S. CO_2 emissions at 5.98 million metric tons because it would have the largest increase in Powder River Basin coal prices, and thus, the largest response in the decrease of U.S. demand. Table 7-1 shows the CO_2 emissions results by scenario and region of origin. Figure 7-1 shows the same emissions information in a chart.

Table 7-1. Average Change in CO_2 Emissions by Scenario and Region—Proposed Action minus No-Action Alternative (million metric tons)

Scenario	Asian Coal	U.S. Coal	U.S. Natural Gas	Total
No Clean Power Plan	1.81	<0.005	<0.001	1.81
Lower Bound	-0.63	-5.98	1.75	-4.86
Upper Bound	52.52	0.07	-0.02	52.58
2015 U.S. and International Energy Policy	0.15	-0.94	0.05	-0.75
Cumulative	20.13	-0.88	0.02	19.28

Figure 7-1. Change in Annual Average CO_2 Emissions from the Consumption of Coal and Natural Gas in the United States for 2025 to 2040—Proposed Action minus No-Action Alternative (million metric tons CO_2 per year)



The results show that the net change in average CO_2 emissions from the combustion of coal would be a net positive for the Upper Bound, Cumulative, and No Clean Power Plan Scenarios, and a net negative for the 2015 U.S. and International Energy Policy and Lower Bound Scenarios.

This analysis also estimated the change in CO_2 emissions from the combustion of natural gas in the United States for use in electric power generation. When the emissions from the consumption of natural gas are included, the net change in CO_2 emissions under the Proposed Action shift slightly higher for all but the Upper Bound and No Clean Power Plan Scenarios.

Chapter 8
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Appendix A

Planned New Generating Capacity and Planned Retirements

Appendix A
Planned New Generating Capacity and Planned Retirements

Table A2-1. Planned New Generating Capacity for 2016 to 2020

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Colorado Bend Energy Center	Generator: CC3	ERCOT	Combined Cycle	2017	1,157
FGE Texas I Project	Generator: CA1	ERCOT	Other	2017	336
FGE Texas I Project	Generator: GT1	ERCOT	Combustion Turbine	2017	231
FGE Texas I Project	Generator: GT2	ERCOT	Combustion Turbine	2017	231
FGE Texas II Project	Generator: CA1	ERCOT	Other	2017	336
FGE Texas II Project	Generator: GT1	ERCOT	Combustion Turbine	2017	231
FGE Texas II Project	Generator: GT2	ERCOT	Combustion Turbine	2017	231
Indeck Wharton Energy Center	Generator: 1	ERCOT	Combustion Turbine	2017	220
Indeck Wharton Energy Center	Generator: 2	ERCOT	Combustion Turbine	2017	220
Indeck Wharton Energy Center	Generator: 3	ERCOT	Combustion Turbine	2017	220
La Paloma Energy Center	Generator: CC	ERCOT	Combined Cycle	2016	700
Lake Livingston Hydroelectric Project	Generator: HY1	ERCOT	Hydro	2018	8
Lake Livingston Hydroelectric Project	Generator: HY2	ERCOT	Hydro	2018	8
Lake Livingston Hydroelectric Project	Generator: HY3	ERCOT	Hydro	2018	8
Los Vientos 4 Wind Project	Generator: GEN1	ERCOT	Wind	2016	200
Los Vientos V Wind Project	Generator: 1	ERCOT	Wind	2016	110
OCI Alamo 1 Solar	Generator: PV3	ERCOT	Solar	2016	355
OCI Alamo 5 (Mega Solar Project)	Generator: OCIA5	ERCOT	Solar	2016	100
P.H. Robinson Peaking CT	Generator: PHR1	ERCOT	Combustion Turbine	2016	65
P.H. Robinson Peaking CT	Generator: PHR2	ERCOT	Combustion Turbine	2016	65
P.H. Robinson Peaking CT	Generator: PHR3	ERCOT	Combustion Turbine	2016	65
P.H. Robinson Peaking CT	Generator: PHR4	ERCOT	Combustion Turbine	2016	65
P.H. Robinson Peaking CT	Generator: PHR5	ERCOT	Combustion Turbine	2016	65

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
P.H. Robinson Peaking CT	Generator: PHR6	ERCOT	Combustion Turbine	2016	65
Tenaska Brownsville Generating Station	Generator: CC	ERCOT	Combined Cycle	2017	800
Texas Clean Energy Project	Boiler: 1 - Generator: IGCC	ERCOT	Coal	2019	400
Wolf Hollow	Generator: 1	ERCOT	Combined Cycle	2017	1,157
Athens Biomass Plant- Cogen	Generator: 1	ISONE	Biomass	2016	8
Ball Mountain Dam Hydro(Blue Heron)	Generator: HY 1	ISONE	Hydro	2019	2
Beaver Wood Energy Fair Haven Biomass Project	Generator: GEN1	ISONE	Biomass	2017	30
Bingham Wind - Blue Sky West	Generator: 1	ISONE	Wind	2017	185
Block Island Offshore Wind	Generator: BIWF	ISONE	Wind	2016	30
Fair Haven Energy Center	Generator: GEN1	ISONE	Biomass	2017	34
Hancock Wind Project	Generator: ANC1	ISONE	Wind	2016	51
Johnston Waste-to-Energy Project	Generator: 1	ISONE	Biomass	2016	3
Lebanon Solar Project (Ecos Energy)	Generator: 1	ISONE	Solar	2016	6
Palmer Renewable Energy	Generator: FB 1	ISONE	Biomass	2016	35
Salem Harbor Gas Project	Generator: 5	ISONE	Combined Cycle	2017	216
Salem Harbor Gas Project	Generator: 6	ISONE	Combined Cycle	2017	216
Salem Harbor Gas Project	Generator: 7	ISONE	Combined Cycle	2017	242
Stafford Solar Project (Stafford Middle School)	Generator: 1	ISONE	Solar	2016	3
WED Coventry 3	Generator: WEDC3	ISONE	Wind	2016	2
WED Coventry 4	Generator: WEDC4	ISONE	Wind	2016	2
WED Coventry 5	Generator: COV5	ISONE	Wind	2016	2
WED Coventry 6	Generator: COV6	ISONE	Wind	2016	2
WED Coventry 6	Generator: COV6A	ISONE	Wind	2016	2
WED Coventry 6	Generator: COV6B	ISONE	Wind	2016	2
WED Coventry Wind Farm	Generator: WT 1	ISONE	Wind	2016	2
WED Coventry Wind Farm	Generator: WT 2	ISONE	Wind	2016	2
Antelope Hills Wind Farm	Generator: 1	MISO	Wind	2016	172
Black Oak Wind Farm-Geronimo	Generator: 1	MISO	Wind	2016	42
border wind project	Generator: WT1 66	MISO	Wind	2016	152
Campbell County Wind Farm (CCWF)	Generator: 1	MISO	Wind	2016	98
deerfield wind	Generator: wt 15	MISO	Wind	2017	114
Ecoharmony West Wind Project	Generator: WT1 134	MISO	Wind	2016	280
Getty Wind Project	Generator: 1	MISO	Wind	2016	40
GLACIAL RIDGE WIND FARM	Generator: WT1 8	MISO	Wind	2019	20

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
H T Pritchard/Eagle Valley	Generator: CC GT1	MISO	Combined Cycle	2017	210
H T Pritchard/Eagle Valley	Generator: CC GT2	MISO	Combined Cycle	2017	210
H T Pritchard/Eagle Valley	Generator: CC ST1	MISO	Other	2017	251
Highland Wind Energy	Generator: WT1 218	MISO	Wind	2016	500
Holland City CC Project	Generator: 10	MISO	Combined Cycle	2016	149
lake country wind energy	Generator: WT2	MISO	Wind	2018	150
lake country wind energy	Generator: WT3	MISO	Wind	2019	150
Mankato Power Plant	Generator: CTG1	MISO	Combustion Turbine	2018	200
Marshalltown Generating Station	Generator: CC1	MISO	Combined Cycle	2017	650
Meade Wind Park	Generator: 1	MISO	Wind	2016	99
Midland Cogeneration Venture	Generator: GT15-6	MISO	Combined Cycle	2017	668
Red Rock Hydro	Generator: HY 1	MISO	Hydro	2018	18
Red Rock Hydro	Generator: HY 2	MISO	Hydro	2018	18
Spiritwood Energy	Boiler: AB - Generator: AB	MISO	Coal	2016	99
Thunder Spirit Wind Farm	Generator: THNDR	MISO	Wind	2016	108
Twin Falls Upgrade (WI)	Generator: 1	MISO	Hydro	2016	9
Walnut Ridge Wind Farm	Generator: WT1 100	MISO	Wind	2016	210
Walnut Ridge Wind Farm	Generator: WT101 150	MISO	Wind	2017	105
Waverly Wind Farm	Generator: GEN1	MISO	Wind	2016	200
CPV Valley Energy Center	Generator: 1	NYISO	Combined Cycle	2016	667
CPV Valley Energy Center	Generator: DUCT	NYISO	Combined Cycle	2018	84
Cricket Valley Energy	Generator: CT	NYISO	Combined Cycle	2018	627
Cricket Valley Energy	Generator: ST	NYISO	Combined Cycle	2018	443
Richwood Greenworks Solar Project	Generator: 1	NYISO	Solar	2016	6
Rochester 2	Generator: 3	NYISO	Hydro	2019	6
TBE-Montgomery LLC	Generator: CTG	NYISO	Biomass	2016	21
Ahoskie 561 Solar Project	Generator: 1	PJM	Solar	2016	5
Ahoskie FIA Solar Project	Generator: 1	PJM	Solar	2016	5
Battleboro Solar Project	Generator: 1	PJM	Solar	2016	5
Brunswick County Power Station	Generator: CC1	PJM	Combined Cycle	2016	1,300
Buckeye Wind Project	Generator: 1A	PJM	Wind	2017	135
Capital Partners Solar Project III	Generator: 1	PJM	Solar	2016	12

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Carroll County Energy Center	Generator: 1	PJM	Combined Cycle	2017	231
Carroll County Energy Center	Generator: 2	PJM	Combined Cycle	2017	231
Carroll County Energy Center	Generator: 3	PJM	Combined Cycle	2017	238
Chowan Jehu Road Solar	Generator: 1	PJM	Solar	2016	5
Coatesville Solar Initiative	Generator: 1	PJM	Solar	2016	9
Colerain Hwy 45 Solar Project	Generator: 1	PJM	Solar	2016	5
CPV St. Charles Energy Center	Generator: GTG	PJM	Combined Cycle	2016	725
CPV Woodbridge Energy Center	Generator: 1	PJM	Combined Cycle	2016	700
CPV Woodbridge Energy Center	Generator: IC1	PJM	Oil/Gas	2016	2
Dans Mountain	Generator: 1	PJM	Wind	2019	48
EC Okisko Solar	Generator: 1	PJM	Solar	2016	5
EcoPower Biomass Plant	Generator: 1	PJM	Biomass	2017	59
Fairfield Renewable Energy Cogen	Generator: ST 1	PJM	Biomass	2016	159
FDS Co-Generation Facility	Generator: 1	PJM	Other	2017	135
FERN Blueribbon Offshore Wind Farm - FACW	Generator: 1	PJM	Wind	2016	25
Frederick Regional Waste-to-Energy Facility	Generator: 1	PJM	Biomass	2016	51
Freeman Farm Solar Project	Generator: 1	PJM	Solar	2016	5
Gliden Jehu Solar Project	Generator: 1	PJM	Solar	2016	5
Good Spring NGCC 1 & 2	Generator: GT1	PJM	Combined Cycle	2016	335
Good Spring NGCC 1 & 2	Generator: HRSG1	PJM	Combined Cycle	2016	108
Hardin Wind Farm	Generator: WT1 200	PJM	Wind	2016	300
Indiana Gasification	Boiler: IGCC - Generator: IGCC	PJM	Coal	2017	134
Lake Erie Offshore Wind Project (Icebreaker)	Generator: WTG1-6	PJM	Wind	2017	18
Middletown Energy Center	Generator: CC CT 1	PJM	Combined Cycle	2018	525
Mill Pond Solar (SunEnergy1)	Generator: 1	PJM	Solar	2016	5
Moxie Liberty Project	Generator: CC1	PJM	Combined Cycle	2017	468
Moxie Liberty Project	Generator: CC2	PJM	Combined Cycle	2017	468
New Creek Wind Farm	Generator: 1	PJM	Wind	2016	98
Northwest Ohio Wind	Generator: NWOH1	PJM	Wind	2016	100
Oregon Energy Centre (OH)	Generator: CC1	PJM	Combined Cycle	2017	800
Pasquotank County Solar Project	Generator: 1	PJM	Solar	2016	5

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Patriot Power Generation Plant (Moxie Patriot)	Generator: CC GEN1-CT1	PJM	Combined Cycle	2016	274
Patriot Power Generation Plant (Moxie Patriot)	Generator: CC GEN1-ST1	PJM	Other	2016	141
Patriot Power Generation Plant (Moxie Patriot)	Generator: CC GEN2-CT2	PJM	Combined Cycle	2016	274
Patriot Power Generation Plant (Moxie Patriot)	Generator: CC GN2-ST2	PJM	Other	2016	141
Peanut Market Farm Solar	Generator: 1	PJM	Solar	2016	5
River Road Solar Project	Generator: 1	PJM	Solar	2016	5
Rockford Solar Project	Generator: PV2	PJM	Solar	2016	3
Roundtop	Generator: GEN1	PJM	Combustion Turbine	2016	4
Roundtop	Generator: GEN2	PJM	Combustion Turbine	2016	4
Roundtop	Generator: GEN3	PJM	Combustion Turbine	2016	4
Roundtop	Generator: GEN4	PJM	Combustion Turbine	2016	4
Roundtop	Generator: GEN5	PJM	Combustion Turbine	2016	4
Shawboro Meads Solar Project	Generator: 1	PJM	Solar	2016	5
Shiloh Hwy 1108 Solar	Generator: 1	PJM	Solar	2016	5
Stephenson Farm Solar Project	Generator: 1	PJM	Solar	2016	5
Stonewall Combined-Cycle Project	Generator: CC	PJM	Combined Cycle	2017	778
Weldon Trueblood Solar	Generator: 1	PJM	Solar	2016	5
Wildcat Point Generation Facility	Generator: CC CT1	PJM	Combined Cycle	2017	1,000
ABD Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Albany Green Energy Cogen Plant	Generator: 1	SERC + FRCC	Biomass	2017	42
Bearford Farm Solar Project	Generator: 1	SERC + FRCC	Solar	2017	5
BG Stewart Solar Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Boaz Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Broadridge Solar	Generator: 1	SERC + FRCC	Solar	2016	5
Calypso Farm	Generator: PV1	SERC + FRCC	Solar	2016	5
Central Energy Plant	Boiler: 1 - Generator: CT 1	SERC + FRCC	Oil/Gas	2016	6
Cline Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Clipperton Holdings	Generator: PV1	SERC + FRCC	Solar	2016	5
Coats Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Creech Solar 2 Project	Generator: 1	SERC + FRCC	Solar	2016	5
Duck Solar	Generator: PV1	SERC + FRCC	Solar	2016	5
Eden Solar Project (Innovative Solar 34)	Generator: IS034	SERC + FRCC	Solar	2016	48
Elm Solar Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Exum Farm Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Faison Farm Solar Project	Generator: PV1	SERC + FRCC	Solar	2016	5
Fremont Farm	Generator: PV 1	SERC + FRCC	Solar	2016	5
Garland Farm	Generator: PV1	SERC + FRCC	Solar	2016	5
Greenville 2 Solar Farm	Generator: PV1	SERC + FRCC	Solar	2016	3
Guernsey Solar Project	Generator: PV1	SERC + FRCC	Solar	2016	5
Haywood Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Highlands Ethanol Cogeneration Facility	Generator: 1	SERC + FRCC	Biomass	2016	30
Hoke County Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Innovative Solar 38 Project	Generator: 1	SERC + FRCC	Solar	2016	35
Innovative Solar 42 Project	Generator: 1	SERC + FRCC	Solar	2016	73
Innovative Solar 46 Project	Generator: 1	SERC + FRCC	Solar	2016	80
Innovative Solar 48	Generator: 1	SERC + FRCC	Solar	2016	5
Innovative Solar 64	Generator: 1	SERC + FRCC	Solar	2016	5
Innovative Solar 72	Generator: 1	SERC + FRCC	Solar	2016	35
Kalish Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Kelly Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Kings Mountain Energy Center	Generator: KMEC1-A	SERC + FRCC	Combined Cycle	2018	272
Kings Mountain Energy Center	Generator: KMEC1-B	SERC + FRCC	Combined Cycle	2018	203

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Manway Solar Farm	Generator: 1	SERC + FRCC	Solar	2017	5
Maxton Solar 1	Generator: 1	SERC + FRCC	Solar	2016	5
McDougald Solar	Generator: 1	SERC + FRCC	Solar	2016	5
Misenheimer Farm Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Montgomery Solar	Generator: PV1	SERC + FRCC	Solar	2016	20
Mount Olive Farm (Chatham Park)	Generator: PV 1	SERC + FRCC	Solar	2016	20
Nan Solar Center	Generator: PV 1	SERC + FRCC	Solar	2016	40
Nash 97 Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Ostrich Solar Farm	Generator: 1	SERC + FRCC	Solar	2016	5
Owen Solar	Generator: PV1	SERC + FRCC	Solar	2016	6
Oxford Solar 1	Generator: 1	SERC + FRCC	Solar	2016	5
Plant Washington	Boiler: 1 - Generator: ST1	SERC + FRCC	Coal	2018	850
Polk 2 Combined Cycle	Generator: C 2A	SERC + FRCC	Combined Cycle	2017	165
Polk 2 Combined Cycle	Generator: C 2B	SERC + FRCC	Combined Cycle	2017	165
Polk 2 Combined Cycle	Generator: C 2C	SERC + FRCC	Combined Cycle	2017	165
Polk 2 Combined Cycle	Generator: C 2D	SERC + FRCC	Combined Cycle	2017	165
Polk 2 Combined Cycle	Generator: CC 9	SERC + FRCC	Combined Cycle	2017	459
Polk Biomass Generating Facility	Generator: FB 1	SERC + FRCC	Biomass	2016	75
Port Everglades Next Generation Clean Energy	Generator: CC 5A	SERC + FRCC	Combined Cycle	2016	250
Port Everglades Next Generation Clean Energy	Generator: CC 5B	SERC + FRCC	Combined Cycle	2016	250
Port Everglades Next Generation Clean Energy	Generator: CC 5C	SERC + FRCC	Combined Cycle	2016	250
Port Everglades Next Generation Clean Energy	Generator: CC 5ST	SERC + FRCC	Combined Cycle	2016	500
Prease Farm Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Roady Lane Solar Farm	Generator: PV 1	SERC + FRCC	Solar	2016	75
Rutherford Farm	Generator: PV 1	SERC + FRCC	Solar	2016	75

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Sampson County Landfill Facility	Generator: IC GEN7	SERC + FRCC	Landfill	2017	2
Sampson County Landfill Facility	Generator: IC GEN8	SERC + FRCC	Landfill	2016	2
Sarasota County Biomass Plant (Sarasota Energy)	Generator: IC 4	SERC + FRCC	Biomass	2016	2
Sedberry Farm Solar Project	Generator: 1	SERC + FRCC	Solar	2017	5
Snow Camp Solar Project	Generator: 1	SERC + FRCC	Solar	2016	12
Spring Hope Solar 2	Generator: 1	SERC + FRCC	Solar	2016	5
Spring Valley Farm 2 Solar Project	Generator: 1	SERC + FRCC	Solar	2017	5
Spring Valley Farm Solar Project	Generator: PV1	SERC + FRCC	Solar	2017	5
Staley Snow Camp Road Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Statesville Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Thomas Solar Project	Generator: 1	SERC + FRCC	Solar	2016	5
Tiburon Holdings Solar Project	Generator: PV1	SERC + FRCC	Solar	2016	5
Toprak Solar Project	Generator: PV1	SERC + FRCC	Solar	2016	20
V C Summer	Generator: 2	SERC + FRCC	Nuclear	2018	1,100
V C Summer	Generator: 3	SERC + FRCC	Nuclear	2019	1,100
Van Slyke Solar Center	Generator: PV1	SERC + FRCC	Solar	2016	5
Vass Solar 2 Project	Generator: 1	SERC + FRCC	Solar	2016	5
Vogtle (GA)	Generator: 3	SERC + FRCC	Nuclear	2019	1,100
Vogtle (GA)	Generator: 4	SERC + FRCC	Nuclear	2020	1,100
Watson Seed Farm PV 1	Generator: PV 1	SERC + FRCC	Solar	2016	20
Watts Bar Nuclear	Generator: NP2	SERC + FRCC	Nuclear	2016	1,122
Westside Solar Farm	Generator: WEST1	SERC + FRCC	Solar	2016	4
Arbuckle Mountain Wind Farm	Generator: GEN1	SPP	Wind	2016	100
Breckinridge Wind Project (Chisholm View Wind II)	Generator: BWP	SPP	Wind	2016	97
Buffalo Dunes Wind Project	Generator: WT	SPP	Wind	2016	180
Goodman Energy Center	Generator: 10	SPP	Combustion Turbine	2016	9

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Goodman Energy Center	Generator: 11	SPP	Combustion Turbine	2016	9
Goodman Energy Center	Generator: 12	SPP	Combustion Turbine	2016	9
Goodwell Wind Project	Generator: 1	SPP	Wind	2016	200
Grand River Energy Center Unit 3 (Chouteau)	Generator: 3CT	SPP	Combined Cycle	2017	495
Grant Wind Farm	Generator: 1	SPP	Wind	2016	150
Kingfisher Wind Farm	Generator: KNG1	SPP	Wind	2016	298
Marshall (Summerfield) Wind Farm	Generator: RPMA	SPP	Wind	2016	37
Marshall (Summerfield) Wind Farm	Generator: WT 1	SPP	Wind	2016	37
Ozark	Generator: 10	SPP	Hydro	2016	20
Riverton CC	Generator: 1	SPP	Combined Cycle	2016	250
Roosevelt Wind Ranch	Generator: GEN1	SPP	Wind	2016	250
Slate Creek Wind Project	Generator: 1	SPP	Wind	2016	150
Stillwater IC Plant	Generator: 1	SPP	Combustion Turbine	2016	19
Stillwater IC Plant	Generator: 2	SPP	Combustion Turbine	2016	19
Stillwater IC Plant	Generator: 3	SPP	Combustion Turbine	2016	19
Western Plains Wind Project	Generator: WT 1	SPP	Wind	2018	400
Alta Wind Energy Center	Generator: WT567 620	WECC	Wind	2016	153
American Solar Greenworks Solar Plant	Generator: 1	WECC	Solar	2016	35
Anderson Facility	Generator: GEN2	WECC	Biomass	2016	31
Antelope Valley I Solar Project	Generator: PV1	WECC	Solar	2016	309
Antelope Valley II Solar Project	Generator: PV1	WECC	Solar	2016	270
Arlington Valley Solar Energy Project	Generator: SS	WECC	Solar	2016	125
Avalon Wind Project	Generator: WT1 127	WECC	Wind	2017	300
Beacon Photovoltaic Project	Generator: PV1	WECC	Solar	2016	88
Beacon Solar (Hectate)	Generator: PV1	WECC	Solar	2016	112
Beacon Solar (Hectate) 2	Generator: PV1	WECC	Solar	2016	50
Beacon Solar Plant Site 2 (SunEdison)	Generator: BEAC2	WECC	Solar	2017	48
Beacon Solar Plant Site 5 (SunEdison)	Generator: BEAC5	WECC	Solar	2017	40
Blackwell Solar Park Project	Generator: 1	WECC	Solar	2016	20
Boise Airport Solar Project	Generator: PV 1	WECC	Solar	2016	10
Carty Generating Station	Generator: 2	WECC	Combined Cycle	2019	460
Carty Generating Station	Generator: GEN1A	WECC	Combined Cycle	2016	272

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Carty Generating Station	Generator: GEN1B	WECC	Combined Cycle	2016	168
Centinela Solar Energy	Generator: PV3	WECC	Solar	2016	105
Cheyenne Power Plant	Generator: CT3	WECC	Combustion Turbine	2018	80
Clark Canyon Hydro	Generator: HY	WECC	Hydro	2017	4
Clark Canyon Hydro	Generator: HY2	WECC	Hydro	2017	4
Copper Mountain Solar IV	Generator: 1	WECC	Solar	2016	94
Del Sur Solar	Generator: PV1	WECC	Solar	2016	19
Del Sur Solar	Generator: PV2	WECC	Solar	2016	19
Frank Bowerman Landfill Project	Generator: 1	WECC	Biomass	2016	20
Gibson Dam	Generator: HY5	WECC	Hydro	2019	8
Gibson Dam	Generator: HY6	WECC	Hydro	2019	8
Glenarm Repowering	Generator: GT5	WECC	Combined Cycle	2016	71
Haxtun Wind Farm	Generator: WT1 20	WECC	Wind	2016	30
Headworks Reservoir	Generator: HY1	WECC	Hydro	2018	4
Hecate Energy Beacon Solar 1	Generator: BEAC1	WECC	Solar	2017	56
Huntington Beach Repowering	Generator: B	WECC	Combined Cycle	2018	487
Huntington Beach Repowering	Generator: E	WECC	Combined Cycle	2020	487
Imperial Solar Energy Center West	Generator: PV1	WECC	Solar	2016	150
K Road Moapa Solar Facility	Generator: PV2	WECC	Solar	2016	100
La Luz Energy Center	Generator: 1	WECC	Combustion Turbine	2016	40
Lake Tahoe Biomass Project (Cabin Creek)	Generator: 1	WECC	Biomass	2016	2
Liberty Energy Center	Generator: ST 1	WECC	Biomass	2017	5
Liberty Energy Center	Generator: ST 2	WECC	Biomass	2017	5
Liberty Energy Center	Generator: ST 3	WECC	Biomass	2017	5
Lincoln Alamosa County Solar	Generator: PV	WECC	Solar	2016	37
Lotus Solar Farm (Borden Solar)	Generator: 1	WECC	Solar	2020	51
McCoy Solar Energy Project	Generator: PV1	WECC	Solar	2016	250
McCoy Solar Energy Project	Generator: PV2	WECC	Solar	2019	500
Midway Solar Farm I	Generator: PV 1	WECC	Solar	2016	50
Neal Hot Springs	Generator: GE 4	WECC	Geothermal	2017	28
Nellis Solar Project - II	Generator: 1	WECC	Solar	2016	15
Newberry Demonstration EGS Project	Generator: EO 1	WECC	Geothermal	2018	30
Newberry Demonstration EGS Project	Generator: EO 2	WECC	Geothermal	2018	30
Newberry Demonstration EGS Project	Generator: EO 3	WECC	Geothermal	2018	30

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Newberry Demonstration EGS Project	Generator: EO 4	WECC	Geothermal	2018	30
Newberry Volcano	Generator: GE1	WECC	Geothermal	2018	45
Newberry Volcano	Generator: GE2	WECC	Geothermal	2019	45
Newberry Volcano	Generator: GE3	WECC	Geothermal	2020	90
North Lancaster Ranch Solar PV Plant	Generator: 1	WECC	Solar	2017	20
Oakley Generating Station	Generator: CC1	WECC	Combined Cycle	2018	624
Potrero Hills Landfill	Generator: 1	WECC	Landfill	2016	8
RE Tranquillity 1 Solar Generating Facility	Generator: 1	WECC	Solar	2016	200
RE Tranquillity 2 Solar Generating Facility	Generator: 1	WECC	Solar	2016	15
RE Tranquillity 3 Solar Generating Facility	Generator: 1	WECC	Solar	2016	15
RE Tranquillity 4 Solar Generating Facility	Generator: 1	WECC	Solar	2016	35
RE Tranquillity 5 Solar Generating Facility	Generator: 1	WECC	Solar	2016	40
RE Tranquillity 6 Solar Generating Facility	Generator: 1	WECC	Solar	2016	35
RE Tranquillity 7 Solar Generating Facility	Generator: 1	WECC	Solar	2016	20
RE Tranquillity 8 Solar Generating Facility	Generator: 1	WECC	Solar	2016	40
Rice Solar Energy Project	Generator: SS1	WECC	Solar	2016	150
Rio Bravo Solar I	Generator: PV1	WECC	Solar	2017	20
San Emidio South Project Phase I-II	Generator: 2	WECC	Geothermal	2016	11
San Luis Solar	Generator: PV1	WECC	Solar	2016	20
Scattergood Repowering CC	Generator: 4	WECC	Combined Cycle	2016	367
Scattergood Repowering CT	Generator: 6	WECC	Combustion Turbine	2016	104
Scattergood Repowering CT	Generator: 7	WECC	Combustion Turbine	2016	104
Searchlight Wind Energy Project	Generator: WT1 87	WECC	Wind	2016	200
SEPV Mojave West Solar Project	Generator: 1	WECC	Solar	2016	20
Silver State South	Generator: SSS	WECC	Solar	2016	250
South Kern Industrial Center (SKIC Solar 1-2)	Generator: SKI10	WECC	Solar	2016	10
Springbok Solar Farm I Project	Generator: 1	WECC	Solar	2016	150
Stateline Solar Project	Generator: STL	WECC	Solar	2016	300
Summit Ridge I Wind Farm	Generator: SRWF	WECC	Wind	2019	194
Utah Red Hills Renewable Park	Generator: 1	WECC	Solar	2016	80
Victorville 2 Hybrid Power Project	Generator: PV1	WECC	Solar	2018	49

Plant Name	Unit Name	Region Name	Capacity Type	Online Year	Capacity (MW)
Watson Cogeneration	Generator: GN97	WECC	Combustion Turbine	2016	80
Western Antelope Blue Sky Ranch B	Generator: B	WECC	Solar	2017	20
Western Antelope Dry Ranch Project	Generator: WADR	WECC	Solar	2017	10
Wildwood Solar Project	Generator: PV1	WECC	Solar	2016	20

Table A2-2. Planned Retirements for 2016 through 2020

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
GADSDEN	1	SERC + FRCC	Coal	2019	64
GADSDEN	2	SERC + FRCC	Coal	2019	66
Greene County (AL)	1	SERC + FRCC	Coal	2016	254
Greene County (AL)	2	SERC + FRCC	Coal	2016	243
Browns Ferry	2	SERC + FRCC	Nuclear	2035	1,104
Browns Ferry	3	SERC + FRCC	Nuclear	2037	1,105
COLBERT	1	SERC + FRCC	Coal	2016	177
COLBERT	2	SERC + FRCC	Coal	2016	177
COLBERT	3	SERC + FRCC	Coal	2016	177
COLBERT	4	SERC + FRCC	Coal	2016	173
JOLIET 29	7	PJM	Coal	2016	518
JOLIET 29	8	PJM	Coal	2016	518
MCKEE RUN	1	PJM	Oil/Gas	2017	17
MCKEE RUN	2	PJM	Oil/Gas	2017	17
TURKEY POINT	3	SERC + FRCC	Nuclear	2032	802
TURKEY POINT	4	SERC + FRCC	Nuclear	2033	802
AVON PARK	P1	SERC + FRCC	Combustion Turbine	2016	24
AVON PARK	P2	SERC + FRCC	Combustion Turbine	2016	25
CRYSTAL RIVER	1	SERC + FRCC	Coal	2018	372
CRYSTAL RIVER	2	SERC + FRCC	Coal	2018	494
G E TURNER	P1	SERC + FRCC	Combustion Turbine	2016	11
G E TURNER	P2	SERC + FRCC	Combustion Turbine	2016	11
HIGGINS	P1	SERC + FRCC	Combustion Turbine	2016	27
HIGGINS	P2	SERC + FRCC	Combustion Turbine	2016	26
HIGGINS	P3	SERC + FRCC	Combustion Turbine	2016	28

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
HIGGINS	P4	SERC + FRCC	Combustion Turbine	2016	32
Suwannee	2	SERC + FRCC	Oil/Gas	2018	28
Suwannee	3	SERC + FRCC	Oil/Gas	2018	71
LANSING SMITH	1	SERC + FRCC	Coal	2016	162
LANSING SMITH	2	SERC + FRCC	Coal	2016	195
ARVAH B HOPKINS	GT2	SERC + FRCC	Combustion Turbine	2017	24
Dresden	2	PJM	Nuclear	2030	883
Dresden	3	PJM	Nuclear	2031	867
JOLIET 9	6	PJM	Coal	2016	314
Quad Cities (EXELON)	1	PJM	Nuclear	2032	908
Quad Cities (EXELON)	2	PJM	Nuclear	2032	911
H T Pritchard/Eagle Valley	2	MISO	Oil/Gas	2016	39
H T Pritchard/Eagle Valley	3	MISO	Coal	2016	43
H T Pritchard/Eagle Valley	4	MISO	Coal	2016	56
H T Pritchard/Eagle Valley	5	MISO	Coal	2016	62
H T Pritchard/Eagle Valley	ST1	MISO	Oil/Gas	2016	39
WABASH RIVER	4	MISO	Coal	2016	85
BIG SANDY	1	PJM	Coal	2016	260
R A Reid	GEN1	MISO	Coal	2016	65
Dale (KY)	3	SERC + FRCC	Coal	2016	74
Dale (KY)	4	SERC + FRCC	Coal	2016	75
CHALK POINT	1	PJM	Coal	2018	334
CHALK POINT	2	PJM	Coal	2018	335
DICKERSON	2	PJM	Coal	2018	178
DICKERSON	3	PJM	Coal	2018	178
DICKERSON	ST1	PJM	Coal	2018	178
B C COBB	4	MISO	Coal	2016	156
B C COBB	5	MISO	Coal	2016	156
Palisades (MI)	1	MISO	Nuclear	2032	782
J C WEADOCK	7	MISO	Coal	2016	155
J C WEADOCK	8	MISO	Coal	2016	151
J R WHITING	1	MISO	Coal	2016	102
J R WHITING	2	MISO	Coal	2016	102
J R WHITING	3	MISO	Coal	2016	124
TRENTON CHANNEL	7	MISO	Coal	2016	110
TRENTON CHANNEL	8	MISO	Coal	2016	100
Twin Falls (MI)	1	MISO	Hydro	2017	1
Twin Falls (MI)	2	MISO	Hydro	2017	1
Twin Falls (MI)	3	MISO	Hydro	2017	1

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
Twin Falls (MI)	4	MISO	Hydro	2017	1
Twin Falls (MI)	5	MISO	Hydro	2017	1
JAMES DE YOUNG	3	MISO	Coal	2020	11
JAMES DE YOUNG	4	MISO	Coal	2020	21
Key City	1	MISO	Combustion Turbine	2017	15
Key City	3	MISO	Combustion Turbine	2017	15
Key City	4	MISO	Combustion Turbine	2017	16
Monticello (MN)	1	MISO	Nuclear	2031	633
Prairie Island	1	MISO	Nuclear	2034	521
Prairie Island	2	MISO	Nuclear	2034	519
JACK WATSON	1	SERC + FRCC	Oil/Gas	2019	76
JACK WATSON	2	SERC + FRCC	Oil/Gas	2019	76
JACK WATSON	3	SERC + FRCC	Oil/Gas	2019	107
MONTROSE	2	SPP	Coal	2016	164
MONTROSE	3	SPP	Coal	2016	176
Sibley (MO)	1	SPP	Coal	2019	54
Sibley (MO)	2	SPP	Coal	2019	54
MERAMEC	1	MISO	Coal	2022	120
MERAMEC	2	MISO	Coal	2022	120
MERAMEC	3	MISO	Coal	2022	268
MERAMEC	4	MISO	Coal	2022	347
Fort Calhoun	1	SPP	Nuclear	2033	479
NORTH OMAHA	4	SPP	Coal	2023	138
NORTH OMAHA	5	SPP	Coal	2023	224
REID GARDNER	4	WECC	Coal	2017	265
FORT CHURCHILL	1	WECC	Oil/Gas	2018	113
Oyster Creek (NJ)	1	PJM	Nuclear	2019	615
RIO GRANDE	6	WECC	Oil/Gas	2017	45
RIO GRANDE	7	WECC	Oil/Gas	2017	46
SAN JUAN	2	WECC	Coal	2018	320
SAN JUAN	3	WECC	Coal	2018	495
Indian Point 2	2	NYISO	Nuclear	2033	1,020
Dunkirk Generating Station	DUN2	NYISO	Coal	2016	78
Nine Mile Point Nuclear Station (NY)	1	NYISO	Nuclear	2029	531
AVON LAKE	7	PJM	Coal	2016	92
St Marys (OH)	7	PJM	Combustion Turbine	2018	12
MUSKOGEE	4	SPP	Coal	2019	511

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
MUSKOGEE	5	SPP	Coal	2019	517
SHAWVILLE	1	PJM	Coal	2016	122
SHAWVILLE	2	PJM	Coal	2016	125
H B ROBINSON	2	SERC + FRCC	Nuclear	2031	741
Oconee	1	SERC + FRCC	Nuclear	2033	846
Oconee	2	SERC + FRCC	Nuclear	2034	846
Oconee	3	SERC + FRCC	Nuclear	2034	846
MCMEEKIN	1	SERC + FRCC	Coal	2016	125
MCMEEKIN	2	SERC + FRCC	Coal	2016	125
Johnsonville (TN)	2	SERC + FRCC	Coal	2017	106
Johnsonville (TN)	3	SERC + FRCC	Coal	2017	106
Johnsonville (TN)	4	SERC + FRCC	Coal	2017	106
Plant X (TX)	1	SPP	Oil/Gas	2019	48
Plant X (TX)	2	SPP	Oil/Gas	2019	102
Plant X (TX)	3	SPP	Oil/Gas	2020	103
CLINCH RIVER	1	PJM	Coal	2016	230
CLINCH RIVER	2	PJM	Coal	2016	230
Surry	1	PJM	Nuclear	2032	872
Surry	2	PJM	Nuclear	2033	872
Point Beach	1	MISO	Nuclear	2030	591
Point Beach	2	MISO	Nuclear	2032	591
Edgewater (WI)	4	MISO	Coal	2018	320
Fox Lake	1	MISO	Oil/Gas	2016	12
Milford (IA)	1	MISO	Combustion Turbine	2018	1
AES Beaver Valley Partners Beaver Valley	GEN2	PJM	Coal	2017	32
Brunswick (NV)	1	WECC	Combustion Turbine	2019	2
Brunswick (NV)	2	WECC	Combustion Turbine	2019	2
Brunswick (NV)	3	WECC	Combustion Turbine	2019	2
Milford (IA)	4	MISO	Combustion Turbine	2018	1
Rolling Hills Generating LLC	CT2	PJM	Combustion Turbine	2016	165
Rolling Hills Generating LLC	CT3	PJM	Combustion Turbine	2016	165
Rolling Hills Generating LLC	CT4	PJM	Combustion Turbine	2016	165
WABASH RIVER	2	MISO	Coal	2016	85
WABASH RIVER	3	MISO	Coal	2016	85

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
WABASH RIVER	5	MISO	Coal	2016	95
NAVAJO	NAV1	WECC	Coal	2019	750
Donald C Cook	1	PJM	Nuclear	2035	1,009
Donald C Cook	2	PJM	Nuclear	2038	1,060
Joseph M Farley	1	SERC + FRCC	Nuclear	2037	874
Brunswick (NC)	1	SERC + FRCC	Nuclear	2037	938
Brunswick (NC)	2	SERC + FRCC	Nuclear	2035	932
Beaver Valley	1	PJM	Nuclear	2036	921
St Lucie	1	SERC + FRCC	Nuclear	2036	981
Edwin I Hatch	1	SERC + FRCC	Nuclear	2035	876
Edwin I Hatch	2	SERC + FRCC	Nuclear	2039	883
Boardman (OR)	1	WECC	Coal	2020	585
James A FitzPatrick	1	NYISO	Nuclear	2036	716
Ginna	1	NYISO	Nuclear	2030	490
Davis Besse	1	PJM	Nuclear	2037	894
North Anna	1	PJM	Nuclear	2038	943
North Anna	2	PJM	Nuclear	2040	943
Three Mile Island	1	PJM	Nuclear	2034	805
Cooper	1	SPP	Nuclear	2034	766
Arkansas Nuclear One	1	SERC + FRCC	Nuclear	2034	836
Arkansas Nuclear One	2	SERC + FRCC	Nuclear	2040	992
Indian Point 3	3	NYISO	Nuclear	2036	1,041
AES Beaver Valley Partners Beaver Valley	GEN3	PJM	Coal	2017	114
Lake Road (MO)	4	SPP	Coal	2019	97
Suwannee	1	SERC + FRCC	Oil/Gas	2018	30
Broadway (CA)	B3	WECC	Oil/Gas	2016	65
Rolling Hills Generating LLC	CT1	PJM	Combustion Turbine	2016	165
Paradise (KY)	1	SERC + FRCC	Coal	2017	628
Paradise (KY)	2	SERC + FRCC	Coal	2017	602
VALMONT	5	WECC	Coal	2017	186
Cherokee (CO)	4	WECC	Coal	2017	352
REDONDO BEACH	GEN5	WECC	Oil/Gas	2019	179
REDONDO BEACH	GEN6	WECC	Oil/Gas	2019	175
REDONDO BEACH	GEN7	WECC	Oil/Gas	2019	480
REDONDO BEACH	GEN8	WECC	Oil/Gas	2019	480
Allen Steam Plant (TN)	1	SERC + FRCC	Coal	2018	245
Allen Steam Plant (TN)	2	SERC + FRCC	Coal	2018	245
Allen Steam Plant (TN)	3	SERC + FRCC	Coal	2018	245
GEORGE NEAL NORTH	1	MISO	Coal	2016	135

Plant Name	Unit Name	Region Name	Capacity Type	Retirement Year	Capacity (MW)
Harding Street	6	MISO	Coal	2016	106
Harding Street	7	MISO	Coal	2016	435
Encina Carlsbad	ST2	WECC	Oil/Gas	2017	104
Encina Carlsbad	ST3	WECC	Oil/Gas	2017	110
Encina Carlsbad	ST1	WECC	Oil/Gas	2017	106
AVON LAKE	9	PJM	Coal	2016	625
James M Barry Electric Generating Plant	1	SERC + FRCC	Coal	2019	138
James M Barry Electric Generating Plant	2	SERC + FRCC	Coal	2019	137
James M Barry Electric Generating Plant	3	SERC + FRCC	Coal	2016	249
Johnsonville (TN)	1	SERC + FRCC	Coal	2017	106
New Castle Plant	3	PJM	Coal	2016	98
New Castle Plant	4	PJM	Coal	2016	98
SHAWVILLE	3	PJM	Coal	2016	175
SHAWVILLE	4	PJM	Coal	2016	175
YORKTOWN	1	PJM	Coal	2017	159
Polk Station	2	SERC + FRCC	Combustion Turbine	2017	159
Polk Station	3	SERC + FRCC	Combustion Turbine	2017	164
PSEG Salem Generating Station	1	PJM	Nuclear	2037	1,168
Polk Station	GT4	SERC + FRCC	Combustion Turbine	2017	149
Polk Station	GT5	SERC + FRCC	Combustion Turbine	2017	149





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