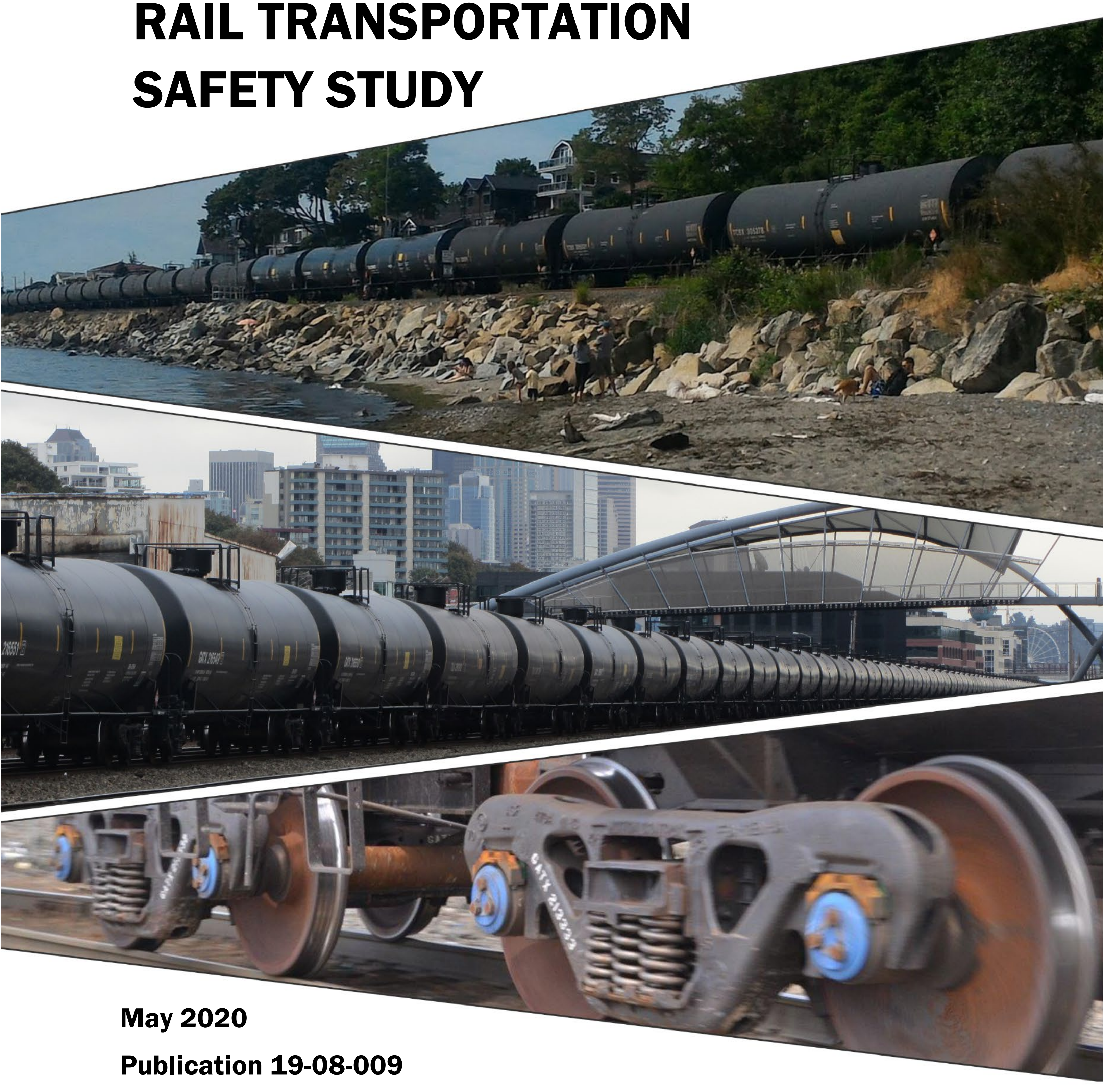
DEPARTMENT OF ECOLOGY
State of Washington

2020 WASHINGTON RAIL TRANSPORTATION SAFETY STUDY



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2020 WASHINGTON RAIL TRANSPORTATION SAFETY STUDY

Prepared by
Environmental Research Consulting

in cooperation with

Washington State Department of Ecology
Spill Prevention, Preparedness, and Response Program
and
Utilities and Transportation Commission

Olympia, Washington

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Executive Summary

Study purpose

The rapid growth of crude oil transport by rail during the years 2011 through 2014 spurred the Washington State Legislature to commission the *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015). The 2014 study provided a broad, detailed expanse of information as a resource and a foundation for further work. Since then, the energy transportation landscape continues to evolve.

In 2018, the Washington State Department of Ecology (Ecology) and the Washington State Utilities and Transportation Commission (UTC) sought an update and expansion of the rail assessment and technical research presented in the 2014 study. The *2020 Washington Rail Transportation Safety Study* (2020 WRTSS) offers state agencies more insight and a better understanding of railroad operations. This may allow the State to identify and develop broad planning measures that look beyond —but do not conflict with — existing laws and regulations in an effort to provide public agencies, tribes, and stakeholders with data and technical information to address issues of significant importance to rail transport.

Efforts to improve rail safety could include forming a Rail Safety Committee. Such a committee could be a voluntary, collaborative partnership with the rail industry. Goals of a rail safety committee could include encouraging non-regulatory actions to identify and address safety issues, protect natural resources, and reduce risks associated with rail transportation of oil and other hazardous materials

Role of 2020 WRTSS

The 2020 WRTSS is a technical report, intended to provide Ecology, UTC, and other readers of the report an updated assessment of:

- Railroads in Washington State and the role they play in the State's and region's economies, as well as in passenger and commuter transport.
- Existing rail safety issues in Washington State and ways in which they have changed in recent years.
- Safety and risk reduction measures that have been developed and implemented or could be developed and implemented in the future to potentially reduce the health, safety, and environmental risks associated with rail transportation.

Additionally, the report provides an educational tool for technical and non-technical readers to gain a common understanding and foster meaningful and productive exchanges about rail safety issues.

Topics covered

The report discusses a broad range of topics in depth. These topics include:

- Washington's railroad infrastructure, freight and passenger traffic, hazardous commodities, and accident rates.
- Potential consequences of rail-related oil and hazardous material releases.
- Existing and potential future measures to reduce the incidence and severity of rail accidents.
- Implementation of positive train control (PTC) and its potential for reducing accidents.
- Electronically-controlled pneumatic (ECP) braking systems and research on technology benefits and costs.
- Historical, current, and emerging inspection standards of rail infrastructure and equipment.
- Current levels of crew training and qualifications, crew sizes, and areas for improvements to promote rail safety.
- Safety concerns related to highway-rail crossings, Quiet Zones, and trespassing incidents.
- Maintenance and infrastructure investment practices used by railroads.
- Tank car design and effects on the safe transport of crude oil, other Class 3 flammable liquids, and hazardous materials, as well as fleet composition.
- Issues related to extended storage, storage during transit, and security protocols of Class 3 flammable liquids on rail.
- Best practices in emergency response for rail accidents, such as toxic spills and passenger train incidents.
- Best practices in communications during rail emergency response operations.
- The Federal Railroad Administration (FRA) Railroad Safety Advisory Committee and other safety-oriented rail programs.
- Industry standards for insurance levels in railroads moving hazardous materials.
- Lessons learned from derailments, accidents, and incidents over the last seven years.
- Analysis of the effects of track geometry, train length, physical properties of commodities, car placement, train speeds, and land management conflicts on rail accident risk.
- Geograpic analysis of rail risk.

Each topic includes a list of recommended areas for further discussion by Ecology, UTC, and a potential rail safety committee. These areas for further discussion could form the basis of new planning measures or voluntary actions to improve rail safety.

Chapter 1: Report Organization and Reader's Guide

Report organization

The *2020 Washington Rail Transportation Safety Study* report provides current information on relevant topics for use by the Washington State Department of Ecology (Ecology), Washington State Utilities and Transportation Commission (UTC), and the potential future Washington State Rail Safety Committee. This information may be used to formulate a Washington State Rail Safety Plan and voluntary safety standards to enhance rail safety in the state in cooperation with a broad range of stakeholders and tribes. To serve these purposes, and with the understanding that technical knowledge and interest varies greatly between parties involved, the report has been organized so different readers can quickly find the section of the report appropriate for their level of interest. Chapter 1 (Report Organization and Reader's Guide), Chapter 2 (Introduction), Chapter 3 (Overview of General Findings), and Chapter 25 (Summary of Discussion Areas) function as non-technical summaries that are intended for all readers.

Beginning with Chapter 4, each chapter contains:

- **Key questions:** A list of research questions that are answered (to the extent possible) in the chapter.
- **Chapter takeaways:** A summation of the most important points on the chapter's topic(s) presented in non-technical language.
- **Chapter in-depth:** A series of sections that provide significantly more technical information on specific sub-topics within the chapter topic(s) for readers that require or have interest in more detailed information. The sub-topics are demarcated with headings that allow readers to scan for specific information as needed. The language in the in-depth content sections is more specific and scientific to assure accuracy from a technical standpoint.
- **Important discussion areas:** A final summary section containing potential areas for discussion on future actions by the Rail Safety Committee or other entities.

Chapter 4 is an overview of the infrastructure and traffic of Washington's railroads presented as context for the rest of the report. There are no specific discussion areas applicable to this chapter. Issues related to highway-rail crossings are addressed in greater depth in Chapter 13.

The Glossary (Chapter 27) provides definitions of key technical terms and acronyms for all chapters. There are no separate glossaries within the chapters.

Topics covered

This report provides updated information on rail safety for use by the potential future Washington Rail Safety Committee to formulate action plans that will address rail safety issues identified by Ecology and UTC. The report contains information on:

- Washington's railroad infrastructure, freight and passenger traffic, hazardous commodities, and accident rates.

- Potential consequences of rail-related oil and hazardous material releases, including potential human health and safety environment risks from fire, explosions, and toxic vapors.
- Existing and potential future measures to reduce the incidence and severity of rail accidents.
- Implementation of positive train control (PTC) and its potential for reducing accidents.
- Electronically-controlled pneumatic (ECP) braking systems and research on technology benefits and costs.
- Historical, current, and emerging inspection standards of rail infrastructure and equipment, including new and emerging technology.
- Current levels of crew training and qualifications, crew sizes, and areas for improvements to promote rail safety.
- Safety concerns related to highway-rail crossings, Quiet Zones, and trespassing incidents.
- Maintenance and infrastructure investment practices used by railroads.
- Tank car design and effects on the safe transport of crude oil, other Class 3 flammable liquids, and hazardous materials, as well as fleet composition.
- Issues related to extended storage, storage during transit, and security protocols of Class 3 flammable liquids on rail.
- Best practices in emergency response for rail accidents, such as toxic spills and passenger train incidents.
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- The Federal Railroad Administration (FRA) Railroad Safety Advisory Committee and other safety-oriented rail programs.
- Industry standards for insurance levels in railroads moving hazardous materials.
- Lessons learned from derailments, accidents, and incidents over the last seven years.
- Analysis of the effects of track geometry, train length, physical properties of commodities, car placement, train speeds, and land management conflicts on rail accident risk.
- Geographic analysis of rail risk.

Chapter 2: Introduction and Purpose

Key questions

- What is the purpose of the 2020 Washington Rail Transportation Safety Study?
- How may the 2020 Washington Rail Transportation Safety Study inform the Rail Safety Committee?

Study purpose

The rapid growth of crude oil transport by rail during the years 2011 through 2014 spurred the Washington State Legislature to commission the *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015). The 2014 study provided a broad, detailed expanse of information as a resource and a foundation for further work. Since then, the energy transportation landscape continues to evolve. In 2018, the Washington Utilities and Transportation Commission (UTC) and Ecology sought an update and expansion of the rail assessment and technical research presented in the 2014 study. The *2020 Washington Rail Transportation Safety Study* (2020 WRTSS) offers state agencies more insight and a better understanding of railroad operations. This may allow the State to identify and develop broad planning measures that look beyond — but do not conflict with — existing laws and regulations in an effort to provide public agencies, tribes, and stakeholders with data and technical information to address issues of significant importance to rail transport.

Role of 2020 WRTSS

The 2020 WRTSS is part of a multifaceted effort by Ecology and UTC to improve rail safety in the state. Besides this technical report, this effort also involves the formation and implementation of a Rail Safety Committee (RSC) and a Rail Risk Geographic Information System (GIS) plan.

Work on the GIS Plan and the 2020 WRTSS occurred concurrently between December 2018 and June 2020. During this period, a potential RSC framework was also drafted.

The 2020 WRTSS is intended to provide a broad range of RSC members and other associated parties with:

- An updated overview of the railroads in Washington State and the vital role they play in the State's and region's economies, as well as in passenger and commuter transport.
- An updated assessment of the existing rail safety issues in Washington State and ways in which they have changed in recent years.
- An updated assessment of the way in which the rail transport of hazardous commodities have brought challenges to the State, as well as ways in which the risks of this transport have been addressed or could be better addressed in the future.
- An updated assessment of safety and risk reduction measures that have been developed and implemented or could be developed and implemented in the future to potentially reduce the health, safety, and environmental risks associated with rail transportation.

- An educational tool that can be used by both technical and non-technical RSC members and other interested parties to learn the vocabulary, concepts, and information necessary to gain a common understanding and foster meaningful and productive exchanges about rail safety issues.

Chapter 3: Overview of General Findings

Key questions

- How are risk reductions examined and considered in railroad transportation?
- What are the major findings of the research and analyses conducted in this report?
- What are the major issues that the potential future Washington State Rail Safety Plan and Washington State Rail Safety Committee might address in enhancing rail safety for the State of Washington?

The big picture: Risks related to railroad transportation

Railroads provide benefits to society by transporting people and goods from one place to another. Passenger trains bring people from one part of the state or other parts of the country. Trains are an important piece of connecting Washington's rural and urban areas. Many people use trains to commute to and from work or school. Railroads bring a large variety of goods and commodities (e.g., oil, lumber, chemicals, and machinery) to consumers and industrial and manufacturing facilities, which benefits the people and economy of the state.

As with other forms of transportation, including automobiles and other motor vehicles, airplanes, vessels, and pipelines, there are potential risks to human health and safety and the environment. For all modes of transportation of goods, including hazardous materials and oil, as well as transportation of people, there have been significant reductions in the frequency and severity of accidents in the last several decades. Nevertheless, there are occasional accidents that can have major consequences, such as human fatalities and injuries, and short- and long-term environmental and human health effects.

Defining risk

"Risk" combines either the likelihood or probability of an event occurring, such as a rail accident, and the severity of the consequences, such as the effects of the release of a hazardous material or human casualties.

There can be low probability events with high consequences, high probability events with low consequences, and everything in between. The incidents with the highest overall "risk" are those with both the highest probability and the highest consequences (Figure 1).

The incidents with the highest probability often have the lowest impacts (e.g., small spills in industrial areas that occur during normal operations). Incidents with the highest impact (e.g., a major spill or catastrophic incident involving a fire) tend to be more rare events (i.e., they tend to have a lower probability). Safety systems are typically designed to prevent such accidents. However, in the risk matrix, the other incidents that can present the greatest challenge for planning are those with low or medium probability and high-impact.

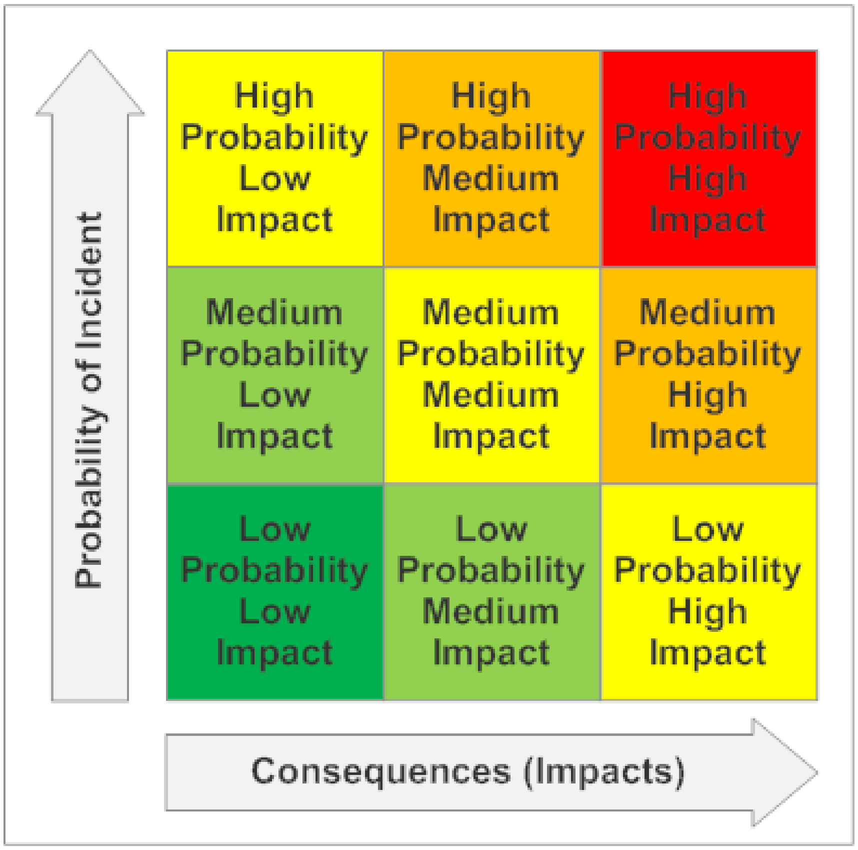

Figure 1: Basic risk matrix[1]

Risk perception issues

One of the most challenging issues related to defining risk is that the perception of risk by the public is often not directly proportional to the actual risk involved (Etkin et al., 2018a). This is especially true for oil and other hazard material spills and rail accidents. When evaluating risk, people sometimes focus on high impact consequences, many of which have a low probability of occurring. If there has been a notable event that has occurred in recent memory (e.g., the Lac-Mégantic crude-by-rail accident, which occurred in Quebec, Canada in July 2013, resulting in 47 fatalities), it is thought to be more probable than it may actually be statistically (Transportation Safety Board of Canada, 2014c).

The factors that tend to make a situation (such as driving an automobile) seem to be of lower risk include:

- The voluntary nature of the situation, such as choosing to drive an automobile.
- Individual control, which is particularly relevant to automobile driving, as the driver is "in control" and "knows what they are doing."
- Knowledge and familiarity, which is certainly relevant to automobile driving.

[1] This figure was developed by Environmental Research Consulting. Used with permission.

- A perceived benefit to the individual from the action, which can easily be seen for driving.

The factors that tend to make a situation, such as crude-by-rail (CBR) trains, appear to be of higher risk include:

- The involuntary or imposed nature of the situation, which is relevant to CBR traffic in that the general public has virtually no control over it.
- The absence of perceived personal benefit, which may be the feeling the public has about the transport of crude oil.
- The lack of knowledge and familiarity about the nature of the situation, such as not understanding the technical aspects of rail transport.
- Most importantly, a sense of outrage about the situation.

Driving an automobile is significantly riskier to individuals and communities than are CBR trains. The degree of outrage (termed the "outrage factor" by risk analysts) is very important in making an activity or situation appear to have higher risk. Outrage is an emotional reaction to risks that are involuntary, industrial, and "unfair." There is a natural tendency to focus on how upsetting a risk is, rather than how dangerous it really may be.

The outrage factors that are most relevant to rail accidents and hazardous releases are (Etkin et al., 2018a):

- **Voluntariness:** Voluntary risk is perceived as more acceptable than coerced risk. Rail accidents and associated spills are rarely voluntary risks for the general public.
- **Control:** When prevention and risk reduction are in an individual's hands, risk is perceived as being much lower than when they are in the hands of a government agency or industry. Rail accidents are typically not in public control.
- **Fairness:** People who endure greater risks than others, without access to greater benefits (e.g., communities on CBR routes) experience greater outrage, especially if rationale for burdening them appears to be political or an environmental justice issue.[2]
- **Process:** If stakeholders are not involved in the decision-making process or are not kept informed, there tends to be greater outrage.
- **Diffusion in time and space:** If Hazard X kills 50 random people each year, and Hazard Y has a 10 percent chance of killing 5,000 over the course of 10 years, risk assessment predicts mortality of 50 per year for both hazards. "Outrage," however, tends to point to Hazard X as "probably acceptable" and Hazard Y as "unacceptable." Rail accidents and spills tend to look more like Hazard Y, with acute, local effects.

Risk mitigation or reduction approaches

Risk can be mitigated or reduced in two principle ways: by reducing the probability, and by reducing the consequences. Incident probability is reduced through prevention measures —

[2] The Environmental Protection Agency (EPA) defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies." See https://www.epa.gov/environmentaljustice for more information.

stopping the incidents from happening in the first place, or at least reducing their frequency. Prevention is the most effective means to reduce risk.

If an accident is not prevented, another strategy is to reduce the severity of the consequences. Addressing the consequences for rail accidents and hazardous material spills or releases (including oil spills) also means considering two things. First, the potential to reduce the damage to the train that may cause the release of a hazardous material warrants consideration. Secondly, there is potential, through emergency response and preparedness, to reduce the degree to which humans and sensitive resources are impacted. Both approaches involve preventing fatalities and injuries from fires and/or explosions, and minimizing exposure of humans and environmental resources to spilled substances. (Exposure can occur either through direct contact or through contact with contaminated or affected land or water.) An effective spill response protects people, minimizes the spread of the oil or other released hazardous material, protects natural resources, and removes oil from the environment to the extent possible. If damage occurs, later phases of response operations include rehabilitation of the affected environmental, cultural, and economic resources (Etkin et al., 2015a).

Rail risk factor and risk reduction approach interrelationships

To better understand the types of risks that may occur with rail transportation and the way in which risk reduction measures may reduce those risks, it is helpful to step back and look at the whole picture. With each rail transit or trip (e.g., each time a train transports oil from North Dakota to Washington's refineries on the Puget Sound, or brings passengers from Vancouver, British Columbia, to Vancouver, Washington), there is a very small chance that there may be an accident. For example, an accident could be caused by an error made by an engineer, a mechanical failure on the train, a broken rail on the tracks, an improperly loaded tank car, or a driver crossing the tracks at a grade crossing to "beat the train."

Such an accident may be prevented using a number of different approaches. For example, better training could have prevented the train operator error, the mechanical failure or broken rail may have been discovered and repaired in an inspection, the tank car could have been loaded more safely by a well-trained person, and a better-designed rail crossing gate, paired with education, could have prevented the driver from making that dangerous choice.

Once the accident has occurred, there are a number of further risk reduction measures that may then reduce the severity of an accident. For example, the design of a tank car might reduce the likelihood of a release of hazardous materials. While the tank car derailment might still occur, the release of oil might be reduced or prevented.

When a hazardous material release has occurred, the properties of the substance and the environmental conditions (e.g., wind) will have an effect on the severity of the consequences. For example, conditioning Bakken crude to make it less volatile will reduce the likelihood of an explosion.[3] In addition, the location of vulnerable people in relation to the railroad tracks (e.g., the proximity of schools, housing, or hospitals) will have an effect on the severity of a fire or explosion event. If there is a fire or explosion, the effectiveness of well-trained and prepared emergency responders can help to mitigate the impacts. In the event of a spill, the combination of

[3] *Conditioning* is a process that reduces volatility by removing some of the more volatile components from crude oil.

the properties of the material spilled, the receiving environment, and the environmental conditions will have an effect on the degree of the environmental impacts. For example, if a spill of a highly-toxic substance occurs in a location with a waterway that currently has spawning salmon, there will likely to be an impact on these species.

A brief overview of these interrelationships is diagrammed in Figure 2.

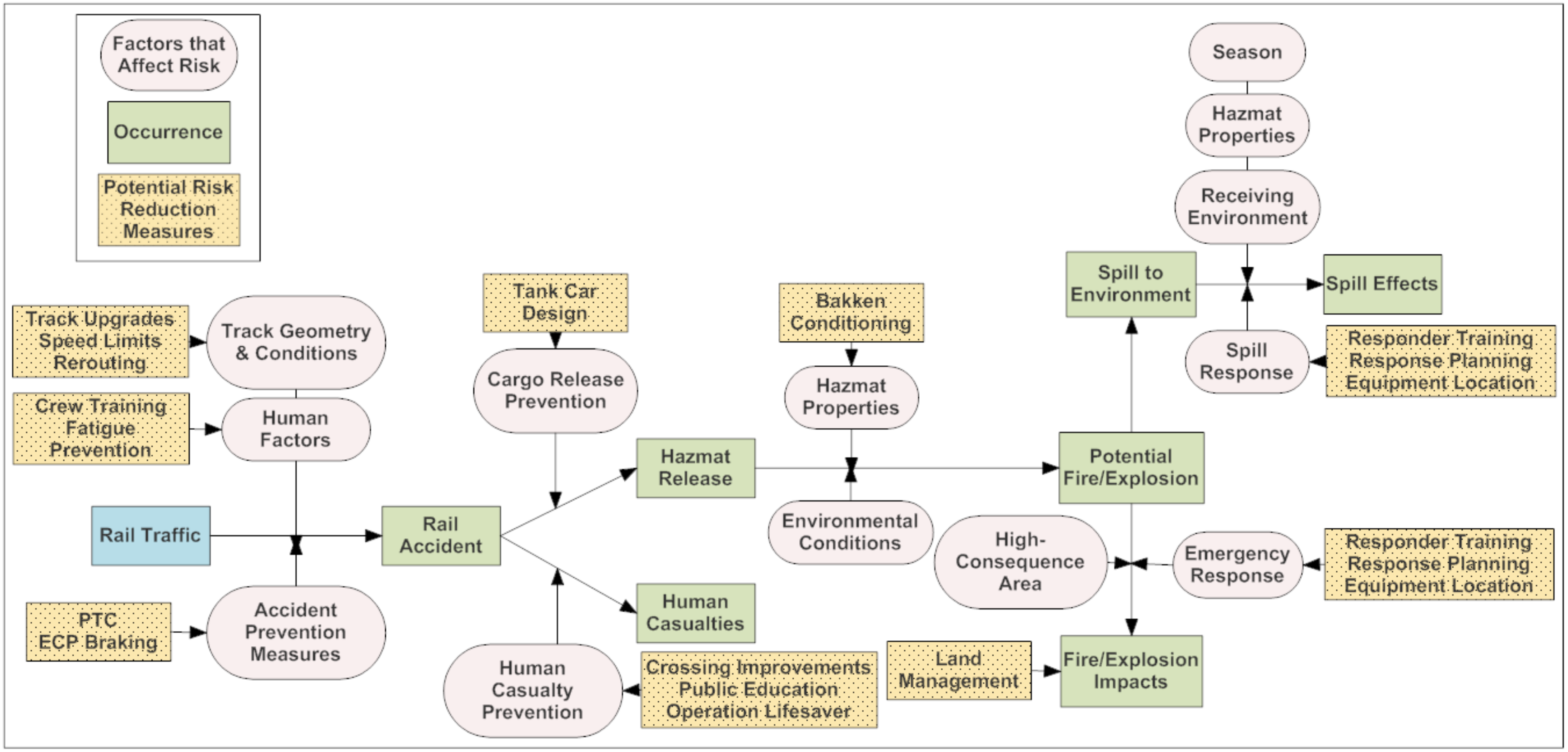

Figure 2: Interrelationships Between Rail Risk Factors and Risk Reduction Approaches[4]

[4] This figure was created by Environmental Research Consulting for this report. Used with permission.

Frequency of rail accidents

The frequency of rail accidents decreased significantly in Washington State and the U.S. as a whole over the last 43 years (Federal Railroad Administration [FRA], 2019a). The greatest reduction occurred between 1975 and 1985 due to significant improvements in rail infrastructure and operations. Accidents continued to decrease over the next decades, albeit at a slower rate (FRA, 2019a).

Currently, there are an average of 11 accidents per year in the U.S. involving freight trains on mainline tracks (FRA, 2019a). In Washington State, there is, on average, one freight train accident for every one million train-miles.[5] Just over half of these are derailments.

Based on analyses of national data for the years 2011 through 2018, as conducted by Environmental Research Consulting for this report using FRA data (FRA, 2019a), track-related problems are the most frequent cause of freight train derailments. Track problems account for 44 percent of incidents. The most common track-related problem is a broken rail. The next most common cause is mechanical or electrical problems, accounting for 42 percent of derailments. Nearly 72 percent of collisions between trains are caused by human error.[6]

For long-distance, inter-city passenger trains (Amtrak) throughout the U.S., there are 1.5 accidents for every one million train-miles (FRA, 2019a).

Consequences of rail accidents

When a rail accident occurs, there may be a number of consequences, such as:

- Human casualties in the case of highway-rail crossing accidents, pedestrian trespassing accidents, or passenger train accidents.
- Spills or releases of hazardous materials, that may cause:
    - Fires or vapor cloud explosions, which may have human health and safety or environmental effects.
    - Dispersion of toxic vapors, which may also have human health and safety or environmental effects.
    - Environmental impacts due to the toxicity, persistence, or adherence of the oil or chemical to wildlife and habitat.

The types and severity of effects of spills or releases depend on the hazardous materials involved, the volume released, the location of the release, the timing of the release (seasonal, day of week, or time of day), and ambient environmental conditions. The impacts of spills and releases may be mitigated by timely and effective emergency and spill response operations.

In Washington State, there are 2,373 grade crossings where roads and highways cross railroad tracks.[7] Each year, there are an average of 33 collisions between trains and vehicles, with 10

[5] A train-mile is the equivalent of a train transiting a single mile.
[6] A more detailed analysis of railroad accidents is presented in Chapter 5 of this report.
[7] Data from WSDOT. Used with permission. See Table 16 in Chapter 4 for details.

injuries and 6 fatalities (Utilities and Transportation Commission [UTC], 2019a). In addition, there an average of 16 fatalities when pedestrians trespass on railroad tracks (UTC, 2019a).

There was also a major Amtrak passenger train accident in DuPont, Washington, in December 2017, in which 12 passenger cars and 2 locomotives derailed on a bridge crossing Interstate 5. This accident resulted in the deaths of three train passengers, injuries to 62 train passengers, and injuries to eight passengers in automobiles on the highway (National Transportation Safety Board [NTSB], 2018a).

There have been no major spills or releases of oil or hazardous materials from rail transport in Washington State in recent years. A derailment accident of a CBR unit train in Mosier, Oregon, in June 2016 caused three tank cars of Bakken crude oil to burn and a small amount of oil to enter the Columbia River. Ecology and other officials from Washington State assisted in the response. There were no injuries or significant environmental damage (Oregon Office of Emergency Management [OOEM], 2016).

Accident risk reduction through prevention

The best method for preventing rail accidents differs by the type of accident and usually involves a combination of different approaches. No one measure will prevent all accidents.

The best approaches to determining the most effective measure or measures for reducing specific types of accidents include understanding the root causes of the accidents (e.g., track conditions or human error) and then applying measures that are practical and effective. Sometimes, there are studies conducted that may provide data that can prove the effectiveness of a prevention method. At other times, there are no reliable data that specifically test the new equipment or method, but it can reasonably be expected to have at least some benefit. The actual benefit may not be realized until the measure has been in place for some time.

There are sometimes disagreements about the potential effectiveness of an accident prevention measure or concerns that there may be unintended "side effects" of the approach.

The accident prevention measures explored in this report include:

- Positive train control (PTC), which can prevent certain types of accidents in which train operators fail to slow down or stop due to the failure to obey signals or speed restrictions, or fail to sound horns at grade crossings.
- Electronically-controlled pneumatic (ECP) braking, which may reduce some types of derailments and other accidents resulting from brake failures.
- Inspection of rails and equipment, which can help prevent derailments related to broken rails and accidents related to equipment failures.
- Crew training and qualification, as well as crew fatigue solutions, which can help reduce human errors that cause accidents.
- Improvements in grade crossing protection and warning systems and education programs that may reduce highway-rail crossing accidents.

In the case of the Amtrak accident that occurred in Dupont, Washington, in December 2017, resulting in three fatalities, the National Transportation Safety Board (NTSB) concluded that PTC would likely have prevented this accident (NTSB, 2018a).

Accident severity reduction including amount spilled

There are a number of specific measures that can reduce the severity of accidents. For example, as with vehicular traffic, speed reductions in trains can reduce the severity of an accident by reducing the force of the impact and thereby reducing the numbers of cars that derail.

Newer designs of tank cars reduce the likelihood of damage to the cars in the event of derailments and collisions. This reduces the chance there will be a release (flowing out or spilling) of a hazardous material, or reduces the amount of material that is released or spilled. Tank cars are currently in use in Washington State are all DOT-117 cars, which are estimated to be half as likely to break open or rupture and allow the release of oil or other hazardous substances contained in the cars as the older DOT-111 cars. Some studies indicate there may be as much as an 84 percent reduction in the likelihood of a release, spill, or outflow of oil or other hazardous material in the event of a rail accident. The older cars had about 27 percent (about 1 in 4) chance of breaking open in the event of an accident. The newer cars have about a 4 percent (1 in 25) chance of rupturing or breaking open (Barkan, 2008a; Barkan et al., 2013; Barkan et al., 2015; Treichel, 2014; Treichel, 2018; Treichel et al., 2006).[8]

Accident risk reduction through preparedness and response

Once an accident has occurred, it will be the actions of emergency responders that will reduce the severity of the consequences of the accident to the extent possible. Human health and safety and the environment will be better protected if there is a well-trained, knowledgeable, and well-equipped first-response team that arrives on scene to rescue and tend to injured people, evacuate people in the vicinity of any released hazardous materials, and supervise and monitor the situation. For spill responses, a well-trained, knowledgeable, and well-equipped response team can help to reduce the spread of the released substance in some cases, or conduct cleanup operations.

In Washington State, common objectives for oil spill incidents are:

- Ensure the safety of citizens and response personnel.
- Control the source of the spill.
- Protect environmentally and culturally sensitive areas.
- Manage response effort in a coordinated manner.
- Contain and recover spilled material.
- Recover and rehabilitate affected wildlife.
- Clean up oil from affected areas.
- Keep the public and stakeholders informed of response activities.
- Minimize economic impacts.

[8] There is a more detailed discussion of tank car safety in Chapter 15 of this report.

- Terminate the response (demobilize at the end).

Timeliness of emergency response is critical in reducing the impacts of an accident. The speed of the response will depend on the location of the incident in relation to emergency response equipment and personnel and access to the site. In some of the more remote parts of Washington State, this presents a challenge.

Geographic factors for Washington rail transportation risk

The risk from rail accidents in the various geographic areas of Washington depends on:

- The likelihood of accidents, which depends on both the rail traffic in the area and the conditions that might increase accidents, such as track geometry, grades, curves, flood zones, landslide-prone slopes, and other track features.
- The number of highway-rail grade crossings and both the rail and vehicular traffic going through those crossings.
- The types of commodities that are being transported through different geographic areas.
- The environmental sensitivity of the area to spills of different types of oils and other hazardous materials.
- The proximity of rails to high-consequence areas, particularly densely-populated areas.
- The accessibility and remoteness of the sites for emergency response operations.

Geographic risk issues are considered in greater detail in Chapter 23.

Potential issues for consideration by the Rail Safety Committee

Many of the safety measures that may prevent or reduce the frequency of rail accidents are under the jurisdiction of the federal government rather than Washington State. However, state officials and members of the Rail Safety Committee can play a vital role in influencing decision-making at the federal level. There are still many issues that can be approached at the state and local levels by the Rail Safety Committee, such as the development of voluntary safety measures or standards, and promoting safety at highway-rail crossings. The committee would foster communication and cooperative approaches to promote safe practices on Washington railroads.

Issues that the Rail Safety Committee may wish to consider are summarized in Chapter 25.

Chapter 4: Washington State Railroads

Key questions

- What roles do railroads play in Washington State?
- What is the infrastructure of the freight rail system?
- What are the patterns of freight rail traffic?
- What types of commodities are currently transported by rail?
- How might commodity transport patterns change in the future?
- What is the infrastructure of the passenger rail system?
- What are patterns of passenger rail traffic?
- Where do railroads pass through populated areas and tribal lands?
- Where do the railroads intersect with roads and highways (crossings)?

Takeaways

This chapter provides an overview of the existing infrastructure of railroads and the roles that railroads play for the people and economy of the state.

> Washington's extensive network of railroads moves passengers on long-distance interstate (and international) travel, and commuters between suburban and metropolitan areas. It transports large variety of freight cargo (commodities) into the state from elsewhere in the U.S. and Canada, between ports and facilities within the state, and out of the state.

In addition:

- Washington's freight railroads support the manufacturing, construction, agriculture, forestry, petroleum refining, and wholesale/retail trade, which employ 1.2 million people, or about 40 percent of the state's total employment (WSDOT 2014).
- Washington State has more than 3,300 miles of railroad track used for freight transport (WSDOT 2017; WSDOT 2019).
- There are two Class I railroads: BNSF Railway and Union Pacific (UP). BNSF operates 44 percent of the track mileage (1,450 miles) in the state. UP operates more than 500 route miles or about 15 percent of the state's track.
- There is one Class II railroad: Montana Rail Link, which operates only as a tenant of BNSF (on BNSF-owned track) (WSDOT 2014).
- There are 25 Class III railroads, including short-line (local) railroads, and switching and terminal railroads, that operate only within limited areas in railyards and terminals. Short-lines own 1,300 routes miles of track in the state.
- From 2008 to 2017, Class I railroads transported an average of 780,000 carloads of freight that originated in Washington State per year. Of that freight, hazardous commodities (including crude oil, chemicals, petroleum products, and hazardous waste) made up about 3.8 percent of these carloads, based on data provided by Washington Utilities and Transportation Commission (UTC) as described later in this chapter (Surface Transportation Board data).

- From 2008 to 2017, Class I railroads transported an average of 912,000 carloads of freight per year that terminated in Washington State (Surface Transportation Board data).
- Of the freight that terminated in Washington, railroads moved an average of 46,544 carloads of hazardous materials between 2008 and 2012 representing 5.5 percent of total freight terminating in Washington for those years. However, by 2017, the hazardous carloads had increased to 154,000 per year and represented 14 percent of all freight terminating in the state. Most of this growth was due to the transport of crude oil (Surface Transportation Board data).

In addition:

- About 15 crude oil unit trains per week transit Washington. The monthly numbers vary between 8 and 20 (Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a).
- A typical crude-by-rail (CBR) unit train has 118 cars.
- About 93 percent of the oil transported by rail in 2018 was Bakken crude (Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a).
- Throughout the U.S., CBR transport peaked in 2014, then decreased, and began to increase again in 2018. The number of CBR trains in Washington State has fluctuated less than in other parts of the country.

Future patterns of CBR transport will depend on economic factors that affect demand for different oil types at refineries and the shifting of transport from pipeline and tank vessel to rail. It is generally less expensive to ship oil by pipeline or by tank vessel than by rail, but if pipelines are not available, or tank vessels are not practical, rail transport may be chosen to move oil to refineries in Washington.

- There are 6 daily long-distance passenger trains (Amtrak) going through Washington State that connect with many cities in the eastern U.S., Canada to the north, and Oregon and California to the south. (It is possible to connect in California to trains going to Tucson, Arizona, that go on to Mexico's Copper Canyon) and 12 intercity trains that run between cities in Washington State as well. Finally, there are also 34 daily commuter trains in the Seattle and Tacoma areas.
- Railroads pass through a large number of densely-populated areas and tribal lands. This could increase the potential for public health and safety risks as well as land management conflicts.
- Serious accidents with fatalities and injuries at grade crossings can also be a public safety risk. There are 2,373 grade crossings in Washington State.[9] The greatest number of grade crossings are in King County, followed by Yakima, Spokane, and Pierce Counties.

The following sections provide a more in-depth look at railroads in Washington State, including freight and passenger trains, and the ways in which railroads intersect with populated areas.

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[9] Data from WSDOT. Used with permission. See Table 16 for details.

The roles of railroads in Washington State

The railroad network in Washington State, including passenger and commuter rails, and different classes of freight rails, covers many areas of the state. Washington State's railroad network is an integral part of the multimodal transportation system that moves freight and passengers throughout the state. Washington State's freight railroads support the state's freight intensive industries, such as manufacturing, construction, agriculture, petroleum refining, forest products, and wholesale/retail trade. These industries employ 1.2 million people, or 40 percent of the state's total employment. These industries contributed about 41 percent of the state's total Gross Domestic Product (GDP) in 2010. Washington State's GDP in 2010 was $365.6 billion, which means that the industries supported by Washington's freight railroads contributed nearly $150 billion. The railroads themselves directly employed 4,700 people in the state with a total annual payroll of $260 million (WSDOT 2014).

For passenger rail, there are regional/commuter rails that connect suburban areas with major metropolitan areas, intercity rail that connect major metropolitan areas, and long-distance rail (Amtrak) that connects to the national system. Sound Transit is the sole commuter rail service in the state that shares tracks with freight rail. Sound Transit shares track with freight rail between Everett and Tacoma. The light rail systems do not share infrastructure with other types of rail. Amtrak has long-distance passenger rail service with routes of more than 750 miles in Washington State (WSDOT 2014). There are two long-distance services in the state — Empire Builder and Coast Starlight (WSDOT 2014).

Freight rail system in Washington State

Washington State is home to more than 3,300 miles of railroad track used for freight transport (WSDOT 2017; WSDOT 2019). There are 30 freight railroads operating in the state traveling more than 10 million track-miles each a year. The federal Surface Transportation Board classifies railroads on a three-tiered structure (WSDOT 2014):

Class I (railroads with annual operating revenue of more than $489.9 million): There are two Class I railroads operating in the state: BNSF (Figure 3) and Union Pacific (UP) (Figure 4). They carry in excess of 1.9 million carloads of freight each year. Together, these two railroads own 60 percent of the track mileage in Washington State (about 2,175 miles).

Class II (railroads with annual operating revenue of between $39.2 million and $489.9 million): The only Class II railroad operating in Washington State is Montana Rail Link, which operates in the state only as a tenant of BNSF.

Class III (railroads with revenues of less than $39.2 million engaged in line-haul transportation): There are 25 Class III operating in Washington State.

Table 1 shows Class III railroads in Washington State. This includes "short-line" (or local) railroads and switching and terminal railroads. Short-lines own about 1,450 miles of track, or 40 percent of the total rail mileage in the state.

Figure 3: BNSF Pacific Northwest Mainline Rail Network (with Subdivisions)[10]

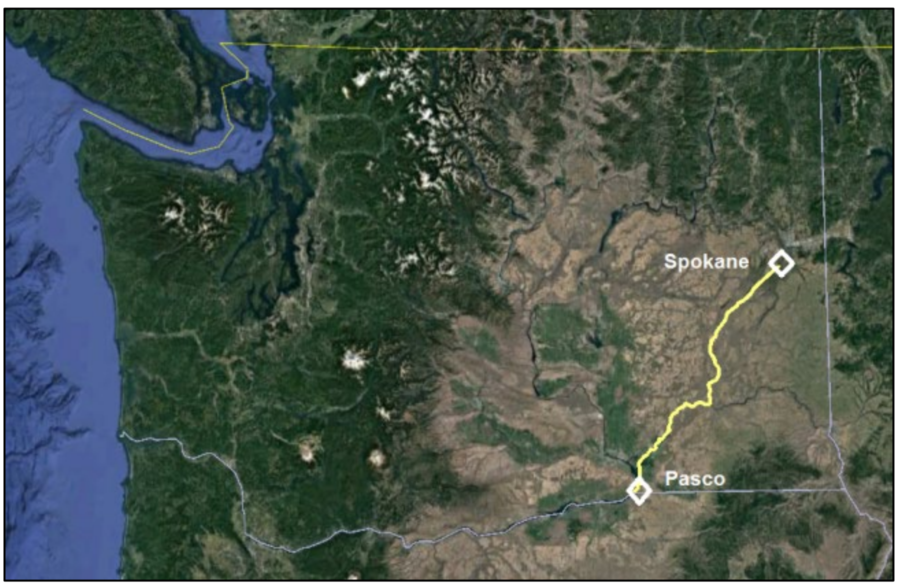

Figure 4: Union Pacific (UP) Mainline Rail between Spokane and Pasco[11]

[10] Prepared by Environmental Research Consulting using data from WSDOT. Used with permission.
[11] The Union Pacific (UP) line runs from Idaho into Oregon, but this figure only shows the section between Spokane and Pascothat is discussed in greater detail in this report. Union Pacific also owns a route between Tacoma and Seattle. Prepared by Environmental Research Consulting using data from WSDOT. Used with permission.

Table 1: Class III railroad operators in Washington State[12]

Name	Parent Company	Miles Operated in Washington State
Ballard Terminal Railroad	Ballard Terminal	3
Eastside Freight Railroad	Ballard Terminal	14
Meeker Southern Railroad	Ballard Terminal	5
Tacoma Rail	City of Tacoma	94
Central Washington Railroad	Columbia Basin Railroad Company	71
Columbia Basin Railroad	Columbia Basin Railroad Company	106
Columbia-Walla Walla Railway	Columbia Rail	82
Kennewick Terminal Railway	Columbia Rail	2
The Washington Royal Line	Columbia Rail	26
Yakima Central Railway	Columbia Rail	22
Olympia & Belmore Railroad	Genesee & Wyoming	5
Cascade & Columbia River Railroad	Genesee & Wyoming	145
Puget Sound & Pacific Railroad	Genesee & Wyoming	158
Mount Vernon Terminal Railway	Mount Vernon Terminal Railway	3
Spokane, Spangle and Palouse[13]	Omaha Track	87
Kettle Falls International Railway	OmniTRAX	36
Columbia & Cowlitz Railway	Patriot Rail	9
Port of Chehalis Rail	Port of Chehalis	1
Pend Oreille Valley Railroad	Port of Pend Oreille	80
Portland Vancouver Juntion Railroad	Portland Vancouver Juntion Railroad	14
St. Paul & Pacific Northwest Railroad	Progressive Rail	69
Rainier Rail	Rainier Rail	40
Washington Eastern Railroad[13]	The Western Group	109
Tri-City Railroad Company	Tri-City Railroad Company	32
Longview Switching Company	Union Pacific and BNSF	9
Great Northwest Railroad	Watco Companies	78
Palouse River & Coulee City Railroad[13]	Watco Companies	84
Total		**1,384**

A number of the rail lines are connected to terminals that provide transfer points where cargo is loaded or unloaded to or from trucks and marine vessels. Transfers can take place by shifting intact containers or truck trailers at intermodal terminals. At facilities, bulk commodities (dry or liquid), including grain, produce, plastic pellets, machinery, and vegetable oil, are directly transferred to trucks or tank vessels as well. There are nine intermodal facilities in Washington State (Table 2). “On-dock rail terminals handle international containers directly moving from ship to rail and vice versa, while near-dock terminals can handle both port-related and highway traffic. Inland terminals generally handle the transfer of containers and highway trailers between truck and rail” (WSDOT 2014).

[12] WSDOT
[13] Private operator of PCC Rail System line owned by WSDOT

Table 2: Intermodal Facilities in Washington State with Type and Rail Service Provider[14]

Facility Name	Type	Rail Service Provider
Port of Seattle Intermodal Terminals	On Dock	BNSF/UP
Port of Tacoma Intermodal Terminals	On Dock	BNSF/UP
Tacoma South Intermodal Facility	Near Dock	UP
Seattle International Gateway	Near Dock	BNSF
Argo Intermodal Facility	Near Dock	UP
South Seattle Intermodal Facility	Off Dock	BNSF
Port of Quincy Intermodal Terminal	Inland	BNSF
Spokane Intermodal Terminal	Inland	BNSF
Port of Pasco Intermodal Terminal	Inland	BNSF

Freight rail traffic in Washington State

Freight rail traffic in Washington State is carried by the Class I railroads (BNSF and UP), as well as various short-line railroads. Traffic may originate in the state, terminate in the state, move entirely within the state, or pass through the state. Traffic may originate or terminate on Class I or short-line railroads. Traffic moving through the state (neither originating nor terminating in Washington State) is primarily carried by the Class I railroads.

Tracking freight rail traffic

Freight rail traffic and commodity transport is tracked in different ways. In Washington State, Class I railroads (BNSF and UP) need to file annual reports with the Utilities and Transportation Commission (UTC) (Washington State Legislature 2018) (UTC 2019b). The annual reports include a table listing the number of carloads and tons carried broken down into originating, terminating, other, and total moves. The carloads and tonnage are classified by Standard Transportation Commodity Code (STCC) codes (Railinc 2019).

STCC codes are unique seven-digit codes that are used to classify commodities (cargo) (Railinc 2019). The first two digits identify the major industry group of the commodity, as shown in Table 3. Note that there are some group numbers in the table that appear to be missing. This is not an error. This is because the industry has chosen by convention to use these specific numbers.

Table 3: Standard Transportation Commodity Code Major Industry Group Numbers

Group	Description
01	Farm Products
08	Forest Products
09	Fresh Fish or Other Marine Products
10	Metallic Ores
11	Coal

[14] WSDOT 2014.

Group	Description
13	Crude Petroleum, Natural Gas, or Gasoline
14	Nonmetallic Minerals; except Fuels
19	Ordnance or Accessories
20	Food or Kindred Products
21	Tobacco Products; except Insecticides (see Group 28)
22	Textile Mill Products
23	Apparel or Other Finished Textile Products or Knit Apparel
24	Lumber or Wood Products; except Furniture (see Group 25)
25	Furniture or Fixtures
26	Pulp, Paper, or Allied Products
27	Printed Matter
28	Chemicals or Allied Products
29	Petroleum or Coal Products
30	Rubber or Miscellaneous Plastics Products
31	Leather or Leather Products
32	Clay, Concrete, Glass, or Stone Products
33	Primary Metal Products, including Galvanized; except Coating, Allied Processing (see Group 34)
34	Fabricated Metal Products; except Ordnance (see Groups 19, 35, 36, or 37)
35	Machinery; except Electrical (see Group 36)
36	Electrical Machinery, Equipment, or Supplies
37	Transportation Equipment
38	Instruments, Photographic Goods, Optical Goods, Watches, or Clocks
39	Miscellaneous Products of Manufacturing
40	Waste or Scrap Materials not Identified by Producing Industry
41	Miscellaneous Freight Shipments
42	Containers, Carriers, or Devices, Shipping, Returned Empty
43	Mail, Express, or Other Contract Traffic
44	Freight Forwarder Traffic
45	Shipper Association or Similar Traffic
46	Miscellaneous Mixed Shipments
47	Small Packaged Freight Shipments
48	Hazardous Wastes
49	Hazardous Materials
50	Bulk Commodity Shipments in Boxcars

The following three digits of the STCC codes indicate subgroups of the major industry group, and the final two digits specifically identify the particular chemical or material. For example, STCC code “29113” indicates: petroleum or coal product (29) - distillate fuel oil (113). Within that category, “2911326” refers to No. 1 Fuel Oil, “2911327” refers to No. 2 Fuel Oil, and “2911329” refers to No. 4 Fuel Oil.

The STCC numbering system allows for accurate tracking of specific substances by avoiding confusion between different names used for the same substance. For example, the substance "ethanol" is also called "ethyl alcohol," "propylene dichloride" is also called "1,2-dichloropropane," and "sodium hydroxide" is often referred to as "caustic soda." Hazardous substances with similar names have very different properties. The use of a numbering system also reduces the amount of characters required. STCC codes are also used in the Surface Transportation Board (STB) Waybills that shippers and carriers use to track specific shipments in train cars.[15]

These data are also used to track movements within different geographic regions and throughout the nation as a whole. The identification of regions is based on groups of counties as established by the U.S. Bureau of Economic Analysis (BEA). For example, some of the BEAs in Washington State include:

- BEA 86: Yakima, Benton, Franklin, Walla Walla, and Columbia
- BEA 93: Garfield and Asotin Counties
- BEA 131: Wahkiakum, Cowlitz, Clark, Skamania, and Klickitat Counties
- BEA 152: Whatcom, Skagit, San Juan Island, Snohomish, King, Kitsap, Clallam, Jefferson, Grays Harbor, Mason, Thurston, Pierce, Pacific, Lewis, and Kittitas Counties
- BEA 157: Ferry, Stevens, Lincoln, Pend Oreille, Spokane, and Whitman
- BEA 177: Okanogan, Chelan, Douglas, Grant, and Adams Counties

[15] For more information about waybills, see Chapter 6.

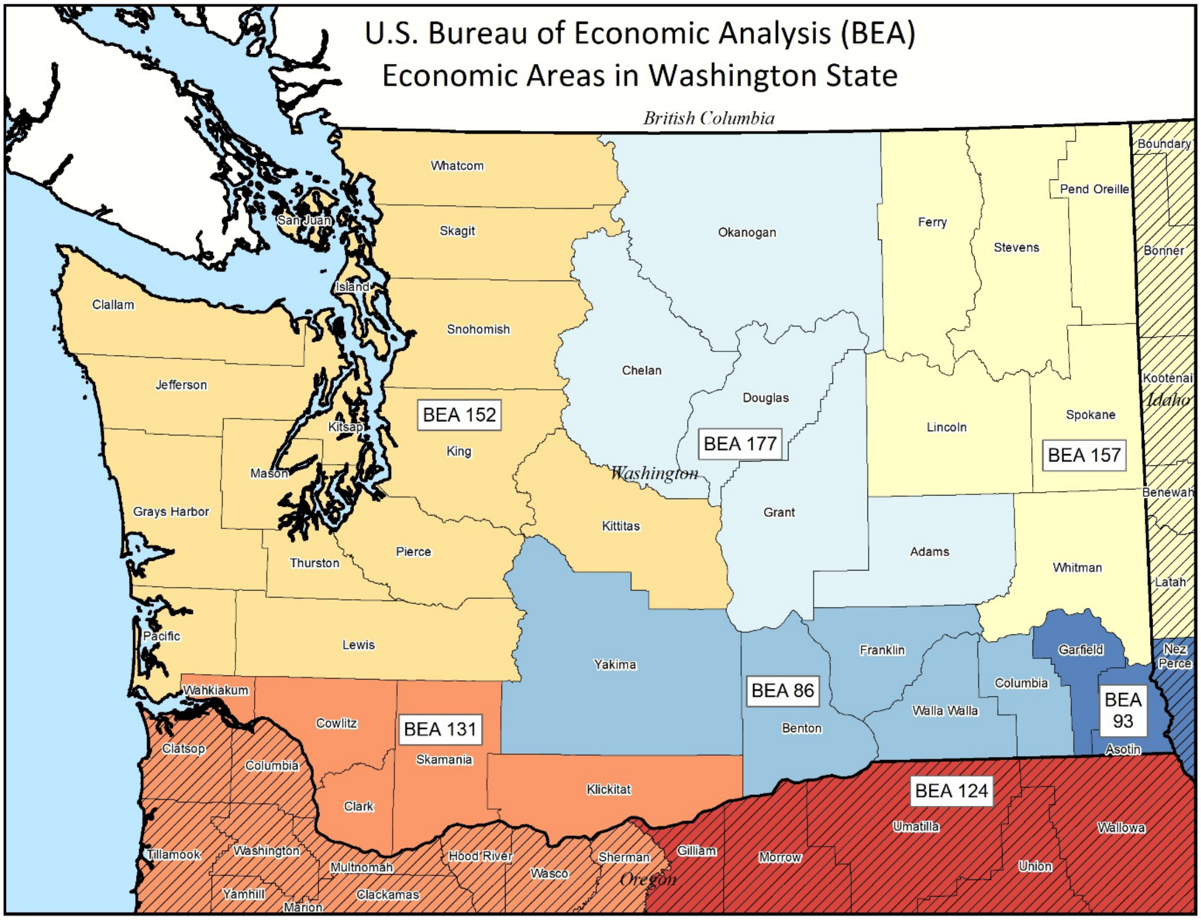

Figure 5: U.S. Bureau of Economic Analysis (BEA) Economic Areas in Washington State[16]

These data can also be used to track patterns of rail traffic and the movement of different types of commodities, including hazardous materials that may cause health and safety issues or environmental effects in the event of a rail accident.

Past and current hazardous material rail traffic in Washington State

From 2008 through 2017, the annual volume of traffic originating on Class I railroads in Washington State averaged approximately 790,000 carloads per year. Traffic ranged from highs of 865,000 carloads in 2008 and 870,000 carloads in 2012, to a low of 670,000 carloads in 2009, at the height of the recession (data from Surface Transportation Board; used with permission).

As described above, commodities are grouped into 2-digit STCC codes. These commodity codes were categorized as hazardous and non-hazardous. The four STCC codes included in the hazardous category were:

[16] Map created based on data from US BEA, "BEA Economic Areas, Western United States, November 2004."

- STCC 13: Crude Petroleum, Natural Gas and Natural Gasoline
- STCC 28: Chemicals and Allied Products
- STCC 29: Petroleum and Coal Products
- STCC 48: Waste, Hazardous

Based on these broad categories, the number of hazardous commodity carloads originating in Washington State averaged approximately 27,100 per year from 2008 through 2017, and ranged from a low of 21,600 to a high of 30,100. In each of the three most recent years (2015, 2016, and 2017), hazardous carload originations ranged from approximately 29,000 to 30,100. Hazardous commodities accounted for 3.8 percent of total originating carloads in 2017, up from 3.0 percent in 2008 (Figure 6 and Table 4) (data from Surface Transportation Board; used with permission).

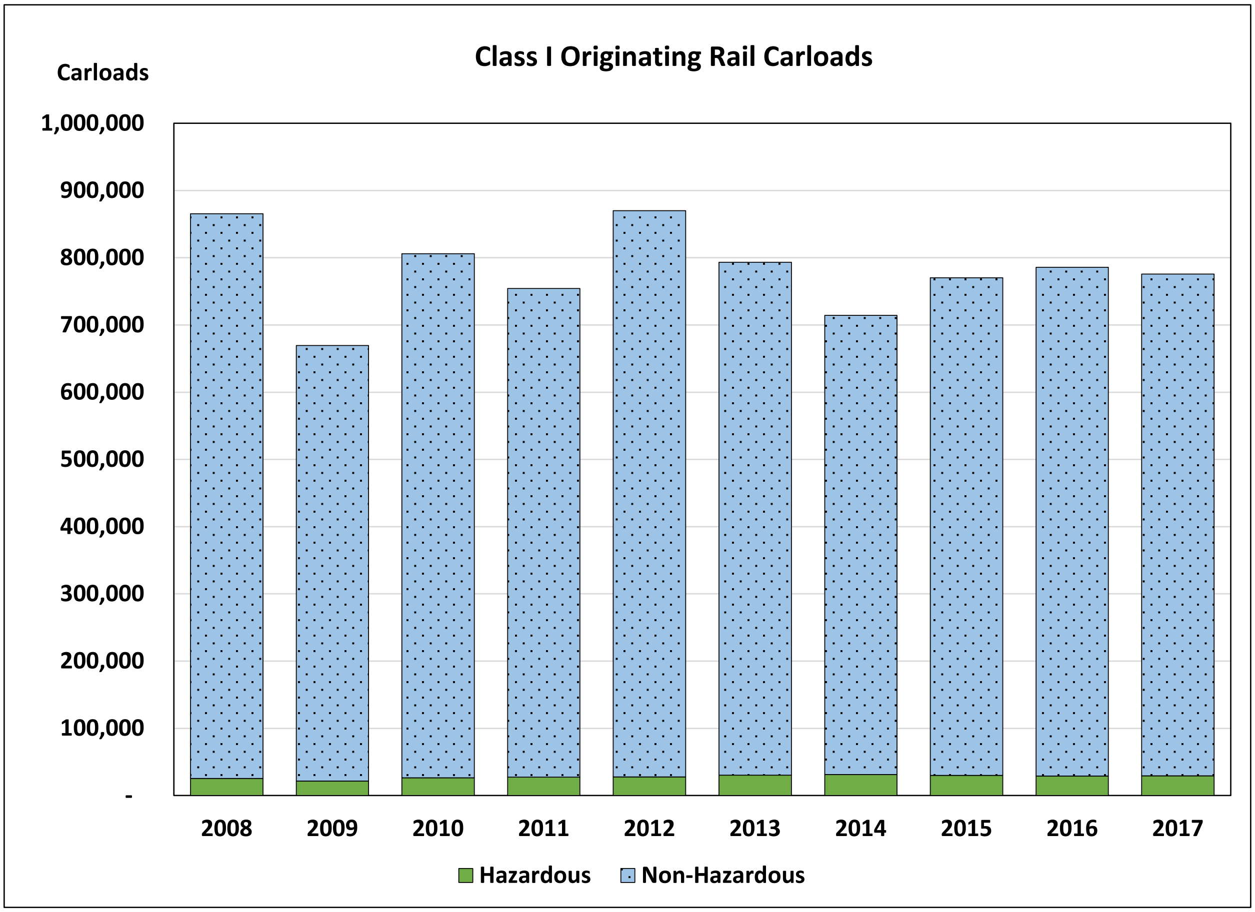

Figure 6: Class I Originating Carload Traffic (2008–2017)[17]

[17] Graphic created by Environmental Research Consulting based on data from Surface Transportation Board. Used with permission.

Table 4: Class I Railroad Carloads Originating in Washington State by Type of Materials (2008–2017)[18]

Year	Crude Petroleum [19]	Chemicals	Petroleum Products	Hazardous Waste	Total Hazardous	Total Non-Hazardous	Total
2008	0	8,005	16,673	850	**25,528**	**839,788**	**865,316**
2009	13	6,780	14,249	518	**21,560**	**647,954**	**669,514**
2010	0	9,912	16,111	456	**26,479**	**779,404**	**805,883**
2011	4	11,356	15,026	894	**27,280**	**727,028**	**754,308**
2012	166	12,632	14,534	409	**27,741**	**842,273**	**870,014**
2013	131	13,831	16,086	174	**30,222**	**762,905**	**793,127**
2014	4	13,783	16,877	620	**31,284**	**683,130**	**714,414**
2015	0	14,225	15,558	309	**30,092**	**740,198**	**770,290**
2016	0	10,895	17,775	261	**28,930**	**756,942**	**785,872**
2017	175	10,790	17,797	481	**29,243**	**746,330**	**775,573**
Average	49	11,221	16,069	497	**27,836**	**752,595**	**780,431**
Minimum	0	6,780	14,249	174	**21,560**	**647,954**	**669,514**
Maximum	175	14,225	17,797	894	**31,284**	**842,273**	**870,014**

The number of hazardous commodity carloads terminating in Washington State grew from 42,100 in 2008 to 154,500 in 2017. Most of this growth occurred from 2012 through 2017. Prior to 2012, an average of 42,200 hazardous commodity carloads terminated in Washington State each year (Figure 7 and Table 5). In 2017, 10.5 percent of carloads contained hazardous commodities. The percentage of hazardous commodities peaked in 2013 at 18.8 percent (data from Surface Transportation Board; used with permission).

[18] Data from Surface Transportation Board. Used with permission.
[19] Crude oil is not produced in Washington State. Any crude oil carloads originating in Washington State are ones that have arrived from outside the state (by rail, pipeline, or tank vessel) that are shifted to other locations in the state.

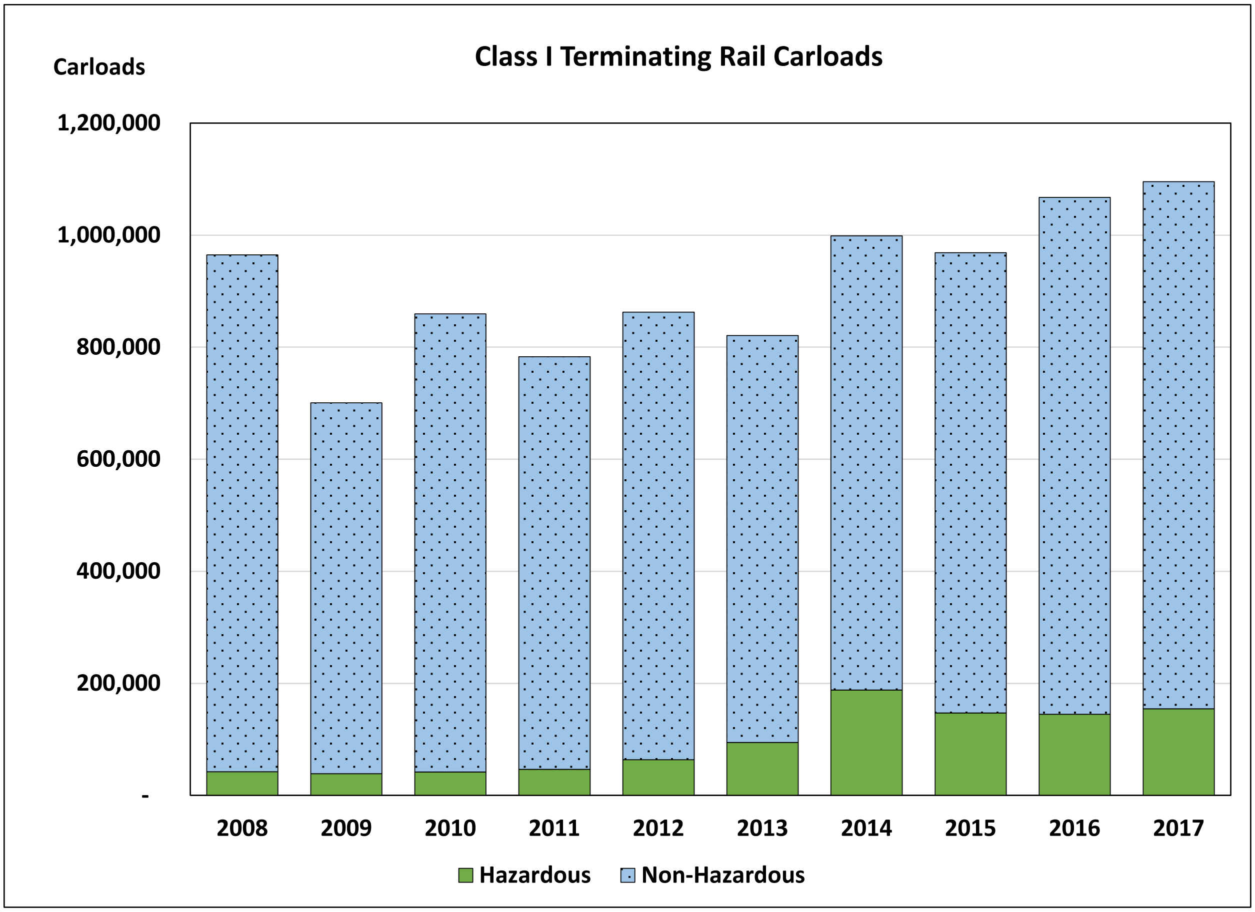

Figure 7: Class I Terminating Carload Traffic (2008–2017)[20]

[20] Graphic created by Environmental Research Consulting based on data from Surface Transportation Board. Used with permission.

Table 5: Class I Railroad Carloads Terminating in Washington State by Type of Materials (2008–2017)[21]

Year	Crude Petroleum	Chemicals	Petroleum Products	Hazardous Waste	Total Hazardous	Total Non-Hazardous	Total
2008	3	26,860	15,188	40	**42,091**	**922,521**	**964,612**
2009	0	24,942	13,884	52	**38,878**	**661,630**	**700,508**
2010	2	29,179	12,478	17	**41,676**	**817,863**	**859,539**
2011	255	33,020	13,009	34	**46,318**	**736,799**	**783,117**
2012	9,361	37,387	17,004	5	**63,757**	**798,620**	**862,377**
2013	32,548	46,335	15,548	2	**94,433**	**726,340**	**820,773**
2014	69,971	97,171	20,750	175	**188,067**	**810,753**	**998,820**
2015	80,575	43,526	22,990	53	**147,144**	**821,647**	**968,791**
2016	77,108	40,940	26,501	64	**144,613**	**922,602**	**1,067,215**
2017	80,144	43,300	31,050	17	**154,511**	**940,781**	**1,095,292**
Average	**34,997**	**42,266**	**18,840**	**46**	**96,149**	**815,956**	**912,104**
Minimum	**0**	**24,942**	**12,478**	**2**	**38,878**	**661,630**	**700,508**
Maximum	**80,575**	**97,171**	**31,050**	**175**	**188,067**	**940,781**	**1,095,292**

Most of the growth in terminating carloads of hazardous commodities was due to crude oil (STCC 13), which grew from two carloads in 2010 to more than 77, 100 in each year from 2015 through 2017. Terminating carloads of chemicals and allied products (STCC 28) grew from approximately 26,900 in 2008 to 43,400 in 2017. Terminating carloads of petroleum and coal products (STCC 29) grew from 15,200 in 2008 to nearly 31,100 in 2017.

A geographic analysis of the movements of the different hazardous commodities during the year 2016 is presented in Table 6. For 2016, the data show no originating traffic for STCC commodity 13 (Crude Petroleum or Natural Gas) or commodity 48 (Hazardous Waste). The UTC rail data for 2016 also showed no originating crude petroleum carloads (as crude oil would be coming into Washington State from either North Dakota or Canada), but did show 261 carloads of hazardous waste originating in Washington State (data from Surface Transportation Board; used with permission).[22]

According to the data, all of the rail traffic for STCC Codes 13, 28, 29, and 48 originates in the Seattle and Portland BEAs. The STCC commodity 28 traffic (Chemicals or Allied Products) is split relatively evenly between the Seattle and Portland BEAs. All of the STCC commodity 29 traffic (Petroleum or Coal Products) originates in the Seattle BEA.

[21] Data from Surface Transportation Board.
[22] The omission of this traffic in the Waybill Sample data could be due to anonymity constraints.

Table 6: Carloads of Hazardous Commodities Originating in Specific Geographies within Washington State and Parts of Oregon (2016)[23]

STCC	Description[24]	Spokane WA	Portland OR	Pendleton OR-WA	Tri-Cities WA	Seattle WA	Total
28122	**Sodium Alkalies**	0	1,200	0	0	0	**1,200**
28181	**Miscellaneous Acyclic Organic Chemicals**	0	1,960	0	0	0	**1,960**
28199	**Industrial Inorganic Chemicals, NEC**	0	512	0	0	0	**512**
28211	**Plastic Materials, Synthetic Resins**	0	0	0	0	680	**680**
28999	**Chemical Products, NEC**	0	0	0	0	3,240	**3,240**
29113	**Distillate Fuel Oil**	0	0	0	0	1,308	**1,308**
29121	**Liquefied Gases, Coal or Petroleum**	0	0	0	0	3,164	**3,164**
	Total Chemicals	**0**	**3,672**	**0**	**0**	**3,920**	**7,592**
	Total Petroleum Products	0	0	0	0	**4,472**	**4,472**

There are nearly seven times as many carloads of hazardous commodities coming into Washington State than originate in the state. As shown in Table 7, in 2016, all of the terminating rail traffic of STCC commodity 13 (Crude Petroleum or Natural Gas) was crude petroleum rather than natural gas.

A majority of the traffic in STCC commodity 28 (Chemicals or Allied Products) was in commodity 28123 (Sodium Compounds, primarily soda ash) and 28125 (Potassium Compounds, primarily potash). Other commodities moved in large volumes in STCC commodity 28 include 28182 (Alcohols), 28211 (Plastic Materials or Synthetic Resins), and 28198 (Anhydrous Ammonia). The remaining commodities accounted for 20 percent of the total, or approximately 18,200 carloads.

In the STCC commodity 29 group, more than 77 percent of terminating carloads was made up of STCC commodity 29121 (Liquefied Gases, Coal or Petroleum). Most of the remainder was STCC commodity 29116 (Asphalt Pitches or Tars, from Petroleum). The Seattle and Portland BEAs accounted for 87 percent of terminating carloads of petroleum and gas products (STCC 29) in 2016. Smaller amounts also terminated in the Spokane, Richland, and Pendleton BEAs.

All of the crude oil traffic (STCC 13) terminated in the Seattle BEA, where all five oil refineries in the state are located.

A majority of the chemical traffic (STCC 28) terminated in the Portland BEA, where export terminals for soda ash and potash are located. The remaining traffic is split among the Seattle, Portland, Richland, and Spokane BEAs.

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[23] Data from Surface Transportation Board. Used with permission.

[24] "NEC" means "not elsewhere classified," that is, a commodity that does not fit into another category in that group.

Table 7: Carloads of Hazardous Commodities Terminating in Specific Geographies within Washington State and Parts of Oregon (2016)[25]

STCC	Description	Spokane WA	Portland OR	Pendleton OR	Tri-Cities WA	Seattle WA	Total
13111	Crude Petroleum	0	0	0	0	74,118	**74,118**
28122	Sodium Alkalies	600	0	0	200	200	**1,000**
28123	Sodium Compounds	0	33,780	0	0	1,120	**34,900**
28125	Potassium Compounds	0	15,303	0	992	0	**16,295**
28126	Barium, Calcium, Magnesium, Strontium	880	440	0	280	200	**1,800**
28181	Miscellaneous Acyclic Organic Chemical	336	1,540	0	1,431	0	**3,307**
28184	Alcohols	0	4,368	0	1,932	7,160	**13,460**
28191	Ammonia, Ammonium Compounds	656	400	0	480	0	**1,536**
28193	Sulfuric Acid	0	880	0	0	0	**880**
28198	Anhydrous Ammonia	956	0	0	2,720	0	**3,676**
28199	Industrial Inorganic Chemicals, NEC	0	672	0	0	0	**672**
28211	Plastic Materials or Synthetic Resins	0	3,440	0	880	1,640	**5,960**
28419	Soap or Other Detergents	0	0	0	0	480	**480**
28712	Superphosphate	0	160	0	0	0	**160**
28713	Ammoniating Fertilizer Solution	236	0	0	603	0	**839**
28714	Miscellaneous Fertilizer Compounds	800	0	0	400	0	**1,200**
28994	Fatty Acids	0	640	0	0	0	**640**
28999	Chemical Products, NEC	0	4,160	0	0	1,480	**5,640**
29114	Petroleum Lubricating or Similar Oils	0	480	0	0	240	**720**
29116	Asphalt Pitches or Tars, from Petroleum	1,136	3,460	0	0	1,832	**6,428**
29121	Liquefied Gases, Coal or Petroleum	780	5,316	316	1,916	15,700	**24,028**
	Total Crude	0	0	0	0	74,118	**74,118**
	Total Chemicals	**4,464**	**65,783**	**0**	**9,918**	**12,280**	**92,445**
	Total Petroleum Products	**1,916**	**9,256**	**316**	**1,916**	**17,772**	**31,176**

Crude oil transportation by rail in Washington State

About 450 million barrels (bbl) of different kinds of oil (crude oil, refined petroleum products, waste oil, and biological oils) are transported through Washington State each year by tank vessel, pipeline, and, in recent years, also by rail (Figure 8) (Washington State Dept. of Ecology 2018d). About 45 percent of this oil is crude oil going to Washington State's refineries. Historically, crude oil was transported to the refineries largely by tank vessel, with some oil being brought in

[25] Data from Surface Transportation Board.

by pipeline from Canada. In 2012, crude oil was transported into the state for the first time by rail.

About 200 million barrels of crude oil are transported into Washington State each year for refining at one of the state's five oil refineries (Table 8). There is also a biofuel refinery, REG Grays Harbor, that produces 4,580 bbl/day of biodiesel from vegetable oils (Etkin et al. 2015).

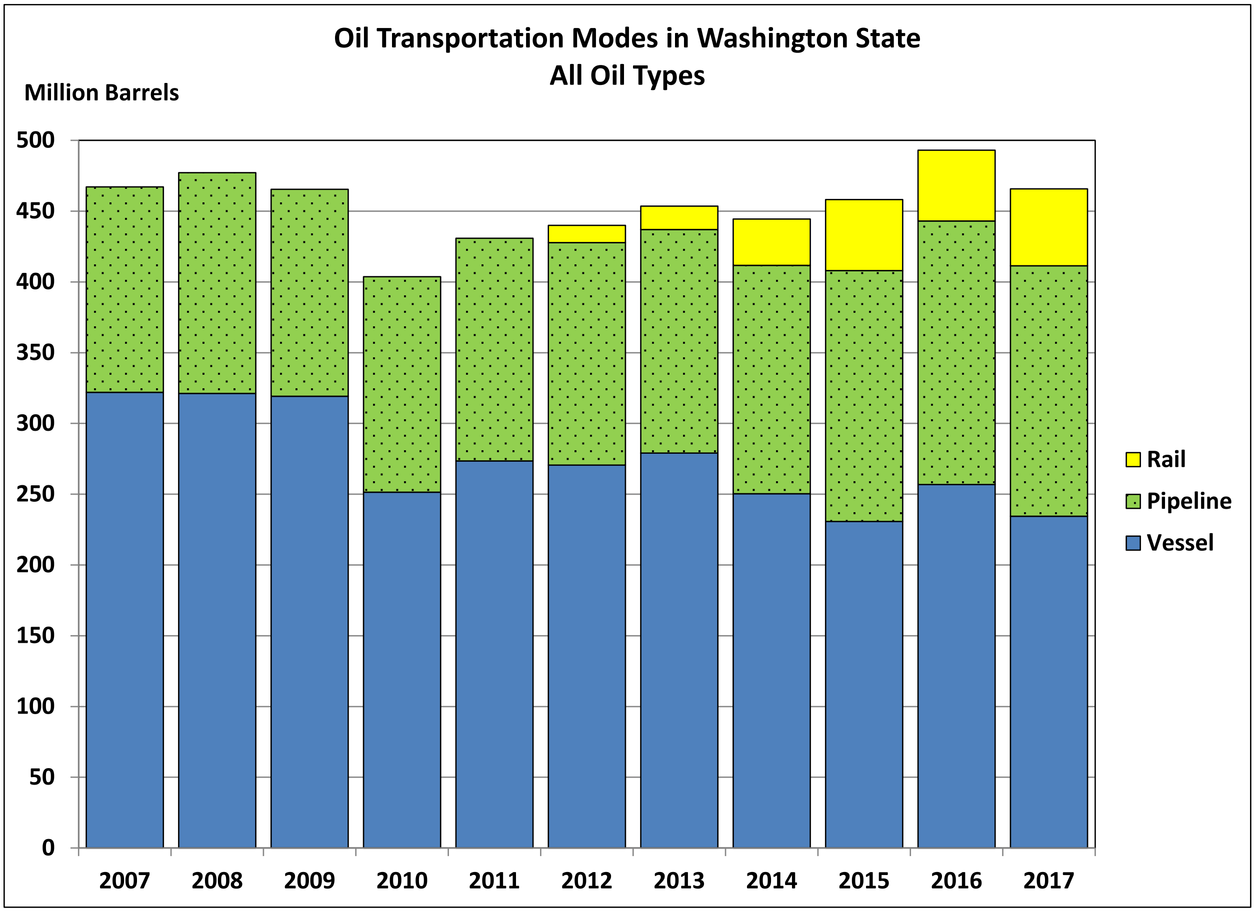

Figure 8: Oil Transportation Modes in Washington State (2007–2017)[26]

Table 8: Washington State Crude Oil Refining Capacity by Refinery[27]

Oil Refinery	Location	Refining Capacity
BP Cherry Point	Blaine	225,000 bbl/day
Shell Anacortes	Anacortes	145,000 bbl/day
Marathon Anacortes	Anacortes	108,000 bbl/day
Conoco Phillips	Ferndale	105,000 bbl/day
US Oil	Tacoma	35,000 bbl/day

[26] All types of oil cargo, including crude oil, petroleum, gasoline, diesel oil, fuel oil, oil sludge, oil refuse, biological oils (vegetables oils), and blends. Data from Washington State Department of Ecology Publication 17-08-014, June 2018. Graphic created by Environmental Research Consulting. Used with permission.
[27] Etkin et al. 2015.

In 2018, the vast majority — 93 percent — of the crude oil brought into Washington State by rail was light crude oil (primarily Bakken crude) (Figure 9). In 2018, 57,141,234 bbl of light crude was transported by rail into Washington State. This represented 93 percent of all crude oil transported into the state by rail. In addition, 3,178,385 bbl of medium crude oil (5 percent of the total crude) and 1,002,284 bbl of heavy crude (2 percent of the total crude) were transported by rail into Washington State. According to Ecology's data (Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a), light crude came from North Dakota and Saskatchewan, Canada, and medium and heavy crude came from Alberta, Canada. Diluted bitumen may be considered to be either medium or heavy crude. No information was available on the amount of diluted bitumen that was transported into Washington State in 2018.

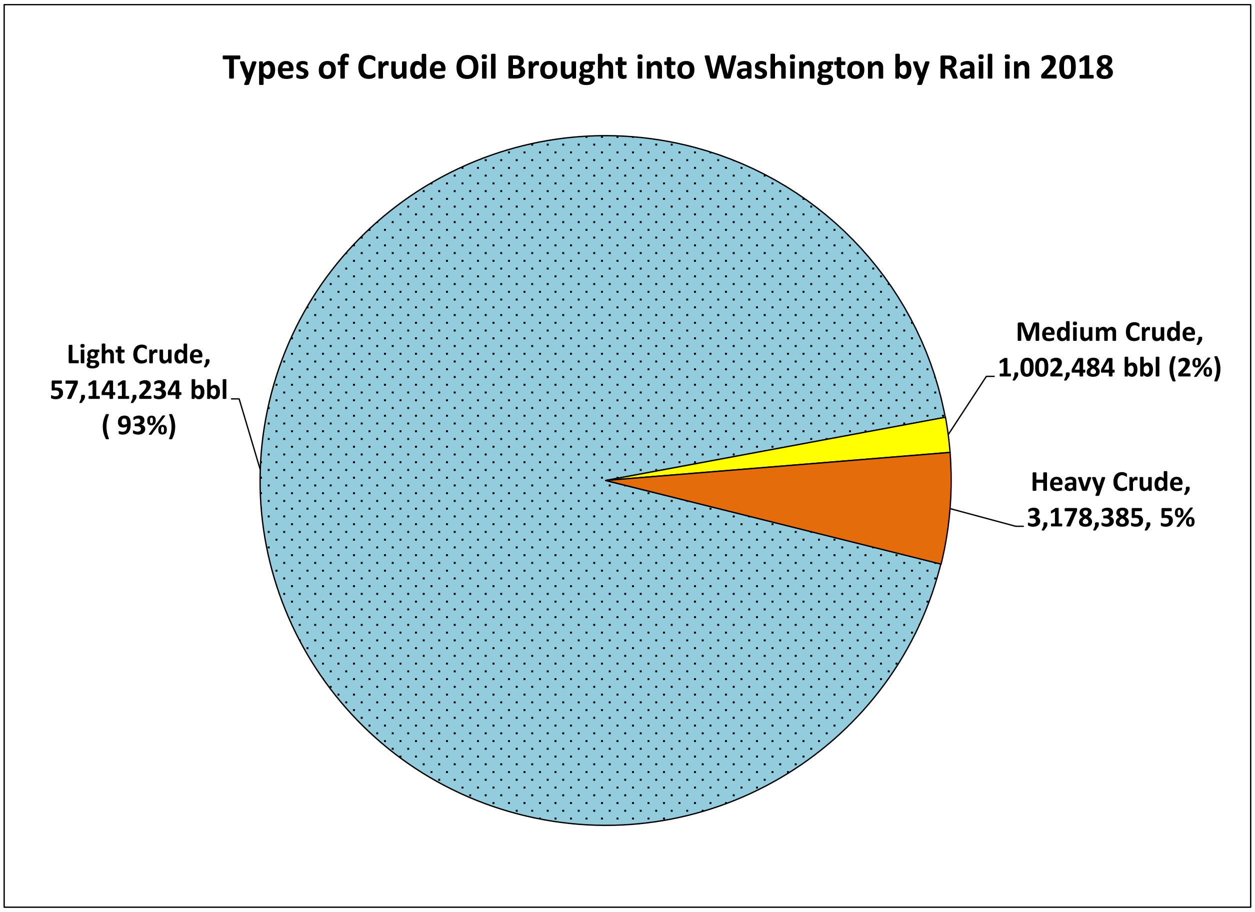

Figure 9: Types of Crude Oil Transported into Washington State by Rail (2018)[28]

Over the course of a year, there are monthly variations in CBR transport, depending on the needs of the refineries, production patterns, and rail capacity issues (Figure 10 and Table 9). The data in Table 10 represent the classifications of crude oil types that Ecology uses in its quarterly reports (Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a).

[28] Graphic created by Environmental Research Consulting based on data in Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019. Used with permission.

According to Ecology's definitions, light crude is a crude oil that has an °API gravity of 31.2–50. A medium crude is a crude oil that has an °API gravity of 22.3–31.1. A heavy crude is a crude oil that has an °API gravity of 10–22.2. An extra heavy crude oil is a crude oil that has an °API gravity of 0–9.9. °API gravity is a measure of the density of an oil used by the petroleum industry. °API is inversely related to density: The higher the °API, the less dense the oil. An oil with an °API of less than 10 is heavier than water.[29]

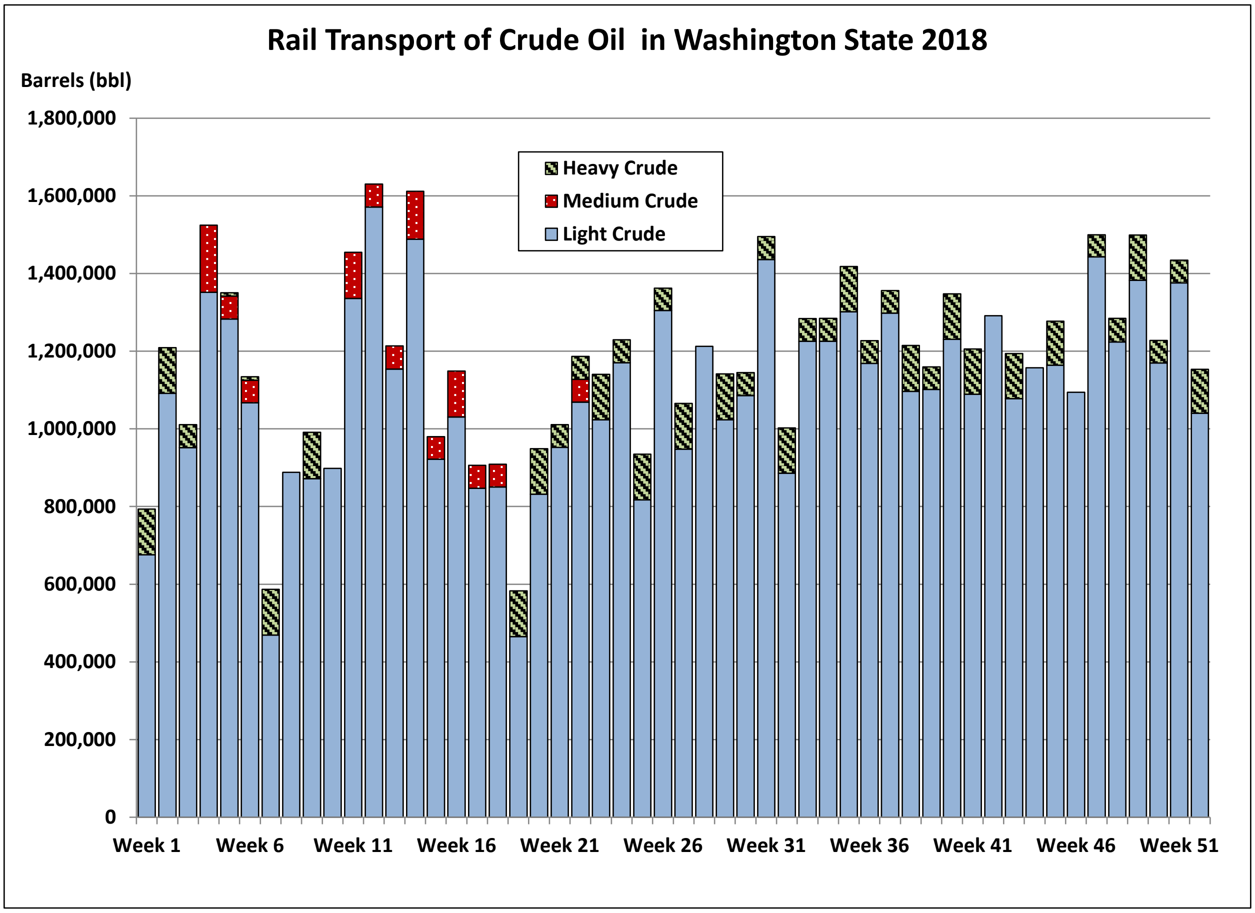

Figure 10: Rail Transport of Crude Oil in Washington State (2018)[30]

[29] There are detailed descriptions of crude oil types and the properties of crude and other types of oil in Chapter 6.
[30] Graphic created by Environmental Research Consulting based on data in Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019. Used with permission.

Table 9: Summary of Rail Transport of Crude Oil into Washington State by Type of Crude Oil (2018)[31]

Statistic	Light Crude (bbl)	Medium Crude (bbl)	Heavy Crude (bbl)	Total (bbl)	TOTAL Cars[32]	Unit Trains[33]
Total 2018	55,136,266	1,002,484	3,178,385	59,317,135	**91,257**	**773**
Monthly Average	1,060,313	19,279	61,123	1,140,714	**1,755**	**15**
Monthly Minimum	465,260	0	0	583,459	**898**	**8**
Monthly Maximum	1,453,298	172,809	119,350	1,512,413	**2,327**	**20**

Due to the refinery destinations of the CBR trains, there are different routes taken, and thus different numbers of trains going through different segments, as shown in the map in Figure 11 and Table 10. Routes 6 and 7, as shown in the map in Figure 12, are generally used for the transport of empty cars back to the originating production areas.

Figure 11: Crude Oil Rail Transport Route Segments[34]

[31] Based on data in Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a.
[32] Given DOT weight restrictions, railroad tank cars transporting oil are typically not loaded with more than 650 barrels.
[33] Based on 118-car train.
[34] Source: Washington State Dept. of Ecology 2018a.

Table 10: Annual Rail Transport of Crude Oil in Washington State by Route and Type of Crude Oil (2018)[35]

Route Segment	Light Crude Tank Cars	Medium Crude Tank Cars	Heavy Crude Tank Cars	Total Crude Tank Cars	Light Crude Bbl	Medium Crude Bbl	Heavy Crude Bbl	Total Crude Bbl
Route 1A	78,187	0	0	**78,187**	53,167,160	0	0	**53,167,160**
Route 1B	0	1,469	4,543	**6,012**	0	998,920	3,089,240	**4,088,160**
Route 2	78,187	0	0	**78,187**	53,167,160	0	0	**53,167,160**
Route 3	78,187	1,469	4,543	**84,199**	53,167,160	998,920	3,089,240	**57,255,320**
Route 4	65,631	0	214	**65,845**	44,629,080	0	145,520	**44,774,600**
Route 5	40,778	0	214	**40,992**	27,729,040	0	145,520	**27,874,560**

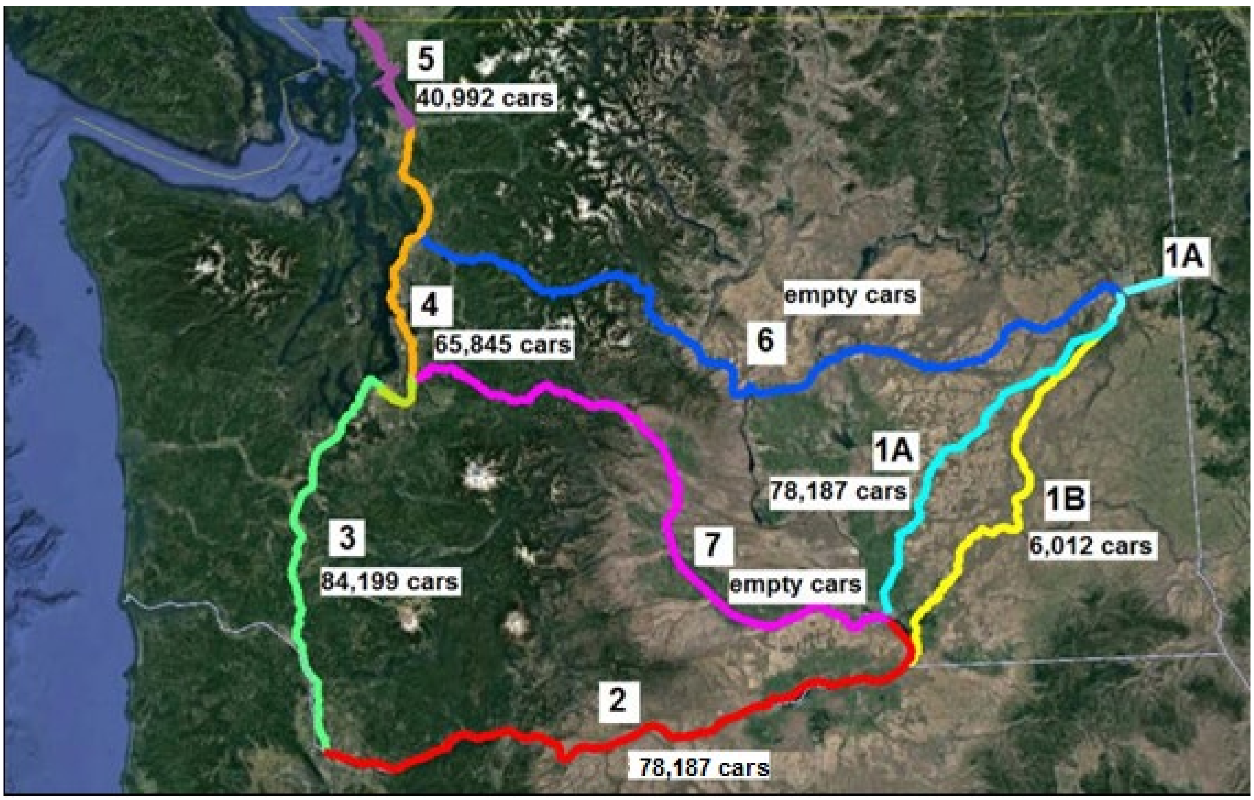

Figure 12: Annual Crude Oil Tank Cars by Route Segment (2018)[36]

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[35] Based on data in Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a.
[36] Map created by Environmental Research Consulting based on the data in: Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019. Used with permission.

Movement of crude oil through Washington to and from other states

During 2011 through 2015, BNSF ran CBR trains from Spokane to Pasco to Wishram, which turned south to head to California. At the peak of the CBR surge in 2015, there was about one train a day running south on this route.

These trains turn south at Wishram and run on BNSF’s track through Oregon and into Northern California at a station named Keddie. At Keddie, the trains enter Union Pacific (UP) tracks and run on UP tracks to Stockton, California, where the trains return to BNSF tracks.

BNSF occasionally uses the route from Spokane to Wishram for moving oil from the Upper Midwestern U.S. to California. Currently, there are very few trains operating in this corridor, because the destination in California is being served by oil sourced from New Mexico and West Texas. If the origin of this oil changes to upper Midwest locations such as North Dakota, train volumes through Washington may increase. It is unknown whether the origin of this oil will change in the future.

Since UP serves US Oil in Tacoma with trains from Canada, there are trains that come into Washington near Spokane on UP track, run to Hinkle on UP track, stay in Oregon to Portland, then turn back north at Portland and re-enter BNSF’s tracks just south of Vancouver, Washington. This currently happens once or twice a month.

BNSF also moves CBR trains from the eastside of Washington, along the northern side of the Columbia river, and west towards Vancouver and then south to the Zenith Energy terminal in Portland.

Potential changes in crude oil transport by rail patterns

Nationwide, there have been considerable changes in crude-by-rail (CBR) transport over the last decade. CBR began in 2010 with about one train every other day to a maximum of about 17 trains per day throughout the U.S. in October 2014. CBR decreased rapidly in January 2015, then increased slightly only to decrease rapidly in January 2016. It began to rise again towards the end of 2017 (Figure 13).

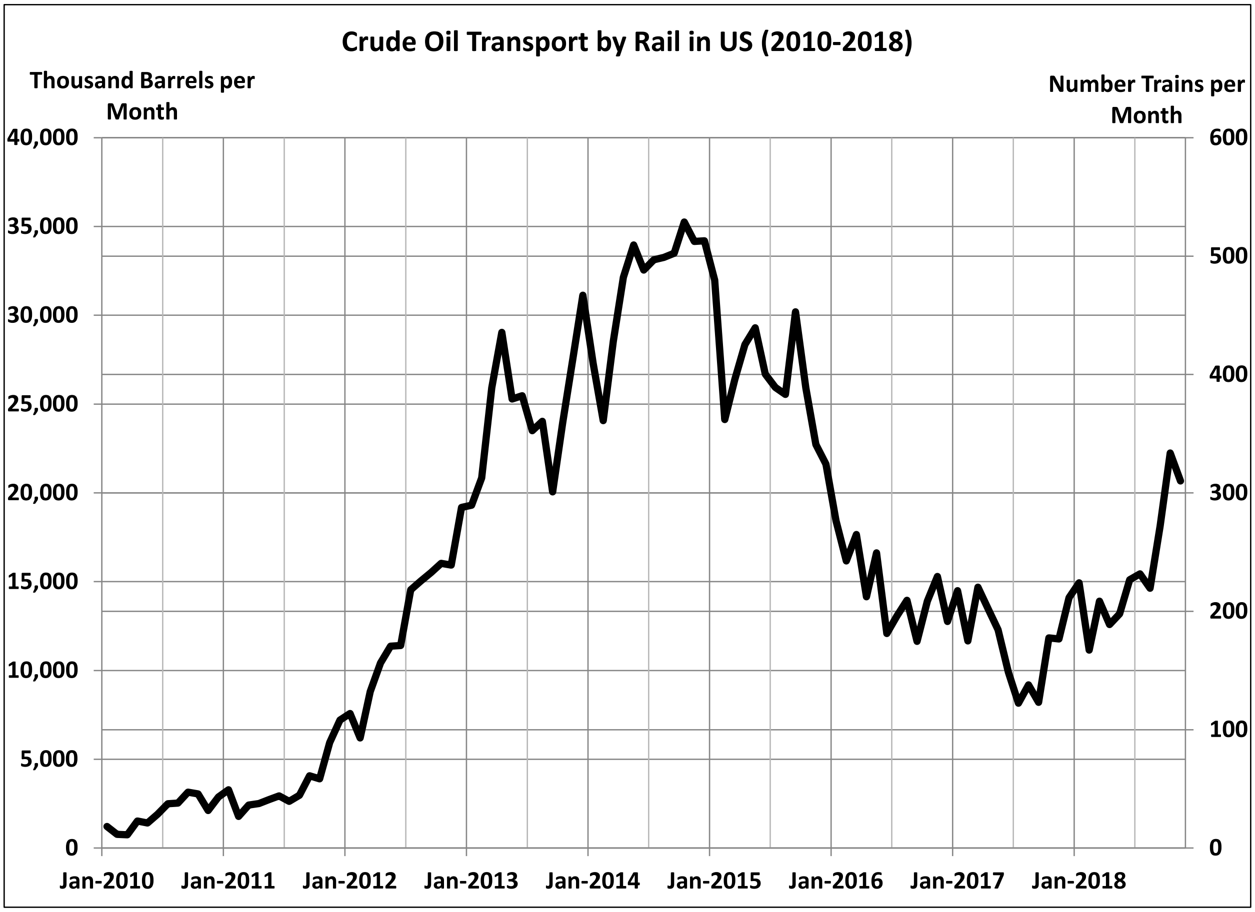

Figure 13: Crude Oil Transport by Rail in U.S., 2010–2018[37]

CBR transport to the West Coast (defined as Petroleum Administration for Defense District 5, or PADD 5), which would include trains to refineries in both Washington State and California, experienced a brief reduction in early 2015, but then returned back to the average levels of 2014 (Figure 14). Although there are significant monthly variations, the overall annual rail transport to the West Coast has not changed substantially since 2016 (Figure 15).

[37] Data from US Energy Information Administration (https://www.eia.gov/dnav/pet/pet_move_railNA_a_EPC0_RAIL_mbbl_a.htm)

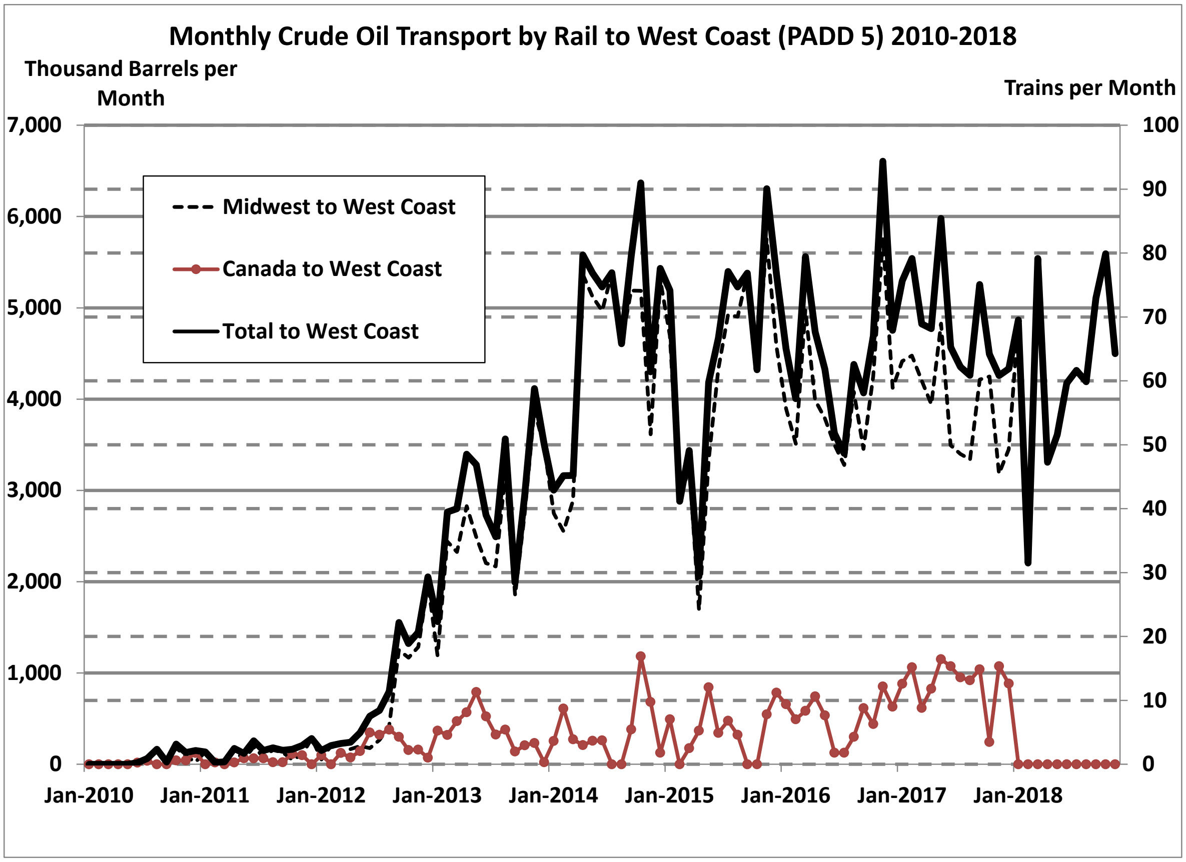

Figure 14: Monthly Crude Oil Transport by Rail to West Coast (PADD 5), 2010–2018[38]

[38] Graph created by Environmental Research Consulting based on data from US Energy Information Administration. Used with permission.

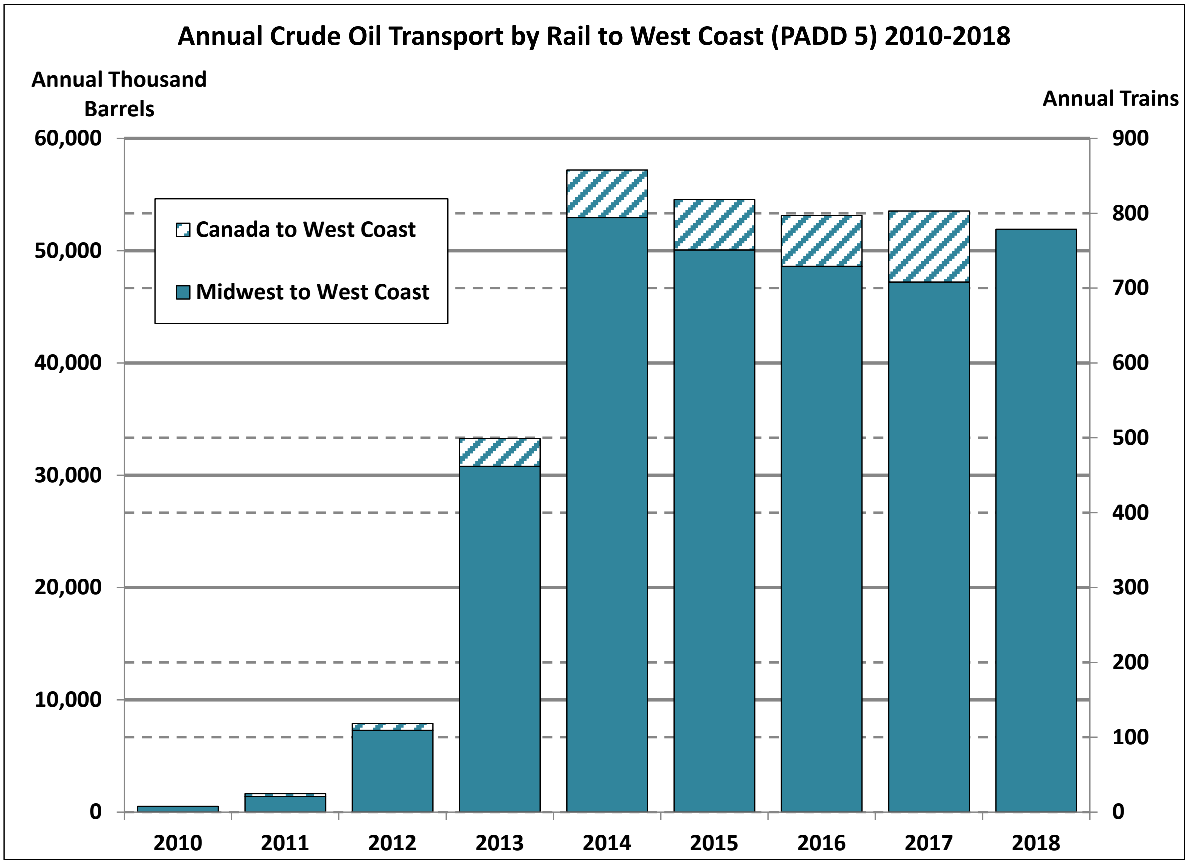

Figure 15: Annual Crude Oil Transport by Rail to West Coast (PADD 5), 2010–2018[39]

The patterns of crude oil transport by rail throughout the U.S. change based on two primary factors: the relatively volatile market price of crude oil and the availability (or unavailability) of pipelines for transport to refineries.

Shipping oil by rail is generally more expensive than shipping it by pipeline. For example, it costs about $10 to $15 per barrel (bbl) to ship oil by rail from North Dakota to the Gulf Coast or Atlantic Coast, compared with about $5 per bbl by pipeline (Frittelli et al. 2014). However, pipelines are not always available or not able to accommodate increased production capacities. There has been stalled development of several pipeline projects (e.g., Keystone XL and Trans Mountain) due to environmental opposition and legal delays. At other times, there are temporary diversions of oil shipments, such as occurred in 2017 when Hurricane Harvey caused the shutdown of refineries in Texas. In that case, the oil was diverted by rail through New York State to refineries on the East Coast.

The economic issues of oil shipments become less important when the price of oil increases. The oil market changes based on a large number of complex factors, including the production of shale oil in the U.S., which has made the U.S. the world's largest crude oil producer, surpassing

[39] Graph created by Environmental Research Consulting based on data from U.S. Energy Information Administration.

Middle Eastern countries. There are also political factors that affect world oil production and consequently price.

Within Washington State, there have already been a series of changes related to potential CBR transport with the withdrawal of some of the proposed CBR facility development projects. At the time of the *2014 Marine & Rail Oil Transportation Study* (Etkin et al. 2015), there were three Washington State refineries receiving crude by rail (BP Cherry Point, Tesoro Anacortes, and US Oil Tacoma). Two more were seeking approval to receive crude oil by rail — Phillips 66 and Shell Anacortes (Figure 16). The Phillips 66 facility proceeded with its project and currently receives 30,000 bbl/day of crude by rail. The Shell Anacortes Rail Unloading Facility opted to withdraw its CBR application in late 2016, attributing its decision to economic concerns about CBR transport. The status in the first half of 2019 is shown in Figure 17.

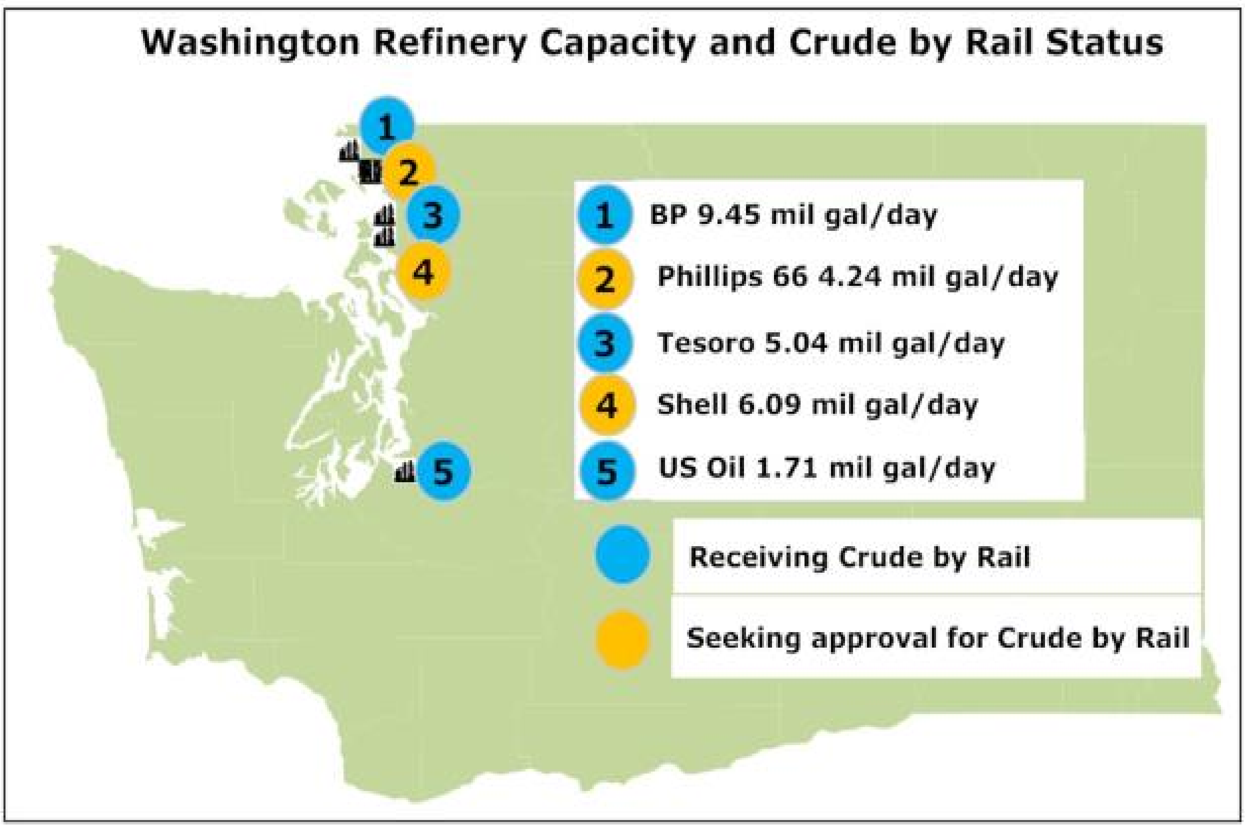

Figure 16: Washington State Refinery Capacity and CBR Status in 2015[40]

[40] Etkin et al. 2015.

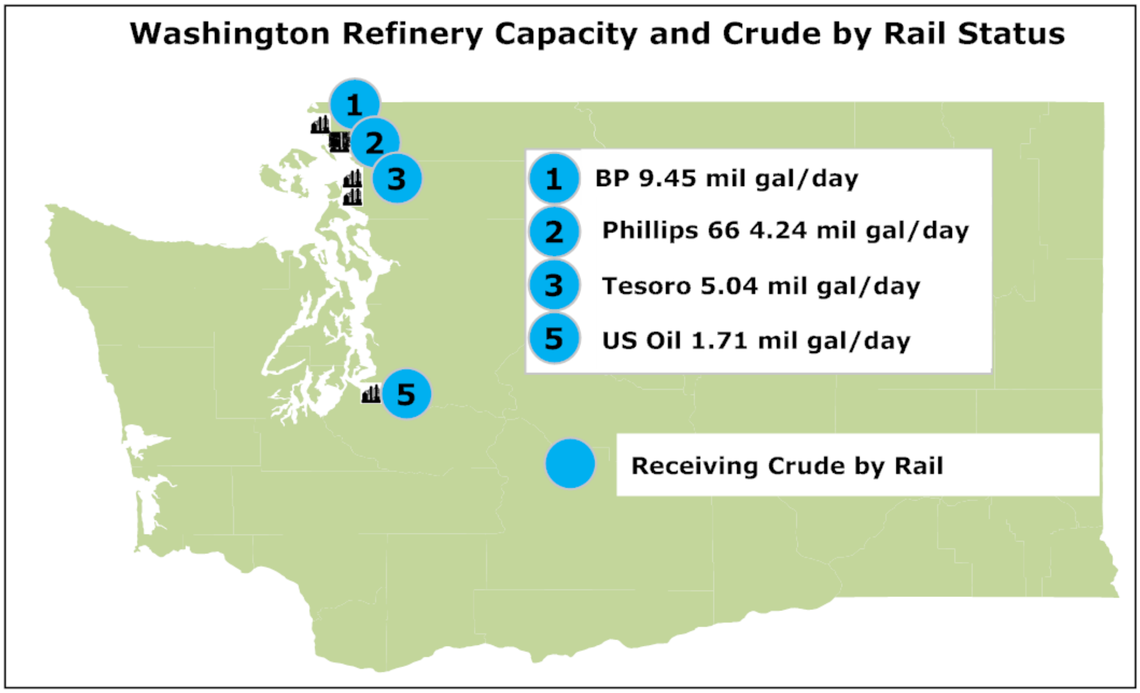

Figure 17: Washington State Refinery Capacity and CBR Status in 2019[41]

In addition to refineries receiving CBR shipments, there were also three storage facilities or terminals that were proposing changes to accommodate CBR shipments as shown in Figure 18. The largest of these proposed facilities was the Vancouver Energy terminal in Vancouver, Washington. The permit for this facility, which would have received four unit trains per day, was ultimately rejected by Washington State Governor Jay Inslee on the advice of the Energy Facility Site Evaluation Council (EFSEC) in January 2018. This decision, along with the withdrawal of the Shell Anacortes Rail Unloading Facility plan, significantly changed the potential number of CBR trains in Washington. However, there may be future proposals for development of facilities to receive CBR shipments, or a shift in the way in which existing refineries receive their oil shipments. This could potentially affect CBR traffic in the future.

Puget Sound refineries supply approximately 90 percent of the refined petroleum products consumed in Washington and Oregon. The remaining 10 percent moves by pipeline from other states, primarily Utah and Montana. The Seattle and Portland areas generate most of the demand for refined products and account for 46 percent and 25 percent, respectively.

Most of the petroleum products manufactured at Washington refineries move by pipeline (approximately 47 percent) or by tank vessel (approximately 42 percent). Of the remainder, approximately 10 percent moves by truck, and the remaining 1 to 2 percent moves by rail. The proportions of oil being moved by these different modes of transportation are projected to remain relatively stable through 2035, with little to no increase in rail volume.

[41] This figure was created by Environmental Research Consulting for this report. Used with permission. Note that Tesoro is now called Marathon Oil.

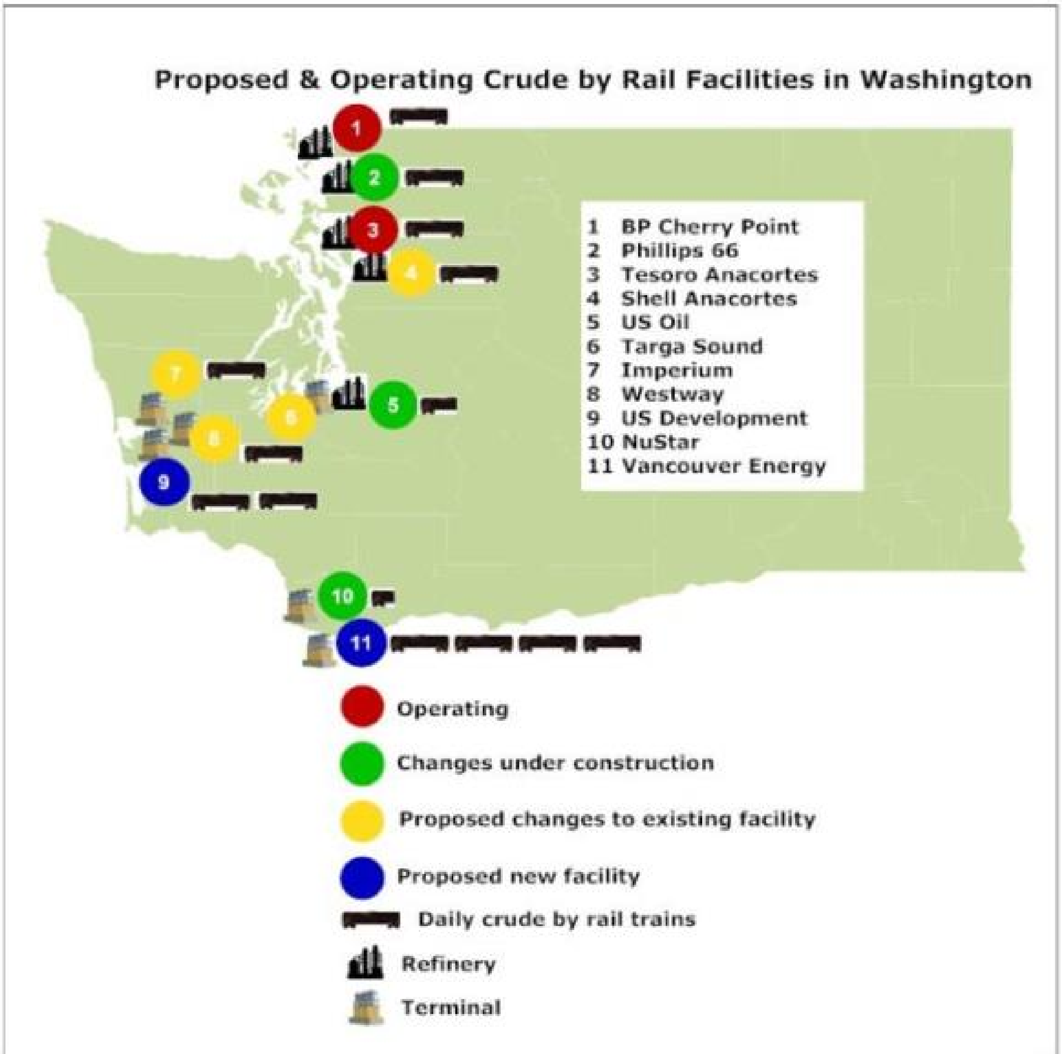

Figure 18: Proposed and Operating Crude by Rail Facilities in Washington State as of 2015[42]

Potential future changes in transport for non-oil commodities

Other liquid bulk commodities transported by rail include a variety of chemicals and fertilizers, such as caustic soda and sodium hydroxide (used in the forest products industry), benzene and toluene (used in the chemical industry), and nitrogenous fertilizers (used in the agricultural industry), among others. Assuming that no new major production facilities or end-users of these commodities move into Washington State, the volumes moving by rail are projected to grow slowly.

[42] Etkin et al. 2015. The locations on this graphic are as they were presented in the 2014 Washington State Marine & Rail Study. They were drawn for schematic purposes only and do not represent the precise geographic locations of the facilities. The refineries at Anacortes were drawn in this figure so that it was possible to see both of the refineries without overlapping the graphical elements. In reality, the two Anacortes facilities are located adjacent to one another on a peninsula into Fidalgo Bay that is approximately 2.7 miles long.

Comparison of freight rail capacity with tank vessels and trucks

Many commodities that are transported by rail, could also, in some cases, be transported by truck or by tank vessel (specifically, tank barge). The practicality of that would depend on the specific routes (origins or starting points and destinations) that the commodities need to travel. While tanker trucks and tractor-trailers would be able to travel in nearly any place that had roads, barge traffic would be limited to navigable waterways.

However, a rough comparison between freight rail cars to the numbers of barges or trucks that would be required to carry the same loads is an important consideration. The comparisons for dry and liquid cargo are shown in Table 11. As a hypothetical comparison, the numbers of tanker trucks that would be required to transport the same amount of crude oil, other hazardous materials, and non-hazardous materials that was brought into Washington state by rail in 2017 is shown in Table 12.

Table 11: Comparison of Cargo Capacities (Rail, Truck, and Tank Barge)[43]

Commodity Type	Train	Equivalent Trucks	Equivalent Tank Barges
Liquid	1 tank car	3.3 tanker trucks	0.025 tank barges
Liquid	100-car unit train	330 tanker trucks	2.5 tank barges
Liquid	120-car unit train	396 tanker trucks	3 tank barges
Dry Bulk	1 hopper car	4.4 tractor trailer trucks	0.06 dry cargo barges
Dry Bulk	100-car train (hopper cars)	440 tractor trailer trucks	6 dry cargo barges
Dry Bulk	120-car train (hopper cars)	528 tractor trailer trucks	7.2 dry cargo barges

Table 12: Hypothetical Truckloads for Rail-Transported Commodities, 2017[44]

Commodity Type	Railroad Carloads	Unit Trains	Truck Loads
Crude Petroleum	34,997	297	115,490
Chemicals	42,266	n/a	139,478
Petroleum Products	18,840	160	62,172
Hazardous Waste	46	n/a	202
Non-Hazardous	815,956	6,915	3,590,206
Total	**912,104**	**n/a**	**3,907,549**

In comparing truck loads to railroad carloads or unit trains, it is important to consider the other factors that differ for highway and rail routing of hazardous materials, namely:

[43] Calculations by Environmental Research Consulting based on typical cargo volumes and capacities.
[44] Calculations by Environmental Research Consulting based on data from Surface Transportation Board and typical cargo volumes and capacities.

- There are fewer routing alternatives for rail between any given origin-destination pair than for trucks on highways.
- Railroads are on private rights-of-way (ROW), whereas highways are public rights-of-way.
- Avoiding populated areas and urban areas is more difficult by rail than by truck.
- Trucks may be able to transit around densely-populated areas on loop highways and other routes.
- Although there are interactions between vehicles operated by the public and trains carrying hazardous materials on at-grade crossings, there would be many more interactions with vehicles on highways and the much larger number of trucks that would be carrying the same commodities.

Passenger rail service in Washington State

In addition to freight trains, there are also passenger trains that transit some of the same routes. The Amtrak Cascades inter-city line runs between Eugene, Oregon (entering Washington State at Vancouver) and Vancouver, British Columbia, Canada. The Amtrak Coast Starlight runs between Seattle and Los Angeles. The Amtrak Empire Builder runs into Spokane (from Idaho), having originated in Chicago, and then splits into two routes — a northern route to Seattle, and a southern route to Portland, Oregon (through Vancouver, Washington State). There are also Sound Transit commuter trains that run between Everett and Tacoma (Everett-Seattle Sounder and Lakewood-Seattle Sounder). There are additional light rail routes between University of Washington State (northern Seattle) to Angle Lake (southern Seattle), and within Tacoma

The approximate numbers of passenger trains are shown in Table 13. Passenger train numbers by corridors are shown in Table 14 and Figure 19. There are two longer Amtrak Empire Builder trains a day that transit between the Idaho border and Spokane. Those trains split up into two separate trains after Spokane. One part of the train continues along to Seattle along the northern route. The other train follows the southern route to Portland, Oregon. There are four Amtrak trains per day that travel between Vancouver, B.C. to Seattle. Two of these trains continue on to Portland, Oregon. There are eight Amtrak trains per day that transit only between Seattle and Portland, Oregon. Additionally, on the Seattle to Everett route, there are eight commuter trains per day. There are 36 commuter trains daily that transit between Seattle and Tacoma.Amtrak also plans to add two more additional round trips between Seattle and Portland sometime in 2020.

Table 13: Number of Passenger Trains in Washington State[45]

Passenger Service	Daily Trains (One-Way)[46]	Weekly Trains (One-Way)	Annual Trains (One-Way)
Amtrak Coast Starlight	2	14	730
Amtrak Empire Builder (Spokane-Seattle)	2	14	730
Amtrak Empire Builder (Spokane-Portland)	2	14	730
Amtrak Cascades (Seattle-Portland)[47]	8	56	2,920
Amtrak Cascades (Seattle-Vancouver, BC)	4	28	1,460
Sound Transit Commuter (Lakewood-Seattle)	26	182	9,490
Sound Transit Commuter (Everett-Seattle)	8	56	2,920
Total Long-Distance Passenger Trains	**6**	**42**	**2,190**
Total Intercity Trains	**12**	**84**	**4,380**
Total Commuter Trains	**34**	**238**	**12,410**

Figure 19: Daily Passenger Trains in Washington State by Corridor[48]

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[45] Calculations by Environmental Research Consulting based on Amtrak schedules and Sound transit schedules as posted on their websites for public use.
[46] A roundtrip is counted twice — once in each direction.
[47] There are plans to expand the service to more round-trips per day.
[48] This map was created by Environmental Research Consulting for this report based on train numbers in Amtrak schedules and Sound transit schedules as posted on their websites for public use. Used with permission.

Table 14: Passenger Trains (One-Way Trips) in Washington State by Corridor[49]

Corridor	Daily Trains	Weekly Trains	Annual Trains
Seattle–Tacoma	36	252	13,140
Everett–Seattle	14	98	5,110
Tacoma–Vancouver, WA	10	70	3,650
Vancouver, BC–Everett	4	28	1,460
Everett–Spokane	2	14	730
Vancouver, WA–Spokane	2	14	730
Spokane–Idaho	2	14	730

Intersection of rails and populated areas and tribal lands

With the extensive rail infrastructure and traffic in Washington State, there are many ways in which railroads intersect with the public. Railroads are an essential part of the economy and transportation system. At the same time, the presence of railroad tracks and passing trains in many populated areas and tribal lands creates a potential for safety issues.

Rail passing through populated areas

Railroads pass through many populated areas in Washington State. The cities and towns along the rail routes for CBR traffic as well as other freight and passenger train traffic are shown in Table 15.

Table 15: Daily Trains through Washington State Cities and Towns with Higher Density[50]

Subdivision	City/Town	Pop.	Density per Square Mile	Loaded CBR Trains	Freight Trains	Passenger Trains	Total Daily Trains
Bellingham	**Anacortes**	15,928	1,356	1.6	20	4	**26**
Bellingham	**Bellingham**	82,631	3,051	1.0	15	4	**20**
Bellingham	**Burlington**	8,470	1,988	1.0	15	4	**20**
Bellingham	**Edmonds**	40,727	4,576	1.6	20	4	**26**
Bellingham	**Everett**	105,370	3,150	1.6	20	4	**26**
Bellingham	**Ferndale**	11,998	1,815	1.0	15	4	**20**
Bellingham	**Lynnwood**	36,275	4,627	1.6	20	4	**26**
Bellingham	**Marysville**	63,269	3,058	1.6	20	4	**26**
Bellingham	**Mt. Vernon**	32,600	2,663	1.6	20	4	**26**
Bellingham	**Shoreline**	54,790	4,695	1.0	21	4	**26**
Bellingham	**Stanwood**	6,422	2,277	1.6	20	4	**26**
Columbia River	**Quincy**	7,013	1,414	0.0	22	2	**24**

[49] In late 2019, Amtrak and Sound Transit trains will use the Lakewood Subdivision between Northern Tacoma and Nisqually. There will be no passenger trains on BNSF freight tracks between Tacoma and Nisqually. Data as analyzed by Environmental Research Consulting for this report based on train numbers in Amtrak schedules and Sound transit schedules as posted on their websites for public use. Used with permission.
[50] Estimated train numbers based on BST Associates et al. 2017.

Subdivision	City/Town	Pop.	Density per Square Mile	Loaded CBR Trains	Freight Trains	Passenger Trains	Total Daily Trains
Columbia River	Wenatchee	32,701	4,160	0.0	22	2	**24**
Eastgate-Hinkle	Cheney	11,251	2,635	1.8	38	2	**42**
Fallbridge	Camas	20,490	1,519	1.8	38	2	**42**
Fallbridge	Vancouver	167,405	3,579	1.8	38	2	**42**
Fallbridge	Washougal	14,750	2,697	1.8	38	2	**42**
Fallbridge	White Salmon	2,259	1,852	1.8	34	2	**38**
Lakeside	Kennewick	75,971	2,821	1.8	38	2	**42**
Lakeside	Pasco	65,600	2,151	1.8	38	2	**42**
Scenic	Cashmere	3,149	3,057	0.0	21	2	**23**
Scenic	Gold Bar	2,089	2,028	0.0	21	2	**23**
Scenic	Monroe	17,724	2,930	0.0	21	2	**23**
Scenic	Mukilteo	20,860	3,290	0.0	21	2	**23**
Scenic	Snohomish	9,401	2,717	0.0	21	2	**23**
Scenic	Sultan	4,715	1,497	0.0	21	2	**23**
Seattle	Algona	3,101	2,404	1.5	8	36	**46**
Seattle	Auburn	74,860	2,527	2.0	13	36	**51**
Seattle	Centralia	16,505	2,224	2.0	39	10	**51**
Seattle	Chehalis	7,298	1,320	2.0	39	10	**51**
Seattle	DuPont	8,808	1,503	2.0	34	10	**46**
Seattle	Edgewood	9,501	1,130	2.0	22	36	**60**
Seattle	Fife	9,333	1,640	2.0	8	36	**46**
Seattle	Kelso	11,832	1,454	2.0	47	10	**59**
Seattle	Kent	124,435	3,700	1.5	13	36	**51**
Seattle	Lacey	43,860	2,731	2.0	34	10	**46**
Seattle	Lakewood	59,097	1,249	2.0	34	10	**46**
Seattle	Longview	36,530	2,521	2.0	47	10	**59**
Seattle	Olympia	48,338	2,713	2.0	34	10	**46**
Seattle	Pacific	6,838	2,826	2.0	8	36	**46**
Seattle	Puyallup	38,609	2,736	2.0	22	36	**60**
Seattle	Renton	27,875	2,779	1.5	13	36	**51**
Seattle	Seattle	652,405	7,782	1.5	13	36	**51**
Seattle	Sumner	9,541	1,270	2.0	22	36	**60**
Seattle	Tacoma	203,446	4,091	2.0	8	36	**46**
Seattle	Tukwila	19,611	2,139	1.5	13	36	**51**
Seattle	Woodland	5,540	1,644	2.0	47	10	**59**
Spokane	Spokane	210,721	3,066	2.0	62	2	**66**
Spokane	Spokane Valley	91,113	2,412	2.0	62	2	**66**
Stampede	Covington	18,830	3,213	0.0	6	0	**6**
Stampede	Ellensburg	18,363	2,654	0.0	6	0	**6**
Stampede	Maple Valley	24,171	4,226	0.0	6	0	**6**
Stampede	Selah	7,333	1,652	0.0	6	0	**6**

Subdivision	City/Town	Pop.	Density per Square Mile	Loaded CBR Trains	Freight Trains	Passenger Trains	Total Daily Trains
Yakima Valley	**Benton City**	3,142	1,277	0.0	8	0	**8**
Yakima Valley	**Mabton**	2,306	2,847	0.0	8	0	**8**
Yakima Valley	**Prosser**	5,799	1,292	0.0	8	0	**8**
Yakima Valley	**Toppenish**	9,015	4,273	0.0	8	0	**8**
Yakima Valley	**Union Gap**	6,060	1,200	0.0	8	0	**8**
Yakima Valley	**Wapato**	5,065	4,329	0.0	8	0	**8**
Yakima Valley	**Yakima**	93,257	3,431	0.0	8	0	**8**

Rail passing through tribal lands

There are also potential risks to tribal culture, tribal community subsistence harvest, and tribal treaty rights. Spills and potential fires associated with CBR transport canimpact tribal lands used for cultural and traditional practices, and lands associated with treaty resources, including U&A (Usual & Accustomed) areas, tribal ceded areas,[51] and tribal fisheries habitat areas (Figure 20).

[51] Areas over which tribes by treaty relinquished control to the federal government in return for compensation in the form of livestock, merchandise, and annuities.

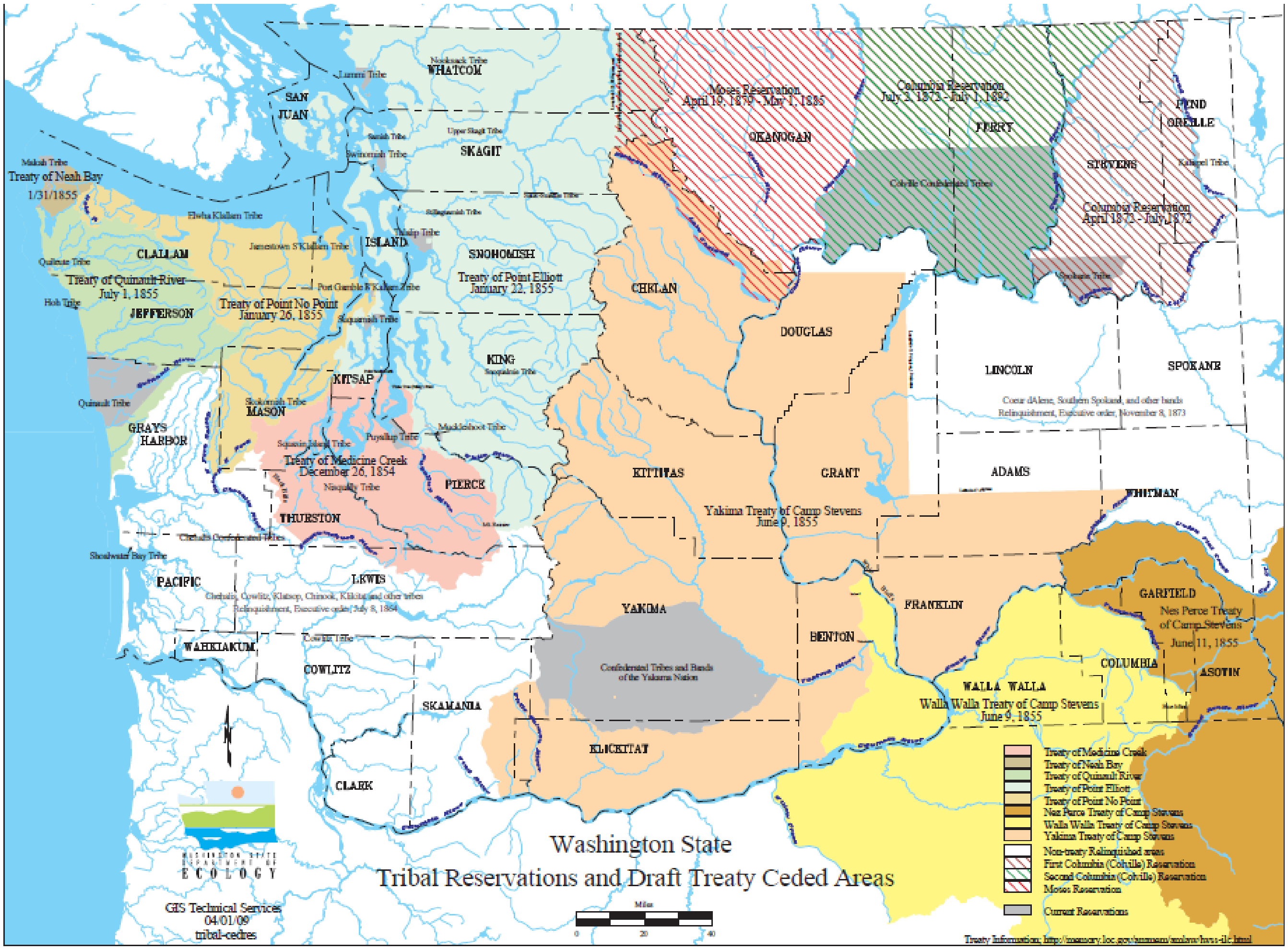

Figure 20: Washington State Tribal Reservations and Draft Treaty Ceded Areas[52] [53]

Conflicts with railroads in populated areas and tribal lands

The current locations of railroads going through populated areas and tribal lands creates many conveniences for the movement of passengers and freight, but also the potential for conflicts in land management and usage, as well as health and safety concerns from the trains and their cargoes. In addition, trains running through populated areas and crossing roadways create safety hazards and inconveniences for pedestrians and vehicular traffic.

Concerns over health and safety surrounding railroads have come to the forefront in the last several years with the dramatic increase in trains carrying crude oil. During workshops held in conjunction with the *2014 Marine & Rail Study* (Etkin et al. 2015), members of the public questioned the reason for trains "running straight through the middle of town." Workshop participants complained about having to wait for long trains to pass through grade crossings.

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[52] Map from Washington Department of Ecology.
[53] Descriptions of tribal lands can be found at https://apps.ecology.wa.gov/gispublic/DataDownload/ECY_BND_TribalLands.htm

Tribal representatives brought up the issue of trains blocking access to traditional fishing and hunting grounds, as well as causing a potential for environmental impacts to important cultural resources. This blocked access occurs when the trains are traveling on the tracks, which requires pedestrians and vehicles to wait at highway-rail crossings until the train passes, and, occasionally, when the trains are temporarily stopped on the tracks.

Grade highway-rail crossings

Since railroad tracks pass through many areas of the state, including several highly-populated areas, there are tracks that intersect with highways and roadways. In some cases, there are overpasses for vehicular and/or pedestrian traffic to cross over the tracks without any chance of contact. In other cases, there are bridges for the railroad tracks to cross over the roadways. There are also some tunnels that allow rail traffic to pass below city streets (e.g., in Seattle). Nevertheless, there are many places in the state with grade crossings. A grade crossing is a roadway for cars and trucks that crosses a railroad track at the same level or grade (Figure 22).

Figure 21: Example of Grade Crossing in Woodinville, Washington State (Map data ©2019 Google)[54]

There are currently 2,373 grade highway-rail crossings in Washington State (Figure 23).[55] These crossings are locations at which there is a danger of serious, often fatal, accidents. The crossings

[54] Image source: GoogleMaps (https://www.google.com/maps/@47.7588387,-122.1565058)
[55] Data from WSDOT. Used with permission. See Table 16 for details.

have different levels of protections and warnings, and will be described in greater detail in Chapter 13.

Many of these crossings are in highly populated areas, such as Spokane (Figure 24) and Seattle (Figure 25). All counties in Washington State have grade crossings except Clallam, Jefferson, Pacific, Wahkiakum, Garfield, Island, and San Juan Counties (Table 16).

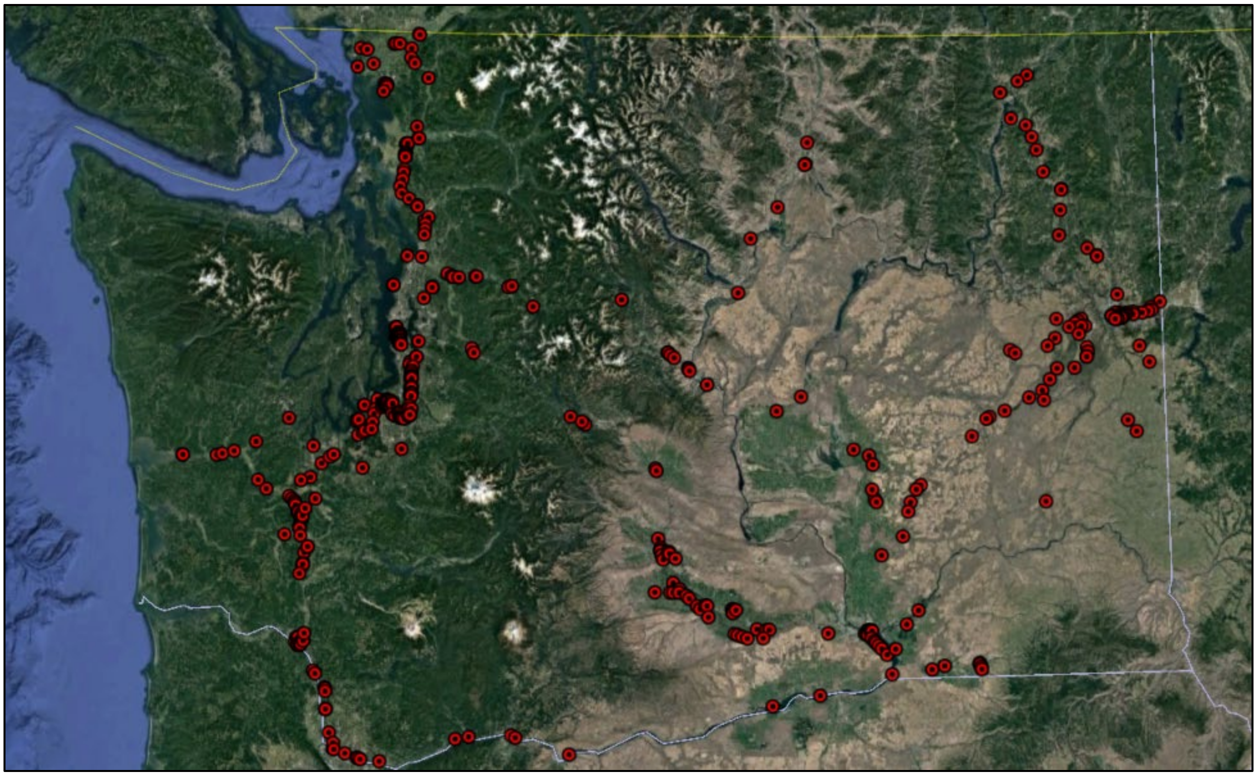

Figure 22: At-Grade Highway-Rail Crossings in Washington State[56]

[56] Map created by Environmental Research Consulting based on WSDOT data. Used with permission.

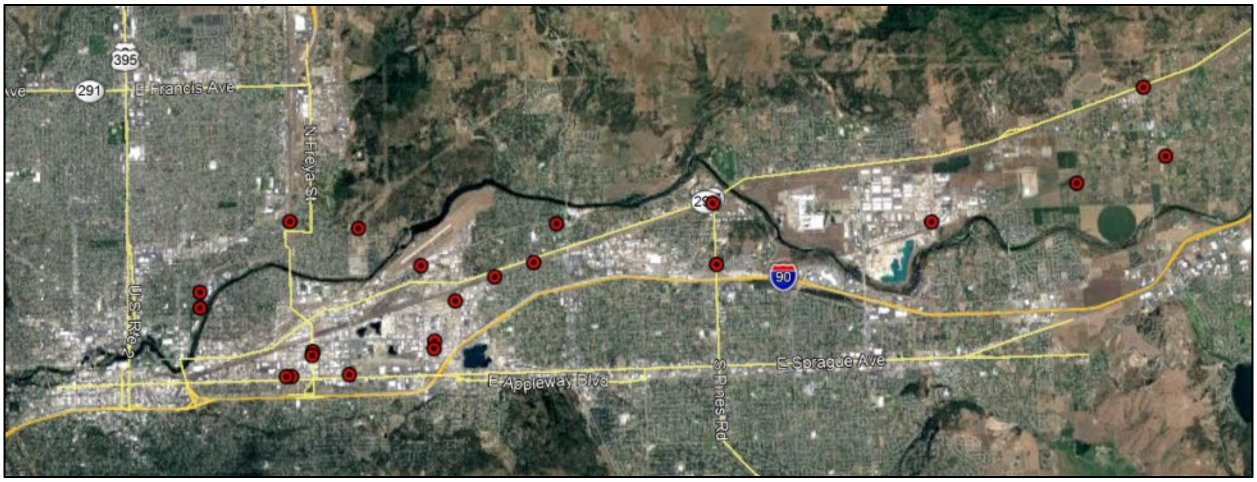

Figure 23: At-Grade Highway-Rail Crossings in Spokane[57]

[57] Map created by Environmental Research Consulting based on WSDOT data. Used with permission.

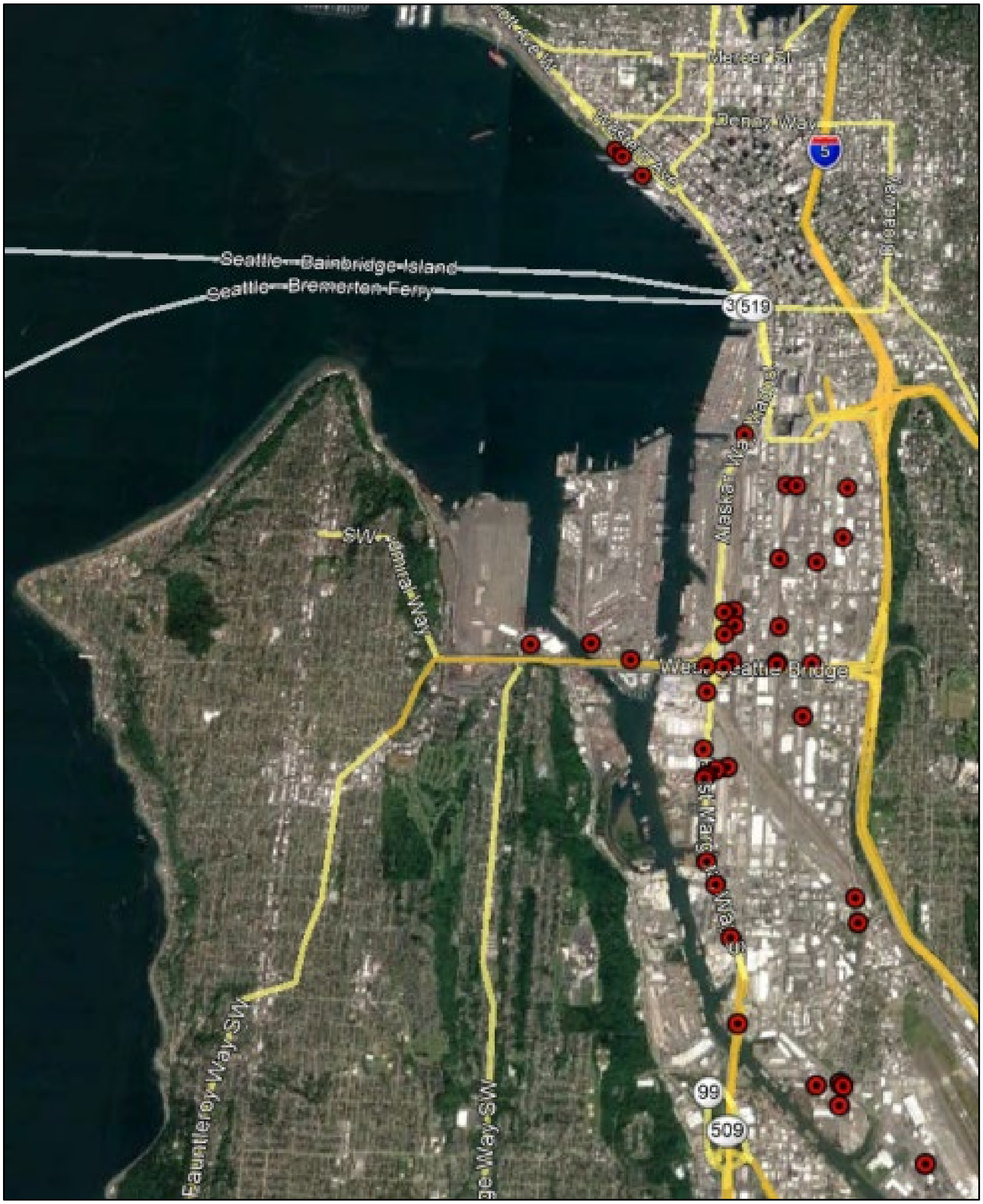

Figure 24: At-Grade Highway-Rail Crossings in Seattle[58]

[58] Map created by Environmental Research Consulting based on WSDOT data. Used with permission.

Table 16: Number of Grade Crossings by County in Washington State[59]

County	Number of Grade Crossings
Adams	47
Asotin	2
Benton	83
Chelan	39
Clark	69
Columbia	2
Cowlitz	47
Douglas	3
Ferry	23
Franklin	34
Grant	78
Grays Harbor	69
King	358
Kitsap	9
Kittitas	23
Klickitat	11
Lewis	81
Lincoln	97
Mason	24
Okanogan	26
Pend Oreille	26
Pierce	191
Skagit	72
Skamania	8
Snohomish	70
Spokane	200
Stevens	56
Thurston	82
Walla Walla	89
Whatcom	85
Whitman	119
Yakima	250
Total	**2,373**

[59] Data from WSDOT.

Chapter 5: Overview of Rail Accidents

Key questions

- What are the types of rail accidents that can occur?
- What are the causes of different types of rail accidents?
- What have the historical trends in rail accidents shown for the US as a whole and for Washington State?

Takeaways

- The rate of freight rail accidents has decreased significantly in the last 40 years. There is only one-sixth as many accidents as there were in the late 1970s nationwide, and in Washington State (analyses conducted on FRA data by ERC).
- The most common type of rail accident is a derailment. In the last decade, about 60 percent of accidents were derailments (analyses conducted on FRA data by ERC).
- Other kinds of rail accidents include collisions between trains, and highway-rail accidents in which trains collide with vehicles at grade crossings (analyses conducted on FRA data by ERC).
- Throughout the U.S., about 44 percent of derailments are caused by track-related problems, and another 32 percent are caused by mechanical and electrical failures in locomotives and cars (analyses conducted on FRA data by ERC).
- In Washington State, track-related causes accounted for 31 percent of derailments, and mechanical and electrical failures accounted for 42 percent of incidents (analyses conducted on FRA data by ERC).
- In Washington State, there is one freight rail accident for every million miles transited by trains (analyses conducted on FRA data by ERC).
- Passenger train accidents occur at a rate 50 percent higher than for freight trains. There are about 1.5 accidents for every million miles transited by passenger trains in Washington, as well as in the U.S. (FRA 2019a).

The following sections provide a more in-depth look at types of rail accidents, their causes, and trends in accident rates over time in both the U.S. as a whole and in Washington State. Both freight train and passenger train accidents are addressed. More detailed analyses of factors that affect the probability and severity of accidents are presented in Chapter 22. Highway-rail accidents are discussed in greater detail in Chapter 13.

Types of rail accidents

Each accident involving a train is a unique event, with specific circumstances that led to the incident and specific outcomes. For accidents that result in human casualties and/or significant damages, investigations by authorities such as the NTSB are required to delve into the intricacies of these events. These investigations provide evidence for litigation, in some cases, but are also helpful for providing "lessons learned" to prevent future accidents.

Recognizing the unique circumstances of accidents, there are general categories of accidents that the FRA and other authorities have recorded over the last several decades. The most common of these accidents are derailments. There are also collisions between trains and highway-rail accidents in which trains hit vehicles that are on the tracks. There are a number of other miscellaneous accidents, such as collisions of trains hitting obstructions on tracks or other stationary objects. Derailments, collisions, and highway-rail accidents are the focus in this report, as these are the accidents that are most likely to impact human health and safety and cultural and environmental resources.

Derailments

A train rolls on wheels that rest on top of steel rails. Wheels are manufactured with a flange on the inside of each wheel that allows the wheel to be guided by the rail. The tread of the wheel rolls along the top of the rail (Figure 26).

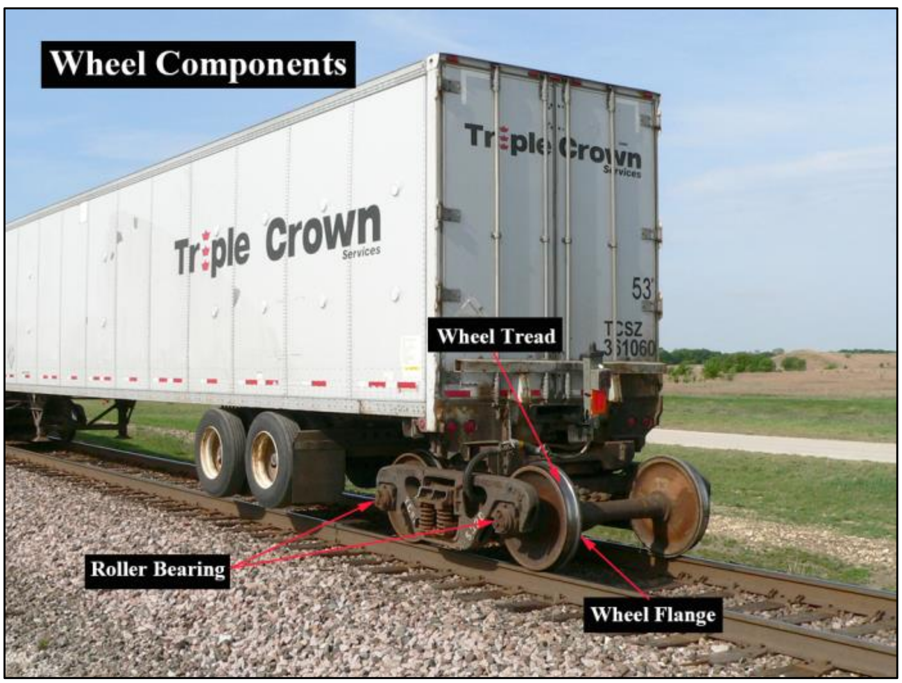

Figure 25: Railcar Wheel Components[60]

The rails are attached to ties by spikes or clips, and the ties are held in place by rock ballast. Ties are made of wood or concrete. Wood ties use spikes to hold the rail while concrete ties use clips to attach the rail. The weight and the movement of the train create forces at the contact points between the wheels and rail.

The tread of a wheel transmits the downward vertical force of the weight of the rail car to the rail. The flange of the wheel counters the lateral forces (forces which push to the right or left)

[60] Image credit: Eric Lyman, Used with permission.

created by movement of the car. So long as the vertical force on a wheel exceeds the lateral force between the flange and the rail, a car remains rolling along a track.

Derailments occur when the lateral force between a rail car's wheel flange and the rail exceed the downward vertical force between the wheel tread and the rail. When this occurs, a rail car's wheel can lift off the rail, or turn the rail over causing the car to derail. When one car derails at a high-speed, in most cases, multiple cars follow the derailing car and also derail. This type of accident can lead to hazardous material release, explosions, major property damage, and injuries or death.

Effects of derailments on railroad industry

Derailments can result in destruction of rolling stock, track components, lading (railcar cargo), and property.. Derailment cleanup is expensive; often the cars and lading involved in a major derailment have to be scrapped. Rail, ties, and track components have to be rebuilt, or signals have to be replaced. Class I railroads are self-insured up to multiple million-dollar limits, therefore the costs associated with derailment cleanup come directly out of the company's profits. For these reasons, the railroad industry has strong incentives to prevent derailment accidents.

Other costs associated with derailments beyond the cleanup cost can include:

- A route can be blocked for several days while the incident is investigated and cleaned up. Trains at the terminals on both ends of the blocked route cannot be dispatched out of the terminal, which creates congestion in yards. Other traffic continues to come into those yards from trains already en route, and that traffic is delayed by both the blocked route and the increasing yard congestion.
- If an alternate route is available, it usually adds miles to the route the traffic normally takes. This can add thousands of dollars to the cost of each rerouted train moving the traffic.
- The number of qualified crews on a route are sized for normal traffic. Rerouted traffic may create crew shortages or imbalances that have to be managed.
- If the profile of the alternate route requires additional locomotives as compared to the blocked route, a locomotive shortage issue may also occur.
- Detour agreements with another railroad exist but add additional cost. The alternate railroad will usually put limits on the amount of detour traffic that can be taken because they continue to run their own traffic first.
- There is a public relations aspect to a derailment. No railroad wants the bad publicity that comes with an oil spill or fire.
- Customer relationships can be jeopardized by delays caused by accidents.

Each of these costs can be incurred by the railroad when a major derailment occurs.

Factors contributing to derailments

Derailments can be caused by many factors. The railroads control some of these factors, and they do not control others. Some of the common factors that contribute to derailments are:

- Track alignment or structure
- Train handling
- Mechanical issues
- Human error

Many issues, beyond the control of the railroad, can cause derailments. Some of these include:

- Flooding of rivers and the potential damage a flood can do to a bridge.
- Earthquakes and damage to track alignment or structures.
- Mudslides/rock slides that can leave large debris on the track that can derail a train.
- Fire damage to wooden structures, ties and rail.
- Weather damage related to wind or tornadoes.
- Grade crossing accidents.

Railways have procedures to deal with each of the above, however, there are times when such an incident occurs, but the railroad cannot implement the procedure. The incidents that are referred to here are acts of nature or unforeseeable events. The railroads can only enact a response procedure if they are aware that the incident has occurred.

A more detailed description of the factors contributing to derailments is presented in Chapter 22.

Detailed analyses of causes of derailment accidents

A 2012 study examined freight train derailments for Class I railroads on mainline tracks, in particular with respect to their root causes (Liu et al. 2012). The researchers concluded that the single most common cause of derailments was broken rails, and that track conditions were the primary cause of 41 percent of derailments. Track-related accidents also resulted in the highest average number of derailed cars per accident.

The study also examined the effect of rail speed at the time of derailment. The researchers found that regardless of speed, broken rails or welds were the most frequent cause of derailments. At speeds below 10 mph, certain track-related and human factor-related accidents occurred more frequently. At derailment speeds greater than 25 mph, human factor accidents (e.g., improper train handling, braking operations, improper use of switches) were almost completely absent. Equipment causes (e.g., bearing failure, broken wheel, axle and journal defects) were common factors. The results of this study are summarized in Table 17. This study did not include passenger train accidents. Note that the Liu et al. 2010 study analyzed data from 2001 through 2010.

Table 17: Class I Railroad Mainline Derailment Causes by Percent and Average Cars Derailed, 2001–2010[61]

Cause	%	Average Cars Derailed[62]
Track: Broken tracks or welds	15.3%	12.8
Track: Track geometry (excluding wide gauge)[63]	7.3%	6.5
Track: Wide gauge	3.9%	10.2
Track: Buckled track	3.4%	12.7
Track: Turnout defects (switches)	2.7%	5.1
Track: Miscellaneous track and structure defects	1.8%	8.6
Track: Joint bar defects	1.5%	15.8
Track: Roadbed defects	1.5%	9.9
Track: Other rail and joint defects	1.3%	20.2
Track: Rail defects at the bolted joint	1.1%	20.2
Track: Non-traffic, weather causes	1.0%	7.7
Track: Turnout defects: frogs[64]	0.3%	8.8
Track: Total	**41.1%**	**11.0 cars**
Mechanical/Electrical: Bearing failure (car)	5.9%	6.8
Mechanical/Electrical: Broken wheels (car)	5.2%	6.4
Mechanical/Electrical: Other axle or journal defects (car)	3.3%	8
Mechanical/Electrical: Coupler defects (car)	3.1%	5.8
Mechanical/Electrical: Other wheel defects (car)	3.0%	5.2
Mechanical/Electrical: Sidebearing, suspension defects (car)	2.9%	6.5
Mechanical/Electrical: Centerplate of carbody defects (car)	2.3%	5.2
Mechanical/Electrical: Stiff truck	1.3%	6.6
Mechanical/Electrical: All other car defects	1.1%	5.3
Mechanical/Electrical: Locomotive trucks, bearings, wheels	1.1%	3.5
Mechanical/Electrical: Track–train interaction (hunting) (car)	0.9%	10.5
Mechanical/Electrical: Other brake defect (car)	0.9%	5.1
Mechanical/Electrical: Truck structure defects (car)	0.8%	7.6
Mechanical/Electrical: Brake rigging defect (car)	0.6%	5.5
Mechanical/Electrical: Air hose defect (car)	0.4%	7.8
Mechanical/Electrical: All other locomotive defects	0.3%	11.9

[61] Based on Liu et al. 2012.
[62] For each general cause category (Track, Mechanical/Electrical, Human Error, Miscellaneous, and Signal), the average number of cars derailed is a weighted average based on the percent of incidents within each subcategory.
[63] Gauge is the distance between the rails. Normal track gauge is 4 feet, 8 ½ inches. Wide gauge is wider than this. When gauge is too wide, because of track defects, it can cause derailments.
[64] A turnout is a section of track where one track diverges from another track (commonly called “switch”). A frog is part of the switch mechanism.

Cause	%	Average Cars Derailed[62]
Mechanical/Electrical: UDE[65] (car or locomotive)	0.2%	10.8
Mechanical/Electrical: Locomotive electrical and fires	0.2%	2.8
Mechanical/Electrical: TOFC–COFC[66] defects	0.1%	1
Mechanical/Electrical: Handbrake defects (car)	0.0%	2
Mechanical/Electrical: Total	**33.6%**	**6.4 cars**
Human Error: Train handling (excluding brakes)	4.6%	7.7
Human Error: Use of switches	2.4%	3.9
Human Error: Brake operation (mainline)	2.2%	9.3
Human Error: Train speed	1.4%	6.6
Human Error: Miscellaneous human factors	1.0%	8.6
Human Error: Handbrake operations	0.9%	4.3
Human Error: Switching rules	0.7%	6.6
Human Error: Mainline rules	0.3%	5.1
Human Error: Employee physical condition	0.1%	13.7
Human Error: Brake operations (other)	0.1%	11.8
Human Error: Failure to obey or display signals	0.1%	5.8
Human Error: Radio communications error	0.1%	4.3
Human Error: Total	**13.9%**	**7.0 cars**
Miscellaneous: Obstructions	3.5%	11.9
Miscellaneous: Track–train interaction	3.4%	7.4
Miscellaneous: Lading problems	3.1%	5.9
Miscellaneous: Other miscellaneous	1.2%	7.8
Miscellaneous: Total	**11.2%**	**8.4 cars**
Signal: Signal failures	0.4%	7.1
Signal: Total	**0.4%**	**7.1 cars**
All Causes: Weighted Average		**8.6 cars**

This analysis was repeated by Environmental Research Consulting for this report for the years 2011 through October 2018 for freight train derailments for Class I railroads on mainline tracks, as shown in Table 18. This involved 1,802 incidents, including 26 incidents in Washington State. An average of 8.6 cars derailed in accidents during 2001–2010, and 6.9 cars during 2011–2018, a nearly 20 percent reduction. A summary of the Washington derailment incidents is shown in Table 19.There are some differences between the U.S. and Washington State in percentages of incident causes, as shown in Figure 27, Figure 28, and Table 19.

Note that track conditions, including inspection for track defects, is discussed in greater detail in Chapter 11.

[65] UDE = undesired emergency.
[66] TOFC = trailer on flat car; COFC = container on flat car (intermodal shipping terms).

Table 18: Class I Railroad Mainline Derailment Causes by Percent and Average Cars Derailed (2011-2018)[67]

Cause	%	Average Cars Derailed[68]
Track: Broken tracks or welds	11.43%	7.4
Track: Track geometry (excluding wide gauge)	5.88%	8.22
Track: Wide gauge	3.39%	5.84
Track: Buckled track	4.61%	8.51
Track: Turnout defects (switches)	2.89%	4.25
Track: Miscellaneous track and structure defects	1.66%	7.77
Track: Joint bar defects	0.83%	11.27
Track: Roadbed defects	2.33%	8.93
Track: Other rail and joint defects	1.28%	2.91
Track: Rail defects at the bolted joint	0.11%	0
Track: Non-traffic, weather causes	7.77%	4.84
Track: Turnout defects: frogs	1.44%	5.5
Track: Total	**43.62%**	**6.8 cars**
Mechanical/Electrical: Bearing failure (car)	4.83%	8.04
Mechanical/Electrical: Broken wheels (car)	6.16%	5.38
Mechanical/Electrical: Other axle or journal defects (car)	3.22%	5.66
Mechanical/Electrical: Coupler defects (car)	3.55%	5.92
Mechanical/Electrical: Other wheel defects (car)	3.61%	6.66
Mechanical/Electrical: Sidebearing, suspension defects (car)	0.94%	10.35
Mechanical/Electrical: Centerplate of carbody defects (car)	1.17%	2.43
Mechanical/Electrical: Stiff truck	0.72%	9.38
Mechanical/Electrical: All other car defects	1.44%	8.04
Mechanical/Electrical: Locomotive trucks, bearings, wheels	0.61%	13
Mechanical/Electrical: Track–train interaction (hunting) (car)	0.50%	14.44
Mechanical/Electrical: Other brake defect (car)	1.50%	10.11
Mechanical/Electrical: Truck structure defects (car)	1.05%	2.68
Mechanical/Electrical: Brake rigging defect (car)	0.44%	6.38
Mechanical/Electrical: Air hose defect (car)	0.61%	10
Mechanical/Electrical: All other locomotive defects	1.00%	12.22
Mechanical/Electrical: UDE (car or locomotive)	0.11%	0
Mechanical/Electrical: Locomotive electrical and fires	0.33%	0
Mechanical/Electrical: TOFC–COFC defects	0.00%	0
Mechanical/Electrical: Handbrake defects (car)	0.06%	0
Mechanical/Electrical: Total	**31.85%**	**6.9 cars**
Human Error: Train handling (excluding brakes)	5.88%	8.37

[67] Analysis by Environmental Research Consulting for use in this report based on FRA accident data.
[68] For each general cause category (Track, Mechanical/Electrical, Human Error, Miscellaneous, and Signal), the average number of cars derailed is a weighted average based on the percent of incidents within each subcategory.

Cause	%	Average Cars Derailed[68]
Human Error: Use of switches	3.11%	4.8
Human Error: Brake operation (mainline)	2.61%	6
Human Error: Train speed	1.33%	6.75
Human Error: Miscellaneous human factors	0.78%	12.64
Human Error: Handbrake operations	0.50%	7.78
Human Error: Switching rules	1.05%	7.79
Human Error: Mainline rules	0.28%	0
Human Error: Employee physical condition	0.17%	0
Human Error: Brake operations (other)	0.06%	29
Human Error: Failure to obey or display signals	0.33%	8.67
Human Error: Radio communications error	0.06%	0
Human Error: Total	**16.15%**	**7.13 cars**
Miscellaneous: Obstructions	2.28%	3.56
Miscellaneous: Lading problems	4.94%	6.38
Miscellaneous: Other miscellaneous	0.55%	10.9
Miscellaneous: Total	**7.77%**	**5.9 cars**
Signal: Signal failures	0.61%	15.91
Signal: Total	**0.61%**	**15.91 cars**
All Causes: Weighted Average		**6.9 cars**

Table 19: Washington State Class I Railroad Mainline Derailment Accidents with Numbers of Cars Derailed, Damaged, and Released Hazmat (2011-2018)[69]

Date	Railroad	Milepost	Cause	Cars Derailed	Cars Damaged	Cars Released Hazmats
Feb-26-2011	BNSF	13.1	Track: Turnout defects: frogs	8	4	2
Mar-21-2011	UP	100.2	Mechanical/Electrical: Broken wheels (car)	0	0	0
Dec-24-2011	BNSF	135.5	Miscellaneous: Lading problems	29	0	0
Jul-02-2012	BNSF	119.5	Track: Non-traffic, weather causes	0	0	0
Jul-18-2012	BNSF	118.3	Track: Buckled track	0	0	0
Oct-05-2012	BNSF	24.6	Human Error: Miscellaneous human factors	1	0	0
Dec-17-2012	BNSF	32.0	Track: Broken tracks or welds	4	1	1
Apr-07-2013	BNSF	31.8	Track: Non-traffic, weather causes	0	0	0
Apr-17-2013	UP	215.0	Mechanical/Electrical: Sidebearing, suspension	0	0	0

[69] Analysis by Environmental Research Consulting for use in this report based on FRA accident data. Entries with 0 Cars Derailed did have derailments occur, but no derailed cars were actually reported to or recorded by FRA.

Date	Railroad	Milepost	Cause	Cars Derailed	Cars Damaged	Cars Released Hazmats
			defects (car)			
Jul-05-2013	BNSF	1782.9	Mechanical/Electrical: Bearing failure (car)	13	0	0
Dec-20-2013	BNSF	121.5	Mechanical/Electrical: Bearing failure (car)	0	0	0
Jan-13-2014	BNSF	18.7 X	Mechanical/Electrical: Broken wheels (car)	0	0	0
Mar-10-2014	BNSF	1636.6	Track: Buckled track	2	2	0
Jul-09-2014	BNSF	22.5 X	Mechanical/Electrical: Locomotive trucks, bearings, wheels	0	0	0
Jul-24-2014	BNSF	3.3	Mechanical/Electrical: Other wheel defects (car)	97	3	0
Oct-15-2015	BNSF	40.1 X	Human Error: Train handling (excluding brakes)	28	0	0
Jun-26-2016	BNSF	10.3	Mechanical/Electrical: Other axle or journal defects (car)	0	0	0
Jun-30-2016	BNSF	1632.0	Human Error: Use of switches	0	0	0
Dec-28-2016	BNSF	15.5	Track: Broken tracks or welds	0	0	0
Jan-10-2017	UP	275.5	Mechanical/Electrical: Truck structure defects (car)	0	0	0
Feb-24-2017	UP	207.42	Mechanical/Electrical: Broken wheels (car)	0	0	0
Apr-22-2017	BNSF	136.1	Track: Broken tracks or welds	0	0	0
Jul-02-2017	BNSF	14.4	Human Error: Failure to obey or display signals	0	0	0
Sep-22-2017	BNSF	224.3	Mechanical/Electrical: Bearing failure (car)	2	2	0
Oct-27-2018	BNSF	215.9	Track: Rail defects at the bolted joint	0	0	0

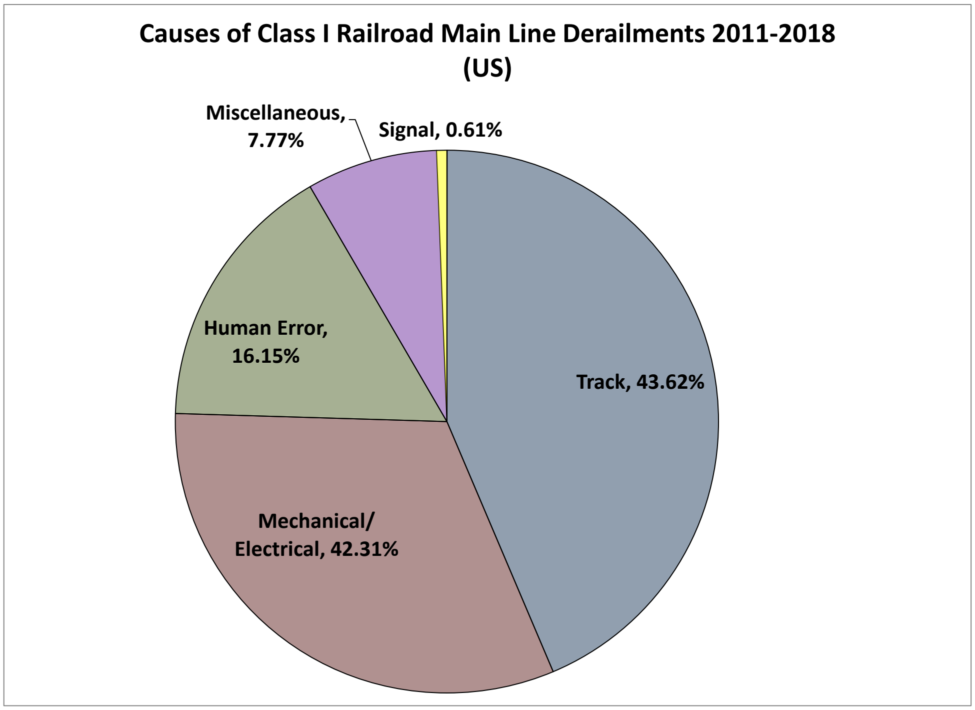

Figure 26: Causes of Class I Railroad Mainline Derailments in the U.S., 2011–2018[70]

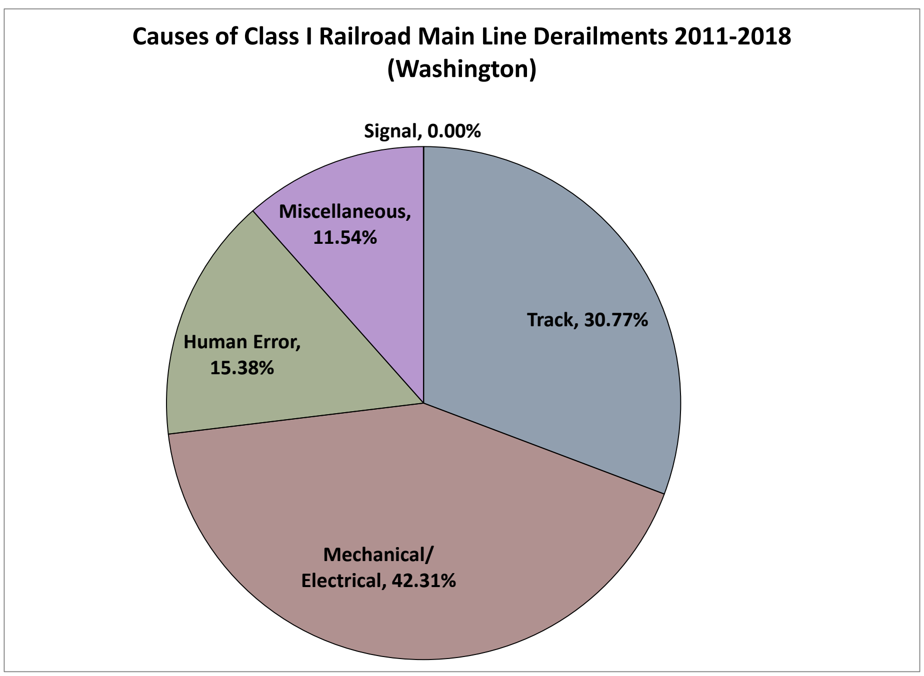

Figure 27: Causes of Class I Railroad Mainline Derailments in Washington State, 2011–2018[71]

[70] Figure prepared by Environmental Research Consulting. Used with permission.
[71] Figure prepared by Environmental Research Consulting. Used with permission.

Table 20: Causes of Class I Railroad Mainline Derailments in the U.S. and Washington State, 2011–2018

Main Cause Type	U.S.	Washington State
Track	43.62%	30.77%
Mechanical/Electrical	31.85%	42.31%
Human Error	16.15%	15.38%
Miscellaneous	7.77%	11.54%
Signal	0.61%	0.00%

Collisions between trains

Collisions between trains include incidents in which a train collides with another train that is moving or stationary. Incidents involving trains and vehicles are classified as highway-rail accidents.

Analysis of collision accidents with casualties

A research team conducted a comprehensive analysis of train collisions on mainlines for the years 2001 to 2015 (Turla et al. 2018). This analysis included both freight and passenger trains. The analyses showed that there was a significant reduction in the numbers of collisions per billion train-miles, as summarized in Table 21 and Figure 29.

Table 21: Mainline Train Collisions and Casualties in U.S., 2001–2015[72]

Year	Billion Train-Miles	Collisions	Casualties	Collisions per Billion Train-Miles with Casualties	Casualties per Collision	Casualties per Billion Train-Miles
2001	0.63	35	129	55.5	3.7	206.2
2002	0.64	30	75	46.9	2.5	117.9
2003	0.65	28	41	43.1	1.5	63
2004	0.67	39	144	58.2	3.7	213.9
2005	0.69	51	87	73.9	1.7	126.6
2006	0.72	27	26	37.5	1	36.1
2007	0.68	31	162	45.6	5.2	236.5
2008	0.67	25	24	37.3	1	36
2009	0.58	18	29	31	1.6	49.8
2010	0.61	16	21	26.2	1.3	34.2
2011	0.63	17	34	27	2	54.1
2012	0.64	22	14	34.4	0.6	21.8
2013	0.65	20	26	30.1	1.3	39.8
2014	0.67	20	63	29.9	3.2	94.2
2015	0.64	13	11	20.3	0.8	17.1

[72] Based on data in Turla et al. 2018.

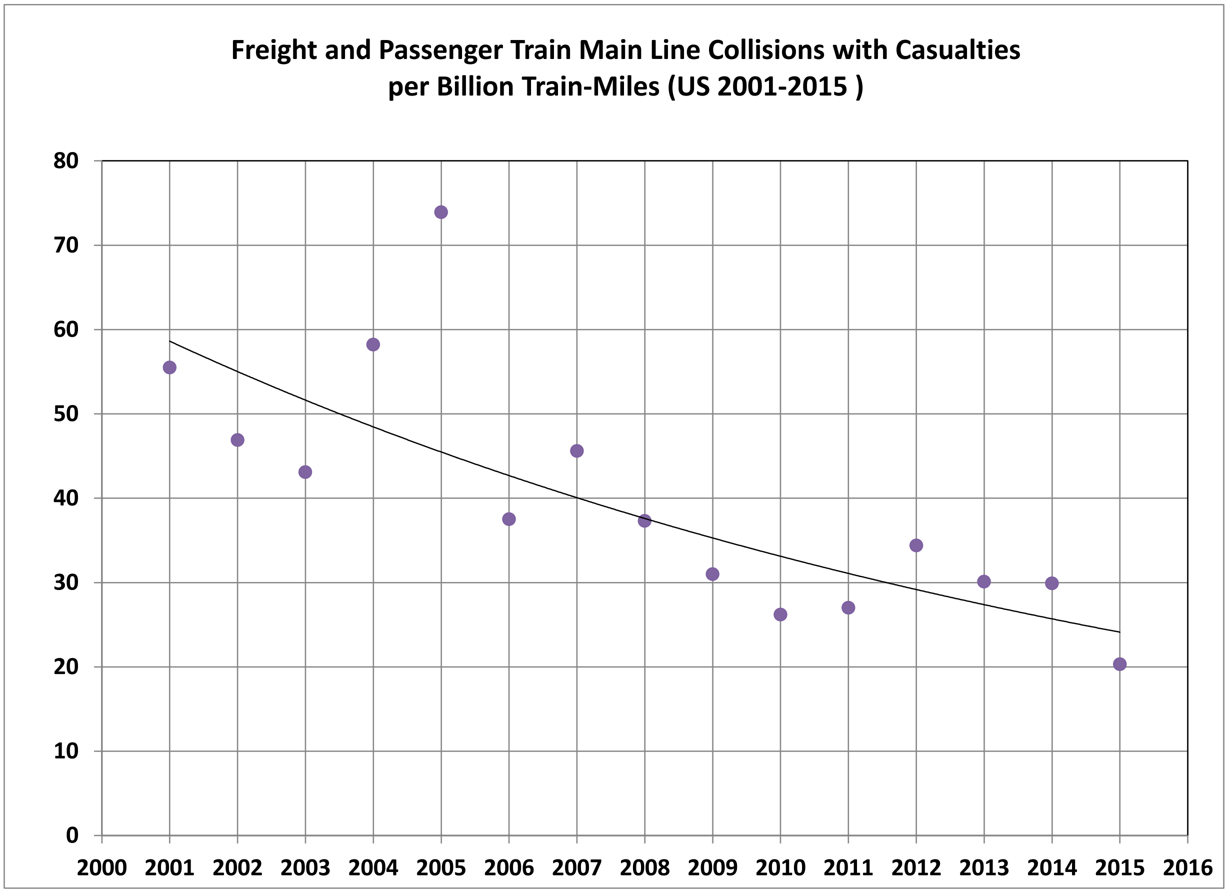

Figure 28: Freight and Passenger Mainline Collisions with Casualties per Billion Train-Miles in the U.S. (2001-2015)[73]

Analysis of causes of mainline train collisions

The collision study (Turla et al. 2018) included an analysis of causes of collisions, as shown in Table 22. Note that 98.5 percent of the collisions were caused by human error, most frequently failure to obey or display signals, followed by train speed and failure to follow mainline rules.

[73] Graph created by Environmental Research Consulting based on data in Turla et al. 2018.

Table 22: Causes of Mainline Train Collisions and Casualties in the U.S. with Number of Incidents, Percentage of Total, and Mean Number of Casualties per Incident, 2001–2015[74]

Cause	Number of Incidents	% Total	Mean Number of Casualties per Incident[75]
Human Error: Failure to obey or display signals	123	31.4%	4.06
Human Error: Train speed	72	18.4%	0.57
Human Error: Mainline rules	66	16.8%	0.43
Human Error: Miscellaneous human factors	33	8.4%	0.15
Human Error: Switching rules	31	7.9%	0.20
Human Error: Handbrake operations	24	6.1%	-
Human Error: Radio communications error	9	2.3%	-
Human Error: Use of switches	9	2.3%	-
Human Error: Employee physical condition	8	2.0%	-
Human Error: Train handling (excluding brakes)	7	1.8%	-
Signal: Signal failures	6	1.5%	-
Human Error: Brake operations (other)	4	1.0%	-
Total	**392**	**100%**	-

Highway-rail crossing accidents

There are currently 2,187 grade highway-rail rail crossings in Washington State. In the last 25 years, there have been 1,218 accidents at these crossings — 1,137 involving vehicles and 81 involving pedestrians (Figure 30 and Table 23) at 734 crossings. There was a decrease in the numbers of vehicle-related accidents — about 25 percent since the 1990s, but it has leveled off.[76]

[74] Turla et al. 2018.
[75] The analyses of casualty rates were only conducted on the top five causes.
[76] For more information on specific grade crossing accidents and accident prevention measures, refer to Chapter 13.

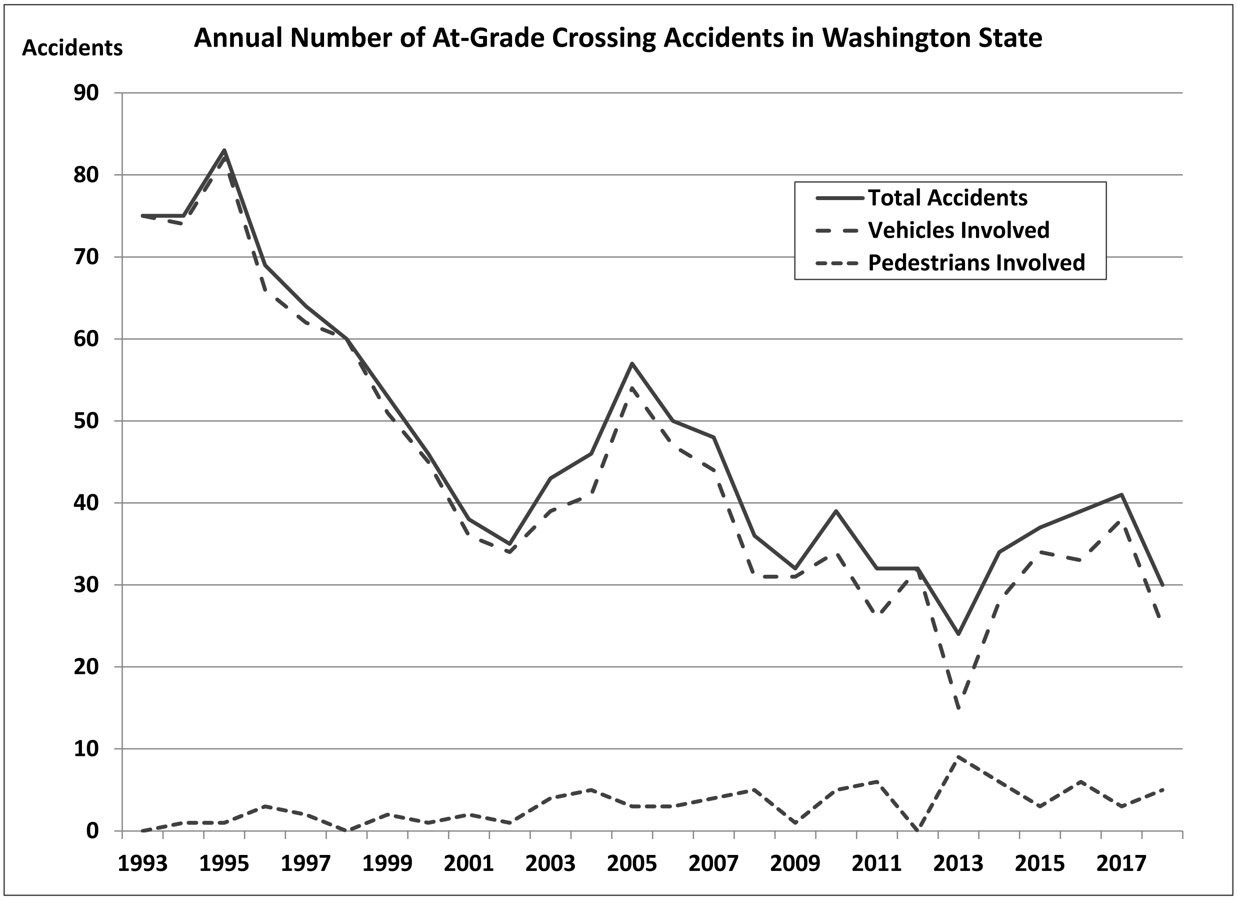

Figure 29: Annual Number of At-Grade Crossing Accidents in Washington State, 1993–2018[77]

[77] Graph created by Environmental Research Consulting based on FRA data. Used with permission.

Table 23: Annual Number of At-Grade Crossing Accidents in Washington State, 1993–2018[78]

Year	Total Accidents	Vehicles Involved	Pedestrians Involved
1993	75	75	0
1994	75	74	1
1995	83	82	1
1996	69	66	3
1997	64	62	2
1998	60	60	0
1999	53	51	2
2000	46	45	1
2001	38	36	2
2002	35	34	1
2003	43	39	4
2004	46	41	5
2005	57	54	3
2006	50	47	3
2007	48	44	4
2008	36	31	5
2009	32	31	1
2010	39	34	5
2011	32	26	6
2012	32	32	0
2013	24	15	9
2014	34	28	6
2015	37	34	3
2016	39	33	6
2017	41	38	3
2018	30	25	5
Total	**1,218**	**1,137**	**81**

Historical trends of freight rail accidents

Analyses of previous rail accidents provide important information about frequencies of accidents of different types, and changing trends over time. This information in turn, can help with predictions of future accidents. However, it is important to consider that there are changes in railroad infrastructure, regulations, industry practices, and implementation of safety measures that have changed accident trends over time and will likely continue to change them in the future.

[78] FRA data.

Federal Railroad Administration freight rail accident data

FRA rail accident data provide information on individual accidents, including train identification and characteristics, location, cause, and outcome with respect to car damage, spillage, and casualties. FRA data only include train accidents involving "one or more railroads that have sustained combined track, equipment, and/or structures damage in excess of the reporting threshold" (FRA undated). This threshold was $10,700 in 2017. This means that incidents below this damage threshold are not recorded. However, accidents that could lead to spillage would generally involve damages of at least the reporting threshold because significant car damage is necessary for there to be a release from tank cars. FRA states:

> The computed accident damage only includes the loss and/or repair of cars and locomotives, repair of signal systems and other structures, and repair of roadbed and track. Not included in this calculation are the costs associated with clean-up, hazmat clean-up (support from fire department and other groups), loss of lading, societal damage (e.g., closing a business area during clean-up), loss of life or injury, loss of use of mainline track, and loss of use of equipment/locomotives.[79]

For the analysis in this report, the data set of 1975 through 2018[80] of 205,053 accidents from all types of rail traffic was analyzed. In this data set, passenger train accidents (commuter rail and long-distance passenger trains) were eliminated from the data set, because of significant differences in mode of operation, regulations, and track usage. (These data were analyzed separately.) Additionally, only freight train accidents on mainline track were included.

"Mainline track means a track of a principal line of a railroad, including extensions through yards, upon which trains are operated by timetable or train order or both, or the use of which is governed by block signals or by centralized traffic control" (23 CFR § 646 Subpart B). Mainline track is used for through trains or is the principal artery of the system from which branch lines, yards, sidings and spurs are connected. It generally refers to a route between towns, as opposed to a route providing suburban or metro services. Switching yards, passing sidings and industry tracks may be part of the principal line of a railroad, but are not considered to be the main line.

This analysis included 68,613 accidents around the U.S., including 1,268 incidents in Washington State, over the course of 1975 through the end of October 2018.

Mainline rail accident probabilities — national

The breakdown of mainline accidents by time period is shown in Table 24 and Figure 31. Overall, about 77 percent of accidents were derailments. Derailments have decreased significantly over the last 44 years (Figure 32 and Table 25 for annual numbers, and Figure 33 for average annual numbers). The reduction in incidents is also true for the last 10 years. Other accident numbers have also decreased. The data in last column of Table 26 is for the entire period of 1975 through 2018, as opposed to smaller 10-year time periods that are shown in the preceding columns. These data are provided to show the average number of accidents that

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[79] http://safetydata.fra.dot.gov/OfficeofSafety/Documents/Railroad%20Safety%20Data%20Frequently%20Asked%20Questions.pdf?V=9

[80] FRA data were current through 31 October 2018.

occurred annually during the entire time period. These data may be of interest in some analyses and are provided as a convenience. However, it can be seen that there are differences in the accident rates for the decadal time periods.

These findings correspond with other studies, including one that showed that the rate of freight train derailments in the U.S. decreased significantly from 2000 to 2012 by a rate of 5.8 percent per year (Liu 2015).

Table 24: US National Freight Train Mainline Average Annual Accidents, 1975–2018[81]

Accident Type	1975–1984	1985–1994	1995–2004	2005–2014	2015–2018	1975–2018
Derailment	3,039	915	736	505	288	**1,206**
Highway-Rail	178	131	159	171	150	**159**
Collision	206	75	62	44	17	**89**
All Other	180	76	84	78	107	**105**
All Accidents	**3,602**	**1,197**	**1,040**	**798**	**562**	**1,559**

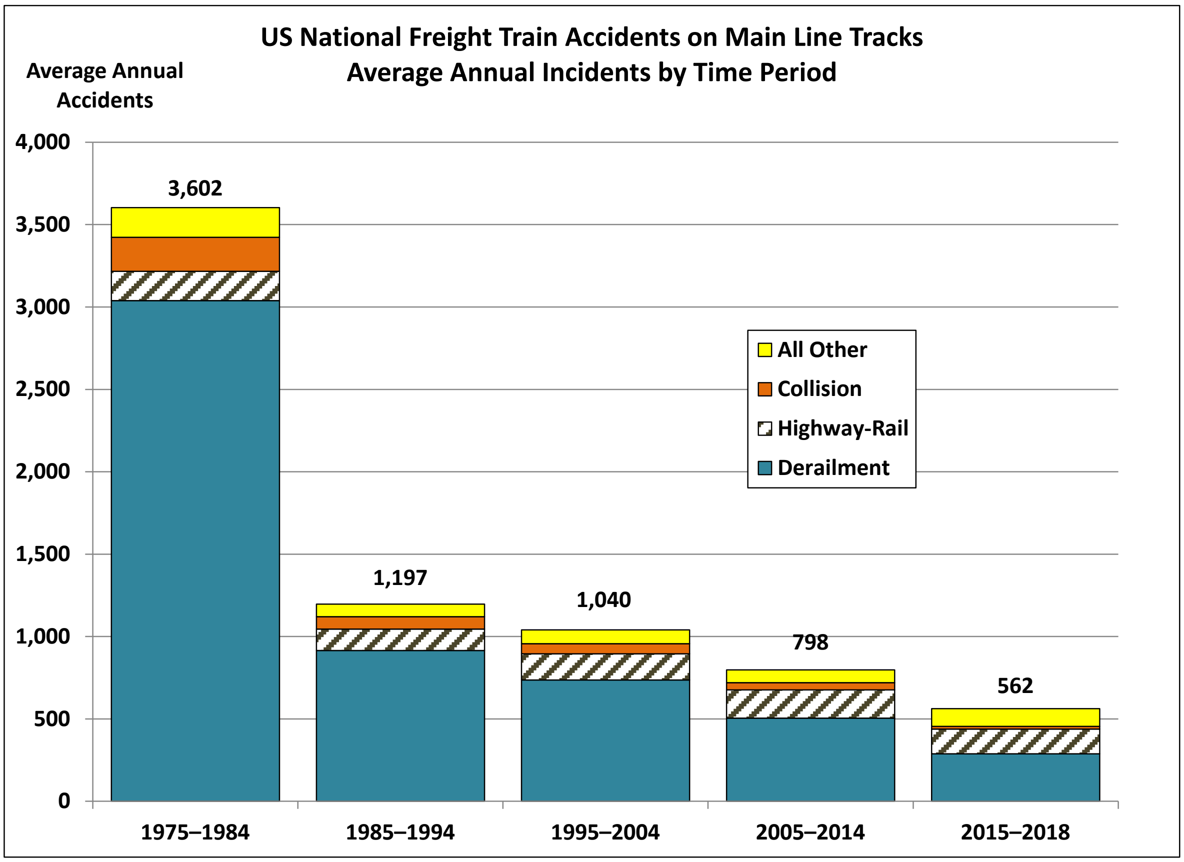

Figure 30: Average Annual Mainline Freight Accidents in the U.S. 1975–2018[82]

[81] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting. Used with permission.
[82] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting. Used with permission.

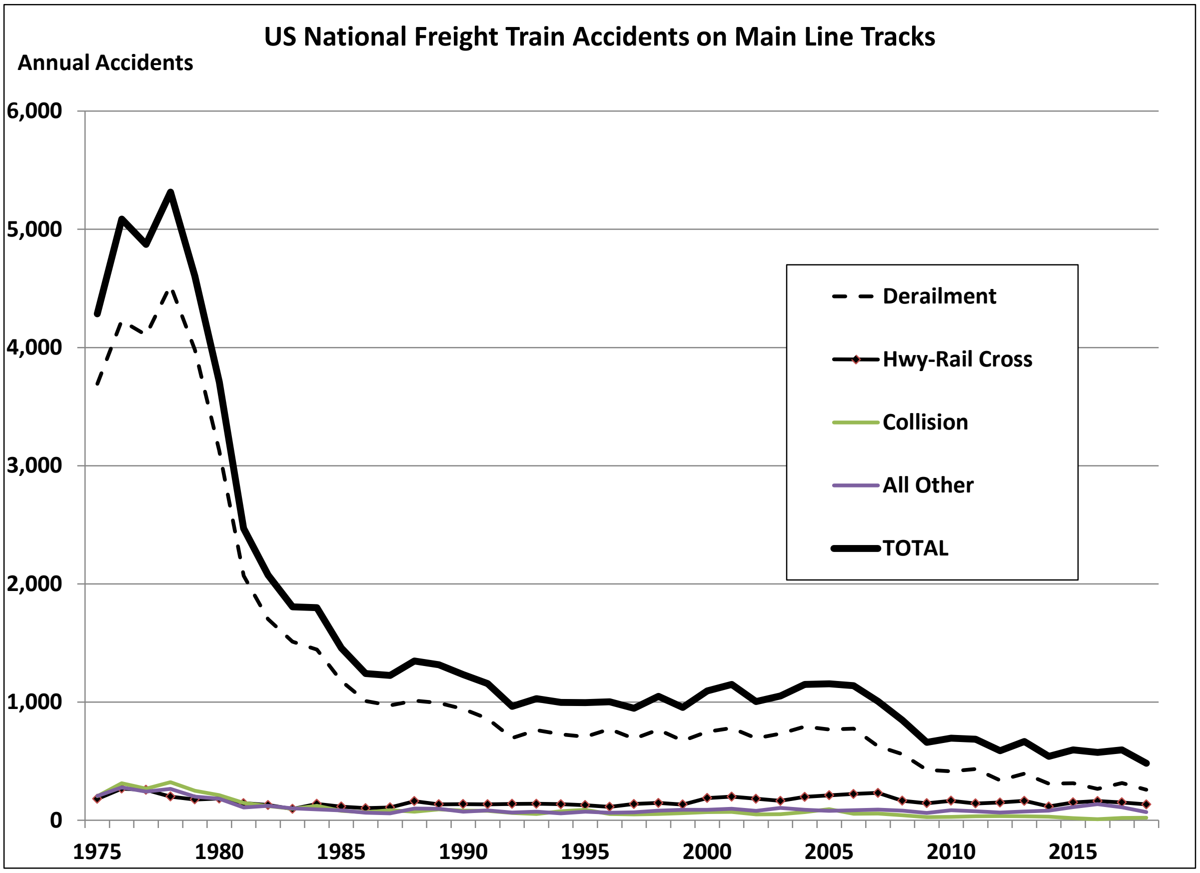

Figure 31: Mainline Freight Accidents in the U.S., 1975–2018 (Annual Data)[83]

Table 25: Mainline Freight Accidents in the U.S. 1975–2018 (Annual Data)[84]

Year	Derailment	Hwy-Rail Cross	Collision	All Other	TOTAL
1975	3,693	181	204	206	4,284
1976	4,227	268	314	278	5,087
1977	4,105	257	267	243	4,872
1978	4,527	201	322	265	5,315
1979	3,980	176	249	201	4,606
1980	3,129	184	212	183	3,708
1981	2,068	145	147	109	2,469
1982	1,702	129	121	123	2,075
1983	1,512	96	97	101	1,806
1984	1,444	139	123	93	1,799
1985	1,178	116	79	84	1,457
1986	1,008	102	68	64	1,242

[83] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting. Used with permission.
[84] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.

Year	Derailment	Hwy-Rail Cross	Collision	All Other	TOTAL
1987	972	109	85	59	1,225
1988	1,013	162	73	99	1,347
1989	992	135	92	97	1,316
1990	941	137	82	73	1,233
1991	860	135	79	83	1,157
1992	696	139	62	66	963
1993	763	140	54	72	1,029
1994	727	136	76	59	998
1995	707	128	89	72	996
1996	771	114	54	64	1,003
1997	691	138	50	68	947
1998	767	147	54	81	1,049
1999	672	133	61	89	955
2000	748	188	69	89	1,094
2001	780	200	71	98	1,149
2002	693	182	49	80	1,004
2003	733	164	51	105	1,053
2004	793	198	69	89	1,149
2005	769	211	94	80	1,154
2006	776	223	55	85	1,139
2007	627	232	56	91	1,006
2008	559	165	42	81	847
2009	426	144	27	62	659
2010	415	165	28	86	694
2011	433	142	33	77	685
2012	338	150	35	66	589
2013	394	164	34	74	666
2014	310	117	31	82	540
2015	314	151	18	112	595
2016	265	163	9	137	574
2017	316	151	19	110	596
2018	258	134	21	69	482
TOTAL	**53,092**	**6,991**	**3,925**	**4,605**	**68,613**

The significant drop in accidents prior to 1985 could be attributed to a series of bankruptcies and mergers of financially troubled large railroads in the 1960s. These railroads included Pennsylvania, New York Central, Chicago Great Western, Erie, Lackawanna, Seaboard Air Line, Atlantic Coast Line, and others. Many railroads were driven out of business by competition with interstate highways and airlines that were established in the 1960s. The financial issues of these railroads had led to neglect of infrastructure, which resulted in large numbers of accidents, primarily derailments in the 1970s into the early 1980s.

In the late 1960s, there were several significant mergers, which created Penn Central, Erie Lackawanna, and several other railroads. When Penn Central went bankrupt in 1970, it had a rippling effect that affected railroads connected with Penn Central throughout the Northeastern U.S. — Lehigh Valley, Reading Railroad, Lehigh & Hudson River Railway, Erie Lackawanna, and Delaware & Hudson. The U.S. federal government setup the Consolidated Rail Corporation (Conrail) with federal backing in 1976 through the Railroad Revitalization and Regulatory Reform Act to help make the bankrupt carriers profitable again. Amtrak was also established in this time period. By the 1980s, there was greater financial stability and greater investment in infrastructure.

In 1980, President Carter signed the Staggers Rail Act, which deregulated the U.S. railroad industry to a significant extent and replaced the regulatory structure that had existed since the 1887 Interstate Commerce Act. According to the U.S. General Accounting Office (called the Government Accountability Office after 2004), the Staggers Rail Act helped to improve Class I railroads' financial health and rehabilitate rail facilities, which were the legislation's two primary purposes (GAO 1990). According to industry analysts, the Staggers Rail Act led to a 51 percent reduction in average shipping rates and a subsequent $480 billion reinvestment by the rail industry into the rail systems (Winston 2005). This reinvestment in infrastructure may have contributed to the significant reduction in railroad accidents.

Mainline rail accident probabilities — Washington State

The same analyses were conducted for Washington State accidents alone. Again, derailments make up the majority (76 percent) of accidents, and these rates have decreased over the last 44 years, as shown in Table 26, Table 27, Figure 33, and Figure 34. There has been a downward trend in the last decade, though it has not been consistent (Figure 35).

Table 26: Washington State Freight Train Mainline Average Annual Accidents, 1975–2018[85]

Accident Type	1975–1984	1985–1994	1995–2004	2005–2014	2015–2018	1975–2018
Derailment	60	14	12	9	6	**22**
Highway-Rail[86]	3	1	1	3	3	**2**
Collision	5	2	2	0	2	**2**
All Other	4	3	3	1	2	**3**
All Accidents	**72**	**19**	**18**	**14**	**11**	**29**

[85] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[86] Note that the numbers of highway-rail accidents in these data may differ from those in other FRA data for highway-rail accidents as these data only include incidents with freight trains on mainline tracks, not other kinds of trains (e.g., passenger) and other track types.

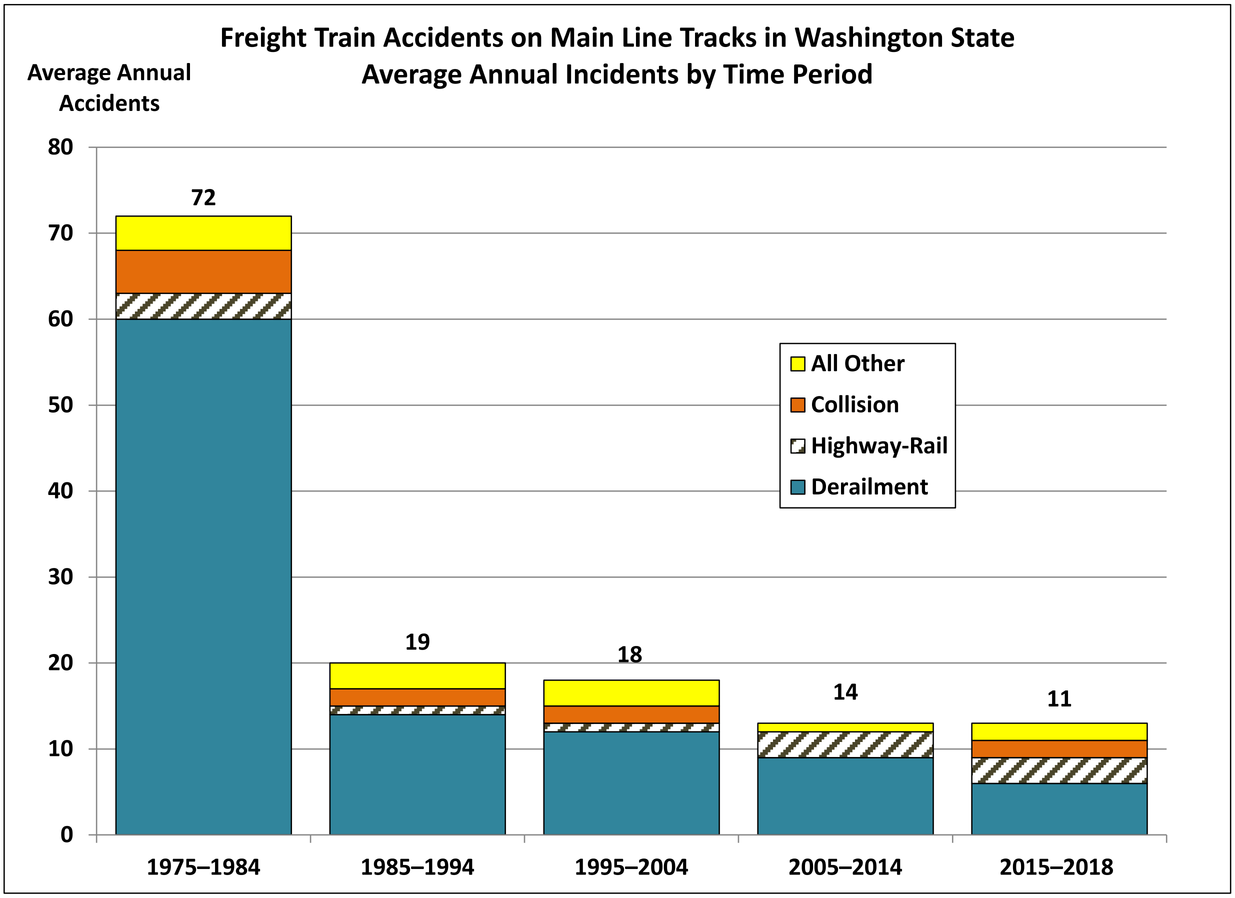

Figure 32: Average Annual Mainline Freight Accidents in Washington State, 1975–2018[87]

[87] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.

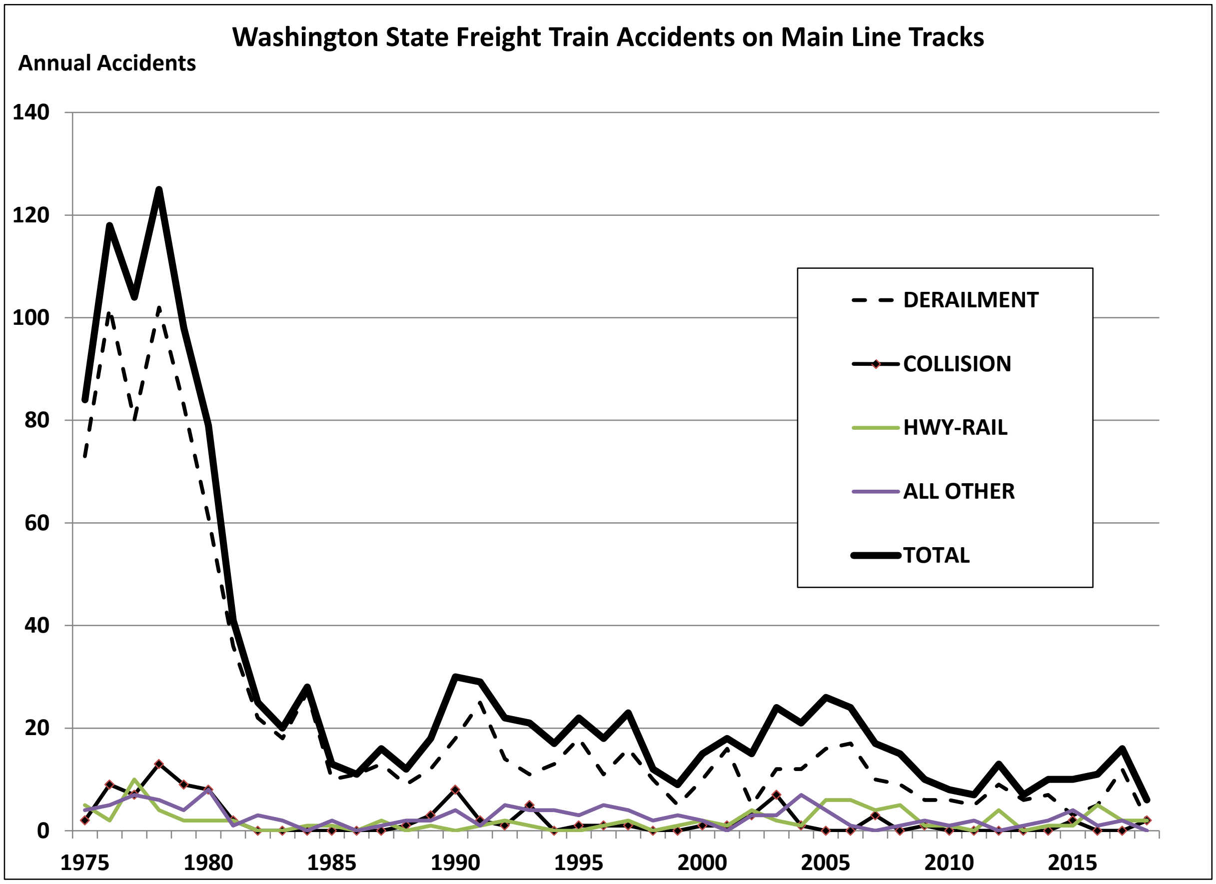

Figure 33: Mainline Freight Accidents in Washington State, 1975–2018[88]

Table 27: Mainline Freight Accidents in Washington State, 1975–2018[89]

Year	Derailment	Collision	Hwy-Rail	All Other	Total
1975	73	2	5	4	84
1976	102	9	2	5	118
1977	80	7	10	7	104
1978	102	13	4	6	125
1979	83	9	2	4	98
1980	61	8	2	8	79
1981	36	2	2	1	41
1982	22	0	0	3	25
1983	18	0	0	2	20
1984	27	0	1	0	28
1985	10	0	1	2	13
1986	11	0	0	0	11

[88] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[89] FRA data.

Year	Derailment	Collision	Hwy-Rail	All Other	Total
1987	13	0	2	1	16
1988	9	1	0	2	12
1989	12	3	1	2	18
1990	18	8	0	4	30
1991	25	2	1	1	29
1992	14	1	2	5	22
1993	11	5	1	4	21
1994	13	0	0	4	17
1995	18	1	0	3	22
1996	11	1	1	5	18
1997	16	1	2	4	23
1998	10	0	0	2	12
1999	5	0	1	3	9
2000	10	1	2	2	15
2001	16	1	1	0	18
2002	5	3	4	3	15
2003	12	7	2	3	24
2004	12	1	1	7	21
2005	16	0	6	4	26
2006	17	0	6	1	24
2007	10	3	4	0	17
2008	9	0	5	1	15
2009	6	1	1	2	10
2010	6	0	1	1	8
2011	5	0	0	2	7
2012	9	0	4	0	13
2013	6	0	0	1	7
2014	7	0	1	2	10
2015	3	2	1	4	10
2016	5	0	5	1	11
2017	12	0	2	2	16
2018	2	2	2	0	6
TOTAL	**968**	**94**	**88**	**118**	**1,268**

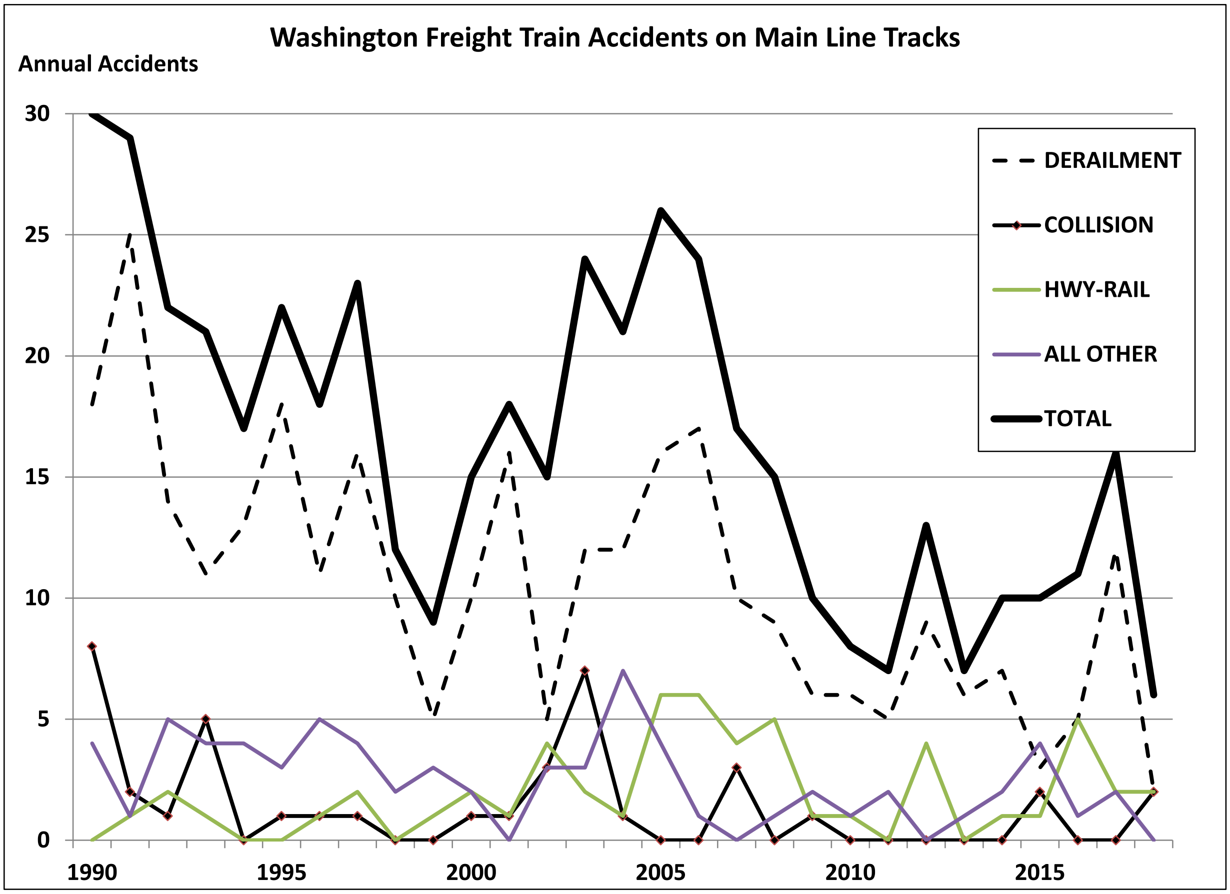

Figure 34: Mainline Freight Accidents in Washington State, 1990–2018[90]

Analysis of causes for freight rail accidents

The various types of accidents can be attributed to five basic primary causes, as classified by the FRA:[91]

- Track conditions
- Mechanical/electrical failures or malfunctions
- Human error
- Signal failures or malfunctions
- Miscellaneous/other

The "miscellaneous/other" category of accidents includes a variety of types of accidents that do not fit into the other four categories (track conditions, mechanical/electrical failures or malfunctions, human error, or signal failures or malfunctions). FRA includes a large variety of causes of accidents in the category of Breakdown of Miscellaneous/Other Causes of Accidents, as shown in Table 28.

[90]Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[91]A spill may be attributable to a derailment, e.g., but the derailment may be caused by human error or track issues.

Table 28: Breakdown of Miscellaneous/Other Causes of Accidents in FRA Data, 1975–2018[92]

FRA Accident Cause Classification	Percent Cases of Miscellaneous/Other Category
Automatic hump retarder failed to sufficiently slow car due to foreign material on wheels of car being humped	0.03%
Cause under active investigation by reporting railroad	1.12%
Emergency brake application to avoid accident	1.68%
Extreme environmental condition - DENSE FOG	0.01%
Extreme environmental condition - EXTREME WIND VELOCITY	1.60%
Extreme environmental condition - FLOOD	0.61%
Extreme environmental condition - TORNADO	0.28%
Failure by non-railroad employee, e.g., industry employee, to control speed of car using hand brake	0.10%
Fire, other than vandalism, involving on-track equipment	1.15%
Highway user cited for violation of highway-rail grade crossing traffic laws	5.89%
Highway user deliberately disregarded crossing warning devices	3.27%
Highway user impairment because of drug or alcohol usage (as determined by local authorities, e.g., police)	0.39%
Highway user inability to stop due to extreme weather conditions (dense fog, ice or snow packed road, etc.)	0.25%
Highway user inattentiveness	14.56%
Highway user misjudgment under normal weather and traffic conditions	5.23%
Highway user unawareness due to environmental factors (angle of sun, etc.)	0.07%
Improperly loaded car	4.22%
Improperly loaded container/trailer on flat car	0.06%
Interaction of lateral/vertical forces (includes harmonic rock off)	13.01%
Interference (other than vandalism) with railroad operations by nonrailroad employee	3.16%
Investigation complete, cause could not be determined	0.39%
Load fell from car	1.62%
Load shifted	6.23%
Malfunction, improper operation of train activated warning devices	0.04%
Miscellaneous loading procedures	0.33%
Object or equipment on or fouling track - other than livestock or motor vehicle	5.59%
Object or equipment on or fouling track (livestock)	0.03%
Object or equipment on or fouling track (motor vehicle - other than highway-rail crossing)	2.31%
Objects such as lading chains or straps fouling switches	0.42%
Objects such as lading chains or straps fouling wheels	0.06%
Other extreme environmental conditions	1.42%
Other miscellaneous causes	13.33%

[92] FRA data

FRA Accident Cause Classification	Percent Cases of Miscellaneous/Other Category
Overloaded car	1.45%
Overloaded container/trailer on flat car	0.50%
Snow, ice, mud, gravel, coal, sand, etc. on track	2.46%
Track damage caused by non-railroad interference with track structure	0.17%
Trailer or container tiedown equipment improperly applied	0.84%
Vandalism of on-track equipment, e.g., brakes released	0.48%
Vandalism of track or track appliances, e.g., objects placed on track, switch thrown, etc.	5.65%

The national accident data were parsed by accident type and cause, as shown in Table 29 and Table 30. The same analyses were conducted for Washington only (Table 31 and Table 32). Note that different types of accidents can be attributed to the same category of causes, or, conversely, different causes can result in different types of accidents. For example, derailments may be caused by track conditions, mechanical/electrical malfunctions, and human error, and human error can cause derailments or collisions.

Table 29: Freight Rail Accident Causes on Mainlines, 1975–2018: Numbers of Accidents[93]

Accident Type	Track Conditions	Mechanical Electrical	Human Error	Signal Failure	Misc.	Total
Derailment	24,112	16,032	6,820	96	6,032	**53,092**
Highway-Rail	2	4	10	1	6,974	**6,991**
Collision	106	399	2,815	17	588	**3,925**
All Other	125	1,686	1,053	11	1,730	**4,605**
Total	**24,345**	**18,121**	**10,698**	**125**	**15,324**	**68,613**

Table 30: Percent Freight Rail Accident Causes on Mainlines, 1975–2018[94]

Accident Type	Track Conditions	Mechanical Electrical	Human Error	Signal Failure	Misc.	Total
Derailment	45.42%	30.20%	12.85%	0.18%	11.36%	**100%**
Highway-Rail	0.03%	0.06%	0.14%	0.01%	99.76%	**100%**
Collision	2.70%	10.17%	71.72%	0.43%	14.98%	**100%**
All Other	2.71%	36.61%	22.87%	0.24%	37.57%	**100%**
Total	**35.48%**	**26.41%**	**15.59%**	**0.18%**	**22.33%**	**100%**

[93] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[94] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.

Table 31: Freight Rail Accident Causes on Washington State Mainlines, 1975–2018: Number of Accidents[95]

Accident Type	Track Conditions	Mechanical Electrical	Human Error	Signal Failure	Misc.	Total
Derailment	345	338	151	0	134	**968**
Highway-Rail	0	0	1	0	87	**88**
Collision	0	8	68	0	18	**94**
All Other	2	35	35	1	45	**118**
Total	**347**	**381**	**255**	**1**	**284**	**1,268**

Table 32: Percent Freight Rail Accident Causes on Washington State Mainlines, 1975–2018[96]

Accident Type	Track Conditions	Mechanical Electrical	Human Error	Signal Failure	Misc.	Total
Derailment	35.64%	34.92%	15.60%	0%	13.84%	**100%**
Highway-Rail	0%	0%	1.14%	0%	98.86%	**100%**
Collision	0%	8.51%	72.34%	0%	19.15%	**100%**
All Other	1.69%	29.66%	29.66%	0.85%	38.14%	**100%**
Total	**27.37%**	**30.05%**	**20.11%**	**0.08%**	**22.40%**	**100%**

Accident rates per train-mile

Accident rates were calculated on a per-train-mile[97] basis for the various types of accidents for the U.S. and for Washington State (Table 33 and Table 34). Note that there are approximately 10 million train-miles in Washington State. The accident types for Washington State and the U.S. for the years 2015 through 2018 are compared in Figure 36.

The reasons for the higher rates of collisions and other accident types (not derailments or highway-rail accidents) are not immediately apparent. The data should be viewed with caution in that there is no statistically significant difference between the overall accident rates in Washington State compared to the U.S.

[95] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[96] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[97] A train-mile is a single train traveling one mile.

Table 33: U.S. Freight Train Mainline Average Annual Accidents per Million Train-Miles, 1975–2018[98]

Accident Type	1975–1984	1985–1994	1995–2004	2005–2014	2015–2018	1975–2018
Derailment	5.81	1.83	1.18	0.76	0.48	**2.22**
Highway-Rail	0.34	0.26	0.25	0.26	0.25	**0.28**
Collision	0.39	0.15	0.10	0.07	0.03	**0.16**
All Other	0.35	0.15	0.13	0.12	0.18	**0.19**
Total	**6.90**	**2.38**	**1.67**	**1.21**	**0.94**	**2.85**

Table 34: Washington State Freight Mainline Average Annual Accidents per Million Train Miles[99]

Accident Type	1975–1984	1985–1994	1995–2004	2005–2014	2015–2018	1975–2018
Derailment	6.00	1.35	1.14	0.90	0.55	**2.19**
Highway-Rail	0.50	0.20	0.16	0.04	0.10	**0.21**
Collision	0.28	0.08	0.14	0.28	0.25	**0.20**
All Other	0.40	0.25	0.32	0.14	0.17	**0.27**
Total	**7.17**	**1.88**	**1.76**	**1.36**	**1.07**	**2.86**

[98] National train mile data from FRA (excludes switching miles). Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.
[99] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting.

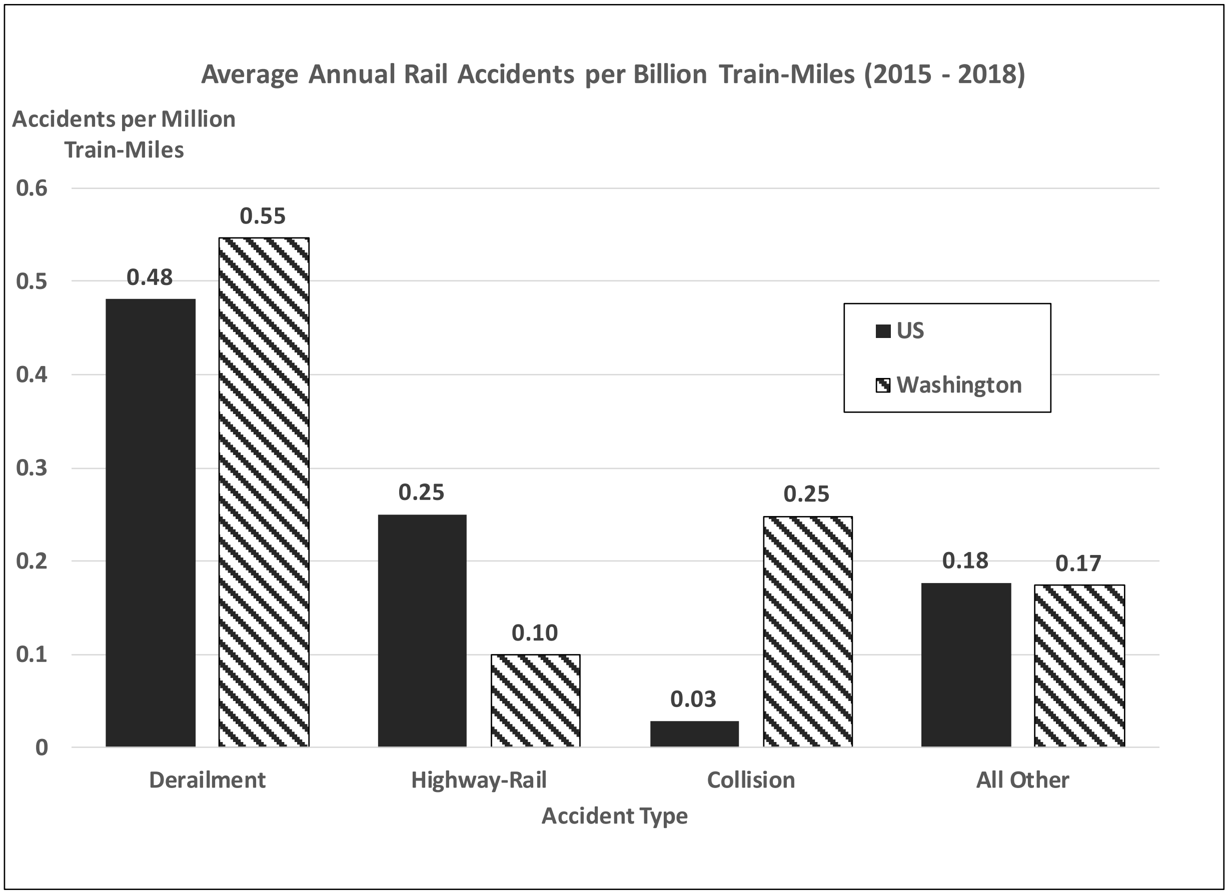

Figure 35: Comparison in Mainline Rail Accident Rates for U.S. and Washington State, 2015–2018[100]

Inter-city passenger train accidents

The Amtrak trains use much of the US rail system.Accidents that occur on Amtrak usually get nationwide attention because they involve passengers and potential casualties.

An analysis of inter-city passenger train accidents (Amtrak) based on FRA data for 4,972 accidents that occurred during the years 1975 through October 2018 was conducted. This analysis included 104 incidents in Washington State. The data for total annual derailments, highway-rail crossing accidents, and collisions are shown in Figure 37.

[100] Analyses conducted on Federal Railroad Administration (FRA) data by Environmental Research Consulting. Used with permission.

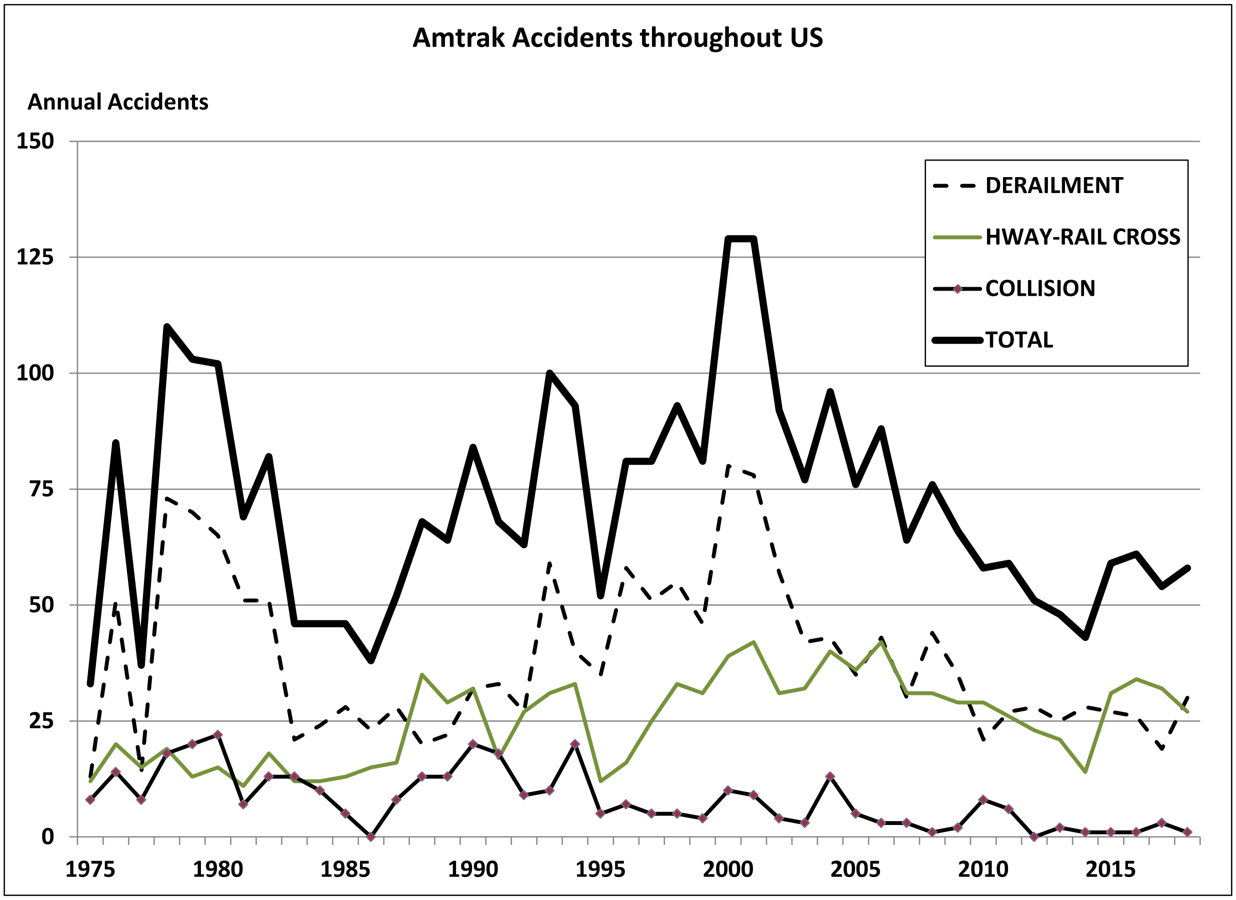

Figure 36: Amtrak Accidents throughout the U.S., 1975–2018[101]

Table 35: US Amtrak Average Annual Accidents per Million Passenger Train-Miles (1975-2018)[102]

Accident Type	1975–1984	1985–1994	1995–2004	2005–2014	2015–2018
Derailment	1.14	0.82	1.43	0.83	0.67
Highway-Rail	0.39	0.65	0.79	0.74	0.81
Collision	0.35	0.30	0.17	0.08	0.04
Total	**1.87**	**1.77**	**2.39**	**1.65**	**1.52**

National freight rail and national Amtrak passenger train accident rates (on per train-mile basis) for 2015–2018 are compared in Table 36: Comparison of Average Annual Accidents per Million Train-Miles (2015-2018). There are about twice as many Amtrak accidents per train-mile as for freight trains throughout the U.S. The rates of derailments and collisions are each about 40 percent higher for Amtrak as for freight trains. The rates for highway-rail crossing accidents are more than three times higher.

[101] Analysis by Environmental Research Consulting based on FRA data.
[102] Based on FRA data on passenger train-miles and accidents.

While these comparative numbers are interesting and noteworthy, it is important to bear in mind that there are significant differences in passenger and freight train operations that may explain some of the differences in accident rates.

Table 36: Comparison of Average Annual Accidents per Million Train-Miles, 2015–2018[103]

Accident Type	Derailment	Highway-Rail	Collision	Total
US Freight	0.48	0.25	0.03	**0.76**
US Amtrak	0.67	0.81	0.04	**1.52**
Amtrak/Freight	**1.15**	**1.06**	**0.07**	**2.28**

Passenger train operations involve higher speeds, but lighter equipment than freight train operations. This means that there may be more damage to the passenger equipment in the event of an accident. This may lead to higher rates of *reportable* accidents. There is a threshold of damage for accident reporting in the FRA data ($10,700 per incident). It is also possible that this difference can be attributed to lighter passenger trains are more likely to derail than heavier freight trains. Research studies have shown that derailments are more likely if lighter rail vehicles are involved (Chadwick 2017). Heavier equipment (locomotives and rail cars) sit more firmly on the tracks and are less likely to derail.

The higher rate of highway-rail accidents (at-grade crossings) is likely due to the higher speed of passenger trains. As discussed in greater detail in Chapter 13, one of the biggest problems with grade crossings is that too often drivers choose to go around crossing gates and ignore warning signals thinking that they can "beat the train." There is an optical illusion that makes an oncoming train appear to be much further away and moving more slowly than it really is (see information from the Operation Lifesaver Program in Chapter 13). Since passenger trains move at higher speeds than freight trains, there is a greater likelihood that the vehicle moving through the crossing will not make it safely to the other side of the tracks.

Potential areas of future discussion

- The FRA accident database is an invaluable tool for analyzing trends and noting issues in specific rail subdivisions or for particular types of trains. The Rail Safety Committee might consider familiarizing itself with the database and utilize it for analyses that might provide useful information for developing voluntary safety standards.
- UTC, Ecology, and/or the Rail Safety Committee may consider regularly reviewing the data for Washington State. It may be in identifying issues and documenting the success of intervention and safety enhancement measures.
- As per recommendations from UTC in the *2014 Washington State Marine & Rail Study* (Etkin et al. 2015), Ecology and UTC might consider working with FRA, in conjunction with other state and local governments (i.e., other states and communities that have railroads passing through them), to review and improve the usability of existing FRA accident databases. Such improvements might include the ability to sort data by state and incident type in a more user-friendly manner than is currently available online. This would save time for the people doing the research and conducting the relevant analyses, as well as improve the ability to search and retrieve accident and incident information.

[103] Analysis by Environmental Research Consulting based on FRA data.

Chapter 6: Washington Rail-Transported Commodities

Key questions

- What are the properties of the hazardous materials transported by rail in Washington?
- How are freight commodities classified and labeled?
- What are the regulations for labeling commodities?
- What are the properties of freight commodities?
- What are the toxicity, flammability, and explosiveness levels of freight commodities?

Takeaways

- Crude oils and the products that are refined from them are all made up of complex mixtures of many different types of hydrocarbons, from very light compounds that evaporate easily to ones that are very heavy and persistent in the environment.
- Crude oil and refined petroleum products are mainly classified by their density or how light or heavy they are compared to water. The lighter oils have more of the lighter hydrocarbons that evaporate easily. The heavier oils have fewer of these hydrocarbons and more of the heavier more tar-like hydrocarbons that tend to persist for a longer time in the environment when spilled.
- The lightest oil types are gasoline, kerosene, and jet fuel. These are called "Group I" oils.
- Group II oils are slightly heavier and include diesel fuel and Bakken crude oil.
- Group III oils include medium to heavy crude oil, including diluted bitumen (often called "dilbit" or "tar sands oil") from Canada.
- Group IV oils are somewhat heavier and include the heavy fuel oils used on ships.
- Oils from Groups I through Group IV are lighter than water and will (generally) float.
- Group V oils are heavier than water and will sink below the surface. These are generally not handled in Washington.
- When oil spills onto water, it tends to float and spread into very thin layers or "sheens" on the water surface. Lighter components of the oilwill begin to evaporate quickly. These lighter parts of the oil are also often more toxic and more flammable.
- The heavier parts of spilled oil tend to stick to surfaces like shoreline features or the feathers or fur of wildlife.
- When the water is very turbulent, as in a rapidly flowing brook, oil may be churned up and form smaller droplets that go under the surface. This oil will tend to rise again, although the smaller the droplets, the more time the refloating takes.
- Some oil may combine with sediment or sand in the water and become heavy enough to sink.
- Bakken crude is particularly volatile. Treatment processes called "conditioning" can make the oil less likely to ignite if spilled.
- There are a variety of other types of hazardous materials that are transported by rail in Washington, including other flammable, poisonous, and corrosive substances. The rail industry is required to properly label tank cars and other types of rail cars that carry these hazardous materials.

- Certain routes that are taken by trains carrying hazardous materials will potentially experience higher consequences in the event of a spill, including cities and towns with a high population density and environmentally sensitive areas.
- In addition to labeling, the rail industry uses very specific safety protocols to handle different types of hazardous cargo, including careful positioning of cars in a long train and inspection of cars. The protection of rail cars from vandalism and terrorism is an important consideration for rail safety. There are specific regulations for security measures that railroads must follow.

The following sections provide a more in-depth look at the types and quantities of hazardous and non-hazardous commodities currently being transported by rail through Washington State, as well as their properties. The labeling and classification for safety purposes is also addressed. This information will provide a context for assessing the relative risks associated with different types of hazardous commodities. More detailed information about quantities and trends in the transport of hazardous commodities in Washington is presented in Chapter 4. The consequences of accidental releases of oils and other hazardous materials are explored in Chapter 7.

Hazardous commodities transported by rail in Washington

At present, about 81,000 carloads of crude petroleum (about 685 unit trains per year) transit into Washington State annually. An additional 60,000 carloads of various refined petroleum products are on the rail corridors each year. This includes products coming into the state and those being produced in Washington's oil refineries for transport within the state and elsewhere. Only 1 to 2 percent of refined petroleum products produced in Washington moves by rail. Another 62,000 carloads of various chemicals are transported by rail annually.

Crude oil and refined petroleum products

Perhaps more than any other factor, the type of oil that is spilled will have a major effect on the way in which it behaves when spilled, as well as the degree and type of impacts that occur after a spill. The characteristics of crude oils and refined products with respect to their behavior in the environment (e.g., evaporation rate and viscosity), will influence ecological impacts.

Other factors that affect the potential for ecological impact include the tendency to affect organisms due to toxicity, the potential for mechanical injury, and the persistence of the oil type.

There are hundreds, if not thousands, of known oil types, including crude oils from many locations that differ with respect to properties, and a broad spectrum of refined products that are created from these crude oils. Each crude oil or refined product is unique to the point that it can be "fingerprinted" forensically in spill cases based on their unique combination of literally hundreds of thousands of hydrocarbon components and other constituents, such as sulfur and heavy metals.

Classification of oil type by density

One of the most important characteristics of a particular type of oil is its density or specific gravity (i.e., how light or heavy it is compared to water) in grams per cubic centimeter (g/cm^3) or gram per milliliter (g/ml). As a reference, freshwater has a density of 1 g/cm^3. Seawater has salt ions in it that are heavier than water. Therefore, the density of seawater is greater than that of freshwater. It varies from about 1.024 g/cm^3 at 20°C (68°F) to 1.0273 g/cm^3 at 0°C (32°F). However, saltwater can be less salty (e.g. estuary with a river flowing into it) or more salty (e.g. Soap Lake, Washington), depending on the location and season.

Another way to express density that is commonly used in the oil industry is degrees API (°API) or "API gravity." It is called API gravity because this unit of measurement was developed by the American Petroleum Institute, or the API. API gravity is inversely related to density.[104] That is, the higher the density, the lower the °API measure. A low ºAPI oil has a high density and specific gravity, and a high ºAPI oil has a low density and specific gravity. A heavy oil is one with an ºAPI gravity less than 20°. Oil density increases with weathering (evaporation of volatile hydrocarbon components) and decreasing temperature (as described in greater detail in Chapter 7).

For the purposes of assessing potential impacts and preparing for spill response, the different oil types need to be grouped into a small number of categories that incorporate their general properties and ecological impact potential. Crude oils are generally defined by their densities. The EPA and U.S. Coast Guard (USCG) define petroleum-based oil groups based on specific gravity (density) as in Table 37.

Table 37: Oil Groups with Attributes and Examples (EPA and USCG)

Group	Density (g/cm^3)	°API	Examples
Group I	Less than 0.80	Over 45.2	Gasoline, kerosene
Group II	0.8–0.85	45.2–34.8	Gas oil, light crude, Bakken crude, diesel
Group III	0.85–0.95	34.8–17.3	Medium to heavy crude; diluted bitumen
Group IV	Over 0.95 to 1.00	Less than 17.3 to 10.0	Intermediate fuel oil, Bunker C
Group V	> 1.00	Less than 10.0	Orimulsion, Boscan crude

In the Washington State Advance Notice of Transfer (ANT) database and in its quarterly reports on crude oil movements (Washington State Dept. of Ecology 2018a, 2018b, 2018c, 2019a), Ecology classifies crude oil by API gravity, as shown in Table 38.

The Rail Safety Committee may want to consider adopting one or the other method of classifying oil. It may be advisable to stick to Ecology's ANT classification system for consistency with reports on shipped oil quantities and other data within the State of Washington. However, when conferring with officials in other states, with the USCG or U.S. EPA, or when

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[104] Density, mass per unit volume of the oil, determines its buoyancy in water. Density is commonly expressed in grams per cubic centimeter (g/cm^3) or in ºAPI. The units are related as: $^{o}API = (141.5 / sp.gr.) - 131.5$.

$$sp.gr. = \frac{141.5}{(^{o}API + 131.5)}$$

evaluating data in reports produced by other entities, the Rail Safety Committee may wish to be mindful of the differences in nomenclature.

Table 38: Department of Ecology Advance Notice of Transfer Crude Oil Classifications[105]

ANT Crude Type	°API	Density (g/cm^3)	Oil Group	Examples
Light Crude	31.2–50	0.7796–0.8697	Group I to Group III	Bakken crude
Medium Crude	22.3–31.1	0.8702–0.9200	Group III	Alberta or Saskatchewan medium crude; some diluted bitumen
Heavy Crude	10–22.2	0.9206–1.0	Group III to Group V	Alberta heavy crude; some diluted bitumen
Extra Heavy Crude	0–9.9	1.0007–1.0760	Group V	None in Washington

Another important characteristic for crude oil is sulfur content, which determines whether a crude oil is “sweet” or “sour.” Any crude with a sulfur content above 0.5 percent sulfur is considered “sour.”

Crude oil is highly variable with respect to content and thus has a wide range of physical and chemical properties. The components of crude oil are refined into a large number of products ranging from jet fuel, kerosene, and gasoline, made from the lightest ends, to diesel, through to heavier components, which are used to make heavy fuel oils, and the heaviest components that make asphalts. Crude oils from different regions and reservoirs have different proportions of these components. Alaska North Slope (ANS) crude is generally heavier than South Louisiana crude, but not as heavy as some types of Venezuelan crude (Note that ANS crude is frequently transported into Washington State by tank vessel.). Even when taken from the same oil fields, crude properties may change over time as different depths and areas within the same field are accessed.

In general, oil floats on water, because it is less dense than water. Slightly heavier oils float more easily on seawater than in freshwater. There are circumstances in which oils that are less dense than water may become submerged in the water column (sink). Sinking oil typically occurs when the oil becomes mixed with sediment or sand that is heavier than water. The combination of oil and heavier particles may become heavier than water and sink. Oil may become mixed with particles suspended in the water column when the water is very turbulent. However, portions of the oil can refloat at a later time when the oil separates from the particles. Another way in which oil may become heavy enough to sink is if there is significant weathering (evaporation, dissolution, degradation) of the lighter aromatic compounds and the remaining heavier compounds form a residual oil that may become dense enough to exceed the density of water.

Other ways to categorize oil are generally based on the density or specific gravity of the oils, but also incorporate the concentrations of aromatic components, which tend to be more toxic and evaporate more easily, versus concentrations of heavier components, which are less toxic, but are highly persistent in the environment. Ultimately, these are the factors that will determine short- and long-term impacts on natural and socioeconomic resources. A typical simplified breakdown

[105] Washington State Dept. of Ecology 2018a.

of oil types is as follows. These groupings are consistent with the classifications shown in Table 38.

Volatile Distillates (Group I): This category includes refined petroleum products that are highly toxic but are non-persistent in the environment because they evaporate relatively rapidly, such as gasoline, jet fuel, kerosene, crude condensate, and No. 1 fuel oil. In the U.S., this category is called “Group I Oil” that consists of hydrocarbon fractions at least 50 percent of which, by volume, distill at a temperature of 645ºF; and at least 95 percent of which, by volume, distill at a temperature of 700ºF. In general, volatile distillates exhibit all of the following behaviors:

- Highly volatile (evaporate completely within one to two days).
- Contain high concentrations of toxic soluble compounds.
- Capable of causing localized, severe impacts to surface and subsurface resources, and contaminating drinking water.
- Generally, because they evaporate so quickly, they are nearly impossible to clean up with conventional response tools.

Light Oils (Group II): This category incorporates crude oils and refined petroleum products that are quite toxic but also contain some persistent components. These oils are considered to be “low persistent” in that they do not evaporate as readily as volatile distillates. The category includes No. 2 fuel, diesel fuel, light crude oil, gas oil, hydraulic oil, and catalytic feedstock. In the U.S., this category is called “Group II Oil,” including crude oil and products that have a specific gravity less than 0.85 [API° >35.0]. In general, light fuels exhibit all of the following behaviors:

- Moderately toxic.
- Will leave a residue of up to one-third of the spill amount after a few days.
- Contain moderate concentrations of toxic soluble compounds.
- Capable of oiling surface and subsurface resources with long-term contamination potential.
- Generally possible to clean up with effective response tools.

Medium Oils (Group III): This category includes crude oils and refined petroleum products that are moderately toxic and moderately persistent, such as most crude oils, and lubricating (lube) oil. This category would also include synthetic crudes. In the U.S., these oils are considered “Group III Oils,” having a specific gravity between 0.85 and less than 0.95 [API° ≤35.0 and >17.5]. In general, these medium oils exhibit all of the following behaviors:

- About one-third will evaporate within 24 hours.
- Oil contamination can be severe and long-term.
- Oil impacts to waterfowl and fur-bearing mammals can be severe.
- Cleanup is most effective if conducted quickly.

Heavy Oils (Group IV): This category includes crude oil and petroleum products that are persistent, though less toxic. This group includes heavy fuel oil, Bunker C, No. 5 or No. 6 fuel, most intermediate fuel oils, and heavy crude oils. This category would also include bitumen blends. In the U.S., these oils are classified as Group IV, having a specific gravity between 0.95 to and including 1.0 [API° ≤17.5 and >10.0]. In general, these heavy oils exhibit all of the following behaviors:

- Heavy oils with little or no evaporation or dissolution.
- Heavy contamination likely.
- Severe impacts to waterfowl and fur-bearing mammals through coating and ingestion.
- Long-term contamination of sediments possible.
- Weather slowly.
- Shoreline and substrate cleanup operations are difficult under all conditions.

Low API° Oils (Group V): Oils that have specific gravities over 1.0 [API° ≤ 10.0] are called "Low API° Oils" (or "LAPIOs"). In the U.S., these oils are classified as Group V. These oils are unique in that they can sink or remain submerged in the water column when spilled without needing aggregation with any sediment to otherwise increase their mass. In other ways, they behave and have impacts much as other heavier oils do and are thus included in this general category.

Densities of some common refined petroleum products are in Table 39.

Table 39: Density for Selected Refined Oils Potentially Transported in Washington State[106]

Oil Type	Typical Specific Gravity (g/cm^3)	Typical °API
Fuel #6 (Bunker C)	0.983	12.4
Fuel #2 (Diesel)	0.838	37.4
Gasoline	0.750	57.2
Jet Fuel or Kerosene	0.820	41.1
Intermediate Fuel Oil (IFO)	0.95	17.4

Other oil properties that determine spill fate and effect

Besides density, there are a number of properties of oil that affect its behavior in spills and its effects in the environment. The particular chemical makeup of the oil — its unique combination of various components, such as aliphatics (e.g., alkanes), monoaromatic hydrocarbons (e.g., benzene, toluene, ethylbenzene, and xylenes), polynuclear aromatic hydrocarbons (PAHs), and many other compounds — determine its behavior and toxicity (SL Ross 2006; SL Ross 2010).

Some of the most toxic substances in oil (e.g., benzene, toluene, ethylbenzene, and xylene [i.e. BTEX]) are also more likely to evaporate and disperse, which reduces the time that they remain concentrated in the aquatic environment. Because of this, other compounds such as heavier molecular weight aromatics and PAHs or aliphatics, traditionally considered less toxic, may be more persistent and may result in larger potential effects (i.e. mortality) than the BTEX. The toxic effects of many oil spills are usually realized in the first hours to days of a spill. Evaporation of the volatile hydrocarbons leaves behind the heavier, more persistent fractions of oil, which typically are not as toxic. Evaporation rates are dependent on temperature and wind speed with higher evaporation in warmer temperatures and higher winds. Evaporation percentages of some common oils are shown in Table 40. The more oil that evaporates (disperses in the atmosphere) and changes its physical form (degrades), the less oil there is to remove mechanically, and the less oil that persists in the environment to impact natural and socioeconomic resources. At the same time, the presence of volatile components means that

[106] This are standard data used by EPA, USCG, NOAA, and other government sources.

there will be at least some toxic impacts from the oil, which translates to ecological consequences as well.

Table 40: Evaporation Percentages for Selected Reference Oils[107]

Oil Group	Representative Oil	Evaporation % (after 24 hours) at 1ºC (33.8ºF)	Evaporation % (after 24 hours) at 15ºC (59ºF)
Volatile Distillate	Gasoline	88	88
Light Oil	Fuel #2 (Diesel)	16	34
Medium Oil	Medium Crude	22	25
Heavy Oil	Fuel #6	6	4

Another property that affects oil behavior is viscosity. Viscosity is a measure of the resistance of oil to flowing once in motion. Oil viscosity increases as weathering progresses and increases with decreasing temperature. Viscosity is one of the most important properties for spill behavior, because it affects the spreading of oil. The more viscous the oil, the more slowly it spreads on the water surface. It also tends to become thicker on the water surface, which means that it creates a thicker layer when it sticks to shorelines. Viscous oils are also more likely to emulsify and remain in an emulsified state. This means that it combines with water droplets to create a frothy mixture. Viscosity, however, does not affect toxicity.

Viscosity also affects the effectiveness of certain spill response measures. Highly viscous oils are difficult to disperse chemically, but are typically found in thicker patches (i.e. they spread less). Natural dispersion is also reduced in highly viscous oils. Increased viscosity decreases the potential for oil to become entrained into the water column, as more energy (turbulence) is required to break apart surface slicks into droplets in the water column. More viscous oils are difficult to recover with skimmers and pumps and thus tend to increase response costs.

The "pour point" of a particular type of oil is the lowest temperature at which the oil will still flow (Fingas 2014). Below this temperature, the oil begins to develop an internal yield stress and, in essence, solidifies (i.e. "freezes"). If the ambient temperature is above the pour point of the oil, it will behave as a liquid. If the ambient temperature is below the pour point, the oil will behave as a semi-solid. Fingas goes on:

> The pour point temperature increases with weathering (evaporation of volatile components). Pour point affects spreading on the water surface. Oils that are at temperatures below their pour points will not spread and are more difficult to disperse. Viscosity increases dramatically at temperatures below the pour point.
>
> Because oils will resist flowing toward skimmers or down-inclined surfaces in skimmers, there are significant challenges in mechanical oil recovery at these temperatures. The solidification of the oil below its pour point also causes problems in storage and transfer. These factors can increase spill response costs because more work needs to be done manually...
>
> The adhesiveness (stickiness) of a particular oil type is the degree to which oil remains on a surface after contact and draining. This character has an effect on spill impacts by way

[107] Information from RPS Group, Inc.

> of the amount of oil that will stick to surfaces, including shoreline substrates and structures (e.g., piers, boats, seawalls). Higher adhesion increases damage costs and shoreline cleanup costs. At the same time, adhesion can increase the effectiveness of some on-water recovery methods, including use of oleophilic (oil-attracting) skimming devices (p. 15).

However, in some circumstances, the reduced spreading especially on cold land surfaces and in snow may keep a spill contained and can ease cleanup efforts by mechanical methods (i.e. shovel or excavator).

There is no standard methodology for determining adhesiveness. One methodology that has been applied is the measure of the grams of oil that stuck to a square meter of surface (g/m^2). This testing allows for a relative comparison of adhesiveness between various oils, as shown in Table 41.

Table 41: Adhesiveness for Selected Reference Oils[108]

Oil Type	Oil Group	Adhesion (g/m^2)
Gasoline or Jet Fuel	Volatile Distillate	**1**
Fuel #2 (Diesel)	Light Oil	**6**
Alberta Sweet Mixed Blend Crude	Medium Oil	**13**
Sweet Louisiana Crude	Light Oil	**18**
Alaska North Slope (ANS) Crude	Medium Oil	**28**
Intermediate Fuel Oil (IFO 180)	Heavy Oil	**49**
Fuel #6 (Bunker C)	Heavy Oil	**85**

Oil can also cause “mechanical injury” based on its adhesive properties. This injury is caused by coating, fowling or clogging of organisms and their appendages and apertures, such that movements and behaviors are mechanically inhibited (French McCay et al. 2009).

For the Washington Compensation Schedule (Washington State Preassessment Screening and Oil Spill Compensation Schedule Rule, Chapter 173-183 WAC, 1992), the Washington State Department of Ecology developed a formula to calculate a relative mechanical injury index (on a scale of 0 to 5) based on specific gravity (or density) relative to water, as follows:

$$MechanicalInjury = \frac{(sp.gr. - 0.688)}{0.062}$$

The result is then rounded to the nearest 0.1 to derive the relative score with higher scores denoting more mechanical injury. Since specific gravity can change with temperature (and weathering), mechanical injury is related to these factors as well. In higher temperatures, mechanical injury reduces slightly. Examples of mechanical injury rankings and other oil properties for eight reference oils are shown in Table 42.

Mechanical injury and coating impacts are related to the persistence of oil in the environment. Persistence is not related to toxicity. This means that very persistent oils may not be very toxic. Coating tends to cause socioeconomic impacts, particularly with regard to longer-term impacts

[108] Information from RPS Group, Inc.

on fisheries, and the coating of shoreline features (e.g., tourist beaches, marinas, shore-front property). Spill response is affected by oil persistence, because shoreline (and soil sediment) cleanup operations, as well as most aspects of on-water recovery, are basically focused on the more persistent fractions of the spilled oil that remain in the environment, as opposed to the more volatile components that evaporate relatively quickly.

Table 42: Washington Compensation Schedule Mechanical Injury Rating for Selected Reference Oils[109]

Oil Group	Representative Oil Type	Mechanical Injury Rank
Medium Oil	Crude	3.6
Medium Oil	ANS Crude	3.4
Medium Oil	Alberta Sweet Mixed Blend Crude	2.5
Light Oil	Sweet Louisiana Crude	2.5
Heavy Oil	Intermediate Fuel Oil (IFO 180)	4.9
Volatile Distillate	Jet Fuel (Jet A/Jet A-1)	2.0
Volatile Distillate	Gasoline	1.0
Light Oil	Fuel #2 (Diesel)	3.2
Heavy Oil	Fuel #6	5.0

Fingas also describes oil spill emulsions:

> A water-in-oil emulsion is a stable emulsion of small droplets of water incorporated in oil.[110] Oil spills on water may form stable water-in-oil emulsions that can have different characteristics than the parent crude oil. The tendency to form emulsions, the stability[111] of those emulsions, and the water content of stable emulsion are all important characteristics of an oil that can affect impacts as well as response.
>
> Emulsification can significantly affect the impacts of a spill response... Emulsified oils can be highly persistent in the environment. Strongly emulsified oils are also highly viscous, often with 10 to 100 times the viscosity of the parent oil. Oils with relatively high concentrations of asphaltenes are most likely to form stable water-in-oil emulsions. Some heavy oils do not easily form emulsions because the high viscosity of the oil prevents the uptake of water. Some light or medium oils do not form an emulsion immediately, but once evaporation occurs and the asphaltene concentration increases, the emulsification process begins and usually proceeds quickly thereafter.
>
> Emulsions can present challenges for all types of response strategies, increasing costs and logistical concerns, such as increases in storage of collected oil (i.e., larger volume with oil/water mixture).
>
> The persistence of the oil in the environment can also significantly affect the impacts of a spill… The heavier, more persistent fractions of oil are those that adhere to the feathers of

[109] Based on Geselbracht and Logan 1993 (Washington DOE Damage Compensation Schedule).
[110] Water-in-oil emulsion is colloquially called “chocolate mousse.”
[111] Emulsion stability can be: low, which indicates the emulsion is unstable and will break quickly once removed from the mixing environment; moderate, which means the emulsion will break within a few hours; or high, which means the oil forms a very stable emulsion that is unlikely to break even after standing for 24 hours.

> birds and fur of mammals, as well as to shoreline and wetland communities. For birds and mammals, this coating can cause hypothermia. For organisms living along shoreline or in wetlands, this coating can cause smothering. Both smothering and hypothermia can result in mortality, which increases environmental damages (p. 15).

The persistence of oil and the degree to which the oil adheres to shoreline substrates and penetrates those substrates will affect the degree of ecological consequences (Etkin et al. 2018a, 2018b; Davis et al. 2004).

There is no direct measure of persistence since it depends on a number of other oil characteristics. It is usually measured in relative terms, comparing one oil type to others, and with regard to the amount of time that oil remains in the environment based on empirical data collected in the aftermath of historical spills. One example of a relative ranking for persistence of oil is that developed by Ecology, as shown in Table 43 (Geselbracht and Logan 1993).

Table 43: Washington Compensation Schedule Relative Ranking Scores for Classified Oils[112]

Oil Group	Representative Oil	Persistence (Scale of 1 to 5)	Anticipated Time in Environment
Medium Oil	Alaska North Slope Crude	5	5–10 years or more
Heavy Oil	Bunker C	5	5–10 years or more
Light Oil	No. 2 Fuel Oil	2	1 month to one year
Volatile Distillate	Gasoline	1	1 day to weeks

Fingas describes toxicity of oil (Fingas 2014):

> The *toxicity* of the oil determines the adverse effects and mortality of fish, wildlife, and invertebrates after short-term exposure (hours to days). Mortality as well as sub-lethal effects (e.g., reduced fecundity) is relevant to both environmental impacts, as well as socioeconomic impacts in as much as commercial fisheries, subsistence fishing (particularly important in Tribal Nation areas), and recreational fishing are affected. Different organisms have different tolerances of exposure (p. 16).

In the field, lethal and sub-lethal toxic effects are determined not only by the composition of the oil itself but also by the length of time that the susceptible organisms are exposed to the oil, i.e., the actual dose exposure (time x toxicity) that the organisms experience.

Oil toxicity is determined by the presence of aliphatics, monoaromatic hydrocarbons, and polycyclic aromatic hydrocarbons (PAHs). Toxicity is generally expressed in terms of "LC_{50}", which is the concentration at which 50 percent of the population of a particular species dies. The lower the LC_{50}, the lower the PAH concentration that causes mortality. In other words, it takes less of the toxic substance to kill an organism. Different organisms have different tolerances of exposure. Some species are particularly sensitive to exposure to hydrocarbons (French McCay 2004).

Another method for determining relative toxicity is an acute toxicity relative ranking score (Geselbracht and Logan 1993). The acute toxicity (OIL_{AT}) is determined by the relative

[112] Based on Geselbracht and Logan 1993 (Washington DOE Damage Compensation Schedule).

composition of 1-, 2-, and 3-ringed aromatic compounds weighted by the aqueous solubility of the aromatic compounds. The Acute Toxicity Score is therefore based on the percentage of bioavailable components in the oil that could cause toxicity to fish, invertebrates, and wildlife. Bioavailable components are those that are soluble or semi-soluble in water (i.e., 1- to 3-ring aromatic compounds), such that they can dissolve from the oil into water and then be taken up by the organisms directly from the water or through the gut (if oil is ingested).

A raw acute toxicity relative ranking score (1 to 5) is calculated as follows:

$$OIL_{AT} = \frac{[(SOL_1 \cdot PCT_{WT1}) + (SOL_2 \cdot PCT_{WT2}) + (SOL_3 \cdot PCT_{WT3})]}{107}$$

Where:

SOLi = solubility in seawater of i-ring aromatic hydrocarbons, where i = 1, 2 or 3

PCTWTi = percent weight of i-ring aromatic hydrocarbons in the spilled oil, i = 1, 2 or 3

The weighted percentages and solubility quotients are divided by the value 107, to bring Prudhoe Bay crude oil, with a raw acute toxicity score of 96.3, to a ranked value of 0.9. The decision to use this approach was based on the recommendation of the oil effects advisory committee that worked with Ecology to develop this ranking system for use by Washington State in the development of the Washington State Preassessment Screening and Oil Spill Compensation Schedule Rule (Chapter 173-183 WAC, 1992). The values are ranked relative to the most and least toxic substances on roughly a five-point scale with gasoline at the highest toxicity of 5.0. Examples of acute toxicity scores for the most common oils are shown in Table 44.

Table 44: Washington Compensation Schedule Acute Toxicity Relative Ranking Scores for Common Oils[113]

Oil Group	Oil Type	Ecology 2003 Ranking
Medium Oil	Crude oils	0.9
Heavy Oil	Heavy oils (Bunker C)	2.3
Light Oil	Diesel	2.3
Volatile Distillate	Gasoline	5.0
Volatile Distillate	Jet fuel	1.4

Toxicity varies by temperature and exposure time. In general, the greater the duration of exposure to toxic compounds, the higher the mortality. Toxicity decreases with increasing temperature. The longer the duration of the exposure, the greater the mortality.

Overall oil classifications

Taking into account all of the characteristics of the oils, the four oil groups have been classified with respect to their general impacts as in Table 44 and Table 45. Based on the types of spills that had occurred in the state and were likely to occur in the future, the Department of Ecology

[113] Based on Geselbracht and Logan 1993.

developed the Washington Compensation Schedule (WAC 173-183) for determining the damages associated with spills of different types of oil into marine and freshwater habitats.

Potential impacts are rated on a numerical scale from low to high, considering oil toxicity, persistence, and the vulnerability of the state's marine and aquatic resources at particular locations and in various types of water bodies. The oil properties of acute toxicity, mechanical injury, and persistence are used to characterize the behavior and impacts of the different oil types.

Diluted bitumen has a medium toxicity, high persistence, and high adherence. The toxicity of the oil comes from its diluent, and would thus vary, depending on the type of diluent used. It has not been classified according to the Washington Compensation Schedule, so it does not appear in Table 45. It would, however, likely be classified in a manner similar to Prudhoe Bay crude oil. For Table 46, it would fall between the medium and heavy oils.

Table 45: Washington Compensation Schedule Oil Class Ranking of Typical Oils[114]

Oil Class	Acute Toxicity	Mechanical Injury	Persistence	Total
Prudhoe Bay Crude Oil	0.9	3.6	5	**9.5**
Bunker C	2.3	5	5	**12.3**
No. 2 Fuel Oil	2.3	3.2	2	**7.5**
Gasoline	5	1	1	**7**
Kerosene	1.4	2.4	1	**4.8**

Table 46: Basic Relative Oil Properties as Affect Wildlife and Habitat Impacts[115]

Oil Group	Toxicity	Persistence	Adherence
Volatile Distillates	High	Low	Low
Light Oils	High	Low	Low
Medium Oils	Medium	Medium	High
Diluted Bitumen	Medium	High	High
Heavy Oils (Including Sinking Oils)	Low	High	High

Recent changes in the transportation of crude oil into and through Washington State have primarily involved the transport by rail of two different types of crude oil — Bakken crude from North Dakota, and diluted bitumen from Alberta, Canada. These two categories of crude oils are vastly different from each other and also vary considerably within each category. The properties of these two categories of crude oil present unique challenges for spill response and may cause different types of environmental impacts than oils that have been previously transported, stored, and used in the state. These oils may not easily fit into the categories described under the Washington Compensation Schedule shown in Table 10.

According to WAC 173-183-340, in cases where the spilled oil is not described by any of the oil classes listed (as in Table 44), or is a mixture of oils, Ecology shall determine the acute toxicity,

[114] WAC Part173-183-340.
[115] Source: Environmental Research Consulting, based on previous studies, including Etkin 2012, modified to include diluted bitumen. Used with permission.

mechanical injury, and persistence scores based on the methodologies described under Acute Toxicity, Mechanical Injury, and Persistence above to the extent possible.

Properties of Bakken crude oil

Bakken crude oil is a light and low viscosity with a high vapor pressure (meaning it is volatile). This oil type has been a notable topic for many regulators and emergency responders, as incidents involving it have resulted in a higher likelihood of fires and explosions. In addition, because it is composed of lower molecular weight, lighter ends such as benzene, toluene, ethylbenzene, and xylene (BTEX) which are highly soluble, it does have a high potential to result in biological effects. However, in general, Bakken crude oil is very similar to other light crude oils.

The characteristics of Bakken crude and the way in which to classify it for the purposes of regulations related to transport and handling, and for preparing for spill responses and potential public health and safety issues has been a matter of considerable disagreement. Due to its low viscosity, it flows much more like diesel or gasoline than a crude oil. It has been described as looking like “two-stroke oil mixed with gasoline” (CDR Hall 2014).

Bakken testing results

Because of concerns about the flammability of Bakken crude oil and its unfamiliarity to spill responders and officials, there has been extensive testing of this type of oil in the last few years. Bakken crude oil, or North Dakota sweet crude, exhibits the properties shown in Table 47. In the table, Bakken crude is compared with West Texas Intermediate crude, which is often used as a “standard” crude oil for comparison purposes (Miller et al. 2010). Relative to the standard oil, Bakken is less dense, is less viscous, and contains less sulfur (i.e., is “sweeter”). Bakken has a somewhat higher Reid Vapor Pressure (RVP), which is a measure of volatility.

Table 47: Properties of Bakken Crude[116]

Test	Unit	Bakken	West Texas Intermediate
Density	°API	42.1	39
Hydrogen Sulfide (H_2S)	Ppm	<1	<1
Pour Point	degrees F	<-27.4	<-27.4
Reid Vapor Pressure (RVP)	psia[117]	5.94	4.86
Sulfur	%	0.0955	0.428
Viscosity @ 100°F	SSU[118]	33.7	37.9
Viscosity @ 60°F	SSU	37.7	45.6

Samples of Bakken crude oil that spilled in the Lac-Mégantic incident in Quebec were analyzed for BTEX content for the Transportation Safety Board of Canada with the results shown in Table 48 (Transportation Safety Board of Canada Laboratory Report LP148/2013). These natural constituents of crude oil are the most toxic and soluble components. They readily enter soil and

[116] Miller et al. 2010.
[117] psia = pounds per square inch absolute
[118] SSU = Sabolt Seconds Universal

groundwater during accidental spills. BTEX compounds are classified as priority pollutants by Environment Canada and the EPA. The results indicate that the BTEX compositions of the Bakken crude samples are comparable to typical crude oils, such as West Texas Intermediate crude. The levels of BTEX compounds measured at the site of the Lac-Mégantic incident were reported to be well above recommended exposure limits in the portions of the derailment site that were extensively contaminated with the spilled crude oil.

Table 48: BTEX Testing Conducted on Lac-Mégantic Incident Bakken Crude Samples[119]

Oil Constituent	Bakken Range (ppm)	Bakken Average (ppm)	Gasoline (ppm)	West Texas Intermediate (ppm)
Benzene	1,470–1,850	1,663	49,000	1,380
Toluene	2,770–3,170	2,933	250,000	2,860
Ethylbenzene	768–852	815	30,000	1,120
m/p-Xylene	2,890–3,500	3,250	-	4,290
o-Xylene	1,500–1,660	1,585	-	-

The property of greatest concern for Bakken crude is its volatility. Concern about the volatility of Bakken crude followed the July 2013 accident in Lac-Mégantic, Quebec, Canada, in which a train derailed near the center of a town causing an explosion that resulted in the deaths of 47 people (Etkin et al. 2015).

Even if volatility is the major concern, measuring it and classifying crude oils with respect to potential for flammability is not straightforward. The Reid Vapor Pressure (RVP),[120] which is often used to measure volatility, or how quickly a petroleum product or fuel evaporates, varies from one sample to another. According to ASTM Standard D-323, an RVP of less than 26 psi is considered “low volatility.” In five different samples of North Dakota sweet crude taken on five different dates roughly one year apart, the RVP varied from 5.94 pounds per square inch (psia) to a high of 9.70 psia, a difference of nearly 39 percent. Other properties, such as density (°API) varied by less than 0.5 percent between sampling dates.[121]

In Capline Pipeline tests of a large number of crudes,[122] RVP varied from a low of 0.623 psia for UK Foinaven crude to a high of 10.0 psia for Nigerian Forcados/Oco Condensate Blend. Bakken crude (North Dakota sweet) falls into the middle.

The presence of increasing amounts of dissolved gases and other light ends (methane, ethane, propane, butanes, and pentanes) increases the crude oil’s vapor pressure, lowering its flashpoint and lowering its initial boiling point. According to an American Fuel & Petrochemical Manufacturers (AFPM) study, Bakken crude oil is within the norm with respect to the hazard characteristics of a light crude oil (AFPM 2014). The AFPM study had results as in Table 49.

[119] ppm = parts per million.
[120] RVP is defined as the absolute vapor pressure exerted by a liquid at 100°F as determined by the test method ASTM D-323.
[121] Based on data from Capline Pipeline, which does testing of crude oils (www.caplinepipeline.com).
[122] Based on data from Capline Pipeline, which does testing of crude oils (www.caplinepipeline.com).

The survey showed maximum RVPs of 15.4 psia, considerably higher than those in the Capline testing.

Table 49: AFPM Survey of Bakken Crude Oil Characteristics[123]

Characteristic	Reported Values	Hazmat Transportation Regulatory Implications
Flashpoint	Range: -74.2°F–122°F (-59°C - 50°C)	Bakken crude oils meet the criteria for Packing Group I, II, or III flammable liquids or as combustible liquids.
Initial Boiling Point	Range: 35.96°F–152.42°F (2.2°C – 66.9°C)	Bakken crude oils with an initial boiling point of 95°F (35°C) or less meet criteria for Packing Group I flammable liquids; others for Packing Group II or III flammable liquids or combustible liquids according to flashpoint.
Vapor Pressure at 50°C (122°F)	Maximum: 16.72 psia	All Bakken crude oils have a vapor pressure below 43 psia at 122°F (50°C) and must be transported as liquids.
Reid Vapor Pressure at 38°C (100.4°F)	Maximum:15.4 psia	Not used by the regulations; confirm the vapor pressure at 122°F (50°C) is well below the above 43psia limit and Bakken crude oils must be transported as liquids.
Rail Tank Car Pressures on Delivery	Maximum:11.3 psig	Demonstrates that Bakken crude may be safely transported in DOT Specification 111 tank cars.
Flammable Gas Content	Maximum:12.0 liquid volume percent	None; with the vapor pressures of all Bakken crudes oils examined not exceeding a vapor pressure of 43 psia at 50°C, all Bakken crude oils examined must be transported as liquids.
Hydrogen Sulfide Content in Vapor Space	Most hydrogen sulfide (H_2S) concentrations below OSHA STEL; one reported maximum level of 23,000 ppm	None when low values are experienced; additional hazard communication to warn of the presence of hydrogen sulfide (H_2S) when inhalation hazard levels are encountered.
Corrosivity	NACE B+ or B++	Data and experience indicate that Bakken crude oil does not corrode steel at a rate of ¼ inch per year or more so that Bakken crude oil is not a corrosive liquid.

The American Petroleum Institute (API) analyzed more than 200 samples of Bakken and other types of crude, primarily West Texas Intermediate (WTI) crude and reported the results (Wybenga 2014) as shown in Table 50. The overall conclusion of this analysis was that Bakken crude oil is "very similar to other light crudes."

[123] AFPM 2014

Table 50: Crude Oil Data Properties: Bakken Oil Compared with Other Light Crudes[124]

Characteristic	Other Light Crudes	Bakken Crude[125]
Vapor Pressure PSI (ASTM D6377) Average Value	7.24	11.81
Vapor Pressure PSI (ASTM D6377) Minimum Value	1.43	3.60
Vapor Pressure PSI (ASTM D6377) Maximum Value	11.46	15.37
Sulfur Weight Percent (ASTM D4294) Average Value	0.14	0.10
Sulfur Weight Percent (ASTM D4294) Minimum Value	0.01	0.02
Sulfur Weight Percent (ASTM D4294) Maximum Value	0.64	0.25
API Gravity (ASTM D5002) Average Value	40.36	42.66
API Gravity (ASTM D5002) Minimum Value	34.40	38.60
API Gravity (ASTM D5002) Maximum Value	46.90	47.07
Initial Boiling Point °F (ASTM D86) Average Value	101.94°F (PG II)	91.96°F (PG I)
Initial Boiling Point °F (ASTM D86) Minimum Value	83.40°F (PG I)	79.10°F (PG I)
Initial Boiling Point °F (ASTM D86) Maximum Value	182.80°F (PG II)	150.80°F (PG II)

On the basis of these results, the API analysis showed that:

- "There is no practical difference in vapor pressures between Bakken and other light crudes" (API 2014).
- The density (API gravity or °API) is similar for Bakken crude and other light crudes.
- Initial boiling points of Bakken is within range of Hazard Class 3, along with other light crudes.

The API analyses indicate that Bakken crude is a Class 3 flammable liquid, which means that it has a flash point of not more than 141°F (60.56°C). The average flash point of light crudes is 101.94°F (38.86°C), whereas the flash point for Bakken crude is somewhat lower at 91.96°F (33.31°C).

Packing Group (PG) I has an initial boiling point of 95°F (35°C) or less. PG II has a flash point of 73°F (22.78°C) or less and an initial boiling point of greater than 95°F (35°C). The PG I category encompasses substances that pose a high hazard level; PG II encompasses substances that have a medium hazard level.

The analyses indicate also that Bakken crude is classified as Packing Group I (PG I), except at the minimum measurements for those samples for which the initial boiling point is 150.8°F (66°C). Other light crudes are classified as Packing Group II (PG II), except for those that have a maximum initial boiling point of 83.40°F (28.56°C). The PG I classification encompasses substances that pose a high hazard level. PG II encompasses substances that have a medium hazard level.

[124] API 2014.
[125] Bakken Crude's average vapor pressure of 11.81 psi is about 63% higher than the Other Light Crudes' average vapor pressure of 7.24 psi.

API maintains that Reid Vapor Pressure (RVP) is not a good indicator of flammability based on preliminary analyses of simulations using the Fire Effects on Tank Cars (AFFTAC) Model (API 2014). The API Crude Oil Physical Properties Ad Hoc Group is considering if other crude oil properties are more appropriate in the selection of rail tank cars for transport (e.g., ignitability, flammability, light-end volumetric percent).

A more reliable and accurate measure of volatility is the analysis of distillation assays. Table 51 shows a comparison between the assay of Bakken crude and those for West Texas Intermediate (WTI) crude and Louisiana Light Sweet (LLS) crude. According to this type of assay, Bakken crude has twice as much volatile light-end components as WTI, and 1.7 times as much as LLS (Hill et al. 2011).

Table 51: Crude Oil Assays–Bakken vs. Other Light Crudes[126]

Assay Components	Unit	Bakken	West Texas Intermediate	Louisiana Light Sweet
API Gravity	°API	>41	40.0	35.8
Sulfur	Weight %	<0.2	0.33	0.36
Distillation Yield Light Ends (C1–C4)	Volume %	3	1.5	1.8
Distillation Yield Naphtha (C5–330°F)	Volume %	30	29.8	17.2
Distillation Yield Kerosene (330°F–450°F)	Volume %	15	14.9	14.6
Distillation Yield Diesel (450°F–680°F)	Volume %	25	23.5	33.8
Distillation Yield Vacuum Gas Oil (680°F–1,000°F)	Volume %	22	22.7	25.1
Distillation Yield Vacuum Residue (over 1,000°F)	Volume %	5	7.5	7.6

PHMSA Operation Safe Delivery

In response to the Lac-Mégantic incident, PHMSA embarked on a project "Operation Classification in the Bakken Shale Formation" to ensure that shippers were properly classifying crude oil for transportation in accordance with federal regulations and to better understand of the unique characteristics of mined gases and oils from the Williston Basin in North Dakota.[127]

PHMSA concluded:

> After months of unannounced inspections, testing, and analysis, Operation Classification has determined that the current classification applied to Bakken crude is accurate under the current classification system, but that the crude has a higher gas content, higher vapor pressure, lower flash point and boiling point and thus a higher degree of volatility than most other crudes in the US, which correlates to increased ignitability and flammability.
>
> Importantly, our review of crude oil transportation data also confirmed that large volumes of this crude are moving at long distances across the country. At any given time, shipments of more than two million gallons are often traveling distances of more than one

[126] Hill et al. 2011.
[127] Source: USDOT PHMSA (https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/07_23_14_Operation_Safe_Delivery_Report_final_clean.pdf).

> thousand miles. Put simply, Operation Classification determined that the US is currently shipping a crude oil product with a higher gas content, lower flash point, lower boiling point and higher vapor pressure than other crude oils in large amounts and for long distances. (pp. 1-2)

In July 2014, PHMSA released a follow-on report titled “Operation Safe Delivery” that included the results of its previous testing of samples of Bakken crude oil as of May 2014. The intent of Operation Safe Delivery’s sampling and analysis component was to determine if shippers are properly classifying crude oil for transportation. The intent was also to quantify the range of physical and chemical properties of crude oil.

The PHMSA testing led to the following conclusions (PHMSA 2014):

> Based upon the results obtained from sampling and testing of the 135 samples from August 2013 to May 2014, the majority of crude oil analyzed from the Bakken region displayed characteristics consistent with those of a Class 3 flammable liquid, PG I or II, with a predominance to PG I, the most dangerous class of Class 3 flammable liquids. Based on our findings, we conclude that while this product does not demonstrate the characteristics for a flammable gas, corrosive liquid or toxic material, it is more volatile than most other types of crude — which correlates to increased ignitability and flammability.
>
> Bakken crude’s high volatility level — a relative measure of a specific material’s tendency to vaporize — is indicated by tests concluding that it is a “light” crude oil with a high gas content, a low flash point, a low boiling point and high vapor pressure. The high volatility of Bakken crude oil, and its identification as a “light” crude oil, is attributable to its higher concentrations of light end hydrocarbons. This distinguishes it from “heavy” crude oil mined in other parts of the United States.
>
> Given Bakken crude oil’s volatility, there is an increased risk of an incident involving this material due to the volume that is transported, the routes, and the extremely long distances it is moving by rail. Trains transporting this material, referred to as unit trains, routinely contain more than 100 tank cars, constituting at least 2.5 million gallons within a single train. Unit trains only carry a single type of product, in this case flammable crude oil. These trains often travel over a thousand miles from the Bakken region to refinery locations along the coasts. (p. 16)

Bakken crude oil conditioning

In December 2014, the Industrial Commission of North Dakota issued new conditioning standards, requiring all crude oil produced in the Bakken Petroleum System to be conditioned. Oil conditioning is a process that is performed at the well site, whereby the crude is subjected to specific temperatures (i.e. heating) and pressures to produce a more consistent product prior to shipment. The intent is to remove lighter more volatile compounds (measured as Vapor Pressure), thereby reducing the risk of fire and explosion. In essence, a portion of the lighter and more flammable components of Bakken crude oil are removed making a safer and more consistent hydrocarbon product.

The new standards seek to address safety concerns stemming from several high-profile train derailments in Quebec, North Dakota, Alabama, and Virginia in the recent past.

According to the North Dakota Industrial Commission Oil and Gas Division (ICND 2014):[128]

> First, this commission order was written as a matter of safety. Rail accidents across the country have drawn attention for the need to better understand how Bakken oil is produced and processed at the well site. The commission initially received 1,114 pages of testimony from 33 groups or individuals, all providing input on how Bakken crude oil is produced and how to make it as safe as possible to transport. Subsequent to the November 13, 2014 Industrial Commission meeting the record was opened and an additional 141 pages of testimony from 25 groups or individuals were provided on the working draft order.
>
> Second, the resulting order is based on science from the testimony received. The goal is to produce crude oil that does not exceed a Vapor Pressure of 13.7 pounds per square inch (psi). National standards recognize oil with a Vapor Pressure of 14.7 psi or less to be stable. Allowing for a Vapor Pressure of 13.7 psi or less, adjusts for an error margin of one psi in the sampling procedures and measurement equipment. It's important to note that winter blend gasoline has a Vapor Pressure of 13.5 psi.
>
> An estimated 80 percent of Bakken wells will be able to produce a product below 13.7 psi Vapor Pressure by complying with temperature and pressure parameters as detailed in the commission order:
>
> a) Operate all well site crude oil conditioning equipment within flow rate, pressure, and temperature ranges specified by the manufacturer.
> b) Operating at a pressure of no more than 50 psi must heat fluid to at least 110 degrees Fahrenheit.
> c) Operating at a pressure greater than 50 psi must heat fluid to at least 110 degrees Fahrenheit and install equipment to recover vapors from the crude oil storage tanks.
>
> Roughly 15 percent of Bakken wells operate equipment described (below). Operators will need to demonstrate through sampling and testing in compliance with national standards that the resulting product does not exceed a Vapor Pressure of 13.7 psi.
>
> d) Operating at temperatures and pressures not described in paragraphs (b) or (c) must demonstrate through sampling and testing in compliance with national standards that Vapor Pressure is no greater than 13.7 psi.
>
> The remaining 5 percent of estimated wells are expected to seek alternative methods for conditioning or stabilizing crude oil and must request approval from the commission through notice and hearing.

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[128] Press release from Industrial Commission of North Dakota, December 9, 2014. "Industrial Commission Adopts New Standards to Improve Oil Transportation Safety" (DMR Order 25417). 7 p.

> e) Facilities utilizing alternate methods for crude oil conditioning other than separators and/or emulsion heater-treaters will only be approved after due notice and hearing.
>
> Finally, the standards described in the order are enforceable. The Oil and Gas Division's more than 30 field inspectors can visually inspect gauges on facility equipment to determine operating temperatures and pressures while oil and gas measurement staff can review and approve Vapor Pressure testing. Additional Department of Mineral Resources staff has been included in the Governor's budget for dedication to western North Dakota. Operators found in violation of the order could be subject to a penalty of $12,500 a day. The order is effective April 1, 2015.
>
> In conclusion, with the strong science and enforceability of this order, the state of North Dakota will be requiring that every barrel of Bakken crude oil will be conditioned. (p. 2)

North Dakota's conditioning standards not only sought to increase rail safety locally, but supplement federal efforts in response to the recent increase in rail shipments of crude and ethanol in the United States.[129]

One industry study on catalytic conditioning of Bakken crude oil showed the results in Table 52. The density (°API) is higher and the flash point is higher for the conditioned Bakken oil.

Table 52: Laboratory Test Date for Baseline Bakken Crude and Conditioned Bakken Product[130]

Test	Bakken Crude Feedstock	Conditioned Bakken Product
°API (D1298)	43	37.2
Flash point (D93)	20°C (68°F)	30°C (86°F)
Vapor Pressure (D6377)[131]	8. 48 psi (58.5 kPa)	1. 2 psi (8.27 kPa)
D86 Initial Boiling Point	38°C (100.4°F)	92°C (197.6°F)

2017 PHMSA Advance Notice of Proposed Rulemaking

In January 2017, PHMSA issued an Advance Notice of Proposed Rulemaking (ANPRM) regarding its intent to establish vapor pressure limits for unrefined petroleum (i.e., crude oil) and potentially all Class 3 flammable liquid hazardous materials (Federal Register Vol. 82, No. 11 Wednesday, January 18, 2017 / Proposed Rules, p. 5,499–5,508). PHMSA was assessing the merits of a petition submitted by the Attorney General of the State of New York requesting that PHMSA implement a Reid Vapor Pressure (RVP) limit of less than 9.0 pounds per square inch (psi) for crude oil transported by rail. At the time, New York State had two to four CBR trains transiting through the state daily. (With the exception of brief period in which a total of eight trains passed through in 2017 during a diversion of oil to east coast refineries when refineries in Texas were shut down due to Hurricane Harvey, there has been no regular CBR transport in New York since late 2015.) The ANPRM invited public comment and stated that in order to grant the

[129] Nettles et al. Undated (http://www.cailaw.org/media/files/IEL/Publications/2015/nd-crude-ela-vol9no1.pdf)
[130] Catalytic Resource LLC. *White Paper: Catalytic Conditioning of Bakken Crude Oil.*
[131] kPa = kilopascals; psi = pounds per square inch.

petition for setting a threshold of 9.0 psi for crude oil trains, PHMSA would first have to (Federal Register Vol. 82, No. 11):

- Determine the best metric or combination of metrics (vapor pressure or other metric) for measuring and controlling fire and explosion risk in crude oil transport;
- Quantify the improvement in safety, if any, due to risk reduction from implementation of vapor pressure thresholds at varying levels;
- Identify the measurement techniques necessary to establish compliance;
- Identify offerors' compliance strategies and market impacts with RVP standards at varying levels of stringency, and estimate their economic costs and environmental impacts;
- Identify other regulations and industry practices, such as volatile organic compound emissions standards imposed through the Clean Air Act, or State regulations, or pipeline operator RVP standards, potentially affecting compliance strategies and costs, and safety benefits;
- Evaluate the extent to which use of USDOT Specification 117 tank cars mitigates the risk of transporting crude oil;
- Compare compliance costs of mitigation strategies with risk reduction from adoption of the petition; and
- Balance the benefits and costs in setting the level of the chosen metric. If RVP is the best metric, PHMSA would have to determine that a particular RVP limit is preferable to any other limit. For example, if 9.0 psi is chosen, PHMSA would need to show that this value is preferable to some other potential limits, such as 8.0 or 11.0. This would include considering whether there is a ''safe'' level of RVP below which risks are minimal (which would lead to little safety benefit from reducing RVP further), or some level of RVP where risks do not further increase (p. 5500).

Besides PHMSA extending the comment period to 19 May 2017, and stating in September 2017 that they planned to review a study by Sandia National Laboratories, there has been no further action on this rulemaking.

Sandia Crude Oil Characteristics Research SAE Plan

In 2015, the FAST Act directed the Department of Energy, in cooperation with USDOT to submit a report to Congress that contains results of the Crude Oil Characteristics Research Sampling, Analysis, and Experiment (SAE) Plan, as well as recommendations for regulations and legislation based on the findings to improve the safe transport of crude oil.

Sandia National Laboratories (US DOE 2015) conducted this review and focused on crude oil's

> …potential for ignition, combustion, and explosion. A partial list of properties surveyed includes density (expressed as API gravity), vapor pressure, initial boiling point, boiling point distribution, flash point, gas-oil ratio, ''light ends'' (dissolved gases, including nitrogen, carbon dioxide, hydrogen sulfide, methane, ethane, and propane, and butanes and other volatile liquids) composition, and flash gas composition. Although the review yielded a large database encompassing a wide variety of crude oils and their properties, it

> also illustrated the difficulty in utilizing available data as the basis for accurately defining and meaningfully comparing crude oils… (p. 1)
>
> An important outcome of the review was formal recognition of the wide-ranging variability in crude oil sample type, sampling method, and analytical method, as well as the acknowledgement that this variability limits the adequacy of the available crude oil property data set as the basis for establishing effective and affordable safe transport guidelines. In recognition of the need for improved understanding of crude oil, and especially tight crude oil properties, the Sandia Study was designed to characterize tight and conventional crudes based on key chemical and physical properties and to identify properties that may contribute to increased likelihood and/or severity of combustion events that could arise during handling and transport (p. 2).[132]

The first task of the study, as presented in Part 1 of the Sandia study report (Lord et al. 2015) reviewed the technical literature on crude oil properties, citing many of the studies that were referenced originally in the *2014 Marine & Rail Oil Transportation Study* (Etkin et al. 2015), as repeated in this chapter.

The second task of the study, as presented in Part 2 of the Sandia study report (Lord et al. 2017) was released in November 2017. It describes in great detail various testing and analytical methods used to evaluate crude oil samples for vapor pressure among other properties.

The third task, which will be presented in Part 3 of the Sandia study report, will involve initial combustion experiments and modeling (U.S. DOE 2015):

> Key focus will be on:
>
> 1. Identifying crude oil properties that can affect the type and level of hazards associated with a combustion incident;
> 2. Assessing the impact of identified properties; and
> 3. Developing a prioritized list of properties/parameters that need to be included in subsequent crude oil characterization activities (p. 4).

The fourth task, which will eventually be presented in Part 4 of the Sandia study report, will involve characterizing tight oil (including Bakken crude) versus conventional oil. The task will research crude oils at rail or pipeline terminals that will be transported to distant refineries. The intent of the fourth task is to "…provide a better understanding of which crude oil properties have the greatest impact on combustion event hazards, and whether, and to what extent these properties are preferentially associated with tight rather than conventional oils. Results will also inform the prioritization of subsequent efforts to compare crude oil properties based on geography, seasonal impacts, environmental conditions, well lifetime, and supply chain point" (US DOE 2015).

[132] Tight crude oils also known as shale oils are light crude oils contained within petroleum-bearing formations with low permeability such as shale or tight sandstone that are extracted through fracking.

The fifth task, which will eventually be presented in Part 5 of the Sandia study report, will involve large-scale testing as shown in Table 53 (Lord et al. 2017).

Table 53: Combustion Events, Properties, and Scale of Sandia Crude Oil Testing[133]

Combustion Event	Properties to be Tested	Testing Scale
All Combustion Events	Heat of combustion; Flammability limits; Boiling point temperatures of components; Density; Molecular weight; Composition in liquid/gas phases	Small; can be conducted in laboratory
Pool Fire	Burn rate; Surface emissive power; Flame height; Heat flux to an engulfed object	3-to 30-foot pool
Fireball/BLEVE134F[134]	Geometry; Surface emissive power; Duration; Fragment characterization (velocities, geometry, range); Overpressures	Rail car (BLEVE); rail car or reduced scale (fireball).
Vapor Cloud	Gas composition	Rail car or reduced scale

Finally, the sixth task, which will eventually be presented in Part 6 of the Sandia study report, will involve developing a comprehensive data set involving 160 samples collected from five oil reservoirs in different geographic locations, at eight points along the production/supply chain, during two different seasons, and at two different points in the lifetime of a well (U.S. DOE 2015).

At this time, it is not clear when Parts 3 through 6 of the Sandia study report will be conducted or when the report on these tasks will be available to the public. There is no timeline or timeframe available at this time.

2019 Washington State legislation to limit crude vapor pressure

PHMSA and North Dakota are not alone in considering vapor pressure as a risk factor for crude by rail transport. In the 2019 Legislative Session, the Washington State Senate passed a bill (ESSB 5579) that would restrict the offloading from rail cars and storage at a refinery (or other facility) of any crude oil with a vapor pressure greater than 9.0 psi. For further details on bill ESSB 5579, which is now Washington State Law, refer to the Washington State Legislative website.[135]

Properties of diluted bitumen and related oils

Another type of crude oil that is being transported by rail is diluted bitumen, also known as "dilbit" or Canadian "tar sands oil." This broad category encompasses a number of different types of bitumen blends. Bitumen is the heavy crude oil that remains in the geologic formation after in situ biodegradation processes occur in regions of Alberta, Canada.

The properties vary by location and by season. Diluted bitumen (dilbit) is a petroleum product produced by mixing bitumen (a highly viscous or solid asphaltic material) with light petroleum compounds (e.g., gas condensate or gas range oil), which are the diluent. Typically, the ratio of

[133] Lord et al. 2017.
[134] BLEVE = Boiling Liquid Expanding Vapor Explosion.
[135] https://app.leg.wa.gov/billsummary?BillNumber=5579&Year=2019

bitumen to diluent is 70:30 or 30 percent diluent. There is a heavier form of diluted bitumen called "railbit", which has only 15 percent diluent in the mixture. Diluted bitumen is considered a heavy crude, but varies considerably from other conventional heavy crudes. Diluted bitumen has been transported via pipeline into Washington for some time, but the transport by rail tank car is a relatively new phenomenon.

The Center for Spills in the Environment (2013) describes the situation with dilbit:

> In order to move bitumen efficiently through transmission pipelines, other petroleum products must be added to dilute it… Dilbit is created by adding naphtha-based oils including natural gas condensate. While approximately 75 percent by weight of the condensate has a low boiling point of 399.2°F, the overall boiling point of the diluted bitumen product remains high at 975.2°F. This is important because it means a small fraction (less than 20 percent by weight) will evaporate rapidly during a spill, but the remaining fraction will not. The slower evaporation of the remaining fraction reduces the potential air quality issues for responders and the public. Synbit is made by diluting bitumen by using synthetic crude oil ("syncrude") from refineries. Like dilbit, synbit maintains a high boiling point for the majority of the material.
>
> Dilbit and synbit that is transported through pipelines must meet certain specifications for viscosity, density, and acidity. In order to meet these specifications, the bitumen requires diluent by lighter oils, 30 percent for dilbit and 50 percent for synbit by volume. (p. 7)

Notably, diluted bitumen may be classified as a heavy oil (high density), or in some cases as a medium oil, depending on its density and depending on the criteria used to classify the oil into density groups. According to Ecology's definitions of "medium" and "heavy" oils, medium oils have API gravity range of 22.3-31.1 API, while heavy oil has API gravity range of 10-22.2 API (Washington State Dept. of Ecology 2019a).

Properties of diluted bitumen products are summarized in Table 55. Diluted bitumen contains approximately 2-3 wt percent of sulfur and average sediment values around 100 ppmw, but as high as 784 ppmw. Due to the light nature of the diluent that is used to dilute the bitumen, the light ends and BTEX values are typically higher than other heavy crude oils. The results in Table 54 show that there is considerable variability in products called "diluted bitumen."

Table 54: Selected Physical Properties and Chemical Data for Diluted Bitumen Products[136]

Name	Density (kg/m^3)	Sulfur (wt%)	Sediment (ppmw)	Light Ends[137] Volume %	BTEX Volume %
Access Western Blend	922.9 ± 4.6	3.94 ± 0.09	89 ± 8	24.1 ± 1.7	1.20 ± 0.15
Borealis Heavy Blend	927.4 ± 5.2	3.67 ± 0.29	94 ± 27	24.1 ± 1.7	0.99 ± 0.09
Christina Dilbit Blend	924.9 ± 5.2	3.88 ± 0.09	88 ± 41	22.8 ± 2.2	1.12 ± 0.17
Cold Lake	927.7 ± 5.0	3.78 ± 0.08	94 ± 42	20.4 ± 1.5	1.06 ± 0.17
Peace River Heavy	930.5 ± 4.7	5 ± 0.1	97 ± 30	22.4 ± 1.1	1.02 ± 0.09
Statoil Cheecham Blend	928.8 ± 4.5	3.81 ± 0.09	169 ± 99	24.1 ± 2.3	1.06 ± 0.14
Western Canadian Select	928.1 ± 4.3	3.50 ±0.07	284 ± 23	18.3 ± 1.3	0.83 ± 0.12
Borealis Heavy Blend	927.4 ± 5.2	3.67 ± 0.29	94 ± 27	24 ± 1.7	0.99 ± 0.09
Statoil Cheecham Blend	928.8 ± 4.5	3.81 ± 0.09	169 ± 99	24.1 ± 2.3	1.06 ± 0.13
Long Lake Heavy	932.6 ± 3.6	3.21 ± 0.16	18	15.9 ± 1.2	0.94 ± 0.10
Statoil Cheecham Synbit	930.5 ± 4.2	3.07 ± 0.09	71 ± 11	13.4 ± 1.3	0.76 ± 0.09
Surmont Heavy Blend	936.1 ± 3.8	3.08 ± 0.11	101 ± 42	11.3 ± 0.9	0.59 ± 0.09
Suncor Synthetic H	936.5 ± 2.2	3.07 ± 0.09	39	10.4 ± 1.0	0.44 ± 0.08
Albian Heavy Synthetic	938.7 ± 3.5	2.46 ± 0.23	784 ± 229	23.3 ± 1.4	0.94 ± 0.14

Dilbit is a combination of a diluent (e.g. lighter petroleum product such as a natural gas condensate) with the bitumen. The diluent is less dense, less viscous, and typically contains more lighter ends (e.g. aromatic compounds and BTEX), when compared to the bitumen. The process of combining diluent with bitumen (typically at an elevated temperature and with thorough mixing) results in a cohesive, blended liquid product that is chemically and physically different from the two original base products. The diluent can be removed from dilbit by distillation and reused, or the entire dilbit can be refined. However, should dilbit be accidentally released, this new cohesive blended product would not separate into condensate and bitumen.

While diluted bitumen is composed of Group V oils mixed with lighter diluents, they typically behave like other medium to heavy oils (i.e. they float when released). Group V oils that are classified as "heavy" because their density is greater than 1.0 g/cm^3, meaning they will sink in freshwater. However, as mentioned above, the diluted bitumen product is a cohesive blended product. According to laboratory and mesoscale weathering experiments, diluted bitumen products have physical properties much aligned with a range of intermediate fuel oils and other heavy crude oils and do not sink following a release based upon weathering alone. Generally, depending on the initial blend and state of weathering, diluted bitumen products are not characterized as sinking oils (Witt O'Brien's et al. 2013). Therefore, the diluted bitumen that may be shipped by rail into Washington State is not a Group V oil.

However, most oils, including the less dense Group III and IV oils, can become neutrally or negatively buoyant (i.e., sink) in freshwater or saltwater through various mechanisms. If the oil comes in contact with suspended sediments within the water column (i.e. total suspended solids [TSS], or suspended particulate matter [SPM]) or sediments in a high-energy setting (i.e., in

[136] Government of Canada 2013, and Crude Quality Inc., 2013. www.crudemonitor.ca/home.php, accessed September 2013.
[137] Light Ends compromise the sum of all butanes through decanes, inclusive.

nearshore surf zone areas) then there is the potential for most oils to sink (Etkin et al. 2015; National Research Council 1999).

Diluted bitumen's potential for sinking after weathering — i.e., losing its light fractions to evaporation — was the impetus for a series of tank test studies on the behavior of diluted bitumen when spilled into freshwater[138] or brackish[139] marine waters.[140] However, these tests did not demonstrate that weathered dilbit would sink by weathering alone but required interaction with suspended sediments.

Mesoscale (field) weathering experiments done in Gainford, Alberta[141] showed that Cold Lake and Access Western Blend diluted bitumen blends exhibited properties typical of a heavy, "conventional" crude oil as they weathered but in no instance was any oil observed to have sunk after 10 days of weathering on 20 ppt (parts per thousand) brackish water under varied physical conditions (Witt O'Brien's et al. 2013). The physical properties of weathering oil measured during those tests showed that diluted bitumen spilled into fresh, brackish, or saltwater will stay on the water surface for days unless another mechanism mixes it into the water column, as would be the case for most Group III and IV oils. Only after extensive weathering and mixing with suspended particulate material, may some portion of weathered dilbit become submerged or sink.

In another series of studies conducted by the Government of Canada on two diluted bitumen products — Access Western Blend and Cold Lake Blend — that represented the highest volume transported by pipeline in Canada during 2012–2013, the researchers concluded (Government of Canada 2013):

- Like conventional crude oil, both diluted bitumen products floated on saltwater (free of sediment), even after evaporation and exposure to light and mixing with water.
- When fine sediments were suspended in the saltwater, high-energy wave action mixed the sediments with the diluted bitumen, causing the mixture to sink or be dispersed as floating tarballs.[142]
- Application of fine sediments to floating diluted bitumen was not effective in helping to disperse the products.
- The two diluted bitumen products display some of the same behaviors as conventional petroleum products (i.e. fuel oils and conventional crude oils), but also some key differences, notably for the rate and extent of evaporation. (pp. 5-6)

The four major factors that have a bearing on whether spilled oil, including diluted bitumen, will float, become neutrally buoyant (suspended in the water column), or sink are (Etkin et al. 2015):

- Density of the oil, which may change with weathering (evaporation);
- Salinity of the water (i.e., density of the water relative to the oil);
- Amount of sediment in the water; and
- Turbidity of the water (stirring up sediment and breaking oil into smaller droplets).

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[138] SL Ross 2010.
[139] Water that has 0.05–3 percent dissolved salts compared with <0.05 percent for freshwater and 3–5 percent for seawater.
[140] Witt O'Brien's et al. 2013.
[141] Witt O'Brien's et al. 2013.
[142] The use of the term "tarball" follows convention in the literature and refers to the consistency of floating, heavily-weathered oil. It does not describe the chemical composition of the product.

As long as the oil is less dense than the water, it will float. It may temporarily become submerged in the water column if broken into smaller droplet in turbulent water, but in those cases the oil will refloat under more calm water conditions. If the oil becomes heavier than the water, either by becoming attached to sediment particles, or, less commonly, by having enough of the lighter ends evaporate to increase the density, it will become neutrally buoyant or sink.

Since salt and brackish water (e.g., water in estuaries) is heavier than freshwater, it takes more of an increase in density to cause oil to sink in salt or brackish water than in freshwater, where the density of water is 999.97 kg/m^3 — or essentially 1,000 kg/m^3 or 1.0 g/ml. Seawater is denser than freshwater and has an average density of 1.025 g/m^3, though it may be as high as 1.028 g/m^3. Brackish water in estuaries varies in density between 1.0 to 1.025 g/m^3. For this reason, heavy oil with a density of 1.01 g/m^3 would float in seawater but sink in a freshwater lake, or in an estuary.

When oil mixes with sediment particles (e.g., sand in the surf zone of a beach), the combinations of sediment and oil — called "oil-mineral aggregates" (OMA) — can become heavier than water to cause sinking. OMA formation is more likely to occur in the following situations:

- The oil is in fine droplets.
- There is a large sediment load in the water column.
- There is a lot of turbulence in the water, which increases the number of smaller oil droplets, stirs up sediment from the bottom, and increases the likelihood of contact between the oil droplets and sediment particles.

OMA sinking is more likely to occur in freshwater than salt or brackish water because of the greater likelihood that the density of the OMA will be higher than the water density. The OMA density has to be somewhat higher to sink in salt or brackish water.

If diluted bitumen were to spill into a freshwater or estuarine system, as would occur in inland areas of Washington State, or in the Columbia River, it would undergo a number of processes (Etkin et al. 2015). The typical transport pathways and fates of spilled oil include entrainment, resurfacing, diffusion, adsorption, settling, degradation, and evaporation. Oil droplets in the water column can degrade into dissolved components of oil or adhere to suspended particulate matter. Once adhered to particulate matter, oil can then sink to the sediments or dilute into pore water. As stated by the Department of Homeland Security:

> Given that there may be sediment in the river, stream, or lake, it is possible for the Dilbit to create OMAs and sink. This situation would be most likely in a shallower stream with a rapid current, high sediment load, and turbulent waters that stir up the bottom sediment and break the oil into smaller droplets. In saltwater, the oil would undergo similar processes, but it is less likely that oil would sink due to the water's salinity causing an increase in the density of the water....
>
> Theoretically, if enough of the light ends of an oil evaporate, the overall density of the oil would increase, perhaps enough to cause the density to be more than that of freshwater or even saltwater. (US DHS 2015)

The phenomenon of "evapo-sinking" has been proposed as an explanation for the sinking of some of the spilled oil during the Macondo MC-252 (Deepwater Horizon) spill in the Gulf of Mexico (Thibodeaux 2013).

There is anecdotal evidence that this evaporative sinking phenomenon can occur, e.g., the Lake Wabamun spill in Alberta in which 185,000 gallons of heavy fuel oil spilled from 40 rail tank cars into a freshwater lake after a derailment in 2005 (Fingas et al. 2006). There is also evidence that this phenomenon may have explained the sinking of Bunker C (heavy fuel oil with a density of 0.967) spilled from the USNS Potomac in 1977 (Michel and Galt 1995).

When spilled into water, lighter hydrocarbon fractions of the entire diluted bitumen blend begin to evaporate. As lighter fractions evaporate, the viscosity of the weathered diluted bitumen would increase, and evaporation of remaining lighter fractions would be progressively inhibited.

Evaporative studies of diluted bitumen blends (e.g., Cold Lake) have shown that the first few hours of exposure to air results in the rapid loss of portions of the diluent with resulting increases in density and viscosity. Evaporative loss rates are affected by air temperature, oil surface area and thickness on the water surface, and wind conditions (Brown and Nicholson, 1991; SL Ross 2010a). But, the studies also showed that because of the minimal light-end content of the diluted bitumen, the final evaporative loss of diluted bitumen was similar to ANS crude. The diluted bitumen exhibited an 8 percent volume loss through evaporation. This corresponds to an 8 percent increase in density. In freshwater, this may cause the oil to become heavier than water. It is unlikely to cause submergence in marine waters or even most estuarine waters, however.

Bitumen in pellet form

Canadian National Rail and Canadian oil producers have developed an alternative solid pellet form of bitumen or heavy crude for shipment by rail hopper cars.[143]

The puck-like pellets called CanaPux™ which are similar in size and shape to a bar of soap, are formed by blending bitumen with coating polymers before shipment. Upon delivery at the destination market, the pellets are processed to remove the polymers. The polymers are recyclable plastic. The pellets are reportedly not flammable or explosive. Temperatures above 145°C (290°F) are required before the pellets will burn. The pellets float on water and do not leach or dissolve into the environment. They do not produce dust when spilled. In the event of a spill, the pellets could be picked up with nets, booms, vacuums, or mechanical construction equipment (e.g., backhoes). According to the Canadian Association of Petroleum Producers, producers are likely to transport only minor volumes of CanaPux (Stephens 2018). The decision on how much CanaPux to ship will be based on the producers' assessment of the marketability of the product, how much they can produce in an economic fashion, and the availability and economic factors for other means of transport, such as pipeline and rail.

Other Class 3 flammable liquids

A Class 3 flammable liquid is a liquid that has a flash point of not more than 60°C (140°F), or any material in a liquid phase with a flash point at or above 37.8°C (100°F) that is intentionally

[143] Canadian National, https://www.cninnovation.ca/

heated and offered for transportation or transported at or above its flash point in a bulk packaging. This includes liquids such as refined petroleum products, crude oil, and ethanol. Class 3 flammable liquids are designated by four-digit United Nations (UN) Numbers or North American (NA) Numbers, these are used to identify hazardous materials worldwide and are required for the shipment of hazardous materials. In all, there are over 400 UN or NA numbers that fall within Class 3 flammable liquids. Flash point is the minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid.

Besides crude oil, the Class 3 flammable liquids transported by rail in Washington State include ethanol, gasoline, diesel fuel, methanol, and aviation fuel. Examples of other Class 3 flammable liquids can be found in Table 152. Ethanol is often transported by unit train through Washington. Each year about 13,000 carloads (about 130 unit trains) travel on Washington rails.

Other hazardous commodities

The chemicals most commonly transported by rail in Washington are anhydrous ammonia and sulfuric acid, with about 3,300 and 850 carloads annually, respectively. About 20,000 carloads of propane, a Class 1 flammable liquid, are transported by rail through Washington annually. The properties of other hazardous commodities transported in Washington State may be found in Appendix A.

Additional safety measures for hazmat rail transport

There are a number of other safety measures that can be taken to reduce the risk of rail accidents and serious consequences in the event of rail accidents for trains transporting hazardous materials.

Position in train

Operators of trains carrying hazardous materials (dangerous goods) need to take care in the placement of cars in a consist (the sequence of cars on a train). The required procedures assure that the contents of cars are not in proximity to other cars that may cause dangerous reactions. The sequencing procedures also assure that there are sufficient “buffer cars” to protect the hazardous material cars in the event of a derailment or other accident.

For these restrictions (CFR 49 § 174.85, 2001), the following Placard Groups apply:

- Placard Group 1: Division 1.1 and 1.2 (Class A Explosives).
- Placard Group 2: Division 1.3, 1.4, 1.5 (Class B and C explosive), Class 2 (compressed gas; other than Div 2.3, PG I, Zone A), Class 3 (flammable liquid), Class 4 (flammable solid), Class 5 (oxidizing), Class 6 (poisonous liquid; other than Div 6.1 PG I, Zone A), and Class 8 (corrosive) materials.
- Placard Group 3: Divisions 2.3 (PG I, Zone A; poisonous gas) and 6.1 (PG I, Zone A; poisonous liquid) materials.
- Placard Group 4: Class 7 (radioactive) materials.

Operators need to abide by the following restrictions for train positions for Placard Group 1 rail cars, Placard Group 2 tank cars, and Placard Group 3 tank cars:

- When train length permits, placarded car may not be nearer than sixth car from engine or occupied caboose.
- When train length does not permit, placarded car must be placed near middle of train, but not nearer than second car from engine or occupied caboose.
- A placarded car may not be placed next to an open-top car when any of lading protrudes beyond car ends or if shifted would protrude beyond car ends.
- A placarded car may not be placed next to a loaded flat car except closed intermodal equipment, auto carriers, and other specially equipped cars with tie-down devices for handling vehicles. Permanent bulk head flat cars are considered same as open-top cars.
- A placarded car may not be placed next to any transport vehicle or freight container having an internal combustion engine or an open-flame device in operation.

In addition, certain cars should never be placed adjacent to other types of cars:

Placard 1 cars may not be placed next to:

- Placard Group 2 tank car
- Placard Group 2 rail car
- Placard Group 3 tank car
- Placard Group 3 rail car
- Placard Group 4 rail car

Placard 2 cars may not be placed next to:

- Placard Group 1 rail car
- Placard Group 3 tank car
- Placard Group 3 rail car
- Placard Group 4 rail car

Placard 3 cars may not be placed next to:

- Placard Group 1 rail car
- Placard Group 2 tank car
- Placard Group 2 rail car
- Placard Group 4 rail car

Placard 4 cars may not be placed next to:

- Placard Group 1 rail car
- Placard Group 2 tank car
- Placard Group 2 rail car
- Placard Group 3 tank car
- Placard Group 3 rail car

According to these rules, there is no prohibition in putting two cars of the same Placard group next to each other.

Switching procedures

In rail switching yards, where train cars are being moved around, there are also specific precautions (CFR 49 § 174.83, 2001), including:

- Placard Group 1 rail cars (Division 1.1 and 1.2, Class A Explosives) should be separated from an engine by at least one non-placarded car.
- Placard Group 1 rail cars should not be placed where there is any probable danger of fire.
- Placard Group 1 rail cars should not be placed under bridges, under overpasses, or along passenger stations.
- Placard Groups 1.1, 1.2, 2.1, 2.3, or 6.1 should not be cut off in motion, struck by any free rolling car, or coupled into with more force than needed to make the coupling.

Inspection procedures

Another important group of safety measures is the inspection of rail cars and tank cars that transport hazardous materials. AAR has outlined specific inspection procedures for hazardous shipments (AAR 2015):

1. **General requirements**

a. To determine that (railcars) are in acceptable condition for transportation, all loaded and residue/empty hazardous material shipments must be inspected at these points:

1) before accepting them from the shipper
2) when receiving them in interchange (Note: Run-through trains received in interchange may continue to the next inspection point before being inspected)
3) when placing them in a train
4) at other points where an inspection is required (e.g., 1,000-mile inspection) (p. 16)

Operators must “accept or transport only those hazardous material shipments that conform to these instructions.”

2. **Inspection Procedures**

In addition to inspecting rail cars for compliance with train make up, adequate buffer cars, shiftable loads and temperature control equipment as well as mechanical requirements, operators should visually inspect each loaded or residue/empty hazardous material shipment (including flat cars transporting placarded or marked trailers or containers) and adjacent rail cars, from ground level (do not climb on or go under the car) and check for:

- leakage
- required placards and markings, including stenciling, car certificates, and qualification dates
- secure fastening of closures.
- signs of tampering, such as suspicious items or items that do not belong, the presence of an “Improvised Explosive Device" (IED), and other signs that the security of the car may have been compromised.

Note: Where an indication of tampering or a foreign object is found, take the following actions:

1) Do not accept or move the rail car.
2) Immediately move yourself and others to a safe location away from the rail car before using radios and cell phones to make notifications;
3) For cars at a customer's facility, immediately contact local plant personnel. If local plant personnel are not available or cannot explain what you see, immediately contact the train dispatcher (follow your specific railroad instructions); and
4) For cars on interchange tracks or in the yard, immediately contact the yardmaster or train dispatcher (follow your specific railroad instructions)."

Inspecting All Car Types (from ground level)

1) Without climbing on the car, the inspector needs to make sure that the hazardous material shipment is not leaking by:

   a) Looking for leaking contents — drips, wetness, or material on the car or on the ground;
   b) Looking for a vapor cloud; and
   c) Listening for hissing sounds of the contents escaping

   Note: If you find a hazardous material shipment leaking, follow (emergency response procedures).

2) Make sure placards and markings are appropriate for the shipment and displayed correctly.

3) Before accepting a hazardous material shipment from the shipper, make sure that:

   a) all customer loading and unloading lines are disconnected
   b) derails, chocks, and blue flags are removed
   c) all platforms are raised or in the clear.

Inspecting Placarded/Marked Tank Cars (from ground level)

Check placarded tank cars or tank cars marked with an identification number to see that:

1) protective housing covers are closed
2) manway cover swing bolts are up and in place
3) all valves and fittings appear to be closed and secure
4) visible plugs or caps (including bottom outlet caps) or other fittings are securely in place; ***Note***: When heater coil caps are provided, they must be applied
5) "double shelf couplers" and roller bearings are present

Inspecting Placarded/Marked Gondola Cars (from Ground Level)

1) Look for loosely fastened gondola covers
2) Make sure the cover or tie downs do not foul any safety appliances

Inspecting Placarded/Marked Hopper Cars (from Ground Level)

Check that discharge gates are closed and secured.

Inspecting Shipments Placarded EXPLOSIVES 1.1 or 1.2 (from ground level)

- Additional inspection requirements for shipments placarded EXPLOSIVES 1.1 and 1.2 are:

a) Look for indications of damage to the contents.
b) Make sure that completed "car certificates" are displayed on both sides of the rail car.
    i. Car certificates must be removed after the rail car, trailer, or container is unloaded.
    ii. Car certificates are either 7.1 by 7.1 inches or 5.9 by 7.9 inches in size.

- Do not accept or transport the car until all damage has been corrected and car certificates are in place.

Inspecting Placarded/Marked Intermodal Shipments (from ground level)

In addition to completing other inspection requirements:

1) Make sure that an intermodal tank container of hazardous material is not transported with a container above or below the tank.
2) Make sure that placards are fully visible when containers are loaded in a well car.
3) Make sure that intermodal tanks are placed so that the bottom outlet valves are pointed toward the ends of the well or platform.

3. Handling Defects

When a hazardous material shipment does not appear to be prepared for transportation:

a. Do not accept or pull the hazardous material shipment or allow it to continue in transportation.
b. Notify the customer, train dispatcher, yardmaster, or your immediate supervisor, as appropriate, and explain the problem (pp. 16-18).

Rail security measures

Protecting hazardous materials in rail cars from vandalism or terrorism is a very important consideration for rail safety. There are specific regulations that address this. PHMSA, in consultation with the Department of Homeland Security, published its Final Rule HM-232F (Hazardous Materials), Risk-Based Adjustment of Transportation Security Plan Requirements on 9 March 2010. This rule addressed issues for security threats associated with the transport of specific types and quantities of hazardous materials considered to be "high consequence" if stolen and used for pernicious reasons.

According to HM-232, each facility that offers for transportation in commerce of a threshold quantity of one or more of the hazardous materials must develop and adhere to a hazardous materials transportation security plan based on Hazard Class/Division and Type classifications, as well as threshold quantity, as follows:

- For Hazard Class/Division 1.1, 1.2, and 1.3 (Explosives): Any quantity.
- For Hazard Class/Division 1.4 (Explosives): Any quantity requiring certain placarding.
- For Hazard Class/Division 1.5 (Explosives): Any quantity.
- For Hazard Class/ Division 2.1 (Flammable Gases): Large bulk quantity.

- For Hazard Class/Division 2.2 (Non-Flammable Gases): Large bulk quantity with Subsidiary Hazard of Division 5.1 Oxidizer.
- For Hazard Class/ Division 2.3 (Poisonous Inhalation Hazard, PIH): Any quantity.
- For Hazard Class 3/Division 4.1 (Desensitized Explosives): Any quantity desentizied explosives.
- For Hazard Class 3 (Flammable Liquids): Large bulk quantity in Packing Group I or II.
- For Hazard Division 4.2 (Spontaneously Combustible): Large bulk quantity in Packing Group I or II.
- For Hazard Division 4.3 (Dangerous When Wet): Any quantity.
- For Hazard Division 5.1 (Oxidizers): Large bulk quantity in Packing Group I or II.
- For Hazard Division 5.2 (Organic Peroxides): Any quantity of organic peroxide, Type B, liquid or solid, temperature controlled.
- For Hazard Division 6.1 (Poisonous Materials Other than PIH): Large bulk quantity in Packing Groups I, II, and III.
- For Hazard Class 8 (Corrosive Materials): Large bulk quantity in Packing Group I.
- For Hazard Class 9 (Miscellaneous Hazardous Materials): Not subject to any requirement.

Note that a “large bulk quantity” is any quantity greater than 3,000 kg (6,614 pounds) for solids or 3,000 liters (793 gallons) for liquids and gases in a single packaging such as a cargo tank motor vehicle, portable tank, tank car, or other bulk container.

The components of a security plan are (49 CFR § 172.802):

a) The security plan must include an assessment of transportation security risks for shipments of the hazardous materials listed in § 172.800, including site-specific or location-specific risks associated with facilities at which the hazardous materials listed in § 172.800 are prepared for transportation, stored, or unloaded incidental to movement, and appropriate measures to address the assessed risks. Specific measures put into place by the plan may vary commensurate with the level of threat at a particular time. At a minimum, a security plan must include the following elements:
    1) ***Personnel security***. Measures to confirm information provided by job applicants hired for positions that involve access to and handling of the hazardous materials covered by the security plan. Such confirmation system must be consistent with applicable Federal and State laws and requirements concerning employment practices and individual privacy.
    2) ***Unauthorized access***. Measures to address the assessed risk that unauthorized persons may gain access to the hazardous materials covered by the security plan or transport conveyances being prepared for transportation of the hazardous materials covered by the security plan.
    3) ***En route security***. Measures to address the assessed security risks of shipments of hazardous materials covered by the security plan en route from origin to destination, including shipments stored incidental to movement…

d) Each person required to develop and implement a security plan in accordance with this subpart must maintain a copy of the security plan (or an electronic file thereof) that is accessible at, or through, its principal place of business and must make the security plan available upon request, at a reasonable time and location, to an authorized official of the Department of Transportation or the Department of Homeland Security.

And CFR 49 § 172.820 includes:

(h) Storage, delays in transit, and notification. Each rail carrier must ensure the safety and security plan it develops and implements under this subpart includes all of the following:

1) A procedure under which the rail carrier must consult with offerors and consignees in order to develop measures for minimizing, to the extent practicable, the duration of any storage of the material incidental to movement.
2) Measures to prevent unauthorized access to the materials during storage or delays in transit.
3) Measures to mitigate risk to population centers associated with in-transit storage.
4) Measures to be taken in the event of an escalating threat level for materials stored in transit.
5) Procedures for notifying the consignee in the event of a significant delay during transportation; such notification must be completed within 48 hours after the carrier has identified the delay and must include a revised delivery schedule. A significant delay is one that compromises the safety or security of the hazardous material or delays the shipment beyond its normal expected or planned shipping time. Notification should be made by a method acceptable to both the rail carrier and consignee.

Rail routing regulations

HM-232 also stipulates that rail carriers must conduct a “rail route analysis” every five years. The rail route analysis is a comprehensive, system-wide review of operations that could impact safety and security. Factors that need to be considered and analyzed in a rail route analysis are:

1) Volume of hazmat
2) Rail traffic density
3) Trip length
4) Railroad facilities
5) Track type and class
6) Track grade and curvature
7) Signals and train control systems
8) Wayside detectors
9) Number and types of grade crossings
10) Single vs. double track
11) Frequency and locations of track turnouts
12) Proximity to iconic targets
13) Environmentally sensitive areas
14) Population density
15) Venues along route
16) Emergency response capability along route
17) Areas of high consequence
18) Passenger traffic

19) Speed of train operations
20) Proximity to en route storage or repair facilities
21) Known threats (from Transportation Security Administration [TSA])
22) Measures in place to address safety and security risks
23) Availability of alternative routes
24) Past incidents
25) Overall time in transit
26) Training and skill level of crews
27) Impact on rail network traffic and operations

Potential areas of future discussion

- The Rail Safety Committee might consider developing a common understanding of the types of the hazardous commodities transported in Washington by rail, as well as their general properties. This could be essential for the Rail Safety Committee, as well as local emergency responders and decision-makers at the state and local levels.
- The Rail Safety Committee and emergency responders might consider familiarizing themselves with the labeling of the various types of hazardous materials, as presented in Appendix A.

Chapter 7: Consequences of Rail Accident Releases

Key questions

- What are the potential consequences or impacts of rail accidents that cause a spill or release?
- What happens when oil spills in a rail accident?
- What happens when a rail accident from a CBR train results in a fire or explosion?
- What happens when other kinds of hazardous materials are released in a rail accident?

Takeaways

- Every spill is different, and the consequence following a release is primarily dependent on:
  - Product type (e.g. crude oil type, chemical, etc.)
  - Volume spilled
  - Location of the spill and the receiving environment (e.g. grassland, forest, river, lake, marsh etc.)
  - Environmental conditions at the time of the release (e.g. summer/winter, rainy/dry, during a migratory period, etc.)
  - Response, or clean up efforts (i.e. timing, equipment/methods, efficiency)
- Once in the environment, a released substance may move (downhill, downstream, or downwind in a waterway) anywhere from a few feet from the release location to tens or even hundreds of miles.
- Released oil and chemicals will behave differently in the environment with many "fate processes" that determine where the released compound will end up. Fate processes include evaporation, dissolution, entrainment, degradation, and many others. These different processes ultimately determine the timing and level of contamination in each ecological environment.
- These ecological environments, or environmental 'compartments' include:
  - Land
  - The water surface
  - The water column
  - Shorelines and sediments
  - The atmosphere
  - A process that alters the substance through photo-oxidation, biodegradation, or other physical processes or chemical reactions
- Biological effects are dependent on the presence and sensitivity of each receptor as well as the concentration and duration of exposure to the hazardous substance. A "receptor" is an organism (animal or plant) or ecological habitat in the environment that may be affected by oil or chemicals that are spilled. The environmental consequences can be the result of:

  - Floating and shoreline oil which may smother or coat a receptor. This can result in thermal regulation issues for birds and mammals, mechanical effects (smothering, prevention of uptake and depuration, interference with motility etc.), and absorption of toxic compounds (via skin or gut).
  - Dissolved hydrocarbons that may be absorbed into tissue resulting in acute or chronic toxicity.
  - Subsurface oil droplets that can result in mechanical interference such as clogged feeding appendages and gills or impeding movement.
  - Changes in behavior such as avoidance of the area, or attraction (resulting in more exposure).
- Effects can be acute (i.e. short term; mortality or death) or chronic (i.e. long term; sub-lethal effects that may ultimately result in mortality).
- Chronic effects can be quite varied and include cardiac effects, blue sac disease, deformities, decreased growth rate, decreased fecundity, behavior changes, etc.
- Releases onto land and into water may infiltrate into drinking water supplies.
- The five largest volumes of hazardous liquid chemicals transported by rail in Washington are:
  - Crude oil
  - Propane
  - Ethanol
  - Ammonia
  - Sulfuric acid

  with shipment quantities ranging from 79,000 carloads per year to 900 carloads per year from largest to smallest.

- The three types of incidents that may occur with a release from trains transporting hazardous and flammable liquids and have potentially serious public health and safety effects are:
  - **Pool fire:** This is a fire that burns from a pool of vaporizing fuel.
  - **Vapor cloud explosion:** A vapor cloud explosion is the result of a flammable gas or vapor mixture that is released into the atmosphere, at which point the resulting vapor cloud is ignited.
  - **Toxic vapor dispersion:** A vapor cloud may present acute or short-term exposures to chemicals that have the ability to quickly overwhelm humans.
- Anhydrous ammonia produces the greatest hazard distance overall among the hazardous liquids. The hazard distance means that it is toxic, with immediate danger to life and health (IDLH) up to a certain distance away. For anhydrous ammonia the distance is 11,167 feet for a single car release. However, the shipment quantity is relatively small, at just 3,319 carloads per year (analysis conducted by Risknology, Inc. for this report).
- Propane produces the greatest explosion hazard distance at 569 feet. This is primarily due to it being heavier than air, which results in significant dispersion distances (analysis conducted by Risknology, Inc. for this report).
- Ethanol produces the greatest fire hazard distance, at 350 feet (analysis conducted by Risknology, Inc. for this report).
- Bakken crude oil produces the greatest flammable vapor cloud distance, at 227 feet (analysis conducted by Risknology, Inc. for this report).

- Hazard distances increase less than proportionately to the quantity released. For example, given a ten-fold increase in quantity released:
    - Dispersion distances increase only up to twice the distance (except in the case of propane, where there is an eight-fold increase associated with a ten-fold increase in quantity).
    - Fire distances increase roughly three times.
    - Explosion distances increase roughly two and a half times.
    - The toxic hazard distance for ammonia increases roughly five times and for sulfuric acid doubles.
- The range of hazard distances varies among the geographic regions across the state:
    - Dispersion hazard distances for crude oil vary the most, dilbit varies by a factor of three, Bakken crude by a factor of two.
    - Fire hazard distances vary up to 30 percent.
    - Explosion hazard distances vary up to 70 percent.
    - Toxic hazard distances remain nearly constant for sulfuric acid, but can vary up to 70 percent for ammonia.

The following sections provide a more in-depth look at the releases or spills that may occur as a result of accidents involving trains carrying hazardous commodities. These releases may involve oil, including crude oil or refined petroleum products, such as diesel fuel, or a broad spectrum of chemicals and other hazardous substances. The behavior, fate, and potential effects of releases of the most common of these substances are addressed. Emergency response measures for releases of oil and other hazardous materials are explored in Chapter 17.

Oil spills

The most common type of release from a rail accident is an oil spill. Oil spills from trains can involve the release of fuel (typically diesel) from locomotives, which can occur from locomotives on any kind of train, including passenger trains. The spills that might involve a greater volume and more consequences are releases of oil cargo (e.g., Bakken crude oil and diluted bitumen).

Trajectory and fate of oil spills

Different chemical compounds have varying degrees of volatility, solubility, etc. and therefore will exhibit different chemical-physical behaviors in the environment. Similarly, because oil contains many chemicals with varying physical-chemical properties and the environment is spatially and temporally variable, the released hazardous substance is likely to separate rapidly into different phases or parts of the environment. As an example, released oil may be found as (French-McCay 2004):

- Surface slicks;
- Emulsified oil (mousse) and tar balls;
- Oil droplets suspended in the water column;
- Dissolved lower molecular weight components (MAHs, PAHs, [and other soluble components]) in the water column;

- Oil droplets adhered and hydrocarbons absorbed to suspended particulate matter in the water;
- [Oil] on and in the sediments;
- Dissolved MAHs, PAHs, [and other soluble components] in the sediment pore water [(water contained in the spaces or pores in the sediment, e.g., the water that is in the spaces between the grains of sand)]; and
- (Oil) on and in the shoreline sediments and surfaces. (p. 2443)

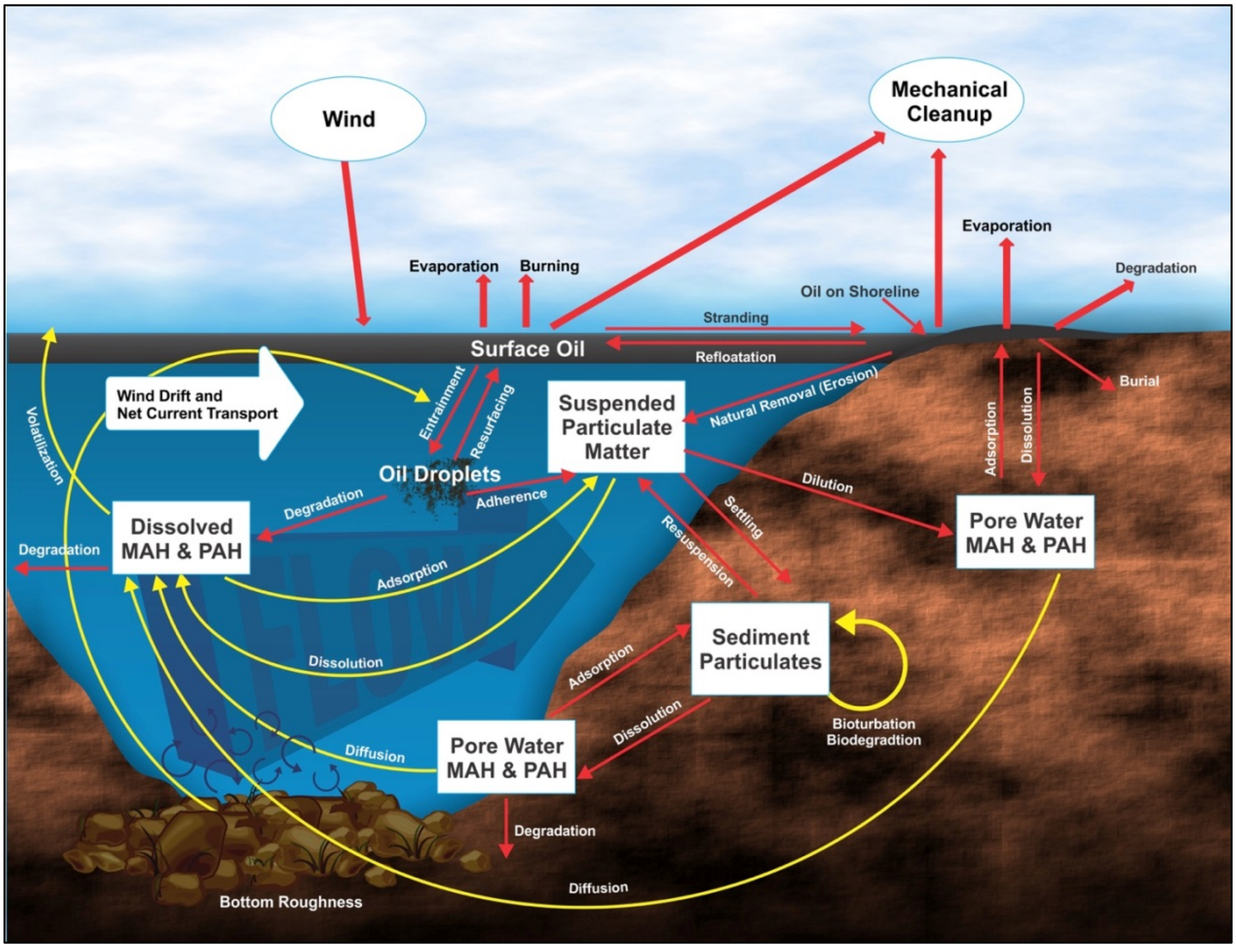

Figure 37: Oil Fate Processes in Lakes and Rivers[144]

The schematic in Figure 38 represents oil fate processes that should be considered in the event of a release. The many different physical and chemical fate processes of released oil are portrayed as multiple red and yellow arrows depicting the many different pathways oil or portions of the oil may move. White ovals and arrows represent factors that may influence the movement of oil such as winds, currents, and mechanical cleanup. White boxes in the figure represent the multiple fractions that oil may be in (e.g., dissolved in the water column or in pore water). Some white boxes also illustrate suspended particles or sediment particles oil may interact with.

[144] Source: RPS Group, Inc. Used with permission.

As an example, released oil on the water surface may interact in the environment in a number of different ways. Oil will spread on the water surface and may be transported by wind or currents (flow). A fraction of the oil may also entrain into the water column by wind induced wave action. Other portions of it may strand on shorelines and ultimately be refloated back onto the water surface. Volatile hydrocarbons may evaporate to the atmosphere and large portions could be removed by burning or mechanical cleanup (i.e. response operations). For whole oil droplets in the water column, portions may refloat to become surface oil in quiescent conditions, or oil droplets could interact with suspended particulate matter and sink to the bottom. The soluble fraction of entrained oil (and the underside of surface slicks) have the potential to dissolve into the water column (mono-cyclic aromatic hydrocarbons [MAH] or polycyclic aromatic hydrocarbons [PAH]). Ultimately, each arrow denotes a portion of the oil that may move or undergo changes within the environment following a release. A bulleted list below highlights each of these processes illustrated in Figure 38 in the event of a release (RPS Group 2012):

- **Spreading** is the thinning and broadening of surface slicks caused by gravitational forces and surface tension. This occurs rapidly after oil is spilled on the water surface. The spreading rate is faster when oil viscosity is lower at higher temperatures. Viscosity increases as oil emulsifies.
- **Transport** is the process where oil is carried by currents (.i.e. wind and water).
- **Turbulent dispersion** is the process by which turbulence (“sub-scale” currents that mix oil in three dimensions) spreads oil components on the surface and into the water column.
- **Evaporation** is the diffusion of volatile compounds from oil into a gaseous phase in the atmosphere. Evaporation from surface and shoreline oil increases as the oil surface area, temperature, and wind speed increase. As lighter components evaporate, the remaining “weathered” oil becomes more viscous.
- **Emulsification** is the mixture of water into the oil, such that the oil forms a matrix with embedded water droplets. The resulting mixture is commonly called mousse, which is technically a water-in-oil emulsion. The rate of emulsification increases with increasing wind speed and turbulence on the surface of the water. Viscosity increases as oil emulsifies.
- **Entrainment** is the process by which waves break over surface oil and carry oil droplets into the water column. At higher wind speeds (about 12 knots) or where currents and bottom roughness induce turbulence in a river or stream, wave heights may reach a threshold where they break. Thus, entrainment becomes increasingly important (higher rate of mass transfer to the water) with higher wind speeds.
- **Resurfacing** of entrained oil occurs rapidly for larger oil droplets. Smaller droplets resurface when the wave turbulence decreases. The smallest droplets do not resurface, as typical turbulence levels in the water keep them indefinitely suspended. Local winds at the water surface can also prevent oil from surfacing.
- **Dissolution** is the diffusion of water-soluble components out of the oil and into the water. Dissolution rate increases as the surface area of the oil relative to its volume increases. Since the surface area to volume ratio is higher for smaller spherical droplets, smaller droplet sizes have higher dissolution rates.

- **Volatilization** of dissolved components from the water to the atmosphere occurs as they mix, diffuse to the water surface boundary, and enter the gas phase. Volatilization rates increase with increasing air and water temperature.
- **Adsorption** of dissolved components to particulate matter in the water occurs because the soluble components (MAHs and PAHs) preferentially adsorb to particulates when the latter are present. The higher the concentration of suspended particulates, the more adsorption occurs. Also, the higher the molecular weight of the compound, the less soluble it is, and the more it tends to adsorb to particulate matter.
- **Adherence** is combination of oil droplets with particles in the water. If the particles are suspended sediments, the combined oil/suspended sediment agglomerate is heavier than the oil and the surrounding water. If turbulence subsides, the oil-sediment agglomerates will settle.
- **Sedimentation (settling)** is the process where oil-sediment agglomerates and particles with adsorbed sparingly soluble components (MAHs and PAHs) settle to the bottom sediments. Sedimentation can be an important oil pathway in nearshore areas when waves are strong and subsequently subside. Generally, oil-sediment agglomerates transfer more PAHs to the bottom than sediments with PAHs adsorbed from the dissolved phase in the water column.
- **Resuspension** of settled oil-sediment agglomerates and particles with adsorbed sparingly soluble components (MAHs and PAHs) may occur if current speeds and turbulence exceed threshold values for overcoming cohesive forces.
- **Diffusion** is the process where dissolved compounds move from higher to lower concentration areas by random motion of molecules and micro-scale turbulence. Dissolved components in bottom and shoreline sediments can diffuse out to the water column where concentrations are relatively low. Bioturbation, groundwater discharge, and hyporheic flow of water through streambed sediments can greatly increase the rate of diffusion from sediments.
- **Hyporheic flow** is the movement of water through streambed sediments, induced by pressure differentials associated with streambed irregularities or groundwater discharge.
- **Dilution** occurs when water of lower concentration is mixed into water with higher concentration by turbulence, currents, or shoreline groundwater.
- **Bioturbation** is the process by which benthic fauna mix the surface sediment layer while burrowing, feeding, or passing water over their gills. In open-water soft-bottom environments, bioturbation effectively mixes the top 10 cm of the sediment layer (in non-polluted areas).
- **Degradation** is when oil components are changed either chemically or biologically (biodegradation) into another compound. Degradation occurs through breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions. Higher temperature and higher light intensity (particularly ultraviolet wavelengths) increase the rate of degradation.
- **Stranding and reflotation** occur when floating oil meets the shorelines and then refloats as water levels rise, allowing the oil to move further down current or downstream. (pp. 18-20)

Oil weathering

The term "weathering" is used to describe the complex physical and chemical changes that occur after oil spills onto water or onto a substrate on land. Depending on the specific type of oil and its chemical makeup, and the environmental conditions (especially temperature) into which the oil spills, the various processes occur at different rates. These processes include spreading on the water surface, evaporation, emulsification, oxidation, dissolution (large black oil droplets dissolving into smaller droplets), dispersion downwards into the water column as oil spreads vertically, sedimentation (oil droplets combining with sediment), and biodegradation. Weathering affects the nature of the oil, including toxicity, and its behavior. The changed properties of the oil often affect spill response as well.

Summary of spill dynamics

For a release of oil or chemicals on land, it propagates over the land surface governed by the physical characteristics of the released oil and the slope of the land surface. Oil will be lost to the land surface by adhesion to land over the oiled path, the formation of small puddles, oil pooling in large depressions on the land surface, and oil evaporation to the atmosphere. Ultimately, the released substance may be transported downhill to a water body or surface water network.

When oil reaches a waterway, it will move downstream based upon the movement of the water (i.e., velocity of the stream). As oil moves downstream, oil will be lost to the shore from adhesion (i.e., stranding oil or shoreline oiling) and to the atmosphere by evaporation. Any oil entering a lake or flatwater body will spread over the water surface thinning out to a minimum thickness that reflects the density and viscosity of the released oil.

For a surface spill on the water surface, "gravitational spreading occurs very rapidly (within hours) to a minimum thickness. Thus, the area exposed to evaporation is high relative to the oil volume. Evaporation proceeds faster than dissolution. Thus, most of the volatiles and semi-volatiles evaporate, with a smaller fraction dissolving into the water. Degradation (photo-oxidation and biodegradation) also occurs at a relatively slow rate compared to these processes" (RPS 2012). In large rivers, lakes, estuaries and other sizeable water bodies, it is important to note that oil is typically found to be both patchy and discontinuous, based upon natural dispersion processes, small scale turbulence, and weathering. The RPS Group goes on (RPS 2012):

> Evaporation is more rapid as the wind speed increases. However, above about 12 knots of wind speed and in open water, white caps begin to form and the breaking waves entrain oil as droplets into the water column. Higher wind speeds (and turbulence) increase entrainment and results in smaller droplet sizes. From Stoke's Law, larger droplets resurface faster and form surface slicks. Thus, a dynamic balance evolves between entrainment and resurfacing. As high-wind events occur, the entrainment rate increases. When the winds subside to less than 12 knots, the larger oil droplets resurface and remain floating. Similar dynamics occur in turbulent streams.
>
> The smallest oil droplets remain entrained in the water column for an indefinite period. Larger oil droplets rise to the surface at varying rates. While the droplets are under water, dissolution of the light and soluble components occurs. Dissolution rate is a function of the surface area available. Thus, most dissolution occurs from droplets, as opposed to

from surface slicks, since droplets have a higher surface area to volume ratio, and they are not in contact with the atmosphere (and so the soluble components do not preferentially evaporate as they do from surface oil).

If oil is released or driven underwater, it forms droplets of varying sizes. The more turbulent the conditions, the smaller the droplet sizes. From Stoke's Law, larger droplets rise faster, and surface if the water is shallow. Resurfaced oil behaves as surface oil after gravitational spreading has occurred. The surface oil may be re-entrained. The smallest droplets in most cases remain in the water permanently. As a result of the higher surface area per volume of small droplets, the dissolution rate is much higher from subsurface oil than from floating oil on the water surface.

Because of these interactions, the majority of dissolved constituents (which are of concern because of potential effects on aquatic organisms) are from droplets entrained in the water. For a given spill volume and oil type/composition, with increasing turbulence either at the water surface and/or at the stream bed: there is an increasing amount of oil entrained; the oil is increasingly broken up into smaller droplets; there is more likelihood of the oil remaining entrained rather than resurfacing; and the dissolved concentrations will be higher. Entrainment and dissolved concentrations increase with (1) higher wind speed, (2) increased turbulence from other sources of turbulence (waves on a beach, rapids, and waterfalls in rivers, etc.), (3) subsurface releases (especially under higher pressure and turbulence), and (4) application of chemical dispersants. Chemical dispersants both increase the amount of oil entrained and decrease the oil droplet size. Thus, chemical dispersants increase the dissolution rate of soluble components. (Note that chemical dispersants are unlikely to be used in fresh water such as a stream when effects on aquatic biota are a primary concern.)

These processes that increase the rate of supply of dissolved constituents are balanced by loss terms in the model: (1) transport (dilution), (2) volatilization from the dissolved phase to the atmosphere, (3) adsorption to suspended particulate material (SPM) and sedimentation, and (4) degradation (photo-oxidation or biologically mediated). Also, other processes slow the entrainment rate: (1) emulsification increases viscosity and slows or eliminates entrainment; (2) adsorption of oil droplets to SPM and settling removes oil from the water; (3) stranding on shorelines removes oil from the water; and (4) mechanical cleanup and burning removes mass from the water surface and shorelines. Thus, the model-predicted concentrations are the resulting balance of all these processes and the best estimates based on our quantitative understanding of the individual processes (pp. 21-22).

Example results of releases of hazardous substances

Several comprehensive risk assessments that included computational modeling of trajectory, fate, and effects were conducted in Washington State and submitted as portions of two separate EIS's (Horn et al., 2016; 2017). This included the proposed Shell Puget Sound Refinery (PSR) Anacortes Refinery Unloading Facility (ARUF) EIS, and the Vancouver Energy Tesoro Savage

EIS (Horn et al., 2017; EFSEC 2017).[145] The modeling results conducted for these two projects are presented in this report as hypothetical examples of the behavior and potential effects of spills from CBR trains.

One key consideration of each hypothetical release is that each oil spill is truly unique. Different product types, release volumes, receiving environments, and environmental conditions result in different movement, behavior, and potential effects once released. Two separate modeling approaches were carried out in these analyses to include 1) a representative site/scenario matrix and 2) an interval approach to identify the range of spill trajectory results that may occur depending on the location and timing of a hypothetical release. The representative site/scenario matrix identified different receiving environments including a river, a tidal mudflat, and an open water region of Puget Sound. These locations were modeled under varying seasonal and environmental conditions including variable river flow, tidal conditions, and wind speeds to capture the range of environmental variability that could result in differences in the trajectory, fate, and timing of potential contamination. Multiple release volumes and product types were also considered to capture the range of potential effects. The interval approach investigated multiple releases (nearly 1,000) to assess potential risk along the entire rail corridor. These scenarios included different oil types and environmental conditions (i.e., river flow conditions). The interval approach is discussed in more detail in Chapter 23.

One scenario was at the proposed Shell Anacortes Rail Unloading Facility. Oil spill trajectory, fate, and effects modeling were performed at three representative locations to support evaluation of the ecological and human health risks resulting from hypothetical releases of crude oil into aquatic environments from railroad tracks supplying the unloading facility in Skagit County in Anacortes, Washington (Teepe et al. 2016; Horn et al 2016). Two release volumes were modeled at each location representing a 5,700-bbl spill (7 to 8 tank cars) and a much larger 20,000-bbl spill (28 to 30 tank cars) (Etkin 2015). The investigation included modeling the variability of targeted environmental conditions that may affect oil trajectory, fate, and potential effects including tides, river flow, and wind conditions. In total, twelve scenarios were run including a combination of three release locations, two seasonal/environmental conditions, and two release volumes. The intent was to bind the range of potential movement and behavior of released oil based upon uncertainty of where and when a release may occur. For each scenario, this was coupled with the appropriate temperature, wind speed and direction, and other values for all of the other environmental parameters.

Conditioned Bakken crude oil (CBAK) and its properties were part of the PSR 2016 spill evalualtion. CBAK is a light crude oil with low viscosity that is volatile, flammable, and soluble in water. In general, the majority of CBAK was predicted to be found on the water surface, forming extensive slicks and evaporating rapidly. On average over the course of each 48-hour model run, approximately 50 percent of the CBAK was expected to evaporate to the atmosphere. More complete evaporation and more extensive shoreline oiling were observed as time progressed. Decay was not an important fate process on a short time scale.

[145] Note that neither of these facilities are currently scheduled to be built. The applicant (Shell) withdrew its application for the Shell PSR facility in October 2016. Washington Energy Facility Site Evaluation Council (EFSEC) rejected the application of Tesoro Savage for its Vancouver Energy (now Marathon Oil) Terminal in December 2017.

Other condsiderations were taken into account for the PSR 2016 spill evaluation such as geographic features, width of channels, oil weathering, and spreading. Geographic features and environmental conditions affect the fate and transport of oil. Under low wind conditions, extensive surface slicks may be maintained, due to lower waves and reduced mixing of oil into the water column. Conversely, under high winds, greater entrainment of oil into the water column can be expected, which can also lead to higher concentrations of dissolved aromatics and more interaction with suspended particulate matter and sinking to the bottom sediments. Wind speed and direction varies by season and can affect evaporation rates as well as the direction of transport.

In narrower channels (i.e., rivers) with higher river flow rates, more extensive shoreline stranding may be observed at farther distances from the spill site, than low river flow conditions. Similarly, floating oil can be carried farther on spring tides than neap tides.[146] High flow rates are also associated with greater potential for oil to adhere to particulates and sink due to higher concentrations of suspended particulate matter in turbulent water. In higher vs. lower volume scenarios, mass balances may be similar due to experiencing the same environmental forcing (Figure 39 through Figure 50), but maximum distances traveled and overall extents of shoreline and surface area oiled are usually greater with more volume spilled.

Mass balance figures provide an estimate of the oil's weathering and fate for a specific model scenario for the entire model duration as a fraction of the total amount of oil spilled up to that point. Components of the oil are tracked over time as vertical "slices" defining the amount of oil in each environmental compartment. In this general form, oil is depicted as an amount of oil (percentage of total release to that point) on the water surface (green), the total entrained hydrocarbons in the water column (purple), the amount of oil on shore (red), the oil evaporated into the atmosphere (blue), the oil on sediments (yellow), and the amount of oil that has decayed (yellow: accounts for both photo-oxidation and biodegradation). Starting on the left-hand side of each figure (Time = 0 days), a release is initiated where oil is on the water surface (100 percent of a vertical line is green, indicating surface oil). Very rapidly, lighter ends evaporate to the atmosphere, observed as a rapid increase in blue, as green decreases. When oil begins to strand on shorelines, the amount of red begins to increase. For more open water environments such as the Edmonds Ferry Terminal, the largest amounts of oil remained on the water surface or evaporated to the atmosphere after two days. However, for a confined Skagit River example, surface oil stranded on river banks depicted with large amounts of red. In the Edmonds Ferry terminal high wind speed (January) scenario, winds were sufficiently high to generate surface breaking waves, which entrained surface oil into the water column (purple). Interactions with shorelines and suspended sediments then resulted in a significant (>10 percent) amount of oil making its way to the sediment after two days. When the same scenarios were run with a smaller release volume (5,700 bbl in Figure 49 as opposed to 20,000 bbl in Figure 48), the smaller release volumes resulted in similar findings with slightly different predicted results. While the oil was still predicted to rapidly evaporate from the water surface (more blue and less green), when oil was predicted to strand on shorelines, a larger percentage of the initial release was predicted to strand. This is due to the holding capacity of the land (total amount of oil that can be held on a given shore type) remaining the same between runs, however, this fixed amount is a larger

[146] A spring tide is strong and evidenced in a large distance between the high and low tides, while a neap tide occurs when the difference between high and low tide is at a minimum.

percentage of the smaller volume release. The mass balance is essentially the "story" of where oil is predicted to be found (i.e. in what environmental compartment) based upon the specific scenario that was modeled.

Overall, with more extensive movement and spreading, lower total hydrocarbon concentrations are predicted on shorelines and sediments, with thinner surface oil thickness possible and patchy and discontinuous coverage. In general, the extents from the larger and smaller volume releases (i.e., 20,000 bbl vs 5,700 bbl) were similar, however 20,000 bbl may travel further over time and oil shorelines more extensively due to more oil being present to transport and strand. Additionally, the 20,000 bbl resulted in thicker surface oil, higher dissolved aromatics, and more extensive shoreline and sediment oiling.

At Swinomish Channel:

- For the larger volume (20,000 bbl) release during spring tide, all oil began at the surface and over half evaporated after two days, leaving about 30 percent on the surface, < 20 percent ashore after steady accumulation, and about 1 percent decayed or entrained (Figure 39).
- For the larger volume (20,000 bbl) release during neap tide, there was a very similar partition of oil compared to the spring tide scenario after two days, however much of the shoreline accumulation occurred rapidly at the end of the simulation increasing from about 3 percent to about 20 percent in the last twelve hours (Figure 40).
- For the smaller volume (5,700 bbl) release during spring tide, all oil began at the surface and over half evaporated after 2 days, leaving <30 percent on the surface, <20 percent ashore after steady accumulation, and about 1 percent decayed or entrained (Figure 41).
- For the smaller volume (5,700 bbl) release during neap tide, over half of released oil evaporated, while decayed or entrained oil only made up 1 percent. More oil washed ashore (about 28 percent) and less oil remained on the surface (about 20 percent) compared to the low-volume spring tide scenario after two days. Additionally, the majority of the shoreline accumulation occurred rapidly at the end of the simulation increasing from about 8 percent to about 28 percent in the last twelve hours (Figure 42).

At Skagit River:

- For the larger volume (20,000 bbl) release during spring tide, all oil began at the surface and over half evaporated after two days, leaving about 3 percent remaining on the surface, < 50 percent ashore, and about 1 percent decayed or entrained. After about 8 hours of strong evaporation, oil evaporation slowed, and mass balance began rapidly shifting from surface to onshore before plateauing around 32 hours (Figure 43).
- For the larger volume (20,000 bbl) release during neap tide, there was a similar partition of oil compared to the spring tide scenario after two days (>50 percent atmosphere, ~40 percent ashore, <10 percent surface, and ~1 percent other), but the rapid shoreline accumulation occurred later, peaking around 20-24 hours (Figure 44).
- For the smaller volume (5,700 bbl) release during spring tide, all oil began at the surface and about half evaporated after two days, leaving about 2 percent remaining on the

surface, 47 percent ashore, and 1 percent decayed or entrained. After about 8 hours of strong evaporation, oil evaporation slowed, and mass balance began rapidly shifting from surface to ashore before plateauing around 32 hours (Figure 45).

- For the smaller volume (5,700 bbl) release during neap tide, <45 percent evaporated, >55 percent stranded ashore, 1 percent decayed, and almost 0 percent of the oil remained on the surface or entrained in the water. Relatively little changes in mass balance occurred during the second day (Figure 46).

At Edmonds Ferry Terminal:

- For the larger volume (20,000 bbl) release during spring tide, all oil began at the surface and over half evaporated, leaving approximately 45 percent remaining on the surface, 3 percent ashore, and about 1 percent decayed or entrained after two days (Figure 47).
- For the larger volume release (20,000 bbl) during neap tide, over half the oil evaporated, >10 percent stranded ashore, >10 percent remaining on the water surface, about 10 percent entrained, over 10 percent was in the sediment, and about 1 percent had decayed by the end of two days. Atmospheric concentrations grew rapidly at first while shoreline accumulation increased steadily after about half a day and entrainment/surface concentrations fluctuated (Figure 48).
- For the smaller volume (5,700 bbl) release during spring tide, all oil began at the surface and over half evaporated, leaving roughly 45 percent on the water surface, 3 percent ashore, and 1 percent decayed or entrained after two days (Figure 49).
- For the smaller volume (5,700 bbl) release during neap tide, over half of oil evaporated, almost 30 percent stranded ashore, 5 percent remained the water surface, 5 percent was entrained, 10 percent was in the sediment, and about 1 percent had decayed by the end of two days. Atmospheric concentrations grew rapidly at first while shoreline accumulation increased rapidly around 12 hours and entrainment/surface concentrations fluctuated (Figure 50).

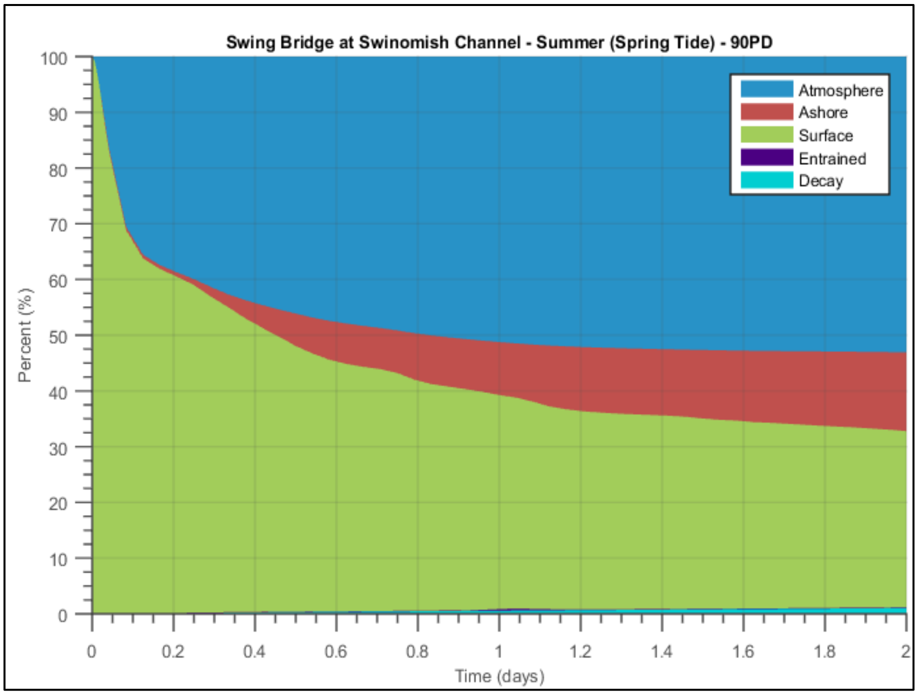

Figure 38: Mass Balance: 20,000-bbl Bakken Spills at Swinomish Channel (Spring Tide)[147]

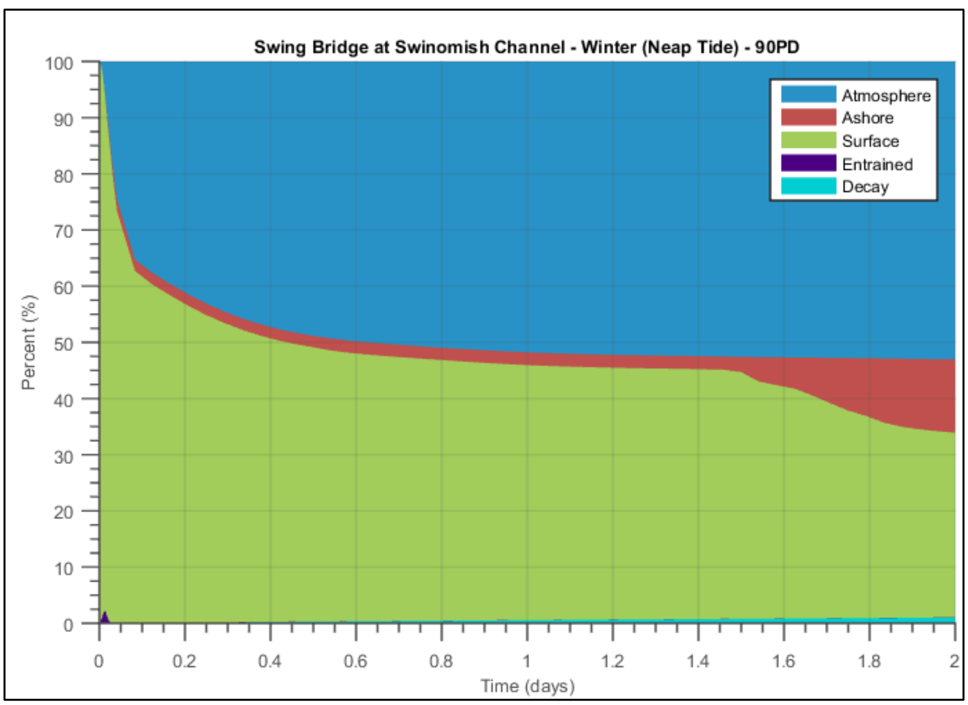

Figure 39: Mass Balance: 20,000-bbl Bakken Spills at Swinomish Channel (Neap Tide)[148]

[147] Graphic by RPS Group, Inc. Used with permission.
[148] Graphic by RPS Group, Inc. Used with permission.

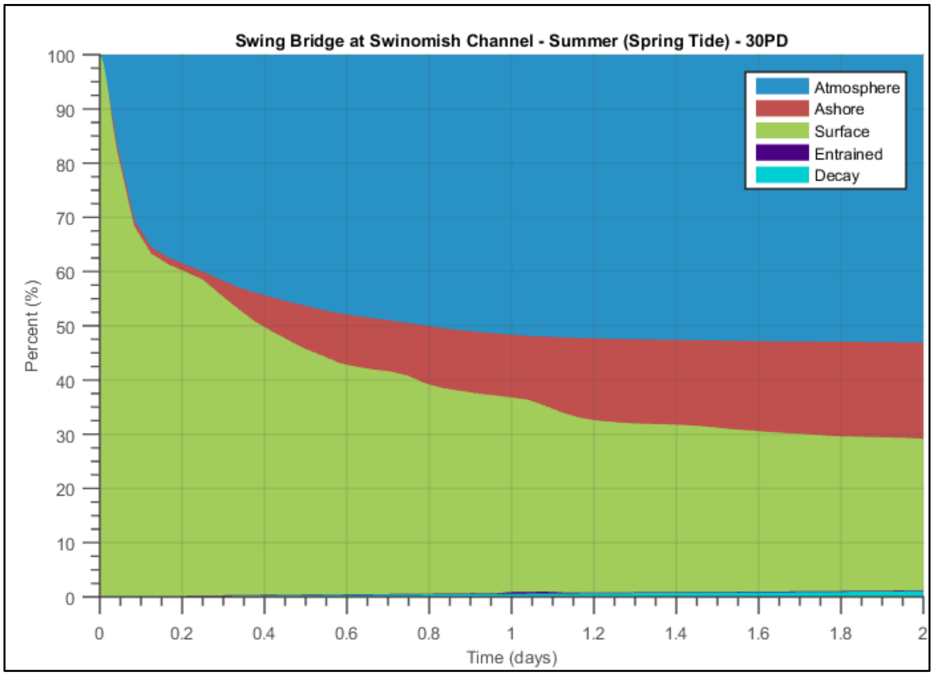

Figure 40: Mass Balance: 5,700-bbl Spills at Swinomish Channel (Spring Tide)[149]

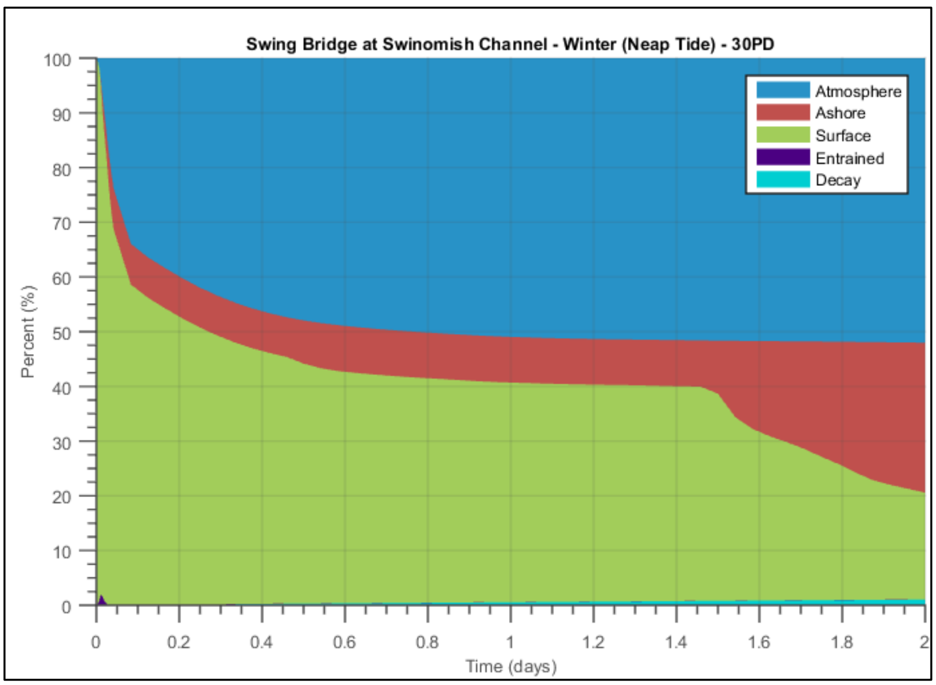

Figure 41: Mass Balance: 5,700-bbl Spills at Swinomish Channel (Neap Tide)[150]

[149] Graphic by RPS Group, Inc. Used with permission.
[150] Graphic by RPS Group, Inc. Used with permission.

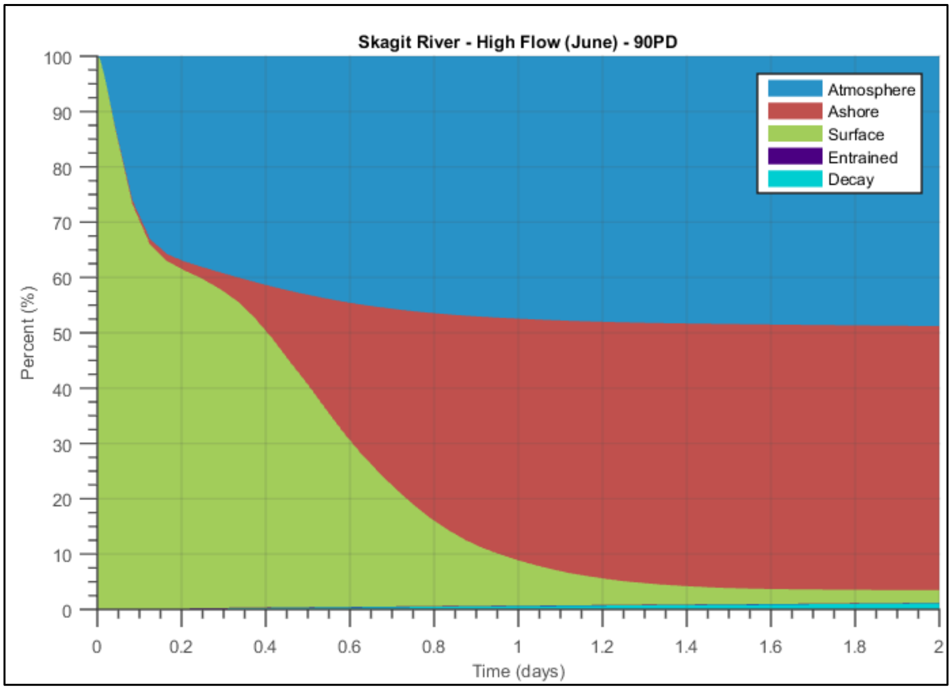

Figure 42: Mass Balance: 20,000-bbl Bakken Spills at Skagit River (Spring Tide)[151]

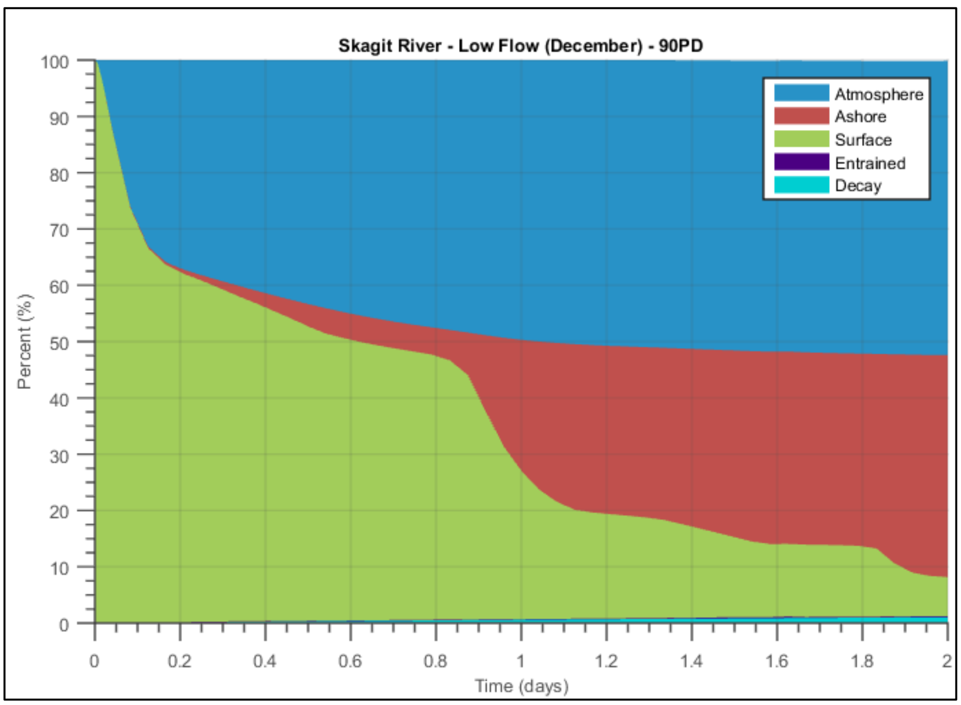

Figure 43: Mass Balance: 20,000-bbl Bakken Spills at Skagit River (Neap Tide)[152]

[151] Graphic by RPS Group, Inc. Used with permission.
[152] Graphic by RPS Group, Inc. Used with permission.

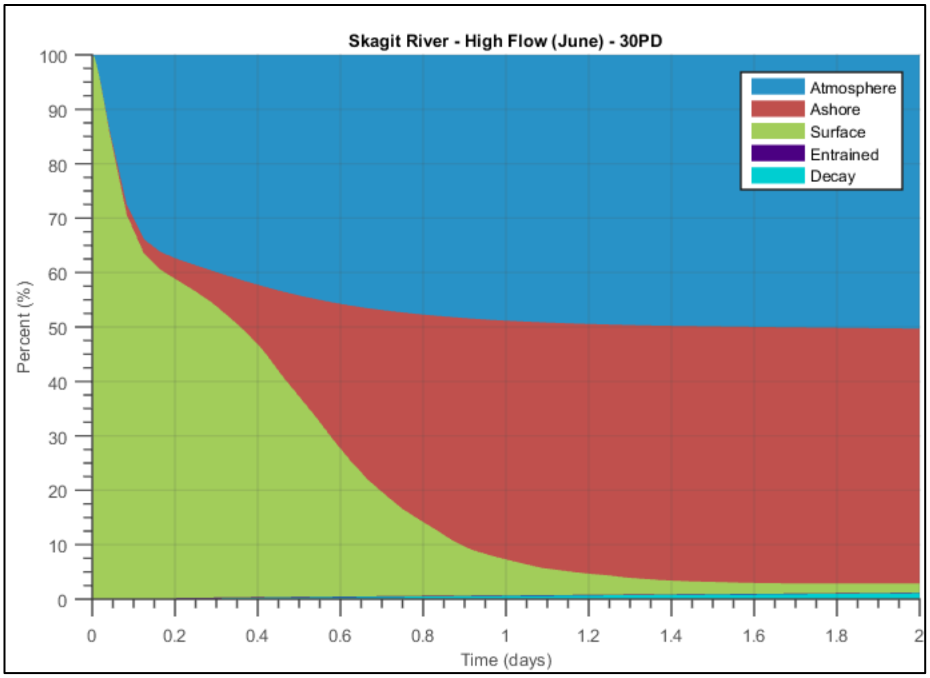

Figure 44: Mass Balance: 5,700-bbl Spills at Skagit River (Spring Tide)[153]

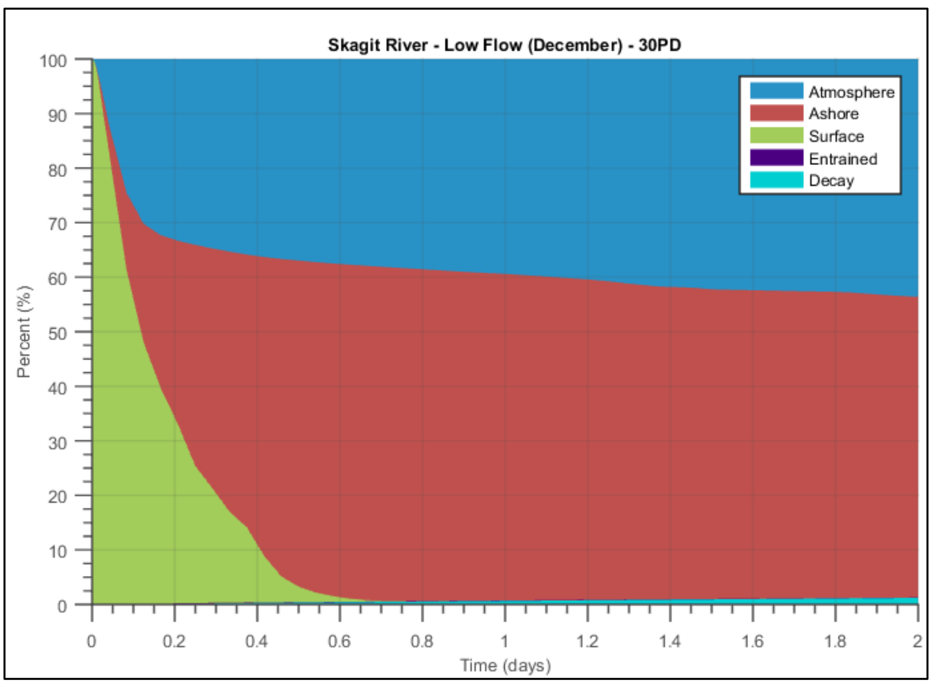

Figure 45: Mass Balance: 5,700-bbl Spills at Skagit River (Neap Tide)[154]

[153] Graphic by RPS Group, Inc. Used with permission.
[154] Graphic by RPS Group, Inc. Used with permission.

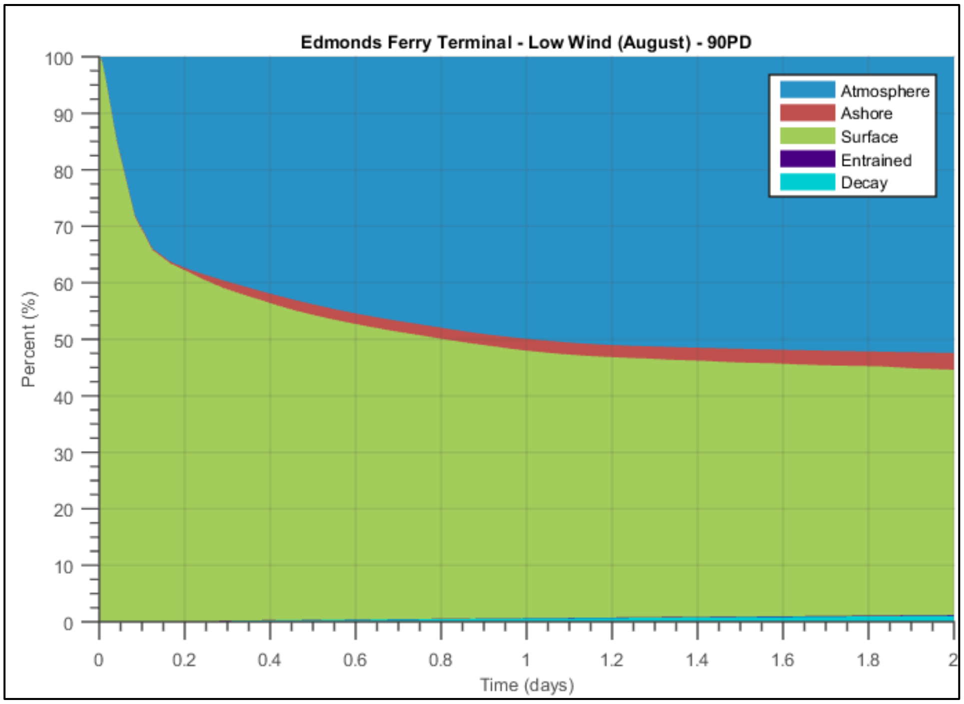

Figure 46: Mass Balance: 20,000-bbl Bakken Spills at Edmonds Ferry Terminal (Spring Tide)[155]

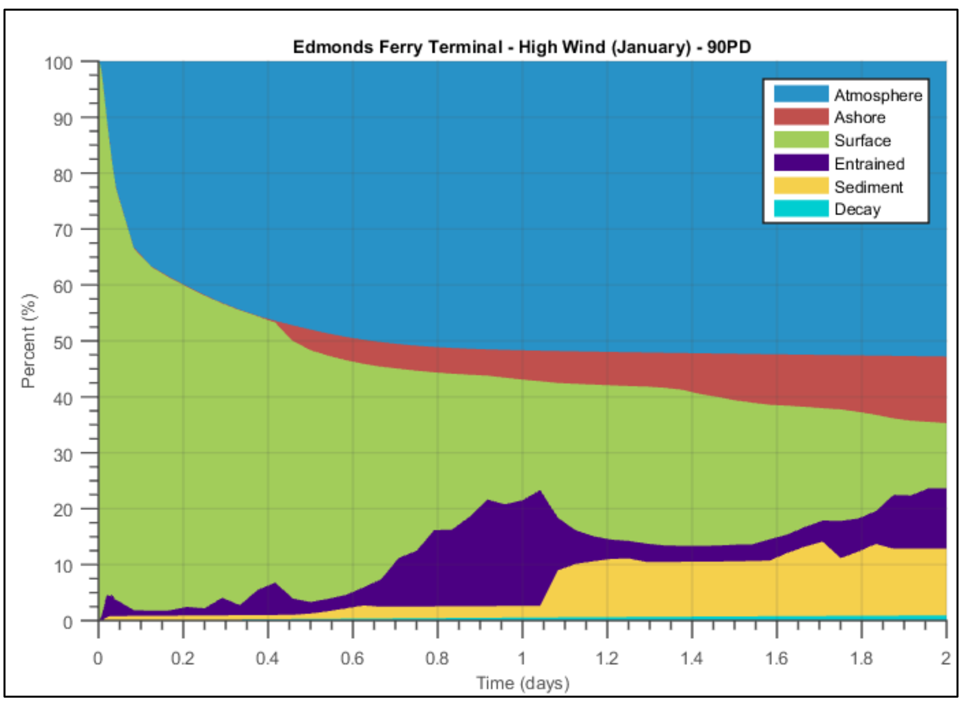

Figure 47: Mass Balance: 20,000-bbl Bakken Spills at Edmonds Ferry Terminal (Neap Tide)[156]

155 Graphic by RPS Group, Inc. Used with permission.
156 Graphic by RPS Group, Inc. Used with permission.

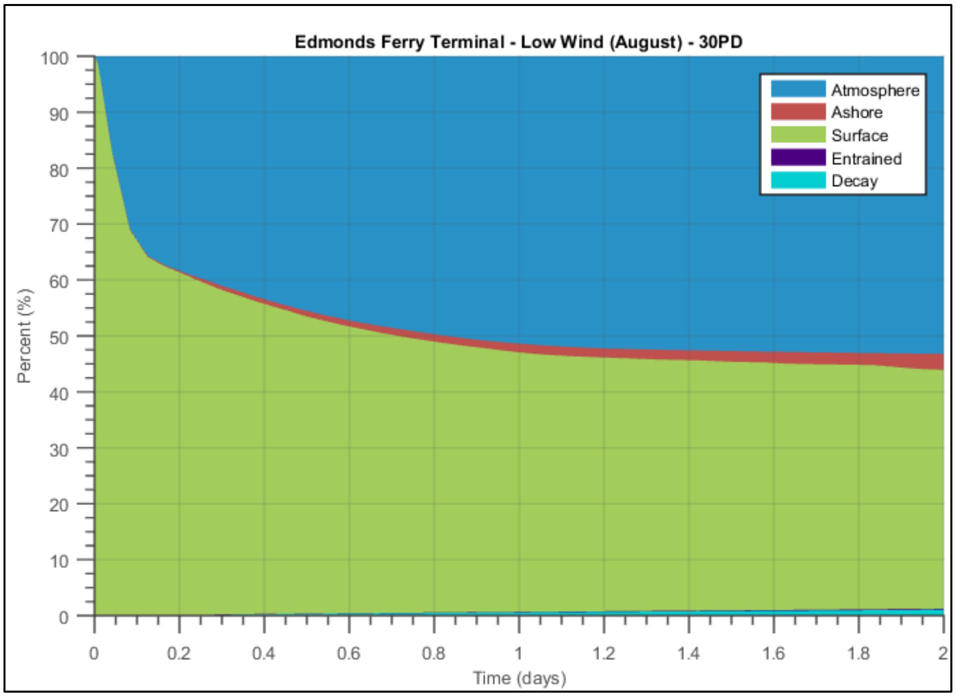

Figure 48: Mass Balance: 5,700-bbl Spills at Edmonds Ferry Terminal (Spring Tide)[157]

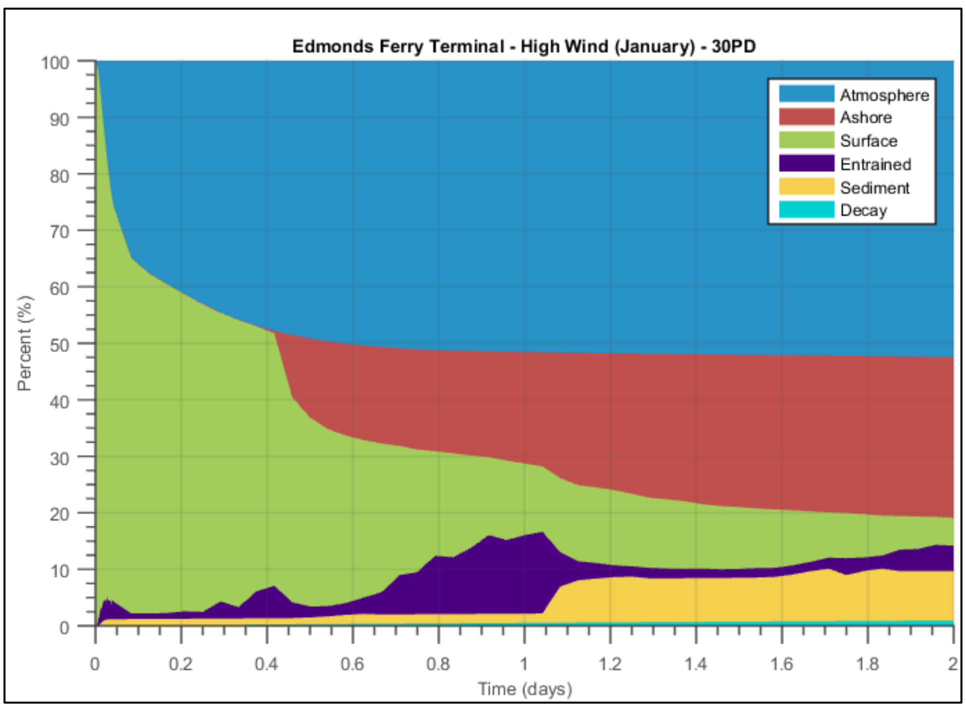

Figure 49: Mass Balance: 5,700-bbl Spills at Edmonds Ferry Terminal (Neap Tide)[158]

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[157] Graphic by RPS Group, Inc. Used with permission.
[158] Graphic by RPS Group, Inc. Used with permission.

For the proposed Tesoro Savage Crude-by-Rail Vancouver Energy project (EFSEC 2017, Horn et al., 2017) oil spill trajectory, fate modeling, and analyses were performed to support evaluation of the ecological and human health risks resulting from hypothetical releases of crude oil from rail tank cars, facilities, and marine vessels from the development and operation of a new 360,000 barrel-per-day (bpd) CBR uploading and marine loading facility at the Port of Vancouver, WA. An estimated average of four unit trains per day would arrive at the proposed facility. Crude oil would be unloaded from the unit trains and pumped through transfer pipelines to a storage area containing six aboveground storage tanks. The crude oil would then be transferred via pipeline from the storage tank area to a marine terminal on the Columbia River, where it would be loaded onto marine vessels. Occasionally, crude oil would be pumped directly from unit trains to marine vessels. The marine vessels would then transport the crude oil down the Columbia River to the Pacific Ocean where they would head to the receiving refineries. For this assessment, hypothetical releases of oil were modeled along the entire length of the rail corridor and at three representative locations including on the railway corridor, at the facility itself, and at a downstream location on the Columbia River. Scenarios also included two oil types, three river flow conditions (high, average, and low river flow), two tidal conditions (flood tide and ebb tide), and the associated season's specific geographic and environmental data. For each combination of representative location and oil type, three cases were identified for further analysis and reporting including the: 1) maximum surface oiling case, 2) maximum shoreline oiling case, and 3) maximum water column contamination case. A “case” represents a unique set of circumstances of river flow, tidal condition, and season that creates the maximum oiling of the water surface, shoreline, or water column. Note that the three cases are generally mutually exclusive. The circumstances that would cause more oil to enter the water column, e.g., greater turbulence, would also tend to reduce the amount of oil on the shoreline.

Because river flow is typically the main factor controlling downstream extent, several river flow conditions were investigated. The analysis also included an assessment of the effects of oil passing over a dam. The dam was assumed to be closed during low flow conditions and open during average and high river flow conditions. When open, the dam would result in a large amount of vertical turbulence and would therefore result in a high potential for oil to be entrained. For the hypothetical release into Lake Wallula, it was assumed that 100 percent of the total volume of oil from the breached tank cars spilled directly into the waterway. The early fall (September) and late spring/early summer (June) scenarios represented velocities that caused the plume to reach McNary dam, resulting in significant entrainment of oil as the plume passed the dam. The June release represented the time of highest river flow (late spring snow melt and large precipitation events) and captured the farthest potential downstream trajectory, when the largest volume of water was moving through the river channel at higher velocity, with the largest amount of turbulence and likely total suspended solids within the water column (175 mg/L was modeled). The winter scenario (March) represented the low flow season with very minimal velocities, turbulence, and total suspended solids (9 mg/L) resulting in the released plume not crossing the McNary Dam, and having the shortest potential downstream trajectory.

Fires, explosions, and toxic releases due to rail accidents

The most hazardous aspect of an oil spill is the possibility that the oil, or other Class 3 flammable liquid, may ignite and cause a fire or possibly an explosion that could cause human injuries or even fatalities. Of particular note is the 2013 Lac-Mégantic, Quebec, CBR train accident that resulted in 47 fatalities.

While these types of incidents are rare events, there are historical examples of tragedies that make concerns about fire and explosion potential valid and worth considering. Technically, any type of oil can burn, but there are certain oil types and circumstances that make ignition to create a fire and/or explosion much more likely.

In order for a fire or explosion to occur, there needs to be a release of flammable liquid or vapors, an ignition source needs to be present, and the environmental conditions need to be conducive to dispersing the vapors to attain a flammable mixture and/or sustained burning. In addition to fires and vapor cloud explosions, releases of hazardous substances in rail car accidents can also potentially cause toxic vapor dispersion.

The three types of incidents that may occur with a release from trains transporting hazardous and flammable liquids and have potentially serious public health and safety effects are (Fingas 2017):

- **Pool fire:** This is a fire that burns from a pool of vaporizing fuel. The primary concern associated with pool fires are hazards associated with increased temperatures from thermal radiation (heat). For crude oil and fuel transported by rail, a pool fire could occur if there is an incident leading to a release of crude oil that forms a pool and then catches fire. A pool fire may occur early in a spill when there are ignition sources, such as sparking or engine heat, available at the beginning of the release. Since the pool of oil has not spread very far at that point, the fire would be more limited. If the ignition occurs later, the pool of oil will have spread more widely, causing a larger fire.
- **Vapor cloud explosion:** A vapor cloud explosion is the result of a flammable gas or vapor mixture that is released into the atmosphere, at which point the resulting vapor cloud is ignited. The primary concern from a vapor cloud explosion is overpressure (pressure caused by a shockwave). For CBR trains, such an explosion could occur if oil was released during an incident and evaporated into the air, forming a vapor cloud. This requires that there be no immediate ignition source. The explosion zone may be some distance from the actual spill site, depending on the dispersion of the flammable vapor.
- **Toxic vapor dispersion:** Depending on the substance involved, a vapor cloud may present a toxic hazard. Acute or short-term exposures to specified concentrations of some airborne chemicals have the ability to quickly overwhelm humans, resulting in a wide spectrum of undesirable health outcomes that may include irritation of the eyes and respiratory tract, severe irreversible health effects, impairment of the ability to escape from the exposure environment, and, in extreme cases, death.

Potential hazards from fires, explosions, and toxic vapor dispersion

The damages that occur as a result of a fire or explosion depend on the location, environmental conditions, and other specific circumstances of the incident. There are two main forms of damage that may occur — one through exposure to thermal radiation (heat) and the other to blast overpressure.

Exposure to thermal radiation requires a direct line-of-sight to the source of heat. Exposure can be shielded by an object between the source and receptor. For example, in the event of an accident causing the burning of Bakken crude oil in a tank car, people that are positioned so that there is a wall or building between them and the burning tank car will not be directly affected by thermal radiation. However, without some kind of shielding, there may be impacts, depending on the intensity of the heat.

The acute damage potential of vapor cloud explosions has been proven by many real-world accidents including the significant potential for loss of life, property and business interruption. A major example is the 2005 Buncefield explosion in the United Kingdom (Atkinson et al. 2017). In this case, a series of explosions occurred in 20 large storage tanks at a large oil terminal that caused at least 43 injuries.

The importance of the unique explosion hazards posed by "tight crudes" — crudes produced by fracking of nonconventional reserves, such as Bakken crude, are beginning to be recognized in the U.S.: "Physical and chemical properties of hydrocarbon vapor clouds and the layout of the surrounding area influences the dynamics of blast propagation during the explosion" (Madrigal 2018).

Fingas describes a scenario with a burning vapor cloud:

> As a vapor cloud burns and expands, the gases start to move and become consumed by the flame front. If the process takes place with the unburned gas flowing smoothly into the consuming flame front, the flame front propagates at the laminar burning velocity, which produces a flash fire. If there is turbulence in the gas, the flame velocity can greatly increase above this laminar burning velocity, which can produce high overpressures. Significant turbulence can be generated by obstacles encountered by a flame as it propagates through the vapor cloud in obstructed regions. This process can be reinforced by positive feedback, so that as more obstacles are encountered, more turbulence is generated, and this further accelerates the flame. The obstacle density is also referred to as *congestion*…
>
> A key factor in determining the magnitude of overpressure generation is the degree to which the cloud is constrained from expanding. As the cloud burns, it heats and expands; if the cloud is constrained to expand in only one or two dimensions then the positive feedback mechanism leads to higher overpressures than if the cloud were to expand freely. This expansion constraint is referred to as *degree of confinement.* (p. 173)

For areas along the rail corridor, confinement and congestion vary considerably. No damaging blast waves can occur for releases out in the open. However, they may occur in urban areas with many buildings and structures in the vicinity of the rail tracks. Note that while there would be no damaging blast waves in an incident out in the open, an explosion could still occur (Fingas 2017).

Modeling of hazard zones for selected rail commodities

To better understand the potential for human health and safety environment effects associated with the transport of hazardous liquids by rail through Washington State, the WRTSS team conducted modeling of pool fires, vapor cloud explosions, and toxic vapor dispersion from hypothetical releases of the most commonly transported hazardous commodities.[159] These hazards would exist throughout Washington rail corridors. Because the range of locations, conditions, and release quantities for hypothetical scenarios can be an intractable number, representative scenarios specific to rail corridor regions were selected to provide a range of representative consequences of hazardous liquid releases.

The objective of the modeling was to:

- Perform consequence modeling for hazardous liquid releases for representative regional locations, using the worst-case weather conditions for each.
- Determine the extent of flammable vapor dispersion.
- Determine the extent of toxic vapor dispersion.
- Determine the extent of thermal hazard zones derived from proposed pool fires.
- Determine the extent of explosion overpressure for vapor cloud explosions resulting from oil releases.

Chemicals considered

The Surface Transportation Board Public Use Waybill data for Washington State were obtained for the years 2014 through 2016. These data were categorized by Standard Transportation Commodity Code (STCC). Review of these data identified the greatest shipments by tonnage of hazardous liquids commodities of interest to this study:

- Crude oil
- Ethanol
- Propane
- Sulfuric acid
- Anhydrous ammonia

Two crude oil types were included: conditioned Bakken crude oil and diluted bitumen, as these represent the most commonly transported crude oils in Washington. They also have distinctly different properties. The data on the carloads of these commodities are shown in Table 55.[160]

Table 55: Hazard Liquids Transported by Rail in Washington State for Modeling (2014, 2015, 2016, and Average Annual)[161]

Commodity	STCC	Carloads in 2014	Carloads in 2015	Carloads in 2016	Average Annual Carloads
Crude Oil	13111	84,781	77,162	74,118	78,687
Propane	29121	16,220	19,372	24,272	19,955
Ethanol	28184	13,352	12,816	13,460	13,209
Anhydrous Ammonia	28198	3,360	2,920	3,676	3,319
Sulfuric Acid	28193	920	760	880	853

[159] Modeling was conducted by Risknology, Inc.
[160] Note that these are the most recent data available.
[161] Data from Surface Transportation Board Public Use Waybill data for Washington State.

Chemical properties of hazardous liquids for modeling

Bakken crude

The crude oil composition used for this analysis is known as "conditioned Bakken crude." It is an extremely flammable liquid (Category 1) with a boiling point of ranging from 70-110°F and a vapor pressure range of 8.5–15 psia. The flash point is about -20°F.

Diluted bitumen

"[Bitumen is] one of the types of crude oil derived from the Canadian oil sands … a heavy, sour oil. Bitumen would not flow through a pipeline efficiently, so it is mixed with diluents to be readied for pipeline transportation as diluted bitumen, or 'dilbit.' Diluents are usually natural gas condensate, naphtha or a mix of other light hydrocarbons. Bitumen is a mixture of heavy oil, sand, clay and water. It is separated from the sand and water in a centrifuge prior to dilution for transportation" (API and AOPL 2013). It is an extremely flammable liquid and vapor. The liquid specific gravity is less than one. The vapor pressure varies significantly, from 375–525 mmHg.

Ethanol

"Ethanol is a renewable fuel made from corn and other plant materials. The use of ethanol is widespread, and more than 98 percent of gasoline in the US contains some ethanol. The most common blend of ethanol is E10 (10 percent ethanol, 90 percent gasoline)" (DOE 2019). It is a highly flammable liquid and vapor (Category 2). It is a heavier than air gas, with a boiling point of 173°F and vapor pressure of 42 mmHg.

Propane

Propane is a three-carbon alkane with the molecular formula C_3H_8 "…and is sometimes referred to as liquefied petroleum gas, LP-gas or LPG. Propane is produced from both natural gas processing and crude oil refining. It is nontoxic, colorless and virtually odorless. As with natural gas, an identifying odor is added so the gas can be readily detected. The propane industry has developed numerous methods to make the transport and use of propane safe… Propane is a versatile fuel… used by millions of people in many different environments — homes, industry, farming and more" (Thompson Gas 2019). Its boiling point is -258°F and its vapor pressure is 109.0 psig. It is a flammable liquid (Category 1).

Anhydrous ammonia

Ammonia is a compound of nitrogen and hydrogen with the formula NH_3. The simplest nitrogen hydride, ammonia is a colorless gas with a characteristic pungent smell. It is a common nitrogenous waste serving as a precursor to food and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceutical products and is used in many commercial cleaning products. It is mainly collected by downward displacement of both air and water.

Although common in nature and in wide use, ammonia is both caustic and hazardous in its concentrated form. It is classified as an extremely hazardous substance, toxic gas (Category 2), and is subject to strict reporting requirements by facilities, which produce, store, or use it in significant quantities. Its boiling point is -28°F and vapor pressure is 128 psia. It absorbs water and moisture from the air and its environment.

Sulfuric acid

"Sulfuric acid, also known as hydrogen sulfate, is a highly corrosive, clear, colorless, odorless, strong mineral acid with the formula H_2SO_4. It is also one of the top 10 chemicals released (by weight) by the paper industry. In modern industry, sulfuric acid is an important commodity chemical, and is used primarily for the production of phosphoric acid. It is also good for removing oxidation from iron and steel so metal manufacturers use it in large quantities.

"Sulfuric acid is a very dangerous chemical. It is extremely corrosive and toxic. Exposure can occur from inhalation, ingestion, and through skin contact. Inhalation of H_2SO_4 may cause irritation and/or chemical burns to the respiratory tract, nose, and throat. Inhalation can also be fatal as a result of spasm, inflammation, edema of the larynx and bronchi, chemical pneumonitis, and pulmonary edema. Chronic inhalation is known to have caused kidney and lung damage in addition to nosebleeds, erosion of the teeth, chest pain, and bronchitis. The effects of ingesting sulfuric acid orally are just as bad as inhalation. Ingestion may cause systematic toxicity with acidosis, which can be fatal" (Cheremisinoff 2010). Although not flammable itself, its strong oxidation reaction produces hydrogen gas, which is highly flammable, therefore flammability concerns must be considered among the hazards of this acid.

Environmental parameters for modeling

The behavior of the released substances will depend on the ambient environmental conditions. To make the model simulations as specific as possible to the conditions in the rail corridors of Washington, regional weather data was required. Daily measurements of wind speed, temperature and humidity were gathered from regional weather stations and analyzed to determine the statistics shown in Table 56.

The wind speeds considered for predicting vapor dispersion hazard distances for this analysis were the 95th percentile values for each of the weather stations, which are the value below which 95 percent of the wind speeds fell, so this value was exceeded only 5 percent of the time.

Table 56: Weather Conditions for Rail Corridor Regions Including Minimum Wind, 5% Wind, Mean Wind, 95% Wind, Maximum Wind, Mean Air Temperature, and Relative Humidity[162]

Rail Corridor	Minimum Wind	5% Wind	Mean Wind	95% Wind	Maximum Wind	Mean Air Temperature	Relative Humidity
Scenic (Inland)	-	-	1.5 mph	3.6 mph	7.2 mph	44.9°F	63.6%
Fall Bridge	0.5 mph	2.5 mph	7 mph	14.6 mph	20.8 mph	55.2°F	62.2%
Columbia River	0.7 mph	2.5 mph	7.9 mph	13.7 mph	22.8 mph	54.2°F	61.1%
Spokane	1.1 mph	3.6 mph	8.3 mph	16.8 mph	26.6 mph	50.6°F	63.6%
Lakeside	0.7 mph	3.4 mph	6.5 mph	14.3 mph	23.9 mph	52.7°F	60.6%
Bellingham	0.2 mph	2.2 mph	6.3 mph	13.9 mph	22.8 mph	-	63.6%
Cherry Point	0.2 mph	1.6 mph	6.3 mph	13.9 mph	22.8 mph	-	63.6%
Stampede	0.2 mph	1.6 mph	6.3 mph	13.9 mph	22.8 mph	-	63.6%
Sumas	0.2 mph	1.6 mph	8.9 mph	21.7 mph	28.4 mph	-	63.6%
Scenic (Coast)	0.9 mph	1.6 mph	7 mph	14.3 mph	25.7 mph	-	63.6%
Seattle	1.1 mph	2.9 mph	7.5 mph	13.7 mph	19.7 mph	54.7°F	63.6%
Yakima Valley	0.2 mph	3.1 mph	5.9 mph	11.2 mph	18.3 mph	54.6°F	63.6%
Kettle Falls	0.2 mph	2 mph	5.7 mph	11.4 mph	19.9 mph	48.3°F	70.4%
Coeur d'Alene	0 mph	1.8 mph	4.6 mph	10.5 mph	21 mph	-	63.6%
New Westminster	1.9 mph	1.1 mph	7.2 mph	12.6 mph	22.4 mph	52.3°F	63.6%

In addition to wind speeds, a measure of the effect of turbulence on dispersion was also required for analysis. Turbulence increases the entrainment and mixing of air into the vapor cloud plume, and thereby acts to reduce the concentration of vapor in the plume (i.e., turbulence enhances the plume dispersion). It was therefore important to categorize the amount of atmospheric turbulence present at any given time.[163]

Humid air absorbs and attenuates more thermal radiation than dry air, thereby decreasing the transmissivity of the air and reducing the thermal hazard distance. Air temperature and humidity were also selected to give realistic but conservative estimates. Air temperature and humidity were taken as the average values observed from the weather station data sets.

Modeling inputs and approach

The modeling involved simulation of:

- Multiphase flashing of vapor
- Liquid pool spread, heat transfer and evaporation
- Vaporization from liquid pool
- Vapor dispersion
- Combustion
- Attenuation of thermal radiation

[162] NOAA weather data.

[163] According to the Pasquill Stability scale, there are six stability classes: A, B, C, D, E and F, with class A being the most unstable or most turbulent, and class F being the most stable or least turbulent. Stability class F was chosen for analysis at each site to ensure conservative results. Stability class F is specified for calculation of the dispersion of natural gas accidental releases in the permit approval process governed by the Federal Energy Regulatory Commission (FERC) for liquefied natural gas facilities. https://www.phmsa.dot.gov/pipeline/liquified-natural-gas/lng-plant-requirements-frequently-asked-questions

It was assumed that there was a catastrophic failure and instantaneous release from a single tank car at each location (rail corridor).

Consequence analysis

Pool size

Realistic representation of pool size depends upon the exact location, topography of the substrate area, rate of release of the hazardous liquid from the breach and rate of vaporization. Pool spread models and Gaussian dispersion models rely on treating the shape of each of these effects as circular. This means that irregular shape release areas must be represented as a circular area for both the spreading phenomena and the vaporization source.

The spread of the pool was calculated using a pool spread model that assumed that the driving force for the spread was formed by the hydrostatic difference between the thickness of the liquid layer and a minimum pool thickness characteristic for the substrate. This results in the rate of spreading decreased as the pool approached the minimum thickness. In this study, the hazardous liquid release occurs on land. Where the pool has spread and vaporized to produce a pool of depth equal to the minimum thickness, the spreading is constrained to be consistent with this thickness. Thereafter the radius would no longer be a simple function of time.

Vapor dispersion hazards

Vapor dispersion was conducted for all hazardous liquid releases along with any vaporization of gas. Dispersions were performed using the validated Uniform Dispersion Model.

To maximize dispersion distances, all simulations were conducted on a flat surface. Objects (i.e., buildings, tanks, and other structures) were incorporated in the analysis as a surface roughness parameter. Objects have the potential to increase mixing, thereby reducing the distance to which the vapor clouds would travel.

Toxic hazards

Toxicity refers to the injurious effects of chemical and physical agents on living organisms, altering structure and function. Injurious effects can be from many mechanisms and include biological, carcinogenic, mutagenic, teratogenic and endocrine disruption. Potential consequences of exposure to the toxic chemicals considered in this study (sulfuric acid and ammonia) are acute, consisting of severe irritation and burning of skin, eyes, throat and respiratory tract, headache, nausea, and vomiting. This can result in bronchiolar and alveolar edema, and airway destruction resulting in respiratory distress or failure.

Pool fire hazards

In the event that an ignition of a spreading hazardous liquid pool occurred, the thermal radiation resulting from the ignited pool was analyzed. The pool fires were modeled using a solid flame model with no obstructions. Treating radiation without obstructions from pool fire radiation calculations increases consequence distances. The solid flame model is used to solve for radiative intensities at distances away from the center of a fire and allows for a change in hazard distance due to tilting of the flame by wind. To determine the hazard distance, an average emissive power, a burn rate, and an atmospheric transmissivity was calculated during the analysis.

Explosion hazards

For areas along the rail corridor, confinement and congestion would vary, hence representative realistic confinement and congestion conditions were assumed. No damaging blast waves can occur for releases in the open.

To properly estimate the potential explosion associated with each release, the scenario in which the cloud or some portion thereof sits in a congested volume needed to be assessed. The explosion overpressure results were calculated with the TNO Multi-Energy model (TNO 1997) using the reactivity of the fuel in the cloud, the mass of fuel within the source volume, and the congestion/confinement level representative of the explosion source. The area surrounding the release point was assigned a representative congestion and confinement level.

Damage thresholds

The impacts expected from different levels of thermal radiation (measured in kilowatts per square meter, kW/m^2) are shown in Table 57 (Lees 2012). A watt is a measure of power, or energy deposition per unit of time. As a reference, the amount of power felt when the sun is at its zenith–directly overhead at sea level –is 1.2 kW/m^2 (Haddad 1981). The table shows that vegetation ignites at a flux of 10 kW/m^2, wood between 12.5 and 25 kW/m^2 and damage to petrochemical process equipment (i.e. leakage from gasketed flange connections, bearing failure in rotating machinery, seizing of valve internal components) occurs at 37.5 kW/m^2.

Table 57: Impacts of Exposure to Thermal Radiation on Receptors[164]

Thermal Radiation	Impacts to Receptors
10-12 kW/m^2	Vegetation ignites
12.5 kW/m^2	Piloted ignition of wood
25 kW/m^2	Non-piloted ignition of wood
37.5 kW/m^2	Damage to petrochemical process equipment

Data compiled by the Department of Defense summarize the effects of increasing blast pressure (overpressure) on various structures, as shown in Table 58. These data originate from weapons tests and blast studies (Glasstone and Dolan 1977; Satori 1983).

[164] Lees 2012.

Table 58: Impacts of Overpressure on Receptors[165]

Overpressure	Impact on Receptors
1 psi	Window glass shatters
2 psi	Moderate damage to houses
3 psi	Residential structures collapse
5 psi	Most buildings collapse
10 psi	Reinforced concrete buildings are severely damaged or demolished
20 psi	Heavily-built concrete buildings are severely damaged or demolished

For toxic vapor dispersion, "immediately dangerous to life or health" (IDLH) is defined by the U.S. National Institute for Occupational Safety and Health (NIOSH) as exposure to airborne contaminants that is "likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment."

For ammonia, it has been found that a change in respiration rate and moderate to severe irritation has been reported in seven subjects exposed to 500 ppm for 30 minutes. The current IDLH for ammonia is 300 ppm based on acute inhalation toxicity data in humans (Henderson and Haggard 1943; Silverman et al. 1946). For sulfuric acid, the IDLH is 15 mg/m^3 based on acute inhalation toxicity data in humans (Amdur et al. 1952). This may be a conservative value due to the lack of relevant acute toxicity data for workers exposed to concentrations above 5 mg/m^3.

Modeling results

The flammability range is delineated by the upper and lower flammability limits (UFL and LFL). Outside this range of air/vapor mixtures, the mixture cannot be ignited (unless the temperature and pressure are increased). The LFL, usually expressed in volume percentage, is the lower end of the concentration range over which a flammable mixture of gas or vapor in the air can be ignited at a given temperature and pressure. The LFL decreases with rising temperatures; therefore, a mixture that is below its LFL at a given temperature may be ignitable if heated sufficiently. The UFL is the maximum percentage of flammable gas or vapor in the air above which ignition cannot take place because the ratio of the gas to oxygen is too high. The upper and lower flammability limits are also known as the upper and lower explosive limits. Lower flammability limits are reported in this study as they are the greatest flammable hazard distances.

Dispersion of a toxic gas does not require ignition to affect human receptors. Only the presence of persons at the time of the vapor or gas cloud is required for a damaging consequence from the release. Hazard distances are determined to the concentration in air defined as the IDLH.

A pool fire occurring early in the release process, perhaps cause by sparking or engine heat, results in a relatively smaller fire compared to a fire that occurs later in the release when time has allowed the pool to spread and cover a larger area. In this study, late pool fires were reported due to their greater hazard distances. In the case of the late pool fire, liquid pool spreading was assumed to take place prior to ignition. The pool diameter was then equal to the maximum dimension attained in the spreading process.

[165] Glasstone and Dolan 1977; Satori 1983.

Overpressure (or blast overpressure) is the pressure caused by a shock wave over and above normal atmospheric pressure. The shock wave may be caused by an explosion and the resulting overpressure receives particular attention when measuring impacts on buildings and structures.

Figure 51 shows the fundamental relationship among the dispersion physics and hazard zones. The rail track is shown running horizontally across the middle of the figure. A release occurs at its midpoint.

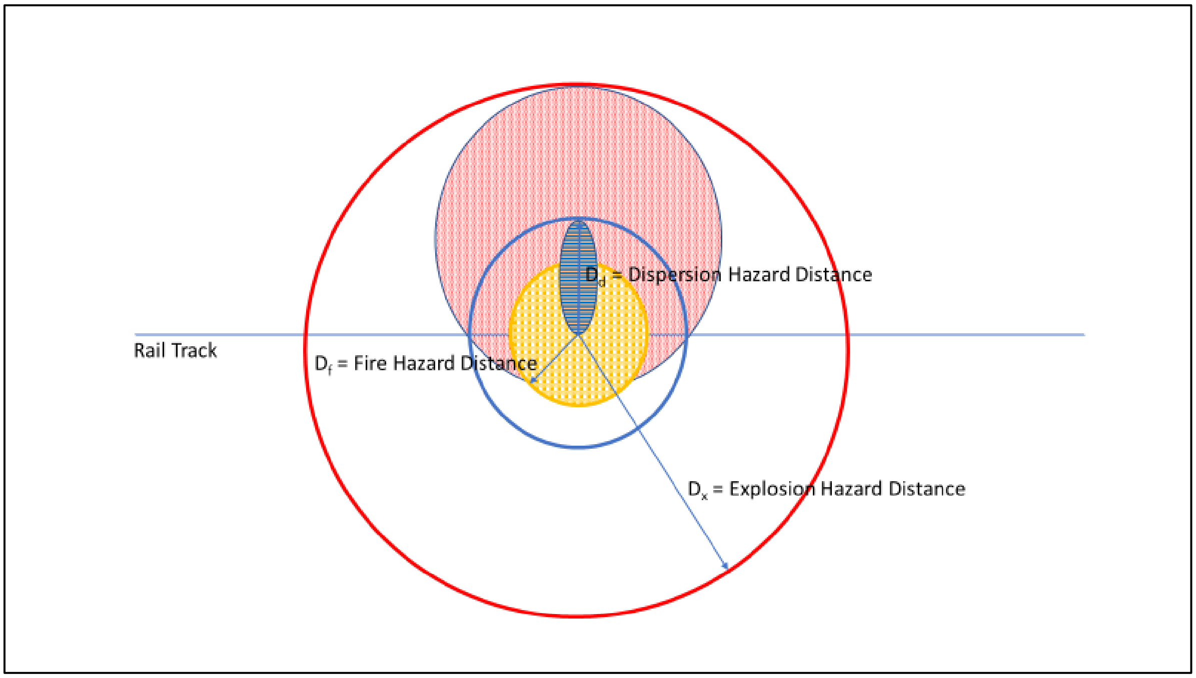

Figure 50: Dispersion and Hazard Zones[166]

The gold circle shows the region where an ignited pool fire's thermal radiation level reaches the specified threshold value of 12.5 kW/m^2. The pool is modeled as a circular liquid on a horizontal plane surface, it has rotational symmetry.

The elliptical shape oriented vertically upward in the figure (crosshatched in blue) represents a plume, or footprint of vapor or gas in air, the outer boundary is the LFL concentration. The footprint is the location of the LFL swept out over the entire duration of the release and dispersion. As this footprint (or plume) can drift in any direction, the blue circle formed by its rotation is the hazard zone for dispersion.

The circle centered on the top of the elliptical plume (dotted in red) represents the boundary that reaches the endpoint overpressure of 2 pounds per square inch (psi). The large red circle formed by its rotation is the hazard zone for explosion overpressure.

Note that the hazard distances are in all directions. The hazard distance is the radius of the circle. For example, a 100-foot hazard distance would mean that the diameter of the circle is 200 feet.

[166] Figure developed by Risknology, Inc. Used with permission.

The degree of hazard within the circle would depend on the wind direction and ambient conditions at the time of the incident.

The maximum flammable vapor dispersion distances for a single-car release scenario are tabulated for each hazardous liquid and rail corridor region in Table 59. If an ignition were to occur within the vapor cloud, the dispersion distance also represents the flash fire hazard distance associated with each hazardous liquid. Bakken crude produces the greatest hazard distances overall (typically 227 feet) and ammonia the least (typically 28 feet). The rail right-of-way is 25 feet on either side of the tracks, therefore hazard distances of about 25 feet would remain within the right-of-way and not pose a direct consequence to neighboring facilities or the public.

Table 59: Dispersion Hazard Distances (LFL) (One Car) by Type of Substance[167]

Rail Corridor	Ammonia	Bakken Crude	DilBit	Ethanol	Propane
Bellingham	28 ft	227 ft	80 ft	33 ft	86 ft
Cherry Point	28 ft	227 ft	80 ft	33 ft	86 ft
Coeur d'Alene	28 ft	208 ft	50 ft	32 ft	77 ft
Columbia River	28 ft	225 ft	78 ft	33 ft	86 ft
Fallbridge	28 ft	231 ft	82 ft	33 ft	89 ft
Kettle Falls	28 ft	213 ft	63 ft	32 ft	77 ft
Lakeside	28 ft	229 ft	82 ft	33 ft	88 ft
New Westminster	28 ft	219 ft	74 ft	33 ft	83 ft
Scenic (Coastal)	28 ft	229 ft	82 ft	33 ft	87 ft
Scenic (Inland)	28 ft	130 ft	33 ft	29 ft	66 ft
Seattle	28 ft	225 ft	77 ft	33 ft	86 ft
Spokane	28 ft	244 ft	92 ft	34 ft	95 ft
Stampede	28 ft	274 ft	104 ft	35 ft	114 ft
Sumas	28 ft	227 ft	80 ft	33 ft	86 ft
Yakima Valley	28 ft	258 ft	86 ft	34 ft	78 ft
Range	**28 ft**	**130–274 ft**	**33–104 ft**	**29–35 ft**	**66–114 ft**
Typical Distance (Mode)[168]	**28 ft**	**227 ft**	**80 ft**	**33 ft**	**86 ft**

The maximum late pool fire distances for a single-car release scenario are tabulated for each hazardous liquid and rail corridor region in Table 60. Ethanol produces the greatest hazard distances overall (typically 350 feet) and ammonia the least (typically 7 feet). Bakken crude contains the greatest fraction of light hydrocarbons (approximately 5 percent of the mixture is methane, ethane, propane and butane). These vapors flash off the liquid pool surface during the time the pool spreads to its maximum extent, and the remaining liquid does not support a late pool fire.

[167] Analysis conducted by Risknology, Inc. for this report.
[168] The "mode" is the most common value in a set of statistical data.

Table 60: Late Pool Fire Hazard Distances (One Car) by Type of Substance[169]

Rail Corridor	Ammonia	Dilbit	Ethanol	Propane
Bellingham	7 ft	168 ft	350 ft	26 ft
Cherry Point	7 ft	168 ft	350 ft	26 ft
Coeur d'Alene	8 ft	166 ft	347 ft	25 ft
Columbia River	7 ft	168 ft	350 ft	26 ft
Fallbridge	7 ft	169 ft	352 ft	26 ft
Kettle Falls	7 ft	167 ft	347 ft	26 ft
Lakeside	7 ft	169 ft	352 ft	26 ft
New Westminster	7 ft	168 ft	348 ft	26 ft
Scenic (Coastal)	7 ft	168 ft	351 ft	26 ft
Scenic (Inland)	7 ft	168 ft	350 ft	26 ft
Seattle	7 ft	170 ft	354 ft	27 ft
Spokane	7 ft	172 ft	358 ft	27 ft
Stampede	7 ft	168 ft	350 ft	26 ft
Sumas	8 ft	167 ft	349 ft	26 ft
Yakima Valley	9 ft	155 ft	327 ft	22 ft
Range	**7–9 ft**	**155–172 ft**	**327–358 ft**	**22–27 ft**
Typical Distance (Mode)	**7 ft**	**168 ft**	**350 ft**	**26 ft**

The maximum vapor cloud explosion hazard distances for a single-car release scenario are tabulated for each hazardous liquid and rail corridor region in Table 61. Propane generates the greatest hazard distance, (typically 569 feet), followed closely by Bakken crude (typically 441 feet) and ethanol the least (typically 44 feet). These explosion distances will be affected strongly by the degree of congestion and confinement at the exact location of a release. A uniform confined explosion strength of 10 and explosion efficiency of 12.5 percent were used to produce these estimates. These conditions could be experienced with flammable gas mixtures in a volume with 2-dimensional expansion (constraint between surfaces such as a parking garage or between multi story buildings), and high obstacle density (such as dense buildings or forested areas).

[169] Analysis conducted by Risknology, Inc. for this report.

Table 61: Explosion Hazard Distances (One Car) by Type of Substance[170]

Rail Corridor	Bakken Crude	Dilbit	Ethanol	Propane
Bellingham	441 ft	173 ft	44 ft	569 ft
Cherry Point	441 ft	173 ft	44 ft	569 ft
Coeur d'Alene	446 ft	184 ft	45 ft	364 ft
Columbia River	441 ft	170 ft	46 ft	536 ft
Fallbridge	442 ft	171 ft	48 ft	570 ft
Kettle Falls	442 ft	183 ft	57 ft	371 ft
Lakeside	441 ft	172 ft	45 ft	570 ft
New Westminster	442 ft	178 ft	44 ft	433 ft
Scenic (Coastal)	441 ft	173 ft	44 ft	570 ft
Scenic (Inland)	441 ft	169 ft	47 ft	536 ft
Seattle	443 ft	175 ft	42 ft	495 ft
Spokane	456 ft	179 ft	56 ft	464 ft
Stampede	441 ft	173 ft	44 ft	569 ft
Sumas	470 ft	189 ft	50 ft	370 ft
Yakima Valley	516 ft	247 ft	42 ft	343 ft
Range	**441–516 ft**	**169–247 ft**	**42–57 ft**	**343–570 ft**
Typical Distance (Mode)[171]	**441 ft**	**173 ft**	**44 ft**	**569 ft**

The maximum toxic distances for a single-car release scenario are tabulated for each hazardous liquid and rail corridor region in Table 62. Ammonia produces the greatest hazard distances overall — typically 11,167 feet, or 2.1 miles. Sulfuric acid has a much lower toxic hazard distance — typically 23 feet.

[170] Analysis conducted by Risknology, Inc. for this report.
[171] The "mode" is the most common value in a set of statistical data.

Table 62: Toxic Exposure Hazard Distances (IDHL) (One Car) by Type of Substance[172]

Rail Corridor	Ammonia	Sulfuric Acid
Bellingham	11,180 ft (2.1 miles)	23 ft
Cherry Point	11,167 ft (2.1 miles)	23 ft
Coeur d'Alene	11,519 ft (2.2 miles)	23 ft
Columbia River	10,797 ft (2.0 miles)	23 ft
Fallbridge	10,788 ft (2.0 miles)	23 ft
Kettle Falls	12,673 ft (2.4 miles)	23 ft
Lakeside	11,131 ft (2.1 miles)	23 ft
New Westminster	11,419 ft (2.2 miles)	23 ft
Scenic (Coastal)	11,256 ft (2.1 miles)	23 ft
Scenic (Inland)	10,722 ft (2.0 miles)	23 ft
Seattle	11,841 ft (2.1 miles)	23 ft
Spokane	10,922 ft (2.2 miles)	23 ft
Stampede	11,167 ft (2.2 miles)	23 ft
Sumas	7,636 ft (1.4 miles)	23 ft
Yakima Valley	12,975 ft (2.5 miles)	22 ft
Range	**7,636–12,975 ft (1.4–2.5 miles)**	**22–23 ft**
Typical Distance (Mode)	**11,167 ft (2.1 miles)**	**23 ft**

Ten-Car Release Scenario

The most likely release scenario involves a single car. However, it is possible that a rail accident will involve a larger number of cars, potentially causing releases from multiple cars. This is particularly true for unit trains and key trains with 20–120 tank cars of Class 3 flammables and other liquid hazardous commodities.

For benchmarking purposes, the modeling was repeated for hypothetical releases from one tank car and ten tank cars for the worst-case situation with respect to rail corridor conditions. The 10-car release is consistent with the PHMSA Fast Act ruling issued on 28 February 2019, which stipulates contingency planning requirements for worst-case discharges of 300,000 gallons (roughly the capacity of ten 714-bbl tank cars).

The results for dispersion are shown in Table 63. Figure 52 shows these data graphically. The graph may be used to roughly calculate hazard distances for intermediate numbers of cars between one and 10.

[172] Analysis conducted by Risknology, Inc. for this report.

Table 63: Dispersion Hazard Distances (LFL) (10 Cars) by Type of Substance[173]

Number of Cars	Ammonia	Bakken Crude	Dilbit	Ethanol	Propane
One Tank Car	28 ft	227 ft	80 ft	33 ft	86 ft
10 Tank Cars	62 ft	643 ft	174 ft	56 ft	932 ft
Times Increase[174]	2.2	2.8	2.2	1.7	10.8

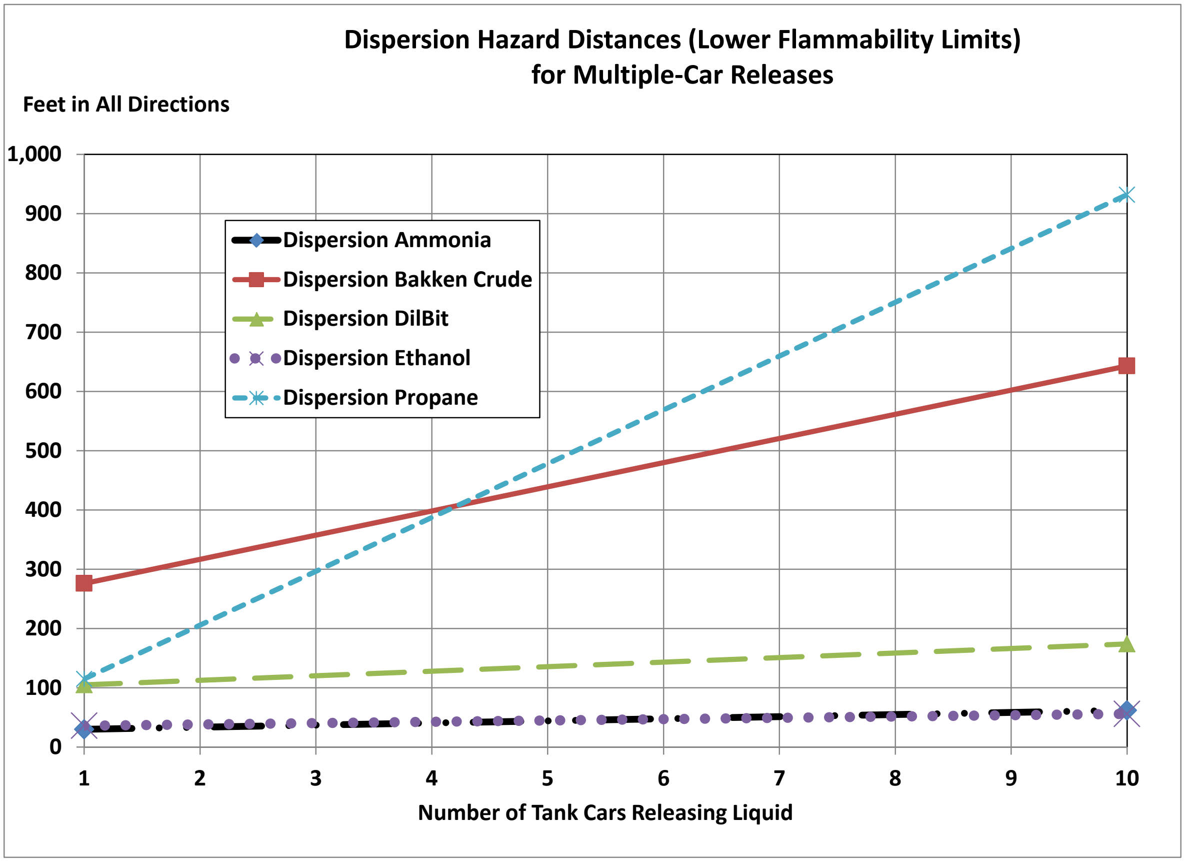

Figure 51: Dispersion Hazard Distances (LFL) for Multiple-Car Releases[175]

The modeled fire hazard distances for one- and 10- car releases are shown in Table 64. Figure 53 shows these data graphically. The graph may be used to roughly calculate hazard distances for intermediate numbers of cars between one and ten.

[173] Analysis conducted by Risknology, Inc. for this report. Used with permission.
[174] 10-car distance divided by one-car distance.
[175] Analysis conducted by Risknology, Inc. for this report. Used with permission.

Table 64: Fire Hazard Distances (10 Cars) by Type of Substance[176]

Number of Cars	Ammonia	Bakken Crude	Dilbit	Ethanol	Propane
One Tank Car	7 ft	n/a	168 ft	350 ft	26 ft
10 Tank Cars	23 ft	n/a	485 ft	987 ft	92 ft
Times Increase	3.2	n/a	2.9	2.8	3.5

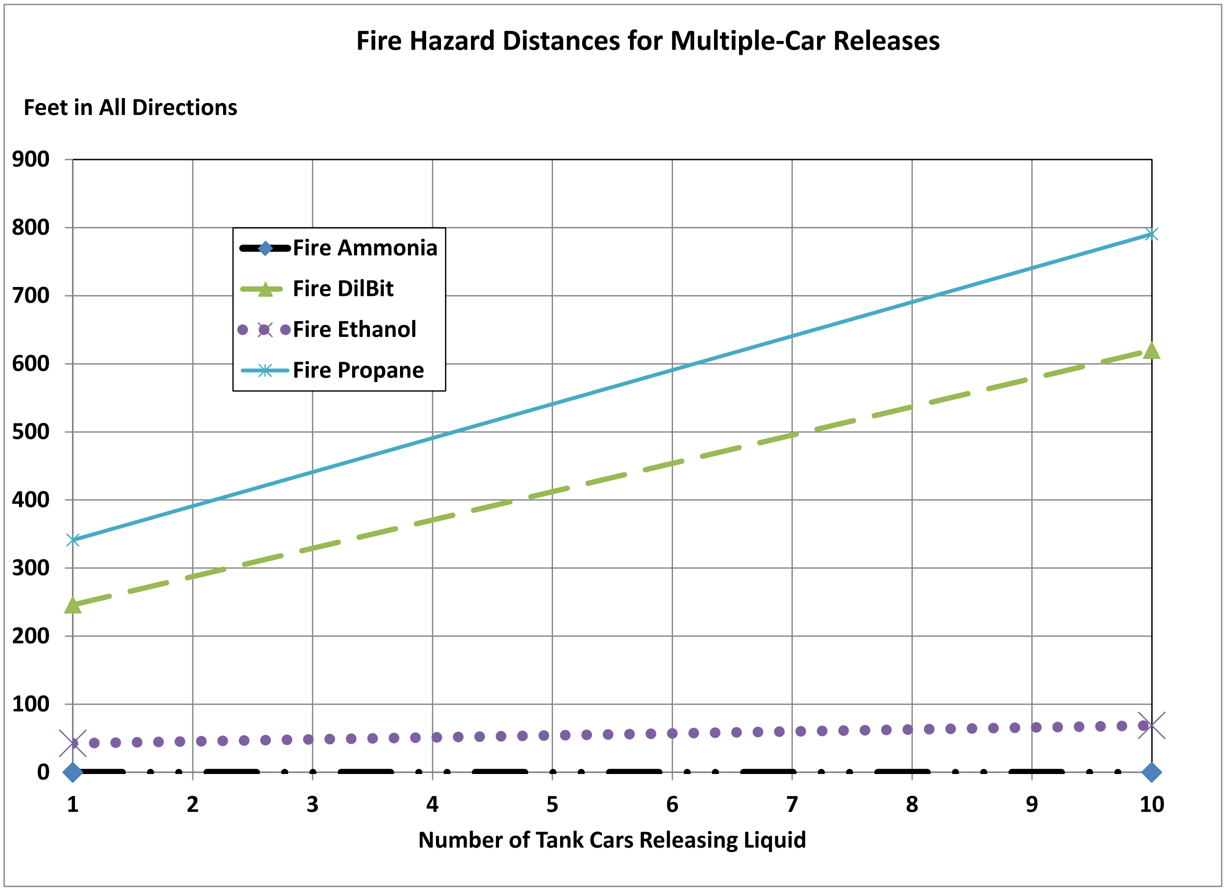

Figure 52: Late Pool Fire Hazard Distances for Multiple-Car Releases[177]

The modeled explosion hazard distances for one- and 10-car releases are shown in Table 65. Figure 54 shows these data graphically. The graph may be used to roughly calculate hazard distances for intermediate numbers of cars between one and 10.

[176] Analysis conducted by Risknology, Inc. for this report.
[177] Analysis conducted by Risknology, Inc. for this report. Used with permission.

Table 65: Explosion Hazard Distances (10 Cars) by Type of Substance[178]

Number of Cars	Ammonia	Bakken Crude	Dilbit	Ethanol	Propane
One Tank Car	n/a	441 ft	173 ft	44 ft	569 ft
10 Tank Cars	n/a	1,342 ft	620 ft	69 ft	790 ft
Times Increase	n/a	3.0	3.6	1.6	1.4

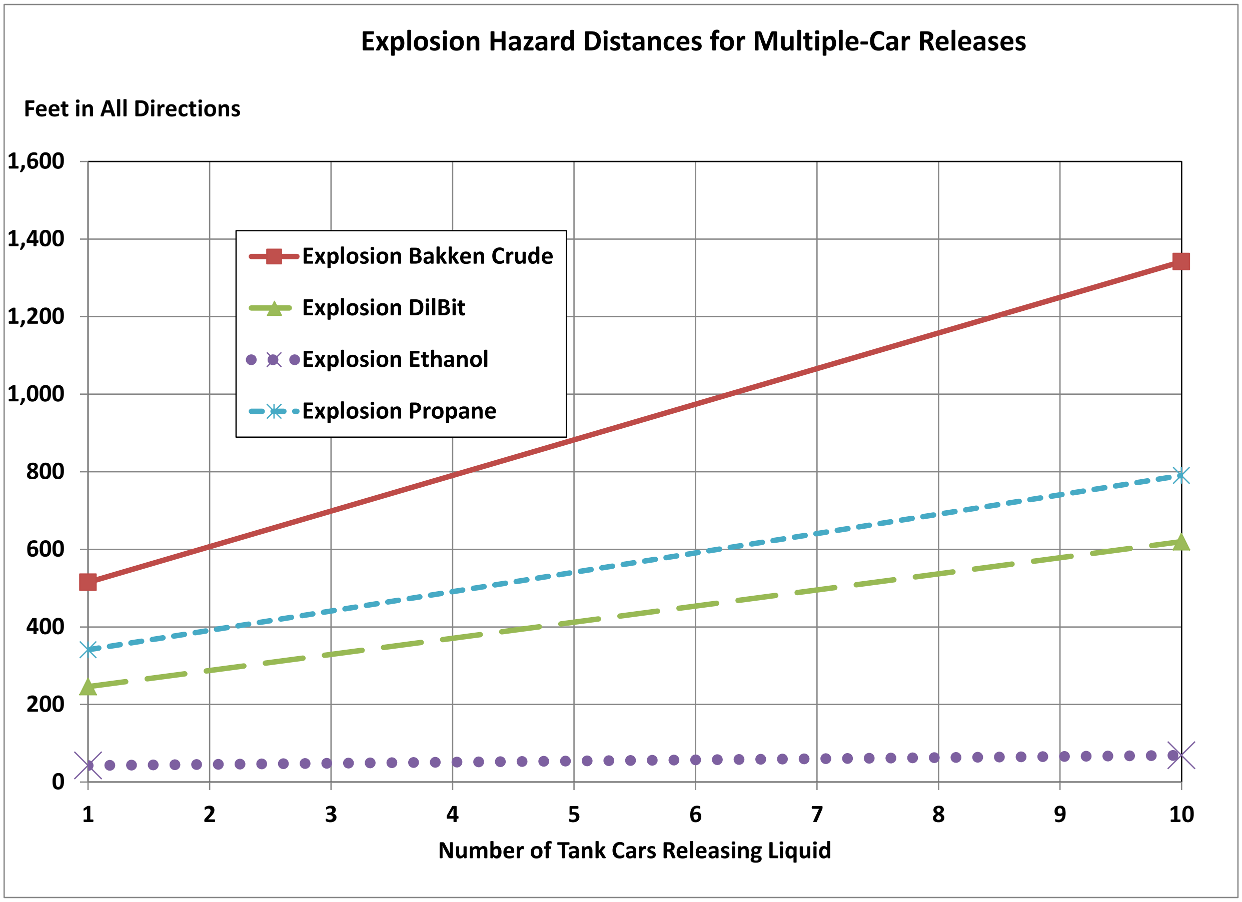

Figure 53: Explosion Hazard Distance for Multiple-Car Releases[179]

The modeled explosion hazard distances for one- and 10-car releases are shown in Table 66. Figure 55 shows these data graphically for anhydrous ammonia. Figure 56 shows the data for sulfuric acid. The graphs may be used to roughly calculate hazard distances for intermediate numbers of cars between one and 10. *Note that these multiple-car scenarios for anhydrous ammonia and sulfuric acid are highly unlikely.*

[178] Analysis conducted by Risknology, Inc. for this report.
[179] Analysis conducted by Risknology, Inc. for this report. Used with permission.

Table 66: Toxic Exposure Hazard Distances (10 Cars) by Type of Substance[180]

Number of Cars	Ammonia	Sulfuric Acid
One Tank Car	11,167 ft (2.1 miles)	23 ft
10 Tank Cars	50,000 ft (9.5 miles)	46 ft
Times Increase	4.5	2.0

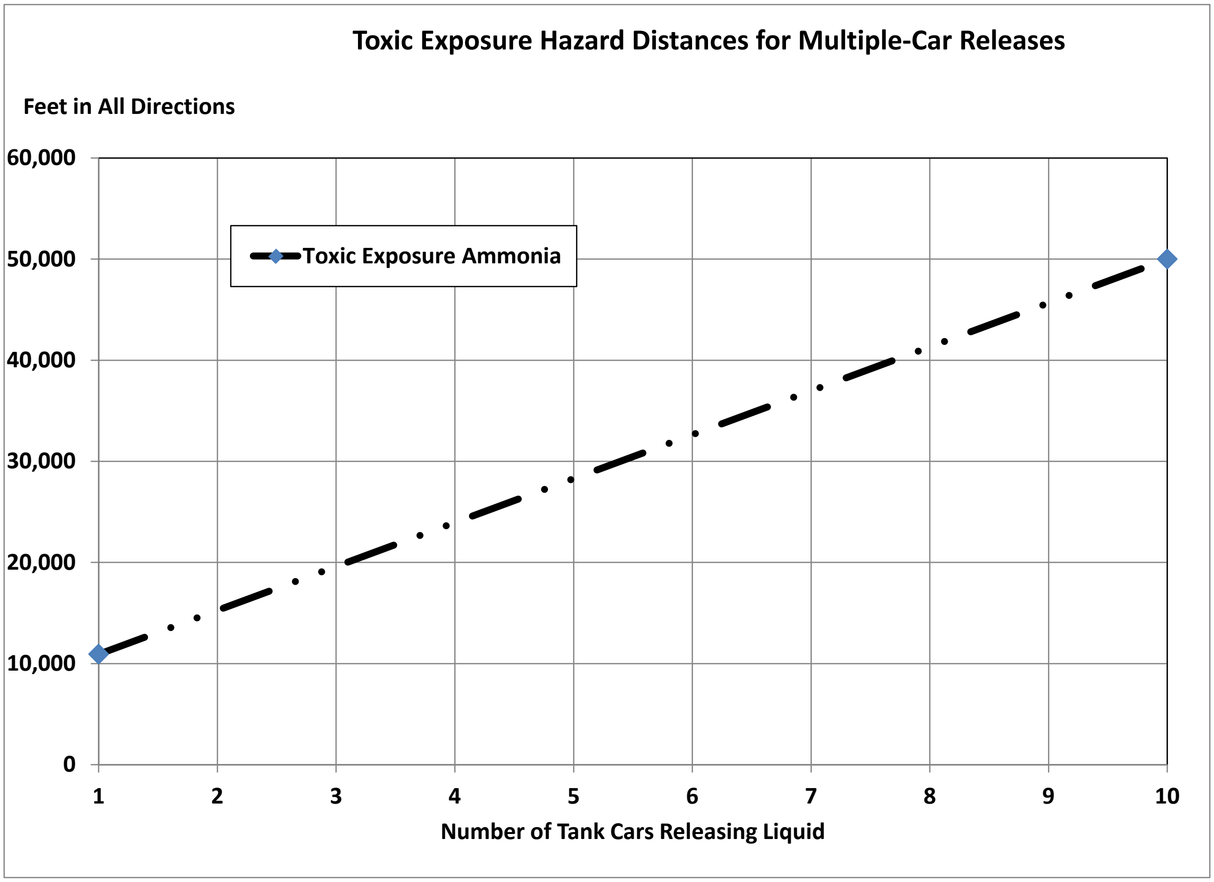

Figure 54: Toxic Exposure Hazard Distances for Multiple-Car Releases of Anhydrous Ammonia[181]

[180] Analysis conducted by Risknology, Inc. for this report.
[181] Analysis conducted by Risknology, Inc. for this report. Used with permission.

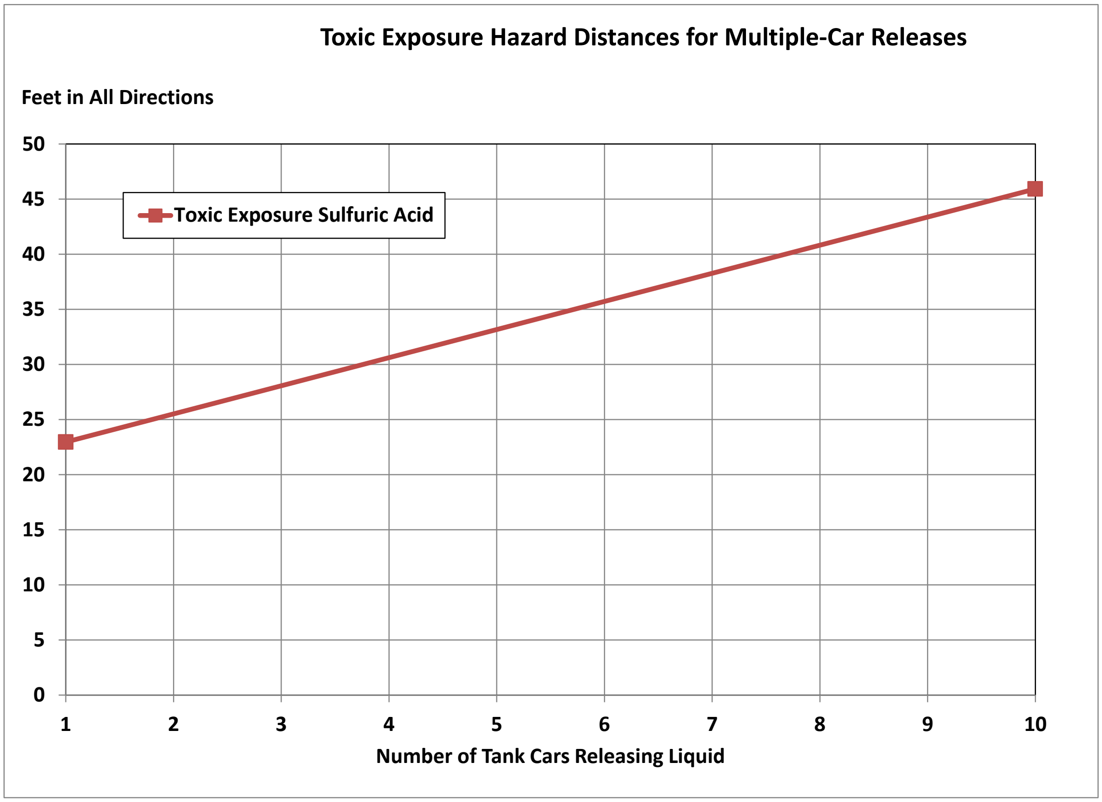

Figure 55: Toxic Exposure Hazard Distances for Multiple-Car Releases of Sulfuric Acid[182]

Summary of modeling results

The rail corridor-specific hazard distances vary by commodity and hazard type. Table 67 summarizes these conclusions for one-car releases, and Table 68 shows the conclusions for 10-car releases. Ammonia travels the furthest, nearly 13,000 feet (approximately 2.5 miles), however over this distance, there can be residential and commercial buildings within which members of the public will naturally take shelter upon detecting the smell of ammonia. Ammonia is also the commodity with the lowest cargo frequency.

For single tank car releases, explosion hazards are dominated by propane, fire hazards are dominated by ethanol and flammable vapor dispersion is dominated by Bakken crude oil, which also has the greatest cargo frequency.

Table 67: Summary of Dominant Hazards and Distances by Commodity (One-Car Release)[183]

Greatest Hazard	Liquid	Hazard Distance for One-Car Release	Carloads per Year
Dispersion	Bakken crude	227 ft	79,000
Fire	Ethanol	350 ft	13,000
Explosion	Propane	569 ft	20,000
Toxic Dispersion	Ammonia	11,167 ft (2.1 miles)	3,000

[182] Analysis conducted by Risknology, Inc. for this report. Used with permission.
[183] Analysis conducted by Risknology, Inc. for this report.

Table 68: Summary of Dominant Hazards and Distances by Commodity (Ten-Car Release)[184]

Greatest Hazard	Liquid	Hazard Distance for Ten-Car Release	Carloads per Year
Dispersion	Propane	932 ft	20,000
Fire	Ethanol	987 ft	13,000
Explosion	Bakken crude	1,342 ft	79,000
Toxic Dispersion	Ammonia	50,000 ft (9.5 miles)	3,000

A summary of the hazard zones for the hazardous liquids most commonly transported by rail in Washington is shown in Table 69. These compile the largest distances to hazard limits from all the regions for each hazardous liquid. The entries marked with a dash (-) indicate that the type of impact is not physical for the commodity (it is not toxic or flammable), or it is minor.

Table 69: Summary Hazard Zones for Hazardous Liquids Shipped by Rail in Washington State[185]

Hazardous Liquid	Lower Flammable Limit	Thermal Radiation at 12.5 kW/m^2	Explosion Overpressure at 2 psi	Immediately Dangerous to Life and Health
Anhydrous Ammonia	28 ft	7 ft	-	11,167 ft (2.1 miles)
Bakken Crude Oil	227 ft	-	441 ft	-
Diluted Bitumen	80 ft	168 ft	173 ft	-
Ethanol	33 ft	350 ft	44 ft	-
Propane	86 ft	26 ft	569 ft	-
Sulfuric Acid	-	-	-	23 ft

Potential areas of future discussion

- The Rail Safety Committee, local emergency responders, and spill cleanup responders may consider familiarizing themselves with the behavior of oil and other hazardous substances when they spill. While the behavior and consequences of oil spills may be more commonly understood and there will likely be more experience in dealing with spilled oil, there are specific safety hazards with more flammable oil, such as Bakken crude.
- The Rail Safety Committee, local emergency responders, and spill cleanup responders may wish to consider ensuring that there is effective training in emergency response for fires, explosions, and vapor cloud releases for Bakken crude and for other hazardous substances transported by rail, such as ethanol, propane, anhydrous ammonia, and sulfuric acid. Emergency response measures for releases of oil and other hazardous materials are explored in Chapter 17.

[184] Analysis conducted by Risknology, Inc. for this report.
[185] Analysis conducted by Risknology, Inc. for this report.

Chapter 8: General Approaches to Rail Accident Risk Reduction

Key questions

- What general types of measures have been or could be taken to reduce the risk of rail accidents and thus improve rail safety by preventing accidents?
- What general types of measures have been or could be taken to reduce the risk of rail accidents and thus improve rail safety by lessening the severity of accident impacts?

Takeaways

- The risk of rail accidents can be mitigated in three primary ways:
    a. Lessening the chance of an accident occurring in the first place.
    b. Reducing the release of hazardous materials from tank cars or reducing the chance that the substances will burn or explode.
    c. Effectively responding to accidents and spills to reduce health and safety effects and reduce environmental damages.
- There are a number of accident prevention measures already in place to reduce derailments and train-to-train collisions. These measures are discussed in greater detail in later chapters of this report.
- There are newer, safer tank car designs that reduce the likelihood of a release of a hazardous material in an accident.
- Preparing for emergency response and spill response operations greatly increases their effectiveness in reducing the health and safety impacts on humans and the environment.
- Highway-rail crossing accidents are a significant problem. Education programs and better warning devices at grade crossings can help to reduce these types of accidents.

The following sections provide a brief overview of the way in which safety measures can mitigate or lessen the risk of rail accidents. Both the safety measures currently in place and those that may be implemented in the future are included. More detailed analyses of some of the important safety measures that have received considerable attention in recent years are addressed in subsequent chapters, including:

- Positive Train Control (PTC) in Chapter 9
- Electronically-Controlled Pneumatic (ECP) Braking Systems in Chapter 10
- Inspection Standards and Practices in Chapter 11
- Rail-Highway Crossing Issues in Chapter 13
- Maintenance and Investment in Infrastructure in Chapter 14
- Tank Car Design in Chapter 15
- Extended Storage of Class 3 Flammable Liquids in Chapter 16
- Rail Emergency Response in Chapter 17.

Because this chapter primarily contains information that is discussed in more detail in other chapters as mentioned, specific references are not provided in some cases. For more specific references, please refer to the chapters mentioned above.

Rail accident risk reduction

Rail accident "risk" encompasses both the probability of accidents occurring and the severity of those accidents. Accordingly, risk reduction can address either or both of those aspects of risk. Mitigation measures can prevent accidents from occurring in the first place, which is usually the most effective approach. If prevention measures fail, other measures may reduce the severity of the accident. For example, the measure may prevent the hazardous material from being released from the tank car or reduce the volume spilled. The risk can also be mitigated by an effective response, such as evacuating people who may be exposed to the hazard or extinguishing the fire. This is considered to be a reduction of the accident consequences.

The three approaches to mitigating rail risk are summarized in Figure 57:

- Mitigating risk by reducing accident probability, which includes such measures as track upgrades, rerouting, speed limits, addressing crew fatigue, crew training, positive train control (PTC), and advanced braking systems (ECP).
- Mitigating risk by reducing the accident severity, which includes measures to reduce the likelihood of a cargo release through tank car design, reducing the amount of the release by limiting speed, and by changing the properties of the hazardous substance by conditioning of Bakken crude oil.
- Mitigating risk by reducing the consequences of the release caused by the accident by effective emergency and spill responses.

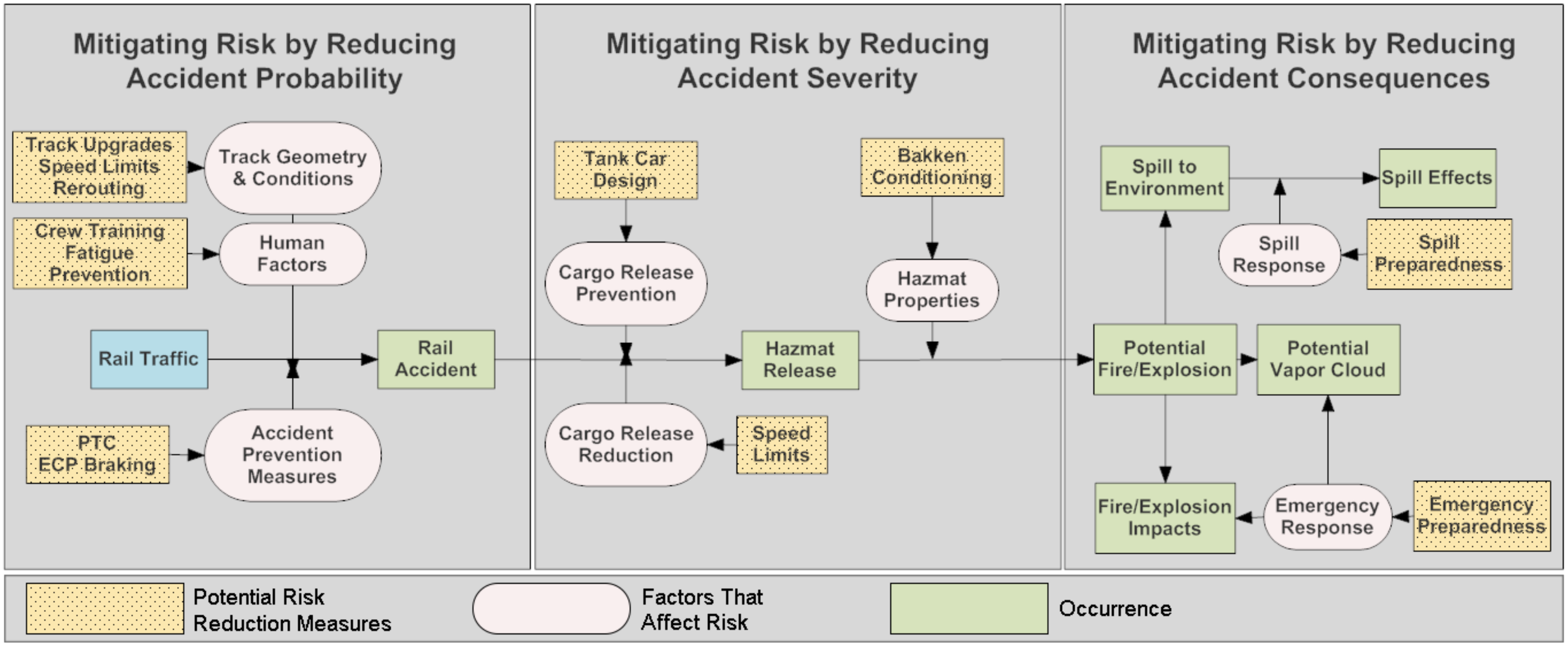

Figure 56: Overview of Approaches to Mitigating Rail Accident Risk[186]

[186] Based on diagram produced by Environmental Research Consulting for this report. Used with permission.

Measures to reduce rail accidents

Derailment and collision prevention

Train derailments can be reduced by improving the condition of the track, which can be accomplished by inspections and continued maintenance. The railroads have made significant progress in improving track conditions, particularly in the late 1970s, by continuing with current ongoing investments in infrastructure improvements.[187]

Inspections on rail equipment (locomotives and cars) are conducted by the use of wayside detection systems installed on rails that can detect anomalies on wheels and other features, as well as dragging of objects. Repairing broken wheels also reduces damage to rails.

Speed reductions in areas of curves, grades, or other features that present train-handling challenges can also reduce derailment accidents.

Positive train control (PTC) is a system that may reduce some types of derailment accidents. PTC is a technology that overlays existing train hardware and software. As mandated by law, PTC is intended to prevent train-to-train collisions, derailments caused by excessive speed, unauthorized incursions by trains onto sections of track where maintenance activities are taking place, and movement of a train through a track switch left in the wrong position. PTC enforces movement authorities, speed restrictions (signal and civil), and protection of roadway workers. PTC is already in place in Washington State.[188]

Other types of accidents may be prevented by effective braking systems, such as the more recently designed electronically-controlled pneumatic (ECP) braking systems. The systems are in place in some areas, but there are significant issues that have interfered with their universal application.[189]

Training programs and measures to address crew fatigue may also be very effective in reducing the accidents caused primarily by human error. There are still many aspects of human error prevention that should still be addressed.[190]

Many of the measures that can reduce accidents are largely out of state and local jurisdiction, being under the authority of the federal government.

Highway-rail accident prevention

Highway-rail accidents are the collisions that occur when vehicles cross railroad tracks in front of oncoming trains at grade crossings. There are a number of prevention measures in place that have had varying success in reducing these types of accidents, which frequently result in human fatalities and serious injuries.

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[187] See Inspection Standards and Practices in Chapter 11 and Maintenance and Investment in Infrastructure in Chapter 14.
[188] See Positive Train Control (PTC) in Chapter 9.
[189] See Electronically-Controlled Pneumatic (ECP) Braking Systems in Chapter 10.
[190] See Crew Training and Qualification Practices in Chapter 12 and Factors that Affect Rail Accident Risk in Chapter 22.

The measures for reducing the incidence of highway-rail accidents include warning devices at grade crossings (e.g., gates, lights, bells) to attempt to get motorists to stop at crossings and not try to "beat the train." Unfortunately, there continue to be significant numbers of motorist who ignore the warning devices or otherwise fail to stop. Education programs and redesigning of particularly problematic grade crossings are vital measures to reduce these tragic accidents.

Preventing highway-rail accidents is an issue that should be of prime concern to the Rail Safety Committee. The Washington Utilities and Transportation Commission (UTC) already has several active programs and projects regarding highway-rail grade crossings.[191]

Measures to reduce rail accident severity

Reducing the severity of rail accidents is largely a matter of preventing the release of hazardous materials from tank cars involved in derailments or collisions, or reducing the amount of outflow from a damaged tank. Another way to reduce the severity of a hazardous material release is to change the properties of the hazardous material itself to make it less hazardous in the event of a spill.

Tank car design

Tank car design is a prevention measure that has received a great deal of public attention in the last several years after several high-profile unit train accidents with fires and explosions after the release of Bakken crude. Older models of tank cars (DOT-111) have been replaced by safer designs, primarily DOT-117 cars. These are now universally used in Washington State and around the U.S.[192]

Speed limits

Speed reduction reduces the kinetic energy involved in any impact accident, whether that is a collision between two trains or the impact of a tank car falling onto its side in a derailment. Speed reductions for trains carrying hazardous materials, such as unit trains of Bakken crude oil or ethanol, are in place.

Bakken crude conditioning

The high volatility of shale oils, such as Bakken crude, contributed to the magnitude of the fires and explosions that occurred in several unit train accidents. There have been several measures taken to "condition" or "pre-treat" Bakken crude oil in the oil fields in North Dakota so that the oil is less volatile. The federal government, North Dakota, and Washington State are currently considering or have regulations that will set standards for the volatility of shale oils when shipping by rail.[193]

[191] See Rail-Highway Crossing Issues in Chapter 13.
[192] See Tank Car Design in Chapter 15.
[193] See Washington Rail-Transported Commodities in Chapter 6.

Measures to reduce rail accident consequences

In the event that the accident has not been prevented and there is a significant release of oil or other hazardous material, the consequences of the release will need to be mitigated by effective emergency response and spill response operations.

Emergency response

Emergency response or "first response" involves protecting the health and safety of people in the vicinity of the rail accident. This includes the public in the area, rail crew, and responders themselves. The release of a hazardous material may cause the dispersion of the substance in the air, fires, explosions, and vapor clouds. Saving lives and reducing health effects and injuries are the primary concern for the emergency response operations.

Pre-planning, training, conducting regular exercises, and placing and maintaining the necessary equipment caches are vital to being able to respond effectively in the event of an actual emergency.[194]

Spill response

In the event of an oil or chemical spill, after human health and safety environment have been protected, responders also need to address the potential for environmental effects from the spill. Oil and chemical spills can cause environmental damage by spreading into waterways and contaminating ground water, as well as oiling wildlife and habitats.

Spill response involves reducing the spread of the substance through containment methods on land and in the water, cleaning up the material that does contaminate shorelines and the ground, and, later, rehabilitating the affected environment. An effective response can help to reduce the environmental damages from a spill.

As with emergency response, pre-planning, training, conducting regular exercises, and placing and maintaining the necessary equipment caches are vital to being able to respond effectively in the event of an actual spill.[195]

Potential areas of future discussion

- The Rail Safety Committee and Washington State officials might want to familiarize themselves with the different approaches to reducing the risk of rail accidents and consider appropriate measures to support the accident prevention measures currently in place, as described in Chapters 9 through 17.
- The Rail Safety Committee and Washington State officials might want to consider measures to reduce highway-rail crossing accidents, as discussed in greater detail in Chapter 13.

[194] See Rail Emergency Response in Chapter 17.
[195] See Rail Emergency Response in Chapter 17.

- The Rail Safety Committee and Washington State officials might want to consider looking closely at ways to reduce rail risk and develop voluntary safety measures that can be supported by the Rail Safety Committee for infrastructure and operations in the state.

Chapter 9: Positive Train Control (PTC)

Key questions

- How does positive train control (PTC) work and how might it reduce accidents?
- What are the limitations of PTC?
- What are the issues that have delayed the implementation of PTC on all rail lines?
- What could be expected if PTC were fully implemented?

Takeaways

- Positive train control (PTC) is a technological system for monitoring and controlling train movements designed to prevent train-to-train collisions, over-speed derailments, entry into established work zones, and the movement of a train through a switch left open in the wrong position. PTC has been legally required on all rail lines that handle passenger trains since late 2008, but there has been a delay in fully implementing PTC. The deadline for extending PTC to all appropriate sections of track was extended to the end of 2018.[196]
- PTC offers the opportunity to minimize the worst of railway accidents that have occurred for numerous years, particularly involving passenger train operations. PTC, however, will not eliminate many accidents from happening, as perhaps much of the general public expects.
- It is unclear in the early implementation of PTC as to what affect it has on rail capacity, an important consideration. PTC may have to be modified to allow trains entering sidings to be allowed to approach the exit signal closer that PTC currently allows to ensure that the train can "fit" into the siding and clear the main line for an approaching train.
- PTC implementation, as mandated, is not completely accomplished but is well along to meeting requirements, particularly for Class 1 railroads and passenger operations. In Washington state, implementation is virtually complete for those operations. It is not clear whether short-line operators are required to or are implementing PTC for their operations, particularly if those operations involve use of Class 1 (BNSF and UP) main lines.
- Training of the various rail crafts that are involved in the administration and operation of PTC is virtually complete for Class 1 railroads and passenger operations, including within the state of Washington. As PTC evolves, continued updated training will occur for all crafts and periodical rules training, as currently is required for all crafts, will include changes and enhancements to PTC operations.
- Rail safety researchers have shown that PTC would likely reduce accidents due to violations or errors on the part of the rail operator by 90 to 99 percent, and 80 percent for accidents of all types.

[196] Note that the extension of the deadline to the end of 2018 also required FRA to approve any railroad's request for an "alternative schedule and sequence" with a final deadline not later than December 31, 2020, if a railroad demonstrated it met certain statutory criteria by December 31, 2018.

- Since 2018, PTC is operable on all BNSF and Union Pacific (UP) tracks in Washington State. The railroads have equipped all locomotives with PTC capability, all track segments have been properly equipped, radio towers have been installed, and nearly all training is complete for rail employees.
- Since 2018, PTC is interoperable on all BNSF and Union Pacific (UP) tracks in Washington state. This allows BNSF, UP, and Amtrak all to use PTC. The only exception is the Sound Transit line from Tacoma to Nisqually (where the Amtrak Cascade train derailed near DuPont).
- The railroads have equipped all locomotives with PTC capability, all track segments have been properly equipped, radio towers have been installed, and nearly all training is complete for rail employees.
- There are some types of accidents that will not be prevented by PTC, such as the type of accident that occurred in Lac-Mégantic, Quebec in which 47 people were killed when a unit train of tank cars filled with Bakken crude oil rolled away when stopped on side tracks near a small community (Etkin et al. 2015).
- It is important to note and understand that PTC will not eliminate all potential rail accidents, particularly as it relates to road/rail crossing incidents. While PTC will likely reduce the number of rail-on-rail incidents, it does have limitations in its current configuration that will not completely eliminate rail incidents.
- PTC can effectively prevent train collisions that are caused by trains over-running limits or signals. PTC can also slow and stop trains that are approaching misaligned tracks or switches that are not operating properly. Trains that are speeding as they approach curves or other speed-restricted areas will be notified, and PTC will attempt to stop them. It is important to remember that even with PTC, it takes a considerable distance to stop a moving train.
- PTC does not intervene when a train is moving at speeds under 20 mph or if a track defect or obstruction does not activate the ABS or CTC signal system. It will not stop a train that is moving toward a vehicle on a crossing or another train that is derailed on the same or adjacent track.
- Railroads will continue to work on technical issues that may come up for very specific types of circumstances that PTC may not be able to control.
- Comments from locomotive engineers indicate a mixed opinion about the impact that PTC has on rail operations, including those engineers who look at PTC as an additional tool that facilitates safe train operations.

The following sections provide a more in-depth look at Positive Train Control (PTC), including its role in accident prevention, its limitations, and issues related to implementation.

Timeline of PTC

The concept of Positive Train Control (PTC) is not new to U.S. railroad systems. In fact, earlier versions of PTC were considered and sometimes implemented as far back as the 1920s. In 1969, the NTSB had conducted the first train accident review that PTC could have prevented. This accident involved a head-on collision between two Penn Central trains near Darien, Connecticut. There were 4 fatalities and over 40 injuries.

PTC in its current form has been a topic of concern in the U.S. since the 1990s. In 1990, the NTSB included PTC on its "Most Wanted List of Transportation Safety Improvements." In the late 1990s, the Railroad Safety Advisory Committee (RSAC) to the FRA was formed (Railroad Safety Advisory Committee 1999). After a September 2008 accident in which a Metrolink train and a Union Pacific freight train collided in the Chatsworth District of Los Angeles, California, killing 25, PTC was mandated by the U.S. Congress on any line segment that handles passenger operations. President George W. Bush signed the Rail Safety Improvement Act of 2008 into law in October 2008. In October 2015, President Obama signed a bill extending the PTC deadline by three years to the end of 2018.

Description of Positive Train Control (PTC)

PTC is defined in federal law as a system designed to prevent train-to-train collisions, over-speed derailments, incursions into established work zone limits, and the movement of a train through a switch left open in the wrong position (49 CFR § 236.1005).

PTC is not an additional type of current signal system. It is a technical overlay to a rail route that can be applied along any route, whether it is signaled or non-signaled. To fully understand what PTC does, one must first understand how trains are authorized to move in both non-signaled (dark) territory and in signaled territory and how errors in those processes can lead to collisions or derailments. Each type of territory requires different methods of operation and are explained in more detail below.

There are no specific technical requirements, and federal law allows railroads to adopt PTC systems suited to their needs (Peters and Fritteli 2012). All PTC systems include the use of radio communications to provide in-cab signals to the train engineer and the ability for a dispatcher to stop the train in an emergency (FRA 2009).

The components of a PTC system are:

- "An *onboard or locomotive system* that monitors a train's position and speed and activates brakes as necessary to enforce speed restrictions and prevent unauthorized train movements;
- A *wayside system* monitors railroad track signals, switches, and track circuits to communicate data on this local infrastructure needed to permit the onboard system to authorize movement of a locomotive; and
- A *back-office server* stores all information related to the rail network and trains operating across it (e.g., speed restrictions, movement authorities, train compositions, etc.) and transmits this information to individual locomotive onboard enforcement systems" (AAR 2019).

PTC is a system that uses Global Positioning System (GPS) satellite data, wayside signal and track circuit data, and locomotive performance and movement data. PTC incorporates technologies that are designed to stop a train automatically before certain accidents caused by human error can occur.

PTC cannot prevent vehicle-train accidents at railroad crossing, or those accidents that are due to track and equipment failures. PTC cannot stop trains when people are walking on tracks.

Authorization of train movements

In non-signaled territory, the movement of a train is authorized verbally by a dispatcher. This is commonly referred to as dark Track Warrant Control territory (TWC). The warrant identifies the territory the train can move over, normally between the starting point and destination location (for example a meet/pass siding), at which point the receiving train must receive further movement authorization for additional movement.

The dispatcher verbally issues a track warrant to the crew on the train, which copies the instructions on a company form. Once the dispatcher is finished, the crew must exactly repeat the instructions back to the dispatcher, with the name of the copying crew member. When the crew has correctly repeated the warrant back, the dispatcher "okays" the warrant which gives the train the authority to proceed based on the instructions contained within the warrant.

The dispatcher also enters the warrant's instructions into a computer system that is designed to keep the dispatcher from issuing a warrant to one train that conflicts with another train's warrant. The computer record of warrants protects the dispatcher from inadvertently issuing instructions that might allow trains to collide.

The train crew receiving the warrant must adhere exactly to the instructions. This includes the limits of the track section they have been given the authority to move over, instructions about entering into a siding, or not proceeding until a specified train or trains have passed. There are multiple boxes on the premade form that may be referenced when giving a track warrant to cover most if not all scenarios for train movement. The repetition of the warrant back to the dispatcher is the only protection a train crew has regarding a track warrant being correct.

Routes with signals generally fall under one of two types of signaled tracks: Automatic Block System (ABS) and Centralized Traffic Control (CTC). ABS signaled territory operates similar to TWC territory.

In ABS territory, the dispatcher verbally authorizes the movement of the train to the crew via a track warrant, and then after the crew repeats it, the dispatcher "okays" it and the train can proceed. The signals in ABS territory only protect a train on the track from another train or the integrity of the rail. This means that an ABS signal system provides information to a train about the condition of the track for the next two signal blocks in front of the train, while protecting the following two signal blocks behind the train.

For a train operating in ABS territory, if there is a train ahead moving in the same direction, once the following train gets within two signal blocks of that train, the signals will show a restricting indication. In general, the first restricting signal the train will come upon is a yellow signal. Following that, there will be a red signal. In some territories, the protection is extended an additional signal block, with a flashing yellow signal preceding the yellow signal.

If the first train is moving in the opposite direction of the second train, once the trains are within two signal blocks (three if flashing yellow signals are part of the system), the signals again will show a restricting indication. However, in that situation, a track warrant should exist that directs one of those trains to enter a siding that is between the trains. No track warrant should ever authorize two trains to operate in opposite directions on a single track where no alternate route for one of the trains is available.

ABS signals will also show a restricting indication if a switch is opened for a diverging route, or if the rail is broken and no longer completes the signal circuit. At no time in ABS territory does the signal authorize a movement; it can only warn of another train that is near or that there is an inconsistency with the track. The track warrant authorizes all movements and must be relied upon to determine how trains proceed.

In CTC territory, the signals convey the authority to move. The dispatcher requests the signals to be set in a certain way to allow a train to advance. If the CTC signal system determines there is no conflict with that request, the signal is displayed based on the dispatcher's request. At that time, the crew of the train must use the signal indication to proceed on the mainline, coming out of a siding or crossing over between two tracks. A crew operating in CTC territory does not need verbal permission to authorize movement if it has a signal that indicates its ability to proceed.

There are multiple potentials for errors in dark TWC or ABS territory. While the computer checks make sure a track warrant being issued does not conflict with another warrant, if the dispatcher hears the train crew repeat the warrant incorrectly but fails to catch the error, a train may be operated into track where it is not authorized. If the crew of the train fails to follow the warrant's instructions, either through misunderstanding of the instructions or inadvertently proceeding incorrectly, there is a high probability that an accident will occur.

CTC territory removes some of the potential errors in the process of authorizing train movements. As mentioned, the dispatcher requests a signal to authorize a train's movement, and if the signal system determines there is no conflict with the request, the system allows the signal indication. If the system does perceive a conflict, it will not issue the signal and the train will not receive an authorizing signal to proceed.

Even with the protection of the logic of the CTC signal system, there is still a possibility for error. For example, the train crew may misinterpret the signal or fail to adhere to the indication. In these cases, the train will still be in jeopardy of colliding with another train.

When a train is authorized to proceed on a route (whether verbally via TWC or via CTC signal indication), the engineer logs into the PTC system. This accesses the train and track information for the route. Train information includes the authorized speed of the train, locomotive information, the train length and the train's weight.

Route information includes the track profiles for the route. These consist of the locations of signals, turnouts, diamonds, curves and any speed restrictions associated with any track feature. Track maintenance slow orders or limits for locations where track work is being performed is also loaded into the track information, so the PTC system is working with real time information.

PTC provides the locomotive engineer with advance warning of movement authority limits, speed limits and track conditions ahead. If any of these parameters are exceeded or ignored, PTC will notify the train that it has to slow, allowing the engineer of the train to act on the information.

If there is no response to the notification, PTC will begin to slow and stop the train in a controlled manner without the engineer's assistance.

From this description, it is clear that PTC does not authorize train movements. In its current form, it is another layer of protection should the engineer or crew of a train fail to obey the signals or authorization of a dispatcher. For example, in dark or ABS TWC territory, if the dispatcher authorizes the train to point B, but the train does not slow as it approaches B, PTC will intervene by first warning the train. If no action is taken, PTC will stop the train. Similarly, if a train in CTC territory approaches an absolute stop signal without slowing, PTC will intervene and first warn, then stop the train. In either of those cases, if there is an opposing train that is threatened by the non-conforming train, that train is also notified by PTC.

Some additional examples of what PTC can do are: If a train approaches a section of track (such as a curve) at a much higher rate of speed than the track's authorized speed, PTC will notify the engineer, then slow the train if no corrective action is taken. If a train is approaching a switch that is incorrectly lined for an authorized movement, it will also notify, slow or stop the train. Finally, if a train approaches a work limit where track work is being performed, and the train does not acknowledge the reduced speed, PTC will intervene.

PTC is being implemented on all tracks that handle regular passenger movements and tracks that handle toxic-by-inhalation materials. The BNSF website referenced previously indicates that all major corridors in Washington State that are under the PTC mandate have been completed and are currently operating with the PTC safety overlay. UP trains running on BNSF tracks are also controlled by the PTC system. Both Union Pacific and Amtrak have completed their PTC implementation in Washington.

Effectiveness of PTC in accident prevention

The actual effectiveness of PTC in reducing accidents is difficult to estimate. There are many accident cases, for which the NTSB concluded, that PTC would have likely prevented the accident, or that the lack of PTC likely contributed to increasing the likelihood or severity of the accident. Some examples of recent accidents in passenger and freight trains that may have been prevented by PTC are listed in Table 70. The accidents include collisions (two trains hitting each other while in motion), allisions (a moving train hitting a stationary object or stationary train), and derailments. Details of some of these accidents are discussed in Chapter 21. Note that the 2008 Chatsworth, California accident is generally considered the impetus for the push for PTC implementation.

Table 70: Features of Example Train Accidents that May Have Been Prevented by PTC[197]

Location	Date	Train Type(s)	Accident Type	Casualties
Chatsworth, CA	September 2008	Passenger-Freight	Collision	25 fatalities, 135 injuries
Two Harbors, MN	September 2010	Freight-Freight	Collision	5 injuries
Mineral Springs, NC	May 2011	Freight-Freight	Collision	2 fatalities, 2 injuries
Red Oak, IA	April 2011	Freight-Maintenance	Collision	2 fatalities
Hoboken, NJ	May 2011	Passenger	Allision[198]	None
Westville, IN	January 2012	Freight-Freight-Freight	Collision	2 injuries
Goodwell, OK	June 2012	Freight-Freight	Collision	3 injuries
Barton County, MO	July 2012	Freight-Freight	Collision	2 injuries
Chaffee, MO	May 2013	Freight-Freight	Collision	2 injuries
Bronx, NY	December 2013	Passenger	Derailment	4 fatalities, 61 injuries
Keithville, LA	December 2013	Freight-Freight	Collision	4 injuries
Philadelphia, PA	May 2015	Passenger	Derailment	8 fatalities, 185 injuries
Hoboken, NJ	September 2016	Passenger	Allision	1 fatality, 114 injuries
DuPont, WA	December 2017	Passenger	Derailment	3 fatalities, 70 injuries
Cayce, SC	February 2018	Passenger-Freight	Collision	2 fatalities, 116 injuries

In a study 20 years ago, the FRA RSAC concluded that effective PTC systems could prevent certain types of collisions and derailments: an estimated 40 to 60 mainline freight accidents per year (Railroad Safety Advisory Committee 1999). With an estimated annual accident number of about 1,450, this would amount to at most a 4 percent reduction.

Another more recent study conducted for the Association of American Railroads (AAR), the main purpose of which was to evaluate the effects of single-person crews, also assessed the benefits of PTC, as summarized in Table 71 (ICF Incorporated 2015). Note that two-person crews are traditional in the U.S.. The results indicate that for a two-person crew, the reduction in accidents was estimated to be 80.3 percent. Their analysis did not include comparing the effect of one- or two-person crews in the absence of PTC. In other words, the researchers compared the absence and presence of PTC in two-person crews, but did not evaluate the effect of having a second crew member over having just one crew member on board the train.

[197] Based on NTSB data.
[198] An "Allision" is when a moving object, in this case a train, hits a stationary object.

Table 71: Annual Accident Frequency Analysis with and without PTC Based on Different Train Accident Scenarios[199]

Train Accident Scenario	Expected Annual Accidents with Two-Person Crew without PTC	Expected Annual Accidents with Two-Person Crew with PTC	Reduction in Accidents with PTC
Accidents due to Violations	11	0.1	99.1%
Accidents due to Selected Route Integrity Failures	13	2.4	81.5%
Accidents due to Rollaways	3	3.0	0.0%
Grade Crossing Accidents/Failure to Sound Horn	2	0.2	90.0%
Accident Totals	**29**	**5.7**	**80.3%**

Other studies provide less optimistic results. According to a 2012 review study, PTC is expected to prevent less than 2 percent of the railroad collisions and derailments that occur annually (Peters and Fritteli 2012). The majority of those accidents are like to be rail yard incidents, which are generally less severe.

There are divergent views on the capacity impact that PTC will make. PTC is designed to remotely monitor train movements and cause a train to be stopped if it appears to be dangerously close to overtaking or colliding with another train. There have been projections that PTC will allow trains, in conjunction with existing signal systems, to be able to operate at faster speeds at closer distances apart than existing signal systems alone will allow. AAR claims that it is possible that PTC may make existing rail operations *less* efficient, especially if put into place without adequate testing (AAR 2015c).

The FRA estimates that there would be $90 million in annual safety benefits nationwide with the full implementation of PTC (Roskind 2009). These safety benefits were calculated by estimating accident costs related to fatalities and injuries, equipment damage, track and off-track damages, hazardous material cleanup, evacuations, wreck cleanup, freight loss, and freight delay. In another FRA study, in one ten-year period (between 1987 and 1997), an annual average of seven fatalities, 22 injuries, $20 million in property damages, and evacuations of 150 people due to potential hazardous material release could have been prevented by PTC (Railroad Safety Advisory Committee 1999). Note that these accidents would not have included any CBR accidents because of the time period involved. Since CBR makes up only a portion of all freight rail transport in the US (an estimated 3 percent), it cannot be assumed that these types of reductions could all be attributed to CBR accidents.

Limitations of PTC implementation

As described previously, train collisions that are caused by over running authorized limits or running past restrictive block signals will be prevented. Trains approaching misaligned switches or tracks that have abnormalities that impact the signal system will be slowed and stopped. Trains that are over speeding approaching curves or other speed restricted areas will be notified

[199] ICF Incorporated 2015.

and PTC will attempt to stop them; a notable exception is described below. And finally, trains approaching work limits that require speed reductions that are over speeding will be prevented from entering those limits at a speed exceeding the speed authorized by the maintenance employees.

Types of accidents not addressed by PTC

PTC will not address grade-crossing issues such as vehicles running around gates or trespassers walking along the right of way.

PTC also does not intervene when a train is running at restricted speed or less. Restricted speed is defined as a speed where the train can stop within one-half the distance of vision, not to exceed 20 mph. While the PTC system does know the speed of the train, it does not interpret what the vision distance is in any situation. Therefore, it will not intervene if the train is moving under 20 mph even if there is a blockage for which the train should be stopped.

PTC will not prevent derailments caused by track or train defects. For example, PTC will not prevent a train from derailing on a thermal misalignment (if the signal system is not affected), nor will it prevent a derailment caused by dragging equipment. If a train on an adjacent track derails, PTC will not prevent a collision with that train, unless the non-derailed train's signal system is affected far enough in advance to provide a restrictive signal to the approaching train.

If the line PTC is installed on has a signal system, but the obstruction does not affect it, PTC will not prevent a train from operating and then hitting that obstruction.

Finally, PTC will not be able to overcome some train handling errors, such as when an engineer uses too much braking air and then does not have enough for further braking in a heavy grade situation. PTC will identify that the train is accelerating beyond safe track speeds. The system will then warn the engineer, and finally, when it gets no response in train speed, will attempt to stop the train using the train's air brakes. However, since the train has already used up the available air for braking, the instructions PTC will relay to the train will do nothing to slow the train and it will likely derail.

PTC in dark territory

"Dark territory" is a term used to describe sections of running track not controlled by wayside detectors and signals. Train movements in dark territory were previously handled by timetable and train order operation, but since the widespread adoption of two-way radio communication, these have been replaced by track warrants and direct traffic control, with train dispatchers managing train movements directly. Today most dark territory consists of lightly used secondary branch lines and industrial tracks with speeds ranging between 10 mph and 40 mph, however, there do exist a small minority of main lines that fall into the category.

The primary safety concerns with dark territory are due to the lack of any form of direct or indirect train detection along the route. Dark territory also lacks the ability to control or lock switches onto the main track, or detect misaligned switches, broken rails, or runaway rail cars.

PTC is being installed in some dark territory areas and is capable of functioning without linkage to automatic block signal systems. PTC will be used in dark territory to perform exactly the same functions it performs in signal territory. However, even in dark territory, PTC is an overlay to the manual block, or track warrant, or timetable-train order operating systems that authorized train movement. PTC will enforce the limitations to that authority based on the fixed "data points," the physical markers of a railroad: stations, mileposts, crossings, etc. (Shanoes 2016). If PTC is installed in dark territory, it will not detect broken rails, flooded tracks, or debris fouling the line.

Implementation of PTC

In the Rail Safety Improvement Act of 2008, the U.S. federal government had originally mandated PTC for all passenger railroads and Class I freight railroads on mainlines by the end of 2015, but in October 2015, the statutory deadline was extended to the end of 2018. There are also provisions for case-by-case extensions possible up to the end of 2020 to allow time for railroads to adequately test their systems (AAR 2015c). This extension was based on the findings of an August 2015 report from FRA on delays in the implementation of PTC (FRA 2015). There were to be further extensions available up to the end of 2020 to allow time for railroads to adequately test their systems. This testing included revenue service demonstration (RSD) testing, an advanced form of testing that occurs while trains operate in regular service (GAO 2018a).

In the summer of 2018, FRA clarified the criteria that passenger and commuter railroads must meet to qualify for the two-year extension beyond the end of December 2018. FRA stated that initial field-testing could potentially qualify as substitute criteria for RSD, but that each railroad would be evaluated on a case-by-case basis.

Current PTC status on freight railroads

The AAR reported the status of PTC for Class I freight railroads as of the end of December 2018 as shown in Table 72.

Table 72: Readiness and Completion of U.S. Class I Freight Railroad PTC Installation by Part of System (As of the End of December 2018)[200]

Part of System	Readiness Measure	Number Ready	Number Required for PTC Operation	% Complete
Locomotives	Equipped and PTC-operable	17,160	16,375	105%
Employees	Trained	100,932	92,929	109%
Radio Towers	Installed	14,912	14,912	100%
Route-Miles or Track-Miles	Installed	44,695	53,732	83%

[200] AAR 2019.

According to FRA,[201] as of the end of September 2018, both BNSF Railway and Union Pacific Railway (UP), the two Class I freight railroads operating in Washington, were PTC-operational with respect to:

- Locomotives being equipped and PTC-operable.
- Track segments completed.
- Radio towers installed.
- Training completed (except for 2 percent of UP employees).

Current PTC status on passenger railroads

A study conducted by the U.S. GAO and released in early October 2018 found that as of the end of June 2018, passenger railroads (28 commuter railroads and Amtrak) remained in the early stages of PTC implementation, including equipment installation and early field testing. Amtrak reported that it had initiated both field testing and RSD testing, an advanced form of field testing required for PTC implementation (GAO 2018b).

Amtrak reported that as of 1 January 2019, PTC was operational on all Amtrak-controlled or operated track except for approximately four miles of slow-speed track in the complex Chicago and Philadelphia terminal areas. As of 28 January 2019, more than 15,297 miles of host-controlled track is reported to be operating with PTC. Amtrak uses tracks owned by others for most of its route network. Amtrak implemented operational risk reduction measures across the remaining 5,000 host railroad track miles that do not have PTC operating. Some examples of alternative risk reduction measures include:

- Posting of signage to remind the locomotive engineer on approach to a critical speed restriction.
- Requiring the locomotive engineer to communicate signals observed to the conductor.
- Establishing speed restrictions at areas known to be at risk of track obstructions.
- Posting targets indicating switch position.
- Relying on the existing wayside signal system.
- Relying on the existing cab signal system with Automatic Train Control and Automatic Train Stop.[202]

In Washington State, as of late 2018, PTC is operational on all Amtrak Cascades trains, as well as on Sound Transit. Sound Transit (Sounder Commuter Rail) had begun using PTC in 2017, but there had been some technical issues so that engineers were able to use the system only on 56 percent of trips at that time. According to FRA, as of the end of September 2018, Sounder Commuter Rail had 80 percent of its locomotives (33 out of 41) PTC-operable, all of its 11 towers installed, and all four of its employees trained.[203]

[201] FRA, https://www.fra.dot.gov/app/ptc/.
[202] Amtrak, https://media.amtrak.com/positive-train-control/
[203] FRA, https://www.fra.dot.gov/app/ptc/

Issues that have delayed PTC implementation

To date, there are no definitive published reports documenting the issues that have delayed PTC implementation.

Issues for future PTC implementation

Testing and validation

In January 2019, the AAR reported that for Class I railroads, PTC components (locomotives, trained employees, and radio towers) were 100 percent complete, although there were over 9,000 track-miles that still required installation (17 percent of total trackage). The association emphasized that testing and validation of the PTC systems will be essential for success. Their conclusions were (AAR 2019):

- From the outset, the railroad industry's PTC efforts have been focused on development and testing of technology that could meet the requirements of the RSIA and that could be scaled to the requirements of a nationwide system. Essential software and hardware for many PTC components first had to be developed from scratch, and then deployed and rigorously tested under real world conditions.
- Ensuring that PTC systems are fully and seamlessly interoperable across all of the nation's major railroads is a difficult task for the railroad industry. It is not unusual for one railroad's locomotives to operate on another railroad's tracks. When that happens, it is essential for the "tenant" locomotives to be able to communicate with, and respond to conditions on, the "host" PTC system. Ensuring this interoperability has been a significant challenge to the industry.
- It is critical that the huge number of potential failure points in PTC systems be identified, isolated, and corrected. By necessity, a mature, well-functioning PTC system is enormously complex, and it is not realistic to think it will perform flawlessly on a daily basis, especially upon initial implementation. That is precisely why testing, first in a simulated environment and then under real-world operating conditions, is so important. Railroads' first priority must be to implement PTC correctly, and to test and validate it thoroughly (p. 3).

Safety issues and potential PTC "failures"

Potential safety issues in the first five years after implementation may include a need to refine PTC to better protect in situations of backing up, locations and time periods for maintenance-of-way (MoW) trains and operations, and restricted speed issues. As problems are identified, PTC programming will need to be updated to address them.

It is likely that many of the safety problems with PTC will not be identified until there is an accident that occurs under circumstances that had not been anticipated. For example, an accident occurred in Arizona in which one MoW worker was killed and another seriously injured in an area under PTC "protection" (Figure 58).

Figure 57: Train Collision with Maintenance-of-Way Equipment, Kingman, Arizona 2018[204]

The PTC operated as programmed, but it still allowed the train to hit the MoW equipment and workers (NTSB 2018c). The combination of lack of sight distance for the engineer to see around the upcoming curve and the fact that the train was operating at 20 mph, which made it not discernible by PTC, allowed the accident to occur. The investigation into this accident is ongoing by NTSB. Some observers have pointed to this accident as evidence that there is a “gap” in PTC logic. PTC is not able to “judge” sight distance and determine if a proceed order has been issued when a train is moving at under 20 mph in a restrictive location. It would be highly impractical for PTC to be designed such that it would intervene and stop a train every time a train is moving under 20 mph towards a restrictive signal or location. This would make it impossible for trains to get into sidings and track yards without stopping and disabling the PTC.

According to AAR, there are many complexities and challenges in making PTC as effective as possible in improving rail safety. There are over 400,000 PTC components that have to be interoperable across various railroads. Interoperability relies on a huge, shared database with information the different railroads need to update and access regularly. This includes information like the precise locations of thousands of railroad switches and wayside signals. A typical 100-mile district could have more than 2,000 track features. This has been an enormous challenge, because rail operators need to keep this information updated even as switch and signal location

[204] Source: NTSB 2018c.

changes are constantly changing. For example, one railroad could have as many as 60 location changes every week, which must be visually checked by engineers each time there is a change before they can be entered into the database.[205]

One of the most significant PTC safety problems that the rail industry has identified is a "false clear." A false clear occurs when a software defect in the locomotive segment of PTC permits an unsafe operation by allowing a locomotive to pass a stop signal. The wayside signal is telling the train to stop, but the train's onboard system is indicating that things are clear.

Field testing has also discovered instances in which trains have been required to stop because the wayside signal equipment failed due to improper configuration or software defects (AAR undated).

Training issues

Potential training issues in the first five years after implementation are not likely to be significant. PTC will, and already has become to some extent, another "chapter" in the Rules book required for study and testing as part of railroad employee agreements. Virtually every class of railroad employee will require some training on PTC, because everyone's job will touch on it to some degree.

FRA training requirements are established under 49 CFR § 236.1041 through 236.1049. Training is required for the following railroad personnel (49 CFR § 236.1041):

1) Persons whose duties include installing, maintaining, repairing, modifying, inspecting, and testing safety-critical elements of the railroad's PTC systems, including central office, wayside, or onboard subsystems;
2) Persons who dispatch train operations (issue or communicate any mandatory directive that is executed or enforced, or is intended to be executed or enforced, by a train control system subject to this subpart);
3) Persons who operate trains or serve as a train or engine crew member subject to instruction and testing under part 217 of this chapter on a train operating in territory where a train control system subject to this subpart is in use;
4) Roadway workers whose duties require them to know and understand how a train control system affects their safety and how to avoid interfering with its proper functioning; and
5) The direct supervisors of persons listed in paragraphs (a)(1) through (a)(4) of this section.

Office control personnel need to be trained in the following areas (49 CFR § 236.1045):

1) Instructions concerning the interface between the computer-aided dispatching system and the train control system, with respect to the safe movement of trains and other on-track equipment;
2) Railroad operating rules applicable to the train control system, including provision for movement and protection of roadway workers, unequipped trains,

[205] Association of American Railroads, https://www.aar.org/article/complexities-challenges-ptc/.

trains with failed or cut-out train control onboard systems, and other on-track equipment; and

3) Instructions concerning control of trains and other on-track equipment in case the train control system fails, including periodic practical exercises or simulations, and operational testing under part 217 of this chapter to ensure the continued capability of the personnel to provide for safe operations under the alternative method of operation.

Locomotive engineers and other operating personnel need to address the following in their training (49 CFR § 236.1047):

1) Familiarization with train control equipment onboard the locomotive and the functioning of that equipment as part of the system and in relation to other onboard systems under that person's control;
2) Any actions required of the onboard personnel to enable, or enter data to, the system, such as consist data, and the role of that function in the safe operation of the train;
3) Sequencing of interventions by the system, including pre-enforcement notification, enforcement notification, penalty application initiation and post-penalty application procedures;
4) Railroad operating rules and testing (part 217) applicable to the train control system, including provisions for movement and protection of any unequipped trains, or trains with failed or cut-out train control onboard systems and other on-track equipment;
5) Means to detect deviations from proper functioning of onboard train control equipment and instructions regarding the actions to be taken with respect to control of the train and notification of designated railroad personnel; and
6) Information needed to prevent unintentional interference with the proper functioning of onboard train control equipment.

Training subject areas for roadway workers who provide protection for themselves or roadway work groups (49 CFR § 236.1049):

1) Instruction for roadway workers shall ensure an understanding of the role of processor-based signal and train control equipment in establishing protection for roadway workers and their equipment;
2) Instruction for all roadway workers working in territories where PTC is required under this subpart shall ensure recognition of processor-based signal and train control equipment on the wayside and an understanding of how to avoid interference with its proper functioning; and
3) Instructions concerning the recognition of system failures and the provision of alternative methods of on-track safety in case the train control system fails, including periodic practical exercises or simulations and operational testing under part 217 of this chapter to ensure the continued capability of roadway workers to be free from the danger of being struck by a moving train or other on-track equipment.

FRA reports that as of the end of 2018, all current employees of both Class I railroads operating in Washington State (BNSF and UP) have completed PTC training, as have Amtrak and Sounder

Computer Rail employees.[206] New employees or those requiring "refresher" training have a number of options, including courses that involve the use of simulators. There are a number of private companies that have developed simulator training programs.[207]

Technical issues

There may be a potential for technical issues in the first five years after implementation. These may include some of the safety issues identified above. In addition, there may be other problems that occur with implementation.

As the development of artificial intelligence (AI) accelerates, PTC will likely be improved based on that advancement. Theoretically, PTC could be used to run the train from a remote location, and a one-person crew would be a conductor rather than an engineer. The person on the train would be responsible for correcting any en route issues, while telecommunications between a remote location and the train would provide information required to address any issue.

Potential areas of future discussion

- Implementation and training are keys to successful PTC operations. In Washington State those components are virtually complete for BNSF and UP freight operations and passenger operations. The Rail Safety Committee may consider working with the railroad industry to support PTC operations.

[206] FRA, https://www.fra.dot.gov/app/ptc/
[207] The issue of training is discussed in Chapter 12.

Chapter 10: Electronically-Controlled Pneumatic (ECP) Braking Systems

Key questions

- What are the different kinds of braking systems on trains?
- What are electronically-controlled pneumatic (ECP) brakes?
- What are the benefits of ECP braking systems?
- What are the potential barriers to universal installation of ECP braking systems?
- How effective are ECP brakes in preventing accidents?

Takeaways

- There are several types of braking used on trains, including:
    a. Conventional air braking, in which the engineer applies the brakes in the head locomotive and the brake signal passes successively through the rail cars.
    b. Distributed power, in which there are several locomotives distributed in the train (head, middle, and end) that can apply air brakes in different parts of the train.
    c. Electronically-controlled pneumatic (ECP) brakes, in which the engineer in the head locomotive applies the brakes causing a signal to travel rapidly to the cars to begin braking simultaneously.
- The NTSB evaluated various studies and concluded that braking distance may be reduced "somewhat" in certain kinds of circumstances with ECP brakes, depending on speed and other factors. For example, ECP brakes would reduce the number of cars in a pileup after a derailment of a unit train of tank cars by fewer than two cars. ECP brakes will only prevent certain types of train accidents.
- The railroad industry has concerns about the reliability and benefits of ECP braking systems. The industry bases their conclusions on the experiences of railroad employees that have used ECP brakes and the fact that braking problems do not account for the majority of rail accidents.
- Industry and government studies have provided different conclusions not only on the effectiveness of ECP braking, but also on the costs involved. The estimated cost of equipping locomotives and tank cars with ECP brakes, as well as training railroad employees in the use of ECP brakes may cost $500 million to $3 billion over the next 20 years. Industry analysts are concerned that there would only be a very small benefit for this cost.
- In September 2018, The Pipeline and Hazardous Materials Safety Administration (PHMSA) formally rescinded the mandate to require crude by rail (CBR) trains to use ECP braking systems (PHMSA 2018). PHMSA had been required to evaluate ECP brakes as part of the 2015 FAST Act. The public has largely seen this as a way for the railroad industry to "save costs," however; the issue is considerably more complex. PHMSA based its decision on FRA testing of ECP brakes and a re-evaluation of its economic analyses.

The following sections provide a more in-depth look at braking systems on trains, with a particular emphasis on electronically controlled pneumatic (ECP) brakes.

Different types of rail brakes

There are four main types of braking systems: conventional, distributed power, dynamic, and ECP.

Conventional braking

Traditional train braking systems use pneumatic valves to control and generate brake applications on the cars along the length of the train. In general, this conventional system consists of a brake pipe that runs the length of the train, which supplies air to reservoirs mounted on each of the cars. When the brake pipe and car components are charged with air, the brakes release. When the engineer needs to make a brake application, control valves in the locomotive reduce the brake pipe pressure. As the brake pipe pressure reduces, the service portion on each car diverts air from their reservoirs to their brake cylinders. To release the brakes, the engineer charges the brake pipe (Booz Allen Hamilton 2006; GAO 2016).

Conventional brakes have a number of identified weaknesses (Booz Allen Hamilton 2006):

- They depend on the reaction time of the engineer and the signal can take up to two minutes to propagate to the back of a long freight train.
- The uneven braking can cause significant forces to build up between the cars in a train.
- Since the brake pipe is typically used for control and supply of air to the cars, if an engineer is not careful, the air supply can be depleted.

It is important to note that the observation is true for mixed freight manifest trains, which often have a mix of various air cylinders on older or newer cars. For modern unit trains, however, which normally utilize the most current series of conventional brake valves on each car (known as the ABDW series), propagation of a brake application is much closer to universal from head of train to rear of train. Each of the brake valves throughout the train is constructed to sense a one to one-and-a-half-pound of change in brake pipe pressure and apply the brakes on each car as that change occurs. The more advanced brake valves on each car also sense an increase of brake pipe pressure and release the brakes in a much quicker manner than older versions of the AB series brake valves.

Distributed power (DP) braking

Distributed power units (DPUs) are locomotives placed in the middle or at the rear of a train that help push the train, but are controlled by the engineer in the front of the train. In distributed power (DP) braking, the head locomotive sends a radio signal to other locomotives in the middle or at the rear of the train to send the brake signal to cars (GAO 2016). The braking is performed such that the locomotives are capable of venting the brake pipe at multiple locations, which speeds up the venting process (i.e., it speeds up the propagation process). This functions exactly the same as a two-way End of Train device (EOT) if the distributed power units (DPUs) are on the rear of the train.

There are some advantages to DP brakes over conventional brakes, including reduced draft forces along the train that reduce lateral forces between the wheels and rails on curves. This reduces fuel consumption and wear. DP braking also provides potential train-handling benefits (Lustig 2010). An advantage of DPU over EOT is that the DPUs also recharge the brake pipe/reservoirs from multiple locations, while an EOT can only vent, not recharge.

Dynamic braking

Dynamic Power Braking utilizes the power generation of a train's locomotives to retard the forward impetus of the weight of a train. Simply put, there are traction motors mounted on each axle of an operating locomotive. During propulsion, electricity created by a generator in each locomotive transfers an electrical current to the traction motors, which, depending on throttle position, causes the traction motors to turn each axle.

During Dynamic Braking (DB), the controls in the control locomotive reverse the electrical current to the traction motors, creating a resistance field, which inhibits the axles from turning freely and retarding the train. Dynamic Braking has been utilized on locomotives for many years and was a requirement of usage for locomotive engineers as a way to reduce brake shoe wear, wheel flat spots, and fuel usage. On mountain grade or other steep descending grades, DB is utilized in conjunction with lighter applications of brake pipe reductions to control train speed. Obviously, this braking method results in changes in slack within a train when converting to power mode to DB mode then back to power so needs to be managed correctly by the locomotive engineer. DB operation is fundamental to locomotive engineer air brake and train handling training on Class I railroads.

ECP braking

Electronically controlled pneumatic (ECP) brakes:

> ...send an electric signal instantly and simultaneously to each individual train car, allowing for faster brake application than on trains with conventional air brakes. With conventional air brakes, each car receives a braking signal — which moves at close to the speed of sound in emergency braking situations — sequentially through an air pipe instead of simultaneously. Use of ECP brakes can result in shorter stopping times and distances. This can reduce the frequency of derailments and their severity when they occur. ECP brakes can reduce the severity of incidents by reducing the number and kinetic energy — or energy in motion — of cars that derail, reducing their likelihood of getting punctured and releasing their contents. (GAO 2016)

Studies on ECP braking effectiveness

In order to quantify the potential benefits of ECP brakes relative to other braking systems, a number of studies have been conducted.

FRA (Booz Allen Hamilton) 2006 study

In 2006, before crude-by-rail (CBR) trains were regularly operating in the U.S., the FRA commissioned a study on the effectiveness of ECP brakes (Booz Allen Hamilton 2006). The study analyzed the potential effectiveness of ECP brakes for all types of freight trains, not specifically CBR trains. However, other rail experts have questioned some of the findings of this study based on newer information. The findings on the safety benefits and effectiveness of ECP brake technology are summarized below:

- **Brake signal transmission rate:** The brake signal transmission rate is increased with ECP brakes. With conventional brakes, an air signal transmits brake communications at approximately two-thirds of the speed of sound. The electrical signal is sent instantaneously so all cars brake at the same time rather than in a slower sequence. This significantly reduces in-train forces (i.e., the push and pull of cars against each other that damages both rail equipment and cargo).
- **Brake application rate:** With ECP brakes, the brakes in each car receive approximately the same cylinder pressure, which also reduces in-train forces caused by temporary differences in cylinder pressure with conventional brakes.
- **Graduated brake release:** The ability of ECP brakes to lower braking level after making a brake application enables the adjustment of braking level to more closely follow safe speed limits.
- **Constant charging reservoirs:** With ECP brakes, the brake pipe acts as a reservoir supply pipe so that it continuously supplies reservoirs. Whether the brake application is released gradually or by a sudden total release, the reservoirs are always recharged so that there is no risk of having no brake pressure.
- **Longer trains:** ECP brakes make it possible to safely operate longer trains. The use of electrical signals instead of air pressure allows the brake pipe to be maintained at full pressure at all times. Uniform braking with constant pressure reduces end-of-train pressure problems and in-train forces that otherwise restrict train length.
- **Elimination of power braking:** ECP brakes eliminate the need for braking well ahead of a reduced-speed area, such as a curve or switch. This reduces unnecessary wear on the brakes and reduces wheel damage.
- **Shorter stopping distances:** ECP brakes can reduce stopping distances by 40 to 60 percent compared with conventional brake stop distances.[208]
- **Improved train handling:** Since ECP brakes allow all cars to brake simultaneously, in-train forces are lessened, which reduce the likelihood of derailments. Improved train handling afforded by ECP brakes also reduces the chance of operating error. Operating a train with conventional brake technology is an extremely complex task, requiring extensive knowledge of the rail line over which the train is running, and constant pre-planning of train speed and braking options several miles ahead. For example, on grades (slopes or hills), the operator is constantly watching gauges, monitoring speed, air pressure, and dynamic brake effort, and must be prepared to make a decision instantly if something goes wrong.

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[208] The Booz Allen Hamilton (2006) study speculated that shorter stopping distances would help to reduce collisions and grade-crossing accidents in which the engineer is able to see the threat on the tracks but would not otherwise be able to stop the train in time to avoid an accident. However, this has been questioned by other rail experts who contend that PTC was mandated to avoid collisions, and better crossing protection is probably more likely to reduce crossing accidents than ECP brakes.

- **Train monitoring:** ECP technology provides the engineer with immediate information on brake failures. Conventional braking systems only provide this information during 1,000-mile physical inspections.
- **Continuous brake pipe pressure:** The continuous brake pipe pressure of ECP brakes provides the ability to stop the train at all times, which removes the threat of premature air reservoir depletion and possible runaway trains.[209]
- **Real-time train status reporting:** The ECP brake system's wire-based communications platform transmits information about each car back to the locomotive.
- **Reduced train crew fatigue:** Since ECP braking systems do not require operators to be constantly focused on pressure levels in the brakes, the crew can better focus on the current train operating environment rather than prepare for likely brake level pressures miles ahead.

There have been a number of developments since the landmark 2006 Booz Allen Hamilton study that should be considered in evaluating the results, including:

- The Booz Allen Hamilton (2006) study was conducted prior to the introduction of 100–120 car unit trains for CBR operations. The use of DPUs has actually made running longer trains possible because the restriction on length is usually associated with the maximum drawbar forces near the head end of the train. The DPUs reduce these forces by shoving a portion of the train; therefore, more cars/tonnage can be added because the head end draw bars remain within their maximum force range.
- The Booz Allen Hamilton (2006) study was conducted before PTC and on-board computer screens were considered. An engineer with ECP brakes is going to have to have exactly the same information as an engineer using conventional brakes. PTC helps with most of it visually (on screens). The ECP braking system does not actually help the engineer run the train.

ECP brakes as related to Lac- Mégantic accident

There was a lot of concern regarding runaway trains in the wake of the July 2013 accident in Lac-Mégantic, Quebec, Canada, in which a train rolled down a hill and derailed in the middle of a town. The resulting fire and explosions caused 47 fatalities.[210] However, it is very rare that a train runs away by mishandling of the air brakes. The Lac-Mégantic accident occurred because the engineer did not set enough hand brakes and then assumed that the air brake system would hold the train on the grade. When the fire broke out and the fire department shut down the locomotive, air leakage left the train without a lot of the braking resistance the air brakes were supplying. It is unclear how ECP would have prevented this if the engineer of the ECP train also did not set the proper number of hand brakes to hold the train.

NTSB 2015 study

In 2015, in the aftermath of a collision between a grain train and a CBR unit train in Casselton, North Dakota, the NTSB conducted a train braking simulation study (Renze 2015). The purpose of the study was to estimate the reduction in stopping distance with ECP brakes compared with

[209] A runaway train due to brake problems was a precipitating cause of the Lac-Mégantic accident.
[210] The accident is described in greater detail in Chapter 21.

conventional brakes and distributed power pneumatic (DP) brakes. NTSB concluded that ECP brakes outperform other systems, including distributed power systems, which in turn outperform conventional brakes.

The results are summarized in Table 73 through Table 75. The net braking ratio (NBR) is the relationship of the braking force against a rail car's wheels to the rail car's weight. An increase in the NBR for any brake system substantially improves the stopping performance.

Table 73: Stopping Distance Reduction at 10 percent Net Braking Ration (NBR) with DP and ECP Brakes Based on Different Braking Configurations at Various Speeds[211]

Braking Configuration at Speed	Stopping Distance Reduction with DP Brakes	Stopping Distance Reduction with ECP Brakes
Emergency at 20 mph	4–17%	5–26%
Emergency at 30 mph	4–11%	5–19%
Emergency at 40 mph	3–9%	4–15%
Emergency at 50 mph	3–8%	4–13%
Full Service at 20 mph	7–46%	37–75%
Full Service at 30 mph	11–39%	37–68%
Full Service at 40 mph	10–39%	30–64%
Full Service at 50 mph	9–37%	25–60%

Table 74: Stopping Distance Reduction with Increased NBR (Relative to 10 percent NBR) with DP and ECP Brakes Based on Different Braking Configurations at Various Speeds[212]

Braking Configuration at Speed	Stopping Distance Reduction: Conventional Brakes at 12.8% NBR	Stopping Distance Reduction: with DP Brakes at 12.8% NBR	Stopping Distance Reduction: with ECP Brakes at 12.8% NBR	Stopping Distance Reduction: Conventional Brakes at 14% NBR	Stopping Distance Reduction: DP Brakes at 14% NBR	Stopping Distance Reduction: ECP Brakes at 14% NBR
Emergency at 40 mph	15%	17%	17%	20%	22%	23%
Emergency at 60 mph	17%	18%	19%	22%	24%	24%
Full Service at 20 mph	8%	8%	16%	11%	11%	21%
Full Service at 40 mph	10%	11%	18%	13%	15%	24%
Full Service at 60 mph	11%	13%	19%	15%	18%	25%

[211] Renze 2015.
[212] Renze 2015.

Table 75: Stopping Distance Reduction for ECP Signal Propagation Rate (With Different Levels of NBR) Based on Different Braking Configurations and Speeds[213]

Braking Configuration at Speed	Stopping Distance Reduction with ECP Brakes 10% NBR	Stopping Distance Reduction with ECP Brakes 12.8% NBR	Stopping Distance Reduction with ECP Brakes 14% NBR
Emergency at 20 mph	5–26%	13–39%	16–43%
Emergency at 30 mph	5–19%	16–33%	21–38%
Emergency at 40 mph	4–15%	17–31%	22–36%
Emergency at 50 mph	4–13%	19–30%	24–36%
Full Service at 20 mph	37–75%	42–80%	45–82%
Full Service at 30 mph	37–68%	45–74%	48–76%
Full Service at 40 mph	30–64%	41–71%	44–73%
Full Service at 50 mph	25–60%	40–68%	44–71%

The overall conclusions of the NTSB study are:

- The benefits from the use of advanced braking systems, such as ECP, comes from:
    a. A reduction in stopping distances (fewer cars in a potential pileup).
    b. A reduction in vehicle kinetic energy (less energy to puncture cars in pileups).d
    c. Lower and more uniform in-train coupler forces (more compatible car-to-car interaction).
- For emergency braking, the ECP brake system provides “somewhat better” stopping performance than the DP configuration.
- The results on overall reductions in stopping distance with ECP (shown in Table 75) indicate that ECP brakes exhibit reduced stopping distances that vary by speed, NBR, and by braking configuration (emergency vs. full service):
    a. At slower speeds, the stopping distance reduction is somewhat greater than for higher speeds.
    b. Full-service braking stopping distance reductions are greater than for emergency braking.
    c. Stopping distances reductions are greatest for the highest NBRs.

AAR 2014 study

The Association of American Railroads (AAR) commissioned a study (Brosseau 2014) that used the same simultation tool as that conducted by the NTSB (Renze 2015). The results are shown in Table 76.

This study evaluated the reduction in energy dissipation and the degree to which that would affect a reduction in the numbers of derailed cars.

[213] Renze 2015.

Table 76: Performance of ECP Systems Compared to Other Types of Braking Systems with Respect to Average Reduction in Energy Dissipated in Derailments and Numbers of Derailed Cars[214]

Performance of ECP System Compared to:	Average Energy Reduction Dissipated in Derailment	Average Reduction in Car Number Reaching Point of Derailment
Conventional Brakes (Head-End)	13.3%	1.6
Conventional Break with End-of-Train Device	11.6%	1.3
Rear-End Distributed Power Pneumatic Brakes	12.8%	1.5
Mid-Train Distributed Power Pneumatic Brakes	10.5%	1.2
Distributed Power Pneumatic Brakes at 2/3	10.8%	1.2

While better braking ability with ECP brakes clearly would be expected to reduce CBR and other rail accidents, as well as reduce the likelihood of damage to tank cars, it is difficult to assess a specific accident reduction rate for ECP brakes. The testing data for reduced stopping distance vary considerably, depending on various parameters, from 4 percent to 82 percent.

AAR Task Force 2011 report

The AAR T86.7 Task Force Summary Report states (AAR Task Force 2011):

> On June 15, 2011, an Industry Consortium consisting of Rail Supply Institute (RSI), Association of American Railroads (AAR), American Petroleum Institute (API), Growth Energy, and the Renewable Fuels Association (RFA) submitted an action plan for the continuous reduction of risk associated with rail transportation of Crude Oil, classified as PG I and II, and Ethanol. The objectives of the action plan were to make recommendations on derailment risk reduction actions that could be quickly implemented; develop a new specification for tank cars transporting the aforementioned commodities and allowance for new cars for these services to be constructed to the standard proposed in P-1577. The Industry Consortium met with the FRA on July 12, 2011 to review the plan. The FRA concurred with the objectives and supported the proposed approach.
>
> On July 20, 2011, at the summer AAR Tank Car Committee meeting docket T87.6 was created with a dual charge to develop an industry standard for tank cars used to transport crude oil, denatured alcohol, and ethanol/gasoline mixtures as well as consider operating requirements to reduce the risk of derailment of tank cars carrying Crude Oil classified as PG I and II, and Ethanol. (p. 1)

The Task Force was split into two groups: the Tank Car Design Working Group and the Operations Working Group. The Design group was tasked with developing new standards for tank cars hauling crude oil and ethanol. The Operations group was tasked with studying ways to reduce derailments.

[214] Brosseau 2014

Of more relevance to the ECP issue is what the Operations group of T87.6 researched and recommended. As previously mentioned, this group was tasked with evaluating operational concepts intended to reduce the number of derailments and the number of tank cars involved in a derailment.

The Task Force found through statistical analysis that broken rails result in the highest severity and frequency of derailments (T87.6 Task Force Summary Report, pg. 10). A graph ("Figure 1" in Liu et al. 2012) in the T87.6 report was taken from a study titled "Analysis of Causes of Major Train Derailment Causes and Their Effect on Accident Rates" (Liu et al. 2012). The graph compared the average number of cars involved in a derailment compared to the number of derailments caused by various causes (AAR Task Force 2011; Liu et al. 2012). Broken rails accounted for 665 derailments between 2001 and 2010, where the average of all other causes was 89 derailments. The next eight largest causes were:

- Track geometry (excluding wide gauge) (317 derailments)
- Bearing failure (257 derailments)
- Broken wheels (226 derailments)
- Train handling (excluding brakes derailments) (201 derailments)
- Wide Gauge (169 derailments)
- Obstructions (153 derailments)
- Buckled track (149 derailments)

It is of note that brake-related derailments were not mentioned in the report by the T87.6 task force. The study by Liu et al. (2012) shows a similar discounting of brake failures as a major cause of accidents. In that study, brake-related issues are listed five times. Brake operation (mainline) has 95 incidents between 2001 and 2010, handbrake operations has 42 incidents, other brake defect (car) has 37 incidents, brake rigging defect (car) has 27 incidents, and brake operations (other) has 4 incidents. These incidents represent 4.6 percent of the total number of derailments accounted for in the 10-year period (Liu et al. 2012).

It is unclear which of these categories would have been affected by ECP brakes as compared to the brake issue that was the cause of the accident. Handbrake and brake rigging incidents (69 total) likely would not have been affected by ECP brakes, and there is a possibility brake defects (car) would not as well. That leaves approximately 100 incidents that might have been affected by ECP brakes, or approximately 2.2 percent of all derailments recorded by the FRA in a ten-year period.

Liu et al. (2012) discusses the impact of speed on the causes of derailments. Again, the focus is on track and mechanical related causes, such as broken rails, track geometry or bearing failure. The paper does note, "At speeds below 10 mph, certain track related and human factor-related causes occurred more frequently than equipment-related causes. But at derailment speeds greater than 25 mph, human factors accidents such as improper train handling, braking operations, and improper use of switches were almost completely absent, replaced by equipment causes, such as bearing failure, broken wheel, and axle and journal defects" (Liu et al. 2012).

What can be concluded from this information is that brake failures are a minor contributor to the overall number of mainline, high-speed derailments. This is relevant to ECP brakes as support for the system often refers to how ECP brakes will reduce derailments. However, if brakes themselves are responsible for very few high-speed derailments, it is hard to conclude that installing ECP brakes will reduce derailments that are infrequently occurring.

The AAR Operations group also explored the value of the brake signal propagation systems that are currently in use and the proposed ECP brake system. The alternative brake signal propagation systems considered included conventional air brakes, electronically controlled pneumatic brakes (ECP), distributed power (DP), and two-way end of train device (EOT) (AAR Task Force 2011). The EOT device performs the same as DP units at the rear of the train for applying brakes. As addressed previously in this section, the DPU or the EOT start a second propagation of venting air pressure from the brake pipe from the rear of the train, which decreases the time required for all brakes to be activated.

In the T87.6 analysis, DP was also assumed to be in the middle of the train to understand that effect on conventional brakes. The difference between having a DPU in the middle of the train is that the release of air from the brake pipe can be achieved both ahead and behind the DPU, as compared to only ahead of the DPU when it is at the rear of the train (or the EOT is at the rear of the train).

A Train Energy and Dynamics Simulator was used to test the dynamics and energy levels of a generic 100 car tank car train. The train was assumed to be on level, tangent track (T87.6 Task Force Summary Report, pg. 12), and the various model runs tested each of the various brake system technologies using the same train makeup and geometry.

The Task Force Summary Report stated (AAR Task Force 2011):

> The modeling tool was…used to determine the remaining energy to be dissipated and the speed at selected locations in the train when a designated tank car reached a Point of Derailment. By comparing the results for each technology, assumptions were made for the difference in number of cars reaching the point of derailment, remaining kinetic energy of each of the cars in the train at a set time interval, and conditional probability of release (CPR) of the train. (p. 12)

For the DP train shown in the table, it was assumed to have one lead locomotive, one DP unit in the middle of the train, and one DP locomotive (or EOT) at the end of the train (AAR Task Force 2011).

Based on the kinetic energy statistical analysis, if the conventional train was assumed to be moving at 50 mph when the derailment occurred, the equivalent ECP train would be moving at 46.5 mph. Using previous work relating to train speed to train CPR, the calculated CPR for the conventional train was 0.48 and the CPR for the ECP train was 0.45. This produced a CPR ratio of 0.938 (.45/.48) or a reduction of 6.25 percent associated with the ECP train.

The T87.6 Task Force Summary Report stated, "In similar analyses, the industry has considered options resulting in a 20 percent reduction in the CPR to be worthy of further consideration and/or adoption" (AAR Task Force 2011). Based upon the result of a 6.25 percent decrease, the task force concluded that the alternatives considered provided marginal benefits (T87.6 Task Force Summary Report, pg. 13). Additionally, the obstacles to implementation represented a considerable time and cost investment. Based on those conclusions, the Operational group did not make a recommendation related to alternative brake signal propagation systems.

Regulatory impact analysis of USDOT's 2015 Enhanced Tank Car Rule

When the U.S. Department of Transportation (USDOT) issued its Regulatory Impact Analysis (RIA) for its Enhanced Tank Car Rule 2015, it summarized its findings as follows (USDOT 2017):[215]

> The potential violence and destruction of a HHFUT accident is substantial and ECP brakes would help to mitigate the magnitude of an accident by providing a faster brake response than conventional pneumatic braking currently offers. ECP brakes replace the air pressure controlled valves, which are used on conventional pneumatic braking, with electronically controlled valves. This allows the response time for braking to occur essentially at the speed of light, rather than the speed of sound. Research shows that the quicker and more uniform braking from ECP brakes can reduce the stopping distance of a train from 40 to 60 percent and has even been shown to reduce Brake shoe wear by 20 to 25 percent. By reducing the stopping distance of a train ECP brakes helps to reduce the number of tank cars that have the potential to go past the point of derailment (POD) and thus reduces the risk associated with tank car punctures. The lower risk of tank car punctures helps to increase safety benefits through reductions in property damages and lower fatalities and injuries. (p. 61)
>
> Based on the new models developed by Sharma & Associates, DOT believes that ECP brakes, in isolation, can be expected to reduce the number of cars punctured by up to 14.0 percent compared to two-way EOT devices. The ECP brake system provides an advantage over two-way EOT devices in terms of the likely number of tank cars punctured.... As trains become shorter, the differences in puncture rates become diminished between ECP brakes and two-way EOT devices because of the reduced time needed to initiate emergency braking across all cars in the train. (pp. 16–17)
>
> There are several additional safety benefits of ECP brakes that have not been monetized. Due to the shorter stopping distances and brake system monitoring associated with ECP braking, these include fewer and less-severe collisions with obstacles on the railroad, including vehicles stuck on grade crossings; fewer and less-severe train-to-train collisions; reduced chances of runaway trains; and fewer train-handling accidents. As PTC is implemented, train sets that operate with ECP brakes can have enhanced braking algorithms with lower variance. PTC and ECP brake systems should work together seamlessly to provide faster braking and enhanced train handling. ECP electronic communication networks can also be configured to transmit car-born sensor data for non-air brake purposes. ECP brakes...can also significantly reduce the possibility of a runaway train. Runaway trains can occur due to a depletion of the main reservoir air. This would be reduced with ECP brakes as the train line operates at a higher pressure and continuously recharges the car reservoirs, as opposed to conventional brakes, which cannot recharge the reservoirs while the brakes are applied. (pp. 83–84)

USDOT's final rule on electronically controlled pneumatic (ECP) brakes resulted from a demanding process, based on conservative assumptions, credible data, and well-respected

[215] See https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/news/69151/electronically-controlled-pneumatic-braking-final-updated-ria-12-4-2017.pdf

dynamic models. USDOT collected and fully considered hundreds of comments and testimonies from the public, railroads, brake manufacturers, and numerous organizations during two comment periods. The Final Rule, developed in multiple iterations with many levels of review and comment, yielded the most safety improvement with the lowest burden and cost.

GAO 2016 report on train braking analysis

In May 2015, after the USDOT issued its final rule requiring trains called highly hazardous flammable unit trains (HHFUT) hauling flammable liquids to equip with ECP brakes as part of the FAST Act, there was opposition from many industry stakeholders (GAO 2016). The Fixing America's Surface Transportation (FAST) Act required USDOT to test ECP brakes and reevaluate the economic analysis supporting the ECP brake requirement and included a provision for GAO to review the potential costs and benefits of ECP.

As part of the 2016 report, GAO (GAO 2016):

> GAO reviewed rulemaking documents; interviewed 13 rail experts selected based on published work and suggestions from the National Academies of Sciences; interviewed USDOT officials and representatives of the seven largest railroads in North America; interviewed industry stakeholders, including the Association of American Railroads; and compared USDOT's estimates and modeling efforts against federal criteria and GAO standards for internal control.

Many of the positives of ECP brakes have been presented earlier in this section. Regardless of those benefits, in December 2017, the FRA canceled the rule requiring ECP brakes to be installed on trains hauling flammable and toxic inhaled commodities. It is likely the GAO investigation and report contributed to this change.

Many rail experts believe that the greatest value of ECP trains is not for unit trains but for mixed freight that have a Key train designation, due to the dynamics between loaded and empty cars throughout the train in a full-service application or undesired emergency application. The ABDW system, particularly with DP units, is almost as universal as ECP. The complication is how to equip multiple manifest trains system-wide with ECP when from one day to the next. HHFUT volumes will most likely vary from train to train, designating many as non-Key trains.

FAST Act 2017 revised regulatory impact analysis

In 2017, USDOT issued a revised Regulatory Impact Analysis (RIA) (USDOT 2017). This analysis concluded:

- The total cost for locomotives to install ECP brakes was $105 million to $140 million.
- There is a significant decrease in any business benefit to railroads because of ECP brakes.
- Safety benefits under the FAST ACT revised RIA lowered primarily because of changes in the crude oil energy market and the total carload forecast number.
- The total 20-year carload forecast was reduced by 29 percent, which in turn significantly reduced the safety benefits of the ECP brakes.
- The 2015 RIA 20-year carload forecast was based on the industry and used the Railway Supply Institute (RSI) projections.

- RSI did not offer the FAST ACT revised RIA an updated projected 20-year carload number so PHMSA and FRA utilized the current and projected energy trends supplied by the Energy Information Administration (EIA).
- RSI was opposed to the ECP brakes stating in a December 19, 2014 letter to the USDOT that "ECP brakes do not offer significant safety advantages during a derailment scenario, as compared to the Distributed Power or two-way End-of-Train braking systems that are already in use. Further, ECP brakes can only be installed at a premium per-car cost of $7,300 for new tank cars and $7,800 for modified tank cars" (RSI 2014).
- The 2015 RIA used a cost for the HHFUT ECP requirement of the final rule, a weighted average unit cost estimate of $7,633 (one-third new construction at $7,300 and two thirds retrofit at $7,800) for ECP brakes.
- The FAST ACT revised RIA lowered the positive impacts of ECP brakes on high consequence events primarily because the carload forecast was reduced. (FAST ACT revised RIA, page 67)
- The FAST ACT revised RIA low consequence events benefits were reduced by 29 percent primarily because of the carload forecast reduction.
- The assumption of ECP brake effectiveness was decreased 29 percent from the 2015 RIA because of FAST ACT required simulation testing and the signal delay time results showing a potential decrease in the number of punctured cars.
- The FAST ACT revised RIA stated that railroads have not made commitments to install ECP on new locomotives. Therefore, ECP would be installed in locomotives solely through retrofitting which increased the costs while not adding any additional business or safety benefits.
- The FAST ACT revised RIA uses an updated 20-year forecast (no carload projections from the RSI) to lower safety mitigation benefits, updated business benefit information to lower benefits of ECP brakes, updated costs like increases to locomotives, because of industry not committing to new orders including ECP brakes which were all done "in order to take into account both recommendations from GAO and stakeholders as well as to incorporate the latest economic data from within the railroad and energy industries."

At the request of the National Academy of Sciences Transportation Research Board, the USDOT performed a simulation of an actual incident. The simulation results were compared with observations from the actual incident. The derailment of a loaded oil train at Aliceville, Alabama was chosen, because, in addition to data on number of punctures and cars derailed, the distance travelled by the rear portion of the train that remained on track was available from the event recorder on the remote distributed power unit (DPU) at the rear of the train. Details of the Aliceville derailment are as follows:[216]

- 90 cars, loaded oil train
- 2 head-end locomotives, 1 DP locomotive at rear
- 38 mph, derailment initiated at head end of train
- Level grade, track on raised embankment
- Rear locomotive travelled 1,240 feet

[216] Also see Chapter 21 for a description of the Aliceville accident.

The USDOT derailment simulation was initiated at the head end of a 100-car, loaded, DP train at 40 mph. In the Aliceville accident, 26 cars derailed and 15 were punctured. The rear car traveled 1,240 feet. In the simulation, which included an ECP brake system, 26 cars were also derailed and 19 were punctured. The rear car traveled a distance of 1,238 feet.

The results of the revised simulations show that ECP brake systems still offer a significant safety benefit over both conventional and DP brake systems. The results of the multi-variate regression analysis confirmed that the key variables considered in the USDOT's Methodology were appropriate, inclusive, and prudent.

USDOT's FAST Act, limited ECP brake system requirements to HHFUTs for a number of reasons:

- The alternative of equipping all of the covered tank cars with ECP brakes allows for additional flexibility for car owners and railroads and results in higher safety benefit, however compliance costs are significantly higher. The total costs for this alternative is $760.4 million with benefits ranging from $485.4 million to $635.7 million, discounted at 7 percent. This provides net benefits (both negative) ranging between -$275.4 million and -$126.6 million, discounted at 7 percent.
- The costs for the alternative of requiring ECP brakes for all covered tank cars would exceed the costs of the final rule by $268.4 million over a twenty-year period, discounted at 7 percent. This is a 55 percent increase in costs. The benefits for this alternative also exceed the costs of the final rule, but not by the same margin. In this alternative, the benefits would increase between $15.1 million and $22.3 million, discounted at 7 percent. This is only a 3.2–3.6 percent increase over the benefits in the final rule.
- PHMSA and FRA believe that the approach focused on HHFUT for ECP brakes results in a better return on investment per unit equipped. This limits the costs of this regulation and ensures optimal utilization of ECP brakes. Under the final rule operational requirements for ECP brakes on HHFUTs, industry may equip additional equipment with ECP brakes on a case-by-case basis to the extent they are able to realize benefits that cover costs.

Differences between USDOT and AAR positions on ECP brakes

There were many differences between the USDOT findings/methodologies and AAR/industry findings/methodologies. The AAR's cost-benefit analysis results differed from USDOT's because they addressed different questions. USDOT answered the question, "After a high-hazard flammable unit train derails, will ECP brakes reduce harm (in terms of tank car punctures) compared to other braking systems?" Industry modeling described the number of cars that would reach the derailment point with different braking systems — a question that does not capture the relationship between train kinetic energy and puncture risk.

Cost of ECP braking systems

There is a significant difference in conclusions about the cost of implementation of ECP braking. AAR believes USDOT underestimated the cost of equipping cars and locomotives with ECP braking equipment. A comparison of the estimated costs is shown in Table 77.

Table 77: Comparison between the USDOT and AAR Estimated Costs of ECP Braking Systems Over 20 Years and Basis of Costs by Numbers of Locomotives, Cars, and Employees (2015 to 2034)[217]

Type of Cost	USDOT Estimate	AAR Estimate
Equipping Locomotives with ECP Brakes	$79.9 million (2,500 locomotives)	$1.77 billion (20,000 locomotives)
Equipping Tank Cars with ECP Brakes	$373.2 million (60,000 cars)	$1.04 billion (133,000 cars)
Training RR Employees on ECP Brakes	$39.9 million (51,500 employees)	$239 million (78,000 employees)
Total Cost	**$493 million**	**$3.04 billion**

Numbers of locomotives and cars requiring ECP braking

In addition to a disagreement on the cost to equip cars and locomotives with technology, AAR and USDOT had a notable discrepancy in the locomotive and car counts that were projected to require ECP brakes or technology. USDOT believed the industry would be able to segregate locomotives and cars with ECP brakes from general use, leaving them only in HHFUT service (GAO, 2016). The 2016 GAO report states AAR and other industry participants, however, argued that USDOT oversimplified U.S. railroad operations in which crude oil and ethanol trains move between multiple origins and destinations and not often by unit train. It further states:

> AAR added that efficient railroad operations require railroads to be flexible in their operations; as a result, railroads move their locomotives around throughout their entire network based on business needs and do not dedicate specific locomotives to specific routes or services. Consequently, railroads cannot dedicate locomotives and tank cars equipped with ECP brakes to HHFUT service. (p. 15)

Assumptions to monetize safety benefits

AAR believes USDOT's assumptions used to monetize safety benefits may have been oversimplified or inaccurate. The derailment rate that was used by USDOT in the analysis assumed a constant derailment rate per thousand car loads based on the previous 5-year period (GAO 2016). AAR took exception stating that USDOT's assumption ignored the projected decline in shipments of crude into the future.

AAR also disputed USDOT's per-gallon cost of oil released estimate of $200 (GAO 2016). They stated this figure is 10 to 18 times higher than costs reported by the railroads. A report produced by Oliver Wyman stated that the USDOT average may be high because of one extreme case which was a pipeline spill. That report believes such an outlying event should not have been considered (Oliver Wyman 2015).

[217] Based on USDOT 2017 and AAR Task Force 2011.

AAR asserted that a significant portion of the benefits claimed in USDOT's analysis for wheel savings and fuel savings may not be realized due to the use of dynamic braking. Dynamic braking is an alternative to pneumatic brakes for slowing a train in non-emergency situation, and its use allows a train to operate more efficiently. When trains use dynamic braking and not ECP brakes, they do not get business benefits from ECP brakes. AAR, with data from the two railroads that had requested ECP brake waivers, estimated that 85 percent of the potential fuel and wheel savings benefits of ECP brakes are already being realized through use of dynamic brakes.

Reliability of ECP brakes

The railroad industry does not believe ECP brakes are reliable. There is disagreement on the reliability of ECP brakes and the extent to which railroads can achieve operational — or business — benefits from ECP brakes (GAO 2016). "According to USDOT in the final rule, ECP brakes are a reliable and 'proven technology' and 'concerns related to maintenance and repair issues that arise during normal operations will be resolved through adequate training of operating crews and maintenance personnel' " (GAO 2016).

Representatives interviewed by the GAO from all five Class I railroads that have used ECP brakes stated "that poor reliability would prevent them from achieving any operational efficiencies. These representatives confirmed that their railroads stopped or reduced their ECP brakes operations in part due to challenges related to their reliability" (GAO 2016).

Extent of business benefits and efficiencies

USDOT and stakeholders disagree over the extent of business benefits and efficiencies. In estimating the benefits of ECP brakes, USDOT estimated business and safety benefits.

The GAO report goes on, stating (GAO 2016):

> In terms of business benefits, DOT estimated a total of about $254 million, resulting from reduced fuel usage, reduced wheel wear, and savings from fewer required brake inspections that according to DOT in the Regulatory Impact Analysis, generally take trains out of service for about 3 hours, among other things...
>
> …DOT estimated that use of ECP brakes would result in 2.5 percent fuel savings for railroads, leading to a benefit of about $121 million based on Canadian Pacific Railway's (CP) and other railroads' experiences with ECP brakes and the price railroads paid for fuel per mile traveled in 2013.
>
> …AAR stated more recently that the updated savings estimate of 2.5 percent is not supportable because railroads have not been able to quantify any fuel savings from ECP brakes. Representatives from three of the five Class I railroads that have used ECP brakes told the GAO that they have been unable to attribute any fuel savings to ECP brakes.
>
> DOT estimated a benefit to railroads of $51.5 million based on FRA regulations allowing ECP-equipped trains to travel up to 3,500 miles, instead of 1,000 or 1,500 miles required for trains with conventional air brakes... No representatives of any

> of the five class I railroads that have used ECP brakes that we interviewed provided any data to verify whether there are any potential savings from reduced required brake inspections.
>
> DOT estimated a benefit of $23.4 million in wheel wear savings in part based on data from Canadian Pacific Railway (CP). Wheel wear savings can result from ECP brakes providing more uniform braking and better train handling. …AAR commented to DOT that the use of dynamic braking by railroads has already reduced wheel wear, limiting the potential benefit provided by ECP brakes. The Oliver Wyman report (2015) also noted that while CP reported some reductions in wheel wear, BNSF Railway reported increased wear and tear; however, the report did not quantify these savings or increases. (pp. 24-27)

ECP benefit modeling approaches

USDOT and AAR modeling approached the issue from two different perspectives, with significantly different results. Both USDOT and AAR utilized computer modeling to estimate the benefits (or differences) between a train that derailed that was equipped with ECP brakes versus one that was equipped with conventional brakes and DPU at the end of the train (or a two-way EOT device).

The USDOT modeling analysis simulated a tank car train derailing at various speeds, with results showing how many cars derailed and how many of those cars were likely punctured in the ensuing pile up. “For the final rule, USDOT found that on trains with ECP brakes, a weighted average of 19.7 percent fewer cars will puncture in a derailment compared to trains with DPUs” (GAO 2016).

AAR approached the issue in a different manner. AAR told the GAO “that derailments are very complex and that USDOT’s modeling did not sufficiently account for these complexities and the number and variability of parameters involved in derailments” (GAO 2016). Instead, their method was to look at how many cars would reach the Point of Derailment under various speed and car placement conditions comparing a train with ECP brakes to a train with conventional brakes and DPUs (GAO 2016).

“Based on its calculations, AAR estimated that on a 100-car train set, 1.2 fewer cars will derail on a train with ECP brakes as compared to DP, and 1.6 fewer compared to conventional brakes (no DPU or two-way EOT). Unlike USDOT’s approach, AAR’s did not estimate the probability of cars puncturing in a derailment” (GAO 2016). AAR’s conclusion from its modeling was that ECP brakes provide a “marginal” benefit;” (GAO 2016).

In reviewing the USDOT analyses, GAO stated:

> “We found that DOT’s approach with the LS-DYNA model and related analysis lacked transparency and the information provided to support the ECP brake requirement was not sufficiently thorough and transparent to enable a third party to reproduce a portion of the modeling methodology.” The report went on stating, “These documents provide many pages of general information on DOT’s modeling process and some specific information, such as sample calculations. However, the information DOT published about the model is limited and would not necessarily allow independent third parties to replicate the

> analysis. Because DOT did not provide some of the specific data and information underlying its modeling efforts and analysis, in a situation where little real-world information about the benefits of ECP brakes exists, the public may not have reasonable assurance as to DOT's projected safety benefits, limiting confidence in DOT's overall findings." (GAO 2016).

Summary of GAO conclusions

A summary of the conclusions of the GAO report include the following:

> Although freight railroads in the United States supported initial development and use of ECP brakes, with the issuance of the rule, AAR and other industry participants have stated that the costs do not justify the benefits of the technology and are strongly opposed to this requirement. In opposing the requirement, AAR has stated that USDOT overestimated the benefits and underestimated the costs of ECP brakes (GAO 2016).
>
> Given that equipping HHFUTs with ECP brakes has sparked a highly polarized debate between the railroad industry and DOT, it is critical that DOT's analysis supporting the ECP brake requirement be based upon the best data possible. However, because those railroads that have had experience with ECP brakes (both in the United States and in other countries) have shared limited data on their use of ECP brakes, DOT may have been hampered in its efforts to estimate the potential effects of ECP brakes, including their potential benefits.
>
> Furthermore, we found the information DOT publicly provided on the modeling it conducted to estimate the potential safety benefits of ECP brakes lacked the transparency that could allow for a third-party reviewer to replicate the analysis. As a result, the public and industry stakeholders may have limited confidence in DOT's projected safety benefits. (pp. 48-49)

Potential barriers to universal ECP braking installation

The effectiveness and benefits of ECP brakes have been hotly contested by industry, particularly by the AAR (AAR 2014). AAR maintains that ECP brakes will not result in fewer accidents and will not provide significant safety benefits. AAR states that less than 1 percent of all train accidents are related to failures in brake equipment. This conclusion contrasts with the data from another study that indicate that 4.5 percent of accidents over the 2001 to 2010 decade are attributable to brake failures (Liu et al. 2012).

The limitation of this study is that the researchers did not describe the brake failures that go into the numbers. Hand brake failures look to be included in the numbers, but have nothing to do with ECP braking.

The time period considered in AAR's analysis could explain the discrepancy. AAR considered accidents that occurred on main and siding track through 2014. In addition, AAR maintains that there have not been any brake-related accidents involving a crude or ethanol train. AAR may not be considering the brake issues involved in the Lac-Mégantic accident in making this statement.

In addition, AAR states that ECP brakes are "costly and have issues with reliability that could erode network efficiency." According to AAR, the FRA estimated the system-wide cost of ECP brakes to be $1.7 billion with a negative cost/benefit ratio of almost 9 to 1 (AAR 2014). ECP technology has been in limited use in rail service for 15 years, and, according to AAR, "has yet to meet reliability standards for service and are more than three times more likely to incur a mechanical delay" (AAR 2014).

These objections and concerns are the basis of the judicial challenges filed by the American Petroleum Institute v. United States (DC Cir. No. 15-1131) after the U.S. Department of Transportation (USDOT) Final Rule (USDOT FAST Act) was issued in May 2015. The FAST Act required ECP braking systems (USDOT 2016).

Recent developments on ECP braking rule

In September 2018, PHMSA formally rescinded the mandate to require CBR trains to use ECP braking systems. PHMSA had been required to evaluate ECP brakes as part of the 2015 FAST Act. PHMSA based its decision on FRA testing of ECP brakes and a re-evaluation of its economic analyses (PHMSA 2018).

Potential areas of future discussion

- There are diverse and complex opinions concerning the value of ECP brakes versus the current conventional braking systems for trains, particularly involving the rail industry and the U.S. Department of Transportation. One important aspect of those opinions involves the cost/benefit of installation of ECP capabilities on a system-wide basis for Class 1 railroads.
- Equally important is the question for what type of trains would ECP braking systems be most effective–unit trains or mixed manifest freight trains. Unit trains, such as CBR trains, involve generally universal modern air brake systems (ABDW) which operate quite similar to ECP braking systems. Manifest trains, which often contain one or more hazardous cars, are often comprised of a mix of older and newer braking valves on each car, making train braking not always uniform throughout the train. Equipping each manifest train carrying hazardous materials nationwide or within Washington with ECP capability (not to mention locomotives) would likely be cost prohibitive.
- The members of the Rail Safety Committee may wish to familiarize themselves with the different types of train braking systems, including ECP brakes. The committee needs to understand the value, application and benefit of ECP usage, including how it is best employed, if at all, to maximize rail operating safety.
- The Rail Safety Committee may wish to consider the various opinions and analyses that have been performed and invite discussion from the involved parties in order to develop an informed opinion of the value and practicality of ECP operations within the state.
- As with PTC, there is likely no clear and easy solution to the ECP implementation question, nationwide or within the state. The Committee may wish to endeavor to assess the various studies and come to a consensus on what is practical and what is not, within federal guidelines.

- The Rail Safety Committee may wish to work with railroad regulators and the railroad industry to better understand and evaluate the benefits of ECP braking, including the types of accidents that could and could not be prevented by ECP brakes.

Chapter 11: Inspection Standards and Practices

Key questions

- What inspection standards and practices for track, bridges, trestles, and equipment (locomotives, rail cars) have been employed, are currently employed, or may be employed in the future in Washington State?
- To what extent are these standards dictated by the FRA?
- Are there differences between Washington State's inspection standards and those of other states?
- Are there new and emerging technologies that might enhance the effectiveness of inspections to promote safety?

Takeaways

- The FRA has regulations that contain very detailed requirements for the inspection of track, switches, track crossings, moveable rail bridges (e.g., swing bridges and lift bridges), and railroad equipment (locomotives and all types of rail cars) on a strict schedule.
- Some inspections are conducted by individual inspectors who examine the specific pieces of equipment or track. Often inspectors travel to different locations with a hi-rail vehicle that is essentially a truck or van that has special railroad track-adapted wheels to allow it to ride on the rails. Other inspections are conducted by automated methods, such as track geometry cars (a rail car that rides on the track measuring and testing the various sections of track). In some areas, drones are used to get into locations that are difficult to reach, such as on railroad bridges, or to check specific issues on a more remote track location.
- Railroad tracks throughout Washington contain a system of "wayside detectors." These detectors, which are located every 10 to 25 miles on all rail corridors in the state (BNSF 2018b), can inspect the condition of wheels and other parts of trains as they pass, as well as detect whether the train is dragging an object or has loose parts.
- BNSF Railway has an extensive system of wayside detectors in Washington State. This system has about two to four times the number of wayside detectors as required by the U.S. Department of Transportation and the Association of American Railroads.
- Researchers estimate that wayside detectors could reduce broken wheels and accidents associated with wheel defects by over 20 percent (AAR 2016). Broken wheels and wheel defects also cause damage to the track, which means that detecting problems with wheels could also reduce track-related accidents.

The following sections provide a more in-depth look at the inspection standards and practices for track and mechanical equipment to which railroads are subject.

Track, rail, and bridge inspection

Track inspection regulations are broken into multiple subgroups in 49 CFR. The FRA has defined various track standards by class of track. There are six categories that generally affect freight operations: Excepted, Class 1, 2, 3, 4, and 5. There are higher classes of track that allow high-speed passenger service. However, this report will not address them as they are not present in Washington State.

In general, the higher the class of track, the higher the speed trains are allowed to run on it. However, with the higher speeds, there are more stringent inspection rules and the tolerances from normal become more stringent. Some of those tolerances will be discussed later in this section.

To understand the differences between classes of track, the following maximum allowable speed restrictions are applicable by class:

- **Excepted:** 10 mph freight, no passenger trains permitted[218]
- **Class 1:** 10 mph freight, 15 mph passenger
- **Class 2:** 25 mph freight, 30 mph passenger
- **Class 3:** 40 mph freight, 60 mph passenger
- **Class 4:** 60 mph freight, 80 mph passenger
- **Class 5:** 80 mph freight, 90 mph passenger (49 CRF 213.9)

There are additional qualifications to some of the track classes, however these are detailed and will not be addressed here. BNSF and UP mainlines are usually Class 4 or 5 track. Heavily-used branch lines are generally Class 2 or Class 3, and lesser used branches that do not handle heavy trains will have sections of Class 2 with some Class 1 track. Normally, major railroads like BNSF and UP operate little if any Excepted track. If there is Excepted track, it is noted in the Employee Time Table so crews will know the restrictions of the track.

Manual track inspection

According to federal regulations (49 CFR § 213.233):

- Manual inspection of track is required to be made on foot or by riding in a vehicle at a speed that allows the person making the inspection to visually inspect the track structure for compliance of the safety standards.
- For Class 3 track, the track must be inspected weekly with no less than three calendar days between inspections. If more than 10 million gross tons (mgt) operate over the line, it must be inspected twice weekly with no less than one calendar day between inspections.
- For Class 4 and Class 5 track, track must be manually inspected twice each week with at least one day between inspections. Note that if an inspection is conducted early in the week, e.g., on Monday, the next inspection cannot occur again until at least Wednesday.

[218] Excepted track is an FRA class of track that carries a 10-mph speed limit restriction. It cannot be used by revenue passenger trains. FRA permits Excepted track under very narrowly-defined conditions. It is always identified in railroad documentation (Timetables) with a description of the limits of Excepted track.

> If this inspection is conducted, it is not necessary to conduct further inspections during that week.

Most inspections of this kind are made in a vehicle that operates on the rails (hi-rail vehicle). The inspector is looking out for spike and tie condition, macro track surface issues (such as dips that indicate soft roadbed conditions), mud pumping between the ties, vegetation incursion onto the right of way that obscures the vision of the engineer, or highway vehicles near crossings and other large visible issues.

The inspector is also looking for visible rail defects, such as engine wheel burns, spalling or shelling of the ball of rail. These types of defects are frequently tell-tale signs of more severe damage to a rail, which can lead to rail breaks. Engine wheel burns are deformities in the rail that are caused when engine wheels spin and slip on rail. The wheel burns can lead to defects in the steel of the rail. Spalling and shelling of the ball of the rail are also rail defects. They can be caused by high levels of usage, rail wear on curves or flaws in the steel of the rail.

More detailed issues, such as broken bolts or worn switch points, are more frequently addressed on foot.[219]

By regulation, a track inspector may operate the inspection vehicle at a speed of their discretion that allows the operator to observe issues with the track. When the inspection vehicle is operating over track crossings or turnouts, the speed must be reduced to 5 mph for safety and for the ability to more closely examine insulated joints, guardrails, crossing planks, and other appliances around turnouts and crossings (49 CFR § 213.233).

As rail traffic becomes heavier on a route, time to inspect the track becomes more difficult to obtain. Dispatchers have to deal not only with train meet/pass plans, but also with track inspection (and maintenance). This can lead to conflicts between operations and maintenance as each has goals that require track time.

Switches, track crossings and moveable bridges

According to federal regulations (49 CFR § 213.235):

a) ...each switch, turnout, track crossing, and movable bridge lift rail assemblies or other transition devices must be inspected on foot at least monthly.

b) Each switch in Classes 3 through 5 track that is held in position only by the operating mechanism and one connecting rod shall be operated to all of its positions during one inspection in every 3 month period.

Track inspectors will inspect switches, crossings and lift assemblies for moveable bridges on foot as part of their vehicle inspection. As stated, these inspections must be done once a month, so the inspectors do not have to do this every trip. A record of the inspection is kept on file for reference should an incident occur on that section of track. An example of a moveable rail swing bridge is shown in Figure 59. A rail lift bridge is shown in Figure 60.

[219] Those inspections are covered in the next section.

Figure 58: Railroad Swing Bridge on Ouachita River, Louisiana[220]

[220] Photo credit: Dagmar Schmidt Etkin, Environmental Research Consulting. Used with permission.

Figure 59: Railroad Lift Bridge on Willamette River, Portland, Oregon[221]

Internal rail inspection

Rails are inspected internally by either induction or ultrasound. Ultrasound is the most frequently used, and induction is used more regularly as a complimentary system to ultrasound (FRA 2015).

Induction

From the FRA Track Inspector Rail Defect Reference Manual (FRA 2015), the following description of induction inspection is provided:

> The basis for induction testing requires the introduction of a high-level direct current into the rail head, establishing a magnetic field around the rail head… The induction sensor unit is then passed through the magnetic field… As the current flows through the rail, any condition, such as a defect, will distort the current path… It is this distortion of the magnetic field that is detected by the search unit. (p. 53)

[221] Photo credit: Dagmar Schmidt Etkin, Environmental Research Consulting. Used with permission.

Ultrasonics

From the same manual, the ultrasonic inspection is described as follows:

> Ultrasonics are briefly described as sound waves, or vibrations… Ultrasound is generated into the rail at test speeds up to 100 km/h... In effect, the ultrasound produced travels through the rail specimen from the top of the rail head. If the sound path is uninterrupted, no reflected signal is returned to the transducer. If a condition exists, such as a rail head surface irregularity or internal rail flaw, the ultrasound produced will reflect back to the transducer and an equipment response is presented to the operator for interpretation. (p. 54)

According to federal regulations, inspection of rail shall be conducted by internal rail inspection equipment at a frequency that maintains the following failure rates (49 CFR § 213.237):

1) 0.01 service failure per year per mile of track for all Class 4 and 5 track.
2) 0.09 service failure per year per mile of track for all Class 3, 4 and 5 track that carries regularly-scheduled passenger train OR [emphasis added] is a hazardous materials route.
3) 0.08 service failure per year per mile of track for all Class 3, 4 and 5 track that carries regularly scheduled passenger train AND [emphasis added] is a hazardous materials route.

49 CFR § 213.237 further requires that failure to meet the failure criteria for two consecutive years forces the rail operator to reduce the class of track to Class 2 track (passenger 30 mph, freight 25 mph) until the rail meets the failure rate. Inspection intervals are reduced from 30 mgt to 10 mgt.

Rail inspection is critical to protect the railroad from experiencing broken rails that can lead to derailments. As described in Chapter 22, a rail can develop minor defects in the steel as trains repeatedly run over the rail. Under cold conditions or under mechanically induced conditions, these defects can lead to a rail break.

As the regulations state, the frequency of rail inspection is based on the number of failures that occur per year and the tonnage that operates over the rail. Failures are broken rails, while defects are the internal flaws found in a rail by inspection.

If an average train is estimated to weigh 8,000 tons, 30 mgt per year can be estimated to be approximately 11 trains per day on a line. Therefore, if in reality 30 trains per day run on the line, the rail will have to be inspected at least every 130 days (approximately four months).

If the line supports multiple loaded and empty unit trains, the average weight of a train will likely be greater than 8,000 tons. This lessens the number of days between required inspections. The railroads record data on the actual tonnage that operates over its lines so there are exact numbers to determine when a line must be inspected.

Failure rates can also create the necessity for additional inspections. As shown in the regulation, Class 3, 4, or 5 track that carries passenger and hazardous material must have a failure rate that does not exceed 0.08 service failures per year per mile. In other words, if the segment being inspected is 100 miles long, there can be no more than eight failures per year. If there are a greater number of failures for two consecutive years, the class of track is downgraded to Class 2 and the maximum tonnage inspection interval is reduced from 30 mgt to 10 mgt.

If a railroad experienced failure rates of that magnitude, it is likely that a major rail relay program would be initiated prior to exceeding the two-year criteria. Downgrading a Class 4 or 5 route to Class 2 would trigger multiple issues with service that no railroad would tolerate.

When a rail is found to be defective, the FRA manual addresses what must be done to protect the rail until it is replaced (49 CFR § 213.113). To summarize:

- Limit operating speed to 30 mph (or the maximum operating speed if less than 30 mph) until temporary repairs can be made.
- Apply joint bars bolted only through the outside holes around the defect within 10 days of identifying the defect. For Class 3 to Class 5 track, after the joint bars are applied, the maximum track speed can be increased to 50 mph (or the maximum operating speed if less than 50 mph).
- The rail must be replaced within four days, or the track speed must be reduced to 30 mph.

There are some further options and regulations, however, the main point is, if a defect is found someone must inspect it to determine that it is safe to temporarily repair and continue operations over it. Once that has been determined, temporary repairs can be made, but permanent repairs must be made in a relatively short time or the speed is further reduced. Permanent repair requires cutting out the defect and replacing it with new rail.

Scheduling of bridge inspections

According to federal regulations (49 CFR § 237.101):

a) Each bridge management program shall include a provision for scheduling an inspection for each bridge in railroad service at least once in each calendar year, with not more than 540 days between any successive inspections.
b) A bridge shall be inspected more frequently than provided for in the bridge management program when a railroad bridge engineer determines that such inspection frequency is necessary considering conditions noted on prior inspections, the type and configuration of the bridge, and the weight and frequency of traffic carried on the bridge.
c) Each bridge management program shall define requirements for the special inspection of a bridge to be performed wheneverthe bridge is involved in an event which might compromise the integrity of the bridge, such as flooding, fire, earthquake, derailment or vehicular or vessel impact.

In the event of an incident that might damage a bridge, such as fire, flooding, earthquake, etc., each railroad must have a plan that defines the requirements for inspection of bridges when such an event occurs.

Automated track inspection

Automated inspection of track constructed with concrete crossties must be done as follows (49 CFR § 213.234):

Class 4 and Class 5 track with regular passenger service and annual tonnage exceeding 40 million gross tons (mgt) must be inspected twice each calendar year with no less than 160 days between inspections. If less than 40 mgt annually, automated inspection must be done once per year.

The automated inspection measurements must be within certain standards addressed in the regulation. The inspection standards are summarized below.

Automated inspections are performed by Geometry Cars (G Cars). These cars are full size passenger cars that contain lasers, sensors, and computers to measure and record the track structure as the car moves across it. The geometry cars are pulled by locomotives, usually as a standalone train. The cars are pulled at track speed.

G Cars measure multiple track criteria. These include gauge, alignment (tangent and curved), super elevation, and cross level (tangent and curved). These terms are defined below.

Gauge

Gauge is the distance between the rails. As discussed in Chapter 5, normal track gauge is 4 feet, 8 ½ inches. The geometry car measures the gauge as it moves, looking for either tight gauge or wide gauge. Gauge is the distance between the rails. Normal track gauge is 4 feet, 8 ½ inches. Wide gauge is wider than this. When gauge is too wide, because of track defects, it can cause derailments.

The following criteria must be met (49 CFR § 213.53 - Gage):

- Class 1 minimum gauge is 4 ft. 8 inches.
- Class 2 and 3 track minimum gauge of 4’8”, maximum gauge of 4’9.75”.
- Class 4 and 5 track minimum gauge of 4’8”, maximum gauge of 4’9.5”.

Track alignment

Track alignment is the lateral deviation the rails make from the midpoint of a 62-foot section of track. This means that in a 62-foot segment of track, the midpoint of that section cannot be more than the listed tolerances to the right or left of the correct centerline. For tangent track, the correct centerline is a straight line between the two end points. For curved track, the correct centerline depends on the degree of curvature. The alignment on a curve must be within the listed tolerances at the midpoint of the 62-foot section of where the curve should be if the alignment were perfect.

The FRA tolerances (49 CFR § 213.55 — Track Alignment) that are listed are:

- Tangent: Deviation from the midpoint of a 62-foot section may not be more than:
    a. Class 3: 1.75 inches
    b. Class 4: 1.5 inches
    c. Class 5: 0.75 inches
- Curved: Deviation from the midpoint of a 62-foot section may not be more than:
    a. Class 3: 1.75 inches
    b. Class 4: 1.5 inches
    c. Class 5: 0.625 inches

Super elevation

Super elevation is the number of inches the outside rail is raised compared to the inside rail's elevation. Chapter 22 describes the purpose of super elevation. Super elevation must be consistent throughout the body of the curve. It also must transition smoothly from level to full elevation in the spirals at each end of the curve. The listed tolerances provide guidance as to how much variation can be present in a 62-foot section of the rail that is super elevated. The FRA tolerances for super elevation stipulate that the deviation at the midpoint of a 62-foot section may not be more than:

- Class 3: 1.25 inches
- Class 4: 0.875 inches
- Class 5: 0.625 inches

Cross level

Cross level is the height of one rail compared to the height of the other rail. In tangent sections, the two rails should be level with each other. In a curve, the outside rail should maintain an elevation difference to the inside rail that is equal to the super elevation of the curve. In a spiral, the cross level should transition from level at the tangent end to an elevation difference of the super elevation at the curved end.

Cross level is similar to track alignment except cross level is the variance in the horizontal direction while alignment is the variance in the lateral direction. The FRA standards (49 CFR § 213.55 — Track Alignment) for cross level state that the deviation from zero cross level at any point on tangent track may not be more than:

- Class 3: 1.75 inches
- Class 4: 1.25 inches
- Class 5: 1.0 inches

Cross level between any two points less than 62 feet apart on curved track may not be more than:

- Class 3: 2.0 inches
- Class 4: 1.75 inches
- Class 5: 1.5 inches

The geometry car makes these measurements as it proceeds along a route, recording the measurements to a database. If a discrepancy is found that exceeds the specified FRA tolerances, a "red tag" is issued and a track gang is immediately dispatched to inspect the location. If the issue can be quickly fixed, it is. If it will take more equipment than available, a slow order is placed on the location until the repair can be made.

The geometry car creates and records an enormous amount of data that can be used to assess the condition of a short or long section of a railroad. While automated inspections are only mandated for up to twice a year (depending on annual tonnage over the segment), it is not uncommon that geometry car inspections are done more frequently to maintain a database that can be used by maintenance-of-way personnel to keep the railroad safe.[222]

How track inspections reduce derailments

Track, bridge, and rail inspections are all performed so that the railroad knows where problems are beginning to occur so that they can be fixed prior to causing an incident.

High-level inspections, such as manual inspections, reveal areas that require monitoring or locations that potentially could become larger problems. Seeing mud pumping between the ties in a location indicates the ballast is fouled with dirt and water, meaning it is not draining properly. This can be an indication of a weak subgrade, bad ties, or even an unknown underground spring. The condition needs to be corrected before it causes surfacing or track alignment issues.

Similarly, a wheel burn on the top of a rail can identify a location where an internal flaw may have been produced. If an external issue is severe enough, the inspector may request a more in-depth inspection such as an internal rail inspection.

Internal rail inspections are done to identify locations that are susceptible to broken rails before they occur. A rail that breaks under a train can often lead to a derailment. Identifying those locations before they become breaks is far more efficient than finding a break after it is actually broken — and has potentially caused a derailment.

Automated inspections also serve to address issues that may cause a derailment before it occurs. Gauge issues can contribute to derailments. It is important to the railroads to know if there is a gauge issue before it becomes so bad it can derail a train.

Track alignment, cross level, and super elevation consistency is similarly important. If tracks exceed the FRA tolerances for any of these measurements, the lateral force they can exert on a high velocity train can create situations where a car might derail. For instance, if the super elevation of a high-speed curve has a severe deviation in the middle of the curve, cars proceeding over that deviation will be rocked as the wheels pass over the deviation. That rocking motion creates additional lateral forces between the wheels and the rail — if severe enough, the car may climb the rail.

Improper cross level can have similar effects, even on tangent track. Alignment issues will also jar a car moving along a track, and if that force is severe enough, damage can potentially occur to the car's load or the car may derail.

The future of track inspections

Railroads are constantly looking for better ways to inspect track and track structures to ensure continued operations and prevent derailments. Two methods in use now are drones and autonomous geometry cars.

[222] This will be discussed more in a later section of this chapter.

Drone technology

Both BNSF and UP have applied for and been granted licenses to use drones to inspect portions of their railways. Bridge and communications tower inspections are both popular drone inspection targets. Drones are useful because an employee does not have to inspect bridges that can be hundreds of feet in the air or towers that are hundreds of feet high.

The new high definition cameras on the drones provide an excellent digital record of the condition of many parts of the bridge that an employee would have a difficult time inspecting. The digital record of bridge inspections from one year can be compared with the digital record of the following year to determine if anything has changed from year to year. If it has, repairs can be planned to address the issue prior to it becoming serious.

BNSF has been using drones to inspect areas prone to slides, as well as inspecting retaining walls designed to prevent slides. Inspections of the hillsides between Seattle and Everett have been performed by drones. Again, the digital records from one inspection to the next can provide information as to whether the area is moving or if it is stable. (Some examples of the use of drones for inspections can be found in: Anon. 2017; Cosoff 2016; Winters 2016.)

Increased use of track geometry cars

BNSF has also increased its use of geometry cars to create databases of track inspection data. This data can be used to predict where issues are likely to surface and correct those issues before they do. BNSF has developed autonomous geometry cars that can be run without civil engineering crews, meaning they can be utilized more often to collect track geometry data.

With more data available, from more frequent inspections, the chances that a track defect will reach or exceed FRA tolerances are reduced. This reduces or eliminates the “red tag” syndrome as described previously. Instead of a defect reaching those levels, data from successive inspections can be compared, and if the section is trending towards a defect, corrective action can be taken before there is a serious issue.

Considering the discussion above of the potential impacts of track defects related to derailments, it should not be surprising that railroads are looking for every avenue possible to maximize the effectiveness of inspections. The cost of a major derailment far exceeds the cost of enhanced track inspections.

The ability of computers to collect, store, and compare the huge amount of data that is generated is an important component to the value of the increased inspections. It is unlikely that a human would be able to compare the amount of data and find the small variances that a computer is able to. It is the small trends in the variances that make this newer technology so useful.

Optimizing rail inspection frequency

Broken rails have been identified in several recent derailments involving crude oil and other flammable liquids, including Aliceville, Alabama in 2013; and Lynchburg, Virginia in 2014. There are various approaches to preventing broken rails, such as rail grinding (Zaremski and Joseph 2005), lubrication (Reddy et al. 2007), rail replacement (Schafer and Barkan 2008), and non-destructive rail defect inspection (Orringer et al. 1988, 1990; Palese and Wright 2000).

Researchers conducted a study on the prevention of derailments through the use of ultrasonic rail defect inspection, the primary non-destructive rail defect inspection technology used by U.S. railroads since the 1930s (Liu and Dick 2016). Their analysis indicated that focusing more frequent inspections on high-risk segments of track could significantly reduce overall risk of derailments for the route with a minimal increase in required resources. The researchers identified high-risk "hot spots" for CBR accidents based on population density in the vicinity of the tracks. They used a population density threshold of more than 1,000 people per square mile in designating high-risk areas.

Based on this approach, the segments of track that should be inspected more frequently in Washington would be those located in the cities shown in Table 78 for population densities of over 2,000 persons per square mile (OFM 2019). Note that not all of the communities listed in Table 78 have railroads running through or near them.

Table 78: Washington Cities with Population Densities Exceeding 2,000 per Square Mile in 2018[223]

City	County	Population (2018 est.)	Density
Seattle	**King**	730,400	8,717.9
Spokane	**Spokane**	220,100	3,141.1
Tacoma	**Pierce**	209,100	4,202.1
Vancouver	**Clark**	183,500	3,591.6
Bellevue	**King**	142,400	4,236.3
Kent	**King**	128,900	3,615.2
Everett	**Snohomish**	111,200	3,246.9
Renton	**King**	104,100	4,323.6
Federal Way	**King**	97,440	4,395.1
Spokane Valley	**Spokane**	95,810	2,507.1
Yakima	**Yakima**	94,190	3,467.4
Bellingham	**Whatcom**	88,500	2,971.2
Kirkland	**King**	87,240	4,997.3
Kennewick	**Benton**	81,850	3,092.3
Auburn	**King/Pierce**	80,615	2,698.4
Pasco	**Franklin**	73,590	2,110.2
Marysville	**Snohomish**	67,040	3,274.8
Redmond	**King**	64,050	3,689.1
Sammamish	**King**	63,470	2,693.5
Lakewood	**Pierce**	59,350	2,966.9
Shoreline	**King**	55,730	4,368.7
Olympia	**Thurston**	52,490	2,598.9
Burien	**King**	51,850	5,227.1
Lacey	**Thurston**	50,170	2,744.2
Bothell	**King/Snohomish**	45,260	3,261.3
Edmonds	**Snohomish**	41,820	4,625.1
Puyallup	**Pierce**	41,100	2,970.1

[223] Office of Financial Management – Washington State (OFM). 2019. *Population Density - Estimates of April 1 Population Density and Land Area by City and Town*. https://www.ofm.wa.gov/washington-data-research/population-demographics/population-estimates/population-density

City	County	Population (2018 est.)	Density
Lynnwood	**Snohomish**	38,260	3,780.6
Longview	**Cowlitz**	37,710	2,393.1
Issaquah	**King**	37,110	2,846.4
Mount Vernon	**Skagit**	35,180	2,774.5
Wenatchee	**Chelan**	34,530	3,434.6
Walla Walla	**Walla Walla**	34,000	2,424.6
Pullman	**Whitman**	33,730	3,090.9
University Place	**Pierce**	32,820	4,118.2
Lake Stevens	**Snohomish**	32,570	3,663.5
Des Moines	**King**	31,140	5,009.4
SeaTac	**King**	29,130	2,314.8
Maple Valley	**King**	25,280	4,131.5
Mercer Island	**King**	24,270	3,914.5
Kenmore	**King**	22,920	3,757.4
Oak Harbor	**Island**	22,780	2,332.5
Mountlake Terrace	**Snohomish**	21,560	5,413.5
Mukilteo	**Snohomish**	21,320	3,474.8
Bonney Lake	**Pierce**	20,940	2,234.8
Battle Ground	**Clark**	20,890	2,516.5
Mill Creek	**Snohomish**	20,470	4,305.4
Covington	**King**	20,080	3,013.5
Tukwila	**King**	19,800	2,156.7
Ellensburg	**Kittitas**	19,660	2,532.7
Monroe	**Snohomish**	18,860	3,303.6
Centralia	**Lewis**	17,060	2,255.3
Sunnyside	**Yakima**	16,850	2,435.0
Washougal	**Clark**	16,020	2,959.7
Lynden	**Whatcom**	14,160	2,683.1
East Wenatchee	**Douglas**	13,670	3,722.7
Lake Forest Park	**King**	13,090	3,556.1
Newcastle	**King**	12,410	2,824.4
Cheney	**Spokane**	12,200	2,805.1
Enumclaw	**King/Pierce**	11,660	2,242.7
Sedro-Woolley	**Skagit**	11,350	2,516.3
Poulsbo	**Kitsap**	10,850	2,284.0
Snohomish	**Snohomish**	10,150	2,890.3
College Place	**Walla Walla**	9,590	3,148.3
Toppenish	**Yakima**	9,090	4,260.9
Burlington	**Skagit**	9,025	2,194.6
Othello	**Adams**	8,270	2,283.7
Orting	**Pierce**	8,105	3,146.6
Milton	**King/Pierce**	7,900	3,085.6
Duvall	**King**	7,655	3,358.0
Clarkston	**Asotin**	7,205	3,460.8
Stanwood	**Snohomish**	6,835	2,275.4
Fircrest	**Pierce**	6,710	4,291.1

City	County	Population (2018 est.)	Density
Brier	**Snohomish**	6,605	2,902.4
Normandy Park	**King**	6,595	2,414.4
Steilacoom	**Pierce**	6,425	2,955.4
Wapato	**Yakima**	5,040	2,468.1
Mattawa	**Grant**	4,900	6,055.3
Granger	**Yakima**	3,945	2,355.2
Medina	**King**	3,245	2,021.8
Clyde Hill	**King**	3,045	2,025.8
Everson	**Whatcom**	2,730	2,151.6
Bridgeport	**Douglas**	2,480	3,859.1
Mabton	**Yakima**	2,315	2,960.7
Royal City	**Grant**	2,275	2,321.7
Millwood	**Spokane**	1,790	2,695.2
Kittitas	**Kittitas**	1,515	2,103.8
Nooksack	**Whatcom**	1,500	2,183.8
Yarrow Point	**King**	1,065	2,997.4
Ruston	**Pierce**	990	3,960.0
La Conner	**Skagit**	940	2,164.7
Beaux Arts Village	**King**	300	3,729.4

Mechanical inspections

Railroad mechanical fleets include cars and locomotives. Both have regulations that cover the inspection and maintenance of the individual vehicles. In addition, there are inspection regulations for initiating a train from its origin terminal as well as inspecting it as it moves on its route to destination. This section will explore these issues.

Mechanical failure on cars or locomotives can lead to a derailment. Dragging equipment, broken wheels, hot bearings, and even air brake line problems can contribute to car derailments. Engine problems or communication issues can lead to engines shutting down, which can cause in-train forces that potentially can derail cars. Inspections of engines and cars are performed to prevent this type of incident from occurring.

Locomotive inspections

Locomotives require multiple inspections over a year. There are daily inspections, 92-day inspections, and annual inspections. Each has a purpose in insuring that the locomotive is safe and running properly.

Daily inspection regulations are covered under 49 CFR § 229. This regulation describes what must be done every 24 hours to ensure the locomotive is safe to operate. Engineers are qualified to make this inspection. The daily inspection includes the following items:

- 92-day inspection card is up to date.
- Cabs, floors, and passageways are free of impediments.
- Audible warning devices (horns, bells) are working.
- Cab and instrument lights are operative.

- Speed indicator is not damaged. After departure, tests will be made to determine accuracy.
- Brake systems for the locomotive and for the air brakes are known to be working.
- If more than one locomotive, all systems shall respond to control from the cab of the controlling locomotive.
- Event recorders are accessible to the crew and have not been tampered with.
- Exhaust and battery gases are not present in the cab.
- Engine temperature and pressure alarms are working properly.
- General condition of the locomotive is safe.
- Pilots or snowplows are in place and in good order.
- Couplers and uncoupling levers are working properly.
- Jumper cables between locomotives are secure and in good condition.
- Sanders are working properly and directing sand to the rail.
- Headlights and auxiliary lights are operable, and work from the switches in the cab.
- Brake piston travel is within specifications.
- Wheels are in good condition, including looking for flat spots, shelled wheels, high/thin flange, gouges in wheel or flange, cracks or breaks in wheel or flange.
- Springs and rigging appear to be in working condition.
- Motors and generators are in working condition.
- Bearings are in working condition.

If any of these categories do not meet the specification, then it must be repaired before the locomotive is allowed to leave the terminal where the inspection is being performed.

The periodic inspection occurs every 92 days. Once completed in a shop facility, it must be certified by a shop supervisor. For example, one 92-day inspection checklist includes the following major categories: [224]

- Safety items — fire hazards, alarm systems, safety appliances, bell and horn, etc.
- Electric components — high voltage system, main generator, electrical cabinet, lights, jumper cable receptacles, traction motors, etc.
- Mechanical system - replace all filters, belts, lube oil samples, torque of engine, drain valves, all fluid levels, cooling system leaks, etc.
- Air brake system — air gauges, operational air brake test, main reservoir safety valves, check brake system.
- Trucks — inspect wheels, brake gear, hand brake chain and pulley, lubricate traction motors, check wheel journals, check sanders, uncoupling device, etc.

The final inspection discussed here is an annual inspection that must be done every 368 days.[225] However, pursuant to 49 CFR § 229.27 through § 229.141, all the specifications that are required for various locomotive components are defined and explained. The annual inspection includes many of the components of that list. It also includes testing the locomotive under load to

[224] A checklist for the 92 periodic inspection can be found at www.sterlingrail.com/files/2441_92DayInspection.pdf
[225] The specific requirements of the annual inspection could not be located in the FRA regulations.

determine that all mechanical and electrical features are working properly. There is also a heavy inspection of the air system testing the regulation compliance of the system.

The annual inspection must also be performed at a certified inspection facility and signed off on by a mechanical supervisor.

Inspection of railcars

There are no specific federal inspection regulations that specify when cars must be inspected. However, there are a number of aspects of car components that can have defects.[226] The car components that should be inspected include, but are not limited to:

- Wheels
- Axles
- Bearing box or wedge
- Roller bearing
- Freight car truck
- Couplers
- Uncoupling device
- Draft gear
- Stenciling

Freight train inspections

Once a train has been assembled in its initial terminal, it must be inspected prior to its departure. This is a primary inspection of each freight car in the train performed by certified car men working in the terminal. These terminal inspections provide a regular method to inspect railcars as they move around the network and between shippers and receivers.

Initial terminal brake test (Class I Brake Test)

The initial terminal test is called a Class I Brake Test (49 CFR § 232.205). This test is to be performed when a train is originally assembled, or when the consist is changed en route. The Class 1 brake test is not required en route if the train is picking up or setting out a single car, a solid block of cars, or is setting out a defective car. The Class I test is comprised of:

- An air leakage test — pressure at the rear of the train shall be within 15 psi of the pressure set at the head end of the train, but not less than 75 psi. Leakage shall not exceed 5 psi per minute after a 20-psi brake pipe reduction. An air flow method test can be substituted for the leakage test with newer brake valve equipment.
- While the brakes are set, an inspector shall inspect each side of each car to make sure all moving parts of the brake system are functioning, including brake piston travel. The inspection will also make sure all valves between cars are properly positioned for operation, air hoses are not kinked or fouling the track, and any other mechanical issue with the car are observed. The brakes on each car must apply correctly. Brake piston

[226] All relevant inspection regulations can be found at 49 CFR 215.103 through 215.305. Brake system requirements for cars can be found at 49 CFR 232.201 through 232.219.

travel must be within designated specifications. Brake rigging must be secured and not fouling the track or binding under the car.

- The brakes shall be released by the controlling locomotive and the pressure at the rear car shall return to within 15 psi of the pressure of the head end. After the brakes are released and the train is departing, an inspector shall "roll by" the train to make sure each brake has released. He will communicate with the head end of the train at the completion of the roll by. Cars that do not meet any of the criteria must be set out or repaired to within standard before the train may continue.

Class IA inspection and brake test

Trains must be inspected every 1000 miles. The Class IA test is the same as the Class I test at a designated inspection point (49 CFR § 232.207). However, a railroad may extend the 1000-mile requirement for inspection to 1500 miles if the train is designated as an extended haul train. The railroad must notify the FRA of the train symbol and the locations of the inspections. The train may not have more than one pick-up or set-out en route, except for setting out defective equipment. At the designated inspection location, an extended haul train will undergo a Class IA inspection and brake test.

Class II inspection and brake test

A Class II inspection and brake tests must be performed when a train has picked up a solid block of cars en route (other than the initial terminal). The same aspects of the test are performed on the block of cars and some on the train as follows (49 CFR § 232.209):

- An air leakage or air flow test is performed on the train. The same criteria as in the Class I test are utilized.
- Each car added to the train shall be inspected after a 20-psi reduction to ensure that the brakes are fully functional. All other criteria of the Class I inspection is applied to the block of cars as well; brakes set up, piston travel is within specifications, no dragging or hanging equipment.
- The brakes are released and each car picked up must be inspected to ensure that brakes fully released. The brakes at the rear of the train must also release, and the brake pipe pressure at the rear of the train is being restored.

As can be seen, a Class I and IA air test requires that each freight car on a train is inspected on both sides for working brake equipment and other potential defects. A Class II test covers inspection of a block of cars when they are picked up en route. When these tests are done properly, cars receive inspections every several days at various terminals through which they travel.

Wheels

The AAR has standards for railway wheels (Form RP-633).[227] Railways inspect and replace wheels based on measurements that they take compared against these standards. Some of the key measurements include flange thickness, flat spots, and profile.

[227] www.mid.aar.com/pdfs/Form_MD-11.pdf

The rim that protrudes around a rail car wheel is called the flange. It is this part of the wheel that is guided by the rail. It has a designated minimum thickness. When that minimum is exceeded, the wheel can derail or pick the points of a switch. Wheels are visually inspected during initial air brake tests, or when a car is in the shop for other repairs or cleaning.

Flat spots occur when a wheel is dragged because of a sticking brake. If the flat spot exceeds certain limits, the wheel must be replaced. Roll by inspections often identify wheels that may have flat spots that exceed limits, as do trackside detectors that are discussed later.

The wheel profile is how the relative flat portion of the wheel (called the tread) transitions to the flange. There are curvature requirements for the wheel tread and the transition. If the transition exceeds the standards, the wheel may “hunt” as it rolls on tangent track, which means it oscillates back and forth. This condition increases the lateral force between the wheel and the rail, which increases the possibility of it derailing at a weak point in the track structure.

Use of wayside detectors for mechanical inspections

A key prevention component in minimizing derailments is the extent to which the railroad employs monitoring equipment to detect anomalies with a train’s operation, its equipment, or other factors that could affect the safe passage of a train (Etkin et al. 2015).

The nationwide wayside detector system is a technology that allows railroads to prevent damage and accidents before they happen. Positioned along 140,000 miles of railroad in the nation, eight kinds of wayside detectors monitor the wheels of passing trains and alert rail car operators to potential defects enabling them to schedule appropriate maintenance in a safe, timely, and cost-effective manner.

Types of wayside detectors

As identified in the *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015), there are eight types of wayside detectors in operation and their functions are:

- **Acoustic Bearing Detector (TADS-ABD):** Uses acoustic signatures to assess the sound of internal bearings as well as identify those likely to fail in the near term.
- **Railway Bearing Detector (RailBAMTM):** Identifies faulty wheel bearings as trains pass by.
- **Truck Bogie Optical Geometry Inspection (TBOGI)**: Measures performance of a rail car’s axle and wheel suspension (“truck”) with laser-based monitoring system.
- **Truck Performance Detectors (TPD):** Evaluates performance of rail car suspension systems or trucks on curved track by appraising each wheel’s lateral forces at major segments of track containing four to six degrees of curvature.
- **Wheel Impact Load Detector (WILD)**: Recognizes any rail wheels worn or damaged into an out-of-round shape before they can damage the track.
- **Wheel Profile Measurement System (WPMS)**: Evaluates complete rail profile by capturing laser images and detecting worn wheel treads or flanges.

- **Hot Box Detector:** Measures the temperature of journal bearings on passing rail cars.[228]
- **Dragging Detector:** Detects loose components and dragging that occurs under freight cars.[229] (Glossary)

The detectors are spaced along routes at regular intervals to check whether a car has developed a defect as it is being moved from origin to destination.

Dragging equipment detectors are located between the rails and to the outside of the rails. If a piece of the car or brake is dragging, it will strike a detector flap, which will activate the detector. The detector will notify the train by radio that there is an issue, and the train must stop and inspect the portion of the train that the detector identifies.

Hot bearing, wheel or axle detectors measure the heat each axle of the train is giving off. A bearing that is failing or a wheel that has a sticking brake will heat up, and an infrared detector will pick up the heat profile. New detectors being implemented are acoustically based, as the bearing will emit a noise that is picked up by the detector before the bearing begins to get hot. This can find a potential defect before the infrared detector, which measures the bearing heat that is generated after it has begun to fail.

If a defect is found, the detector will contact the train and provide information as to the axle count of the defect and the side the defect is on. A crew member will check the wheel and determine if the car must be set out or if the train can continue.

Wheel impact load detectors are also acoustically based. If a flat spot on a wheel is making a pounding sound of a certain magnitude, the detector notifies the train of the axle count and the side the wheel is on. A crew member must then check the wheel to determine if the train can proceed or if the car must be set out.

An unbalanced weight detector measures how the load is sitting on the car. This detector was developed for double stack container cars; occasionally, the top container in a double stack car will shift. The detector measures the imbalanced load and contacts the train, which must stop and inspect to determine if the car can continue.

Wayside detector standards and best practices for key train routes

The USDOT, FRA, and AAR consider wayside detectors to be an important means for inspecting and assuring the safety of key trains carrying hazardous materials (Federal Register, 2015; USDOT 2014).[230] According to AAR's Recommended Operating Practices for Transportation of Hazardous Materials (AAR 2016), key trains must be equipped with roller bearings. If visual inspection cannot confirm a defect bearing as reported by a wayside detector, the train should be operated at speeds not to exceed 30 mph until passing the next detector or an

[228] There are more than 6,000 hot box detectors on 140,000 miles of track in North America.
[229] More than 1,000 dragging equipment detectors are installed on the North American freight rail network.
[230] A key train is: one tank car load of poison or toxic inhalation hazard (PIH or TIH), anhydrous ammonia (AA) or ammonia solutions; 20 carloads or intermodal portable tanks of a combination of PIH, TIH, AA, ammonia solutions, flammable gas, Class 1.1 or 1.2 explosives, and environmentally sensitive chemicals; or one or more carloads of spent nuclear fuel (SNF) or high level radioactive waste (HLRW).

inspection can take place. If a second wayside detector confirms the defect, the car must be pulled off the train.

Routes on which key trains operate — or key routes — have FRA requirements regarding wayside detectors or equivalent technology to be placed no more than 40 miles apart (AAR 2016). The wayside detector requirement is, in conjunction with inspection requirements for mainline track inspection by rail defect detection and track geometry cars, no less than twice per year. Siding track inspections are to occur at least annually.

Wayside detectors in Washington State

In Washington, BNSF Railway has an extensive distribution of wayside detectors. The advanced wayside detector system installation project was completed in Washington State as of May 2016, according to the Washington Department of Transportation (WSDOT).[231]

In the BNSF Oil Spill Contingency Plan for Washington State (BNSF 2018b), BNSF states that it has wayside detectors placed more frequently along its tracks than required by USDOT and AAR (every 40 miles), as shown in Table 79.

Table 79: BNSF Wayside Detector Placements in Washington State Rail Subdivisions with Data on the Average Mileage between Detectors and the Degree to which the Placement Exceeds the USDOT/AAR Requirement[232]

Rail Subdivision	Endpoints	Average Mileage between Detectors	Exceedance of USDOT/AAR Requirement
Lakeside	**Spokane to Pasco**	22 miles	Factor of 1.8
Fallbridge	**Pasco to Vancouver**	10 miles	Factor of 4
Seattle	**Vancouver to Seattle**	18 miles	Factor of 2.2
Scenic	**Seattle to Wenatchee**	21 miles	Factor of 1.9
Bellingham	**Everett to Bellingham**	21 miles	Factor of 1.9
Columbia River	**Wenatchee to Spokane**	23 miles	Factor of 1.7
Stampede	**Rainier to Ellensburg**	23 miles	Factor of 1.7
Yakima Valley	**Pasco to Ellensburg**	15 miles	Factor of 2.7

BNSF and UP identify the wayside detectors and other features of the various subdivisions on their mainline corridors in Washington State in their respective "Timetables" (BNSF 2018a; UP 2008). These documents provide detailed information on track conditions, including the locations of wayside detectors and critical risk areas (e.g., flash flood zones), among other data by milepost (MP) along the tracks. This information is used by engineers transiting these routes. The Timetables are updated periodically with new information.[233] Table 80 shows the most recent information on Tracking Warning Device (TWD) Wayside Detectors in the Washington Subdivisions.

[231] WSDOT. http://www.wsdot.wa.gov/projects/rail/advancedsignal/
[232] BNSF 2018b.
[233] These railroad timetables should not be confused with timetables that list the times that trains are expected to arrive and depart from stations.

Table 80: Wayside Detectors on Washington Mainline Rail Subdivisions[234]

Subdivision	Mileposts (MP) and Endpoints	Total Route Miles	Number TWDs	Average TWD Gaps (miles)	Longest Gap between TWDs (miles)	Longest Gap Mileposts (MPs)
Spokane	MP44.6–MP82.9 Rathdrum–Lakeside Jct.	38.3	16	4.74	10.2	MP60.3–MP70.5
Lakeside	MP1.1–MP147.5 Spokane–Pasco	146.4	28	4.76	7.7	MP6.1–MP13.8
Fallbridge	MP9.9–MP229.7 SP&S Jct.–Vancouver	219.8	32	7.85	17.0	MP190.8–MP207.8
Seattle	MP0.3–MP136.5 Vancouver–Seattle	136.5	14	9.75	29.5	MP57.9–MP87.4
Scenic	MP0.0–MP1661.2 King Street Station–Cashmere	155.7	34	4.41	23.9	MP1697.3–MP1721.2
Bellingham	MP0.0–MP119.3 PA Jct.–Blaine	119.6	20	4.24	16.0	MP94.3–MP110.3
Columbia River	MP1650.2–MP1481.6 Wenatchee–Latah Jct.	171.3	14	10.62	27.7	MP1580.2–MP1607.9
Yakima Valley	MP1.9–MP127.0 SP&S Jct.–Ellensburg	125.1	13	8.05	30.2	MP49.6–MP79.8
Stampede	MP0.0–MP102.6 Ellensburg–Auburn	102.6	21	4.09	16.4	MP20.5–MP36.9
Cherry Point	MP0.0–MP5.1 Custer–Arco	5.1	0	n/a	n/a	n/a
Kettle Falls	MP1476.7–MP56.5 Spokane–Valley	45.4	1	22.7	32.0	MP1476.7–MP56.5
Sumas	MP120.8–MP16.6 Nooksack–Burlington	107.4	3	35.8	67.5	MP20.9–MP88.4
UP Spokane	MP140.7–MP2.5 Eastport–BNSF Connect	138.2	3	46.07	112.10	MP114.6–MP123.2
UP Ayer[235]	MP221.0–MP343.3	170.5	4	42.63	124.2	MP343.3–MP219.1

There are no definitive studies that provide a reliable quantification of accident reduction rates with wayside detectors (McWilliams 2015). According to the AAR, since the wayside detector system was developed in 2004, the broken wheel and accident rate has dropped over 20 percent (AAR 2016).

Inspection standards in Washington State

Rail and equipment inspection standards within Washington State have to comply with the minimum standards established by CFR 49 and the FRA. In many cases, Class 1 railroad testing programs exceed FRA minimums. In Washington State, UTC track inspectors work in conjunction with Class 1 rail inspectors to identify where current and potential track conditions are. More importantly, UTC inspectors monitor track and operation conditions on Washington

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[234] Analysis by MainLine Management, Inc., based on data in BNSF and UP Timetables.
[235] UP operates on BNSF track through Spokane and is thus monitored by BNSF TWDs in Spokane area.

State short-line railroads and various industries that are rail operations private from the Class 1 rail operations.

In addition, UTC inspectors continually review the safety and road/rail conflict issues at at-grade crossing around the State, including private crossings.

Role of FRA in dictating inspection standards

The federal minimum inspection and safety requirements for track and rail equipment is contained in 49 CFR and is administered by the FRA. As such, those regulations apply to every interstate rail operation in the U.S., including all Class 1 railroads and smaller rail operations that operate interstate.

Intrastate rail operations (all within one state) are somewhat different in that FRA (49 CFR) regulations are not universally applied as requirements. However, that is where UTC and other State Rail Committees have an impact as the charters for the state agencies mandate the monitoring of safe operations of all rail operation, including those exclusively within the state.

Comparison of inspection standards with other states

There do not appear to be any significant differences between Washington State and other states regarding inspection standards for rail. FRA minimum requirements are necessary universally for all interstate traffic in the U.S. How the inspection of intrastate rail traffic is handled from state to state, along with road/rail conflict issues (public and private) is unclear.

Potential areas of future discussion

- UTC has an important role to play in monitoring Class 1 compliance with 49 CFR track and equipment requirements, safe operation of intrastate rail operations, and road/rail crossing conflict issues. The future Rail Safety Committee may wish to consider supporting UTC in its programs to enhance inspection of railroad track and equipment as appropriate.
- Future use of drones to inspect difficult areas of access to rail will increase, as will increased use of track inspection vehicles that are unmanned. The future Rail Safety Committee may wish to consider supporting UTC in its use of drones as part of its inspection regime.

Chapter 12: Crew Training and Qualification Practices

Key questions

- What types of training and certification are required for locomotive engineers and conductors?
- Who develops the standards for these training and certification processes?

Takeaways

- The FRA establishes minimum qualification standards for locomotive engineers and conductors through a certification program. FRA does not license train operators.
- FRA does not train or certify locomotive engineers and conductors. Training and certification are conducted by the railroad industry and commercial entities. These programs need to meet minimum qualification standards.
- In May 2019, FRA published a Notice of Proposed Rulemaking to establish minimum qualification standards for locomotive engineers and conductors. This rulemaking came in the aftermath of the Amtrak rail accident in Dupont, Washington.[236]

Chapter 12 in-depth

May 2019 FRA Notice of Proposed Rulemaking[237]

On May 9, 2019, the FRA issued a notice proposing to revise its regulation governing the qualification and certification of locomotive engineers to make it consistent with its regulation for the qualification and certification of conductors. The proposed changes to 49 CFR § 240 are identified in Docket No. FRA-2018-0053, Notice No. 1 and include:

1. Amending the program submission process.
2. Handling engineer and conductor petitions for review with a single FRA review board (Operating Crew Review Board or OCRB).
3. Revising the filing requirements for petitions to the OCRB. [not numbered in Docket but done here for clarity]

The proposed revisions would result in cost savings and benefits for railroads and locomotive engineers by adopting the conductor certification regulation's streamlined processes developed twenty years after the engineer certification regulation. (p. 20472)

FRA expects this rulemaking will reduce the railroad industry's overall regulatory, paperwork, and cost burden without affecting safety on the nation's railroad system and, at the same time, benefit individual locomotive engineers.

[236] This accident is discussed in Chapter 21.
[237] The text in this section comes directly from *49 CFR 240, Agency/Docket Number: Docket No. FRA-2018-0053, Notice No. 1*, with corrections for typographical errors as shown in brackets.

> FRA believes consistency in the processes, procedures and criteria between Part 240 and Part 242 will not only lead to an overall reduction in the regulatory, paperwork and cost burden on the railroad industry, but also benefit individual locomotive engineers by making the processes, procedures and requirements of the two certification systems consistent to the extent possible. (p. 20473)

The relevant sections of the federal regulations are listed below.

- 49 CFR § 240 - QUALIFICATION AND CERTIFICATION OF LOCOMOTIVE ENGINEERS
- 49 CFR § 242 - QUALIFICATION AND CERTIFICATION OF CONDUCTORS
- 49 CFR § 243 - TRAINING, QUALIFICATION, AND OVERSIGHT FOR SAFETY-RELATED RAILROAD EMPLOYEES

"The FRA is not involved in the actual certification process for individual engineers. The final rules establishing minimum qualification standards for locomotive engineers is a certification program, not a licensing program" (FRA 2012). The goal of many of the programs utilized by the railroad industry and prospective employees either through private institutions or through the individual railroads, railroad academy is to obtain the necessary training in areas like:

- Duties and responsibilities of Locomotive Engineer and Conductor
- Communication: Radio, face-to-face, fax, and phone
- Rail Operations Procedure, Safety, and Rules
- General Code of Operating Rules (GCOR) and Northeast Operating Rules Advisory Committee (NORAC)
- Hours of Service regulations
- Signal System: hand signals and train movement
- Yard switching Operations both freight and Passenger
- Hazmat Material: Class, Group, practices and handling rules

FRA Operating Practices Compliance Manual goes into the standards (FRA 2012):

> The rules require that railroads have a formal process for evaluating prospective operators of locomotives and determine that they are competent before permitting them to operate a locomotive or train. The rule requires that railroads:
>
> (1) Make a series of four determinations about a person's competency.
>
> (2) Devise and adhere to an FRA-approved training program for locomotive engineers.
>
> (3) Employ standard methods for identifying qualified locomotive engineers and monitoring their performance. (p. 16-1)

The development of engineer and conductor training standards focused on the directive and objectives assigned to the FRA with the purpose to assure that safety-related railroad employees are trained and qualified on any federal railroad safety laws, regulations, and orders the employee is required to comply with. These objectives and questions posed during the rulemakings by the FRA included:

- Develop regulations responsive to the statutory mandate.

- Establish reasonable oversight criteria to ensure training plans are effective.
- Which employees should be covered by this regulation?
- Consider criteria we should use to determine which, if any, FRA-required training programs may be exempted from the new minimum training standards.
- Establish training methodologies the regulated community should employ to ensure current employees understand which tasks are covered by Federal laws, regulations, and orders, as well as the railroad rules and procedures, which implement them.
- Should annual proficiency checks be established for all safety-related railroad employees, similar to those required for locomotive engineers and conductors? Should periodic training intervals be extended if such checks were used?
- Criteria for grandfathering current safety-related railroad employees;
- Criteria for analysis of the oversight data;
- Methodology for the submission, review, and approval process;
- How to identify and designate employees covered by the regulation;
- The oversight program (we are in the early discussion stages); and
- The type of analysis that will be required to ensure the training programs cover all Federal Railroad Safety Laws, Regulations, and Orders.

As a result of the Amtrak derailment that occurred on December 18, 2017 near DuPont Washington, the NTSB performed an intensive investigation and developed a series of recommendations, some related to crew and training:

> The National Transportation Safety Board determines that the probable cause of the Amtrak 501 derailment was Central Puget Sound Regional Transit Authority's failure to provide an effective mitigation for the hazardous curve without positive train control in place, which allowed the Amtrak engineer to enter the 30-mph curve at too high of a speed due to his inadequate training on the territory and inadequate training on the newer equipment....
>
> The following recommendations made by the NTSB were directly related to training:
>
> - Ensure operating crewmembers demonstrate their proficiency on the physical characteristics of a territory by using all resources available to them, including; in-cab instruments, signage, signals, and landmarks; under daylight and nighttime conditions; and during observation rides, throttle time, and written examinations....
> - Revise classroom and road training program to ensure that operating crews fully understand all locomotive operating characteristics, alarms and the appropriate response to abnormal conditions....
> - Require that all engineers undergo simulator training before operating new or unfamiliar equipment (at a minimum, experience and respond properly to all alarms), and when possible, undergo simulator training before operating in revenue service in a new territory and experience normal and abnormal conditions on that territory....

- Implement a formal, systematic approach to developing training and qualification programs to identify the most effective strategies for preparing crewmembers to safely operate new equipment on new territories....[238]

Potential areas of future discussion

- The Rail Safety Committee might consider inviting railroad representatives to present more detailed information about training and certification programs.

[238] See https://www.ntsb.gov/investigations/AccidentReports/Reports/RAR1901.pdf for the full NTSB report.

Chapter 13: Highway-Rail Crossing Issues

Key questions

- What kinds of highway-rail crossing safety measures exist in Washington?
- How frequently do rail crossing and trespassing fatalities and injuries occur?
- What is a "Quiet Zone" on a railroad?
- How are quiet zones designated or permitted?
- How many of these exist in Washington State and where are they located?
- How do quiet zones affect rail safety, especially rail-vehicle accident rates?
- What can be done to prevent rail suicides?
- How do the Operation Lifesaver program and other efforts at public rail safety education help in reducing rail-vehicle and rail-pedestrian accidents?

Takeaways

- There are 2,373 grade crossings in Washington State.[239] A grade crossing is a place where a roadway crosses directly over train tracks. Each year, there are about six people killed in accidents where a vehicle crosses railroad tracks. In nearly all cases, the driver of the vehicle is at fault.
- Grade crossings have different types of devices, such as signs, gates, flashing lights, and ringing bells to warn drivers and pedestrians that a train is approaching. Trains also sound their horns when approaching most crossings, except in "Quiet Zones" where communities have requested horn blowing to be eliminated.
- Too many people try to drive around the gates or other warning devices to "beat the train," which is extremely dangerous. Trains need over a mile to stop. There is an optical illusion that makes a train seem to be further away and moving more slowly than it actually is, leading people to think that they can cross safely in time.
- The Washington Utilities and Transportation Commission (UTC) has worked on increasing the level of protection and visibility at a number of the most dangerous crossings in the state. However, even with these types of improvements, people need to be educated about the dangers of crossings. Washington Operation Lifesaver is an educational program that addresses this issue.
- Each year in Washington State, there are, on average, 16 fatalities of pedestrians trespassing on railroad tracks, bridges, and trestles. There are also intentional suicides on rails. Besides education about the dangers of trespassing on rails, there are ways to make tracks more inaccessible in populated areas with different types of fencing and other barriers.

The following sections provide a more in-depth look at accidents at highway-rail grade crossings and other safety issues for vehicles and pedestrians on railroad tracks. The chapter includes

[239] Data from WSDOT. Used with permission. See Table 16 in Chapter 4 for details.

descriptions of the various types of crossing protections, and addresses safety issues related to "Quiet Zones" and pedestrian trespassing, as well as rail suicide.

Highway-rail crossing safety concerns

As discussed in Chapter 4, highway-rail (or roadway) crossings are locations at which there is a danger of serious, often fatal, accidents. Both vehicular and pedestrian accidents occur at grade crossings. Pedestrian accidents also occur due to trespassing on or near railroad tracks (railroad rights-of-way). Statistics for these accidents in Washington State are summarized in Table 81. Note that the data in Table 81, which relies on data from Washington UTC, may differ from the data in Table 90 because they are from different data sources. It is possible that there are discrepancies in records or that the definition of "injury" may differ between the two data sets. Note that there may be more injuries or fatalities than the number of accidents, because some accidents will result in multiple injuries or fatalities.

Table 81: Number of Washington Rail Crossing and Trespassing Incidents by Type of Incident (2011-2018)[240]

Year	Crossing Vehicle Collisions	Crossing Injuries	Crossing Fatalities	Pedestrian Trespass Fatalities
2011	29	4	8	22
2012	33	18	2	10
2013	20	10	4	17
2014	35	10	5	9
2015	37	7	4	23
2016	40	13	7	7
2017	40	5	10	21
2018	n/a	n/a	6	18
Average[241]	**33.4**	**9.6**	**5.8**	**15.9**

There are currently 2,373 grade crossings in Washington.[242] Crossings by county in Washington State along with the principal warning devices currently place are shown in Table 82. Of the grade crossings, 47 percent of crossings — 1,122 in all — have only a crossbuck warning device. 167 crossings have no warning device and 92 have only a stop sign.

[240] Data from Washington Utilities and Transportation Commission.
[241] Not counting 2018 for crossing vehicle collisions and crossing injuries due to the lack of data for this year.
[242] Data from WSDOT. Used with permission. See Table 16 in Chapter 4 for details.

Table 82: Grade Crossings by County in Washington State with Principal Warning Device Currently in Place[243] [244]

County	Total	No Warning Device	Other Warning Device	Cross-bucks	Stop Signs	Special Warning Device	Traffic Signals/ Wigwags/ Bells	Flashing Warning Device	Gates	Four-Quad	Quiet Zone
Adams	**47**	0	0	22	4	0	0	5	16	0	0
Asotin	**2**	0	0	0	1	0	0	1	0	0	0
Benton	**83**	3	0	25	3	0	1	10	41	0	0
Chelan	**39**	2	0	11	2	0	0	5	19	0	4
Clark	**69**	7	0	34	1	0	0	7	20	0	10
Columbia	**2**	0	0	1	0	0	0	1	0	0	0
Cowlitz	**47**	2	0	18	1	0	1	11	14	0	0
Douglas	**3**	0	0	2	1	0	0	0	0	0	0
Ferry	**23**	0	0	20	0	0	0	1	2	0	0
Franklin	**34**	2	0	17	1	0	0	2	12	0	2
Grant	**78**	3	0	38	4	0	0	12	21	0	0
Grays Harbor	**69**	2	0	29	6	0	2	8	22	0	0
King	**358**	69	3	151	9	0	6	39	79	2	4
Kitsap	**9**	0	0	4	0	0	0	1	4	0	0
Kittitas	**23**	1	0	8	4	0	0	3	7	0	0
Klickitat	**11**	0	0	5	0	0	0	2	4	0	1
Lewis	**81**	3	1	32	3	0	0	6	36	0	0
Lincoln	**97**	0	0	69	1	0	0	3	24	0	0
Mason	**24**	0	0	10	3	0	0	4	7	0	0
Okanogan	**26**	2	0	9	1	0	0	6	8	0	0
Pend Oreille	**26**	0	0	18	2	0	0	5	1	0	0
Pierce	**191**	7	0	80	5	2	2	36	59	0	0
Skagit	**72**	0	0	20	2	0	0	5	45	0	4

243 FRA data.
244 Data from WSDOT. Used with permission. See Table 16 in Chapter 4 for details.

County	Total	No Warning Device	Other Warning Device	Cross-bucks	Stop Signs	Special Warning Device	Traffic Signals/ Wigwags/ Bells	Flashing Warning Device	Gates	Four-Quad	Quiet Zone
Skamania	**8**	0	0	1	0	0	0	4	3	0	1
Snohomish	**70**	3	0	12	1	0	0	6	48	0	1
Spokane	**200**	4	0	92	9	0	2	15	78	0	2
Stevens	**56**	1	0	36	1	0	0	5	13	0	0
Thurston	**82**	3	0	38	6	0	0	16	19	0	0
Walla Walla	**89**	3	0	64	3	0	1	14	4	0	0
Whatcom	**85**	1	0	29	4	0	0	6	45	0	1
Whitman	**119**	1	0	98	0	0	2	14	4	0	0
Yakima	**250**	48	0	129	14	0	4	14	41	0	0
Total	**2,373**	**167**	**4**	**1,122**	**92**	**2**	**21**	**267**	**696**	**2**	**30**

Standard grade crossing protection

Grade crossing incidents are in large part out of the control of the railways. Railways cannot control individual drivers that ignore warning lights or gates, or inattentive drivers that stop on a crossing even as a train is approaching. As described in Chapter 4, grade crossings contribute to accidents and potential derailments.

Unintentional trespassing (e.g., entering tracks or dangerous sections of rail rights-of-way) may be prevented by effective barriers and warning systems that deter errors made by pedestrians or by vehicle drivers (Burkhardt et al. 2014).

Railways have tried to improve grade crossing protection devices to minimize the potential for incidents. To understand how this has been done, a basic overview of how grade crossing protection works is necessary. There are four basic types of grade crossings:

- Passive system
- Basic active warning system
- Motion sensor system
- Predictor system

Passive system

In a passive system, the crossing is identified by a stop sign or crossbuck. The passive system approach relies on the vehicle driver or pedestrian to take the initiative to "stop, look, and listen" before proceeding safely. This type of crossing is generally used at very lightly used grade crossings, either by highway traffic or by rail traffic, or at private grade crossings (farm roads, driveways or business entrances). Crossbuck signs are often used in conjunction with advance warning signs.

Basic active warning system

Active warning systems include flashing lights and bells and may include gates that come down to block the highway. An older form of active warning system, a wigwag (also called a magnetic flagman), has largely been replaced by flashing lights, but may be present in some locations.

The actions of a driver or pedestrian are different in that they are warned that a train is approaching. The driver or pedestrian must then take the appropriate action to stop and not attempt to evade the warning by bypassing or crossing through the crossing thereby risking a collision.

For the basic type of system, there is a circuit established a specific distance from the crossing in both directions (called the approach circuits), with a circuit around the crossing itself (called an island circuit). The distance the approach circuits are from the crossing is determined by the fastest train that uses the route and the desired warning time for the crossing protection. The island circuit is usually located between 50 and 100 feet on both sides of the crossing.

Under this system, when a train fouls or touches the approach circuit, the crossing protection is activated and remains active until the rear of the train leaves the island circuit on the other side of the crossing. The speed of the train does not matter — if the train is moving 60 mph or 20 mph, the protection is activated when the train is in the circuit.

The problem with this type of circuit is that while a 60-mph train may activate the crossing protection 30 seconds prior to the train entering the crossing, a 30-mph train will activate the protection one full minute prior to entering the crossing. For slower trains, the activation time is even longer. Additionally, a stopped train will leave the crossing protection activated until it leaves the approach circuit and clears the island circuit. This can lead to accidents if drivers or pedestrians choose to bypass the signal and cross the tracks.

Motion sensor system

A motion sensor system has two approach circuits and an island circuit, similar to the basic active warning system. In a motion sensor system, however, the crossing signal's electronic circuitry measures the voltage in both approach circuits. Once a train has fouled or touched one of the circuits as it approaches the crossing, the voltage of the circuit drops. The electronics of the crossing recognizes the drop in voltage, and activates the grade crossing protection. Once the train enters the island circuit, the circuit voltage becomes zero because the train is causing a dead short of the circuit. As the train clears the island circuit and moves away from the crossing in the opposite approach circuit, the voltage starts to climb again. The electronics recognize the increase in voltage, and the grade crossing protection is turned off. The advantage of a motion sensor type of circuit is that if a train stops on the approach to the crossing, the voltage quits declining and stays at a constant level. If the voltage remains constant for more than 10 seconds, the circuitry allows the warning protector to stop operating. In other words, the lights quit flashing and the gates recover to the upright position. Once the train begins to move towards the crossing again, the voltage starts to decline and the gates and flashers are reactivated. If the stopped train reverses its direction and moves away from the crossing, the voltage begins to increase and the gates and flashers do not reactivate.

The motion sensor grade crossing circuit suffers from the same issue as the basic sensor. Once a train enters the approach circuit, as long as it is proceeding towards the crossing, the gates and flashers remain activated. So again, while a 60-mph train may create a 30-second warning, a 30-mph train will create a one-minute warning activation before the train enters the crossing.

Predictor system

The final type of crossing circuitry is a predictor system (also called a constant warning time circuit). In a predictor system, the desired gate warning time is set to a constant time (for example, 30 seconds). Under this system, when a train enters the approach circuit, the crossing electronics calculate the slope of the decline of the voltage as the train approaches. Once the slope is acquired, the electronics can calculate how long the activation of the gates and flashers must be delayed to meet the desired activation time.

With this type of system, a 60-mph train would activate the crossing almost immediately after entering the approach circuit. However, a 30-mph train would create a situation where the electronics would delay activation until the train was halfway through the approach circuit before activating the gates and flashers. This would create a relatively constant warning time for both trains, regardless of their speeds.

The predictor system also has the electronics that determine if a train stops within the approach circuit or if it reverses and moves away from the crossing. Under both of these circumstances, after 10 seconds, the gates would be allowed to recover to their upright position so the highway crossing would no longer be blocked.

Studies have been conducted that showed motorists who have to wait longer than 50 seconds are more prone to run the crossing protection after that amount of time. In a 2008 study conducted by the FRA, it states (FRA 2008):

> To obtain more data, Bowman conducted a field study in which he observed driver behavior at 12 grade crossings, half that were equipped with constant warning time systems and half with fixed-distance systems. Half of these sites were equipped with flashing lights only, and the other with flashing lights and gates. The field analysis showed significant reductions in violations at crossings protected with constant warning time systems. Most of the violations occurred when the warning time was greater than 50 seconds, even at gated crossings. At flashing light crossings, violations increased when the warning time exceeded 35 seconds" (p. 38).

This is where the predictor system has a distinct safety advantage over the basic or motion detector system. Whereas with the basic or motion detector systems, a slow train can create long activation times that might incentivize a motorist to attempt to run through the crossing, a predictor system can be set at an activation time for varying train velocities for which most motorists will wait.

Constant warning time systems are being utilized in most new crossings and are upgrades for older crossings. They are also required for Quiet Zone crossings. This is one way that the railroads are attempting to improve safety at grade crossings.

Effectiveness of crossing warning systems

Since the consequences of highway-rail crossing accidents are so high (e.g., human injuries and fatalities) various agencies and researchers have conducted studies aimed at determining the effectiveness of different types of systems and programs. The studies focus mainly on human factors: driver (or pedestrian) behavior, perceptions, and decision-making, and their interaction with the various types of technology and approaches used as crossing warnings.

Comparison of different types of warnings

The Federal Highway Administration (FHA) reviewed a number of studies and concluded that upgrading passive warning systems to active warning systems improves safety, as shown in Table 83 (FHA 2007).

Table 83: Effectiveness of Active Crossing Warning Devices in Terms of Percent Reduction in Accidents[245]

Crossing Warning Upgrade Type	Range of Effectiveness (Percent Reduction in Accidents)
Passive System to Flashing Lights	63% to 70%
Passive System to Automatic Gates	83% to 96%
Flashing Lights to Automatic Gates	66% to 69%

This is supported by a survey of professional drivers (Benekohal and Aycin 2004) that provided ratings of the effectiveness of different types of crossing warning systems (where 5 meant "very high effectiveness" and 1 meant "very low effectiveness"):

- Crossing gates (rated 4.7)
- Flashing lights (rated 4.5)
- Clanging bells (rated 3.5)
- Train horns (rated 3.3)
- Crossbuck signs (rated 3.1)
- Advance warning signs (rated 3.0)

If it is not practical to install an active system, there are still modifications that can be made to improve safety at a passive crossing. Train-vehicle collisions at passive crossbuck crossings can be reduced by the addition of a stop sign and advance warning signs, especially if there is insufficient sight distance for drivers to see approaching trains (Yan et al. 2010).

Driver behavior issues

It is important to recognize that drivers have different driving behaviors on approaching typical active crossings (with gates and/or red flashing lights) and passive crossings. Unusual traffic control devices used in the vicinity of railroad grade crossings, such as stop signs and traffic light signals, should be implemented carefully to avoid confusion to drivers (Jeng 2005). Driver education manuals and training should include sections about railroad crossing devices and safe driving practices at crossings to familiarize drivers with the various types of crossing warning systems and enhance safe driving practices (Jeng 2005).

However, driver education programs may not be as effective as might be assumed. In an earlier study conducted for the Minnesota Department of Transportation (Stackhouse 1997), researchers found no evidence that additional education programs or public awareness campaigns had any lasting effect on the frequency of grade crossing accidents. They also found no evidence that bigger or brighter or other modifications of traditional crossing signs or signals led to any favorable changes in drivers' behaviors at grade crossings.

The commonly accepted reasons for drivers' involvement in grade crossing accidents are: inattention, inappropriate speed, unnecessary risk-taking, and disregard for signals and signs. However, one researcher for the Minnesota Department of Transportation (Stackhouse 1997) cautioned that, "drivers should not be treated as reckless, inattentive speeders. Instead, they should be considered decision makers who use information of limited quantity and quality

[245] US DOT FHA 2007.

against a background of knowledge shaped primarily by their experience of trains rarely appearing when they cross."

When drivers see a train in the distance, they must use the information at hand in deciding whether or not to cross the tracks. This involves the perceived distances of the train and the vehicle to the crossing and train speed. The problem is complicated by optical illusion of large objects. It is nearly impossible to properly assess the speed of a large object moving towards a person. A train moving looks as though it is barely moving, much like an airplane landing looks as though it is nearly stationary even though it is obvious to the viewer that must be moving in excess of 100 mph. The train could be much closer than it seems and/or it could be moving much more quickly than it seems.

Another problem with drivers' perceptions is that they explicitly or tacitly realize that an accident at a particular crossing is extremely unlikely. According to the FHA study (Lerner 1990), at an average crossing, a driver could safely cross twice a day for 15 years even if the driver could only see or hear what is on the pavement directly in front of him.

Drivers are also often unaware that it takes a greater distance to stop a train than a vehicle, even a large truck. In one study, researchers found that 45 percent of drivers believed that when a train engineer saw vehicles crossing the tracks that they should slow or stop the train (Richards and Heatherington 1988), not realizing that it may be impossible for the engineer to do so.

With these challenges, other approaches may be needed to reduce crossing accidents (Stackhouse 1997). One approach suggested by researchers is to use available sensor-processor-message display technology, configured in a way to promote improved driver decision making. These signs would give more specific information, such as "A TRAIN IS AT THE INTERSECTION. SLOW AND STOP," "A TRAIN WILL BE AT THE CROSSING BEFORE YOU WILL. SLOW AND STOP," or "IT IS SAFE TO CROSS THE TRACKS." The round railroad crossing signs could be enhanced with a more attention-getting sign, such as "TRAINS KILL. TRAIN TRACKS IN 1,000 FEET."

One of the issues that has been raised about these types of signs is liability in the event that the electronically-presented message is not functioning properly. If drivers are expecting a sign that says "TRAIN APPROACHING," the absence of such a message may be interpreted as the absence of a hazard, when this might not be the case. This type of system would require redundancy and fail-safe measures.

Quiet Zones

Federal railway regulations require trains to whistle at grade crossings to warn vehicle drivers of the approaching train. Recently, however, new guidelines have been published to allow the railways to not have to whistle when approaching grade crossings in certain areas. These types of crossings are called Quiet Zones. Their design is more restrictive than regular grade crossings.

The federal requirements for establishing a new Quiet Zone (QZ) are described in *49 CFR Appendix C to Part 222, Guide to Establishing Quiet Zones*. FRA has established several approaches that may be taken in order to establish a new Quiet Zone under this rule:

Requirements for public authority designation and application

1. The public authority must provide a written Notice of Intent to the railroads that operate over the proposed quiet zone, the State agency responsible for highway and road safety, and the State agency responsible for grade crossing safety...
2. Determine all public, private, and pedestrian grade crossings that will be included within the quiet zone. Also, determine any existing grade-separated crossings that fall within the quiet zone...
3. Ensure that the quiet zone will be at least one-half mile in length...
4. A complete and accurate Grade Crossing Inventory Form must be on file with FRA for all crossings (public, private, and pedestrian) within the quiet zone...
5. Every public crossing within the quiet zone must be equipped with active warning devices comprising both flashing lights and gates. The warning devices must be equipped with power out indicators. Constant warning time circuitry is also required unless existing conditions would prevent the proper operation of the constant warning time circuitry...
6. Private crossings must have cross-bucks and “STOP” signs on both approaches to the crossing...
7. Each highway approach to every public and private crossing must have an advance warning sign that advises motorists that train horns are not sounded at the crossing, unless the public or private crossing is equipped with a wayside horn...
8. Each pedestrian crossing must be reviewed by a diagnostic team and equipped or treated in accordance with the recommendation of the diagnostic team.

New Quiet Zones — Public Authority Designation

a. One or more Supplement Safety Measures (SSMs) as identified in Appendix A are installed at each public crossing in the quiet zone; or
b. The Quiet Zone Risk Index is equal to, or less than, the Nationwide Significant Risk Threshold without SSMs installed at any crossings in the quiet zone; or
c. SSMs are installed at selected crossings, resulting in the Quiet Zone Risk Index being reduced to a level equal to, or less than, the Nationwide Significant Risk Threshold; or
d. SSMs are installed at selected crossings, resulting in the Quiet Zone Risk Index being reduced to a level of risk that would exist if the horn were sounded at every crossing in the quiet zone.[246]

The process that public authorities follow to establish Quiet Zones are summarized in Figure 61.

[246] https://www.law.cornell.edu/cfr/text/49/appendix-C_to_part_222

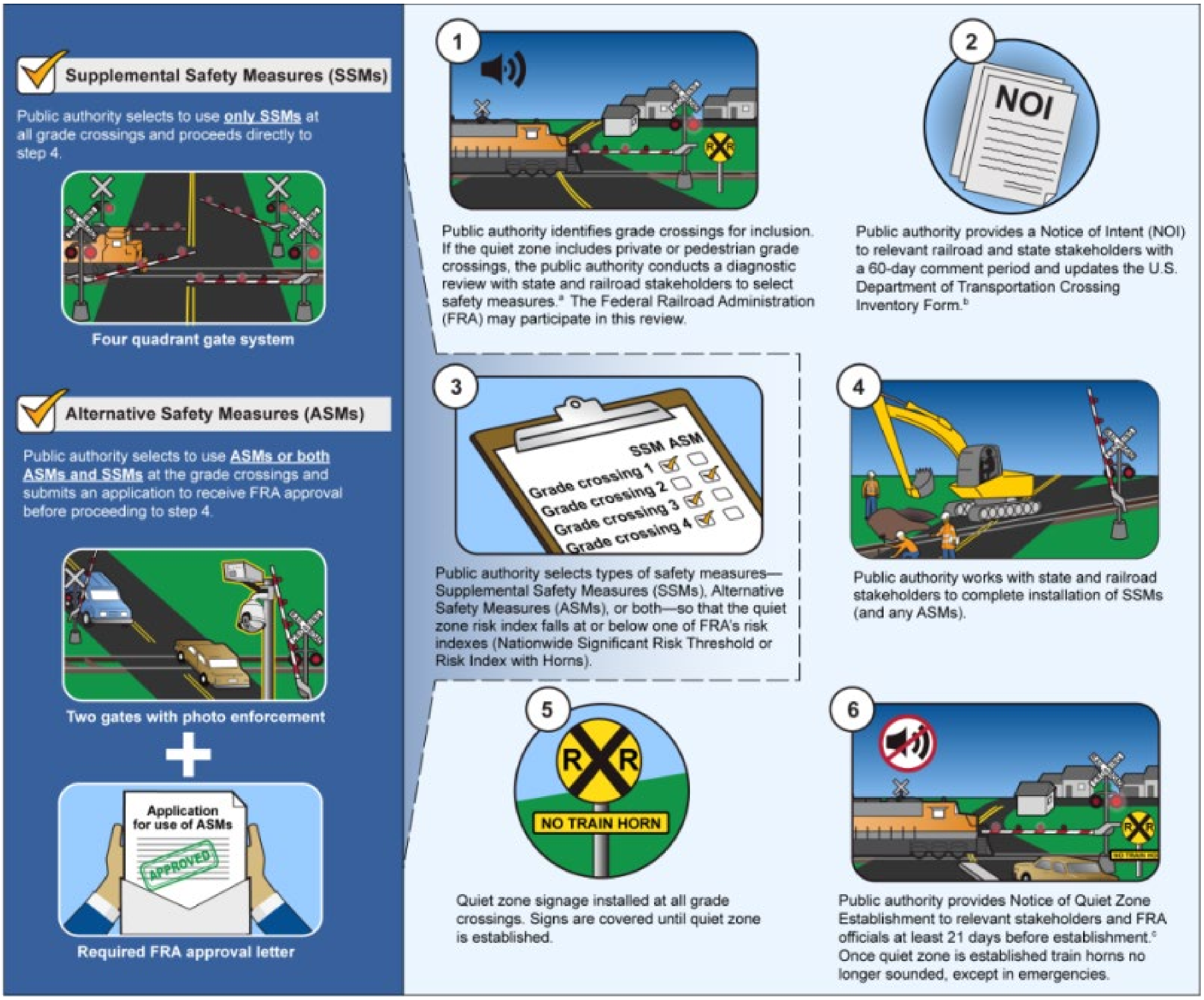

Figure 60: Process Public Authorities Follow to Establish Quiet Zones[247]

The approved SSMs required for a Quiet Zone (QZ) crossing, as presented in 49 CFR Appendix A to Part 222:[248]

1. Temporary Closure of a Public Highway-Rail Grade Crossing: Close the crossing to highway traffic during designated quiet periods. (This SSM can only be implemented within Partial Quiet Zones.)
2. Four-Quadrant Gate System (Figure 62): Install gates at a crossing sufficient to fully block highway traffic from entering the crossing when the gates are lowered, including at least one gate for each direction of traffic on each approach.

[247] GAO 2017.
[248] Appendix A to Part 222 - Approved Supplementary Safety Measures (49 CFR Appendix A to Part 222, Approved Supplemental Safety Measures)

Figure 61: Quiet Zone Crossing with Four Quadrant Gates[249]

Four-quadrant gate systems shall conform to the standards for four-quadrant gates contained in the MUTCD and shall, in addition, comply with the following:

a. When a train is approaching, all highway approach and exit lanes on both sides of the highway-rail crossing must be spanned by gates.
b. Crossing warning systems must be activated by use of constant warning time devices unless existing conditions at the crossing would prevent the proper operation of the constant warning time devices.
c. Crossing warning systems must be equipped with power-out indicators.
d. The gap between the ends of the entrance and exit gates (on the same side of the railroad tracks) when both are in the fully lowered, or down, position must be less than two feet if no median is present. If the highway approach is equipped with a median or a channelization device between the approach and exit lanes, the lowered gates must reach to within one foot of the median or channelization device.
e. “Break-away” channelization devices must be frequently monitored to replace broken elements.

[249] Image credit: Eric Lyman. Used with permission.

Figure 62: Quiet Zone Crossing with Median[250]

3. Gates with Medians or Channelization Devices (Figure 63): Install medians or channelization devices on both highway approaches to a public highway-rail grade crossing denying to the highway user the option of circumventing the approach lane gates.
   a. Opposing traffic lanes on both highway approaches to the crossing must be separated by either: (1) medians bounded by non-traversable curbs or (2) channelization devices.
   b. Medians or channelization devices must extend at least 100 feet from the gate arm, or if there is an intersection within 100 feet of the gate, the median or channelization device must extend at least 60 feet from the gate arm.
   c. Intersections of two or more streets, or a street and an alley, that are within 60 feet of the gate arm must be closed or relocated. . . .
   d. Crossing warning systems must be activated by use of constant warning time devices unless existing conditions at the crossing would prevent the proper operation of the constant warning time devices.
   e. Crossing warning systems must be equipped with power-out indicators...

[250] Image credit: Eric Lyman. Used with permission.

   f. The gap between the lowered gate and the curb or channelization device must be one foot or less, measured horizontally across the road from the end of the lowered gate to the curb...
   g. "Break-away" channelization devices must be frequently monitored to replace broken elements...
4. One Way Street with Gate(s): Gate(s) must be installed such that all approaching highway lanes to the public highway-rail grade crossing are completely blocked.
   a. Gate arms on the approach side of the crossing should extend across the road to within one foot of the far edge of the pavement. If a gate is used on each side of the road, the gap between the ends of the gates when both are in the lowered, or down, position must be no more than two feet.
   b. If only one gate is used, the edge of the road opposite the gate mechanism must be configured with a non-traversable curb extending at least 100 feet.
   c. Crossing warning systems must be activated by use of constant warning time devices unless existing conditions at the crossing would prevent the proper operation of the constant warning time devices.
   d. Crossing warning systems must be equipped with power-out indicators.

Analysis of safety in Quiet Zones

There are few formal studies that analyze the safety of Quiet Zones compared with standard grade crossings. There are two studies conducted by the FRA Office of Railroad Safety Grade Crossing Division (FRA 2011, 2014; Ries 2014).

Both studies found there was no statistical difference between crossing incidents that occurred before, and after Quiet Zones were established. FRA concluded, "No significant difference in collisions before and after the establishment of quiet zones; overall, pre-rule or new and by year except for the latest year–unexplained and will need further analysis" (Ries 2014).

However, a 2017 General Administration Office (GAO 2017) report found that the benefits of quiet zones — i.e., highway-rail grade crossings (Grade Crossings) where train horns are not sounded — have not been quantified and that the costs to establish quiet zones vary. The FRA's train horn regulations allow public authorities (e.g., cities or towns) the opportunity to establish quiet zones if they install safety measures that reduce risks associated with the absence of the train horn (Figure 64). While GAO did not identify any research that has quantified the benefits of quiet zones, most stakeholders GAO interviewed said that these quiet zones provide benefits to communities, such as reducing noise or increasing economic development. According to FRA guidance, the factors that affect the costs to establish quiet zones can vary based on the number of grade crossings and types of safety measures used. Public authorities, which typically incur the costs and receive the benefits of quiet zones, must therefore decide whether the benefits of quiet zones exceed the costs.

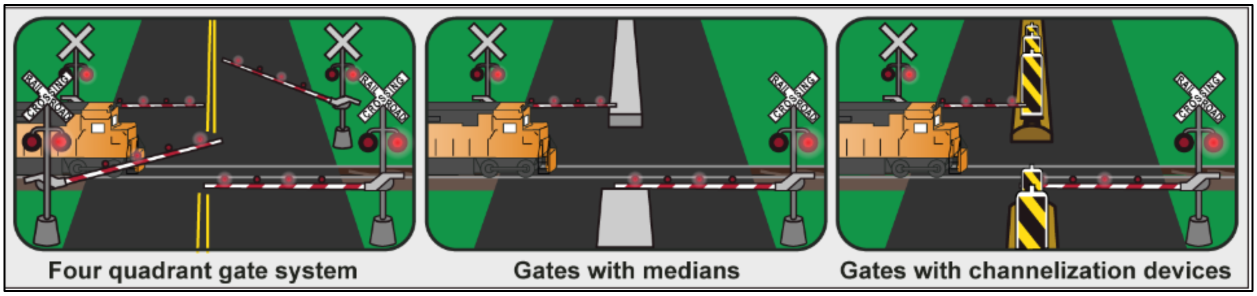

Figure 63: Examples of FRA Approved Quiet Zone Safety Measures[251]

To evaluate the effectiveness of its train horn regulations, FRA has analyzed data on grade crossings in quiet zones and is transitioning to a formal process for inspecting quiet zones (FRA 2011, 2014). FRA's analyses showed that grade crossings in quiet zones were generally as safe as they were when train horns were sounded. However, these analyses did not control for changes to grade crossings' characteristics over time — e.g., train speeds or frequency. Such changes may decrease the reliability of the analyses. A revised methodology that accounts for these changes could provide FRA with better information on the long-term effects of the train horn regulations, including the safety of quiet zones.

While the FRA report may have weaknesses in its analysis, there are two issues that support the conclusion that Quiet Zones are as safe as standard crossings. Both relate to the requirements to establish Quiet Zone crossings:

- All Quiet Zone crossings require gates and flashers that utilize predictive (constant time) circuitry. This means all Quiet Zone crossings will have active warning barriers to highway traffic that will be activated for approximately the same length of time whether the approaching train is moving quickly or slowly. Standardizing the warning wait time for motorists at all Quiet Zone crossings should minimize the number of drivers that are tempted to run the crossing because the train is taking too long to reach the crossing.
- The Standardized Safety Measures (SSM) mentioned in Appendix A of the FRA report also should minimize the number of drivers attempting to run the crossing while the protection is activated. All four scenarios described in Appendix A of the FRA report essentially cut off possible methods to get around the active gates. Short of just ignoring the gate and running through it, a Quiet Zone crossing does not provide a route that a vehicle can take to get to the tracks once the gates have been activated.

If a driver does take excessive evasive action to go around or through a gate at a Quiet Zone crossing, the train operator still has the available tool of using the horn to warn the motorist. It seems likely that a driver motivated to run through a crossing that includes Quiet Zone SSMs would not be stopped by a standard crossing either. In both cases, the engineer of the train would be able to whistle freely at the motorist in an attempt to get them to stop short.

[251] GAO 2017.

Quiet Zone locations in Washington

The following Quiet Zone crossings in Washington State are identified in BNSF's 2018 Timetable as:

- Bellingham Sub - Bellingham - Yacht Club Rd. (Milepost 89.39)
- Columbia River Sub - Wenatchee - Orondo St., Worthern St., 5th St UC, 9th St. North Miller St., Hawley St. (Mileposts 1,650.40 to 1,652.36)
- Fallbridge Sub - White Salmon - S. Dock Grade Rd (Milepost 74.20)
- Stevenson - Russell Ave. (Milepost 53.89)
- Washougal - 32nd St., 24th St., 20th St., 6th St., 3rd St.
- Vancouver - SE 164th Ave, SE 147th Ave, MP18.32 Private Xing, SE 139th Ave, Chelsea Dr., Wintler
- Lakeside Sub - Connell - E Adams St, Clark St.
- Scenic Sub - Mukilteo - Mount Baker Ave.
- Seattle - Broad St., Clay St., Vine St., Wall St.
- Seattle Sub - Tacoma - McCarver St.
- Steilacoom - Sunnyside Pedestrian Crossing, Union Ave.
- Spokane Sub - Spokane Valley - University Rd.

Grade crossing accidents in Washington State

There are currently 2,187 grade rail crossings in Washington State. In the last 25 years, there have been 1,218 accidents at these crossings — 1,137 involving vehicles and 81 involving pedestrians at 734 crossings. There was a decrease in the numbers of vehicle-related accidents — about 25 percent since the 1990s — but it has leveled off.

Between the years 1993 through 2018, grade crossing accidents in Washington State resulted in the deaths of 133 persons, and injuries to 301 persons (Table 84 and Figure 65), including crossing users (vehicles and pedestrians), railroad employees, and train passengers. Note that there may be more injuries or fatalities than the number of accidents, because some accidents will result in multiple injuries or fatalities.

Table 84: Deaths and Injuries of Crossing Users, Rail Employees, and Rail Passengers in Accidents at Grade Crossings in Washington, 1993–2018[252]

Year	Crossing Users Killed	Rail Employees Killed	Rail Passengers Killed	Total Killed	Crossing Users Injured	Rail Employees Injured	Rail Passengers Injured	Total Injured
1993	5	0	0	**5**	15	1	0	**16**
1994	4	0	0	**4**	18	3	0	**21**
1995	4	0	0	**4**	21	0	0	**21**
1996	6	0	0	**6**	18	0	0	**18**
1997	7	0	0	**7**	19	1	0	**20**
1998	6	0	0	**6**	5	0	0	**5**
1999	3	0	0	**3**	8	1	0	**9**
2000	1	0	0	**1**	9	1	0	**10**
2001	5	0	0	**5**	7	0	0	**7**
2002	2	0	0	**2**	5	2	1	**8**
2003	6	0	0	**6**	10	0	0	**10**
2004	4	0	0	**4**	10	1	0	**11**
2005	6	0	0	**6**	11	2	1	**14**
2006	7	0	0	**7**	11	0	0	**11**
2007	6	0	0	**6**	12	4	0	**16**
2008	5	0	0	**5**	5	1	0	**6**
2009	2	0	0	**2**	4	1	0	**5**
2010	5	0	0	**5**	11	2	0	**13**
2011	8	2	0	**10**	9	1	0	**10**
2012	2	0	0	**2**	13	1	4	**18**
2013	4	0	0	**4**	7	0	0	**7**
2014	5	0	0	**5**	7	0	1	**8**
2015	6	0	0	**6**	7	2	0	**9**
2016	5	0	0	**5**	12	0	3	**15**
2017	11	0	0	**11**	4	0	0	**4**
2018	6	0	0	**6**	9	0	0	**9**
Total	**131**	**2**	**0**	**133**	**267**	**24**	**10**	**301**

[252] Data from Federal Railroad Administration (FRA).

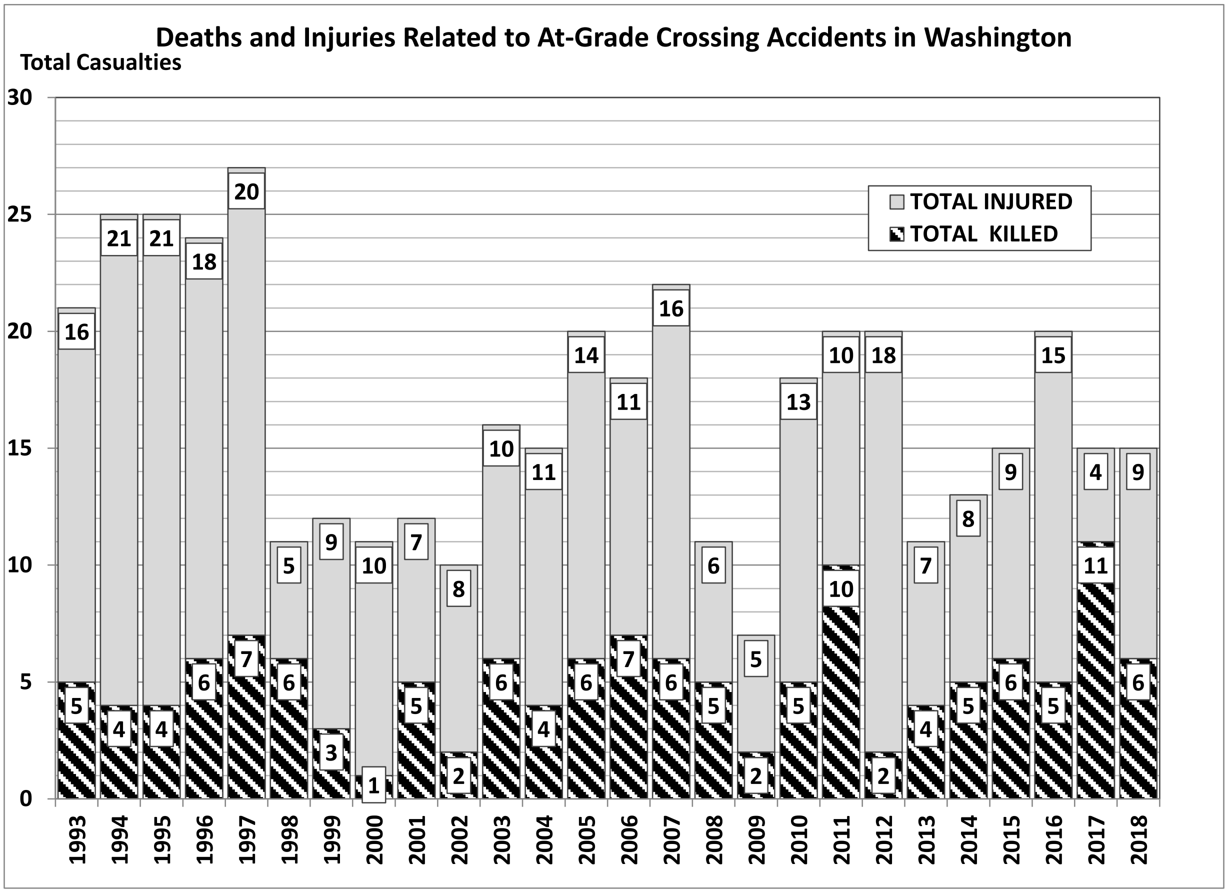

Figure 64: Deaths and Injuries Related to At-Grade Crossing Accidents in Washington State, 1993–2018[253]

One third of the grade crossings in the state have had accidents, and 229 have had more than one accident (Figure 66 and Table 85). The grade crossings that had five or more accidents in the last 25 years are detailed in Table 86. Note that there may be more injuries or fatalities than the number of accidents, because some accidents will result in multiple injuries or fatalities.

[253] Data from Federal Railroad Administration (FRA). Graph created by Environmental Research Consulting. Used by permission.

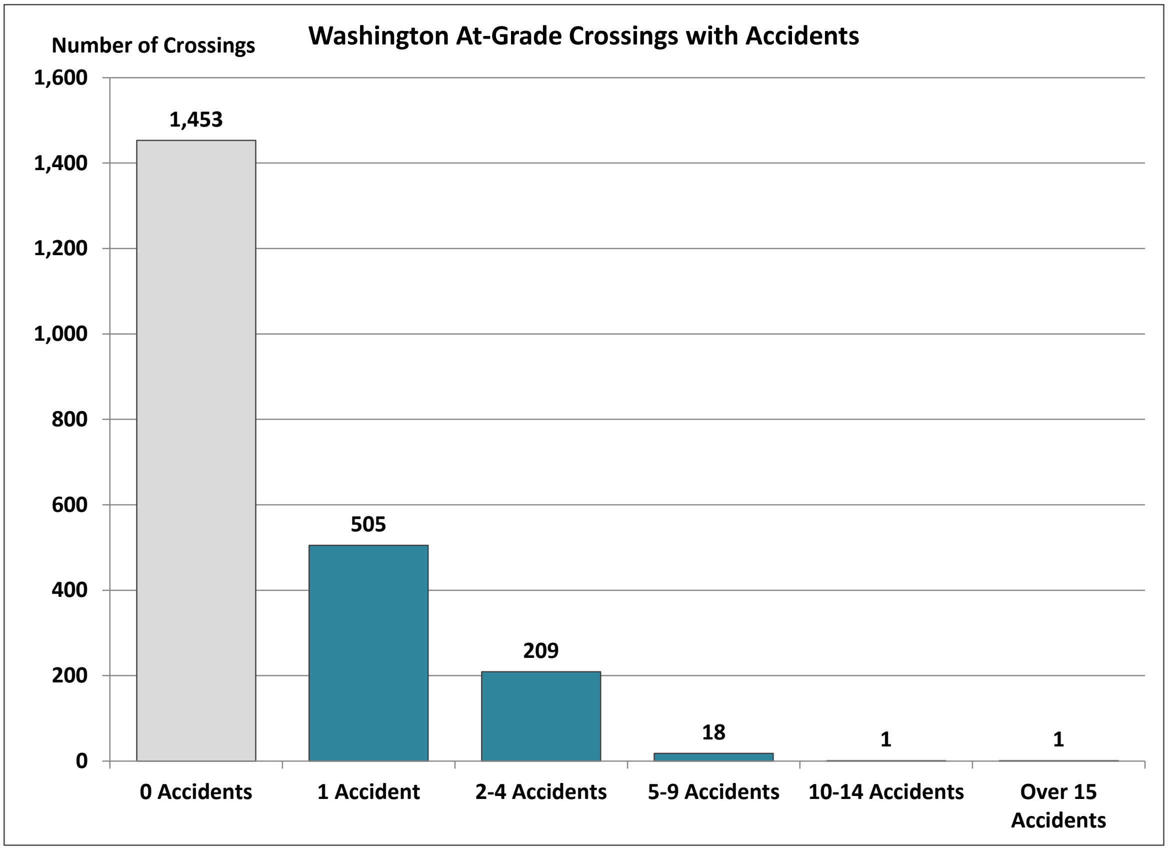

Figure 65: Washington State At-Grade Crossings with Accidents[254]

Table 85: Washington State At-Grade Crossings with Accidents[255]

Number of Accidents	Number of Crossings
0 Accidents	1,453
1 Accident	505
2–4 Accidents	209
5–9 Accidents	18
10–15 Accidents	1
Over 15 Accidents	1

[254] Data from Federal Railroad Administration (FRA).
[255] Data from Federal Railroad Administration (FRA).

Table 86: Washington State At-Grade Crossings with Most Accidents, 1993–2018[256]

USDOT Crossing ID	Location[257]	Latitude	Longitude	Accident Numbers	Deaths	Non-Fatal Injuries
096445R	E. Marginal Way, Seattle	47.5706210	-122.3396720	17 vehicular	17	2
101339W	Royal Brougham, Seattle	47.5920444	-122.3306793	7 vehicular, 3 pedestrians	5	6
085416A	Galer Street, Interbay, Seattle	47.6325990	-122.3394010	9 vehicular	8	1
101039H	Atlantic Street, Seattle	47.5926020	-122.3292010	8 vehicular	8	0
085633A	Smith Street, Kent	47.3831567	-122.2330888	5 vehicular, 2 pedestrians	6	6
085691V	15th Avenue SE, Puyallup	47.1888753	-122.2740920	6 vehicular, 1 pedestrian	9	1
101128A	Royal Brougham, Seattle	47.5926020	-122.3292010	7 vehicular	6	1
085613N	SW 43rd Street, Kent	47.4411840	-122.2409730	6 vehicular	5	4
085629K	James Street, Kent	47.3867047	-122.2331250	4 vehicular, 2 pedestrians	8	1
085661D	C Street SW, Auburn	47.2948490	-122.2319730	6 vehicular	6	0
085696E	Meridian Street, Tacoma	47.1923856	-122.2937380	2 vehicular 4 pedestrians	6	1
090072Y	Beach Drive, Vancouver*	45.6131558	-122.6088079	6 vehicular	12	0
809513N	S. Lucille St/8th Avenue, Seattle	47.5533600	-122.3216770	6 vehicular	6	0
809515C	Corson Avenue S, Seattle	47.5514710	-122.3202220	6 vehicular	6	0
066394B	Havana Street, Spokane	47.6673164	-117.3468972	5 vehicular	5	0
085414L	Broad Street, Interbay, Seattle*	47.6145757	-122.3538231	4 vehicular, 1 pedestrian	5	0
085730J	McCarver Street, Tacoma	47.2755522	-122.4652872	3 vehicular, 2 pedestrians	5	1
098592K	Edison Street, Sunnyside	46.3238690	-119.9940150	5 vehicular	5	0
809712R	E. Marginal Way S., Seattle	47.5690760	-122.3397290	5 vehicular	5	0
852612Y	Milwaukee Way, Tacoma	47.2560750	-122.4056720	5 vehicular	3	2

[256] Data from Federal Railroad Administration (FRA).
[257] Crossings with asterisk (*) are designated Quiet Zones.

The FRA Office of Safety Analysis Highway-Rail Crossing Safety & Trespass Prevention has a Web Accident Prediction System (WBAPS) model that is applied to determine the probability of highway-rail accidents at each grade crossing. For the most recent data available (the calendar year 2017), the top 20 grade crossings with the highest accident rates are shown in Table 87. Note that the crossing with the highest accident rate in 2017 at Port of Tacoma is predicted to have an accident once every other year.

Table 87: Predicted Accidents at Top 20 Most-Dangerous Grade Crossings in Washington State[258]

USDOT Crossing ID	Location	Predicted Accidents per Year	Collisions Total 2013–2017	Average Annual Daily Traffic Count	Maximum Train Speed mph	Total Trains Per Day
852638B	Port of Tacoma	0.493283	2	9,987	10	5
085584F	Lander St., Seattle	0.318261	4	13,280	50	68
085691V	15th St. SE, Puyallup	0.248652	4	9,943	79	64
085661D	C St. SW GSA Trk, Auburn	0.231002	4	6,240	79	4
085730J	McCarver St., Tacoma	0.229642	4	4,240	57	72
096445R	E. Marginal Way, Seattle	0.192867	2	3,000	50	56
085629K	James St., Kent	0.178936	2	24,324	79	64
852612Y	Milwaukee Sim, Tacoma	0.162705	2	1,671	10	2
857729Y	Marshall Ave., Tacoma	0.155007	1	493	10	12
085655A	West Main St., Auburn	0.147328	2	6,754	79	66
809503H	South Lander St., Seattle	0.142611	0	11,800	10	2
085647H	37th St. NW, Auburn	0.140127	2	5,005	79	62
085714A	East "D" St., Tacoma	0.134267	0	5,620	37	72
085585M	Horton St., Seattle	0.123561	2	1,600	50	68
085680H	Zehnder St., Sumner	0.122671	1	2,793	79	64
084758W	4th St. N, Mt. Vernon	0.119564	2	16,640	50	14
084764A	Greenleaf St., Burlington	0.118567	2	2,091	79	14
092519S	Locust St., Centralia	0.111590	2	1,937	60	52
066375W	Vista Road, Spokane	0.107476	1	2,185	79	56
085414L	Broad St., Seattle	0.100464	1	8,649	30	56

At-risk grade crossings for Washington CBR routes

In June 2014, after the release of the *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015), Governor Inslee issued Directive 14-06, which asked UTC to identify risks along CBR rail lines, including grade crossing risks. UTC identified 347 public grade crossings along the routes used by BNSF and UP to transport crude oil across the state.

[258] WBAPS 2018 Report.

UTC identified the following risk factors for grade crossings (UTC 2015):

- Crossings protected only by passive traffic control devices, such as crossbucks and/or stop or yield signs.
- Crossings protected only by train-activated flashing lights.
- Crossings with limited sight distance down the tracks, in one or both directions, and not protected by automatic gates.
- Crossings with a significant grade or slope approaching the crossing and not protected by automatic gates.
- Crossings with nearby roadway intersections that may cause traffic to queue over the tracks and not protected by automatic gates.
- Roadways that cross the tracks at an acute angle at a crossing not protected by automatic gates.
- More than one mainline track intersects the roadway at a crossing not protected by automatic gates.
- The crossing exposure factor (i.e., the number of trains per day times the average number of vehicles using the crossing per day) is at a level that poses a higher risk. The number of vehicles using a crossing each day is called “Average Daily Traffic” or ADT (p. 1).

UTC also noted that USDOT Federal Highway Administration (FHA) (2007) had identified certain crossing configuration issues, such as:

- On a level surface, it generally takes a truck 3.8 times as long to accelerate through a crossing as a passenger car.
- On a grade of 5 percent, it can take a truck over five times as long to clear a crossing as a passenger car.
- A truck can take 40 percent longer to clear a crossing with an approach grade of 5 percent than a level crossing.

Crossings with steep approach grades can be particularly problematic for “lowboy” trucks. A lowboy truck is a semi-truck and trailer combination with two drops in deck height: one right after the gooseneck where the tractor attaches to the truck and one right before the wheels. This allows the deck to be extremely low compared with other trailers. Lowboys are used to haul heavy equipment such as bulldozers, industrial equipment, and excavators. Because of low ground clearance, it is possible for this type of truck to bottom-out on the tracks and either become unable to move or to damage the tracks in some way.

Evaluating the grade crossings along CBR routes, UTC identified 14 crossings that are under-protected and would benefit from investments in protection (UTC 2015). Their findings are summarized in Table 88.

Commission staff expects that interim upgrades can be completed within one year and that long-term recommendations may take up to three years. Both interim and long-term projects will require the support and cooperation of the railroad and the road authority.

Table 88: UTC Recommended Grade Crossing Projects in Washington State (In Order of Priority)[259]

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
48th Avenue NW, Snohomish County, USDOT #084683A	n/a	Install active warning devices consisting of shoulder-mounted Light Emitting Diode (LED) lights and gates.	This crossing is on BNSF's mainline. The crossing is currently protected by crossbucks and stop signs. Both approach grades are over 5 percent, which limits sight distance down the tracks; makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing; and may cause some vehicles such as low-boy semi-trailers to high-center and get stuck on the tracks. There have been two accidents at the crossing in the past five years and three accidents in the past 10 years.
Walnut Street, City of Bingen, Klickitat County, USDOT #090168N	Replace incandescent bulbs with LED.	Upgrade active warning devices to shoulder-mounted LED lights and gates. Install concrete crossing surfaces.	This crossing is a triple-track crossing on BNSF's mainline. The crossing is currently protected by flashing lights with no gates. A motorist must stop when lights are flashing but may proceed across the crossing when he or she perceives it to be safe. The three tracks make it a very wide crossing, which takes longer to clear than a standard one-track crossing. In addition, multiple track crossings can deceive a motorist into thinking it is safe to cross when one train passes, not realizing there is a second train approaching on another track. The exposure factor is over 4000 (number of trains per day x number of vehicles per day, which represents the number of opportunities for a collision every day). There is limited sight distance in one quadrant, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. There is a warehouse on one side of the tracks and large trucks may stop in the roadway, either loading or unloading from the warehouse. When this happens, vehicles may stop on the tracks and be unable to move when a train approaches.

[259] Source: UTC 2015, pages 3-8. According to UTC, the estimates contained in the table are preliminary in nature. They were calculated based on these sources: The Safe Transportation Research and Education Center at the University of California Berkeley; Quandel Consultants in Chicago, IL, a company specializing in pre-construction planning and engineering for railroad projects; and Commission Grade Crossing Protective Fund grant documents.

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
Spearfish Road, Columbia Hills State Park, Klickitat County, USDOT #090183R	Install constant-flashing solar-powered LED light stop signs.	Construct a single span bridge grade separation near the existing crossing and close the at-grade crossing.	This crossing is on BNSF's mainline. The crossing is currently protected by crossbucks and stop signs. The south approach grade is over 5 percent which limits sight distance down the tracks and makes it difficult for some vehicles (in this case vehicles towing boat trailers) to stop, restart, and quickly clear the crossing. This crossing leads to a seasonal high-use boat launch. There is no parking on the river side of the crossing. A motorist must cross the tracks in his or her vehicle, launch the boat, drive back across the tracks to park the vehicle, then cross the tracks on foot to reach the boat. After boating, the motorist must do the reverse to get the boat back on its trailer. This means each time a boat is launched, a person crosses the tracks six times.
Butler Road, Skamania County, USDOT #090135B	Replace incandescent bulbs with LED. Replace crossbucks and 2-track signs. Move stop signs to expand containment.	Relocate bungalow. Install concrete crossing surfaces.	This crossing is a double-track crossing on BNSF's mainline. The crossing is currently protected by flashing lights. A motorist must stop when lights are flashing but may proceed across the crossing when he or she perceives it to be safe. The second track is used for trains to pass each other when going in opposite directions. In addition, multiple track crossings can deceive a motorist into thinking it is safe to cross when one train passes, not realizing there is a second train approaching on another track. The south approach grade is over 5 percent which limits sight distance down the tracks and makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing. There is limited sight distance, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. This crossing is in close proximity to SR-14 with limited containment, meaning vehicles stopped at the tracks for a train can back up to SR-14. This makes it difficult to enter or exit the highway safely. Likewise, cars stopped to enter SR-14 can back up over the tracks, unable to clear the tracks if a train approaches.

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
Scribner Road West, Spokane County, USDOT #065968K	Install constant-flashing solar-powered LED light stop signs.	Close crossing.	This crossing is on BNSF's mainline. The crossing is currently protected by crossbucks and stop signs. The south approach grade is over 5 percent, which limits sight distance down the tracks and makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing. In addition, the approach is on a gravel/dirt road, making it even more difficult for vehicles to stop, restart and clear the crossing.
Scribner Road, East Spokane County, USDOT #095923K	Install constant-flashing solar-powered LED light stop signs.	Close crossing.	This crossing is on BNSF's mainline. The crossing is currently protected by crossbucks and stop signs. The south approach grade is over 5 percent, which limits sight distance down the tracks and makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing. In addition, the approach is on a gravel/dirt road, making it even more difficult for vehicles to stop, restart and clear the crossing. There is limited sight distance on the north approach, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. This crossing is in close proximity to Cheney-Spokane Highway with limited containment, meaning vehicles stopped at the tracks for a train can back up the highway. This makes it difficult to enter or exit the highway safely. Likewise, cars stopped to enter the Cheney-Spokane Highway can back up over the tracks, unable to clear the tracks if a train approaches.

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
Wellesley Avenue, Spokane County, USDOT #662535B	n/a	Upgrade active warning devices to shoulder-mounted lights and gates and median barriers. Install LED hard-wired active advance warning signs.	This crossing is on UP's mainline. The crossing is currently protected by flashing lights. A motorist must stop when lights are flashing but may proceed across the crossing when he or she perceives it to be safe. Almost 4000 vehicles travel this road every day. The tracks cross the highway at a severe angle, making it difficult for a motorist to look down the tracks and see a train approaching. There is limited sight distance, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. There is an intersection with Railroad Avenue between crossing signals, which is confusing and poses a potential conflict with other traffic at the crossing.
Marguerite Street, City of Millwood, Spokane County, USDOT #662513B	Move/install signage to change traffic flow and improve safety at the crossing.	Install active warning devices to shoulder-mounted LED lights and gates.	This crossing is on UP's mainline. The crossing is currently protected by crossbucks and stop signs. The north approach grade is over 5 percent, which limits sight distance down the tracks and makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing. The crossing is in close proximity to Euclid Avenue with limited containment. Vehicles stopped at the tracks for a train can back up the highway. This makes it difficult to enter or exit the roadway safely. Likewise, cars stopped to enter Euclid Avenue can back up over the tracks, unable to clear the tracks if a train approaches.
Port Kelley Road, Walla Walla County, USDOT #844389C	Improve asphalt approaches.	Install active warning devices to shoulder-mounted LED lights and gates.	This crossing is on UP's mainline. The crossing is currently protected by crossbucks and stop signs. There is limited sight distance on the north approach, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. The exposure factor (number of trains per day x vehicles per day which represents the number of opportunities for a collision everyday) is over 1500. There is high seasonal truck and recreational vehicle traffic.

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
Brown Road, Whatcom County, USDOT #096134P	n/a	Install active warning devices consisting of shoulder-mounted LED lights and gates Install concrete crossing surfaces. Widen roadway approach lanes to at least 11 feet.	This crossing is on a BNSF branch line. The crossing is currently protected by crossbucks and stop signs. The exposure factor (number of trains per day x number of vehicles per day which represents the number of opportunities for a collision everyday) is over 1500. The crossing is on a very narrow road with heavy use by BP Cherry Point refinery for employees and deliveries.
Lower Norton Avenue, City of Everett, Snohomish County, USDOT #084620V	Limit access to vehicle traffic on Lower Norton Avenue using signage. Stripe roadway approaches to better define travel lanes. Install stop lines until crossing upgrades are implemented.	Upgrade active warning devices to LED lights and four-quad gates. Install concrete crossing surfaces.	This crossing is a triple-track crossing on BNSF's mainline. The crossing is currently protected by flashing lights. A motorist must stop when lights are flashing but may proceed across the crossing when he or she perceives it to be safe. The crossing is currently semi-inactive due to closure of a nearby pulp mill. The three tracks make it a very wide crossing, taking longer to clear than a standard one-track crossing. In addition, multiple track crossings can deceive a motorist into thinking it is safe to cross when one train passes, not realizing there is a second train approaching on another track. The tracks cross the highway at a severe angle, making it difficult for a motorist to look down the tracks and see a train approaching. There is limited sight distance, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross. There are multiple rail car switching movements nearby which may cause the lights to flash even if the train never enters the crossing. The switching can also cause confusion if a moving train is visible and no lights are flashing.
Hailey Road, Franklin County, USDOT #089696T	Install constant-flashing solar-powered LED light stop signs.	Close crossing.	This crossing is on BNSF's mainline. The crossing is currently protected by crossbucks and yield signs. The exposure factor (number of trains per day x number of vehicles per day which represents the number of opportunities for a collision everyday) is over 1500.

Crossing Location (USDOT #)	Interim Recommendation	Long-Term Recommendation	Commission Summary of Risk Factors
Dodd Road, Walla Walla County, USDOT #844396M	n/a	Upgrade active warning devices to shoulder-mounted LED lights and gates.	This crossing is on UP's mainline. The crossing is currently protected by flashing lights. A motorist must stop when lights are flashing but may proceed across the crossing when he or she perceives it to be safe. The exposure factor (number of trains per day x number of vehicles per day which represents the number of opportunities for a collision everyday) is over 4000.
Charles Tobin Road, Whitman County, USDOT #814028R	n/a	Reduce approach grades.	This crossing is on UP's mainline. The crossing is currently protected by crossbucks and stop signs. Both approach grades are over 5 percent, which limits sight distance down the tracks; makes it difficult for some vehicles (e.g. large trucks and vehicles towing trailers) to stop, restart, and quickly clear the crossing; and may cause some vehicles such as low-boy semitrailers to high-center and get stuck on the tracks. In addition, there is limited sight distance, which means a motorist cannot see far enough down the tracks to make an informed decision on whether or not it is safe to cross.

Crossings in first-class cities

The UTC has jurisdiction under RCW 81.53 over the construction, closure, modification and any other alteration to the intersection of a highway and a railroad track, commonly called a railroad crossing. However, RCW 81.53.240 provides, in part, that Chapter 81.53 RCW "…is not operative within the limits of first-class cities…" This means the UTC does not have regulatory jurisdiction over any aspect of a crossing within a first-class city for the purposes of enforcing safety standards.

RCW 81.53.291 allows first-class cities, on a crossing-by-crossing basis, to seek UTC approval for the limited purposes of installing, modifying or otherwise altering crossing signals or warning devices, apportioning costs and providing funding from the Grade Crossing Protective Fund. There are a few first-class cities that have opted-in to the petition process for selected crossings.

There are ten first-class cities in Washington, with almost 500 crossings within these cities, as shown in Table 89. Bremerton is the only first-class city with no crossings.

Table 89: First-Class Cities in Washington State with Railroad Crossings[260]

City	Number of Crossings
Aberdeen	15
Bellingham	24
Bremerton	0
Everett	25
Richland	14
Seattle	161
Spokane	82
Tacoma	132
Vancouver	29
Total	**482**

UTC staff performs on-site assessments of these nearly 500 crossings at least once every three years to collect information about the crossing to maintain a crossing inventory. Staff does not conduct the same in-depth inspection with follow-up on any defects with the city or the railroad since UTC does not have jurisdiction. However, if UTC staff observes a severe defect at a crossing while on-site, staff contacts the appropriate stakeholder (railroad or road authority) and provides a courtesy notice of the condition. An analysis of the available data indicates that, for the calendar year 2013, motor vehicle accident data at crossings is as shown in Table 90.

Table 90: Analysis of Motor Vehicle Accident Rates at Railroad Crossings for 2013[261]

City Type	Number of Accidents	Number of Crossings	Ratio of Accidents to Crossings
1st Class Cities	5	482	1.04
All Other Cities	21	2,174	0.96

Because first-class cities are exempt from UTC safety regulation, it presents a potential gap in public safety for railroad crossings, although the accident data for crossings within and outside of first-class cities are similar.

These cities are free to open, close, modify, or otherwise alter railroad crossings without UTC knowledge or consent. This is problematic because UTC does not know whether the 482 crossings identified for first-class cities include all crossings. Cities can open their own crossings without notifying the UTC, so it is possible crossings exist that UTC has not identified and are not included in UTC railroad crossing inventory records.

UTC staff does not believe first-class city crossings are inherently more dangerous than other crossings. The 2013 accident data show that the rate of accidents at first-class city crossings is similar to those at other public crossings. However, UTC is concerned that the lack of information presents a regulatory gap for these crossings. Additionally, it is not clear that each of the first-class cities have the resources and programs necessary to conduct appropriate safety inspections of crossings within the city.

[260] Data from UTC.
[261] Data from UTC.

As part of ESHB 1449, RCW 81.53 was amended to essentially:

- Allow first-class cities to opt-in to the UTC railroad crossing inspection and enforcement program. For those cities that choose to opt-in, UTC staff would conduct inspections, record defects, and ensure corrections were made, whether by the city or by the railroad.
- Require first-class cities to inform the UTC when a crossing is opened or closed. The cities would not be subject to UTC approval before opening or closing crossings unless they request such action by the UTC.

The UTC inspects approximately 1,000 crossings per year and issues about 200 citations for defects.

Private cossings

UTC has jurisdiction over the construction, closure, modification, and any other alteration of highway-railroad crossings. RCW 81.53.010 defines highways as "all state and county roads, streets, alleys, avenues, boulevards, parkways, and other *public* places actually open and in use, or to be opened and used, for travel by the public" [emphasis added].

This means the UTC does not have regulatory jurisdiction over any aspect of a road that is not in a public place, that is "open and in use, or to be opened and used for travel by the public." These non-public crossings are commonly called private crossings.

Private crossings over mainline railroad track present a safety hazard both for those persons using the crossing to cross the track, but also to railroads, who are not required to blow their horns or whistles at such crossings. Private crossings are not always properly signed, so the driver of the vehicle over the crossing might not know they are approaching a railroad crossing. In addition, the crossing may have an approach grade or slope, which may result in a vehicle getting stuck, or high-centered, on the track.

In its report, *Private Highway-Rail Grade Crossing Safety Research and Inquiry* (FRA 2010), the FRA defines private crossings as "…intersections of highways and railroads on roadways either not open to public travel or not maintained by a public authority." Private crossings include those that provide access to two separate sections of the same farm that lie on both sides of the railroad tracks, industrial plant crossings that provide access between two separate facilities of the same plant on either side of the tracks, or access to a residential site that lies across the tracks by way of a private road. The FRA does not regulate the safety of or establish safety standards for private crossings. Private crossings are generally governed by contracts between the railroad and the landowner. In its report, the FRA reaches a number of conclusions about private crossings on a national basis:

- Accidents at public crossings have decreased by almost 61 percent between 1985 and 2006, while accidents at private crossings have decreased only 26 percent.
- Federal Section 130 funding is used for safety improvements at public crossings, but cannot be used at private crossings. This lack of funding, combined with the high cost of making safety improvements, means private crossing safety improvements are rare.
- Accidents at public crossings generally involve automobiles. Accidents at private crossings generally involve semi-trucks and trailers.

- Requiring a minimum set of warning devices most likely would be effective in reducing the number of accidents at private crossings.

Accident statistics at private crossings, using the most recent five-year average, show the following (FRA 2019b):

- Nationally:
    a. Accidents at public crossings, as a ratio to million train miles traveled, is 2.72.
    b. Accident ratio at private crossings is 0.40.
- Washington State:
    a. Accidents at public crossings, as a ratio to million train miles traveled, is 2.65.
    b. Accident ratio at private crossings is 1.02.

For the last five years, on average, Washington State has a higher accident ratio (1.02 per million train miles) than the national average of 0.40.

The FRA does not currently have jurisdiction over private crossings, which presents a potential gap in public safety. However, in 2015, ESHB 1449 amended Chapter 81.53 RCW. The amendment allows the UTC to adopt minimum safety language, probably requiring a sign, at private crossings and gives UTC authority to inspect the crossings. There are approximately 3,000 private crossings in Washington State with 350 along the oil routes. The safety measures prescribed for private crossings could be funded, in part, by the Grade Crossing Protective Fund.

Private crossings are not inspected by UTC or FRA staff. Because neither agency has jurisdiction, staff does not inspect the safety conditions at private crossings. Even if such an inspection did occur, neither agency has the ability to enforce any safety standards.

Rail-related suicide

Unintentional trespassing (e.g., entering tracks or dangerous sections of rail rights-of-way) may be prevented by effective barriers and warning systems that deter errors made by pedestrians or by vehicle drivers (Burkhardt et al. 2014). However, there are also circumstances in which individuals may intentionally go onto tracks or rail rights-of-way for the purpose of suicide.

While there has been a lot of emphasis on safety improvements to prevent deaths at crossings and by trespass in past decades, there has been little done to prevent suicides by rail until about 2011. According to the U.S. Department of Transportation (USDOT), the two leading causes of rail-related deaths in the U.S. have been due to trespassing or suicide. In 2011, the FRA began collecting suicide data and actively participating in suicide prevention efforts and studies.

The FRA discusses rail suicides in its 2014 report (FRA 2014b):

> Despite a small percentage of suicides occurring on railroad rights-of-way, these incidents greatly impact not only the individuals involved and their family and friends, but also train crews, first responders, and bystanders. The railroad carriers are also impacted by the resulting operational disruptions and delays and the need to address the potentially debilitating physical and psychological effects on those involved in the incident. (p. 1)

Rail suicide in Washington State

Estimated annual rail suicide fatalities for the years 2011 through 2018 for Washington State are shown in Figure 67. In total during these years, there have been 31 deaths and 7 injuries.

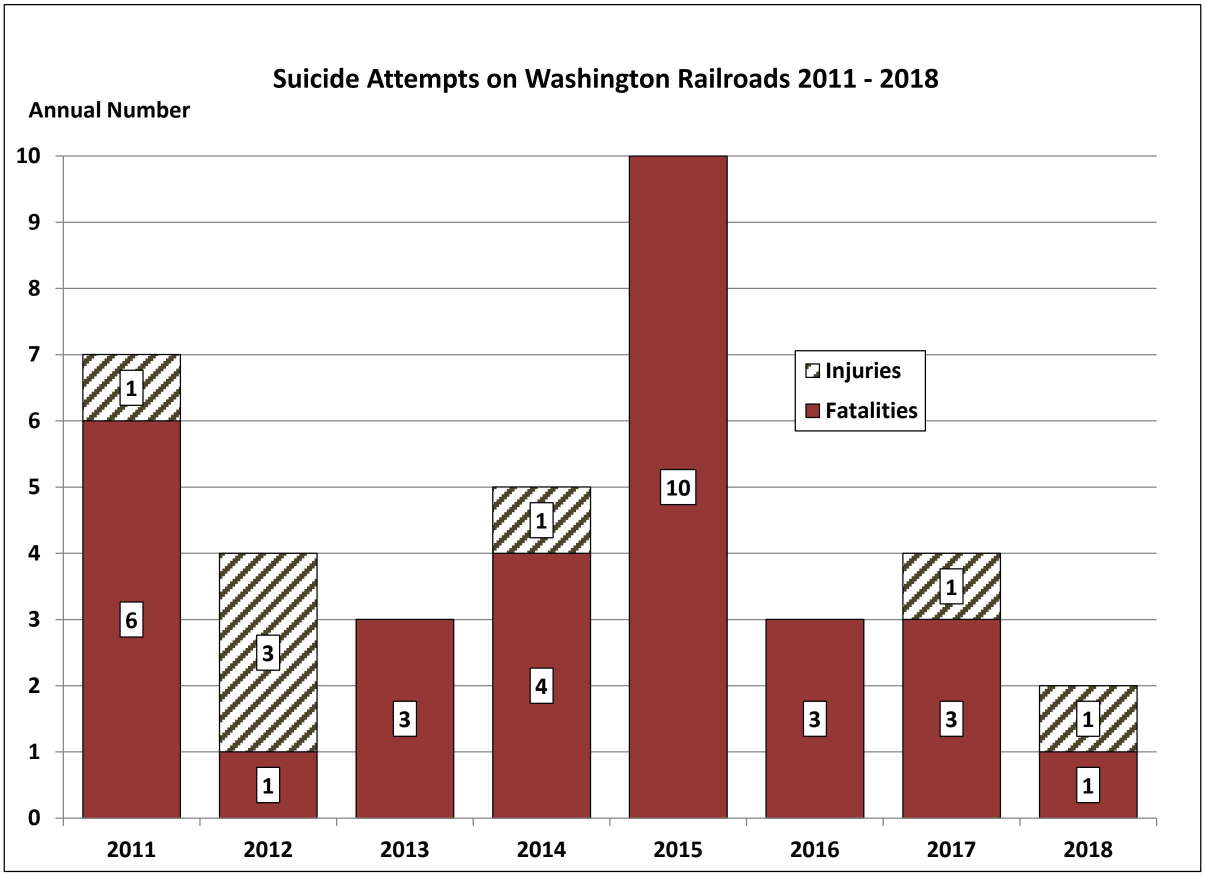

Figure 66: Annual Number of Suicide Attempts on Washington Railroads[262]

[262] FRA data.

Table 91: Annual Number of Suicide Attempts on Washington Railroads[263]

Year	Fatalities	Injuries	Total Attempts
2011	6	1	7
2012	1	3	4
2013	3	0	3
2014	4	1	5
2015	10	0	10
2016	3	0	3
2017	3	1	4
2018	1	1	2
Total	31	7	38

Rail suicide prevention

The decision of an individual to attempt suicide involves a complex series of steps outside the control of railroads, however, there are specific measures that can be taken to prevent suicide by rail (Burkhardt et al. 2014).

The U.S. Department of Transportation Volpe Center and FRA have identified six key research areas that might provide insights into mitigating and preventing rail suicide:

1. **Suicide countermeasure pilot projects**: FRA and Volpe work with rail carriers that are implementing strategies to mitigate suicide. Volpe evaluates the effectiveness of various strategies and then passes on findings and best practices from pilot tests to carriers considering similar strategies. Some of these measures involve the use of physical barriers, but others address psychological approaches, such as advertising help services.
2. **Media reporting of trespass and suicide incidents:** Media that irresponsibly report on a rail suicide incident can elicit copycat attempts. This focus area started by examining how U.S. media outlets report on rail suicides and will continue to refine recommendations for how to responsibly report on these types of incidents.
3. **The Global Railway Alliance for Suicide Prevention (GRASP):** The GRASP working group is made up of international experts in rail suicide prevention. GRASP shares best practices and resources for improving rail suicide prevention.
4. **Trespasser intent determination:** The training and qualifications required for coroners or medical examiners is decided at the local level, and varies by state or county. This may lead to inconsistencies in the criteria that an official death determination is based on, and can lead to rail suicides being underreported. This work aims to understand variations in rail suicide reporting and develop consistent criteria for the rail industry to use internally when determining probable cause of death.
5. **Demographic and environmental characteristics of rail suicides:** This work provides an overview of the types of people injured or killed through acts of suicide

[263] FRA data.

on the US rail system. It includes other data, such as common locations or times when incidents are more likely to occur.

6. **GIS Mapping:** Mapping trespass and suicide incidents can provide insight into why an incident occurred in a specific location at a particular time. As data grows, this technology may help identify potential at-risk areas before they become a problem.[264]

Recommendations for prevention strategies for railroads, particularly metro and commuter rail systems that run through highly-populated areas, include (Sherry 2016):

- Identifying hotspots and erecting barriers to reduce access to right-of-way (Figure 68).
- Installing signage with warnings and contact information for crisis services (Figure 69).
- Use of drones equipped with video monitoring systems to work in tandem with trespasser intrusion alert technology in remote locations.
- Training programs for railroad employees designed to increase their confidence and skill in intervening with suicidal individuals.
- Maximizing prevention efforts of railroads by partnering with other groups devoted to suicide prevention, as well as government agencies. (Abstract, p. ii)

Figure 67: Examples of Fencing along Railroad Rights-of-Way[265]

[264] https://www.volpe.dot.gov/rail-suicide-prevention
[265] Source: USDOT FRA 2014b.

Figure 68: Examples of Suicide Crisis Hotline Signage (As Used by Caltrain)[266]

Rail suicide media issues

Suicide prevention is a complex topic, particularly as there appears to be a phenomenon of "copy-cat" or suicide clusters (several suicides amongst students at one school or community), particularly among teenagers. Notably, there have been a number of suicide clusters of teenagers stepping in front of trains.

One of the lessons learned from studies of suicide clusters is that the manner in which an incident is reported to the public can have an effect on other vulnerable people. Rail safety committees, railroads, and officials can work with local media to reduce the risk of these types of tragedies.

The FRA reviewed recommendations for media reporting from the International Association for Suicide Prevention and then reviewed its own media practices, as follows (FRA 2017b):

- **Do not include the term "suicide" in the headline of an article**. This can sensationalize a particular incident and highlight the potential notoriety of such an act. Nearly 25

[266] Source: USDOT FRA 2014b.

percent of analyzed articles about FRA-reported suicide incidents included the term "suicide" in their headlines.

- **Do not provide detailed information on where a suicide occurred.** The name of a specific crossing, street, or station was provided in 26 percent of analyzed articles about FRA-reported suicide incidents.
- **Do not provide vivid depictions and details of the event.** This can create imagery that a vulnerable individual may relate to and consider acting upon. Forty-five percent of analyzed articles about FRA-reported suicide incidents included details about behaviors immediately before train-person collisions.
- **Do not include an image of a train.** Although including an image of a train may seem reasonable, doing so depicts the manner of suicide, which is strongly discouraged. Sixteen percent of analyzed articles about FRA-reported suicide included an image of a train, and the majority of those articles included "suicide" in their headlines.
- **Include information for those seeking help.** Among articles where the reporter identified an incident as a rail suicide, only 5 percent included such information. (p. 8)

Rail trespassing accidents

There is also a significant issue with fatalities involving pedestrians trespassing on tracks and rail rights-of-way for the purposes of "taking short-cuts," taking photographs (including "selfies"), crossing train trestles, "daring" behavior amongst teenagers, jogging and running, bungee jumping or diving from bridges, fishing from trestles and bridges, attempting to jump aboard trains, and other dangerous activities.

Pedestrians who walk or play around railroad tracks are trespassing on private property and could be fined, seriously injured, or killed. According to FRA statistics, there were 33 trespassing-related casualties in Washington State in 2017 — 22 deaths and 11 injuries.[267]

Best practices in public rail safety education

The prevention of rail accidents with vehicles and pedestrians requires significant public educational efforts, as well as an appreciation of the large amount of misinformation about trains in the general public.

Operation Lifesaver

Arguably, the most successful public rail safety education program is Operation Lifesaver, Inc. (OLI). Operation Lifesaver is a nonprofit public safety education and awareness organization dedicated to reducing collisions, fatalities and injuries at highway-rail crossings and trespassing on or near railroad tracks. The organization was established in 1972 and now is active in all 50 states.

[267] Operation Lifesaver. https://oli.org/about-us/news/statistics/trespassing-fatalities-by-state

In the year 2017, OLI reached 2.1 million people directly via 21,226 safety presentations, 245 training sessions, and 1,821 special events nationwide (2018 Operation Lifesaver Annual Report).

OLI stresses the following as important messages for the general public:

- "Railroad tracks, trestles, yards and equipment are private property. Walking or playing on them is not only dangerous it is illegal. Trespassers can be arrested and fined–the ultimate penalty is death.
- "The ONLY legal, safe place to cross tracks is at designated pedestrian or roadway crossings. Observe and obey all warning signs and signals.
- "Do not walk, run, cycle or operate all-terrain vehicles (ATVs) on railroad tracks, rights-of-way or through tunnels....
- "Do not walk, jog, hunt, fish or bungee jump on railroad trestles. They are not designed to be sidewalks or pedestrian bridges; there is only enough clearance on the tracks for a train to pass.
- "Do not attempt to jump aboard railroad equipment at any time. A slip of the foot can cost you a limb, or your life."[268] An optical illusion makes trains appear to be farther away and slower-moving than they actually are.
- Do not assume that trains can always be heard. Particularly, in the winter with snow covering the area between and around the tracks, the sound of an approaching train may be deadened.
- "It takes the average freight train hauling 6,000 tons and traveling at 55 mph a mile or more — the length of 18 football fields — to stop." [269]
- Do not cross the tracks immediately after a train passes. A second train could be coming from either direction. Wait to cross until you can see clearly both directions.
- If a truck (or automobile) is stuck on a railroad crossing, the driver and passengers should immediately get out of the vehicle and get away from the tracks *even if there is no train visible*. The safest place to run is towards the oncoming train at an angle of 45 degrees away from the train. This gets the persons away from debris that will be flying when the train collides with the abandoned vehicle.
- When crossing tracks in a vehicle in a line of traffic, only cross when the rear bumper of the vehicle ahead (and on the other side of the tracks) is 15 feet or more away from the track.
- In the event of a long wait at a crossing, never assume that the gate, lights, and bells are "malfunctioning" and go around them. Find another route and/or contact the Emergency Notification System number on the sign.[270]

Operation Lifesaver offers the following safety tips for emergency responders:

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[268] Operation Lifesaver. Rail Safety Education. Trespassing Casualties by State. https://oli.org/about-us/news/statistics/trespassing-fatalities-by-state
[269] Operation Lifesaver.Rail Safety Ecuation. Safety Tips for Emergency Responders. https://oli.org/training/safety-tips-for-emergency-responders
[270] Operation Lifesaver. Rail Safety Education. Driving Safety Tips.https://oli.org/education-resources/driving-safety-tips

- "A train always has the right of way. Plan routes allowing drivers and other crew members clear views down the railroad tracks in both directions.
- "Know which railroad controls the tracks and have emergency numbers for them at dispatch centers. This is especially important if there is more than one railroad operating in your community.
- "If a train is blocking an intersection you must use, contact your emergency dispatcher or the local railroad office.
- "Don't place emergency vehicles on tracks and expect a train to be able to stop quickly enough to avoid a collision.
- "To stop a train, contact the railroad. Use all available reference points, checking signal housing for USDOT crossing number, to give exact locations. If known, supply railroad mile posts, road name, crossroads and town.
- "When fighting long-term brush or structure fires, contact the railroad to obtain clearance to move ballast stones and feed hoses under the tracks. Doing so allows both safe, effective fire fighting and train passage."[271]
- Trains cannot effectively yield to an emergency vehicle because of the distance required for a train to stop, which is dependent on train speed and weight.
- "Even if emergency sirens and air horns are deactivated as emergency vehicles approach crossings, ambient noise levels in their cab could mask the sound of an approaching train horn." [272]
- When drivers of emergency vehicles approach highway-rail intersections, they should turn off sirens, air horns and other sound-producing devices. The emergency vehicle drivers should slow down, open the vehicle's window, and look both ways to see if a train is approaching. At crossings with obstructions or severe curves interfering with vision, the drivers of emergency vehicles should stop the emergency vehicle and ask a crew member to go out and check on crossing safety.[273]

Washington Operation Lifesaver

There are state chapters of Operation Lifesaver. Washington Operation Lifesaver (WAOL) is a free public service education program dedicated to preventing and reducing fatalities and injuries at highway-rail grade crossings and along railroad rights-of-way.

WAOL educates the public on highway-rail grade crossing safety and provides vital information about the dangers encountered when people trespass on railroad property. WAOL also gets involved with engineering projects to improve public safety, and works with the law enforcement community in an effort to reduce grade crossing and trespass incidents.

[271] Operation Lifesaver. Rail Safety Education. Safety Tips for Emergency Responders.https://oli.org/training/safety-tips-for-emergency-responders
[272] Ibid.
[273] Ibid.

Potential areas of future discussion

- The Rail Safety Committee may wish to work closely with UTC to improve safety at any of the more dangerous grade crossings that have yet to be addressed.
- The Rail Safety Committee may wish to work with UTC in tracking the data maintained by the FRA on grade crossing accidents.
- The Rail Safety Committee may wish to support and expand on the efforts of Washington Operation Lifesaver in its education efforts.

Chapter 14: Maintenance and Investment in Infrastructure

Key questions

- What types of industry-led maintenance practices are in place for infrastructure (i.e., tracks, bridges, trestles)?
- What investment has the rail industry made, or plans to implement in the future, for the improvement of infrastructure?
- What has been done, or is being planned, for Washington infrastructure compared with other states and the U.S. as a whole?

Takeaways

- The rail industry is motivated to prevent derailments, collisions, and other types of accidents on their lines, because these incidents not only harm the public and the environment, but also cause injuries and potential fatalities to their own employees. Further, the damages to the environment cost the industry money for cleanup, and damages to their equipment and rails are also an expense.
- Railroads invest large amounts of money each year to maintain and improve their infrastructure–rails, locomotives, and other equipment. This expenditure is called an annual Capital Budget, a major portion of which is used for capital maintenance to ensure a safe and efficient operation. BNSF has invested $69 billion in its system-wide mainline network since 2000. In 2019, BNSF will spend approximately $3.57 billion on capital expenditures in addition to its ongoing operating maintenance expenditures year-round. Approximately 54 percent of the total capital budget will be for capital maintenance (BNSF 2019).
- The railroads have invested in such improvements as: positive train control (PTC), track geometry cars for inspections, and wayside detectors.
- The railroads have also invested in improving tracks by eliminating joints, replacing wooden ties with concrete ties, and upgrading crossing protection.
- The railroads have also changed some of their operating practices to improve safety, such as restricting speed, especially when the weather is hotter, because this helps to maintain the track in a safer condition, thereby reducing accidents.

The following sections provide a more in-depth look at maintenance of and investment in railroad infrastructure and the ways in which this may affect safety.

Rail industry investments in infrastructure improvement

The railroad industry is using technology and improved components to advance safety in all areas of their operations.

Railroads invest large amounts of money each year to maintain and improve their infrastructure — rails, locomotives, and other equipment. This expenditure, called a Capital Budget, includes capital maintenance to ensure an efficient and safe operation. BNSF has invested approxiamately $65 billion in its U.S.-wide mainline network since 2000. In 2019, BNSF will spend approximately $3.6 billion on capital expenditures, including approximately $2.5 billion devoted to maintenance (BNSF 2019). The balance of the Capital Budget goes to equipment (locomotive and car), signal enhancements, PTC, and other miscellaneous improvements.

Deferred maintenance, with resultant slow orders, has a very large impact on corridor/route capacity. The capital maintenance expenditures are in addition to on-going operating maintenance expenditures that occur year around.

Positive Train Control (PTC)

As described in Chapter 9, PTC is being implemented on mainlines that handle passenger and toxic inhalation hazard (TIH)-carrying trains. The overlay to the control systems for the lines it is being implemented on will reduce a number of human error related causes for accidents or collisions. While it will not prevent every incident, it should assist with alleviating errors that could potentially lead to major incidents.

Upgrading control and authorization systems

Similarly, railroads continue to upgrade control systems for the authorization of train movements. Line segments that were dark, or are protected by ABS signals, are being upgraded to CTC operations. This is being done for two reasons: It increases velocity on these lines, which increases capacity, and it adds another layer of protection from human error into the operation.

Turnouts in dark or Automatic Block System (ABS) Track Warrant Control (TWC) territory must be hand operated at meet points. This means that the train that is heading into the siding must stop, throw the switch and then proceed into the siding. Since trains no longer operate with a caboose or men at the rear of the train, the switch usually remains open to the siding. The approaching train using the mainline must then stop and realign the switch back for the main track, resulting in delays for both trains.

By upgrading to a Centralized Traffic Control (CTC) type of system, a control operator such as the dispatcher can remotely line the switch for either or both trains, so the delay to the trains is reduced. This increases the velocity of the line, which positively impacts capacity.

Additionally, as described in Chapter 9, a CTC signal system checks the requests the dispatcher makes for signals to ensure there are not conflicts. Once that has been determined, the system posts the signal. This adds another layer of protection against human error to the system.

At the same time, track segments that utilize TWC to authorize movements are recorded in computer programs that assist a dispatcher by not allowing a conflicting track warrant to be issued. Computer aided dispatching is also being implemented to reduce the burden on dispatchers and to develop more efficient operations.

Geometry cars

Geometry cars have been upgraded with better technology that allows them to record and store more data. With this improvement, the cars are being used more to identify areas where tracks have repetitive problems, and to use the data collected to predict where problems are likely to occur. Once those areas are identified, corrective action can be taken before the issues affect or threaten safe rail service.

Train speed restrictions

Railroads have agreed to limit the speed of certain trains in the interest of safety, even though a velocity reduction negatively affects the capacity of rail lines. There are two major efforts of this nature.

Hazardous material “key trains” have been mandated to operate at no greater than 50 mph. This has been done by the FRA and accepted by the railways. It is done so that if this type of train does derail, the impact of the derailment is reduced (AAR 2016). In Washington, key trains are limited to a maximum speed of 35 mph through many urban areas (Etkin et al. 2015).

Additionally, heavy wheel loads associated with loaded unit trains have been restricted in speed to reduce their impact on bridges and rail. As discussed in Chapter 22, the repetitive flexing of a rail can lead to fatigue flaws and ultimately, to broken rails. Limiting the speed of heavy wheel loads reduces the flexing that the rail experiences, which will reduce the potential for broken rails.

Similarly, reducing the speeds of heavy wheel loads reduces the impact on bridges. Again, the repetitive flexing of a bridge structure can lead to it becoming worn, which can lead to a bridge failure. Reducing the impact of the wear on a bridge decreases the chance of a failure and the resulting potential derailment.

Finally, by reducing the speeds of heavy trains, the stopping distance of those trains is reduced. Again, this potentially could avoid or minimize the potential for a derailment in certain situations.

Temperature speed restrictions

Railroads have identified the dangers associated with thermal misalignments, which are discussed in Chapter 22. To reduce the threat these misalignments can cause to safe rail operations, railroads have implemented speed restrictions when temperatures exceed certain limits. These restrictions are identified in the timetables by subdivision.

In addition, railways carefully monitor the temperature a rail is laid at to understand how the ambient temperatures in the area might affect the expansion of the rail. In areas such as deserts that are prone to high summer time temperatures, rails are laid at high temperatures. This is done using gas heaters to heat the rail to a target temperature, which is based on heat profiles for the area. Heating a rail prior to spiking or clipping it to the ties insures that the rail has already expanded.

Similarly, the temperature in which a rail is laid in colder temperatures is recorded since in many cases the temperature difference between the hottest and coldest temperatures year around can be significant in many areas of rail operations.

The temperature at the time that the rail is laid is recorded so if an incident does occur, there is a record of the history of the rail. The history is used to assign laying temperatures for future rail replacement projects.

Wayside defect detectors

Defect detectors have been technologically improved and have been placed more regularly along track side to provide better warning of potential defects that might cause a derailment. For example, in 2003, the Fallbridge Sub showed there were 16 defect detectors in operation between Pasco and Vancouver, Washington. In 2018, that number had increased to 31 detectors. (BNSF 2003; 2018a).

Additionally, new technologies such as acoustic detectors are being installed to identify a failing bearing before they begin to heat up from friction between parts. Wheel load detectors also use acoustics to determine the possibility that a wheel might fail or a rail might be negatively affected by a flat spot or other defect.

Concrete ties

To strengthen the track structure, concrete ties are now being installed on many heavy-haul mainlines as tie or rail replacement programs occur. The concrete ties improve the track structure in two ways: First, the method by which the rail is attached, and second, the stiffness and weight of the track structure. The method by which the rail is attached to concrete ties is superior to the way rail is attached to wood ties.

Concrete ties are manufactured with the fastening system incorporated into the concrete creating a fixed gauge. The concrete ties use spring steel clips that hold the rail to the tie, which does not loosen over time the way in which a spike can (Figure 70).

Vibrations from trains moving over the rail can loosen spikes in wood ties over time as the movement wallows out the hole the spike is driven into (Figure 71). The incorporated clip holders on a concrete tie hold gauge better, and unless the tie breaks, will not move.

Additionally, since the clip holder on a concrete tie is a fixed part of the tie itself, it does not cut into the tie like a tie plate may on a wooden tie. In conjunction with the fixed gauge, this reduces maintenance for loose fasteners, decreasing the potential for track related derailments.

Second, the concrete tie creates a more rigid support of the rail because it is heavier than a wooden tie. This helps minimize the deflection of the rail as a wheel rolls over it, which reduces the flex the rail experiences. Wood ties, as they age, will crush, which allows the rail to flex more, leading to a higher chance of broken rails.

The heavier structure with concrete ties also requires more force to move around than a wooden tie structure. This can reduce the chances for thermal misalignments caused by high rail temperatures.

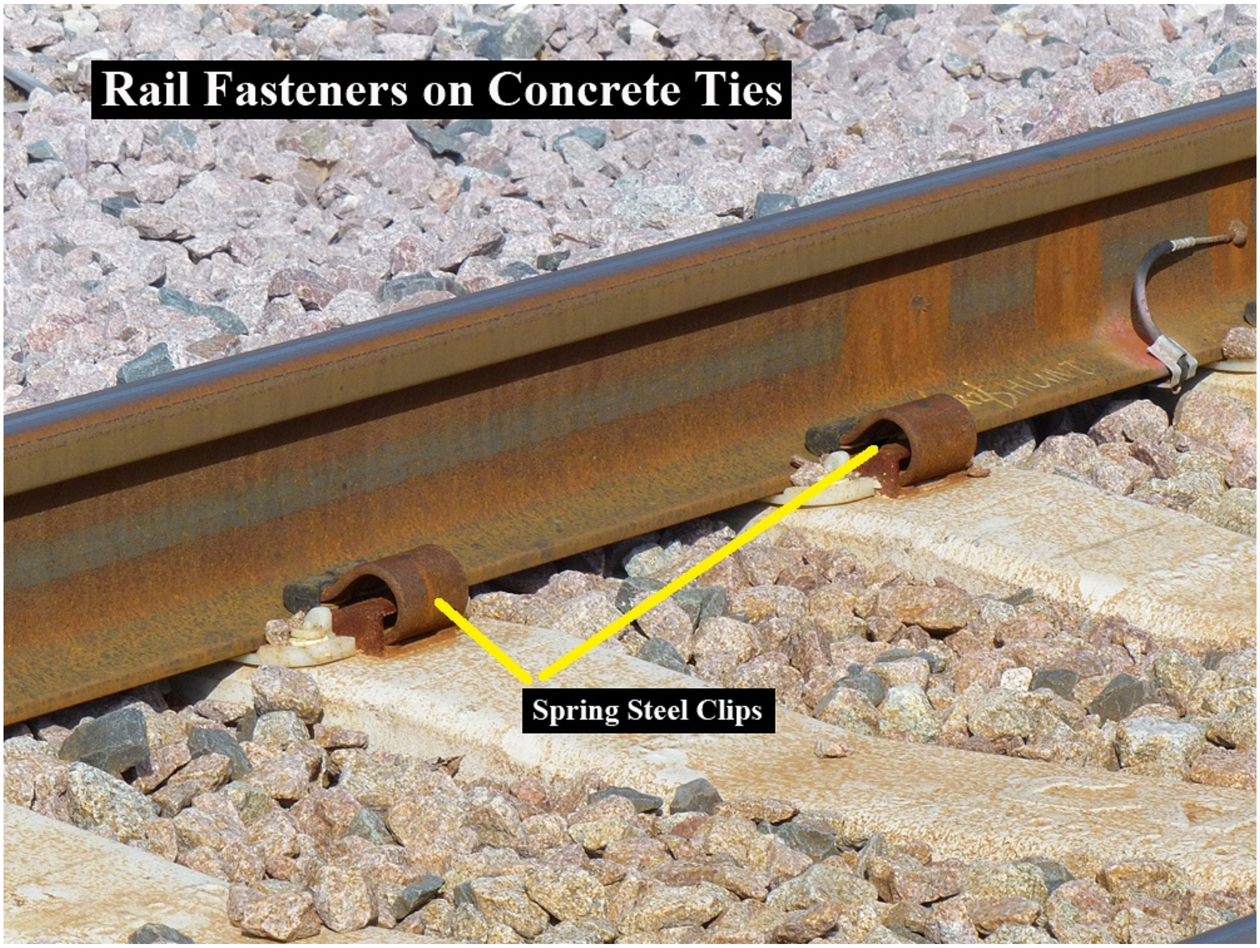

Figure 69: Rail Fasteners on Concrete Ties (Spring Steel Clips)[274]

[274] Image credit: Eric Lymanc. Used with permission.

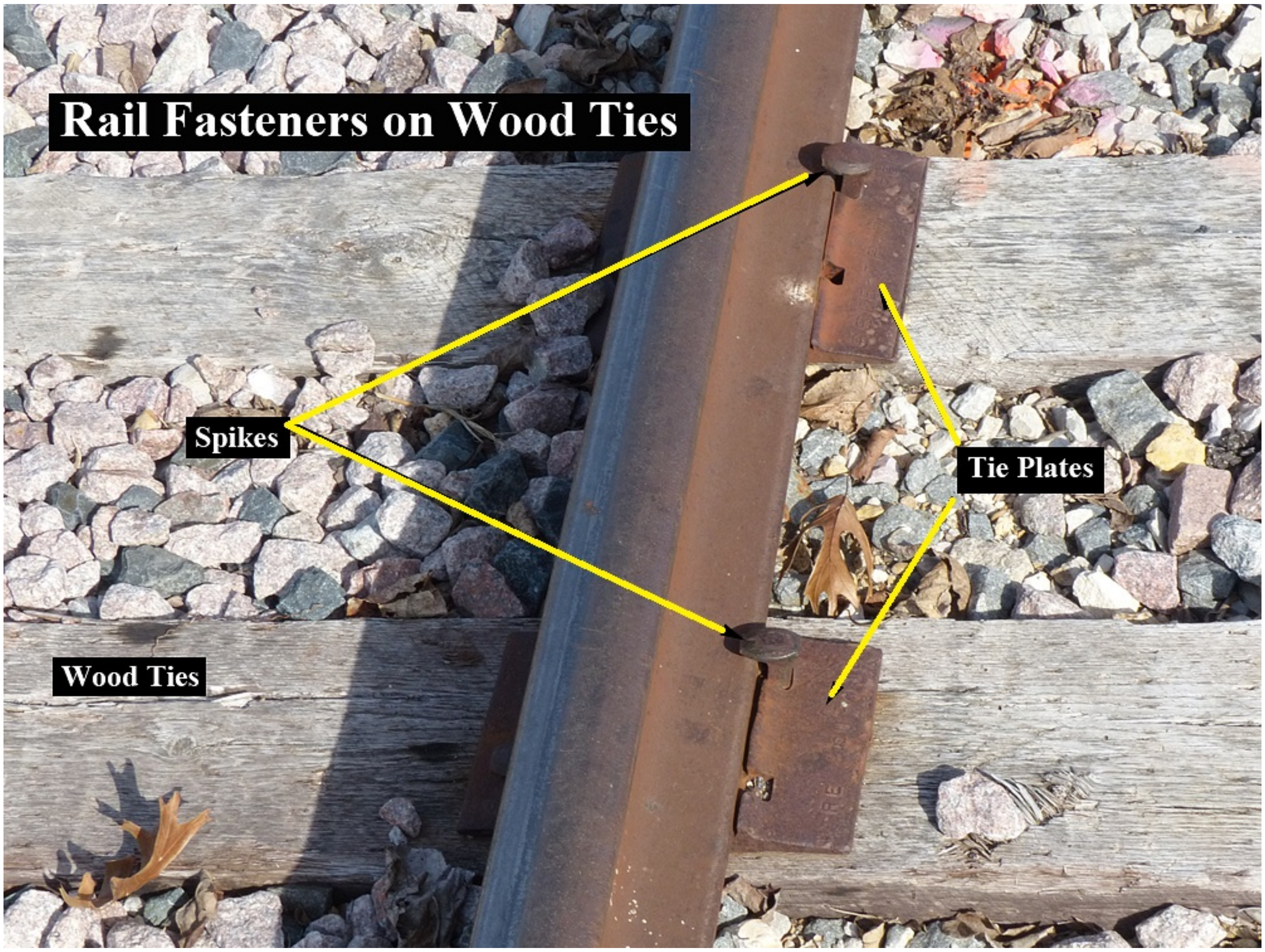

Figure 70: Rail Fasteners on Wood Ties[275]

Turnouts and moveable point frogs

To minimize the possibility of a derailment at the frog of a turnout, railroads have developed moveable point frogs for heavy use areas. Rather than having a gap where the two rails cross, a moveable point frog has a mechanism that shifts the rails so that the route the train is moving over has no gap. The frog moves in conjunction with the switch points, so if the points are lined down the main route, the frog is aligned that way as well. Similarly, if the points are lined for the diverging route, the frog aligns that way.

This eliminates the pounding the point of a conventional frog absorbs as the wheels of a train move over the gap that is created where the rails cross. By eliminating that gap, the chance that the point of frog will become damaged and potentially contribute to a derailment is minimized.

A standard turnout frog is shown in Figure 72.

[275] Image credit: Eric Lyman. Used with permission.

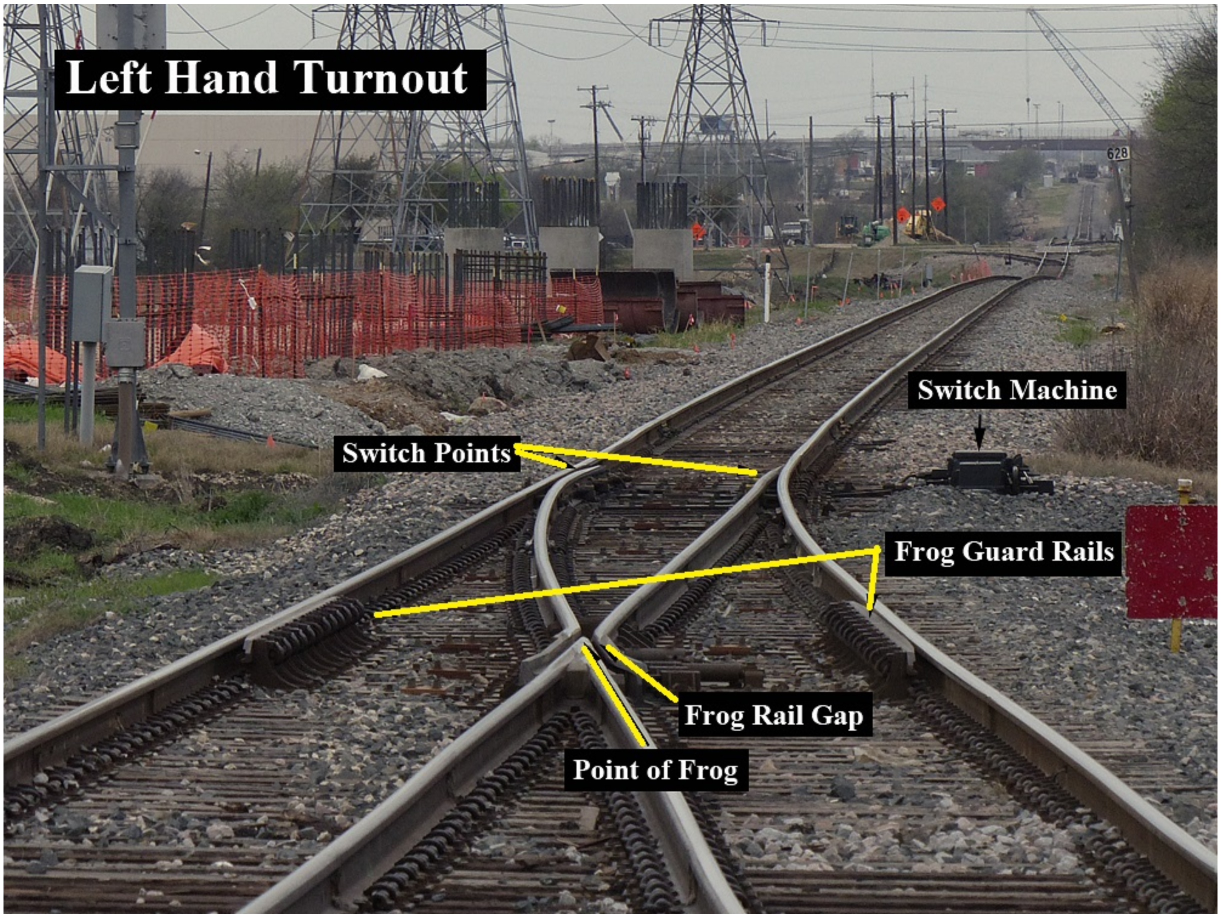

Figure 71: Left Hand Turnout Showing Switch Points, Frog, and Switch Machine[276]

Joint elimination

Joints between rails are weak spots in the continuous rails. The railroads have identified this and have attempted to eliminate as many joints as possible from heavily traveled routes.

One way this is done is to replace jointed rail with continuous welded rail (CWR). When the rail is replaced by CWR, all joints from the old structure are eliminated. The joints between welded rails are then field welded to eliminate those joints as well.

The second method the railways use to eliminate joints is field welding (Figure 73). When a defect is identified and a piece of rail must be cut out, it creates two joints that have to be addressed. The railways field weld these two joints to eliminate them. The railroads have developed methods to field weld that create rail that is as strong as continuous welded rail.

[276] Image credit: Eric Lyman. Used with permission.

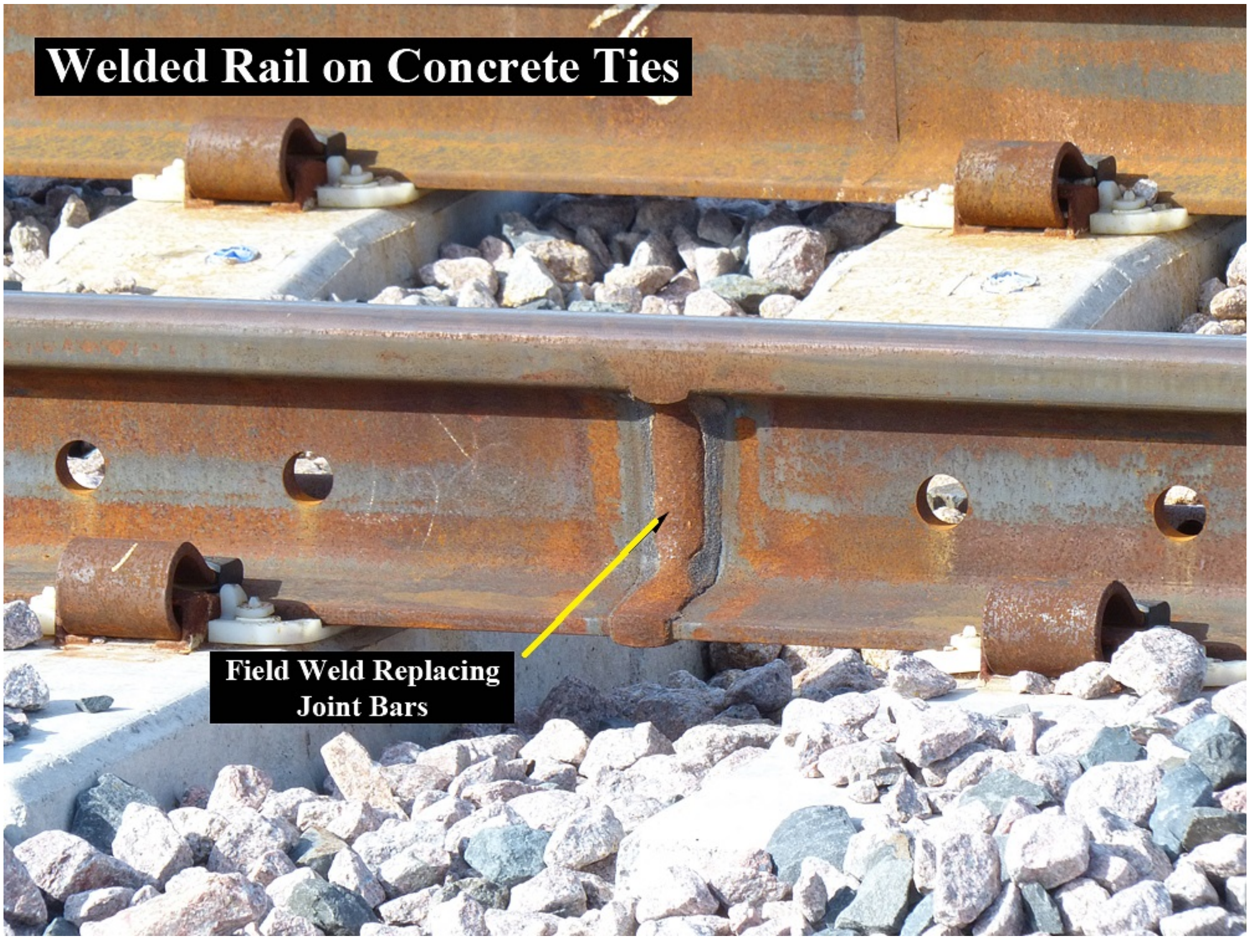

Figure 72: Welded Rail on Concrete Ties (Field Weld Replacing Joint Bars)[277]

Upgraded crossing protection

As described in Chapter 13, as more quiet zones are implemented, newer and better technology is utilized to protect grade crossings. As described, gates and flashers are required at all quiet zone crossings, which can frequently be an upgrade to the crossing protection that was in place before the upgrade.

Additionally, constant warning time predictor circuitry is required at quiet zone crossings, which also reduces the risk that a motorist will become impatient and try to run through a crossing that has the protection activated for too long because of a slow train. In both cases, the improvements are likely to reduce the risk of an incident occurring at an upgraded crossing. Note that grade crossing protection upgrades are not a railroad responsibility.

[277] Image credit: Eric Lyman. Used with permission.

Potential areas of future discussion

- The Rail Safety Committee may wish to consider inviting a rail engineering representative, perhaps from BNSF's Regional Engineering office in Seattle, to participate in a presentation/question/answer forum discussing infrastructure maintenance, standards, daily maintenance practices and capital expenditure planning.
- The Rail Safety Committee may wish to consider inviting a Pacific Northwest Regional operating manager representative to discuss operational and capacity impacts of slow orders, derailments and other mainline disruptions.
- The Rail Safety Committee may wish to consider that a similar forum be held with a representative of a railroad's Public Affairs department to discuss the regulatory and public issues that a railroad has to be aware of in an ongoing manner and railroad's outreach involved stakeholders.

Chapter 15: Tank Car Design

Key questions

- What types of tank cars exist?
- How might tank car designs affect safety in the event of an accident?
- How effective are the newer tank car designs in reducing the likelihood of release?
- What types of tank cars are currently in use in Washington and how might that change in the future?

Takeaways

- Rail tank cars are used to carry a variety of hazardous liquid and pressurized gas commodities on trains, including crude oil, gasoline, ethanol, sulfuric acid, and propane. Tank cars can be used to carry individual carloads of a hazardous material in a train with other types of cargo, in groups of up to 20 in key trains, or in unit trains that may have 100 to 120 cars carrying the same commodity.
- Tank cars are designed to protect the contents, keeping it at a certain temperature or under pressure in some cases, preventing contamination, and generally assuring that the commodity arrives at its destination safely.
- At the same time, tank car designs also include a number of safety measures that assure that the contents do not leak out in the event of an accident, such as a derailment or collision. If a tank car bursts open, punctures, or has a tear in its shell due to impact during an accident or exposure to heat, the contents may spill, leak out, explode, or be released into the air. Tank cars may also leak or drip if they are not handled correctly in the loading process or they have a defect in a sealing ring or other part.
- After a few explosion and fire accidents in 2013 with unit trains carrying Bakken crude oil in DOT-111 and similar tank cars, including one in Canada in which 47 people were killed (Etkin et al. 2015), the U.S. Department of Transportation (USDOT) and the rail industry looked into upgrading the safety features of tank cars that carried this type of crude oil and other flammable liquids. The industry produced a safer type of tank car, the DOT-117, which had various features that would make it much less likely to break open in an accident and be more resistant to heat damage in a fire.
- USDOT published regulations requiring the phase-out of the older, less-safe DOT-111 cars to be replaced by DOT-117 and other safer tank car designs to transport flammable liquids. In early 2019, there were no DOT-111 cars in use for Class 3 flammable liquids, such as Bakken crude oil, in use in the U.S. The two rail carriers that transport Bakken crude and other Class 3 flammable liquids in Washington, BNSF and UP, use only DOT-117 cars or other cars that meet even higher safety standards.
- Currently there are sufficient supplies of DOT-117 and other safe tank cars for use in Washington. There may be shortages of these cars if there are dramatic increases in shipments of Bakken crude or other oil into Washington, if the existing refineries shift from pipeline and/or tank vessel delivery of crude oil to rail, or if a storage terminal is built. The building of new facilities or shifts to rail delivery would not occur without a

thorough Environmental Impact Study (EIS), part of which would require plans for ensuring the use of DOT-117 or safer cars.

- DOT-117 tank cars may still break open, however, they are more than six times less likely to have a release in the event of an accident than the older DOT-111 cars.
- Tank cars carrying other types of hazardous substances have similar safety requirements.
- Besides spills or releases that occur in derailments and collisions, there are also "non-accident releases" (NARs) that may occur because of improper loading or unloading that leaves the manway (the entry hole at the top) or other fittings not adequately sealed, or other defects, such as missing gaskets. NARs tend to be small, but can still present health and safety concerns due to the high toxicity, flammability, or other properties of the hazardous material.
- Tank cars need to be regularly inspected and properly maintained to prevent NARs. In addition, operators need to be trained in safe procedures for loading and unloading hazardous materials from tank cars. The USDOT has inspection requirements and protocols for tank cars that carry flammable liquids and other hazardous materials. There are fines for non-compliance.
- The FRA has recommended training programs, and the Association of American Railroads (AAR) and the Bureau of Explosives (BOE) have developed specific guidelines for loading and unloading procedures for tank cars.

The following sections provide a more in-depth look at different types of tank cars that are used to transport a variety of hazardous commodities by rail through Washington State. The chapter covers recent tank design improvements that are intended to reduce the risk of rupture in the event of a derailment or collision.

Tank car designs

One of the standards that has been addressed in the rulemaking process for rail safety, and clearly the one that has captured public attention, is the tank car standard. Because tank car designs are intended to reduce the probability of spillage in the event of an accident, and not the precipitating accident *per se*, this issue is addressed in the analysis related to *spillage* probability, not rail *accident* probability.

There are four basic components of a rail tank car that may release material during an accident: the tank head, the tank shell, the top fittings, and the bottom fittings (Figure 74). All tank car safety improvements focus on these components (Figure 75).

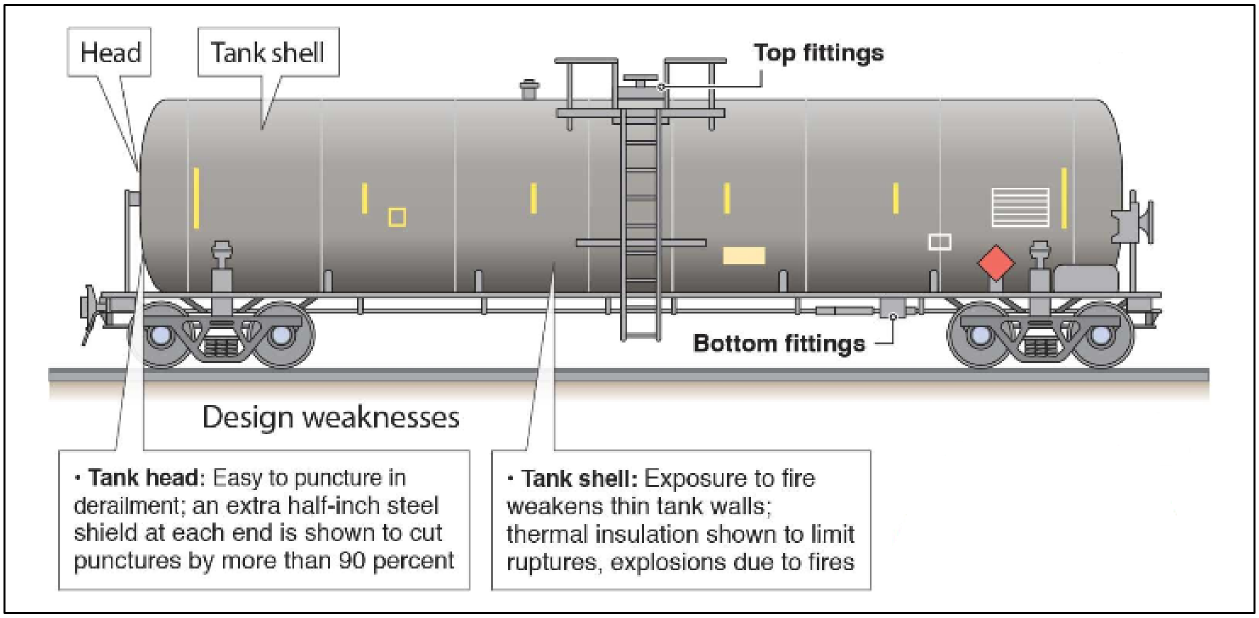

Figure 73: Key Tank Car Components that May Release Material during Accidents[278]

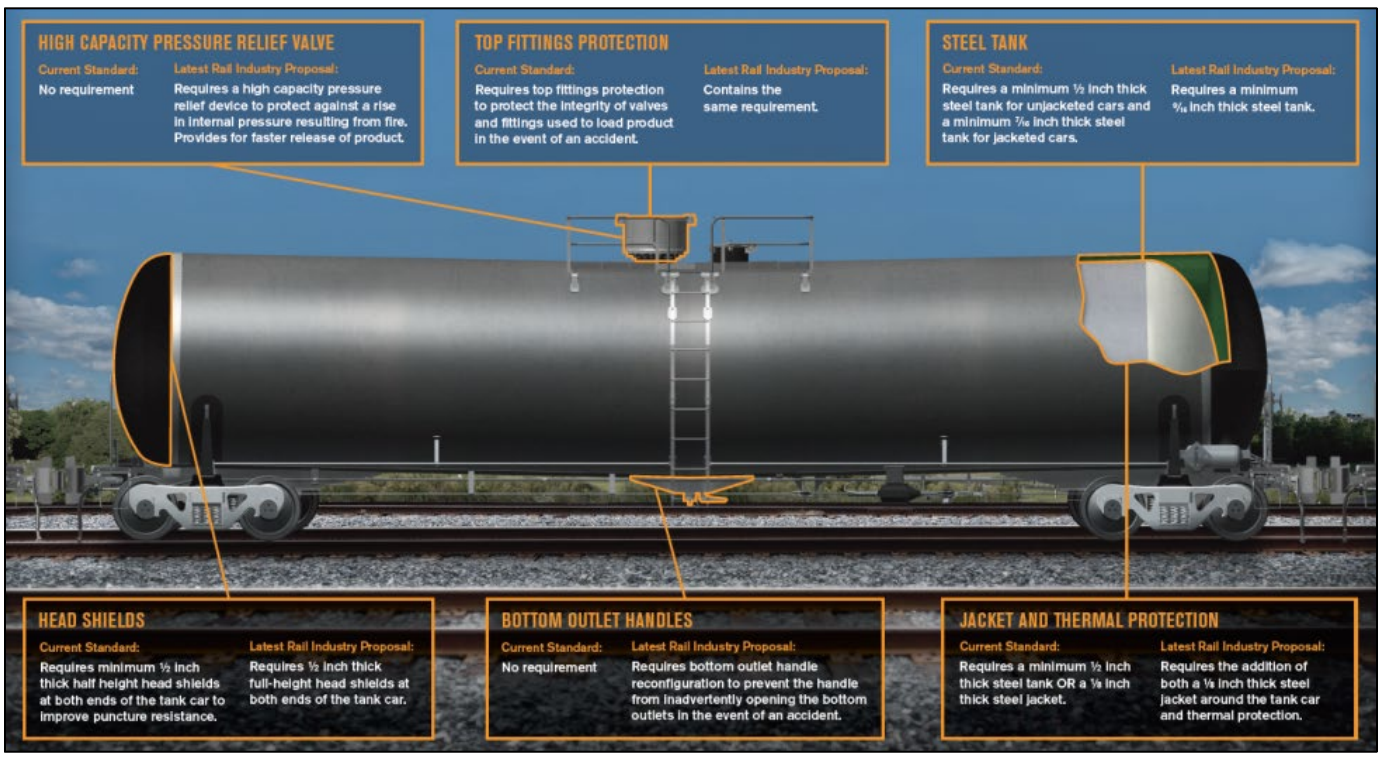

Figure 74: Rail Tank Car Component Safety Improvements[279]

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278 Noll and Hildebrand 2016.
279 Source: Association of American Railroads.

DOT-111 and CPC-1232 tank cars

A ”safer” tank car design (CPC-1232) is analogous to a double-hulled tanker with similar reductions in spillage probability from older, legacy “DOT-111” tank cars (Figure 76).

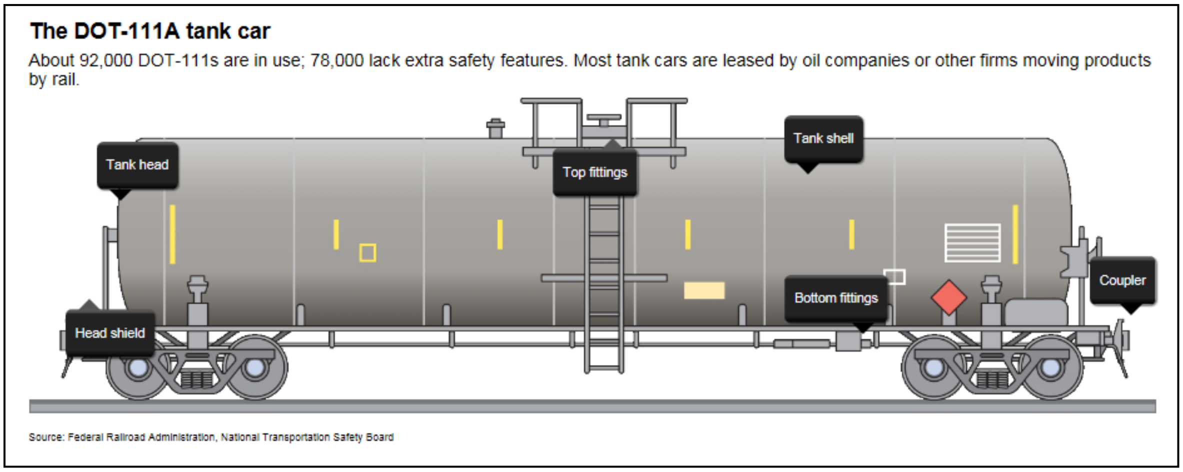

Figure 75: DOT-111 Tank Car Design[280]

A 1991 NTSB study found that the DOT-111 tank car is significantly more likely to release its product, suffer a failure, or experience a head or shell puncture than other tank car models (DOT-105, DOT-112, and DOT-114 pressurized tank cars), which have a tank shell thickness of 14.3 millimeters (mm) and thermal protection. The CPC-1232 (Figure 77) standard originated with Transport Canada in October 2011 (NTSB 1991). However, anecdotal evidence from recent CBR accidents indicates that the newer tank car standards (CPC-1232) do not necessarily prevent spillage. Notably, in the Lynchburg, Virginia, accident,[281] the only tank cars that spilled oil were of the newer CPC-1232 design built after 2011. In addition, two recent derailments in Canada and in Galena, Illinois, involved CPC-1232 cars that spilled oil and burned.

[280] Federal Railroad Administration.
[281] The 30 April 2014 Lynchburg, Virginia, accident involved 15 derailed cars; three cars spilling oil and burned.

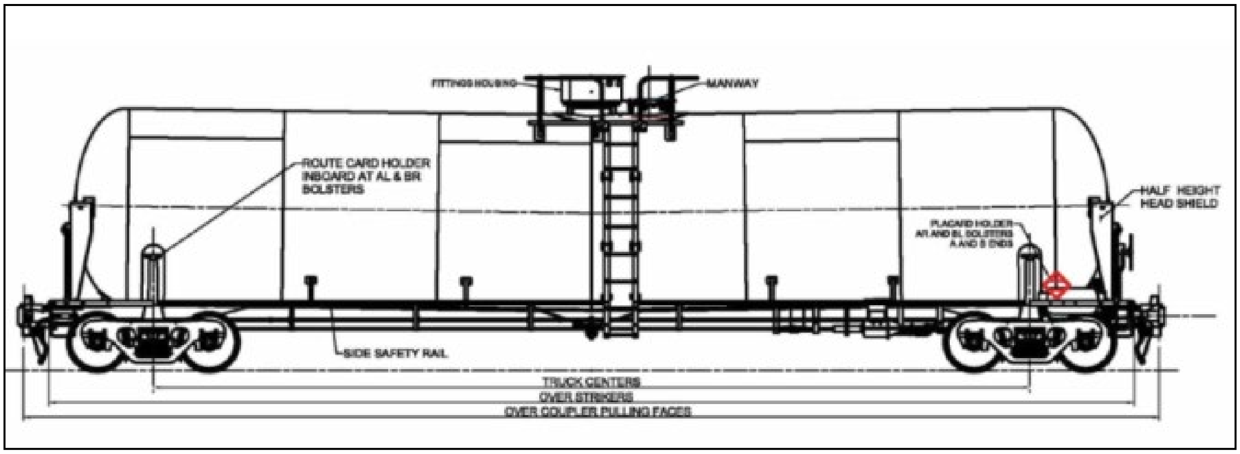

Figure 76: CPC-1232 Compliant Tank Car Design[282]

DOT-117 Tank Cars

On May 1, 2015, the U.S. Department of Transportation (PHMSA and FRA) issued a final rulemaking, "Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains,"[283] that included a number of provisions aimed at reducing risk from these trains (HHFTs).[284] This rulemaking, called HM-251, contained a new standard for tank cars — the DOT-117 specification (Figure 78).

[282] Barkan et al. 2013.
[283] 49 CFR Parts 171, 172, 173, 174, and 179: DOT Pipeline and Hazardous Materials Safety Administration Docket No. PHMSA-2012-0082 (HM-251) ROM 2137-AE91.
[284] HHFTs are trains with a continuous block of 20 or more tank cars loaded with a flammable liquid or 35 or more cares loaded with a flammable dispersed through a train (i.e., with other cargo-type cars interspersed)

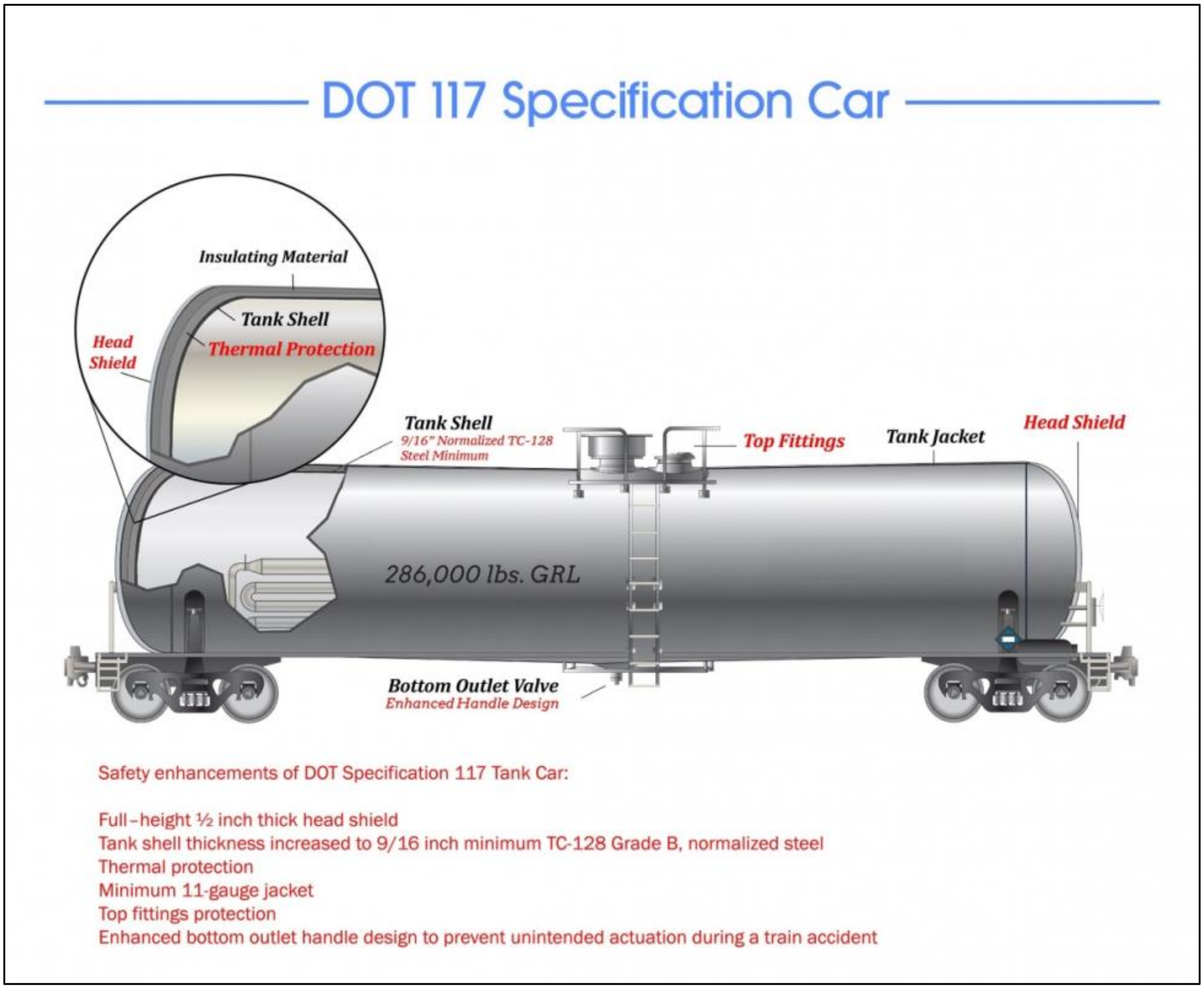

Figure 77: DOT-117 Specification Car[285]

[285] USDOT. Rule Summary: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains.http://www.dot.gov/mission/safety/rail-rule-summary.

The specifications for a DOT-117 car are:

- **Capacity:** Increased from 263,000 lbs. to 286,000 lbs.
- **Thickness:** Increased from 7/16” to 9/16” steel
- **Thermal protection:** Required
- **Jacketing:** Minimum 11-gauge steel and weather-tight
- **Head shield:** Full-height, ½ inch thick
- **Bottom outlet:** Removed or designed to prevent unintended actuation
- **Top fittings:** Required (in accordance with AAR Spec. Tank Cars, Ap. E, p. 10.2.1)

Tank car phase-out schedules (2015 HM-251 and 2016 Fact Act)

According to the HM-251 rule, new tank cars constructed after October 1, 2015 are required to meet enhanced USDOT Specification 117 design or performance criteria for use in an HHFT. Existing tank cars must be retrofitted in accordance with the USDOT-prescribed retrofit design or performance standard for use in an HHFT. Retrofits must be completed based on a prescriptive retrofit schedule. A timeline for retrofitting of affected tank cars for use in North America for HHFTs, including CBR trains, was initially developed. The retrofit timeline focused on two risk factors, the packing group and differing types of DOT-111 and CPC-1232 tank car.

Retro-fitted tank cars must be in line with USDOT Specification 117R; a slightly modified version of USDOT Specification 117 applicable to newly-constructed tank cars. Recognizing that it would be infeasible to “add steel” to existing DOT-111 and CPC-1232 tank cars, the DOT-117R allows for the use of 7/16” steel. In addition, the shell material in the tank cars may be the steel that was authorized under the regulations when they were originally constructed, and the existing top-fittings protection are acceptable without retrofitting.

In August 2016, PHMSA issued a final rule, FAST Act Requirements for Flammable Liquids and Rail Tank Cars, that finalized a revised phase-out schedule for all DOT-111 tank cars used to transport crude oil, ethanol, and other Class 3 flammable liquids. The FAST Act requires that each tank car be built to DOT-117 specifications, and each non-jacketed tank car retrofitted to DOT-117R specifications be equipped with a thermal protection blanket that is at least one half-inch thick and meets existing thermal protection standards. In addition, the FAST Act mandates minimum top fittings to meet DOT-117R specifications. The revised phase-out schedule is detailed in Table 92.

Table 92: FAST Act Phase-Out Schedule Dates for Tank Cars Carrying Class 3 Flammable Liquids by Flammable Liquid Type and Tank Car Type[286]

Flammable Liquid	Tank Car Type	FAST Act Phase-Out Date
Petroleum Crude Oil	**Non-jacketed DOT-111**	January 1, 2018
Petroleum Crude Oil	**Jacketed DOT-111**	March 1, 2018
Petroleum Crude Oil	**Non-jacketed CPC-1232**	April 1, 2020
Petroleum Crude Oil	**Jacketed CPC-1232**	May 1, 2025
Ethanol	**Non-jacketed DOT-111**	May 1, 2023
Ethanol	**Jacketed DOT-111**	May 1, 2023
Ethanol	**Non-jacketed CPC-1232**	July 1, 2023
Ethanol	**Jacketed CPC-1232**	May 1, 2025
Other Flammable Liquids, Packing Group I	**Non-jacketed DOT-111**	May 1, 2025
Other Flammable Liquids, Packing Group I	**Jacketed DOT-111**	May 1, 2025
Other Flammable Liquids, Packing Group I	**Non-jacketed CPC-1232**	May 1, 2025
Other Flammable Liquids, Packing Group I	**Jacketed CPC-1232**	May 1, 2025
Other Flammable Liquids, Packing Group II/III	**Non-jacketed DOT-111**	May 1, 2029
Other Flammable Liquids, Packing Group II/III	**Jacketed DOT-111**	May 1, 2029
Other Flammable Liquids, Packing Group II/III	**Non-jacketed CPC-1232**	May 1, 2029
Other Flammable Liquids, Packing Group II/III	**Jacketed CPC-1232**	May 1, 2029

DOT-120 tank cars

The DOT-120 tank car (Figure 79) has safety enhancements that exceed those of DOT-117 cars (Table 94). According to the manufacturer, UTLX, the DOT-120 tank car is made compatible with existing crude oil loading and unloading facilities, whereas the DOT-117 car is built to "general service car standards" (Tesoro 2015).

[286] USDOT.

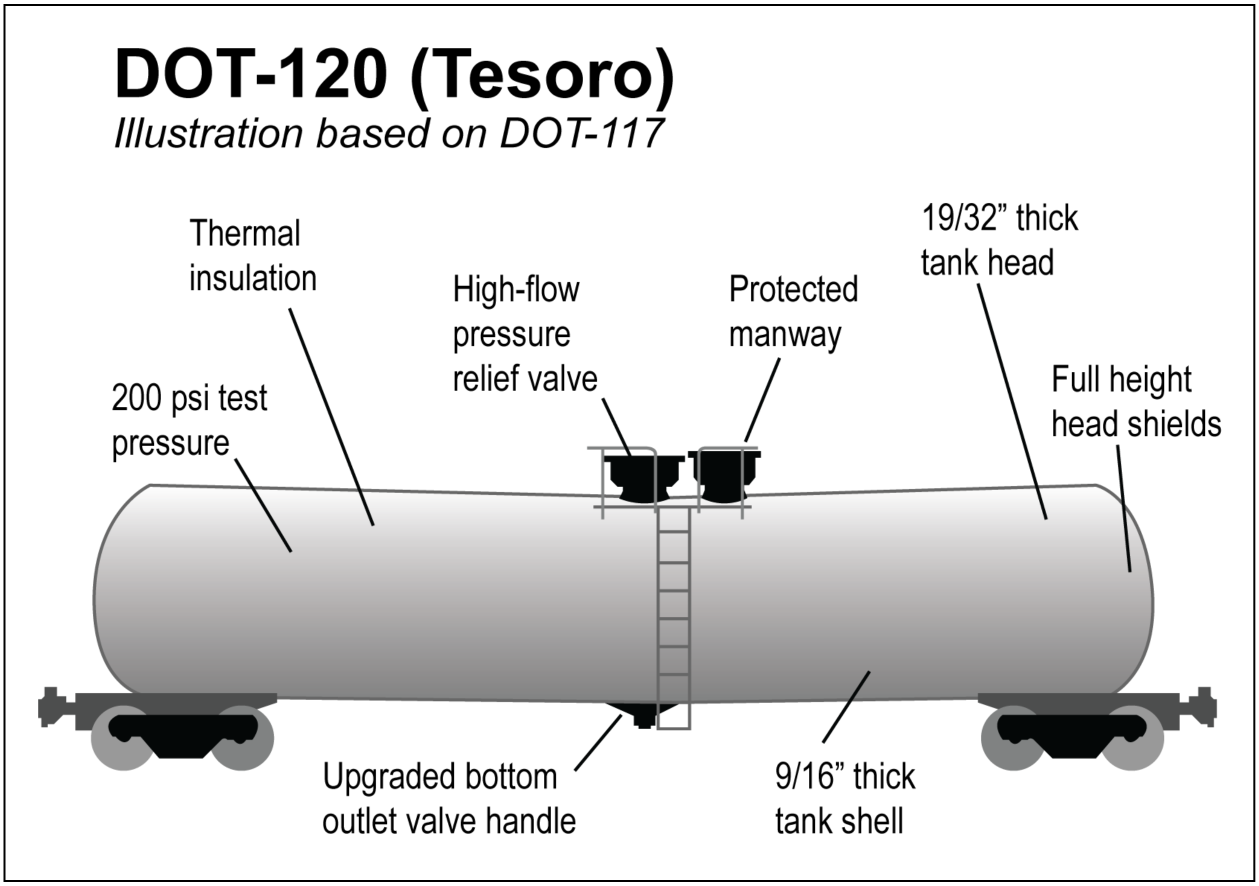

Figure 78: DOT-120 Tank Car (Tesoro 2015)

Table 93: DOT-120 Tank Cars Specifications in Comparison to DOT-117 Tank Cars[287]

Specification	DOT-117	DOT-120	Difference with DOT-120
Tank Shell Thickness	9/16”	9/16”	None
Head Shields	Full-height	Full-height	None
Tank Head Thickness	9/16”	19/32”	5.6% thicker
Tank Jacket	Yes	Yes	None
Thermal Protection Mode	Insulation *or* high-flow pressure-relief valve	Insulation *and* high-flow pressure-relief valve	Both modes of protection
Manway	Exposed	Protected	Greater protection
Bottom Outlet Valve Handle	Upgraded	Upgraded	None
Test Pressure	100 psi	200 psi	Double pressure standard

Release reduction effectiveness in new tank cars

Hazardous material release accidents decreased significantly between 1980 and 1993, and then remained relatively steady until another drop in 2008. Overall there has been a 90 percent decrease in spillage with improvements in tank car safety design, as well as a substantial reduction in accidents (Barkan et al. 2013). Much of this reduction in spillage may be attributable to the reduction in accidents. The reduction depends on the specific time period analyzed.

PHMSA/USDOT estimations of tank car design safety

A significant emphasis has been placed on reducing the likelihood of spillage from CBR trains with the implementation of safer tank car designs, emphasizing an increase in wall thickness. Wall (tank) thickness is inversely related to the probability of release (Barkan 2008a; Hughes et al. 1998). This means that the thicker the tank car wall, the less likely it is to release in an accident. The effectiveness of the new tank car designs was estimated and modeled by PHMSA, as shown in Table 94 based on the specifications in Table 95.

[287] Tesoro 2015.

Table 94: Effectiveness of Newly Constructed Tank Car Options Relative to DOT-111 Based on Percent of Head Punctures, Shell Punctures, Thermal Damage, Top Fittings, and Bottom Outlet Valve Release Probabilities[288]

Tank Car Type	Total	Head Puncture	Shell Puncture	Thermal Damage	Top Fittings	Bottom Outlet Valve
PHSMA/FRA (DOT-117)	55%	21%	17%	12%	4%	<1%
AAR 2014 Design	51.3%	21%	17%	12%	1.3%	<1%
Enhanced CPC-1232	41.3%	19%	9%	12%	1.3%	0%

Table 95: Summary of Options for Tank Car Standards (PHMSA/FRA, AAR 2014, and Enhanced CPC-1232) by Feature (Post October 1, 2015)[289]

Feature	PHMSA/FRA	AAR 2014	Enhanced CPC-1232
Wall Thickness	9/16”	9/16”	7/16”
AAR/TC-128 Grade B Steel	Required	Required	Required
Full Head Shield, ½ inch	Required	Required	Required
Thermal Protection[290]	Required	Required	Required
Reclosing Pressure Relief Device	Required	Required	Required
Jacket[291]	Required	Required	Required
Bottom Outlet Handle[292]	Required	Required	Required
Top Fittings Protection	TIH 9 mph rollover	AAR App. E 10.2.1	AAR App. E 10.2.1
Braking[293]	ECP Brakes	DP or EOT	DP or EOT
286,000 GRL[294] **Authorized**	Required	Required	Required

Other studies on tank car release rates

In another analysis conducted by AAR in conjunction with the Railway Supply Institute (RSI) as part of the RSI-AAR Railroad Tank Car Safety Research and Test Project, the conditional probability of release for various types of tank cars were found to be as shown in Table 96 (API/AAR 2014; Treichel 2014; Barkan et al. 2015).

[288] Federal Register Vol. 79, No. 108 (August 1, 2014), Part III Department of Transportation, Pipeline and Hazardous Materials Safety Administration (49 CFR Part 171, 172, 173, 174, 179) pp. 45,016–45,079.
[289] Federal Register Vol. 79, No. 108 (August 1, 2014), Part III Department of Transportation, Pipeline and Hazardous Materials Safety Administration (49 CFR Part 171, 172, 173, 174, 179) pp. 45,016–45,079.
[290] In accordance with 49 CFR Part179.18.
[291] Minimum 11-gauge jacket constructed from A1011 steel and weathertight.
[292] Bottom outlet handle removed or designed to prevent unintended actuation during train accident.
[293] ECP = electronically-controlled pneumatic brakes; DP = distributed power; EOT = end of train device.
[294] Gross rail load.

Table 96: Feature Description and Conditional Probability of Release by Tank Car Type[295]

Tank Car Category and Features	Conditional Probability of Release of Any Volume	Conditional Probability of Release of More than 2.4 bbl
DOT-111 (Legacy) with 7/16-inch Shell	26.6%	19.6%
DOT-111 (Legacy) with 7/16-inch Shell + Jacket	12.8%	8.5%
CPC-1232 with ½-inch Shell with Half-Height Head Shield and Top-Fittings Protection	13.2%	10.3%
CPC-1232 with 7/16-inch Shell + Jacket with Full-Height Head Shield and Top-Fittings Protection	6.4%	4.6%
CPC-1232 with ½-inch Shell + Jacket with Full-Height Head Shield and Top-Fittings Protection	5.2%	3.7%
DOT-117 with 9/16-inch Shell with Full-Height Head Shield and Top-Fittings Protection	4.2%	2.9%

Taking the data in Table 96, the calculated reductions in probabilities of release (spillage) from the newer design tank cars are shown in Table 97.

Table 97: Estimated Reductions in Release Probability with Newer Tank Cars (CPC-1232 and DOT-117) Compared to Non-Jacketed and Jacketed DOT-111 Tank Cars[296]

Tank Car Category and Features	Estimated Reduction in Release Probability of Any Volume Compared with Non-Jacketed DOT-111 Cars	Estimated Reduction in Release Probability of at Least 2.4 bbl Compared with Non-Jacketed DOT-111 Cars	Estimated Reduction in Release Probability of Any Volume Compared with Jacketed DOT-111 Cars	Estimated Reduction in Release Probability of at Least 2.4 bbl Compared with Jacketed DOT-111 Cars
CPC-1232 with ½-inch Shell with Half-Height Head Shield and Top-Fittings Protection	50.4%	47.4%	-3.1%	-21.2%
CPC-1232 with 7/16-inch Shell + Jacket with Full-Height Head Shield and Top-Fittings Protection	75.9%	76.5%	50.0%	45.9%
CPC-1232 with ½-inch Shell + Jacket with Full-Height Head Shield and Top-Fittings Protection	80.5%	81.1%	59.4%	56.5%
DOT-117 with 9/16-inch Shell with Full-Height Head Shield and Top-Fittings Protection	84.2%	85.2%	67.2%	65.9%

Another study estimated the reduction in the average probability of release from tank cars that meet the specifications of the DOT-117 car to be 85 percent compared with the probability of

[295] Probability that there will be a release or spill from a tank car given an accident. USDOT.
[296] USDOT.

release from the current non-jacketed DOT-111 car (Barkan et al. 2015). In addition, the enhanced design is expected to reduce considerably the likelihood of secondary failures caused by fire.

DOT-117R (retrofitted) tank cars

Retro-fitted tank cars must be in line with USDOT Specification 117R, which is slightly modified from the USDOT Specification 117 for newly-constructed tank cars. Recognizing that it would be infeasible to "add steel" to existing DOT-111 and CPC-1232 tank cars, the DOT-117R allows for the use of 7/16" steel. In addition, the shell material in the tank cars may be the steel that was authorized under the regulations when they were originally constructed, and the existing top-fittings protection are acceptable without retrofitting. There are no studies on release potential of retrofitted DOT-117 cars.

Thermal protection

In early April 2015, the NTSB issued a Safety Recommendation for thermal protection systems for tank cars, which neither the DOT-111 nor the CPC-1232 designs have. This thermal protection is intended to limit the heat flux to the tank car containers when exposed to fire. According to NTSB (NTSB 2015):

> Appropriately designed thermal protection systems will prevent a rapid increase in the temperature of the lading and commensurate increase in vapor pressure in the tank, and are intended to limit the volume of materials required to be evacuated through the pressure relief device, thereby limiting dangerous over-pressurization of the tank.
>
> Exposing a bare steel, flammable-liquid filled tank car to a large pool fire from product released in an accident can result in tank failure from a thermal tear in the tank that was not otherwise breached in a derailment. When the tank is exposed to heat from a pool fire, the internal pressure increases while the strength of the tank decreases. The tank will rupture if the pressure relief device cannot sufficiently relieve internal pressure. The resulting thermal tear in the shell material suddenly releases built-up pressure, ejecting vapor and liquid to ignite in a violent fireball eruption. Research studying accidents involving tank cars has shown that use of tank cars with thermal protection and a jacket will significantly reduce the amount of product released in accidents (Treichel et al. 2006). PHMSA estimates that jacketed CPC-1232 tank cars with thermal protection systems could provide an 18 percent reduction in lading loss in accidents relative to comparable accidents involving non-jacketed CPC-1232 tank cars.[297] (p. 2)

NTSB made the following safety recommendations to PHMSA:

- **R-15-14**: Require that all new and existing tank cars used to transport all Class 3 flammable liquids to be equipped with thermal protection systems that meet or exceed the thermal performance standards outlined in Title 49 CFR 179.18(a) and are appropriately qualified for the tank car configuration and the commodity transported.

[297] *Calculating Effectiveness Rates of Tank Car Options*, PHMSA Docket PHMSA-2012-0082.

- **R-15-15**: In conjunction with thermal protection systems called for in safety recommendation R-15-14, require that all new and existing tank cars used to transport all Class 3 flammable liquids to be equipped with appropriately sized pressure relief devices. Those devices must allow the release of pressure under fire conditions to ensure thermal performance that meets or exceeds the requirements of Title 49 CFR 179.18(a), and minimizes the likelihood of energetic thermal ruptures.
- **R-15-16**: Require an aggressive, intermediate progress milestone schedule, such as a 20-percent yearly completion metric over a 5-year implementation period, for the replacement or retrofitting of legacy DOT-111 and CPC-1232 tank cars to appropriate tank car performance standards, that includes equipping these tank cars with jackets, thermal protection, and appropriately sized pressure relief devices.
- **R-15-17:** Establish a publicly available reporting mechanism that reports at least annually, progress on retrofitting and replacing tank cars subject to thermal protection system performance standards as recommended in safety recommendation R-15-16. (p. 9)

Availability issues for DOT-117 tank cars

The adoption of the DOT-117 tank cars depends upon the practice of the individual operators of the trains and on the availability of these tank cars for all of the current and potential future CBR traffic in Washington State. While all newly-constructed tank cars are required to meet the DOT-117 specifications by 1 October 2015, the timeline for retrofitting of older tank cars would allow for some non-compliant tank cars to be in use until mid-2025. Some of the interim retrofitted designs do provide better protection against spillage than DOT-111 cars, but are not quite as effective as the DOT-117 design.

When the PHSMA/USDOT regulations regarding tank cars were released in May 2015, industry experts warned that there may be significant shortages of DOT-117 tank cars while manufacturers try to meet the sudden high demand (Thomas 2015). Based on the retrofitting timetable, a large portion of the existing unjacketed and jacketed DOT-111 tank cars were removed from service in early 2018. According to the Railway Supply Institute Committee on Tank Cars, there was concern that the retrofitting process could result in capacity shortfalls, which would have significant impacts on the availability of tank cars (Neels and Berkman 2014). The committee expressed concern over the possibility that there may not be sufficient DOT-117 cars to meet the demands for all of the future CBR traffic in Washington State.

Status of DOT-117 conversion and manufacturing

The Association of American Railroads (AAR) released data on the numbers of tank cars in service over the last several years as summarized in Table 98 and Figure 80.

Table 98: Number of Unique Tank Cars Making at Least One Shipment in the Year (US) by Tank Car Type and by Year, 2013–2018[298]

Type of Tank Car	Year 2013	Year 2014	Year 2015	Year 2016	Year 2017	Year 2018 1st Quarter
DOT 111 Non-Jacketed	18,212	13,711	6,188	543	61	3
DOT 111 Jacketed	3,128	2,638	810	248	122	45
DOT 111 (Total)	**21,340**	**16,349**	**6,998**	**791**	**183**	**48**
CPC 1232 Non-Jacketed	11,966	17,163	17,962	8,498	4,502	1,066
CPC 1232 Jacketed	6,514	17,120	21,947	11,588	11,410	8,662
CPC 1232 (Total)	**18,480**	**34,283**	**39,909**	**20,086**	**15,912**	**9,728**
DOT 117 117J	0	0	1,818	2,731	3,315	3,420
DOT 117 117R	0	0	132	652	1,425	1,611
DOT 117 (Total)	**0**	**0**	**1,950**	**3,383**	**4,740**	**5,031**
DOT 115	0	10	6	0	0	0
AAR 211	513	171	59	7	0	0
Total Non-Pressure Cars	**40,333**	**50,813**	**48,922**	**24,267**	**20,835**	**14,807**
DOT 105	6	0	0	0	0	0
DOT 112	3	78	53	47	0	0
DOT 114	0	0	0	0	0	0
DOT 120	0	0	4	598	734	732
Total Pressure Cars	9	78	57	645	734	732
GRAND TOTAL	**40,342**	**50,891**	**48,979**	**24,912**	**21,569**	**15,539**

298 Source: AAR 2018c.

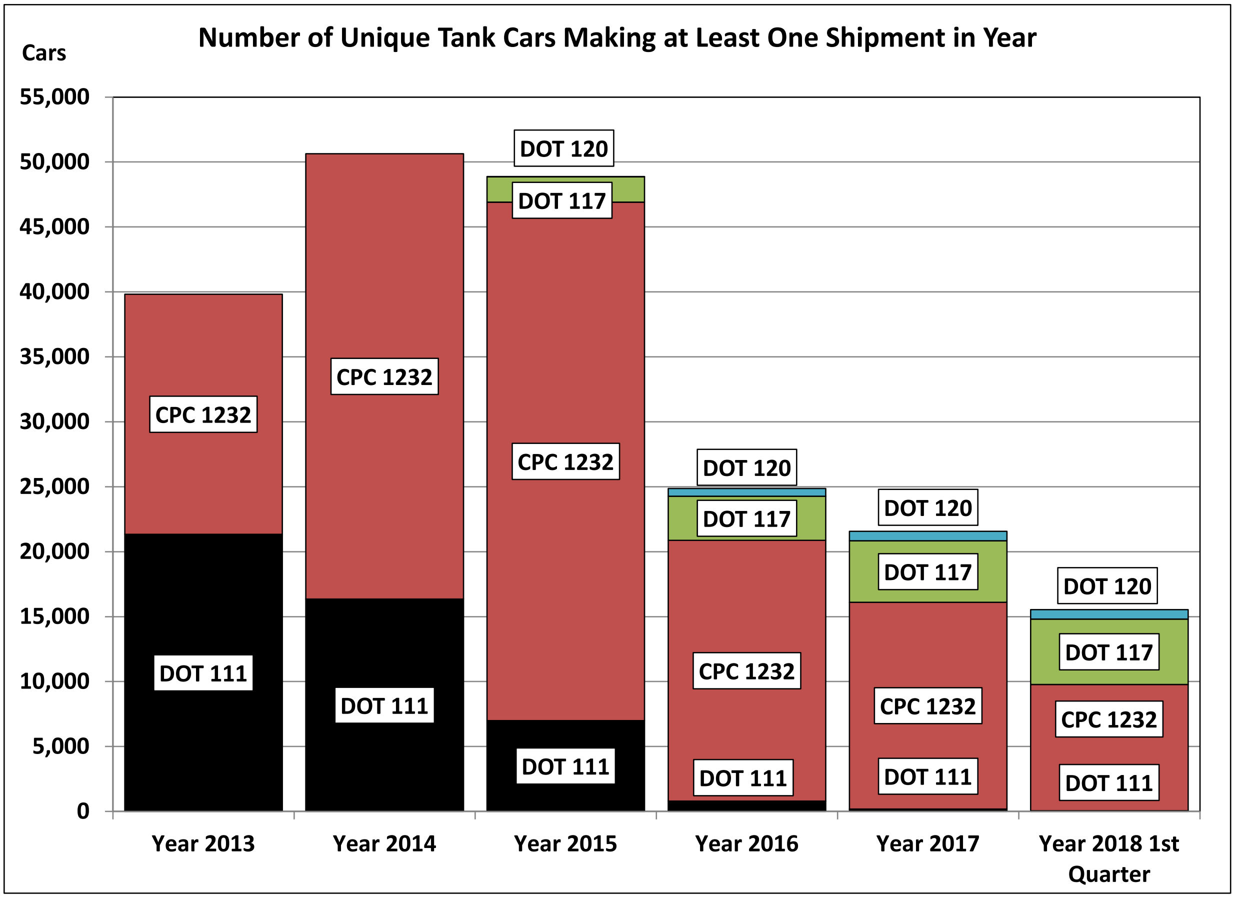

Figure 79: General Types of Tank Cars Making Shipments in U.S., 2013–2018[299]

A more detailed analysis was conducted by the Bureau of Transportation Statistics (BTS 2018) for data through 2017, as shown in Table 99.

[299] Based on: AAR 2018c.

Table 99: Tank Cars in Use in 2017 by Type and Car Service (Crude, Ethanol, Class 3 Flammable, and Multiple Service) Based on Total Car Numbers and Percent of Total Cars[300]

Car Type	Crude Cars	Ethanol Cars	Other Class 3 Flammable Cars	Multiple Service Cars	Crude % Total Cars	Ethanol % Total Cars	Other Class 3 Flammable % Total Cars	Multiple Service% Total Cars
Non-Jacketed DOT-111	58	17,826	10,926	7,533	0.5%	68.9%	56.3%	55.9%
Jacketed DOT-111	80	116	3,629	186	0.7%	0.4%	18.7%	1.4%
Non-Jacketed CPC-1232	3,925	1,394	1,453	1,324	32.4%	5.4%	7.5%	9.8%
Jacketed CPC-1232	4,551	226	1,824	762	37.5%	0.9%	9.4%	5.7%
DOT-117 Retrofit	1,029	2,399	576	1,849	8.5%	9.3%	3.0%	13.7%
DOT-117 New	2,484	3,899	1,004	1,824	20.5%	15.1%	5.2%	13.5%
Total	12,127	25,860	19,412	13,478	100.0%	100.0%	100.0%	100.0%

Current tank car types in use in Washington State

According to BNSF's Oil Spill Response Plan (BNSF 2018b), the railroad has not used DOT-111 tank cars in unit trains since August 2016. Moreover, the DOT-111 cars are no longer authorized for use in transporting Class 3 flammable liquids since January 1, 2018.

BNSF utilizes only DOT-117 and CPC-1232 tank cars for the transport of crude oil. Other types of flammable liquids or oils are transported by DOT-112 and DOT-120 tank cars.

There is no apparent shortage of appropriate tank cars at this time. However, there have been significant reductions in the potential need for these cars because the Shell Anacortes Rail Unloading Facility decided to withdraw its application in early 2016 and the denial of a permit to the Vancouver Energy Distribution Terminal in January 2018. These facilities together would

[300] Based on data in: BTS 2018.

have required an additional 560 loaded cars per day, effectively increasing the demand for tank cars by 48 percent.[301]

Tank cars for other commodities

Tank cars are used to transport a large variety of both hazardous and non-hazardous commodities other than crude oil. There are different types of tank cars that are employed for this transport.

There are two main categories of tank cars — pressurized and non-pressurized tanks. Currently, about 80 percent of the North American tank car fleet of 414,780 cars are non-pressurized cars (331,824 cars), and 20 percent are pressurized cars (82,956 cars) (Railway Supply Institute). There are also cryogenic liquid tank cars.

Non-pressurized tank cars are for general use for liquid commodities that do not need to be pressurized in transit. These would include the tank cars previously described for use in the transport of crude oil (DOT-117, CPC-1232, DOT-111/AAR-211). The DOT-111 cars, and the equivalent AAR-211 cars can be used for non-regulated service. This means that they can be used for anything other than flammable liquids. The ten most common non-regulated commodities shipped by tank car in 2015 were (Railway Supply Institute undated):

- Corn syrup
- Soybean oil
- Nitrogen fertilizer solution
- Petroleum lubricating oil
- Rapeseed oil (e.g., canola oil)
- Methyl esters
- Petroleum oil
- Kaolin clay slurry
- Vegetable oil
- Limestone slurry

Pressurized tanks are built with thicker tanks to withstand higher internal pressures, making them stronger than non-pressurized tank cars. They are used for shipping commodities that need to be under pressure (e.g., propane, liquefied petroleum gas), poison/toxic inhalation hazards, and some corrosive materials.

Cryogenic cars are vacuum-insulated cars that have an inner container (tank) and a carbon steel outer shell tank. They are used to transport refrigerated (extremely cold) liquefied gases that have a boiling point colder than minus 130°F at atmospheric pressure (e.g., liquid hydrogen, ethylene, oxygen, nitrogen, and argon).

[301] The existing facilities require about five trains per day. The additional facilities would have added nearly another five, with the trains going to Shell Anacortes being shorter (102 cars rather than the more typical 118 cars).

- About 75 percent of the shipments in tank cars involve regulated hazardous materials. The ten most common commodities shipped by tank car in 2015 were (Railway Supply Institute undated):
    - Petroleum crude oil
    - Alcohol
    - Liquefied petroleum gases
    - Elevated temperature liquids
    - Sodium hydroxide
    - Sulfuric acid
    - Propane
    - Molten sulfur
    - Diesel fuel
    - Butane

The types of tank cars used for shipping commodities other than crude oil and other Class 3 flammable liquids are described in Table 100. The breakdown of numbers of the most common tank cars by type is shown in Table 101.

Table 100: Descriptions of Tank Car Classes and Types (Non-Class 4 Flammable Service)[302]

Car Class	Type	Description
DOT-111	Non-pressurized	Insulated or non-insulated, without an expansion dome.
DOT-115	Non-pressurized	Insulated with a carbon or alloy (stainless) steel or an aluminum inner container (tank) and a carbon steel outer shell (tank, not jacket). Otherwise known as a tank within a tank.
DOT-206	Non-pressurized	Insulated with an inner-container (tank) and carbon steel outer-shell. Similar to DOT-115.
DOT-211	Non-pressurized	Insulated or non-insulated, without an expansion dome. Similar to DOT-111.
DOT-105	Pressurized	Insulated carbon or alloy steel.
DOT-109	Pressurized	Insulated or non-insulated, carbon steel or aluminum.
DOT-112	Pressurized	Insulated or non-insulated, carbon or alloy steel.
DOT-114	Pressurized	Insulated or non-insulated, carbon or alloy steel.
DOT-120	Pressurized	Insulated carbon steel or aluminum.
DOT-113	Cryogenic Liquid	Vacuum insulated with a high alloy or nickel alloy inner container (tank) and carbon steel outer shell (tank, not jacket).
AAR-204	Cryogenic Liquid	Vacuum insulated with an inner alloy steel container (tank) and carbon steel outer shell (tank, not jacket). Similar to DOT-113.

[302] USDOT.

Table 101: Numbers of Cars and Percentages in North American Tank Car Fleet by Car Class, Type of Service (Non-Pressurized and Pressurized) Including Types of Commodities Carried[303]

Car Class	Type of Service	Number of Cars	% Fleet	Types of Commodities
DOT-117	Non-Pressurized	16,591	4%	Flammable liquids
DOT-111	Non-Pressurized	261,311	63%	Non-regulated liquids
AAR-211	Non-Pressurized	58,069	14%	Non-regulated liquids
DOT-105	Pressurized	20,739	5%	Gases under pressure, low-pressure high-hazard materials
DOT-112	Pressurized	58,069	14%	Gases under pressure, low-pressure high-hazard materials, including some flammable liquids
Total	**Non-Pressurized**	**111,911**	**80%**	
Total	**Pressurized**	**78,808**	**20%**	
Total	**All Service**	**414,780**	**100%**	

Accidents with hazmat tank cars

With the movement of hazardous materials in tank cars, there is a potential for accidents that may cause releases or spills. Most accidents are attributable to human error and track or roadbed issues (see Chapter 5). Those attributable to mechanical and electrical represent about 20 percent of all accidents. Of these mechanical causes of derailments, less than 10 percent are attributable to car body (tank car) issues per se. However, an accident that causes a derailment can cause an impact to a tank car and result in a release.

Hazmat tank car accident rates

Overall, the annual numbers of rail accidents in the U.S. that have resulted in the release of hazardous materials have declined by 70 percent since 2007 (AAR Analysis of FRA data, as presented by Railway Supply Institute.[304] The rate rail accidents with hazardous material release per carload decreased from 0.241 per thousand carloads to 0.072 per thousand carloads between 2005 and 2015 (AAR Analysis of FRA data, as presented by Railway Supply Institute).[305] This means that with each carload of hazardous material shipped there is a one in 140,000 chance of a release or spill.

Safety measures for hazmat tank cars in accidents

Like tank cars that are used for shipping crude oil, tank cars used for other commodities are also equipped with various devices and safety systems designed to protect the tank and fittings from damage during an accident or severe impact (Maty 2012). These devices include:

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[303] Railway Supply Institute.
[304] Railway Supply Institute. Tank Car Resource Center. https://tankcarresourcecenter.com/tankcar101/#1499694206621-d3e6b712-ac21.
[305] Ibid.

- Pressure relief devices
- Coupler vertical restraint systems (double-shelf couplers)
- Tank head puncture-resistance systems (head shields)
- Thermal (fire) protection
- Service equipment (filling, discharge, venting, safety, heating, and measuring devices)
- Protection systems

Tank cars carrying hazardous liquids other than crude oil are subject to the same types of potential accidents as the tank cars in CBR unit trains. These shipments usually come in smaller numbers of tank cars per train.

Tank car releases in accidents

The FRA data for 68,613 freight train accidents on mainline tracks during 1975–2018 were analyzed to determine release rates for tank cars. The most important findings are summarized in Table 102 and Figure 81. The results are presented in greater detail by accident type in Table 103.

Overall, the average number of hazmat cars has increased nearly four times over 40 years. At the same time, the percentage of cars that are damaged in accidents has decreased 74 percent. The percentages of damaged cars releasing hazardous materials have decreased by 81 percent.

Table 102: Hazmat Tank Cars in Freight Train Accidents by Time Period Including Average Numbers of Hazmat Cars on Trains, Average Percent of Cars Damaged Per Accident, Average Percent of Cars Releasing Hazmats, and Average Percent of Damaged Cars Releasing Hazmats[306]

Time Period	Average Number Hazmat Cars on Train	Average % Cars Damaged per Accident	Average % Total Cars Releasing Hazmats	Average % Damaged Cars Releasing Hazmats
1975-1984	5.2	36.38%	9.02%	11.68%
1985-1994	7.8	27.29%	5.01%	7.41%
1995-2004	10.8	19.33%	1.99%	3.68%
2005-2014	15.0	12.61%	1.10%	3.17%
2015-2018	19.0	9.63%	0.60%	2.27%

306 Analysis by Environmental Research Consulting based on FRA data.

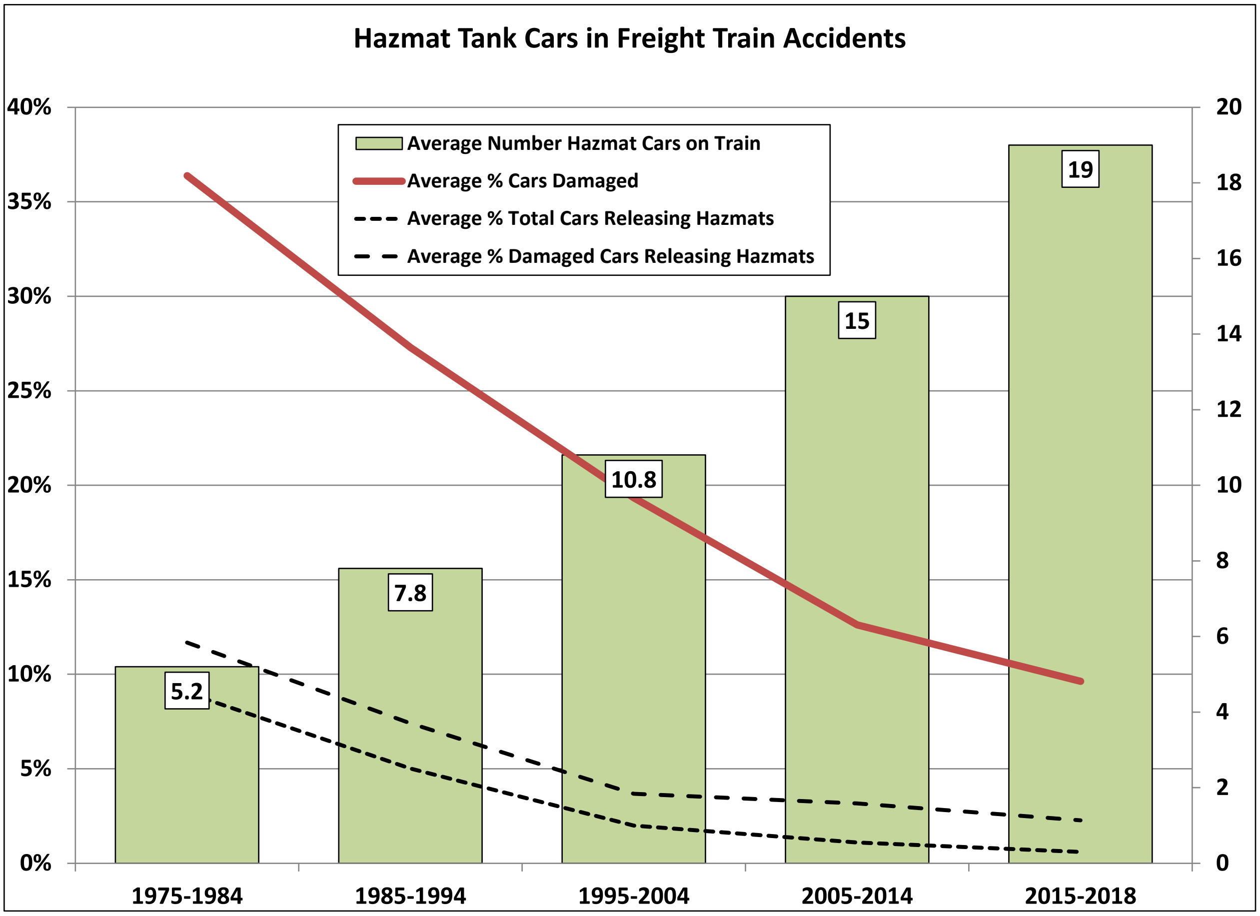

Figure 80: Hazmat Tank Cars in Mainline Freight Train Accidents by Time Period[307]

[307] Analysis by Environmental Research Consulting based on FRA data. Used with permission.

Table 103: Hazmat Tank Car Damage in Rail Accidents by Time Period Broken Out by Accident Type Including the Average Number of Hazmat Cars on Train, Average Number of Cars Derailed or Damaged, Average Number of Cars Releasing Hazmats, Average Percent of Cars Damaged, Average Percent Cars Releasing Hazmats, and Average Percent of Damaged Cars Releasing Hazmats[308]

Accident Type	Time Period	Average Number Hazmat Cars on Train	Average Number Cars Damaged or Derailed	Average Number of Cars Releasing Hazmats	Average % Cars Damaged	Average % Total Cars Releasing Hazmats	Average % Damaged Cars Releasing Hazmats
Collision	**1975-1984**	5.9	0.6	0.1	19.72%	6.26%	8.29%
Collision	**1985-1994**	8.7	0.4	0.1	11.40%	3.30%	5.05%
Collision	**1995-2004**	10.0	1.0	0.1	14.71%	1.79%	3.88%
Collision	**2005-2014**	16.2	0.8	0.1	6.72%	0.98%	2.76%
Collision	**2015-2018**	18.2	0.8	0.1	14.73%	0.70%	3.33%
Collision	**All Years**	**10.3**	**0.7**	**0.1**	**13.64%**	**3.11%**	**5.07%**
Derailment	**1975-1984**	5.2	1.3	0.3	39.54%	9.67%	12.53%
Derailment	**1985-1994**	7.8	1.6	0.3	31.52%	5.55%	8.32%
Derailment	**1995-2004**	11.1	1.7	0.2	22.27%	2.20%	4.19%
Derailment	**2005-2014**	15.4	1.7	0.3	17.64%	1.45%	4.11%
Derailment	**2015-2018**	21.1	1.8	0.4	15.25%	1.03%	3.77%
Derailment	**All Years**	**9.3**	**1.5**	**0.3**	**29.57%**	**5.50%**	**8.11%**
Explosion	**1975-1984**	1.0	1.0	0.0	100.00%	0.00%	0.00%
Explosion	**1985-1994**	n/a	n/a	n/a	n/a	n/a	n/a
Explosion	**1995-2004**	n/a	n/a	n/a	n/a	n/a	n/a
Explosion	**2005-2014**	7.0	2.0	0.0	28.57%	0.00%	0.00%
Explosion	**2015-2018**	n/a	n/a	n/a	n/a	n/a	n/a
Explosion	**All Years**	**4.0**	**1.5**	**0.0**	**64.29%**	**0.00%**	**0.00%**
Fire	**1975-1984**	3.7	0.1	0.1	8.25%	4.50%	6.67%
Fire	**1985-1994**	9.4	0.3	0.1	18.06%	6.94%	11.11%
Fire	**1995-2004**	8.3	0.0	0.0	0.00%	0.00%	0.00%

[308] Analysis by Environmental Research Consulting based on FRA data.

Accident Type	Time Period	Average Number Hazmat Cars on Train	Average Number Cars Damaged or Derailed	Average Number of Cars Releasing Hazmats	Average % Cars Damaged	Average % Total Cars Releasing Hazmats	Average % Damaged Cars Releasing Hazmats
Fire	**2005-2014**	15.1	0.0	0.0	0.00%	0.00%	0.00%
Fire	**2015-2018**	25.1	0.0	0.0	0.00%	0.00%	0.00%
Fire	**All Years**	**10.2**	**0.1**	**0.0**	**6.61%**	**3.19%**	**4.84%**
Hwy-Rail Cross	**1975-1984**	5.0	0.5	0.1	14.72%	3.52%	4.51%
Hwy-Rail Cross	**1985-1994**	7.9	0.5	0.1	10.75%	2.69%	3.15%
Hwy-Rail Cross	**1995-2004**	9.5	0.3	0.0	5.73%	0.54%	0.54%
Hwy-Rail Cross	**2005-2014**	14.0	0.2	0.0	2.11%	0.08%	0.57%
Hwy-Rail Cross	**2015-2018**	15.6	0.2	0.0	1.65%	0.15%	0.66%
Hwy-Rail Cross	**All Years**	**11.3**	**0.3**	**0.0**	**5.63%**	**1.00%**	**1.45%**
Obstruction	**1975-1984**	6.3	1.1	0.1	14.72%	6.88%	12.50%
Obstruction	**1985-1994**	4.7	0.5	0.2	9.15%	4.00%	4.00%
Obstruction	**1995-2004**	11.8	0.6	0.1	4.73%	0.61%	1.53%
Obstruction	**2005-2014**	13.1	0.4	0.1	3.52%	1.33%	5.17%
Obstruction	**2015-2018**	26.6	0.1	0.0	0.58%	0.00%	0.00%
Obstruction	**All Years**	**12.9**	**0.5**	**0.1**	**5.26%**	**1.82%**	**3.88%**
Other	**1975-1984**	n/a	n/a	n/a	n/a	n/a	n/a
Other	**1985-1994**	n/a	n/a	n/a	n/a	n/a	n/a
Other	**1995-2004**	10.6	0.2	0.0	5.92%	1.85%	1.85%
Other	**2005-2014**	14.2	0.1	0.0	3.96%	1.56%	1.56%
Other	**2015-2018**	12.0	0.1	0.0	10.42%	0.00%	0.00%
Other	**All Years**	**12.5**	**0.1**	**0.0**	**5.80%**	**1.41%**	**1.41%**
Other Impacts	**1975-1984**	5.6	0.3	0.0	9.78%	2.92%	1.62%
Other Impacts	**1985-1994**	5.7	0.4	0.1	10.00%	1.33%	1.67%
Other Impacts	**1995-2004**	8.2	0.5	0.1	22.22%	3.85%	3.85%
Other Impacts	**2005-2014**	12.7	0.3	0.0	10.45%	0.24%	3.13%
Other Impacts	**2015-2018**	10.8	0.9	0.0	23.12%	0.00%	0.00%

Accident Type	Time Period	Average Number Hazmat Cars on Train	Average Number Cars Damaged or Derailed	Average Number of Cars Releasing Hazmats	Average % Cars Damaged	Average % Total Cars Releasing Hazmats	Average % Damaged Cars Releasing Hazmats
Other Impacts	**All Years**	**7.4**	**0.4**	**0.0**	**13.26%**	**2.23%**	**2.28%**
RR Grade Cross	**1975-1984**	16.3	0.0	0.0	0.00%	0.00%	0.00%
RR Grade Cross	**1985-1994**	9.5	0.5	0.0	2.94%	0.00%	0.00%
RR Grade Cross	**1995-2004**	6.1	0.0	0.0	0.00%	0.00%	0.00%
RR Grade Cross	**2005-2014**	35.5	0.0	0.0	0.00%	0.00%	0.00%
RR Grade Cross	**2015-2018**	8.0	0.0	0.0	0.00%	0.00%	0.00%
RR Grade Cross	**All Years**	**12.7**	**0.1**	**0.0**	**0.39%**	**0.00%**	**0.00%**
All Accidents	**1975-1984**	**5.2**	**1.2**	**0.3**	**36.38%**	**9.02%**	**11.68%**
All Accidents	**1985-1994**	**7.8**	**1.3**	**0.24**	**27.29%**	**5.01%**	**7.41%**
All Accidents	**1995-2004**	**10.8**	**1.4**	**0.15**	**19.33%**	**1.99%**	**3.68%**
All Accidents	**2005-2014**	**15.0**	**1.2**	**0.18**	**12.61%**	**1.10%**	**3.17%**
All Accidents	**2015-2018**	**19.0**	**1.0**	**0.19**	**9.63%**	**0.60%**	**2.27%**
All Accidents	**All Years**	**9.7**	**1.3**	**0.2**	**24.67%**	**4.65%**	**6.87%**

The numbers in Table 102, Table 103, and Figure 81 are averages. They also include large numbers of trains that carry limited numbers of tank cars. In fact, 94 percent of the incidents in these data involve trains with fewer than 20 tank cars on a train, 56 percent have fewer than 6 cars on a train. Considering only key trains (with at least 20 hazmat tank cars on a single train) and unit trains of tank cars (with all cars on a train containing a single commodity), the analyses were redone with the results shown in Table 104. There is still a significant reduction in the percentages of damaged cars with releases.

Table 104: Hazmat Tank Cars in Freight Key and Unit Train Accidents by Time Period Including the Average Number of Hazmat Cars on Train, Average Number of Cars Derailed or Damaged, Average Number of Cars Releasing Hazmats, Average Percent of Cars Damaged, Average Percent Cars Releasing Hazmats, and Average Percent of Damaged Cars Releasing Hazmats[309]

Time Period	Total Number of Accidents with Key or Unit Trains	% Incidents with 80 or More Cars	Average Number Hazmat Cars on Train[310]	Average % Cars Damaged	Average % Total Cars Releasing Hazmats	Average % Damaged Cars Releasing Hazmats
1975-1984	170	5.9%	38.0	15.23%	3.08%	10.04%
1985-1994	219	4.6%	35.2	12.16%	2.12%	7.32%
1995-2004	433	3.0%	34.5	10.87%	1.27%	5.24%
2005-2014	584	6.0%	38.4	6.60%	0.95%	4.96%
2015-2018	196	18.4%	47.9	4.03%	0.77%	4.82%

Non-accident releases from hazardous material tank cars

Other types of incidents that may cause releases from tank cars during loading and unloading are called "non-accident releases" (NARs). These NAR incidents typically involve relatively small quantities and are generally due to cars not being properly secured after loading or unloading. These types of accidents may occur when the cars are moving, or stationary.

Rates of non-accidental releases from hazmat tank cars

The rate of NAR accidents has declined by 49 percent since 2005, from 0.43 incidents per thousand hazmat carloads to 0.22 incidents per thousand carloads (AAR analysis of FRA data, as presented by Railway Supply Institute).[311] In other words, these smaller spills occur about once for every 4,500 carloads.

Analyses of the 456 NAR incidents that occurred during the year 2017 for the U.S. and Canada show that the most common commodity released was liquefied petroleum gas (LPG), followed by alcohols (ethanol), as summarized in Table 105 (Treichel 2018; AAR 2018a). Of these NAR incidents, eight occurred from tank cars in Washington State. Two occurred from intermodal containers.

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[309] Analysis by Environmental Research Consulting based on FRA data.
[310] Minimum is 20 cars (the definition of a "key train").
[311] Railway Supply Institute. Tank Car Resource Center. https://tankcarresourcecenter.com/tankcar101/#1499694206621-d3e6b712-ac21

Table 105: Top Commodities for Non-Accident Releases from Tank Cars with the Numbers of Non-Accident Releases (U.S. and Canada 2017)[312]

Commodity	Number of Non-Accident Releases
Liquefied Petroleum Gases	66
Alcohols (Ethanol)	35
Fuel Oils	33
Sodium Hydroxide	22
Hydrochloric Acid	17
Molten Sulfur	16
Environmental Hazardous Substances	14
Sulfuric Acid	14
Elevated Temperature Materials	11
Corrosive Liquids	11
Hydrocarbon Liquids	11
Flammable Liquids	10
Anhydrous Ammonia	10
Waste Flammable Liquids	8
Gasoline	8
Argon Gas	7
Petroleum Distillates	7
Petroleum Crude Oil	3

Rates of NARs (releases per carload) generally decreased by 25 percent between 2012 and 2017, as shown in Table 106. However, the rates and trends vary between the commodities with some rates increasing, such as for ammonia.

Table 106: Tank Car Non-Accident Rate per 1,000 Carloads by Year and Hazardous Class/ Major Commodity Category, U.S. & Canada, 2012–2017[313]

Hazardous Class/ Major Commodity[314]	Year 2012	Year 2013	Year 2014	Year 2015	Year 2016	Year 2017
Class 2.1 Flammable Gas	**0.17**	**0.18**	**0.11**	**0.15**	**0.17**	**0.22**
LPG	0.17	0.17	0.09	0.13	0.18	0.26
Class 2.2 Non-Flammable Gas	**0.57**	**0.45**	**0.49**	**0.43**	**0.76**	**0.69**
Ammonia	0.40	0.34	0.21	0.06	0.15	0.34
Class 2.3 Poison Gas	**0.24**	**0.18**	**0.13**	**0.10**	**0.07**	**0.09**
Chlorine	0.11	0.11	0.15	0.12	0.08	0.08
Class 3 Flammable Liquid	**0.36**	**0.27**	**0.28**	**0.20**	**0.20**	**0.19**
Ethanol	0.20	0.24	0.23	0.19	0.15	0.11
Petroleum Crude Oil	0.40	0.24	0.27	0.10	0.03	0.01
Combustible Liquid	**0.47**	**0.43**	**0.50**	**0.50**	**0.65**	**0.21**

[312] Based on data in Treichel 2018; AAR 2018a.
[313] AAR 2018a
[314] Annual values for major hazard classes are shown in bold. Beneath the class totals are values for the most commonly transported commodities within that class.

Hazardous Class/ Major Commodity[314]	Year 2012	Year 2013	Year 2014	Year 2015	Year 2016	Year 2017
Class 5.1 Oxidizer	**0.44**	**0.44**	**0.12**	**0.19**	**0.06**	**0.31**
Class 6.1 Poisonous Material	**0.31**	**0.31**	**0.27**	**0.32**	**0.26**	**0.33**
Class 8 Corrosive	**0.34**	**0.31**	**0.37**	**0.40**	**0.36**	**0.39**
Sulfuric Acid	0.19	0.17	0.28	0.31	0.20	0.24
Hydrochloric Acid	0.87	0.60	0.59	0.73	0.96	0.55
Phosphoric Acid	0.24	0.16	0.27	0.18	0.24	0.29
Sodium Hydroxide	0.15	0.14	0.27	0.24	0.14	0.29
Class 9 Miscellaneous	**0.18**	**0.21**	**0.27**	**0.25**	**0.15**	**0.20**
Other Classes (4.1, 4.2, 4.3, Mixed Freight)	**0.44**	**0.14**	**0.41**	**0.21**	**0.59**	**0.92**
Total (US and Canada)	**0.32**	**0.27**	**0.27**	**0.23**	**0.23**	**0.24**

Causes of non-accidental releases from hazmat tank cars

Treichel (2018) analyzed the causes of NARs in both non-pressurized and pressurized cars for incidents in 2017. The analyses showed that for non-pressurized cars, the most commonly involved car component causing the release was the manway/pressure plate, accounting for 31 percent of incidents. The top specific causes of non-pressurized car NARs were loose nuts and bolts, and deteriorated gaskets on manways. The components and causes of NARs in non-pressurized cars are summarized in Table 107 and Table 108.

Table 107: Components Involved in Non-Accidental Releases in Non-Pressurized Cars 2017 Including Numbers of Incidents and Percent Total Incidents[315]

Component	Incidents	% Incidents
Manway/Pressure Plate	115	31%
Liquid Line	73	20%
Bottom Fittings	69	19%
Pressure Relief Valve	25	7%
Safety Vent	18	5%
Fill Hole	15	4%
Vapor Line (Air Inlet)	14	4%
Other	8	2%
Vacuum Relief Valve	7	2%
Sample Line	7	2%
Shell or Head	6	2%
Thermometer Well	5	1%
Heater Coils	2	1%
Gauging Device	1	1%

[315] Treichel 2018.

Table 108: Top Specific Causes of Non-Accidental Releases in Non-Pressurized Cars 2017 Including Numbers of Incidents and Percent Total Incidents[316]

Component	Incidents	% Incidents
Manway–Bolts/Nuts Loose	55	55%
Manway–Gasket Deteriorated	34	9%
Fill Hole–Bolts/Nuts Loose	10	3%
Liquid Line–Mounting Flange Bolts/Nuts Loose	9	2%
Liquid Line–Valve Loose	9	2%
Bottom Outlet Valve–Cap Loose, Valve Closed	9	2%
Liquid Line–Closure Plug Loose, Valve Open	9	2%
Other (e.g. Vandalism)	8	2%
Pressure Relief Device–Frangible Disc Rupture	8	2%
Bottom Outlet Valve–Cap Loose, Valve Open	8	2%
Manway–Gasket Missing	8	2%

The analyses showed that for pressurized cars, the most commonly involved car component causing the release was the liquid, accounting for 52 percent of incidents. The top specific cause of pressurized car NARs was a loose closure plug and open valve. The components and causes of NARs in pressurized cars are summarized in Table 109 and Table 110.

Table 109: Components Involved in Non-Accidental Releases in Pressurized Cars 2017 Including Numbers of Incidents and Percent Total Incidents[317]

Component	Incidents	% Incidents
Liquid Line	64	52%
Vapor Line (Air Inlet)	30	24%
Pressure Relief Valve	9	7%
Sample Line	6	5%
Other	4	3%
Manway/Pressure Plate	4	3%
Safety Vent	1	1%

[316] Treichel 2018.
[317] Treichel 2018.

Table 110: Top Specific Causes of Non-Accidental Releases in Pressurized Cars 2017 Including Numbers of Incidents and Percent Total Incidents[318]

Component	Incidents	% Incidents
Liquid Line–Closure Plug Loose, Valve Open	34	29%
Air Inlet–Closure Plug Loose, Valve Open	12	10%
Liquid Line–Closure Plug Loose, Valve Closed	4	3%
Other (e.g., Vandalism)	4	3%
Air Inlet–Vapor Value Closure Cap Not Tight, Valve Open	4	3%
Liquid Line–Closure Plug Loose	4	3%
Liquid Line–Closure Cap Loose, Valve Open	4	3%

Safety measures to prevent non-accidental releases

Recognizing and understanding the causes of NARs is important for reducing their occurrence. The various industries that utilize tank cars, such as fertilizer industry, which ships over 50,000 tank cars of ammonia each year, have developed educational programs about safe practices for loading and unloading and inspection of tank cars. The Fertilizer Institute points out the consequences of NARS:

- Fines from the Department of Transportation between $6,000 to $12,000 per incident (49 CFR 107, Subpart D, Appendix A, Part G.5 – offering a hazardous material for transportation in a package that leaks during conditions normally incident to transportation).
- Fines from the railroads, which can range from $3,000 per incident to $10,000 in some instances.
- Shipment/train delays.
- Employee injuries.
- Evacuation costs.
- Environmental cleanup.
- Public safety risk.
- Approximately $20,000 to purge a leaking residue car.
- Approximately $50,000 to trans-load a full leaking car.
- Negative publicity.
- Cost of ativating response teams[319]

The FRA has long recommended training practices to prevent NARs, recognizing that training programs for individuals responsible for loading and unloading tank cars can help to minimize these incidents (Gertler et al. 1999). The AAR and Bureau of Explosives (BOE) have developed specific guidelines for loading and unloading that are taught in training programs.

[318] Treichel 2018.
[319] Association of American Railroads Website. https://www.aar.org/wp-content/uploads/2018/02/AAR-Anhydrous-Ammonia-Loading-Unloading-Guide-NAR.pdf

The AAR/BOE Pamphlet 34, *Recommended Methods for the Safe Loading and Unloading of Non-Pressure (General Service) and Pressure Tank Cars* (AAR/BOE 2013) provides specific instructions that should be followed.

Potential areas of future discussion

- Since tank car design regulations are under the jurisdiction of the federal government, state officials have no authority to make any regulations regarding tank car safety. This would be unnecessary at this point at the railroads are all now required to use DOT-117 and safer tank cars. The Class I railroads that transport Class 3 flammables in Washington are in full compliance with these regulations.
- The Rail Safety Committee and Washington State officials may wish to consider supporting training programs and inspection programs that would increase safety and reduce non-accidental releases (NARs).
- It is unclear whether Washington State has the authority to conduct its own safety inspections on tank cars. It may be feasible for UTC to develop an additional "best achievable practice" program on tank car inspections and safety procedures.

Chapter 16: Extended Storage of Class 3 Flammable Liquids

Key questions

- What is the current practice of extended storage of tank cars containing crude oil or other Class 3 flammable liquids on rail lines or in transit in Washington? Where is this occurring?
- What types of safety measures, including security protocols and requirements for "facility" designation for the purposes of contingency planning, are or should be in place to reduce safety risks?

Takeaways

- Low crude oil prices have caused the growing U.S. crude-by-rail industry to experience significant reductions in ton-mile movements. This deterioration in ton-miles combined with the earlier high demand for CBR transportation, has led growth of a previous low demand market: loaded and unloaded crude oil tank car storage. Reduction in demand for shale crude oil[320] transported on rail recently left some owner/operators with a surplus of tank cars. These surplus rail cars have been stored due to a lack of leasing or buying interest.
- Storing crude oil in tank cars is a tactic that some owners/operators use when higher prices for crude oil are expected than what their current market value is.
- As bulk storage tank crude oil inventories increase around the country because of sufficient supplies, owner/operators are looking to store tank cars wherever they can store them. Particularly attractive are those potential storage locations that provide loaded storage. Keep in mind not all locations will accept loaded car storage.
- As CBR grew in recent years, overproduction of oil on a global basis caused crude oil prices to become depressed. Due to the drastic reduction of crude oil prices, refiners on the coasts evaluated whether it was more advantageous to purchase CBR transportation for domestic shale crude barrels, or look for foreign waterborne sources for their crude oil. As CBR slowed into the refineries, crude oil tank car loadings experienced a significant decline.
- Rail tank car storage remains a significant issue for rail owners/operators. Factors including the completion of new pipelines, and upgrading to the DOT-117 design, caused rail owner/operators to have a surplus of rail tank cars that necessitated storage on sidings[321]. Other rail owner/operators provided these sidings in exchange for much-needed revenue. As late as 2017, approximately 350,000 railcars of the 1.6 million rail tank cars operating in North America were in storage either loaded or empty.

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[320] Shale oil is an unconventional oil produced from oil shale rock rather than from conventional extraction from an oil well.
[321] A siding is a low-speed track section distinct from other types of rail lines such as a main line. Sidings are used for a variety of reasons including classifying, stabling, storing, loading, and/or unloading trains.

- The research of the relevant Washington State codes reveals that rail tank cars, whether loaded or empty, with remaining hazardous material residue on a private track, are not considered a facility by Washington State.
- Under the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 312, "any facility in Washington that stores over a certain amount (reporting threshold) of a hazardous chemical must submit a Tier II report by March 1 each year**."**
- "The threshold levels for reporting chemicals stored onsite at any one time are: 10,000 pounds for hazardous substances and 500 pounds or the threshold planning quantity, whichever is less for an Extremely Hazardous Substances (EHS). This report is submitted to:
    a. The Washington State Emergency Response Commission (SERC);
    b. Their Local Emergency Planning Committee (LEPC); and
    c. Their local fire department."

The following sections provide a more in-depth look at the issue of longer-term storage of Class 3 flammable liquids on rail lines in Washington.

Hazmat tank car storage issue

The U.S. Hazardous Materials Regulations (HMR) (49 CFR Part 172.101) define "transportation" generally as the "movement of property and loading and unloading, or storage incidental to that movement." This HMR requires that "transportation in commerce begins when a carrier takes physical possession of a hazardous material for the purpose of transporting it and continues until the hazardous material is delivered to the destination indicated on a shipping paper." There is an exception to this general rule and it applies to rail transportation. Specifically, a railcar in the process of transporting Hazardous Material (HMT) is considered "in transportation" pursuant to the requirements of the HMR until it is delivered to a "private track or siding," even if the railcar is not delivered to its final destination indicated on its shipping paper.

Note: The definition of a "Private Track or Private Siding", as stated in 49 CFR § 171.8(14)(ii):

> Track leased by a railroad to a lessee, where the lease provides for, and actual practice entails, exclusive use of that trackage by the lessee and/or a general system railroad for purpose of moving only cars shipped to or by the lessee, and where the lessor otherwise exercises no control over or responsibility for the trackage or the cars on the trackage.

The classification of cars on private siding as being "in storage" or in transportation" is addressed in EPA's Risk Management Plan (RMP) Rule. The RMP Rule implements Section 112(r) of the 1990 Clean Air Act amendments. RMP requires facilities that use extremely hazardous substances to develop a Risk Management Plan. These plans must be revised and resubmitted to EPA every five years.

Under the EPA's RMP Rule, "railcars on a private siding that are used as storage tanks until they are dispensed for processing should be considered to be part of the facility." However, there is a stipulation that railroads can lease track to petroleum/chemical owner/operators. That railcar storage could then be designated as "storage in transit." This allows the track leasers to leave hazardous material railcars on private siding indefinitely and load and unload product as needed. EPA's RMP Rule, these arrangements are called "leased sidings, storage in transit or storage incidental to transportation."

USDOT's Research and Special Programs Administration (RSPA) rulemaking (HM-223/Final Rule issued March 2003) the Department of Transportation attempted to better define the jurisdiction of their regulations on the issue of "storage in transit." Specifically, the U.S. Department of Transportation (USDOT) stated, "that they do not have regulatory authority over railcars on leased sidings. This would allow state and local officials to bring railcar storage under Emergency Planning & Community Right-To-Know regulations."

Safety, contingency, and security planning

Rail tank cars in all likelihood will be covered by the receiving facility's oil spill contingency plan once the train consist is within the jurisdiction of that receiving facility. Rail tank cars on track outside of a facility will remain within the responsibility domain of the railroad's oil spill contingency plan written in compliance with the final PHMSA rule issued in the February 28, 2019 Federal Register.

Security measures for extended storage

Relevant security measures that apply to facilities and railyards storing hazardous materials under HM-232 (49 CFR § 172.800) (see Chapter 6, Additional Safety Measures for Hazmat Rail Transport) would apply to the extended storage of tank cars.

As required in HM-232, 49 CFR § 172.820(h):

> …each rail carrier must ensure the safety and security plan it develops and implements includes all the following:
>
> 1. A procedure under which the rail carrier must consult with offerors and consignees in order to develop measures for minimizing, to the extent practicable, the duration of any storage of the material incidental to movement.
> 2. Measures to prevent unauthorized access to the materials during storage or delays in transit.
> 3. Measures to mitigate risk to population centers associated with in-transit storage.
> 4. Measures to be taken in the event of an escalating threat level for materials stored in transit.
> 5. Procedures for notifying the consignee in the event of a significant delay during transportation; such notification must be completed within 48 hours after the carrier has identified the delay and must include a revised delivery schedule. A significant delay is one that compromises the safety or security of the hazardous material or delays the shipment beyond its normal expected or planned shipping time. Notification should be made by a method acceptable to both the rail carrier and consignee.

Relevant USDOT regulations

All railroads are required by 49 CFR § 174 to advance USDOT-regulated hazardous materials railcars toward their destination within 48 hours. Regulations set forth in 49 CFR § 174.14 and § 174.16 provide details as to the disposition of hazardous materials cars after 48 hours at destination serving yard. Railroad customers and their agent industries must use their best efforts to ensure that all railcars containing a hazardous commodity are accepted by the customer or its agent industry within 48 hours of its arrival in the destination's serving yard.

49 CFR Part 174.14: Movements to be expedited

According to 49 CFR § 174.14:

> A carrier must forward each shipment of hazardous materials promptly and within 48 hours (Saturdays, Sundays, and holidays excluded), after acceptance at the originating point or receipt at any yard, transfer station, or interchange point, except that where biweekly or weekly service only is performed, a shipment of hazardous materials must be forwarded on the first available train.
>
> A tank car loaded with any Division 2.1 (flammable gas), Division 2.3 (poisonous gas) or Class 3 (flammable liquid) material, may not be received and held at any point, subject to forwarding orders, so as to defeat the purpose of 49 CFR § 174.14 and § 174.204.

49 CFR Part 174.16: Removal and disposition of hazardous materials at destination

According to 49 CFR § 174.16:

> (a) Delivery at non-agency stations. A shipment of Class 1 (explosive) materials may not be unloaded at non-agency stations unless the consignee is there to receive it or unless properly locked and secure storage facilities are provided at that point for its protection. If delivery cannot be so made, the shipment must be taken to next or nearest agency station for delivery.
>
> (b) Delivery at agency stations. A carrier shall require the consignee of each shipment of hazardous materials to remove the shipment from carrier's property within 48 hours (exclusive of Saturdays, Sundays, and holidays) after notice of arrival has been sent or given. If not so removed, the carrier shall immediately dispose of the shipments as follows:
>
> (1) Division 1.1 or 1.2 (explosive) materials: If safe storage is available, by storage at the owner's expense; if safe storage is not available, by return to the shipper, sale, or destruction under supervision of a competent person; or if safety requires, by destruction under supervision of a competent person.
>
> (2) Hazardous materials, except Division 1.1 or 1.2 (explosive) materials, in carload shipments: By storage on the carrier's property; by storage on other than the carrier's property, if safe storage on the carrier's property is not available; or

> by sale at expiration of 15 calendar days after notice of arrival has been sent or given to the consignee, provided the consignor has been notified of the non-delivery at the expiration of a 48-hour period and orders for disposition have not been received.
>
> (3) Hazardous materials, except Division 1.1 or 1.2 (Class A explosive) materials, in less-than-carload shipments: By return to the shipper if notice of non-delivery was requested and given the consignor as prescribed by the carrier's tariff, and orders for return to shipper have been received; by storage on the carrier's property; by storage on other than the carrier's property, if safe storage on carrier's property is not available; or by sale at expiration of 15 calendar days after notice of arrival has been sent or given to the consignee, provided the consignor has been notified of non-delivery at expiration of a 48-hour period and orders for disposition have not been received.

In other words, as Ernie Sirotek put it in a hazmat seminar (Sirotek 2013):

- For safety and security reasons, HMR generally encourages expedited movement of hazardous materials from origin to destination.
- 48-hour rule (49 CFR § 174.14) requires rail carriers to forward shipments “promptly” and within 48 hours after acceptance at origination or receipt at any yard.
- Exception for limited service — must be forwarded on “first available train” that services the location.
- Applies to loads only (arguably, a residue car is not a “shipment” or a revenue move — thus, 48-hour rule does not apply) (slide 13)

49 CFR Part 173.29: Empty packagings

According to 49 CFR § 173.29:

> …except as otherwise provided in this section, an empty packaging containing only the residue of a hazardous material shall be offered for transportation and transported in the same manner as when it previously contained a greater quantity of that hazardous material.

Application of USDOT regulations

If a decision is made to have rail tank cars stored on track meeting the definition of “private track,” rail tank cars can be stored on railroad property. The rail tank cars would be out of transportation. HMR does not apply to this situation (except with respect to the lessee’s responsibility to comply with security plan requirements, if applicable).

If is is decided to have rail tank cars stored on track not meeting the definition of private track, it is considered “storage incidental to movement” and can only be accomplished in certain circumstances. The rail tank cars are then considered to be “in transportation” and HMR applies in this situation.

State of Maine approach to rail tank car storage

The State of Maine applies 06-096 Chapter 696: Oil Discharge Prevention and Pollution Control Rules for Rail Tank Cars for the storage of rail tank cars, which was effective 26 March 2015.

Response plan

According to State of Maine 06-096 Chapter 696:

> Any person or operator who stores, leaves, or temporarily parks five (5) or more rail tank cars containing oil at a siding for more than five (5) consecutive days shall submit to the Department (Department of Environmental Protection composed of the Board of Environmental Protection and the Commissioner) copies of the written Response Plans specified in 49 CFR § 130.31. If revised plans are submitted under 49 CFR § 130.31, copies of those revisions must also be submitted to the Department.

Inspections

According to State of Maine 06-096 Chapter 696:

> Any person or operator who stores, leaves, or temporarily parks five (5) or more rail tank cars containing oil at a siding for more than five (5) consecutive days shall visually inspect the tank cars for evidence of oil discharges a minimum of every 12 hours and maintain a written log of the findings of such inspection. The inspection shall include:
>
> A. The date and time of the inspection;
> B. The location of the siding;
> C. The number of rail tank cars containing oil;
> D. The name of the inspector; and
> E. The results of the inspection including a determination that there is no evidence of discharge of oil from the rail tank cars.
>
> A copy of the written log may be requested from the operator by the Commissioner and shall be made available as soon as practicable upon such request.

Designation of stored cars as "facilities" in Washington State

The relevant regulations in Washington State are RCW 90.56.010, WAC 173-180-025, and WAC 173-186-040.

RCW 90.56.010: Definitions

The relevant definitions included in RCW 90.56.010(12) are stated as:

a) "Facility" means any structure, group of structures, equipment, pipeline, or device, other than a vessel, located on or near the navigable waters of the state that transfers oil in bulk to or from a tank vessel or pipeline, that is used for producing, storing, handling, transferring, processing, or transporting oil in bulk.
b) For the purposes of oil spill contingency planning in RCW 90.56.210, facility also means a railroad that is not owned by the state that transports oil as bulk cargo.

c) Except as provided in (b) of this subsection, a facility does not include any: (i) Railroad car, motor vehicle, or other rolling stock while transporting oil over the highways or rail lines of this state.

WAC 173-180-025: Definitions

The relevant definitions in WAC 173-180-025(8) are:

> "Class 1 facility" means a facility as defined in RCW 90.56.010 [are stated] as:
>
> (a) Any structure, group of structures, equipment, pipeline, or device, other than a vessel, located on or near the navigable waters of the state that transfers oil in bulk to or from a tank vessel or pipeline that is used for producing, storing, handling, transferring, processing, or transporting oil in bulk.
>
> (b) A Class 1 facility does not include any:
>
> i. Railroad car, motor vehicle, or other rolling stock while transporting oil over the highways or rail lines of this state.
>
> "Class 2 facility" means a railroad car, motor vehicle, portable device or other rolling stock, while not transporting oil over the highways or rail lines of the state, used to transfer oil to a non-recreational vessel.

Potential areas of future discussion

- The Rail Safety Committee may want to consider working with the Washington Department of Ecology and UTC to develop an inventory for rail car storage. This inventory list might be used to conduct physical audits of the rail sidings being utilized for extended storage to ensure compliance with SPCC/Oil Spill Response Plans and Security Plans. This is especially relevant for those private track rail tank car storage sidings where rail tank cars are stored, loaded or empty with hazardous material residue.
- The Rail Safety Committee may want to consider working with UTC to develop a program to inspect each hazardous material compliant/approved rail tank car storage in order to ensure compliance with the federal and state security and oil spill response regulations. The committee may want to consider the program of the State of Maine, which prioritizes periodic safety, human health, environmental and security inspections of the rail tank cars with the completion of an inspection log concerning the results of the daily safety, human health and security inspections.

Chapter 17: Rail Emergency Response Issues

Key questions

- What are the major human health and safety environment concerns in the event of a major rail accident involving the release of hazardous materials?
- What are the current best practices for emergency response and spill response in major rail accidents involving hazardous materials?
- How do the rail emergency response practices in Washington State differ with those of other states?
- How do the approaches to response for rail-related accidents differ from those for vessel, pipeline, or facility accidents?
- What potential conflicts might arise amongst first responders, rail responders, and spill responders in a complex, major incident?
- What are the specific challenges presented for first/emergency responders and spill responders for rail accidents in Washington State?

Takeaways

The inherent risks posed by the rail transport of crude oil, flammable liquids, and volatile chemicals present some of the greatest challenges for emergency responders and the public when dealing with contamination, containment, and remediation/response issues. Primary objectives when transporting dangerous goods is to successfully transport each shipment from origin to destination safely and without incident. One should be cognizant that, despite preventive efforts, actual incidents can and do occur. It is vital for states and local communities to be prepared/pre-plan to respond in an emergency.

Preparedness/pre-planning includes, but is not limited to:

- Assessment of the risks.
- Knowledge of the potential hazards of the materials and the transportation mode.
- Comprehensive contingency plan development and plan maintenance
    a. Inclusiveness of stakeholder input (first responders, public, jurisdictional authorities).
    b. Responser resource needs, resource assessment and availability.
    c. Evacuation procedures, notification and implementation.
    d. Communications between the incident management team and the affected community stakeholders.
    e. Training and funding of responders.
- Recovery planning of the impacted community.

The following sections provide a more in-depth look at emergency response for rail emergencies, including accidents involving spills or releases of hazardous substances and passenger train accidents that may involve casualties.

Response as a risk mitigation measure

The most effective ways to mitigate or reduce risk and incident consequences are by evaluating and implementing incident prevention measures to minimize incidents from occurring. After evaluation and implementation of preventative measures, risk mitigation comes from effective responses to incidents, which attempts to minimize damage consequences from the incident. For rail-related train incidents, the possibility of fire and/or explosion means that emergency preparedness must focus, first and foremost, on public safety since the area of impact from the incident expands due to the fire and explosion damage radius, as well as potential air issues for the health and safety of the public.

Protecting the environment is also a high priority, to reduce adverse effects. Spills from rail cars require appropriate responses to limit the volume of oil released, reduce the spread of oil, protect the most sensitive habitats as prioritized by geographic response plans and other means, and clean up oil that is released to the environment.

Appropriate contingency planning has repeatedly been shown to be instrumental in assuring rapid and effective consequence reduction of spill incidents, regardless of the source or location of the incident. Washington State has developed a comprehensive program to prepare for and respond to emergency incidents through the Department of Ecology Spill Prevention, Preparedness, and Response Program. This program needs to be able to prepare and plan for the changing types of incidents that may occur from rail tank cars along a variety of routes having environmental and geographic differences.

Emergency/first response practices pre-incident planning

As stated in the Pipeline and Hazardous Material Safety Administration (PHMSA) *Transportation Rail Incident Preparedness & Response: High Hazard Flammable Trains Instructor Lesson Plan*:

> Pre-incident planning is required by federal law under the Emergency Planning and Community Right-to-Know Act (EPCRA). It [also] helps establish relationships with other agencies prior to response; it requires facilities to report types and quantities of certain hazardous materials in a community; and results in responders being better prepared to deal with a major incident in their community.
>
> EPCRA came into being in 1986 as a part of the Superfund Amendment and Reauthorization Act (SARA), which is often called “SARA Title III.” EPCRA also required the establishment of state/tribe emergency response commissions (SERCs/TERCs); in turn, SERCs/TERCs are responsible for appointing local emergency planning committees (LEPCs).
>
> The Association of American Railroads (AAR) published circular OT-55N in August 2013. Section V of this circular directs AAR member railroads to provide information about hazardous commodities transiting a given community/area: in part, ‘Upon written request, AAR members will provide bona fide emergency response agencies or planning groups with specific commodity flow information covering at a minimum the top 25 hazardous commodities transported through the community in rank order’ (AAR 2013).

On May 7, 2014, the DOT issued an Emergency Restriction/Prohibition Order, Docket No. DOT-OST-2014-0067. In part, the Order requires any railroad carriers 'who transport 1 million gallons or more of crude oil in a single train in commerce within the United States… provide certain information in writing to the SERC in each state in which the railroad carrier operates trains transporting 1 million gallons or more of Bakken crude oil.'

The notification must:

- Provide a reasonable estimate of the number of trains operating through each county in the state;
- Identify and describe petroleum crude oil expected to be transported;
- Provide applicable emergency response information required by 49 CFR § 172, Subpart G; and
- Identify routes over which material will be transported." (Emergency Restriction/Prohibition Order, Docket No. DOT-OST-2014-0067)

LEPC are required to update their plans annually and must:

- Identify facilities and transportation routes of extremely hazardous substances;
- Describe emergency response procedures, on and off site;
- Designate a community coordinator and facility coordinator(s) to implement the plan;
- Outline emergency notification procedures;
- Describe how to determine the probable affected area and population by releases;
- Describe local emergency equipment and facilities and the persons responsible for them;
- Outline evacuation plans;
- Provide a training program for emergency responders (including schedules); and,
- Provide methods and schedules for exercising emergency response plans. (pp. 21-22)

The developed local plan should be consistent with the Northwest Area Contingency Plan (NWACP) to ensure a well-coordinated response that is integrated and compatible between local and area resources and jurisdictions. Local stakeholders can participate in the development of the Northwest area plan through Area Planning Committees.

Pre-incident planning for rail tank accidents involving flammable liquids will provide an important assessment of the capabilities of the community to manage an incident. Pre-incident planning may help to identify resource equipment and responder training deficiencies.

Regulatory requirements for rail spill response planning

The rapid expansion in domestic crude oil production has created large volumes of crude oil being transported to refineries and other transport-related facilities throughout the country via pipelines and by rail tank cars. With the expectation that there will be continued domestic crude oil production, CBR provides a flexible alternative to transportation by pipelines or vessels, which have historically delivered most of the crude oil to U.S. refineries. One must be cognizant that the current production fields are not in close proximity to waterborne transportation, nor is there sufficient pipeline capacity to absorb the increase in crude oil production, thus creating the necessity for CBR.

CBR commonly includes high volumes and large quantities, either as several cars of material contained in a consist, along with other commodities in a manifest train, or as a single commodity train (commonly referred to as a "unit train"). Significant risks of train accidents could reasonably be expected to cause substantial harm to the environment by discharging product into the navigable waters and adjoining shorelines, posing significant challenges for responders.

Oil Pollution Act of 1990 (OPA90)

The Oil Pollution Act of 1990 (OPA90) amended the Federal Water Pollution Control Act (FWPCA), also known as the Clean Water Act (CWA) at 33 U.S.Code § 1321, by adding oil spill response planning requirements for 'facilities'' that handle oil. The CWA required owners and operators of onshore facilities "to prepare and submit (for approval oil spill contingency plans for facilities that) could reasonably be expected to cause substantial harm to the environment by discharging into or on the navigable waters and adjoining shorelines, or the exclusive economic zone." The CWA applies to railroads or ''rolling stock," which is included in the definition of "onshore facility."

History of USDOT spill planning requirements

The Department of Transportation's oil spill planning requirements for rolling stock and motor carriers are found at 49 CFR § 130. Part 130 currently requires "comprehensive oil spill response plans" that comply with the CWA for the transportation of oil in a quantity greater than 1,000 barrels or 42,000 gallons per package (Federal Register, Vol. 81, No. 146, Friday, July 29, 2016). Since the approximate capacity of a rail car carrying crude oil is 30,000 gallons, Part 130, as written, did not require that railroads prepare comprehensive written plans. However, Part 130 includes an additional requirement to prepare "basic plans" for containers with 3,500 gallon or more carrying capacity for petroleum oil. Consequently, basic oil spill response plans were required for most, if not all, tank car shipments of petroleum oil (Federal Register, Vol. 81, No. 146, Friday, July 29, 2016.

On January 23, 2014, the NTSB issued Safety Recommendation R-14-05,[322] recommending that PHMSA revise the oil spill response planning thresholds for comprehensive oil spill response plans. The NTSB also issued Safety Recommendation R-14-02, recommending that FRA audit spill response plans (Federal Register, Vol. 81, No. 146, Friday, July 29, 2016; Docket No. PHMSA-2014-0105 (HM-251B)).

The Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation (USDOT), in consultation with the FRA, issued a Notice of Proposed Rule Making (NPRM) in the July 29, 2016, Federal Register concerning revisions to regulations that

[322] January 23, 2014, the NTSB, Safety Recommendation R-14-05, https://www.ntsb.gov/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=R-14-005.

would expand the applicability of comprehensive oil spill response plans (OSRPs) based on thresholds of liquid petroleum oil that apply to an entire train consist.

The PHMSA 2016 Notice of Proposed Rulemaking went on to state (Docket No. PHMSA-2014-0105 (HM-251B)):

> Specifically, we are proposing to expand the applicability for comprehensive OSRPs so that any railroad that transports a single train carrying 20 or more loaded tank cars of liquid petroleum oil in a continuous block or a single train carrying 35 or more loaded tank cars of liquid petroleum oil throughout the train consist must also have a current comprehensive written OSRP. We are further proposing to revise the format and clarify the requirements of a comprehensive OSRP (e.g., requiring that covered railroads develop response zones describing resources available to arrive onsite to a worst-case discharge, or the substantial threat of one, which are located within 12 hours of each point along the route used by trains subject to the comprehensive OSRP). We also solicit comment on defining high volume areas and staging resources using alternative response times, including shorter response times for spills that could affect such high volume areas.

On February 28, 2019, PHMSA, in coordination with the FRA, issued a final rule that requires railroads to develop and submit Comprehensive Oil Spill Response Plans for route segments traveled by high hazard flammable trains (HHFTs). The rule applies to HHRTs transporting petroleum oil or Class 3 Flammable Liquids in a block of 20 or more loaded tank cars (key trains) and trains that have a total of 35 loaded petroleum oil or Class 3 Flammable Liquids tank cars. The effective date is 180 days after publication in the Federal Register (after 27 August 2019) (Docket No. PHMSA-2014-0105 (HM-251B)).[323]

Final PHMSA rule for oil spill contingency plans

The summary of the final rule stated:

> PHMSA, in consultation with the FRA and pursuant to the Fixing America's Surface Transportation Act (FAST Act) of 2015, issued the final rule to revise and clarify requirements for comprehensive oil spill response plans (COSRPs) and to expand their applicability based on petroleum oil thresholds that apply to an entire train consist. Specifically, the final rule:
>
> - Expands the applicability for COSRPs;
> - Modernizes the requirements for COSRPs;
> - Requires railroads to share information about high-hazard flammable train (HHFT) operations with State and tribal emergency response commissions to improve community preparedness; and
> - Incorporates by reference a voluntary standard." (Docket No. PHMSA-2014-0105 (HM-251B).

[323] See https://www.hygieneering.com/single-post/2019/05/13/DOT-Requiring-Spill-Response-Plans-for-High-Hazard-Flammable-Trains

Preemption in final rule

In the final rule, PHMSA stated the following regarding preemption (Docket No. PHMSA-2014-0105 (HM-251B)):

> After evaluating the comments on the issue of Federal preemption and the permissibility of state oil spill response planning requirements for railroads, PHMSA continues to believe that the discussion in the proposed rule accurately stated the application of the existing statutory authorities. The Clean Water Act allows for states to regulate requirements, liabilities, and removal activities with respect to the discharge of oil or hazardous substances, including oil spill response planning requirements; however, any state or local regulation of railroad safety standards or hazardous materials containment or communication standards under the guise of oil spill response planning will be preempted under the Federal Railroads Safety Act (FRSA) and Hazardous Materials Transportation Act (HMTA).
>
> The HMTA provides that a State law or Indian tribe requirement is preempted in the following cases:
>
> - Compliance with both the State law or Indian Tribe requirement and the Federal requirement is not possible;
> - The State law or Indian Tribe requirement creates an obstacle to accomplishing or executing the Federal requirement; or
> - The Federal requirement has covered the subject and the State law or Indian Tribe requirement is not substantially the same.
>
> Covered subjects under the HMTA include:
>
> - The designation, description, and classification of hazardous materials;
> - The packing, repacking, handling, labeling, marking, and placarding of hazardous materials;
> - The preparation, execution, and use of shipping documents related to hazardous materials and requirements related to the number, contents, and placement of those documents;
> - The written notification, recording, and reporting of the unintentional release in transportation of hazardous materials and other written hazardous materials transportation incident reporting involving state or local emergency responders in the initial response to the incident; and
> - The design, manufacture, fabrication, inspection, marking, maintenance, reconditioning, repair, or testing of a package, container, or packaging component that is represented, marked, certified, or sold as qualified for use in transporting hazardous material in commerce. (p. 6937)

Applicability

PHMSA's 2019 Final Rule, described in Docket No. PHMSA-2014-0105 (HM-251B)), "…expands the applicability of comprehensive OSRPs based on thresholds of crude oil that apply to the train consist. Specifically, the final rule expands the applicability for OSRPs so that no person may transport an HHFT quantity of liquid petroleum oil unless that person has implemented a comprehensive OSRP" (p. 50107).

The final rule "…expands the applicability of comprehensive OSRPs to railroads transporting a single train of 20 or more loaded tank cars of liquid petroleum oil in a continuous block, or a single train carrying 35 or more loaded tank cars of liquid petroleum oil throughout the train consist. These railroads, that are currently required to develop a basic plan, are now required to develop a comprehensive plan" (p. 50119).

"Each railroad subject to (the final rule) must prepare and submit a plan including resources and procedures for responding, to the maximum extent practicable, to a worst-case discharge and to a substantial threat of such a discharge of oil" (p. 50126).

OSRP contents

According to and as stated in the 2019 PHMSA Final Rule, each comprehensive plan must include (Docket No. PHMSA-2014-0105 (HM-251B)):

I. **Core plan:** A core plan includes an information summary, as required in CFR 49 § 130.105, and any components which do not change between response zones. Each plan must:

- Use and be consistent with the core principle of the National Incident Management System (NIMS) including the utilization of the Incident Command System (ICS):
- Include an information summary as required by §130.105 and §130.120.
- Certify that the railroad reviewed the National Contingency Plan (NCP) and each applicable Area Contingency Plan (ACP) and that its response plan is consistent with the NCP and each applicable ACP and follows Immediate Notification procedures, as required by §130.110 and §139.115.
- Include notification procedures and a list of contacts as required in §130.125.
- Include response and mitigation activities and resources as required in §130.130.
- Certify that applicable employees were trained per §130.135.
- Describe procedures to ensure equipment testing and a description of the exercise program per §130.140
- Describe plan review and update procedures per §130.145.
- Submit the plan as required by §130.150.

II. **Response zone appendix:** For each response zone, a railroad must include a response zone appendix to provide the information summary, as described in § 130.120, and any additional components of the plan specific to the response zones. Each response zone appendix must identify:

- A description of the response zone, including county(s) and state(s);
- Identification of any environmentally sensitive areas along the router per §130.115; and
- Identification of the location where the response organization will deploy, and the location and description of equipment required by §130.130.

- In addition, the final rule requires plan holders to identify an OSRO, provided through a contract or other approved means, to respond to a worst-case discharge within 12 hours. (pp. 50117–50118)

Worst-case discharge definition

The Final Rule defines a "worst-case discharge" of oil for response planning as *the greater of*:

- 300,000 gallons (7,143 bbl), or approximately the content of 10 tank cars; or
- 15 percent of total lading of liquid petroleum oil transported within the largest unit train consist reasonably expected to transport liquid petroleum oil in a given response zone. For a 100-car unit train, this would be 15 cars, for a 120-car unit train, this would be 18 tank cars.

The worst-case discharge calculated from tank cars exceeding 42,000 gallons is equal to the capacity of the cargo container.

Information sharing

The Final Rule requirements provide emergency responders with an integrated approach to receiving information about HHFTs. As required by this final rule, the notification must meet the following requirements (Docket No. PHMSA-2014-0105 (HM-251B), p 50129):

1) At a minimum, the information railroads are required to provide to the relevant state or tribal agencies must include the following:
   i. A reasonable estimate of the number of HHFT that the railroad expects to operate each week, through each county within the State or through each tribal jurisdiction;
   ii. The routes over which the HHFTs will operate;
   iii. A description of the hazardous material being transported, and all applicable emergency response information required by subparts C and G of part 172 of this subchapter;
   iv. An HHFT point of contact: at least one point of contact at the railroad (including name, title, phone number and address) with knowledge of the railroad's transportation of affected trains and responsible for serving as the point of contact for the SERC, TERC, or other state or tribal agency responsible for receiving the information; and
   v. If a route is… additionally subject to the comprehensive spill plan requirements… the information must include a description of the response zones (including counties and states) and contact information for the qualified individual and alternate, as specified under §130.104(a);
2) *Recordkeeping and transmission.*
   The HHFT notification must be maintained and transmitted in accordance with all of the following requirements:
   i. On a monthly basis, railroads must update the notifications. If there are no changes, the railroad may provide a certification of no change.
   ii. Notifications and updates may be transmitted electronically or by hard copy.
   iii. If the disclosure includes information that railroads believe is security or proprietary and exempt from public disclosure, the railroads should indicate that in the notification.

iv. Each point of contact must be clearly identified by name or title and role (e.g. qualified individual, HHFT point of contact) in association with the telephone number. One point of contact may fulfill multiple roles.
v. Copies of HHFT notifications made must be made available to the Department of Transportation upon request.

Washington State rail oil spill response plan regulations

Under the 2015 Oil Transportation Safety Act, Ecology now requires rail lines to have contingency plans that guarantee they can respond to a spill quickly and effectively. The specifics of Washington's regulations (Oil Spill Contingency Plan — Railroad: WAC 173-186-220) are stated as follows:

1) Contingency plans shall include all the content and meet all the requirements in this section.
2) In Washington State, the Northwest Area Contingency Plan (NWACP) serves as the statewide master oil and hazardous substance contingency plan required by RCW 90.56.060. Rail plan holders shall write plans that refer to and are consistent with the NWACP.
3) All contingency plans shall include the following:
    a. Each plan shall state the name, location, type and address of the facility and the federal or state requirements intended to be met by the plan.
    b. Each plan shall state the size of the worst-case spill volume. If oil handling operations vary on different rail routes, more than one worst case spill volume may be submitted to Ecology for consideration.
    c. Each plan shall have a log sheet to record revisions and updates to the plan. The log sheet shall identify each section amended, including the date and page of the amendment and the name of the authorized person making the change.
    d. Each plan shall have a table of contents and a cross-reference table reflecting the locations in the plan of each component required by this chapter.
    e. Each plan shall provide a list and map of expected rail routes in Washington and a description of the operations covered by the plan, including locations where fueling occurs and an inventory of above ground storage tanks and the tank capacities.
    An inventory of above ground storage tanks and tank capacities is not required if the total above ground storage capacity from containers with capacity of at least fifty-five gallons is less than one thousand three hundred twenty gallons.
    f. Each plan shall list all oil cargo transported, including region of origin, oil types, physical properties, and health and safety hazards of the oil cargo. A safety data sheet (SDS) or equivalent information may satisfy some of these requirements; the plan shall identify where the SDS or equivalent is kept for emergency response use.
    g. Each plan shall have the Primary Response Contractor's (PRC) name, address, phone number or other means of contact at any time of the day, and include:
        i. A contract or letter summarizing the terms of the contract signed by the PRC, shall be included in the plan. If the entire contract is not

submitted, that document shall be available for inspection, if requested by Ecology.

ii. For mutual aid agreements that a rail plan holder relies on to meet the planning standards, the plan shall include a copy of the agreement and describe the terms of that document in the plan.

h. Each plan shall contain information on the personnel (including contract personnel) who will be available to manage an oil spill response. This includes:

   i. An organizational diagram depicting the chain of command for the spill management team for a worse-case spill.
   ii. An organization list of one primary and one alternate person to lead each Incident Command System (ICS) spill management position down to the section chief and command staff level as depicted in the NWACP standard ICS organizational chart. If a response contractor is used to fill positions, they shall agree in writing to staff the positions. If the entire contract for additional spill management team support is not included in the plan, that document shall be made available for inspection, if requested by Ecology.
   iii. A detailed description of the planning process and job description for each spill management position; except if the rail plan holder follows without deviation the planning process or job descriptions contained in the NWACP. If the planning process or job descriptions are consistent with those contained in the NWACP, then the rail plan holder may reference the NWACP rather than repeat the information.
   iv. Include a description of the type and frequency of training that the spill management team receives, which shall include at a minimum ICS, NWACP policies, use and location of geographic response plans (GRPs), the contents of the plan and worker health and safety. New employees shall complete the training program prior to being assigned job responsibilities, which require participation in emergency response situations.
   v. Identify a primary and alternate incident commander's representative that can form unified command at the initial command post, and if located out-of-state, a primary and alternate incident commander that could arrive at the initial command post within six hours.

i. Each plan shall include procedures for immediately notifying appropriate parties that a spill or a substantial threat of a spill has occurred. The procedures shall establish a clear order of priority for immediate notification and include:

   i. A list of the names and phone numbers of required notifications to government agencies, response contractors and spill management team members. The notification section shall include names and phone numbers, except that the portion of the list containing internal call down information need not be included in the plan but shall be available for review by Ecology upon request and verified during spills and drills.

  ii. Identify the central reporting office or individuals responsible for implementing the notification process.
  iii. Include a form to document those notifications.

j. Each plan shall contain the procedures to track and account for the entire volume of oil recovered and oily wastes generated and disposed of during spills. The responsible party shall provide waste disposal records to Ecology upon request.
k. Each plan shall state how an oil spill will be assessed for determining product type, potential spill volume, and environmental conditions including tides, currents, weather, river speed and initial trajectory as well as a safety assessment including air monitoring.
  i. Each plan shall list procedures that will be used to confirm the occurrence and estimate the quantity and nature of the spill. An updated notification report is required if the initially reported estimated quantity or the area extent of the contamination changes significantly. Rail plan holders and responsible parties are required to document their initial spill actions and the plan shall include the forms that will be used for such documentation.
  ii. The plan shall contain a checklist that identifies significant steps used to respond to a spill, listed in a logical progression of response activities.
l. Each plan shall include a description of the methods to be used to promptly assess spills with the potential to impact groundwater, including contact information in the plan for resources typically used to investigate, contain and remediate/recover spills to groundwater.
m. Each plan shall include concise procedures to manage oil spill liability claims of damages to persons or property, public or private, for which a responsible party may be liable.
n. Each plan shall include a description of the sensitive areas and a description of how environmental protection will be achieved, including containment, enhanced collection and diversion tactics.
  i. The plan shall include information on natural, cultural, and economic resources, coastal and aquatic habitat types, and sensitivity by season, breeding sites, presence of state or federally listed endangered or threatened species, and presence of commercial and recreational species, physical geographic features, including relative isolation of coastal regions, beach types, and other geological characteristics; public beaches, water intakes including both drinking and agricultural water supplies, private and public wells that supply drinking water, and marinas; shellfish resources, significant economic resources and vulnerable populations to be protected in the geographic area covered by the plan.
  ii. The Geographic Response Plans (GRPs) have been developed to meet these requirements and plans may refer to the NWACP to meet these requirements. If railroad facilities occur in areas where descriptions of the sensitive areas and a description of how environmental protection

will be achieved do not exist, railroad plan holders will submit summary descriptions of the sensitive areas and prepare booming strategy “control points" for waterways in the vicinity of the railroad tracks.

o. Each plan shall identify potential initial command post locations.
p. Each plan shall contain a description of how the rail plan holder meets each applicable planning standard in Section C of [Chapter 173-186 WAC].

Washington State approved rail oil spill contingency plans

To date, Washington State has approved the following railroad oil spill contingency plans:

- BNSF Railway Company
- Columbia Basin Railroad Company
- Central Washington Railroad Company
- Great Northwest Railroad
- Portland Vancouver Junction
- Puget Sound & Pacific Railroad
- Tacoma Rail
- Union Pacific Railroad

Washington State contingency plan and drill requirements

Washington State railroad contingency plan and exercise requirements are contained in Chapter 173-186 WAC. Washington State categorizes railroads for the purpose of contingency planning and drill requirements based on their oil-carrying capacities. Their routes are shown in the map in Figure 82:

- **Type A** (crude carriers): BNSF, Union Pacific, and Tacoma Rail;
- **Type B** (railroads transporting oil in bulk that is not crude oil with 49 or more tank cars transported annually): Puget Sound and Pacific Railroad, and Columbia Basin Railroad; and
- **Type C** (railroads transporting oil in bulk that is not crude oil with less than 49 tank cars transported annually): Central Washington Railroad, Great Northwest Railroad, and Vancouver Portland Junction Railroad.

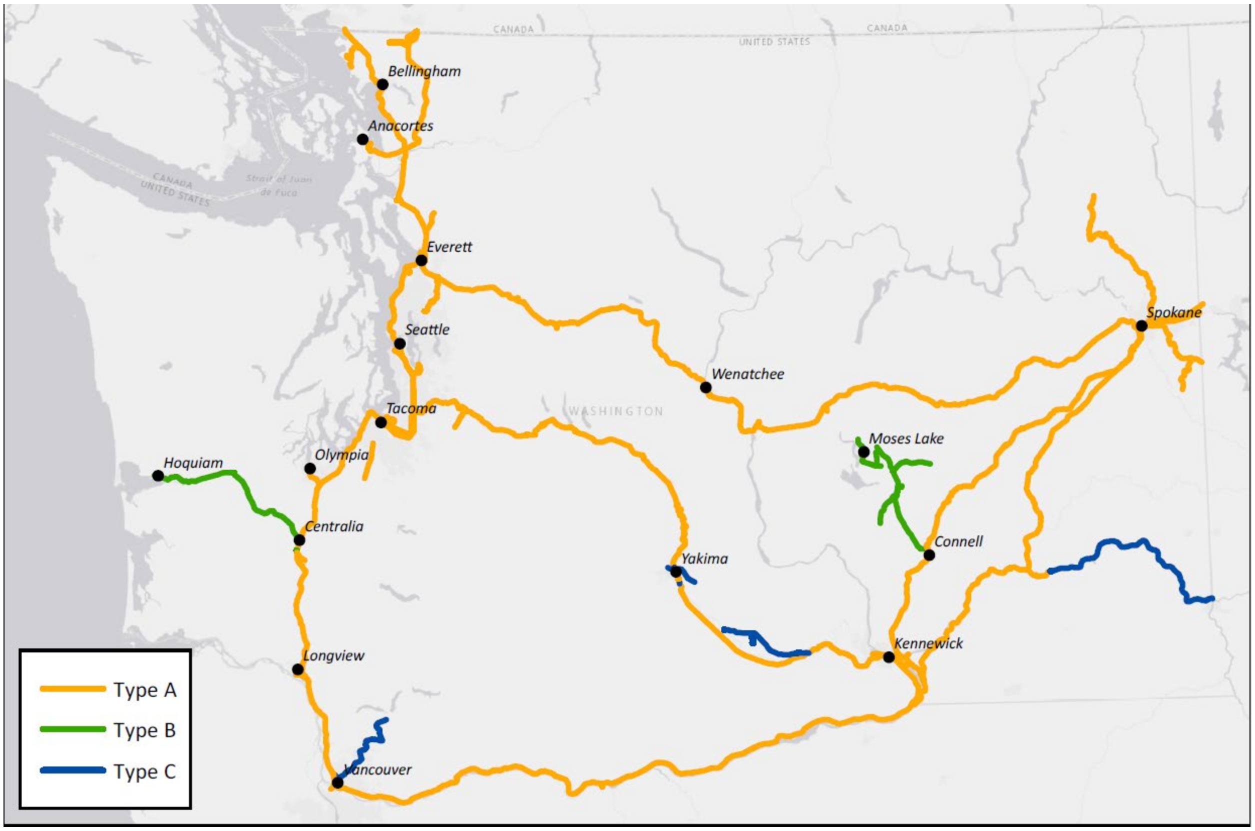

Figure 81: Washington State Railroad Type Category Map[324]

The draft rule language for WAC 173-186 will require:

Type A carriers are required to:

a) Have a Full Contingency Plan that is reviewed with a five-year approval by Ecology.
b) Conduct drills during a triennial cycle (three-year cycle):
    i. Three Table Top Drills–One in each year of the three-year cycle, with one of the three being a worst-case discharge drill.
    ii. Six Deployment Drills–Two in each year of the three-year cycle, with one of the exercises being a wildlife drill.

Type B carriers are required to:

c) Have a Full Contingency Plan that is reviewed with a five-year approval by Ecology. The railroad will not have to have a contract for access to response equipment.
d) One Table Top Drill every three years.

Type C carriers are required to:

e) Have a Basic Contingency Plan that is kept on file and reviewed by Ecology. It is to be updated annually.
f) No Drills are required.

[324] Source: Washington Department of Ecology.

Railroads with Washington State response plans

To date, as shown in Table 111, there are eight railroad companies that have spill response plans filed with Washington Ecology.

Table 111: Washington State Railroad Response Plan Holders with Types, Contingency Plan Type, and Expiration Date[325]

Company Plan Holder	Type	Contingency Plan Type	Expiration Date
BNSF Railway Company	A	Full Contingency Plan	1 March 2023
Columbia Basin Railroad Company	B	Full Contingency Plan	23 October 2023
Central Washington Railroad Company	C	Basic Contingency Plan	19 March 2023
Great Northwest Railroad Company	C	Basic Contingency Plan	27 April 2023
Portland Vancouver Junction	C	Basic Contingency Plan	19 March 2023
Puget Sound and Pacific Railroad	B	Full Contingency Plan	23 October 2023
Tacoma Rail	A	Full Contingency Plan	5 November 2023
Union Pacific Railroad[326]	A	Full Contingency Plan	14 November 2019

Example of Type A crude carrier full contingency plan (BNSF)

BNSF Railway Company's *Oil Spill Contingency Plan — Washington State* issued in December 2018 (BNSF 2018b) and approved until March 1, 2023, addresses the required topics:

- Rail Facility Information
- Railroad Worst Case Spill Volume[327]
- Equipment Planning Standards
- Response Organization Information
- Initial Response Actions
- First Responder and Community Air Monitoring Plan
- Environmental Resource Protection
- Post-Emergency Response Actions

Rail Facility Information

BNSF may transport oil via both unit trains (the entire train comprised of buffer cars and a string of tank cars all moving oil) and manifest trains (a train comprised of mixed loads of merchandise, tank cars, and/or bulk intermodal portable tanks).

These BNSF transportation operations in Washington can generally be described as:

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[325] Washington Department of Ecology.
[326] This plan has conditional approval. Plans are given conditional approval status for 18 months or less. During this time, the plan holder must address the conditions and gain final plan approval.
[327] Worst-case spill (WCS) is used interchangeably with worst-case discharge (WCD).

- Unit Train Operations: Up to 4 locomotives and 118 loaded tank cars transporting oil in 714-bbl (29,988-gallon) capacity DOT-approved tank cars.[328]
- Manifest Train Operations: Individual loaded tank cars with up to four locomotives and approximately ten tank cars transporting refined oil products (diesel, lubrication oil, gasoline) in 714-bbl (29,988-gallon) capacity DOT-approved tank cars.

In both unit and manifest trains, BNSF uses the following types of cars to move Class 3 Flammable Liquids (including crude oil) in:

- DOT-approved DOT-117 and CPC-1232 Tank Cars; and
- DOT-approved DOT-112 and CPC-120 Tank Cars.[329]

Since August 2016, BNSF no longer moves DOT-111 tank cars in unit trains.[330]

The commodities that have been moved by BNSF unit trains are shown in Table 112 with their destinations. The commodities moved by manifest trains are shown in Table 113 for shipments originating in Washington and Table 114 for shipments with destinations in Washington.

Table 112: Unit Trains with Crude Oil Cargo Moved by BNSF[331]

Destination	Cars Moved (September 2014 to mid-December 2016)	Estimated Annual Cars	Estimated Annual Unit Trains[332]	Estimated Daily Unit Trains
Tacoma	29,730	13,028	110	0.3
Ferndale–Cherry Point	13,777	6,037	51	0.1
Fidalgo	59,683	26,154	222	0.6
Blaine–Cherry Point	67,242	29,466	250	0.7
Total	**170,432**	**74,685**	**633**	**1.7**

328 Given DOT weight restrictions, railroad tank cars transporting oil are typically not loaded with more than 650 barrels.
329 For more information on different types of tank cars, see Chapter 15.
330 DOT-111 cars are not authorized to be used in DOT Class 3 Packing Group I services since 1 January 2018.
331 BNSF Railway 2018.
332 Based on 118 cars per train.

Table 113: BNSF Manifest Train Oil Cargo Cars with Origins in Washington[333]

STCC [334]	Commodity	Origin	Cars Moved (September 2014 to mid-December 2016)	Estimated Annual Cars
1311110	**Petroleum Crude Oil**	Spokane	101	44
1311110	**Petroleum Crude Oil**	Tacoma	100	44
1311110	**Petroleum Crude Oil**	Blaine–Cherry Point	18	8
2814167	**Toluene**	Kalama	1	0
2911135	**Gasolines Blend**	Vancouver	1	0
2911135	**Gasolines Blend**	Spokane	1	0
2911140	**Gasoline Black**	Tacoma	3	1
2911140	**Gasoline Black**	Chehalis	1	0
2911315	**Petroleum Fuel**	Pasco	285	125
2911315	**Petroleum Fuel**	Spokane	5	2
2911315	**Petroleum Fuel**	Seattle	174	76
2911315	**Petroleum Fuel**	Blaine–Cherry Point	3,008	1,318
2911329	**No. 4 Fuel Oil**	Tacoma	24	11
2911415	**Petroleum Lube Oil**	Seattle	1	0
2911720	**No. 5 Fuel Oil**	Pasco	1	0
2911720	**No. 5 Fuel Oil**	Spokane	14	6
2911720	**No. 5 Fuel Oil**	Tacoma	5	2
2911720	**No. 5 Fuel Oil**	Everett	1	0
2911720	**No. 5 Fuel Oil**	Velox	8	4
2911740	**Petroleum Oil Residuum**	Tacoma	9	4
2911791	**Petroleum Oil, Other**	Seattle	1	0
2911791	**Petroleum Oil, Other**	Tacoma	69	30
2911791	**Petroleum Oil, Other**	Burlington	2	1
2911791	**Petroleum Oil, Other**	Mt. Vernon	1	0
2911791	**Petroleum Oil, Other**	Fidalgo	27	12
2911791	**Petroleum Oil, Other**	Blaine–Cherry Point	1	0
2911901	**Transformer Oil**	Spokane	2	1
2911901	**Transformer Oil**	Velox	3	1
2911903	**Octene**	Fidalgo	44	19
2911942	**Nonene**	Fidalgo	501	220
2911982	**Petroleum Naphtha**	Pasco	3	1
2911982	**Petroleum Naphtha**	Tacoma	11	5
Total			**4,426**	**1,939**

[333] Surface Transportation Board data. Does not include empty cars (STCC 3742217).
[334] Standard Transportation Classification Code.6

Table 114: BNSF Manifest Train Oil Cargo Cars with Destinations in Washington[335]

STCC[336]	Commodity	Origin	Cars Moved (September 2014 through mid-December 2016)	Estimated Annual Cars
1311110	Petroleum Crude Oil	Spokane	101	44
2814158	Refinery Cracking Stock	Tacoma	71	31
2814158	Refinery Cracking Stock	Fidalgo	69	30
2814167	Toluene	Kalama	60	26
299885	Additives Fuel	Tacoma	6	3
299885	Additives Fuel	Seattle	2	1
2911130	Jet Fuels	Mobase	14	6
2911135	Gasolines Blend	Tacoma	1	0
2911135	Gasolines Blend	Spokane	571	250
2911135	Gasolines Blend	Longview	4	2
2911135	Gasolines Blend	Hillyard	3,264	1,430
2911135	Gasolines Blend	Epasco	6	3
2911140	Gasoline Black	Seattle	1	0
2911190	Gasoline, Other	Spokane	180	79
2911190	Gasoline, Other	Seattle	30	13
2911315	Petroleum Fuel	Tacoma	14	6
2911315	Petroleum Fuel	Pasco	810	355
2911315	Petroleum Fuel	Spokane	1	0
2911315	Petroleum Fuel	Seattle	894	392
2911315	Petroleum Fuel	Hillyard	11	5
2911315	Petroleum Fuel	Quincy	22	10
2911315	Petroleum Fuel	Fidalgo	2	1
2911315	Petroleum Fuel	Blaine–Cherry Point	298	131
2911315	Petroleum Fuel	Epasco	4	2
2911329	No. 4 Fuel Oil	Tacoma	10	4
2911331	Diesel Fuel	Tacoma	3	1
2911415	Petroleum Lube Oil	Kent	5	2
2911415	Petroleum Lube Oil	Tacoma	53	23
2911415	Petroleum Lube Oil	Pasco	11	5
2911415	Petroleum Lube Oil	Vancouver	49	21
2911415	Petroleum Lube Oil	Kalama	181	79
2911415	Petroleum Lube Oil	Seattle	55	24
2911415	Petroleum Lube Oil	Wheeler	7	3
2911415	Petroleum Lube Oil	Aberdeen	73	32
2911415	Petroleum Lube Oil	Yakima	3	1
2911415	Petroleum Lube Oil	Rye Junction	2	1

[335] Surface Transportation Board data. Does not include empty cars (STCC 3742217).
[336] Standard Transportation Classification Code.6

STCC[336]	Commodity	Origin	Cars Moved (September 2014 through mid-December 2016)	Estimated Annual Cars
2911415	**Petroleum Lube Oil**	Hoquiam	1	0
2911415	**Petroleum Lube Oil**	Glade	8	4
2911415	**Petroleum Lube Oil**	Blaine–Cherry Point	4	2
2911415	**Petroleum Lube Oil**	Interbay	8	4
2911415	**Petroleum Lube Oil**	Marysville	50	22
2911425	**Mineral Oil**	Kalama	3	1
2911425	**Mineral Oil**	Elma	2	1
2911717	**Fuel Oil Bunker C**	Tacoma	9	4
2911717	**Fuel Oil Bunker C**	Fidalgo	1	0
2911720	**No. 5 Fuel Oil**	Tacoma	592	259
2911720	**No. 5 Fuel Oil**	Seattle	16	7
2911720	**No. 5 Fuel Oil**	Everett	1	0
2911720	**No. 5 Fuel Oil**	Fidalgo	81	35
2911740	**Petroleum Oil Residuum**	Tacoma	10	4
2911791	**Petroleum Oil, Other**	Tacoma	830	364
2911791	**Petroleum Oil, Other**	Yakima	9	4
2911791	**Petroleum Oil, Other**	Elma	10	4
2911791	**Petroleum Oil, Other**	Fidalgo	2	1
2911901	**Transformer Oil**	Seattle	1	0
2911901	**Transformer Oil**	Rye Junction	5	2
2911982	**Petroleum Naphtha**	Kent	14	6
2911982	**Petroleum Naphtha**	Tacoma	8	4
2911982	**Petroleum Naphtha**	Pasco	3	1
2991231	**Lubrication Oil**	Arco	65	28
Total			**8,621**	**3,777**

Railroad Worst Case Spill Volume

According to Washington Administrative Code (WAC) 173-186-040:

> "Worst case spill" means, in the case of a railroad, a spill that includes the entire fuel capacity of the locomotive and the entire cargo capacity of the largest number of cargo rail cars carried by the railroad, based on seven hundred fourteen barrels per tank car,[337] complicated by adverse weather conditions unless Ecology determines that a larger or smaller volume is more appropriate given a particular facility's site characteristics and storage, unique operations, industry spill history, and transfer capacity.

Based on WAC 173-186-040, the default method for calculating the Worst-Case Spill (WCS) volume for BNSF would be:

[337] Given DOT weight restrictions on rail cars, tank cars transporting oil are typically not loaded with more than 650 bbl.

- 118 cars x 714 bbl/car = 84,252 bbl
- 4 locomotives x 130 bbl/locomotive = 520 bbl
- Total WCS = 84,772 bbl (3,560,424 gallons)

BNSF takes an alternate approach in its calculation (BNSF Railway 2018). BNSF's method for determining an inland facility-specific WCS volume uses BNSF-specific facility site characteristics, unique operations, industry spill history, and transfer capacity as allowed by the statute and regulations. BNSF's contingency plan describes the operating practices, track and equipment inspections, tank car design changes, etc. that constitute Best Available Protection (BAP) for unit train oil transportation and provides response details for the calculated WCS using USDOT and PHMSA WCS analysis and methodologies. The BNSF WCS is calculated in consideration of BNSF's safety strategy, derailment prevention, risk reduction, and highly evolved response program.

The PHSMA WCD approach involves multiplying the total lading of liquid petroleum by 15 percent. Using this approach, the WCS for BNSF is 12,642 bbl (530,964 gallons).

In its Contingency Plan, BNSF presents information that shows that its derailment prevention measures exceed the requirements of USDOT and AAR, as show in Table 115.[338]

Table 115: BNSF Unit Train Route Derailment Prevention Measures in Washington[339]

Prevention Measure	BNSF in Washington	Comparison with USDOT/AAR Requirement
Maximum Speed of High Hazard Flammable Trains (HHFTs)	50 mph/35 mph in locations of population density of 100,000	50 mph/40 mph in locations of population density of 100,000 when moving DOT-111 cars[340]
Visual Track Inspections	4 to 7 times per week	Exceeds FRA requirement by a factor of at least 2
Track Geometry Inspections	3 times per year (minimum)	Exceeds FRA requirement by a factor of at least 1.5
Rail Defect Inspection	Every 18 days	Exceeds FRA requirement by a factor of at least 2
Wayside Detectors–Spokane to Pasco	22-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 1.8)
Wayside Detectors–Pasco to Vancouver	10-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 4)
Wayside Detectors–Vancouver to Seattle	18-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 2.2)
Wayside Detectors–Seattle to Wenatchee	21-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 1.9)
Wayside Detectors–Everett to Bellingham	21-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 1.9)
Wayside Detectors–	23-mile average between	Placed at a maximum of 40 miles apart

[338] For more information on Inspections and Wayside Detectors, see Chapter 11.
[339] BNSF Railway 2018.
[340] DOT-111 cars are not authorized to be used in DOT Class 3 Packing Group I services since 1 January 2018.

Prevention Measure	BNSF in Washington	Comparison with USDOT/AAR Requirement
Wenatchee to Spokane	detectors	(Exceeds FRA requirement by a factor of 1.7)
Wayside Detectors–Rainier to Ellensburg	23-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 1.7)
Wayside Detectors–Pasco to Ellensburg	15-mile average between detectors	Placed at a maximum of 40 miles apart (Exceeds FRA requirement by a factor of 2.7)

In addition to the prevention of accidents, BNSF factored in the safety features of DOT-117 and CPC-1232 tank cars, which reduce the likelihood of a release of oil in the event of an accident. CPC-1232 cars are 50 percent less likely to have a release, and DOT-117 cars are 84 percent less likely to have a release than DOT-111 cars, which are no longer in use (Treichel 2014).[341]

Equipment Planning Standards

The detailed summary of BNSF's contracted Primary Response Contractor (PRC) oil spill containment, recovery, and storage equipment, used to fulfill Ecology's response resource planning standards for 6-, 12-, 24-, and 48-hour requirements at applicable planning points are shown in Table 116. The contracted resources that BNSF has to meet these standards are shown in Table 117. The contingency plan includes planning standard calculation methods and equipment inventory summaries which comply with the Ecology planning standards for Crude Oil, In-situ Burning, and Shoreline Clean-up (BNSF 2018b).

Table 116: Ecology Planning Standards for 12,642-bbl Worst-Case Spill[342]

Requirement	6-Hour Response Time	12-Hour Response Time	24-Hour Response Time
Boom	5,000 feet	25,000 feet	More as necessary
Minimum Recovery	1,264 bbl/day	6,321 bbl/day	12,624 bbl/day
Minimum Storage	1,264 bbl/day	6,321 bbl/day	12,624 bbl/day

Table 117: BNSF Primary Response Contractor Resources for Planning Standards[343]

Planning Point	Requirement	6-Hour Response Time	12-Hour Response Time	24-Hour Response Time
Bellingham	**Boom (feet)**	84,980	204,520	209,160
Bellingham	**Minimum Recovery (bbl/day)**	76,862	145,010	188,843
Bellingham	**Minimum Storage (bbl/day)**	34,802	81,077	97,437
Bingen	**Boom (feet)**	61,320	290,900	290,900
Bingen	**Minimum Recovery (bbl/day)**	84,618	160,839	142,264
Bingen	**Minimum Storage (bbl/day)**	4,780	16,966	12,801

341 For more information on different types of tank cars, see Chapter 15.
342 BNSF Railway 2018.
343 BNSF Railway 2018.

Planning Point	Requirement	6-Hour Response Time	12-Hour Response Time	24-Hour Response Time
Centralia/Chehalis	Boom (feet)	152,280	217,900	221,075
Centralia/Chehalis	Minimum Recovery (bbl/day)	124,546	142,264	143,704
Centralia/Chehalis	Minimum Storage (bbl/day)	6,064	12,801	12,701
Longview/Kelso	Boom (feet)	121,955	221,075	269,160
Longview/Kelso	Minimum Recovery (bbl/day)	106,391	143,704	270,647
Longview/Kelso	Minimum Storage (bbl/day)	5,358	11,301	98,973
Mukilteo/Everett	Boom (feet)	88,680	266,020	224,600
Mukilteo/Everett	Minimum Recovery (bbl/day)	46,394	235,813	142,609
Mukilteo/Everett	Minimum Storage (bbl/day)	10,620	93,977	12,789
Seattle	Boom (feet)	88,140	265,020	266,520
Seattle	Minimum Recovery (bbl/day)	58,165	235,813	249,316
Seattle	Minimum Storage (bbl/day)	7,055	70,677	98,973
Spokane	Boom (feet)	8,300	163,380	224,600
Spokane	Minimum Recovery (bbl/day)	1,262	112,921	142,609
Spokane	Minimum Storage (bbl/day)	1,684	10,639	12,789
Tacoma	Boom (feet)	103,300	264,360	266,520
Tacoma	Minimum Recovery (bbl/day)	57,852	219,049	249,316
Tacoma	Minimum Storage (bbl/day)	18,616	32,391	94,973
Tri-Cities (Kennewick)	Boom (feet)	33,600	217,900	217,900
Tri-Cities (Kennewick)	Minimum Recovery (bbl/day)	3,756	142,264	142,264
Tri-Cities (Kennewick)	Minimum Storage (bbl/day)	2,288	12,801	12,801
Vancouver	Boom (feet)	104,120	217,900	217,900
Vancouver	Minimum Recovery (bbl/day)	101,246	142,264	142,264
Vancouver	Minimum Storage (bbl/day)	4,712	13,301	12,801
Wenatchee	Boom (feet)	6,400	217,900	217,900
Wenatchee	Minimum Recovery (bbl/day)	1,280	142,604	142,264
Wenatchee	Minimum Storage (bbl/day)	1,650	11,301	13,301
Yakima/Union Gap	Boom (feet)	33,600	217,900	217,900
Yakima/Union Gap	Minimum Recovery (bbl/day)	3,756	142,264	142,604
Yakima/Union Gap	Minimum Storage (bbl/day)	2,288	11,301	12,701

Response Organization Information

Presentation of the BNSF Incident Management Team (IMT) emergency response organization including descriptions of the BNSF incident management planning process and IMT members who will assume Qualified Individual (QI), Incident Command (IC), and Section Chief responsibilities, as aligned with the Northwest Area Contingency Plan (NWACP) (BNSF Railway 2018).

Initial Response Actions

Description of an Initial Response Checklist, Health and Safety assessment, spill reporting and notification processes, and key agency and stakeholder contact information included in a comprehensive "Emergency Response - Oil Spill Plan - Field Document." The contingency plan also outlines spill assessment and trajectory mapping processes, which are compatible with NWACP guidance (RRT and NWAC 2019; Washington State Dept. of Ecology 2019b). BNSF developed an environmental permit matrix screening process designed to expedite applicability determination(s) for U.S. Army Corps of Engineers (USACE) and Ecology permits for response efforts in jurisdictional waters of the state or the U.S. This program is designed to ensure the Environmental Unit obtains the proper permits such that effective containment and recovery actions for oil spill response are not delayed (BNSF Railway 2018).

First Responder and Community Air Monitoring Plan

BNSF developed a "Site Worker and Community Air Monitoring Plan" based on an extensive air monitoring and worker protection program demonstrated to be effective around the U.S. (BNSF 2018b).

Environmental Resource Protection

The BNSF Contingency Plan includes a summary of readily-available sensitive environmental, cultural, and economic resources-at-risk data compiled in a geographic information system-based format, and includes references to NWACP-developed Geographic Response Plans (GRPs). For areas in WA along BNSF-owned track where GRPs do not exist, BNSF developed oil spill response strategies for significant waterways in the vicinity of the tracks (BNSF 2018b).

GRPs are developed by the Northwest Area Committee[344] as part of the NWACP.[345] GRPs are intended for use as a guide in minimizing the impact of oil on natural, cultural, and certain economic resources at risk during spills. Each plan covers a specific geographic area and contains information meant to aid the response community in managing the incident through, and as necessary beyond, the initial phase of the response. Information contained in the plans include site descriptions, reference maps, recommended response strategies, shoreline information, resource at risk details, and logistical information. GRPs are living documents, subject to change as new information is received. Coastal and inland Geographic Response Plans (GRPs) for Washington State including the lower Columbia River are maintained by Washington Department of Ecology. The Spokane River GRP, Snake River GRPs, and Middle Columbia River GRP are jointly maintained by Ecology and the US Environmental Protection Agency (RRT Region 10).

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[344] Members include: Oregon Department of Environmental Quality, Washington Department of Ecology, Idaho Office of Emergency Management, US Coast Guard Sector Columbia River, US Coast Guard Sector Puget Sound, US Environmental Protection Agency (EPA), Bureau of Indian Affairs, and Tribal officials.
[345] Region 10 Regional Response Team and the Northwest Area Committee website. https://www.rrt10nwac.com/GRP/Default.aspx

Post-Emergency Response Actions

The BNSF Contingency Plan includes Wildlife Response assessment, protection, and rehabilitation expertise and groundwater assessment processes designed to minimize and mitigate the effects of an oil spill. Waste management plans reflect the NWACP and rely on BNSF-approved treatment, storage and disposal facilities (TSDFs) and/or transporters in WA, Oregon, and Idaho (BNSF 2018b).

Spill Preparedness Requirements for Washington

The requirements for response capability in Washington State are summarized in Table 118. The requirements for spill drills are summarized in Table 119.

Table 118: Response Capability Requirements for Washington State[346]

Time	Boom/Assessment	Minimum Oil Recovery Rate (% of WCS Volume per 24 hours)	Minimum Storage (bbl)
6 hours	Safety assessment of the spill by trained crew and appropriate air monitoring could have arrived. 5,000 feet of boom available for containment, recovery or protection could have arrived. Alternatively, resources identified to deploy a site-specific strategy to keep oil from entering surface waters or penetrating the ground could have arrived	Capacity to recover the lesser of 10 percent of worst-case spill volume or 4,100 barrels within 24-hour period could have arrived.	1 time the effective daily recovery capacity (EDRC) appropriate to operating environment.
12 hours	Additional 20,000 feet of boom to be used for containment, protection or recovery could have arrived.	Capacity to recover the lesser of 15 percent of worst-case spill volume or 12,000 barrels within 24-hour period could have arrived.	1.5 times the EDRC appropriate to operating environment.
24 hours	More boom as necessary for containment, recovery or protection.	Capacity to recover the lesser of 20 percent of worst-case spill volume or 16,000 barrels within 24-hour period could have arrived.	2 times the EDRC appropriate to operating environment.

[346] Washington Department of Ecology.

Time	Boom/Assessment	Minimum Oil Recovery Rate (% of WCS Volume per 24 hours)	Minimum Storage (bbl)
48 hours	More boom as necessary for containment, recovery or protection.	Capacity to recover the lesser of 25 percent of worst-case spill volume or 20,000 barrels within 24-hour period could have arrived.	More as necessary to not slow the response.

Table 119: Drill Requirements for Washington State[347]

Type of Drill	Frequency Within the Triennial Cycle	Special Instructions
Tabletop Drills	3 - One in each year of the cycle	One of the three shall involve a worst-case discharge scenario. The worst-case discharge scenario drill shall be conducted once every three years
Deployment Drills	6 - Two per year	These drills include notification, safety assessments, GRP and equipment deployments
Ecology Initiated Unannounced Drills	As necessary	This drill may involve testing any component of the plan, including notification procedures, deployment of personnel, boom, recovery and storage equipment
Wildlife Deployment Drill	1 - One in each three-year cycle. This is an additional drill unless it is incorporated into a large multi-objective deployment drill	This drill will be a deployment of wildlife equipment and wildlife handlers

[347] Washington Department of Ecology.

Other State Oil Spill Response Emergency Regulation

State of Maine oil spill response emergency regulation

The State of Maine has oil spill emergency response regulations for rail tank cars that are dictated by 06-096 Chapter 696: Oil Discharge Prevention and Pollution Control Rules for Rail Tank Cars. The regulations set forth minimum inspection, preparedness, and reporting requirements for operators of rail tank cars transporting or storing oil in Maine.

According to The State of Maine 06-096 Chapter 696:

> Oil Discharge Prevention and Pollution Control Rules for Rail Tank Cars, "Any person or operator discharging or suffering the discharge of oil prohibited by 38 Maine Revised Statutes Annotated (MRSA) § 543 shall immediately undertake to remove such discharge to the Commissioner's satisfaction as required by 38 MRSA § 548. Notwithstanding the above requirement, the Commissioner may undertake the removal or cleanup of that discharge, investigate and sample sites where an oil discharge has occurred, and may retain agents and contractors for those purposes. (p. 2)

Minnesota oil spill response regulations for railroads

Minnesota authorizes the agency (Minnesota Pollution Control Agency/MPCA) overseeing oil transportation in the state to perform rail and pipeline spill and discharge preparedness activities and requires certain owner/operators, including railroads, to submit state spill response plans. In addition, the law imposes a fee on operators that transport oil in the state to provide local fire departments with response equipment and spill response training. The state will also study oil transportation incident preparedness.

According to Minnesota Statutes 115E.04–Prevention and Response Plans (Subdivisions 3 and 4 and Section 115E.04), persons who own or operate railroad car rolling stock transporting an aggregate total of more than 100,000 gallons [the equivalent of three to four tank cars] of oil or hazardous substance as cargo in Minnesota in any month. The Minnesota regulation states (Minnesota Statutes 115E.04–Prevention and Response Plans (Subdivisions 3 and 4 and Section 115E.04):

> Subdivison 1. **Plan Contents.** Persons required to show specific preparedness shall prepare and maintain a prevention and response plan for a worst-case discharge. The plan must:
>
> 1. Describe how it is consistent with the requirements of the national or area contingency plans developed under the Oil Pollution Act of 1990;
> 2. Describe the measures taken to prevent discharges from occurring, including prevention of a worst-case discharge, prevention of discharges of lesser magnitude, and prevention of discharges like those that have occurred from the vessel or facility during its history of operation;
> 3. Identify the individual or individuals having full authority to implement response actions, and those individuals' qualifications and titles;

4. Identify how communication and incident command relationships will be established between the individuals in command of a vessel or facility response and the following persons:
    a. Individuals in the employ of the owner or operator of the vessel or facility who are responding to the discharge;
    b. Appropriate federal, state, and local officials; and
    c. Other persons providing emergency response equipment and personnel;
5. Describe the facility or vessel and identify the locations and characteristics of potential worst-case discharges from the vessel or facility;
6. Identify the means that will be used to satisfy the requirement to have adequate equipment and personnel to respond to a worst-case discharge;
7. Contain copies of contracts, correspondence, or other documents showing that adequate personnel and equipment will be available to respond to a worst-case discharge;
8. Describe the actions that will be taken by the persons in the event of a worst-case discharge; and
9. Describe the training, equipment testing, periodic drills, and unannounced drills that will be used to ensure that the persons and equipment are ready for response.

A plan submitted to the federal government under the Oil Pollution Act of 1990 [OPA90] or prepared under other law may be used to satisfy the requirements in clauses (1) to (9) provided that the information required by clauses (1) to (9) is included in the plan.

California oil spill response plan regulations for railroads

California passed a law requiring that railroads and other entities that transport oil across the state prepare comprehensive oil spill response plans and demonstrate financial responsibility to clean up a worst-case oil spill. The court judgement permits California to implement regulations which would require enhanced accountability from railroads considering the significant expansion of CBR shipments and the resulting consequences from rail tank car incidents of derailments, spills, and explosions.

California Code, Government Code, GOV § 8670.29 states:

> a) In accordance with the rules, regulations, and policies established by the administrator pursuant to Section 8670.28, an owner or operator of a facility, small marine fueling facility, or mobile transfer unit, or an owner or operator of a tank vessel, non-tank vessel, or vessel carrying oil as secondary cargo, while operating in the waters of the state or where a spill could impact waters of the state, shall have an oil spill contingency plan that has been submitted to, and approved by, the administrator pursuant to Section 8670.31.
>
> An oil spill contingency plan shall ensure the undertaking of prompt and adequate response and removal action in case of a spill, shall be consistent with the California oil spill contingency plan, and shall not conflict with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).
>
> b) An oil spill contingency plan shall, at a minimum, meet all the following requirements:

1) Be a written document, reviewed for feasibility and executability, and signed by the owner or operator, or his or her designee.
2) Provide for the use of a recognized incident command system to be used during a spill.
3) Provide procedures for reporting spills to local, state, and federal agencies, and include a list of contacts to call in the event of a drill, exercise, threatened spill, or spill.
4) Describe the communication plans to be used during a spill, if different from those used by a recognized incident command system.
5) Describe the strategies for the protection of environmentally sensitive areas.
6) a. Identify at least one rated OSRO, rated pursuant to Section 8670.30. Each identified rated OSRO shall be directly responsible by contract, agreement, or other approved means to provide oil spill response activities pursuant to the oil spill contingency plan. A rated OSRO may provide spill response activities individually, or in combination with another rated OSRO, for a particular owner or operator.
   b. For purposes of this paragraph, "other approved means" includes the owner or operator relying on its own response equipment if the response equipment and personnel have been rated by the administrator consistent with the requirements of Section 8670.30.
7) Identify a qualified individual.
8) a. Identify at least one certified spill management team that can manage a spill of the reasonable worst-case spill volume identified in the plan. An owner or operator may demonstrate incident management capabilities with one or more spill management teams. Each identified certified spill management team shall be directly responsible by contract, agreement, or other approved means to provide spill response activities pursuant to the oil spill contingency plan.
   b. For purposes of this paragraph, "other approved means" includes the owner or operator relying on its own spill management team if that spill management team has been certified by the administrator consistent with the requirements of Section 8670.32.
9) Provide the name, address, and telephone and facsimile numbers for an agent for service of process, located within the state and designated to receive legal documents on behalf of the owner or operator.
10) Provide for training, drills, and exercises on elements of the plan at least annually, with all elements of the plan subject to a drill or exercise at least once every three years.

…

d) An oil spill contingency plan for a facility shall also include, but is not limited to, all the following requirements:

   1) Provisions for site security and control.
   2) Provisions for emergency medical treatment and first aid.
   3) Provisions for safety training, as required by state and federal safety laws for all personnel likely to be engaged in oil spill response.
   4) Provisions detailing site layout and locations of environmentally sensitive areas requiring special protection.

5) Provisions for vessels that are in the operational control of the facility for loading and unloading.

e) Unless preempted by federal law or regulations, an oil spill contingency plan for a railroad also shall include, but is not limited to, all the following:

1) A list of the types of train cars that may make up the consist.
2) A list of the types of oil and petroleum products that may be transported.
3) A map of track routes and facilities.
4) A list, description, and map of any pre-staged spill response equipment and personnel for deployment of the equipment.

f) The oil spill contingency plan shall be available to response personnel and to relevant state and federal agencies for inspection and review.

g) The oil spill contingency plan shall be reviewed periodically and updated as necessary. All updates shall be submitted to the administrator pursuant to this article.

h) In addition to the regulations adopted pursuant to Section 8670.28, the administrator shall adopt regulations and guidelines to implement this section. The regulations and guidelines shall provide for the best achievable protection of waters and natural resources of the state. The administrator may establish additional oil spill contingency plan requirements, including, but not limited to, requirements based on the different geographic regions of the state. All regulations and guidelines shall be developed in consultation with the Oil Spill Technical Advisory Committee.

i) …a facility operating where a spill could impact state waters that are not tidally influenced shall identify a rated OSRO in the contingency plan no later than January 1, 2016.

In 2015, the California Legislature passed Senate Bill (SB) 84, which created the Regional Railroad Accident Preparedness and Immediate Response Force (RRAPIRF), as a section in the Cal Office of Emergency Services (OES). The RRAPIR Force is responsible for providing regional and onsite response capabilities for fire and public health in the event of a release of hazardous materials from a rail car or a railroad accident involving a rail car. The RRAPIR Force is also responsible for implementing the state regional railroad accident preparedness and immediate response plan for releases of hazardous materials from railroad accident involving a rail car.

Human health and safety environment concerns in rail accidents

Crude oil as a Class 3 flammable liquid

Crude oil is a Class 3 flammable liquid as described in Chapter 6.

Health and safety concerns for Bakken crude oil spills[348]

The NW Area Committee RRT 10 document "Bakken Crude Oil"[349] states (NW Area Committee 2015):

> In general, Bakken crude oil presents the same physical properties as light Group II oils or other fuels. It will float on water, as its specific gravity is less than 1, and it is considered moderately volatile. This type of crude oil will contain higher concentrations of light end petroleum hydrocarbons (such as methane, ethane, propane, and butane).
>
> These dissolved gases and lighter ends will:
>
> - Increase the vapor pressure
> - Lower the flashpoint
> - Lower the initial boiling point (p. 4)

The Hudson River Oil Spill Risk Assessment, Volume 6: Risk Mitigation, May 2018, states that (Etkin et al. 2018b):

> While Bakken oil is generally considered to be a type of "sweet" crude, there may be instances where hydrogen sulfide (H_2S) may be present in higher concentrations than may be expected.
>
> Emergency responders must remain cognizant of the fact light sweet crude oil, such as that coming from the Bakken region, is typically assigned a packing group (PG) I or II.
>
> The PGs means that the material's flashpoint is below 73° Farenheit and, for packaging group I materials, the boiling point is below 95° Farenheit. This means the materials pose significant fire risk if released from the package in an accident.
>
> Typical Bakken crude oil properties (at 60°F) are typically:
>
> - Specific Gravity 0.7–0.8: floats on water
> - Vapor Density 2.5–5.0: heavier than air
> - Vapor Pressure, 280–360 mmHg: moderate volatility
>
> Bakken flammability characteristics are:
>
> - NFPA Flammability = 3-4
> - Sensitive to static discharge
> - Explosive Limits variable: LEL 0.4 percent; UEL 15.0 percent
> - Flash point: -40° to 212°F (-74° to 122°F: AFPM data)
>
> Emergency personnel need to account for the chemical and physical characteristics as well as the health and safety issues associated with a Bakken oil spill/fire explosion response incident. Bakken crude is more volatile than other crude oils because of

[348] Source: much of the information contained in this section has been derived from MASSDEP 2015, NW Area Committee, 2015, and DOT ERG 2016
[349] NW Area Committee RRT 10 document Bakken Crude Oil, February 2015

> dissolved gases and other petroleum hydrocarbon light ends and may contain hydrogen sulfide in high concentrations. (pp. 84-85)

Bakken crude oil has up to 30 percent (by volume) light volatiles. In the early stages of a Bakken release incident, the potential for fire and explosion is the single largest risk to responder and public health regarding this type of oil. Therefore, extreme caution should be exercised during the initial stages of response .

The Hudson River Oil Spill Risk Assesssment goes on:

> The potential human exposure pathways during spill situations depend on the nature of the spill. In general, given the volatile nature of Bakken crude and other light crudes, inhalation exposures are the most likely exposure scenarios for both first responders and nearby workers or residents.
>
> Skin contact (dermal exposure) is possible, but unlikely, since responders should be wearing appropriate protective clothing. If a fire occurs following a spill or release, burning can result in inhalation exposures to smoke particles and [volatile organic compounds] (VOCs) in the immediate proximity of the spill, but also at some distance. Ingestion exposure is also unlikely, although if the spill reaches surface water, components of crude oil will dissolve, and could affect a drinking water source. Water supply intakes have been shut down during several incidents. In addition, contact could occur as a result of other uses of surface water, such as swimming or boating, or use for cooling or production water.
>
> Crude oil has been found to have a relatively low acute toxicity. Fresh or weathered crude can cause skin irritation and other irritant reactions in response workers, although these effects may be a result of repeat exposure.
>
> Crude oil ingestion in small quantities may result in nausea, vomiting, and diarrhea. Vomiting and subsequent aspiration of hydrocarbons can result in significant lung injury.
>
> Acute effects in exposure related to oil spill effects include respiratory, eye, and skin symptoms, headache, nausea, dizziness, and fatigue.
>
> Exposed residents in proximity to an oil spill may show acute symptoms such as headache, throat irritation and itchy eyes.
>
> In summary, for Bakken crude:
>
> - Inhalation or contact with material may irritate or burn skin and eyes;
> - Fire may produce irritating, corrosive and/or toxic gases;
> - Vapors may cause dizziness or suffocation;
> - Runoff from fire control or dilution water may cause pollution;
> - As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions;
> - Keep unauthorized personnel away;
> - Stay upwind;
> - Keep out of low areas;

- Ventilate closed spaces before entering;
- Wear positive pressure self-contained breathing apparatus (SCBA); and
- Structural firefighters' protective clothing will only provide limited protection (pp. 92-93)

On-water spill response considerations for Bakken crude

A 2015 CB&I Environmental and Infrastructure, Inc. report, *Bakken Crude Oil Spills — Response Options and Environmental Impacts*, stated:

> In general, crude oil floats on water until oil densities change through weathering and/or sediment uptake. Crude oil may gradually over-wash, become suspended in the water column, or sink, depending on the degree of weathering and formation of oil-mineral aggregates.
>
> The strategy for cleaning up a spill in water bodies begins with localizing the spill, using a variety of boom strategies. Booms can be used in several ways: a containment strategy keeps the oil from spreading; collection holds the oil near the source; deflection steers the oil towards collection areas and away from sensitive areas; and protection creates barriers that keep oil from affecting sensitive areas. Booms work best in calm waters, and this effectiveness decreases as wave heights and currents increase.
>
> Cleanup tools include skimmers, sorbents, and chemical dispersants. Skimmers are mechanical devices that physically remove the oil from the surface of the water. Sorbents, available as pads, pillows, or booms, remove oil sheens and thin slicks that are too scattered for skimming.
>
> Barriers are commonly used to mechanically impede oil spreading and movement. Booms, dams, and weirs are used to contain and concentrate oil on water. Containment challenges with booms include flow relative to the boom (current or towing speeds), turbulence, wave action, oil load in boom, and oil density relative to water.
>
> An underflow dam of gravel and earth or traditional materials for adjustable underflow dams should be considered for use in shallow waters, narrow waterways, calm waters, or low-flow conditions. Contained oil can be recovered with vacuum trucks, skimmers, dredging and other traditional oil recovery techniques.
>
> As oil becomes entrained into the water column, either through turbulence, or combination of flow and densities near those of the receiving water body, conventional surface booming becomes less effective. Conventional booms may be effective in containing oil that has only slightly submerged below the immediate surface, but other methods such as trawl nets specifically designed to recover heavy oil may become necessary....
>
> Responders need to prepare for both a light, floating oil and the potential for a heavy, submerged or sinking oil. In addition, material that initially floats will lose

> light hydrocarbons to evaporation and mix with fine sediments and may eventually move into the water column and sink to the bottom at natural collection points. The ability to detect, monitor, contain, and recover submerged or sunken oil is limited. Research and development continues in the design of equipment for responding to sinking or submerged oil spills.
>
> In fast moving water, recovering oil is more difficult as oil tends to entrain in the water column. Oil will flow under containment booms and reduce the efficiencies of most conventional oil recovery equipment. Installing underflow dams, overflow dams, sorbent barriers, or a combination of these techniques will often increase recovery efficiencies.
>
> High wind or turbulent conditions also present challenges so sufficient length and size of containment booms should be fully considered to contain the oil.
>
> Bakken crude oil has a low viscosity and will quickly spread and evaporate. It will also adhere to suspended solids in the water column. Recoverable product may persist for only 4 to 8 hours, depending on size of spill. Its lighter components volatilize, posing human health hazard near spill location, and the low molecular weight polycyclic aromatic hydrocarbons (PAHs) dissolve in the water column potentially causing toxic aquatic effects. (pp. 9-9 to 9-11)

Shoreline cleanup for Bakken crude spills[350]

In the 2018 *Hudson River Oil Spill Risk Assessment, Vol. 6*, Etkin et al. describe shoreline cleanup for Bakken crude spills:

> Oil spill cleanup operations may cause more harm to a fragile coastal marsh environment than the oil itself. One of the major fates of spilled petroleum in the coastal environment is its incorporation into the sediments.
>
> Treatment options for shoreline cleanup vary for shoreline types and as a function of oil type. For example, low pressure flushing may be an applicable treatment technique for medium oil on coarse and sand-mixed substrate; however, the technique may be ineffective for heavy oil. Treatment tactics for shoreline cleanup include natural recovery, washing recovery, manual removal, mechanical removal, in situ mixing relocation, in-situ burning, and bio-remediation. Shoreline effects are less likely where current or flow transport the material away from the shoreline. Effects are more likely in calm waters. Chemical shoreline cleaners are available to treat oil that has adhered to the shoreline. Appropriate regulatory approval is necessary prior to application of these techniques (p. 9-10)

Bakken spill event response actions[351]

The *Hudson River Oil Spill Risk Assessment* study describes Bakken spill response (Etkin et al. 2018b):

[350] Hudson River Oil Spill Risk Assessment Volume 6: Risk Mitigation, Scenic Hudson, 2018
[351] Hudson River Oil Spill Risk Assessment Volume 6: Risk Mitigation, Scenic Hudson, 2018

First Responders should consider implementing the following procedures during the initial phase of the emergency response:

- Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area);
- Isolate the area and consider evacuation, if necessary;
- All equipment used when handling the product must be grounded;
- Determine the concentrations of any flammable or toxic vapors using air monitoring instruments;
- Evaluate the need for continuous air monitoring with technical specialists;
- Do not touch or walk through spilled material;
- Stop leak if you can do it without risk;
- Prevent entry into waterways, sewers, basements or confined areas;
- A vapor suppressing foam may be used to reduce vapors; Determine if adequate foam supplies and equipment available for vapor suppression;
- Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers;
- Use clean non-sparking tools to collect absorbed material;
- Large spill: Dike far ahead of liquid spill for later disposal.
- Water spray may reduce vapor but may not prevent ignition in closed spaces (pp. 9-1 to 9-2)

Bakken fire-explosion event actions[352]

The *Hudson River Oil Spill Risk Assessment* study found that (Etkin et al. 2018b):

> Flammability is the greatest hazard associated with crude oil in a spill incident, particularly in a rail incident. The flash point of crude oil is variable, but generally ranges from -59°C to 50°C for Bakken crude. Because of its flammable nature, the crude may ignite resulting in explosions, fireballs, and pool fires. Long duration fires involving crude stored in tanks may result in a boil over, in which the contents of the tank may be expelled beyond the container or containment area. Bakken crude floats on water and can be reignited on surface water.
>
> Explosion may occur following a major tank rupture, spilling fuel, which vaporizes, contacts an ignition source, and explodes and rapidly burns in a fireball. The pressure safety valve may or may not be able to vent the increase in pressure fast enough, resulting in tank failure, fireball, and a partial explosion....
>
> Due to the flammability of Bakken crude, the elimination of sources of ignition (e.g., static electricity, pilot lights, mechanical/electrical equipment, and electronic devices) and the use of explosion-proof electrical equipment is recommended and may be required depending on the relevant fire codes. Explosive hazards can occur in tanks in a spill situation. In addition, spilled

[352] Hudson River Oil Spill Risk Assessment Volume 6: Risk Mitigation, Scenic Hudson, 2018

material entering low-lying areas, sewers, storm drains, or other confined areas have the potential for the creation of explosive conditions. (p. 7-3)

Summary of Bakken crude issues of concern[353]

- HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames;
- Vapors may form explosive mixtures with air;
- Vapors may travel to source of ignition and flash back;
- Most vapors are heavier than air and will spread along ground and collect in low or confined areas (sewers, basements, tanks);
- Vapor explosion hazard indoors, outdoors or in sewers;
- Runoff to sewer may create fire or explosion hazard;
- Containers may explode when heated;
- Many liquids are lighter than water; and
- Substance may be transported hot (p. 194)

Fire emergency response UN 1267 Class 3 flammable crude oils[354]

For crude oil that has the number UN Number 1267 Petroleum crude oil, regardless of Packing Group, Guide No. 128 of the most recent edition of the *Emergency Response Guidebook* (ERG) (PHMSA 2016) provides a first responder with instructions on what steps to take upon arrival at the scene of an accident or incident:

iii. CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.
iv. CAUTION: For mixtures containing alcohol or polar solvent, alcohol-resistant foam may be more effective.
v. Small Fire: Dry chemical, CO_2, water spray or regular firefighting foam.
vi. Large Fire: Water spray, fog or regular firefighting foam.
    1) Do not use straight streams.
    2) Move containers from fire area if you can do it without risk.
vii. Fire involving Tanks or Car/Trailer Loads
    1) Withdraw from the area and let fire burn if proper equipment is not available
    2) Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Utilize water spray, fog, or regular foam. Do not use straight streams.
    3) Cool containers with flooding quantities of water until well after fire is out to prevent reignition and explosion of heated containers.
    4) Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
    5) ALWAYS stay away from tanks engulfed in fire.

[353] Source: DOT Emergency Response Guidebook 2016.
[354] Source: DOT ERG 2016.

viii. For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn. (p. 195)

The *2018 Hudson River Oil Spill Risk Assessment*, Volume 6 stated,

> In the event of a derailment scenario with a spill and fire, confinement and containment operations (i.e., spill control) are a priority. Traditional firefighting strategies and tactics may not be effective in these situations. If fire suppression operations are initiated, responders need enough foam concentrate supplies, adequate water supply, foam appliances, equipment, and properly trained personnel to effectively implement and sustain fire suppression and post-fire suppression operations. The strategy that provides the highest level of safety to responders is defensive to protect exposures, or non-intervention tactics, which allow the fires to burn out. The decision to protect exposures and let the product burn must be considered. Major fires may require withdrawal, allowing the tank to burn.
>
> Burning unit trains containing crude oil and adjacent cars should be cooled at the vapor space with unmanned hose lines to prevent heat-induced tears and further minimize personnel exposure. Use water fog spray to cool containers, control vapors, and to protect personnel from exposures. There is potential that containers of liquid that are not properly cooled may rupture violently if exposed to fire or excessive heat. Isolate the ends of tank(s) involved in fire but realize that shrapnel from exploding containers may travel in any direction and the tank may rupture at any point in the structure....
>
> Apply Class B firefighting foam with the same procedures as applied on fires involving other hydrocarbons. Alcohol Resistant Aqueous Film-Forming Foam Concentrate (AFF), as well as regular AFFF will effectively extinguish a fire.[355] Class B foam blankets prevent vapor production and ignition of flammable and combustible liquids. Foam is most effective on static fires that are contained in some manner. Firefighting foam is not effective on hydrocarbon fuels in motion (i.e., three dimensional fires) that include product leaking or spraying from manways, valves, fractures in the tank shell (e.g., rips, tears, etc.) or spills on sloping terrain....
>
> Most crude oil spills are not water soluble and will tend to float on water. Some crude oil will sink, and some fractions of crude oil are water soluble. For those fractions that float on water, burning crude oil may be carried on flowing water from the immediate area and may reignite away from the immediate source area. (pp. 9-3 to 9-4)

[355] Note that the use of AFFF is prohibited in Washington State when water sources are involved.

Procedures for Bakken crude spill without fire

The *Emergency Response Guidebook* (ERG) (PHMSA 2016) advises the following procedure for spills with no fire[356]:

- SMALL Spill: Isolate 150 ft. in all directions.
- LARGE Spill: Evacuate 1,000 ft. downwind.
- Secure potential ignition sources; use air monitoring; apply foam for vapor suppression; and begin spill confinement operations (diking, damming and boom deployment) to limit spread of spilled product.

Procedures for Bakken crude spill with fire

The *Emergency Response Guidebook* (ERG) (PHMSA 2016) advises the following procedure for spills with a fire:

If FIRE: Isolate ½ MILE in all directions and shelter downwind.

EXTINGUISH vs. LET IT BURN: Do you need to extinguish the fire?

- Evaluate life hazard, property/critical infrastructure at risk and environmental effect (in that order).
- If a life hazard exists: Focus available foam operations or use water fog patterns on oil fires to protect rescue operations. Conduct structural firefighting as necessary and from uphill and upwind if possible. Beware of any running spill or spill fed fire, which may cut off routes to safe zones. Consider defensive operations once life hazard is addressed.
- If NO life hazard and more than three tank cars are involved in fire OFPC recommends LETTING THE FIRE BURN unless the foam and water supply required to control is available. Withdraw and protect exposures, including cooling exposed tank cars with unmanned monitors if possible.
- If three tank cars or fewer are involved, do you need to extinguish the fire? (Evaluate hazard to property and environment.)
- If YES, determine whether foam and water resources are available to extinguish the fire.

Fire suppression for Class 3 flammables (including Bakken crude)

New York State Office of Fire Prevention and Control (OFPC)[357] estimates for crude oil rail scenarios are listed below:

[356] See https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/ERG2016.pdf for complete instructions.
[357] New York State Homeland Security & Emergency Services, *Strategic and Tactical Guidance for Rail Incidents Involving Crude Oil,* October 8th, 2014
http://www.dhses.ny.gov/ofpc/alerts-bulletins/information/documents/2014/crude-oil.pdf

(These estimates are based upon applying Class B foam at 3 percent concentration and can be adjusted as needed.)

Polar solvents such as Ethanol may require greater amounts of foam and water and higher application rates (0.2gpm/ft²).

- 1 tank car on fire = 600 gallons of foam concentrate; apply solution at a target rate of 660 gallons per minute (gpm) for 15 minutes; and reapply as necessary to maintain foam blanket;
    - Total water supply required = (+/-) 38,000 gallons for foam and cooling water.
    - NOTE: Stream reach for single 600 gpm foam nozzle = 150 feet max
- 3 tank cars on fire = 1,500 gallons of foam concentrate; apply solution at a target rate of 1,680 gpm for 15 minutes; and reapply as necessary to maintain foam blanket;
    - Total water supply required = (+/-) 80,000 gallons for foam and cooling water.
    - NOTE: Stream reach for single 1,000 gpm foam nozzle= 200 feet max
- Use cooling water on exposed and involved cars; minimum rate = 200 gpm applied to the exterior of the vapor space of each car during extinguishment and maintain for 30 minutes thereafter. Note water application may interfere with the foam blanket. Continue to re-apply foam as needed to maintain post-fire security (vapor suppression).
- ALL RESOURCES MUST BE AVAILABLE PRIOR TO BEGINNING SUPPRESSION (FOAM OPS)
- USE AIR MONITORING. Withdraw at 10 percent LEL (Combustible Gas Indicator).

The following information is provided to assist with determining pump discharge pressures needed to provide required inlet pressure at foam master stream appliances:

- Friction loss for 4” LDH at flows noted above: 7 psi/100’ at 600 gpm; 19.0 psi/100’ at 1,000 gpm.
- Friction loss for 5” LDH at flows noted above: 3 psi/100’ at 600 gpm; 7 psi/100’ at 1,000 gpm.

To determine Foam requirements for a specific crude oil surface spill, use the following formula:

Spill Area (ft²) X Application Rate (0.10 gpm/ft²) = GPM Foam Solution x 15 mins.

NOTE: Large storage tank fires require higher application rates for longer duration. (pp. 2-3)

Air monitoring during a Bakken crude spill[358]

The following air monitoring precautions should be taken during a Bakken crude spill response as stated in the NYS Homeland Security & Emergency Services[359] protocol (New York State Homeland Security & Emergency Services 2015):

- All personnel inside exclusion zone should wear structural Personal Protective Equipment (PPE) and Self-Contained Breathing Apparatus (SCBA);
- Air monitoring should be conducted to protect personnel operating within the exclusion zone and to verify isolation and protective action distances established are effective; and
- Lower Explosive Limit (LEL) at or above 10 percent = WITHDRAW FROM AREA.

For unprotected personnel:

- Photoionization Detector (PID) reading above 10ppm = withdraw or don SCBA and PPE;
- Hydrogen Sulfide (H_2S) reading above 10ppm = withdraw or don SCBA and PPE;
- Oxygen (O_2) reading below 20.8 percent = withdraw or don SCBA and PPE; and
- Colorimetric tube for benzene (if available): any color change = withdraw or don SCBA and PPE.

In addition to the half-mile isolation distance, evacuate the public downwind in areas affected by smoke and particulates. (p. 2)

Findings and recommendations from rail incident reports

Mosier, Oregon Derailment (2016)[360]

A Union Pacific train, with close to 100 tank cars carrying Bakken crude oil, derailed and caught fire in the Columbia River Gorge, evacuating schools in the nearby town of Mosier, Oregon, and closing Interstate 84 between Hood River and The Dalles on 3 June 2016. Sixteen cars in the 96-car unit train derailed, with three of the derailed cars catching fire. The tracks were about 600 feet from the Columbia River. Twenty-eight fire and hazmat departments responded from Oregon and Washington.

[358] Note: These action levels are intended to provide basic, quick reference guidance for the initial phase of emergency operations. As any crude oil release will likely include other hazards, detailed guidance should be obtained and a complete air monitoring plan implemented.
[359] http://www.dhses.ny.gov/ofpc/documents/crude-oil-guidance.pdfhttp://www.dhses.ny.gov/ofpc/documents/crude-oil-guidance.pdf
[360] Oregon Office of Emergency Management, 2016 Mosier Rail Incident State Agency Response After-Action Report, November 10, 2016

The Wasco County Sheriff evacuated about 100 residents within one-quarter mile around the incident. I-84 was closed for 10 hours. Approximately one acre of wildland burned in an adjacent wooded area; wildland fire controlled within 24 hours after derailment.

Recommended areas for improvement for the state of Oregon from the Mosier incident as stated in the *2016 Oregon Office of Emergency Management After Action Report* includes (Oregon OEM 2016):

Communications

- A reliance on social media for the public information communications dissemination resulted in limited pathways for incident notification and announcements.
- Enhanced coordination of situational calls between primary and supporting state agencies, and personnel during the incident, including briefings provided to off-site senior state leadership, would expand and expedite overall coordination.
- The Joint Information System (JIS) was activated but lacked coordination with liaison and enough staff support. Confusion and integration conflicts arose between Unified Command and public information officers at the off-site Joint Information Center issuing incident information releases.

Organization

- State agency executives and senior officials need a practiced process to ensure the timely and accurate flow of information with incident command or state incident liaisons.
- State agencies need a better understanding of how they individually operate within the NWACP. They also need to better understand Geographical Response (GR) Plans, State Emergency Operations Plan (EOP), and Emergency Support Functions (ESF).

Resources

- State agencies needed a better understanding of Oregon Office State Fire Marshal (OSFM) All-Hazard State Incident Management Teams (IMTs) request process, capabilities, and function. Early request for the OSFM IMT could have reduced operational capabilities for the Unified Command organization used.
- Greater coordination required between incident commanders and Oregon Department of Transportation (ODOT) relating to highway closure management.
- Although site safety was established by local first responders for their individual emergency operation needs, state agencies must have a better understanding of roles and responsibilities when establishing site/incident safety.

Agency Policy and Protocol

- It is recommended that each state agency identified involved in the primary response of a rail/hazardous materials incident review operational staffing requirements, both from the perspective of conducting multiple operations as well as in providing field relief. Additional consideration should be given to identifying non-response staff that can be readily placed into positions of logistical support, information management, public information coordination, incident documentation, and leadership oversight within Incident Command.

Incident Management Organization

- Understanding the purpose, function, and structure of the Incident Command System — particularly the establishment of a Unified Command structure during a major incident is essential for effective interagency coordination and operational efficacy. State agencies should partake in periodic supplemental and/or refresher trainings and orientation sessions associated with ICS and the Unified Command structure and process and integrate ICS into drills and exercises. This is especially critical when multiple levels of government and interagency response operations are required. ICS training should extend to agency personnel having a direct incident response or emergency management function.
- Consideration should be given to the development of a state-level complex incident assessment and support structure to ensure appropriate state level resources are made available to assist impacted jurisdictions and to advocate for state interests during such incidents.

Interagency Coordination

- Establish situational triggers that stipulate when senior state leadership should be contacted and briefed. Identify incident parameters that generate action on the part of state agency responders and the Office of Emergency Management to initiate timely notifications and begin the process of scheduled and formatted briefings to senior state management and elected leadership.
- Identify situational conditions that involve such factors as, incident complexity; scope and scale of impact to public health and safety; interruption of critical infrastructure functioning; and the environment; public, political and social sensitivities; expanded media interest; cross boundary collaboration requirements; extended operational containment projections; significant incident complexity; and other parameters that indicate the need for immediate senior leadership notification and information sharing.
- Development of triggers and associated guidance and procedures would require a collaborative effort on the part of primary state response agencies along with coordination and oversight from the Governor’s office.

Operational Communications

- State agencies should evaluate communications needs in support of field response activities, especially in consideration of remote incident operations. When available, state agencies should look for enhancing interoperability, as

well as increasing optional communication capabilities to reduce potential gaps in existing radio, cell phone and satellite systems.
- Moreover, primary state response agencies should consider immediate activation of mutual aid mobile incident communication resources, and to employ field communication coordination capabilities available through the Office of State Fire Marshal Incident Management Teams.

Public Information Communications

- Consideration should be given to strengthening the state's ability to organize staff and operate a Joint Information Center (JIC) in support of response and public safety activities in support of significant interagency response operations involving rail incidents. It is recommended that the coordination of state agency Joint Information System (JIS) activities should be centralized within the state agency having primary lead for Emergency Support Function (ESF)-15 (Public Information) during emergencies.
- Additionally, all primary state response agencies should be trained in Joint Information System (JIS) concepts and JIC operations, with activities unified to avoid duplication, conflicts, communication errors or confusion. The existing Oregon Public Affairs Team (OPAT) would serve as foundational to an expanded Oregon State Public Information Officer (PIO) effort.

Response Plans, Procedures and Resources

- Existing traffic management plans should be evaluated and revised, as needed, to ensure adequacy and scalability for atypical, long-duration, complex incidents. Furthermore, incident managers must remain cognizant of available resources and secondary and tertiary planning and resource needs as an incident becomes more complex. Ensuring appropriate agency perspectives are represented in critical command decisions should be incorporated into ICS training and reinforced during drills and exercises. Establishing policy groups may mitigate or remedy conflicts arising from inadequate integration of stakeholders into critical command decisions.
- Consideration should also be given to the level of resources provided to state agencies with critical emergency or disaster preparedness, response, recovery, and risk reduction roles across all hazards, and those resources should align with expectations to protect life, property, and the environment. (pp. 16-21)

IAFC unit train derailment study

The International Association of Fire Chiefs (IAFC 2015) in association with the Renewable Fuels Association, conducted a March 2015 study, *Unit Train Derailment Site Case Study: Emergency Response Tactics Executive Summary*. This study was conducted in response to increased railroad hazardous materials train derailments resulting in fires and other hazards in Illinois, Iowa, North Dakota, and Virginia. This study states (IAFC 2015):

> These types of incidents have raised concerns from emergency responders and industry. The extreme growth in rail transport of shale crude oil originating from the Bakken region and its associated unconventional hydrocarbon products,

surpassing the high volume of ethanol rail transport, have changed the traditional portfolio of unit train logistics. (p. 3)

To assess the level of awareness and preparedness of the emergency response community to train derailments of hazardous materials, International Association of Fire Chiefs (IAFC) conducted an analysis into past incidents for the Renewable Fuels Association (RFA). This case study format was used to gather multiple perspectives of the emergency response actions taken when these incidents occurred, attempted to capture effective risk reduction techniques and any necessary response equipment as well as identify best practices or gaps/impediments to an effective response to the incident. The project team identified five unit train derailment incidents as the focus of the case study:

- Crude oil spill in Lynchburg, Virginia, on April 30, 2014 (Metropolitan area);
- Crude oil spill in Casselton, North Dakota, on December 30, 2013 (Rural area);
- Ethanol spill in Tiskilwa, Illinois, on October 7, 2011 (Rural area);
- Ethanol spill in Cherry Valley, Illinois, on June 19, 2009 (Metropolitan area); and
- Liquid petroleum gas (LPG) spill in Lester, Iowa, on November 4, 2012 (Pressurized commodity).

The lessons learned from this case study can be broken down into three main categories (IAFC 2015):

Preplanning

- Even though there was an overall awareness of the railroad activity in each of these incident areas, none of the fire departments had an emergency pre-plan dedicated to railway related incidents.
- In the Lynchburg case, a county wide / broad Emergency Operations Plan (EOP) was available to emergency management systems and the railroad hazardous materials teams were identified in the plan. However, there was no official role or required actions of the rail personnel in the event of an incident.
- In the Lester case, emergency response personnel were generally unaware of the types of hazards being transported by rail.
- Varying types of incident command training are used. Training varies between Incident Command System (ICS) or National Incident Management Systems (NIMS). Future training should include Incident Command.

Resources

- In the Cherry Valley, and Tiskilwa cases, mutual aid systems, when available, provided timely and much needed resources.
- The Casselton, Lester, and Tiskilwa cases showed that a general lack of training on tank car emergency response was common to each of the municipalities called to respond.
- In the Casselton case, railroad emergency response resources were extensive, but the local fire department emergency response teams were unaware of these resources and their availability.
- None of the fire departments, whether career, combination, or volunteer, had enough alcohol-resistant aqueous film-forming foam (AR-AFFF) to respond

effectively to the ethanol incidents. The Casselton volunteer fire department had enough aqueous film-forming foam (AFFF) to respond effectively to the crude oil incidents. In Casselton, Tiskilwa, and Lester, water was a needed commodity.

Communication

- In Cherry Valley, Lynchburg, and Tiskilwa, personnel were generally aware of the National Incident Management System (NIMS), but the lack of preexisting relationships between local emergency medical services (EMS), railroad personnel, and federal investigators complicated the communication / line of command during an incident. This awareness extended both ways: first responder to rail personnel, and rail personnel to first responder.
- Including rail personnel in the incident command structure was often delayed or nonexistent in Lynchburg and Tiskilwa. In Casselton and Lester, when rail personnel were involved in the incident command, improved communications and resources were identified, which effectively assisted in controlling the incident.
- In Cherry Valley, Lynchburg, and Tiskilwa, information on the hazardous materials being transported were was not immediately available to the local emergency response command; many times, the train consist had to be tracked down and not available until many hours into the incident.

General Lessons Learned

- An important gap identified during the review of the incidents was the general lack of a comprehensive Railway Emergency Response Operations Plan. A Railway Emergency Response Operations Plan can be developed for each community, municipality, county, and/or state that identifies key emergency response personnel, resources available, environmental considerations and other pertinent details that support an effective emergency response.
- The above plan should identify emergency response leadership, their roles during an incident, environmentally sensitive areas such as drinking water intakes, protected wetlands, etc., and available emergency response resources.
- Training personnel expected to respond to a railway emergency on key elements and actions that will be needed in the event of an emergency must be completed on some determined frequency.
- All the derailments surveyed seem to be caused by a fault in the rail infrastructure, either from use (equipment failure) or weather (wash-out). None of the selected incidents were caused by any rail car issues (wheel failure, mechanical failure of a car component, coupling failure, brake failure, etc.).
- In the selected incidents, there was adequate response from the railroad, but there may have been opportunities for improved communications. One example identified was splitting rail crews after a derailment, one to walk back and apply brakes and the other to get back to the scene with the train cars. When a train crew notified a dispatcher of the derailment, there was a lag time before the railway dispatcher shared an electronic copy of the train's consist (the contents of the various cars on the train) with the local authorities.

- The incidents surveyed all had a direct correlation to the number and severity of derailed rail cars and speed. Certainly, key and unit ethanol and crude oil trains are concerning, but trains carrying tank cars of other hazards classes such as: toxic inhalation hazard (TIH), (e.g., anhydrous ammonia, and chlorine) and flammable gases (LPG) also need to be considered.
- None of the fire departments surveyed had a pre-plan for railway emergencies, even though some served communities that had tracks that split their municipality into two sections. Such a split could cause situations like long unit trains blocking every railway crossing or tracks blocking access to water.
- No fire department surveyed, whether career, combination or volunteer, had enough ARAFFF foam for the ethanol incidents; same applies to AFFF foam for the crude oil incidents. Many departments cannot afford the cache needed. This includes overhaul and recovery operations of the damaged tank cars. Further, if municipalities cannot afford to stock the necessary quantity of foam and application equipment, they also cannot conduct training using the resource.
- Some local fire departments had negative experiences with outside agencies that were performing duties within Incident Command. Bringing a more cooperative approach to an incident would be very helpful to the Incident Commander. Basic NIMS and ICS training is needed for these support personnel so that they realize the important function they play in an incident.
- Many of the municipalities surveyed did not have an active or strong Local Emergency Planning Committee (LEPC).
- At incidents such as a derailment, the ICS form must be completed to maximize the available resources, especially planning, logistics and finance. An Incident Action Plan (IAP) must be written, planning for the next operational periods must be accomplished, resources such as food and porta potties must be brought in, and costs for expenses must be captured for cost recovery purposes.
- The responders should bring in experienced dispatchers to handle the multiple radio communications and scribes to capture orders, communications, benchmarks, and establish timelines.
- Like most incidents, a train derailment with hazardous materials involved is multi-dimensional involving firefighting and hazardous material response. Firefighters should be trained to, at least, the Firefighter II/Hazardous Materials Operations Level. Officers must be at the Incident Commander Level.
- Non-intervention, which is a defensive/offensive decision to let the fire burn, allows the resources on hand to focus on establishing a perimeter, protecting exposures, evacuating the public, and mustering the needed resources via mutual aid.
- Railroads, through TRANSCAER and the Association of American Railroads (AAR), have been offering additional training to departments having derailments. More municipalities need to try to take advantage of this offer.

- Four of the five surveyed departments utilized the U.S. Department of Transportation (USDOT) Emergency Response Guidebook (ERG) at some point in their incidents. The evacuation section proved to be especially helpful.
- Bringing in extra alarms early for civilian evacuation would enhance safety. This is normally a police function, but many times they cannot muster up enough of their own mutual aid to accomplish the task and command must augment them with firefighters. Bringing in extra EMS units to assist with evacuation in anticipation of the number of limitations who could not self-evacuate would be beneficial.
- Assigning a timekeeper to advise Incident Command every hour how long the operations have continued is important. After 5-6 hours, it is easy to lose track of time, which may cause exhaustion and other health and safety impacts to responders.
- Do not take unnecessary risks for ethanol, crude oil, or any other hazardous product salvage in the event of incident. (pp. 6-9).

Lynchburg, Virginia Derailment 2014[361]

After the April 30, 2014, derailment and fire in downtown Lynchburg of a 105-car CSX unit train hauling crude oil from the Bakken shale formation to a terminal in York County, Governor Terry McAuliffe established the Virginia Railroad Safety and Security Task Force (Commonwealth of Virginia 2015). The Task Force was comprised of state officials from agencies with various responsibilities for rail safety and security, the Task Force conducted four public meetings with participation from local, state, and federal agencies, environmental groups, railroads, industry experts, news media, and other stakeholders. The focus of the initial report was on rail transportation of flammable liquids, particularly crude oil and ethanol. However, most of the Task Force's recommendations were broadly applicable to overall railroad safety and security in Virginia.

The Task Force's recommendations as stated in the Railroad Safety and Security Task Force Initial Report and Recommendations, May 1, 2015, focused on nine sections shown as follows: (Commonwealth of Virginia 2015):

Prevention

1. Increase risk-based rail safety inspections. Under authorities delegated by the FRA, the Virginia State Corporation Commission (SCC) is expanding its existing rail safety inspection program to address the challenges posed by high-hazard flammable trains. Based on several factors continuously reviewed by the Commission's Division of Utility and Railroad Safety, the State Corporation Commission (SCC) intends to add additional inspectors. This will continue an effective rail safety inspection program and better supplement FRA's inspection activities in Virginia.
2. Allow states to access FRA's enforcement process. Advocate for revisions to the FRA's enforcement process to provide Virginia and other states with

[361] Virginia Railroad Safety and Security Task Force Initial Report and Recommendations, May 1, 2015.

access to the disposition of all violations cited in their respective states and consider states' input in the enforcement process.

3. Include inspection data from states in the FRA's plans and processes. State inspection data should be included in FRA's National and Regional Inspection Plan development and risk modeling activities. The inspection data should also capture the exact location of defects to allow mapping in a Geographic Information System (GIS) database to better identify areas with repeated safety issues.
4. Require more frequent ultrasound examination of rail (Sperry Car) on tracks carrying passengers, crude oil, or bulk hazardous materials. Currently, 49 CFR Part 213.237 Inspection of Rail, requires an internal rail inspection on Class 4 and 5 track, or Class 3 track with regularly-scheduled passenger trains or on a hazardous materials route, at intervals not exceeding 370 days. The frequency of these examinations should be increased within the Commonwealth.
5. Require automated track inspection car (Geometry Car) inspections on tracks carrying passengers, crude oil, or bulk hazardous materials. Currently, the only requirement for the use by a Geometry Car is found in 49 CFR Part 213.234, Automated Inspection of Track Constructed with Concrete Crossties. This regulation only speaks to Class 3, 4, and 5 tracks used for passenger service, not crude oil or other bulk hazardous materials. In addition, there is no requirement for the use of a Geometry Car on rail with wooden crossties, or on slower speed Class 1 and 2 tracks.
6. Increase sight distance visibility at railroad crossings. Recognizing that some railroads have voluntarily done so, consider amending Part 56411 of the Code of Virginia to increase sight distance visibility at crossings; the current requirement is only 100 feet on both sides of the crossing regardless of train speed. Further, there is no requirement that the railroad keep structures such as signal control buildings out of the sight plane. Most rail-related injuries and fatalities occur at grade crossings.
7. Require railroads to share all safety-related records. The Task Force recommends that railroads should be required to share all safety related records and data with the SCC upon request; including, but not limited to:
    - Geometry and Sperry car data
    - Accident information
    - Downloads from locomotive event recorders and braking logs
    - Crew schedules and timesheets
    - Freight manifests
    - Other railroad operational data
8. The Task Force recommends that FRA require the development of rail Safety Management Systems (SMS) by the railroad industry. Studies have demonstrated the effectiveness of SMS on the safety of rail operations in Canada, and several other industries such as the airline, nuclear and chemical industries here in the United States.
9. Expand public education to reduce trespassing on railroad rights-of-way. Identify options for a statewide outreach campaign to help educate citizens

about the individual perils, and potential community consequences, of trespassing on railroad property.

10. Increased state and local enforcement of existing state trespassing laws. The opportunity for increased, targeted enforcement of existing trespassing laws holds promise for preventing accidents along rail lines in Virginia. Expanded enforcement, coupled with public education, can reasonably be expected to provide some level of deterrence against trespassing. Analyzing enforcement trends may also identify specific locations where railroads could make capital improvements to facilitate safe and lawful access across their rights-of-way.

Planning

11. Develop comprehensive railroad response plans. Each local government and state agency with railroad exposure should develop a rail safety and security response plan as part of its all-hazards emergency operations plan (EOP). These hazard-specific plans/annexes should identify the threats, vulnerabilities, and potential consequences of a spill, release, or fire associated with a derailment or other incident.
12. Review, evaluate, and suggest improvements to Local Emergency Planning Committees' (LEPCs) community hazardous materials response plans for bulk transport of flammable liquids. All Virginia localities are responsible, through their LEPCs, to develop community hazardous materials response plans. The Task Force recommends that all communities along routes that routinely transport bulk flammable liquid shipments ensure that their response plans adequately address this hazard. The Task Force recommends that localities submit their plans to VDEM for review, evaluation, and suggested improvements.
13. Conduct various threat assessments for HAZMAT transportation, to include cyber impacts. As part of the overall Commonwealth Threat and Hazard Identification and Risk Assessment (C-THIRA) process, address the transportation of bulk flammable liquids by rail and other transportation modes. This assessment should incorporate all natural and human-caused threats to public safety that may result from a spill or release due to a derailment or other intentional or accidental situation.
14. Complete targeted physical security assessments for railroad and adjacent critical infrastructure along rail lines. The Commonwealth, U.S. Department of Homeland Security (DHS), and the railroads should ensure all appropriate physical security assessments are complete/updated, with the resulting information made available to state agencies and local governments with the appropriate safeguards for Protected Critical Infrastructure Information (PCII).
15. Develop an inventory of high-priority corridors and potential improvements. Based on the assessments described above, the Task Force recommends that Department of Rail and Public Transportation (DRPT) identify those track segments that could be improved through reasonable infrastructure enhancements.

16. Continue monitoring intelligence and analyzing threats or suspicious activities involving railroad infrastructure or assets. Continued threat monitoring is a vital action for the Commonwealth. Through this monitoring, state and local law enforcement, in conjunction with the railroads, may provide early warning of any criminal activity and other threats to railroad infrastructure or trains.
17. Consider railroad safety and security in the overall Port of Virginia risk assessment. The Hampton Roads Area Maritime Security Executive Committee (AMSEC), co-chaired by the USCG and Federal Bureau of Investigation (FBI), is currently working on a comprehensive revision to the overall risk assessment for the entire Port of Virginia, including the Yorktown terminal facility that receives crude oil for transfer to barges and further maritime transport to refineries along the East Coast. Multiple local, state, and federal agencies, including the Office of the Secretary of Public Safety and Homeland Security, are represented on the AMSEC and its risk assessment working group.
18. Continue existing regional/collaborative planning efforts. The Federal Clean Water Act, and subsequent Oil Pollution Act of 1990, established a requirement for the existence of regional response teams and, at the local level, inland and coastal area committees. These organizations serve as preparedness and response planning bodies whose membership is made up of federal, state, local, and Non-Governmental Organizations (NGOs) entities that have roles in all-hazards response planning. Virginia Department of Environmental Quality (VDEQ), Virginia Department of Emergency Management (VDEM), and other state agencies will continue working with planning partners in the framework of these existing contingency planning entities (EPA Regional Response Team III, the Coastal Virginia Area Committee, and the Upper Chesapeake Estuary Committee) to evaluate gaps associated with threats posed by shipments of bulk flammable liquids.
19. Develop a Geographic Response Plan (GRP) for above the tidal James (i.e., up the James River from the fall line in Richmond). GRPs provide responders with tactical guidance including maps, descriptions of at-risk sensitive areas, key resources, booming and equipment deployment strategies to protect those areas/resources, and environmental protection priorities for various spill scenarios. Virginia's Coastal Area Contingency Plan contains GRPs for Virginia's tidal waters including the James River up to Richmond; however, no formal GRPs exist above the tidal James except as issues are addressed through local emergency operations plans (EOPs). The Task Force proposes a collaborative local, state, federal, and NGO effort to identify at-risk sensitive areas and key resources for the current CBR route; and to develop integrated GRPs/EOPs for this corridor.

Response

20. Develop/improve air and water plume modeling capabilities for response/recovery activities. Plume models are an important tool for predicting the fate and transport of airborne vapors and combustion products, and waterborne transport of materials following a spill or release of

flammable liquids. While some modeling capability does exist within the Commonwealth, the predictive quality and efficacy of such models should be evaluated by the relevant Task Force agencies and improvements made as needed.

21. Maintain capability to assess impacts on public health and drinking water systems. Virginia Department of Health (VDH), with support from its federal partners and their deployable experts, has the capacity to determine the potential health impacts of hazardous materials spills on the public at-large, and on drinking water systems. The Task Force recommends that VDH maintain these capabilities at the highest level.
22. Provide improvements/upgrades to regional HAZMAT Teams. The Task Force recommends that VDEM continue supporting the regional contract HAZMAT response teams, identify a mechanism to increase funding to the localities providing staff for these teams, and increase the number of VDEM regional hazardous materials officers in areas with substantial volumes of bulk flammable liquids and other hazardous materials.
23. Coordinate behavioral health response. VDH has legal authority over behavioral health response at the state level. The Task Force recommends that VDH ensure that incidents arising from the bulk transport of flammable liquid by rail are included in their behavioral health response plans.

Information Sharing

24. Information sharing regarding transport and derailment. The Task Force believes the bulk transport of flammable liquids by rail deserves greater transparency and communication. The Task Force recommends that stakeholders explore better mechanisms to share information, while still honoring the legitimate security and competitive advantage concerns associated with rail transport. Similarly, there is a need to pass information regarding derailments of all types in a more timely and accurate manner.
25. Develop a standard reporting template. The USDOT Emergency Order of May 7, 2014, does not specify a reporting template for CBR shipments or derailments. The Task Force supports the development of a standardized reporting template for use nationwide.
26. Develop a national comment forum. The Task Force notes that there is no current vehicle for the easy exchange of information on bulk transport of flammable liquids by rail between states. The Task Force supports the development of such a vehicle at the federal level.
27. Notify stakeholders of all updates and safety issues received. The operational environment around the bulk transport of flammable liquids by rail is dynamic and involves many groups and areas of concern. The Task Force recommends that a process be established where relevant technical, safety, and incident information updates can be distributed to all affected parties, with the appropriate safeguards against unauthorized use.
28. Formalize and strengthen information sharing agreements at all levels of government and with the private sector. The issue of rail safety and security cuts across all levels of government, the private sector, and the citizenry at

large. The Task Force recommends that all groups review their formalized agreements, where they exist, and ensure that they address rail safety and security issues. Where they do not already exist, it is recommended that formal agreements be established in accordance with applicable regulations.

29. Improve availability of federal subject matter experts. Much subject matter expertise relevant to the bulk transport of flammable liquids by rail resides within the federal government. The Task Force recommends that all state agencies leverage this federal expertise where available, especially during an event. Agencies are encouraged to strengthen existing coordination with federal counterparts and ensure clear information exchange is expected during incidents.
30. Improve situational awareness. There is a need to improve situational awareness, and information flow in general, surrounding the bulk transport of flammable liquids by rail. The Task Force recommends an aggressive study of how best to ensure timely and accurate information sharing and situational awareness regarding an incident involving hazardous materials.

Training

31. Schedule and regularly conduct railroad safety training in order to maintain proficiencies in the latest hazard-specific safety issues. VDEM, in coordination with other state agencies and first responder stakeholder groups, should develop and maintain training programs for first responders at the local and state level to address rail-related safety issues. In developing these programs, VDEM should work with industry partners (e.g., CSX, NS, Plains, etc.) to ensure the most accurate and recent information is used. Similarly, technical expertise from DRPT, VDH, and VDFP should be leveraged for best practices surrounding HAZMAT incident response and recovery. A partnership with Virginia Department of Fire Programs (VDFP) is also recommended to determine whether railroad safety and response workshops could be included in VDFP's regional schools.
32. Encourage the use of existing online training platforms by first responders. Existing online training programs provided by industry, NGOs, and government agencies should be identified and utilized by first responders at the state and local level.
33. Provide information and training for suspicious activity reports. Suspicious activity reports (SARs) are the primary vehicle for tracking suspicious activities involving critical infrastructure within the Commonwealth. The Task Force supports additional training on SARs for appropriate state and local agency officials.
34. Develop a bulk liquids spill course for HAZMAT operations, technician, and specialist level responders. The Task Force believes that enhanced, hazard-specific training for bulk transport of flammable liquids may be appropriate. The training should be presented at two levels: the operations level for first responders, and the technician/specialist level for members of HAZMAT response teams. Agencies should determine whether off-the-shelf training is

adequate, or if Virginia should develop new training curricula that addresses the Commonwealth's specific needs.

35. Create a rail specialist qualification program for certified HAZMAT specialists. Other states have created a Rail Hazardous Materials Specialist designation for hazardous materials response specialists. The Task Force recommends that VDEM investigate these programs and adopt or develop such a certification for Virginia.
36. Improve access to specialized training at the Security and Emergency Response Training Center (SERTC) and Texas A&M Engineering Extension Service (TEEX), to include leveraging railroad scholarships and a mechanism to provide backfill costs. SERTC and TEEX provide specialty training at reasonable or no cost. Full-scale railroad hazardous materials emergency training is available through the American Association of Railroads (AAR) SERTC facility in Pueblo, CO, while TEEX is a global leader in foam firefighting training. The Task Force recommends that VDEM and VDFP, in coordination with other state agencies, explore and develop a strategy to allow a greater number of Virginia responders to attend training opportunities at these facilities. This strategy should leverage existing scholarships provided by Virginia's railroads, and address the costs to backfill front-line positions while students are attending this training.
37. Purchase additional training props and simulators, and other equipment specific to bulk flammable liquid response, for Virginia's Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) Response Training Center in Yorktown. The CBRNE Training Center in Yorktown provides classroom and hands-on training for hazardous materials and CBRNE response activities. Funding for additional props and simulators to support training for bulk flammable liquids in rail transportation will improve Virginia's overall response posture. The Task Force also recommends that agencies identify other appropriate training aids to enhance current fire and hazardous materials training across the Commonwealth.
38. Provide additional incident command training. Given the multi-jurisdictional and collaborative nature of any successful response to a railroad emergency, the Task Force recommends additional incident command system training across the Commonwealth—with scenarios related to HHFT incidents—be delivered to local, state, federal, and industry partners.

Exercises

39. Conduct tabletop exercises with key agencies and officials. Exercises occur along a spectrum from tabletop discussions to field-based activities. The Task Force encourages exercises involving scenarios including the bulk transport of flammable liquids by rail. The Homeland Security Exercise and Evaluation Program (HSEEP), administered by VDEM, provides a vehicle for conducting such exercises. All agencies and localities are encouraged to participate in the HSEEP and, where relevant, to include rail scenarios in their exercise programs.

40. Evaluate the utility of an exercise-in-a-box program for railroad emergencies. VDEM should explore the feasibility and utility of a simple and efficient "exercise-in-a-box" for rail incidents that could be easily implemented at the local level with minimal support.
41. Fund regional and interagency drills. The Task Force supports the provision of additional exercises and drills, in localities across the Commonwealth, which address the bulk transport of flammable liquids by rail, road, and maritime conveyance.

Equipment

42. Purchase and stockpile additional containment booms to address waterway spills. Containment booms can be an effective waterborne spill countermeasure under some circumstances. The Task Force recognizes a need for additional booming equipment strategically placed throughout the Commonwealth. This recommendation includes: a review of existing boom capabilities; identifying appropriate additions and upgrades; and choosing appropriate locations for the cached booms.
43. Maintain and expand foam firefighting capability. Beyond the need for specialized training described previously, the Task Force recommends continued investment in, and synchronization of, foam firefighting capabilities deployed by state and local response agencies across Virginia. The Commonwealth might also consider alternative methods for ensuring the availability of the specialized expertise, equipment, and supplies that would be required for a major spill/fire incident involving shale crude oil or ethanol.

Funding

44. Create a sustainable state-level funding source. The Task Force recommends that Virginia consider creating a sustainable funding source that could be used to support the activities recommended in this report for state and local agencies/organizations. This recommendation may require legislative or regulatory action.
45. Leverage existing federal homeland security grant funding sources. State agencies and localities are encouraged to propose eligible projects to the DHS funded State Homeland Security Grant Program (SHSGP) and Urban Areas Security Initiative (in eligible geographic areas) to implement recommendations contained in this report.
46. Encourage development of new and expanded federal grant programs specific to preparing for high-hazard flammable trains. Given that rail safety regulation is predominately addressed at the federal level, the Task Force believes that existing federal grant programs should be enhanced, and new ones created, to address the hazards posed by HHFTs in states where they travel.
47. Encourage railroads operating in Virginia to enhance their existing grant programs. The Task Force acknowledges the voluntary financial support of Virginia's railroads and, given the expanding nature of the threats posed by

HHFTs, hopes that an enhanced level of funding will be considered to help support local government and NGO preparedness activities.

48. Encourage railroads to make targeted infrastructure improvements. Recognizing that providing state funds to private corporations for infrastructure improvements may be difficult, the Task Force recommends that Virginia explore other mechanisms to encourage safety and security-related infrastructure improvements within the rail sector.

Regulatory and Legislative

49. Provide comments on federal rulemaking activities. The Task Force recommends that all state agencies and localities take the opportunity to comment on any proposed rulemaking by USDOT or other federal agencies involving the bulk transport of flammable liquids by rail.
50. Federal legislation regarding DOT 111 tank cars. The Task Force recommends that all affected stakeholders take the opportunity to comment and provide testimony on any rulemaking action involving the design, construction, and operation of DOT 111 and similar railcars.
51. Affixing additional placards. The Task Force encourages USDOT to consider requiring the placement of additional HAZMAT identification placards on railcars transporting bulk flammable liquids.
52. Improve the characterization and classification of shale crude oil. The Task Force encourages USDOT to continue its efforts to promote rigorous testing and characterization/classification of shale crude oil through PHMSA's Operation Safe Delivery program.
53. Restrict rail speeds based upon the commodity being transported. The Task Force recognizes that FRA has imposed speed restrictions on crude oil trains and recommends consideration of additional restrictions that may be appropriate in densely populated or environmentally sensitive areas.
54. Develop a compliance monitoring program and increase fines for deficiencies. The Task Force recommends that DRPT explore the possibility of monitoring railroad safety and security compliance and consider increasing fines for deficiencies or recurring issues that may be found.
55. Explore modifications for DRPT funding programs available to railroads operating in Virginia. Allow railroads to utilize FRA fines as a local match, allow safety-related capital improvements to be an eligible use of program funds, and allow use of some safety enhancement funds as a match. The Task Force believes this is a reasonable use of such fines and encourages legislative or regulatory action to allow it (pp. 25-36).

Emergency response for other hazardous materials

Pipeline and Hazardous Materials Safety Administration, Hazardous Materials: Revisions of the Emergency Response Guidebook, Notice No.2018–10, for request of input for the 2020 Emergency Response Guide update,[362] states that (PHMSA 2017):

> The Federal hazardous materials transportation law, 49 USC 5101 et seq., authorizes the Secretary of Transportation to issue and enforce regulations deemed necessary to ensure the safe transportation of hazardous materials in commerce. In addition, the law directs the Secretary to provide law enforcement and firefighting personnel with technical information and advice for responding to emergencies involving the transportation of hazardous materials. The Pipeline and Hazardous Materials Safety Administration (PHMSA) developed the United States version of the Emergency Response Guidebook (ERG) for use by emergency services personnel to provide guidance for initial response to hazardous materials transportation incidents. Since 1980, it has been PHMSA's goal that all public emergency response personnel (e.g., fire-fighting, police, and rescue squads) have immediate access to the ERG. (p. 2)

The U.S. Department of Transportation, 49 CFR Sub Title B, Section 172.604 Emergency Response Telephone Number, requires all shippers of hazardous materials to include a 24-hour emergency phone number on all hazardous material shipping papers (49 CFR Part 172.604). Most shippers register with CHEMTREC to meet this requirement. The shipper is responsible for determining which products being shipped are subject to U.S. Hazardous Materials Regulations (HMR) 49 CFR Part 172.101.

The American Chemistry Council website[363] states,

> Established in 1971 as a public service of the American Chemistry Council (ACC), CHEMTREC is an around-the-clock service available to fire fighters, law enforcement officials and other emergency responders who need immediate critical response information for emergency incidents involving chemicals, hazardous materials and dangerous goods. CHEMTREC's highly trained personnel receive hundreds of calls every day and provide assistance during incidents that range from minor to critical. CHEMTREC provides services that allow shippers of hazardous materials to comply with government hazardous materials regulations.

Initial isolation and protective action distances for hazmats

In the event of a rail accident that results in the release (or potential release) of one or more hazardous materials, emergency responders need to take steps to protect human health and safety. This generally involves isolation of the accident area followed by protection of people in the general vicinity of the spill depending on the toxicity of the substance, its likelihood to disperse into the air, and environmental conditions, particularly wind speed and direction.

[362] https://www.reginfo.gov/public/do/DownloadDocument/objectID=79094701
[363] American Chemistry Council website. https://www.americanchemistry.com/CHEMTREC/.

Precautionary isolation and protective distances downwind from the spill site for various hazardous materials are shown in Table 120. The 2016 ERG goes on (PHMSA 2016):

> If the dangerous goods vapor plume is channeled in a valley or between many tall buildings, distances may be larger than shown in (Table 120) due to less mixing of the plume with the atmosphere. Daytime spills in regions with known strong inversions or snow cover, or occurring near sunset, may require an increase of the protective action distance because airborne contaminants mix and disperse more slowly and may travel much farther downwind. In such cases, the nighttime protective action distance may be more appropriate. In addition, protective action distances may be larger for liquid spills when either the material or outdoor temperature exceeds 30°C (86°F). (p. 289)

Table 120: Initial Isolation and Protective Action Distances for Hazardous Material Spills[364]

UN No.	Substance	Small Spill Isolation Distance[365]	Small Spill Protection Downwind Day	Small Spill Protection Downwind Night	Large Spill Isolation Distance	Large Spill Downwind Protection Distance Day Low Wind[366]	Large Spill Downwind Protection Distance Day Moderate Wind[367]	Large Spill Downwind Protection Distance Day High Wind[368]	Large Spill Downwind Protection Distance Night Low Wind	Large Spill Downwind Protection Distance Night Moderate Wind	Large Spill Downwind Protection Distance Night High Wind
1005	**Anhydrous Ammonia**	100 ft	0.1 mi	0.1 mi	1,000 ft	1.1 mi	0.8 mi	0.6 mi	2.7 mi	1.4 mi	0.8 mi
1008	**Boron Trifluoride**	100 ft	0.1 mi	0.1 mi	1,250 ft	1.4 mi	1.4 mi	1.4 mi	3.0 mi	3.0 mi	3.0 mi
1017	**Chlorine**	200 ft	0.2 mi	0.7 mi	3,000 ft	6.2 mi	4.0 mi	3.2 mi	7.0+ mi	5.6 mi	4.2 mi
1026	**Cyanogen**	100 ft	0.1 mi	0.3 mi	200 ft	0.2 mi	0.2 mi	0.2 mi	0.7 mi	0.7 mi	0.7 mi
1040	**Ethylene Oxide**	100 ft	0.1 mi	0.1 mi	600 ft	1.0 mi	0.5 mi	0.5 mi	2.1 mi	0.9 mi	0.5 mi
1045	**Fluorine**	100 ft	0.1 mi	0.1 mi	300 ft	0.3 mi	0.3 mi	0.3 mi	1.4 mi	1.4 mi	1.4 mi
1048	**Hydrogen Bromide**	100 ft	0.1 mi	0.2 mi	500 ft	0.6 mi	0.6 mi	0.6 mi	1.6 mi	1.6 mi	1.6 mi
1050	**Hydrogen Chloride**	100 ft	0.1 mi	0.2 mi	1,500 ft	2.3 mi	1.2 mi	1.1 mi	6.2 mi	2.1 mi	1.5 mi
1051	**Hydrogen Cyanide**	200 ft	0.2 mi	0.6 mi	1,000 ft	0.7 mi	0.7 mi	0.7 mi	1.5 mi	1.5 mi	1.5 mi
1052	**Hydrogen Fluoride**	100 ft	0.1 mi	0.3 mi	1,250 ft	1.9 mi	1.2 mi	1.0 mi	3.8 mi	1.8 mi	1.2 mi
1053	**Hydrogen Sulfide**	100 ft	0.1 mi	0.3 mi	1,250 ft	1.3 mi	1.3 mi	1.3 mi	3.4 mi	3.4 mi	3.4 mi
1061	**Methylamine**	100 ft	0.1 mi	0.1 mi	600 ft	0.4 mi	0.4 mi	0.4 mi	1.2 mi	1.2 mi	1.2 mi

[364] Based on PHMSA 2016. A small spill is defined as one that involves less than 208 liters (55 US gallons–or roughly 1 bbl or less) for liquids, and less than 300 kilograms (660 lbs) for solids. A large spill is a spill that is larger than this. Note that a release involving a single tank car on a train would always be considered a large spill even if it does not involve the release of all of the contents.
[365] Isolation in all directions. The distance shown is the radius of the circle.
[366] Low wind = less than 6 mph.
[367] Moderate wind = 6–12 mph.
[368] High wind = more than 12 mph.

UN No.	Substance	Small Spill Isolation Distance [365]	Small Spill Protection Downwind Day	Small Spill Protection Downwind Night	Large Spill Isolation Distance	Large Spill Downwind Protection Distance Day Low Wind [366]	Large Spill Downwind Protection Distance Day Moderate Wind [367]	Large Spill Downwind Protection Distance Day High Wind [368]	Large Spill Downwind Protection Distance Night Low Wind	Large Spill Downwind Protection Distance Night Moderate Wind	Large Spill Downwind Protection Distance Night High Wind
1062	**Methyl Bromide**	100 ft	0.1 mi	0.1 mi	500 ft	0.2 mi	0.2 mi	0.2 mi	0.4 mi	0.4 mi	0.4 mi
1064	**Methyl Mercaptan**	100 ft	0.1 mi	0.2 mi	600 ft	0.7 mi	0.7 mi	0.7 mi	1.9 mi	1.9 mi	1.9 mi
1067	**Nitrogen Dioxide**	100 ft	0.1 mi	0.3 mi	1,250 ft	0.8 mi	0.8 mi	0.8 mi	1.9 mi	1.9 mi	1.9 mi
1069	**Nitrosyl Chloride**	100 ft	0.2 mi	0.6 mi	1,500 ft	2.1 mi	2.1 mi	2.1 mi	5.2 mi	5.2 mi	5.2 mi
1076	**Phosgene**	300 ft	0.4 mi	1.5 mi	1,500 ft	1.9 mi	1.9 mi	1.9 mi	5.6 mi	5.6 mi	5.6 mi
1079	**Sulfur Dioxide**	300 ft	0.4 mi	1.4 mi	3,000 ft	7.0+ mi	7.0+ mi	4.4 mi	7.0+ mi	7.0+ mi	6.1 mi
1082	**Refrigerant Gas R-1113**	100 ft	0.1 mi	0.1 mi	200 ft	0.2 mi	0.2 mi	0.2 mi	0.5 mi	0.5 mi	0.5 mi
1581	**Methyl Bromide/ Chloropicrin**	100 ft	0.1 mi	0.4 mi	1,000 ft	1.3 mi	1.3 mi	1.3 mi	3.7 mi	3.7 mi	3.7 mi
1582	**Methyl Chloride/ Chloropicrin**	100 ft	0.1 mi	0.3 mi	200 ft	0.2 mi	0.2 mi	0.2 mi	1.1 mi	1.1 mi	1.1 mi
1589	**Cyanogen Chloride**	1,000 ft	1.1 mi	3.9 mi	1,000 ft	5.8 mi	5.8 mi	5.8 mi	7.0+ mi	7.0+ mi	7.0+ mi
1605	**Ethylene Dibromide**	100 ft	0.1 mi	0.1 mi	100 ft	0.1 mi	0.1 mi	0.1 mi	0.1 mi	0.1 mi	0.1 mi
1612	**Hexaethyl Tetraphosphat e**	300 ft	0.5 mi	1.7 mi	1,250 ft	2.2 mi	2.2 mi	2.2 mi	5.1 mi	5.1 mi	5.1 mi
1613	**Hydrocyanic Acid**	100 ft	0.1 mi	0.1 mi	300 ft	0.3 mi	0.3 mi	0.3 mi	0.7 mi	0.7 mi	0.7 mi
1647	**Ethylene Dibromide/ Methyl Dibromide**	100 ft	0.1 mi	0.1 mi	500 ft	0.2 mi	0.2 mi	0.2 mi	0.4 mi	0.4 mi	0.4 mi
1660	**Nitric Oxide**	100 ft	0.1 mi	0.4 mi	300 ft	0.4 mi	0.4 mi	0.4 mi	1.4 mi	1.4 mi	1.4 mi

UN No.	Substance	Small Spill Isolation Distance [365]	Small Spill Protection Downwind Day	Small Spill Protection Downwind Night	Large Spill Isolation Distance	Large Spill Downwind Protection Distance Day Low Wind [366]	Large Spill Downwind Protection Distance Day Moderate Wind [367]	Large Spill Downwind Protection Distance Day High Wind [368]	Large Spill Downwind Protection Distance Night Low Wind	Large Spill Downwind Protection Distance Night Moderate Wind	Large Spill Downwind Protection Distance Night High Wind
1741	**Boron Trichloride**	100 ft	0.1 mi	0.2 mi	300 ft	0.4 mi	0.4 mi	0.4 mi	0.8 mi	0.8 mi	0.8 mi
1744	**Bromine**	200 ft	0.5 mi	1.5 mi	1,000 ft	2.3 mi	2.3 mi	2.3 mi	4.7 mi	4.7 mi	4.7 mi
1829	**Sulfur Trioxide**	200 ft	0.2 mi	0.6 mi	1,000 ft	1.8 mi	1.8 mi	1.8 mi	3.6 mi	3.6 mi	3.6 mi
1859	**Silicon Tetrafluoride**	100 ft	0.1 mi	0.5 mi	300 ft	0.3 mi	0.3 mi	0.3 mi	1.1 mi	1.1 mi	1.1 mi
1911	**Diborane**	200 ft	0.2 mi	0.6 mi	600 ft	0.8 mi	0.8 mi	0.8 mi	2.5 mi	2.5 mi	2.5 mi
1975	**Nitric Oxide/ Nitrogen Dioxide**	100 ft	0.1 mi	0.4 mi	300 ft	0.4 mi	0.4 mi	0.4 mi	1.4 mi	1.4 mi	1.4 mi
2188	**Hydrogen Arsenide**	500 ft	0.6 mi	2.4 mi	3,000 ft	3.5 mi	3.5 mi	3.5 mi	6.3 mi	6.3 mi	6.3 mi
2189	**Dichlorosilane**	100 ft	0.1 mi	0.2 mi	600 ft	0.8 mi	0.8 mi	0.8 mi	1.6 mi	1.6 mi	1.6 mi
2190	**Oxygen Difluoride**	1,000 ft	1.0 mi	4.2 mi	3,000 ft	6.1 mi	6.1 mi	6.1 mi	7.0+ mi	7.0+ mi	7.0+ mi
2191	**Sulfuryl Fluoride**	100 ft	0.1 mi	0.3 mi	1,000 ft	1.2 mi	1.2 mi	1.2 mi	2.7 mi	2.7 mi	2.7 mi
2192	**Germane**	500 ft	0.5 mi	1.9 mi	1,500 ft	1.8 mi	1.8 mi	1.8 mi	4.2 mi	4.2 mi	4.2 mi
2194	**Selenium Hexafluoride**	600 ft	0.7 mi	2.1 mi	2,000 ft	2.1 mi	2.1 mi	2.1 mi	4.9 mi	4.9 mi	4.9 mi
2195	**Tellurium Hexafluoride**	2,000 ft	2.2 mi	5.4 mi	3,000 ft	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi
2196	**Tungsten Hexafluoride**	100 ft	0.1 mi	0.5 mi	500 ft	0.6 mi	0.6 mi	0.6 mi	1.8 mi	1.8 mi	1.8 mi
2197	**Hydrogen Iodide**	100 ft	0.1 mi	0.2 mi	500 ft	0.6 mi	0.6 mi	0.6 mi	1.5 mi	1.5 mi	1.5 mi
2198	**Phosphorus Pentafluoride**	100 ft	0.1 mi	0.5 mi	500 ft	0.5 mi	0.5 mi	0.5 mi	1.8 mi	1.8 mi	1.8 mi
2199	**Phosphine**	200 ft	0.2 mi	0.6 mi	1,000 ft	0.8 mi	0.8 mi	0.8 mi	2.4 mi	2.4 mi	2.4 mi
2202	**Hydrogen Selenide**	1,000 ft	1.1 mi	3.7 mi	3,000 ft	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi

UN No.	Substance	Small Spill Isolation Distance [365]	Small Spill Protection Downwind Day	Small Spill Protection Downwind Night	Large Spill Isolation Distance	Large Spill Downwind Protection Distance Day Low Wind [366]	Large Spill Downwind Protection Distance Day Moderate Wind [367]	Large Spill Downwind Protection Distance Day High Wind [368]	Large Spill Downwind Protection Distance Night Low Wind	Large Spill Downwind Protection Distance Night Moderate Wind	Large Spill Downwind Protection Distance Night High Wind
2204	**Carbonyl Sulfide**	100 ft	0.2 mi	0.2 mi	1,000 ft	0.8 mi	0.8 mi	0.8 mi	2.0 mi	2.0 mi	2.0 mi
2418	**Sulfur Tetrafluoride**	300 ft	0.3 mi	1.5 mi	1,250 ft	1.3 mi	1.3 mi	1.3 mi	3.8 mi	3.8 mi	3.8 mi
2420	**Hexafluoro-acetone**	300 ft	0.4 mi	1.6 mi	3,000 ft	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi	7.0+ mi
2421	**Nitrogen Trioxide**	200 ft	0.2 mi	0.7 mi	500 ft	0.6 mi	0.6 mi	0.6 mi	1.9 mi	1.9 mi	1.9 mi
2534	**Methylchloro-silane**	100 ft	0.1 mi	0.2 mi	300 ft	0.4 mi	0.4 mi	0.4 mi	0.9 mi	0.9 mi	0.9 mi
2676	**Antimony Hydride**	200 ft	0.2 mi	1.0 mi	600 ft	0.8 mi	0.8 mi	0.8 mi	2.6 mi	2.6 mi	2.6 mi
2901	**Bromine Chloride**	300 ft	0.3 mi	1.1 mi	2,500 ft	2.8 mi	2.8 mi	2.8 mi	6.2 mi	6.2 mi	6.2 mi
3057	**Trifluoroacetyl-chloride**	100 ft	0.1 mi	0.6 mi	2,000 ft	2.5 mi	2.5 mi	2.5 mi	5.9 mi	5.9 mi	5.9 mi
3083	**Perchloryl Fluoride**	100 ft	0.2 mi	0.7 mi	2,500 ft	2.8 mi	2.8 mi	2.8 mi	6.0 mi	6.0 mi	6.0 mi
3160	**Toxic Liquefied Gas, Flammable**	500 ft	0.6 mi	2.4 mi	3,000 ft	3.5 mi	3.5 mi	3.5 mi	6.0 mi	6.0 mi	6.0 mi
3162	**Liquefied Toxic Gas**	300 ft	0.3 mi	1.6 mi	3,000 ft	3.5 mi	3.5 mi	3.5 mi	6.3 mi	6.3 mi	6.3 mi
3307	**Liquefied Toxic Gas, Oxidizing**	300 ft	0.3 mi	1.6 mi	2,500 ft	3.3 mi	3.3 mi	3.3 mi	7.0+ mi	7.0+ mi	7.0+ mi
3308	**Liquefied Toxic Gas, Corrosive**	300 ft	0.4 ft	1.5 mi	1,500 ft	1.9 mi	1.9 mi	1.9 mi	5.6 mi	5.6 mi	5.6 mi
3309	**Liquefied Toxic Gas, Corrosive Flammable**	500 ft	0.6 mi	2.4 mi	3,000 ft	3.5 mi	3.5 mi	3.5 mi	6.3 mi	6.3 mi	6.3 mi

UN No.	Substance	Small Spill Isolation Distance [365]	Small Spill Protection Downwind Day	Small Spill Protection Downwind Night	Large Spill Isolation Distance	Large Spill Downwind Protection Distance Day Low Wind [366]	Large Spill Downwind Protection Distance Day Moderate Wind [367]	Large Spill Downwind Protection Distance Day High Wind [368]	Large Spill Downwind Protection Distance Night Low Wind	Large Spill Downwind Protection Distance Night Moderate Wind	Large Spill Downwind Protection Distance Night High Wind
3310	**Liquefied Toxic Gas, Oxidizing, Corrosive**	300 ft	0.3 mi	1.6 mi	2.500 ft	3.3 mi	3.3 mi	3.3 mi	7.0+ mi	7.0+ mi	7.0+ mi
3318	**Ammonia Solutions**	100 ft	0.1 mi	0.1 mi	500 ft	0.5 mi	0.5 mi	0.5 mi	1.2 mi	1.2 mi	1.2 mi

Best practices for response in rail accidents

The states of Minnesota, Washington, and California have developed programs and taken actions to enhance public safety and emergency management for the freight rail infrastructure, integral to their communities and surrounding areas.

Minnesota Department of Public Safety

Minnesota has enhanced railway safety and ensured safe and efficient rail operations through infrastructure improvements, first responder training and support, monitoring of rail movements, and coordination with community stakeholders and railroad companies. To help with funding for emergency response and preparedness training, the Minnesota Department of Public Safety's Homeland Security and Emergency Management (HSEM) Division has a Railroad and Pipeline Safety Account for interested communities.

Some recommendations from the Minnesota Department of Public Safety (DPS) (Minnesota Department of Public Safety 2015)[369] that were included in the report:

> **Recommendation/Intended Action 1: To increase awareness about oil transportation incidents, and develop additional capacity**
>
> DPS intends to engage in a comprehensive approach to expanding awareness about oil transportation incidents, to include:
>
> - Conducting the awareness-level training already underway for fire departments and other responders.
> - Developing online resources for the public and first responders, such as awareness materials and training videos.
> - Developing guidance for first responders and local governments on responding to an oil incident, including assessment and evacuation protocols. This initial focus on building awareness more consistently across the state should be augmented by plans for large-scale drills and hands-on training for those jurisdictions that are prepared for those activities. Ultimately, DPS recommends expanding the State's training program to support more hands-on training and exercises related to emergency preparedness in general.
>
> **Recommendation/Intended Action 2: Connect funding for training and equipment to regional coordination**
>
> DPS recommends that resources from the Railroad and Pipeline Safety Account be used first to support the training program underway at the state level. Local emergency managers are in the best position to assess their area's capabilities and needs, but many need additional information about risks and available resources related to oil transportation incidents. Additionally, DPS agrees with the findings in this study related to the need for increased coordination and collaboration.

[369] There is a 2017 update to the 2015 report.

DPS therefore intends to direct HSEM to develop a process for organizations to apply for training or equipment funding available in the Railroad and Pipeline Safety Account. Requirements for funding should include the formation or expansion of a multi-county or regional collaborative group to identify and share resources. Wherever possible, existing organizations, joint powers authorities, or public/private partnerships should be utilized. Additionally, funding requests should include descriptions of intended evaluation methods.

To support the formation of these collaborative groups, agencies participating in the State Agency Responders Committee (particularly DPS and MPCA) should develop guidelines, model charters, and other templates. These state agencies should also develop a recommended evaluation format for these groups to use.

Because the information from these groups will be valuable in the state's planning and preparedness efforts, DPS intends to investigate the possibility of reimbursing members of these groups under state statutes regarding advisory boards. DPS intends to direct HSEM to administer funds in a similar way as HSEM grant programs, with established regional advisory committees as the funnel for applications.

Based on the information in this study, DPS recommends that funding priorities be set in this order: training (including reimbursement for associated staffing costs); planning and coordination; and equipment that will most likely be used by first responders during an oil transportation incident, such as air monitoring equipment. Applications for funding for large-scale response equipment should include a rigorous assessment of local and regional resources and risks....

Recommendation/Intended Action 4: Develop a state-level program evaluation approach to assess hazardous materials preparedness activities

In order to effectively evaluate the state's actions under the 2014 legislation, DPS recommends that the state develop a program evaluation process and framework for hazardous materials incident preparedness. Agencies participating in the State Agency Responders Committee (particularly DPS and MPCA) should jointly develop a list of priority results for preparedness activities and establish timelines and measures to show progress towards these results. DPS recommends that information on these results be incorporated in the annual report to the legislature on hazardous materials and oil discharge readiness.

DPS recommends that these state agencies also agree to collect and share data needed under the evaluation process, and that the agencies jointly request railroad companies provide a report on their coordination efforts required under Minnesota Statutes 2014 §115E.042.

DPS further recommends that resources from the Railroad and Pipeline Safety Account be used to partially offset any costs of evaluation, with the remaining costs shared equally among the responder agencies.

Recommendation/Intended Action 5: Enhance existing databases (or develop new databases) to provide more comprehensive information about response resources across the state

> DPS intends to direct HSEM to identify whether its existing resource database system can be modified to include additional information regarding resources from state agencies, private sector organizations, and local governments, including but not limited to resources needed to respond to an oil transportation incident. The existing database is accessible to the Minnesota Duty Officer and to local government first responders.
>
> DPS intends to direct HSEM to gather information from railroad and pipeline companies regarding their resources and their contractors' resources to populate the database. HSEM should develop a set of categories for response equipment and resources to ensure consistency.
>
> As an interim step while the database is being developed, DPS intends to direct HSEM to compile the information regarding private sector resources and provide it to local governments on its secure network to aid local first responders in their planning efforts.
>
> If it is not feasible to utilize existing systems, DPS will work with the Minnesota Geospatial Information Office (MnGEO), other agency partners, and private sector advisors to develop mapping and database capabilities and to determine what funding may be needed to support database development and maintenance. (pp. 15-19)

California[370]

Reporting on an October 2017 series of presentations and discussions on freight rail safety and security, Kay Goss reports:

> In a statewide gap analysis, California Governor's Office of Emergency Services (CalOES) found that several local municipalities had created specialized hazardous material response units (hazmat teams), which are responsible for protecting their communities, public resources, the environment, and property when an incident involving hazardous materials occurs (State of California Interagency Rail Safety Working Group 2014). These teams are mostly located in densely populated metropolitan areas throughout the state and vary in their capabilities. To facilitate possible expansion and ensure regional mutual aid response when needed, CalOES integrated these hazmat teams into its Standardized Emergency Management System (SEMS), National Incident Management System (NIMS), and Statewide Fire, Rescue, and Hazardous Materials Mutual Aid Plan. In addition, CalOES created a HazMat Team Typing Program to better identify and coordinate these specialized resources for emergency response.
>
> Since 2004, the Fire and Rescue Branch of CalOES and FIRESCOPE (Firefighting Resources of California Organized for Potential Emergencies) have been certifying the state's hazmat team response competency and ensuring

[370] Goss, K. (2017, Nov. 22). Freight rail safety and emergency management [Website]. Retrieved from https://www.domesticpreparedness.com/resilience/freight-rail-safety-and-emergency-management/.

coordination of hazmat response teams with the State Master Mutual Aid System, in accordance with accepted FIRESCOPE mutual aid and SEMS response standards. California's system provides a coordinated and reliable mechanism for local, regional, and state authorities to leverage when additional resources, specialized capabilities, and multijurisdictional responses are needed following a major hazmat incident. Four significant objectives drive this system:

- Requirements for standardized and certified training;
- Development and sustainment of a standardized Hazardous Materials Equipment List (based on performance typing standard);
- Development of the HazMat Team Typing concept (based on intervention/response capability); and
- On-site inspections of hazmat teams for compliance, certification, and standardization.

As of March 2015, CalOES had certified 60 hazmat teams that voluntarily entered the HazMat Team Typing Program. However, gap analysis reflects that qualified hazmat teams throughout rural California are still lacking. To address this gap, CalOES strives to enhance its emergency hazmat response capabilities, which includes response times, equipment, new and refresher responder training, and additional resources. Adding to the challenge in California, around 32 percent of its 56,000 firefighters are assigned for sustainment of critical hazmat response and recovery capabilities and resources to ensure rural rail safety.

States and local governments contribute significantly to freight rail safety and work with federal agencies, particularly US DOT in the Operation Lifesaver Program and share best practices with each other and programs for each of their surrounding communities.

New York

In January 2014, as CBR began to transit through New York, the Governor issued Executive Order 125 (EO 125)[371], directing state agencies to immediately conduct a coordinated review of New York State's crude oil incident prevention and response capacity. In EO 125, Governor Cuomo called upon state agencies to address the following specific issues:

- The State Agency's readiness to prevent and respond to rail and water incidents involving petroleum products;
- Statutory, regulatory, or administrative changes needed at the State level to better prevent and respond to incidents involving the transportation of crude oil and other petroleum products by rail, ship, and barge;
- The role that local governments across the State play in protecting their communities and their residents from spills of petroleum products shipped by rail and water; and

[371] No. 125: Directing DEC, DOT, DHSES, DOH, and NYSERDA to Strengthen the State's Oversight of Shipments of Petroleum Products, January 28, 2014, https://www.governor.ny.gov/news/no-125-directing-dec-dot-dhses-doh-and-nyserda-strengthen-states-oversight-shipments-petroleum

- Enhanced coordination between the State and federal agencies to improve the State's capacity to prevent and respond to incidents involving the transportation of crude oil and other petroleum products by rail, ship, and barge.

On April 30, 2014, five state agencies submitted to the Governor a report (NYSDEC 2014a) that provided an overview of the crude oil boom and New York State's capacity to effectively prevent and respond to incidents involving the transportation and storage of crude oil. It included recommendations for action by the federal government as well as steps that could be taken by state and local governments and industry.

In December 2014, a status update report was issued (NYSDEC 2014b). Since then, no further updates as to the status of the EO 125 Report findings have been made. CBR has also waned in the state.

However, the state did develop Geographic Response Plans specific to rail incidents, such as the one shown in Figure 83 and Figure 84.

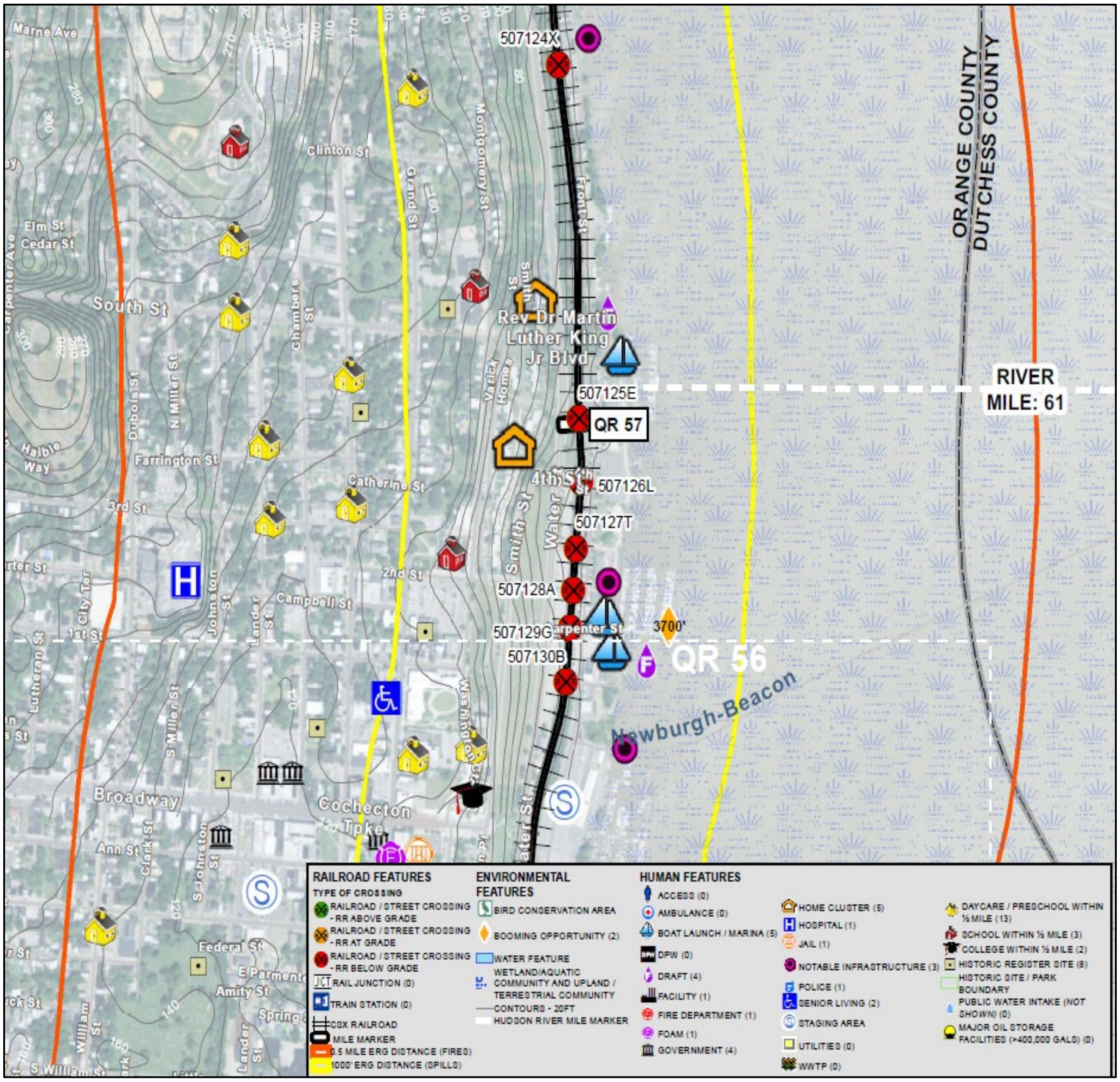
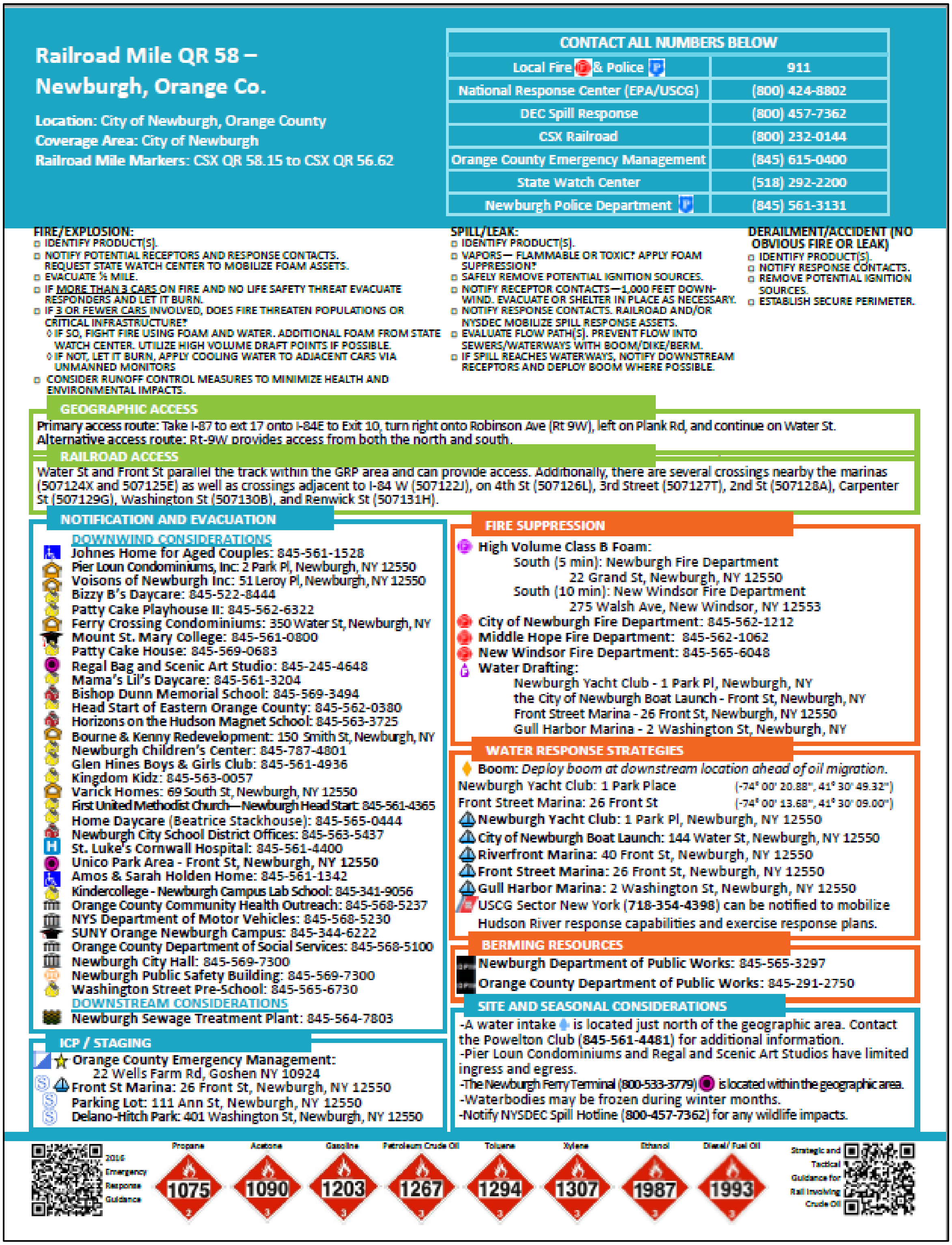


Figure 82: Example of New York State Geographic Response Plan for Rail Accident[372]

[372] New York State Department of Environmental Conservation Geographic Response Plans.



Railroad Mile QR 58 – Newburgh, Orange Co.

Location: City of Newburgh, Orange County
Coverage Area: City of Newburgh
Railroad Mile Markers: CSX QR 58.15 to CSX QR 56.62

CONTACT ALL NUMBERS BELOW	
Local Fire & Police	911
National Response Center (EPA/USCG)	(800) 424-8802
DEC Spill Response	(800) 457-7362
CSX Railroad	(800) 232-0144
Orange County Emergency Management	(845) 615-0400
State Watch Center	(518) 292-2200
Newburgh Police Department	(845) 561-3131

FIRE/EXPLOSION:
- IDENTIFY PRODUCT(S).
- NOTIFY POTENTIAL RECEPTORS AND RESPONSE CONTACTS. REQUEST STATE WATCH CENTER TO MOBILIZE FOAM ASSETS.
- EVACUATE ½ MILE.
- IF MORE THAN 3 CARS ON FIRE AND NO LIFE SAFETY THREAT EVACUATE RESPONDERS AND LET IT BURN.
- IF 3 OR FEWER CARS INVOLVED, DOES FIRE THREATEN POPULATIONS OR CRITICAL INFRASTRUCTURE?
  - IF SO, FIGHT FIRE USING FOAM AND WATER. ADDITIONAL FOAM FROM STATE WATCH CENTER. UTILIZE HIGH VOLUME DRAFT POINTS IF POSSIBLE.
  - IF NOT, LET IT BURN, APPLY COOLING WATER TO ADJACENT CARS VIA UNMANNED MONITORS
- CONSIDER RUNOFF CONTROL MEASURES TO MINIMIZE HEALTH AND ENVIRONMENTAL IMPACTS.

SPILL/LEAK:
- IDENTIFY PRODUCT(S).
- VAPORS— FLAMMABLE OR TOXIC? APPLY FOAM SUPPRESSION?
- SAFELY REMOVE POTENTIAL IGNITION SOURCES.
- NOTIFY RECEPTOR CONTACTS—1,000 FEET DOWN-WIND. EVACUATE OR SHELTER IN PLACE AS NECESSARY.
- NOTIFY RESPONSE CONTACTS. RAILROAD AND/OR NYSDEC MOBILIZE SPILL RESPONSE ASSETS.
- EVALUATE FLOW PATH(S). PREVENT FLOW INTO SEWERS/WATERWAYS WITH BOOM/DIKE/BERM.
- IF SPILL REACHES WATERWAYS, NOTIFY DOWNSTREAM RECEPTORS AND DEPLOY BOOM WHERE POSSIBLE.

DERAILMENT/ACCIDENT (NO OBVIOUS FIRE OR LEAK)
- IDENTIFY PRODUCT(S).
- NOTIFY RESPONSE CONTACTS.
- REMOVE POTENTIAL IGNITION SOURCES.
- ESTABLISH SECURE PERIMETER.

GEOGRAPHIC ACCESS

Primary access route: Take I-87 to ext 17 onto I-84E to Exit 10, turn right onto Robinson Ave (Rt 9W), left on Plank Rd, and continue on Water St.
Alternative access route: Rt-9W provides access from both the north and south.

RAILROAD ACCESS

Water St and Front St parallel the track within the GRP area and can provide access. Additionally, there are several crossings nearby the marinas (507124X and 507125E) as well as crossings adjacent to I-84 W (507122J), on 4th St (507126L), 3rd Street (507127T), 2nd St (507128A), Carpenter St (507129G), Washington St (507130B), and Renwick St (507131H).

NOTIFICATION AND EVACUATION

DOWNWIND CONSIDERATIONS
Johnes Home for Aged Couples: 845-561-1528
Pier Loun Condominiums, Inc: 2 Park Pl, Newburgh, NY 12550
Voisons of Newburgh Inc: 51 Leroy Pl, Newburgh, NY 12550
Bizzy B's Daycare: 845-522-8444
Patty Cake Playhouse II: 845-562-6322
Ferry Crossing Condominiums: 350 Water St, Newburgh, NY
Mount St. Mary College: 845-561-0800
Patty Cake House: 845-569-0683
Regal Bag and Scenic Art Studio: 845-245-4648
Mama's Lil's Daycare: 845-561-3204
Bishop Dunn Memorial School: 845-569-3494
Head Start of Eastern Orange County: 845-562-0380
Horizons on the Hudson Magnet School: 845-563-3725
Bourne & Kenny Redevelopment: 150 Smith St, Newburgh, NY
Newburgh Children's Center: 845-787-4801
Glen Hines Boys & Girls Club: 845-561-4936
Kingdom Kidz: 845-563-0057
Varick Homes: 69 South St, Newburgh, NY 12550
First United Methodist Church—Newburgh Head Start: 845-561-4365
Home Daycare (Beatrice Stackhouse): 845-565-0444
Newburgh City School District Offices: 845-563-5437
St. Luke's Cornwall Hospital: 845-561-4400
Unico Park Area - Front St, Newburgh, NY 12550
Amos & Sarah Holden Home: 845-561-1342
Kindercollege - Newburgh Campus Lab School: 845-341-9056
Orange County Community Health Outreach: 845-568-5237
NYS Department of Motor Vehicles: 845-568-5230
SUNY Orange Newburgh Campus: 845-344-6222
Orange County Department of Social Services: 845-568-5100
Newburgh City Hall: 845-569-7300
Newburgh Public Safety Building: 845-569-7300
Washington Street Pre-School: 845-565-6730
DOWNSTREAM CONSIDERATIONS
Newburgh Sewage Treatment Plant: 845-564-7803

ICP / STAGING

Orange County Emergency Management: 22 Wells Farm Rd, Goshen NY 10924
Front St Marina: 26 Front St, Newburgh, NY 12550
Parking Lot: 111 Ann St, Newburgh, NY 12550
Delano-Hitch Park: 401 Washington St, Newburgh, NY 12550

FIRE SUPPRESSION

High Volume Class B Foam:
South (5 min): Newburgh Fire Department, 22 Grand St, Newburgh, NY 12550
South (10 min): New Windsor Fire Department, 275 Walsh Ave, New Windsor, NY 12553
City of Newburgh Fire Department: 845-562-1212
Middle Hope Fire Department: 845-562-1062
New Windsor Fire Department: 845-565-6048
Water Drafting:
Newburgh Yacht Club - 1 Park Pl, Newburgh, NY
the City of Newburgh Boat Launch - Front St, Newburgh, NY
Front Street Marina - 26 Front St, Newburgh, NY 12550
Gull Harbor Marina - 2 Washington St, Newburgh, NY

WATER RESPONSE STRATEGIES

Boom: *Deploy boom at downstream location ahead of oil migration.*
Newburgh Yacht Club: 1 Park Place (-74° 00' 20.88", 41° 30' 49.32")
Front Street Marina: 26 Front St (-74° 00' 13.68", 41° 30' 09.00")
Newburgh Yacht Club: 1 Park Pl, Newburgh, NY 12550
City of Newburgh Boat Launch: 144 Water St, Newburgh, NY 12550
Riverfront Marina: 40 Front St, Newburgh, NY 12550
Front Street Marina: 26 Front St, Newburgh, NY 12550
Gull Harbor Marina: 2 Washington St, Newburgh, NY 12550
USCG Sector New York (718-354-4398) can be notified to mobilize Hudson River response capabilities and exercise response plans.

BERMING RESOURCES

Newburgh Department of Public Works: 845-565-3297
Orange County Department of Public Works: 845-291-2750

SITE AND SEASONAL CONSIDERATIONS

-A water intake is located just north of the geographic area. Contact the Powelton Club (845-561-4481) for additional information.
-Pier Loun Condominiums and Regal and Scenic Art Studios have limited ingress and egress.
-The Newburgh Ferry Terminal (800-533-3779) is located within the geographic area.
-Waterbodies may be frozen during winter months.
-Notify NYSDEC Spill Hotline (800-457-7362) for any wildlife impacts.

2016 Emergency Response Guidance

Propane	Acetone	Gasoline	Petroleum Crude Oil	Toluene	Xylene	Ethanol	Diesel/ Fuel Oil
1075	1090	1203	1267	1294	1307	1987	1993

Strategic and Tactical Guidance for Rail Involving Crude Oil

Figure 83: Example of Geographic-Specific Information in New York State Rail GRP[373]

[373] New York State Department of Environmental Conservation Geographic Response Plans.

Fire and explosion concerns for rail incidents

There are a number of specific concerns relating to fire and explosion hazards associated with rail incidents involving the release of hazardous liquids. These include factors that determine the extent of the fire and strength of explosion, factors that can escalate the magnitude of the initial consequence by a cascading event, and factors that can influence the effects of the consequences on the impacted population. These should be considered in planning response.

Boiling liquid expanding vapor explosion

For hazardous liquids transported by rail tank car, a pool fire could occur if there is an incident leading to a release of the chemical that forms a pool on the land below and then ignites. Due to the kinetic energy, the large number of tank cars and the friction creating ignition sources, rail accidents are particularly susceptible to pool fires with subsequent escalation. A pool fire acting on rail cars containing a flammable liquid inventory can result in release, either from the relief system or by a thermal tear (Boiling Liquid Expanding Vapor Explosion–BLEVE). A BLEVE is an explosion that results when a tank of liquefied gas is heated by fire to a point at which the pressure inside has increased and the strength of the tank has been reduced to the point that it ruptures. The concerns of a BLEVE are the generation of overpressure and projectiles from the explosion.

Strength of explosion — confinement and congestion

A vapor cloud explosion is the result of a flammable material that is released into the atmosphere, at which point the resulting vapor cloud is ignited. The primary concern from a vapor cloud explosion is overpressure (pressure caused by a shockwave). High overpressures can be produced with turbulence in a burning vapor cloud. Significant turbulence can be generated by obstacles encountered by a flame as it propagates through the vapor cloud in obstructed regions. The obstacle density is referred to as congestion. Another factor in determining the magnitude of overpressure generation is the degree to which the cloud is constrained from expanding. If the cloud is constrained to expand in only 1 (as in a tunnel) or 2 (as in an urban canyon formed by high rise buildings on both sides of the rail corridor) dimensions, then the positive feedback mechanism leads to higher overpressures than if the cloud were to expand freely. This expansion constraint is referred to as degree of confinement.

Weather conditions

A vapor cloud which evolves from spilled hazardous liquid is affected by weather conditions. In general, greater wind speed leads to larger dispersion distances due to bulk momentum. Greater atmospheric stability also leads to greater dispersion distances as the vapor cloud is allowed to disperse downwind without turbulent effects increasing the mixing of the cloud.

Ignition sources

As the rail network across Washington is extensive, it traverses a large variety of terrain and surrounding land use, from rural open land to dense urban development. The surrounding density of natural features and structures define two parameters, which define the potential for vapor cloud explosions, confinement and congestion.

Surrounding population density

The density of population varies along the rail corridor. Population density determines the potential exposure of the public to a rail incident hazard. Higher densities of people in the hazard zone must be managed by incident command including evacuation, shelter-in-place, and re-entry activities for impacted populations.

Surrounding hazards

Hazardous facilities such as flammables storage, petrochemical process plants and reactive chemical storage may be located along the rail corridor. These types of facilities can be receptors of an initiating rail accident by impacts of exposure to fire or explosion overpressure.

Marshalling yards, sidings

Areas where rail consists are temporarily staged create an accumulation of rail cars that can lead to temperature changes of the rail car cargo, create congestion, and possibly be located near vulnerable receptors (e.g. highways, industrial areas).

Emergency procedures for other hazardous materials

Emergency responder considerations for hazardous materials, other than crude oils, address toxic preparedness and safeguards in addition to fire and explosion hazards. These are listed briefly below. One source for full details of hazards, public safety, and emergency response is the *Emergency Response Guidebook (ERG)* (Barbalace 2019).

Important safety guidelines for sulfuric acid spills[374]

- Fully encapsulating, vapor protective clothing should be worn for spills and leaks with no fire.
- Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.
- Stop leak if you can do it without risk.
- Use water spray to reduce vapors. Do not put water directly on leak, spill area or inside container.
- Keep combustibles (wood, paper, oil, etc.) away from spilled material.

Fire

- When material is not involved in fire, do not use water on material itself.

Large Fire

- Flood fire area with large quantities of water, while knocking down vapors with water fog. If insufficient water supply, knock down vapors only.

Fire Involving Tanks or Car/Trailer Loads

- Cool containers with flooding quantities of water until well after fire is out.

[374] Follows ERG GUIDE 137 SUBSTANCES–WATER-REACTIVE–CORROSIVE (Barbalace 2019).

- Do not get water inside containers.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire

Important safety guidelines for anhydrous ammonia spills[375]

- Fully encapsulating, vapor protective clothing should be worn for spills and leaks with no fire.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- If possible, turn leaking containers so that gas escapes rather than liquid.
- Prevent entry into waterways, sewers, basements or confined areas.
- Do not direct water at spill or source of leak.
- Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material.
- Isolate area until gas has dispersed.

Large Fire

- Water spray, fog or regular foam.
- Move containers from fire area if you can do it without risk.
- Do not get water inside containers.
- Damaged cylinders should be handled only by specialists.
- Fire involving tanks
    - Fight fire from maximum distance, or use unmanned hose holders or monitor nozzles.
    - Cool containers with flooding quantities of water until well after fire is out.
    - Do not direct water at source of leak or safety devices — icing may occur.
    - Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
    - ALWAYS stay away from tanks engulfed in fire.

Important safety guidelines for ethanol spills[376]

CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.

- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Prevent entry into waterways, sewers, basements or confined areas.
- A vapor suppressing foam may be used to reduce vapors.

[375] Follows ERG GUIDE 125 GASES–CORROSIVE (Barbalace 2019).
[376] Follows ERG GUIDE 127 FLAMMABLE LIQUIDS (Polar / Water-Miscible) (Barbalace 2019).

- Absorb or cover with dry earth, sand, or other non-combustible material and transfer to containers.
- Use clean non-sparking tools to collect absorbed material.

Large Spill

- Dike far ahead of liquid spill for later disposal.
- Water spray may reduce vapor; but may not prevent ignition in closed spaces.

Small Fire

- Dry chemical, CO2, water spray or alcohol-resistant foam.

Large Fire

- Water spray, fog or alcohol-resistant foam.
- Use water spray or fog; do not use straight streams.
- Move containers from fire area if you can do it without risk.

Fire involving Tanks or Car/Trailer Loads

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

Evacuation / safety zone precautions in release events

The modeling of hypothetical release events, as presented in Chapter 7, have relevance in planning for the need for potential evacuations and safety zone precautions for responders, as well as the general public, in the vicinity of the accident and release site.

For reference, the dispersion and hazard zones are shown in Figure 85. The gold circle shows the region where an ignited pool fire's thermal radiation level reaches the specified threshold value of 12.5 kW/m^2. The pool is modeled as a circular liquid on a horizontal plane surface; it has rotational symmetry.

The elliptical shape oriented vertically upward in the figure (crosshatched in blue) represents a plume, or footprint of vapor or gas in air, the outer boundary is the LFL concentration. The footprint is the location of the LFL swept out over the entire duration of the release and dispersion. As this footprint (or plume) can drift in any direction, the blue circle formed by its rotation is the hazard zone for dispersion.

The circle centered on the top of the elliptical plume (dotted in red) represents the boundary that reaches the endpoint overpressure of 2 pounds per square inch (psi). The large red circle formed by its rotation is the hazard zone for explosion overpressure.

Note that the hazard distances are in all directions. The hazard distance is the radius of the circle. For example, a 100-foot hazard distance would mean that the diameter of the circle is 200 feet. The degree of hazard within the circle would depend on the wind direction and ambient conditions at the time of the incident.

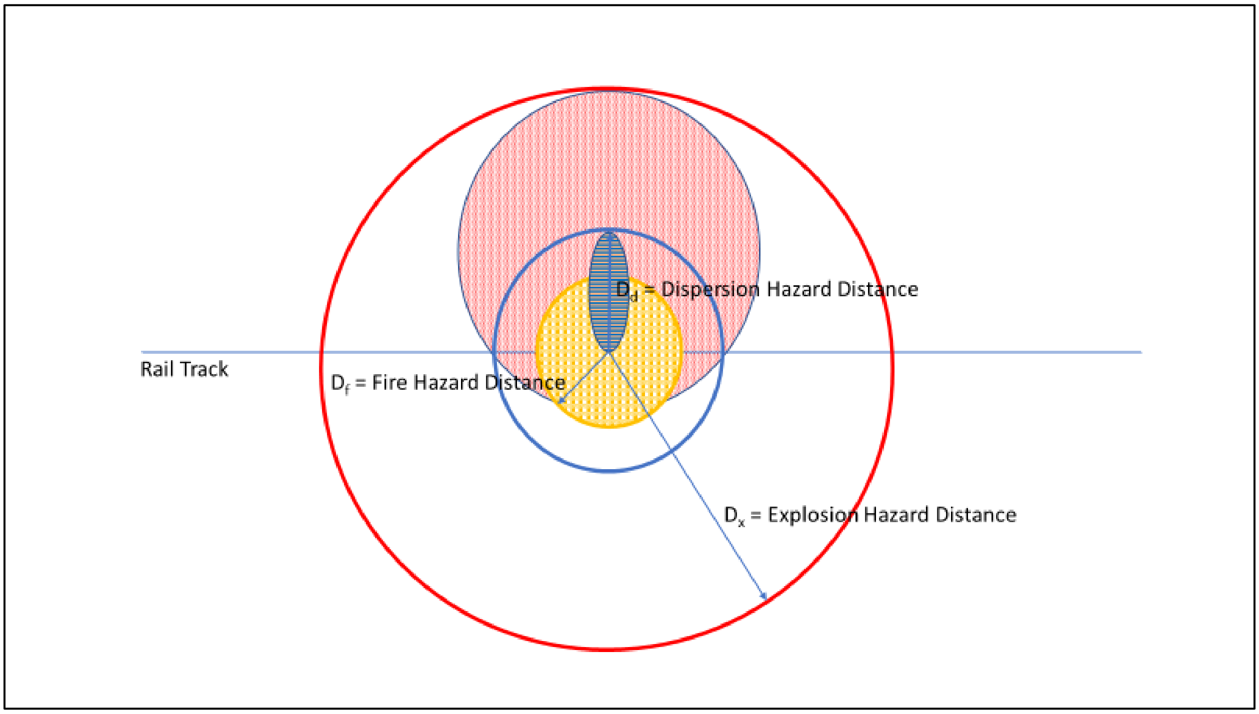


Figure 84: Dispersion and Hazard Zones (for Evacuation and Safety Zone Precautions)[377]

The general guidance for hazard zones is presented here. For greater detail on specific rail corridors, refer to Chapter 7.

To be conservatively cautious, worst-case hazard distances for one-car releases of various hazardous substances are shown in Table 121. (There are variations in conditions in the rail corridors that may make these distances greater than actually required.) Note that the rail right-of-way is generally 25 feet on either side of the tracks, therefore hazard distances of about 25 feet would remain within the right-of-way and not pose a direct consequence to neighboring facilities or the public.

[377] Figure produced by Risknology, Inc. Used with permission.

Table 121: Hazard Distances for Evacuation and Safety Zones (One-Car Release)[378]

Hazardous Material	Dispersion Hazard	Fire Hazard	Explosion Hazard	Toxic Exposure Hazard
Ammonia	28 ft	7 ft	n/a	2.1 miles
Sulfuric Acid	n/a	n/a	n/a	23 ft
Bakken Crude	227 ft	n/a	441 ft	n/a
DilBit	80 ft	168 ft	173 ft	n/a
Ethanol	33 ft	350 ft	44 ft	n/a
Propane	86 ft	26 ft	569 ft	n/a

The most likely release scenario involves a single car. However, it is possible that a rail accident will involve a larger number of cars, potentially causing releases from multiple cars. This is particularly true for unit trains and key trains with 20–120 tank cars of Class 3 flammables and other liquid hazardous commodities. Hazard distances for 10-car releases[379] are shown in Table 122. Note that the hazard distances are in all directions.

Table 122: Hazard Distances for Evacuation and Safety Zones (Ten-Car Release)[380]

Hazardous Material	Dispersion Hazard	Fire Hazard	Explosion Hazard	Toxic Exposure Hazard
Ammonia	62 ft	23 ft	n/a	9.5 miles
Sulfuric Acid	n/a	n/a	n/a	46 ft
Bakken Crude	643 ft	n/a	1,342 ft	n/a
DilBit	174 ft	485 ft	620 ft	n/a
Ethanol	56 ft	987 ft	69 ft	n/a
Propane	932 ft	92 ft	790 ft	n/a

Plume modeling

The New York State Emergency Response Commission conducted a workshop on the modeling of Bakken crude plumes in December 2014. This had been one of the recommendations from the first report (NYSERC 2015). The major finding was that New York State's toxic plume modeling capabilities are limited. A large-scale emergency exhausts resources at the municipal and county levels of government and warrants support from the state to effectively respond to the event.

The NYSERC report stated:

> Plume modeling provides the capability to predict the geographic extent, or hazard area affected by an incident, in this scenario due to an accident/explosion involving a rail car carrying crude oil. This analysis then informs first responders

[378] Analyses conducted by Risknology, Inc.
[379] The 10-car release is consistent with the PHMSA Fast Act ruling issued on 28 February 2019, which stipulates contingency planning requirements for worst-case discharges of 300,000 gallons (roughly the capacity of 10 714-bbl tank cars).
[380] Analyses conducted by Risknology, Inc.

> and public officials on areas that may need to be evacuated due to health and safety issues....
>
> Emergency air plume modeling poses a variety of challenges, particularly with regard to interpreting model results given the uncertain nature of what is released during an emergency, and the capability to conduct modeling given the overall mission or focus of an agency, and the resources that it employs. (pp. 1-2)

The workshop participants concluded that 90 percent of the local hazardous materials teams along the Bakken crude virtual pipeline possess a rudimentary plume modeling capability to support the initial phase of an incident. None of the currently available modeling software has Bakken crude as a specific source term (or input) into that model. Other products that have similar physical and/or chemical properties such as paraffin hydrocarbons (n-hexane) can be used to make a determination of a plume associated with a spill or release (not combustion), but will come with a degree of uncertainty as to the exact contents of that plume.

The workshop participants also concluded that a good knowledge of potential human exposure and chemical toxicity is important to make decisions about health effects. Toxicity of the various surrogates (hexane, n-heptane, generic particles) used to model the plume during the workshop will not be the same as toxicity of the Bakken crude, and therefore model outputs using surrogates cannot be solely used as the basis for health decisions. Additionally, some emergency response models compare estimates of dose to emergency planning guidelines, such as Acute Exposure Guidelines (AEGLs) or Temporary Emergency Exposure Limits (TEELs). These guidelines are derived assuming exposure to a single chemical (not mixtures) and are associated with serious health effects. These kinds of values should only be used when more appropriate values are not available and if used, AEGL-1 or TEEL-1 values should be used for determining protective actions since these are levels that are not associated with death, impaired abilities, or irreversible effects.

As stated in the NYSERC report:

> There are several models that are available to the State to conduct plume modeling. These models vary in capability and applicability including some that are in use by local response agencies, and some that are only available to the State or Federal agencies. The following is a brief overview of modeling software...
>
> ### HPAC V5.0 (Hazard Prediction and Assessment Capability)
>
> HPAC predicts hazards and provides exposure information for populations in the vicinity of accidents involving releases from nuclear and chemical facilities, and facilities/transportation containers. HPAC models atmospheric dispersion of vapors, particles, or liquid droplets from multiple sources using pre-defined (not site-specific) release rates, and using meteorological input that may range from wind speed and direction at only a single measurement location to 4-dimensional gridded wind and temperature fields.

WISER (Wireless Information System for Emergency Responders)

WISER[381]is a system designed to assist emergency responders in hazardous material incidents. WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, health information (e.g., Material Safety Data Sheets and Emergency Response Guidelines), and containment and suppression advice. WISER is an emergency "look-up" resource and not a dispersion model.

CAMEO/ALOHA/MARPLOT (NOAA)

The CAMEO (Computer Aided Management of Emergency Operations) suite of software contains several separate integrated software applications, including ALOHA and MARPLOT. ALOHA is the air hazard modeling program. MARLPOT is a mapping program. Both programs were developed jointly by NOAA and the Environmental Protection Agency (EPA). The programs can provide users with initial guidance on protective action decisions for chemical releases, and can model plumes to give users predictions of what level of contamination may exist. Data extrapolated from the model can then be used to make decisions regarding dose/exposure and any follow-on protective actions.

HYSPLIT (Hybrid Single Particle Lagrangian Trajectory Model)

The HYSPLIT model is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. The program includes the integration of ALOHA, and advanced advection algorithms, updated stability and dispersion equations, and the option to include modules for chemical transformations. Without the additional dispersion modules, HYSPLIT computes the advection of a single pollutant particle, or simply its trajectory. Some of the applications include tracking and forecasting the release of radioactive material, volcanic ash, wildfire smoke, and pollutants (such as mercury) from various stationary emission sources.

CAL3QHC, CAL3QHCR, and AERMOD

The CAL3QHC and CAL3QHCR are steady-state Gaussian based dispersion models, and the AERMOD is a dispersion model capable of providing hourly pollutant concentrations due to various sources (point, areas, volume). These models are used for regulatory compliance purposes to demonstrate compliance with National Ambient Air Quality Standards (NAAQS) of criteria pollutants, and are not suitable for plume modeling for emergency applications.

[381] WISER is a mobile app. https://wiser.nlm.nih.gov/

SAFER STAR

The SAFER STAR (SAFER) program is a tool designed by Center for Toxicology & Environmental Health LLC (CTEH) to help manage an emergency and to provide early warning to those who may risk exposure to a potentially harmful substance. CTEH claims that SAFER accurately models the effects of chemical accidents (toxic releases, fires, and explosions), and that the program includes state-of-the-science algorithms for addressing atmospheric dispersion, thermal radiation and blast overpressure modeling. In addition, SAFER provides mapping and topographical databases for the region of interest. Once the release is identified, SAFER rapidly assembles appropriate maps and topographical data". (pp. 7-8)

Plume modeling for Washington State

For Washington State, having modeling capability and training of personnel in the use of these models would be valuable for incorporation into training and table-top exercises to simulate a variety of hypothetical catastrophic events. A model may assist in determining areas of greatest concern for exposure, and to determine evacuation zones. The use of a plume model would require training for users. It would also be necessary to assure that there is access to appropriate input data on the chemical substances involved, as well as geographic and environmental data on local conditions.

In the event of a real spill emergency, however, it may take too much time to use the model to make any meaningful predictions and decisions.

The use of modeling for plumes of toxic substances is different than the use of trajectory models for oil spills, which can be used, especially in larger spills, to strategize the placement of protective booms and on-water recovery equipment. Many plumes from releases from a limited number of tank cars would be dissipated within minutes or hours. In an actual emergency, air monitoring would likely be a more valuable approach to determining concentrations of concern.

Regardless of the plume model chosen, in a real emergency situation the accuracy and availability of the data on the chemical composition of the released material combined with the thermodynamic conditions and the real-time weather conditions will have significant effects on the reliability of the model outputs. For releases in urban areas with high buildings and other obstructions, the reliability of the modeled plume outcome may be questionable.

Plume modeling with accurate input data would help determine more precisely the geographic areas for evacuation for simulated scenarios, and if conducted in advance, inform decision-making in an actual emergency.

Passenger train accident emergency response

Emergency response considerations extend to passenger train accidents, such as the December 2017 Amtrak accident in DuPont, Washington. Although these accidents might involve the spillage of diesel fuel from locomotives, the primary concern is for the rescue and medical care of trapped passengers, some of whom may be seriously injured or dead.

The FRA has specific regulations regarding emergency response preparedness plans for the operators of passenger trains that would come into play in the event of an accident. However, aside from any trained railroad employees, it is the local fire departments and emergency responders that would be on-scene first to deal with most casualty situations.

FRA-required emergency preparedness plan for passenger trains

In May 1998, the FRA published rail safety regulations for the preparation, adoption, and implementation of emergency preparedness plans by railroads connected with the operation of passenger trains, including railroads hosting the operations of rail passenger service (63 Federal Register (FR) 24676). These regulations became effective on July 6, 1998, and are codified in Part 239 of Title 49 of the Code of Federal Regulations (CFR).

The emergency preparedness plan extends to both the passenger railroad itself and any railroad hosting the passenger service (e.g., Amtrak trains running on BNSF track).

The basic elements of the Emergency Preparedness Plan include (FRA 2010a):

Communication

i. Initial and on-board notification

An on-board crewmember shall quickly and accurately assess the passenger train emergency situation and then notify the control center as soon as practicable by the quickest available means. As appropriate, an on-board crewmember shall inform the passengers about the nature of the emergency and indicate what corrective countermeasures are in progress.

The plan should describe the entire communication process, beginning with the notification by the on-board crewmember to the control center.

The plan must also detail the means by which the on-board crewmember will quickly and accurately assess the emergency situation and provide the notification to the control center (e.g., by radio, cell phone, etc.). In addition, the plan must describe how notifications and updates will be provided to passengers (e.g., public address (PA) system, megaphones). This section should also identify what procedures on-board crewmembers are to follow if the PA system (which is to be used for emergency communication to passengers) becomes inoperative because of the incident (e.g., car-to-car oral briefings)....

ii. Notifications by control center

The control center shall promptly notify outside emergency responders, adjacent rail modes of transportation, and appropriate railroad officials that a passenger train emergency has occurred. Each railroad shall designate an employee responsible for maintaining current emergency telephone numbers for use in making such notifications.

A railroad and, if applicable, any host railroad must provide specific details in the plan regarding the process of how control center personnel are to promptly notify outside emergency responders, adjacent rail modes of transportation, and appropriate railroad officials about the passenger train emergency that has occurred. The plan must also identify the railroad employee (at a minimum by title) who is responsible for maintaining current emergency telephone numbers for the railroad. If one or more host railroads are involved, the plan must also identify the host railroad employee (at a minimum by title) who is responsible for maintaining such numbers for each host railroad. . . .

Employee Training and Qualification

i. On-board personnel

The railroad's emergency preparedness plan shall address individual employee responsibilities and provide for initial training, as well as periodic training at least once every two calendar years thereafter, on the applicable plan provisions. As a minimum, the initial and periodic training shall include [for on-board personnel]:

(A) Rail equipment familiarization;
(B) Situational awareness;
(C) Passenger evacuation;
(D) Coordination of functions; and
(E) "Hands on" instruction concerning the location, function, and operation of on-board emergency equipment.

FRA expects the plan to describe the initial training and the periodic training provided at least once every two calendar years for all employees that have responsibilities under the plan. While "on-board personnel" is not defined in Part 239, the term includes, at a minimum, all crewmembers and any non-passengers assigned duties under the plan. . . .

Regarding the requirement that both initial and periodic training of on-board employees include "hands-on" instruction concerning the location, function, and operation of onboard emergency equipment, FRA expects that the instruction would focus on the following:

- How to open emergency windows, doors, and, if applicable, roof exits with an emphasis on how to operate these types of exits in adverse conditions (e.g., overturned rail car);
- How to use emergency tools and fire extinguishers;
- How to use portable lighting when the passenger train's main power source is unavailable; and
- How to use PA systems or alternative mass-communication devices (e.g., megaphones).

Note that FRA will not approve a plan that provides for "hands-on" instruction exclusively by allowing employees to watch a video, as this can be ineffectual. Using a video as an instructive tool in combination with a scale model of an emergency window (e.g., if small groups of employees take turns practicing emergency escape techniques through the scale model of the window), however, would be acceptable. . . .

ii. Control center personnel

The railroad's emergency preparedness plan shall require initial training, as well as periodic training at least once every two calendar years thereafter, on appropriate courses of action for each potential emergency situation. As a minimum, the initial and periodic training shall include:

(A) Dispatch territory familiarization; and
(B) Protocols governing internal communications between appropriate control center personnel whenever an imminent potential emergency situation exists...

Special Circumstances

i. Tunnels

When applicable, the railroad's emergency preparedness plan shall also reflect readiness procedures designed to ensure passenger safety in an emergency situation occurring in a tunnel of 1,000 feet or more in length.

If any portion of the passenger service operates through a tunnel of 1,000 feet or more in length, the railroad and, if applicable, host railroad(s) must describe in its emergency preparedness plan what procedures will be implemented to ensure passenger safety if an emergency situation occurred while the train was in the tunnel. The discussion in the emergency preparedness plan must address at a minimum:(1) availability of emergency lighting; (2) access to emergency evacuation exits;(3) bench wall readiness; (4) ladders for detraining; (5) effective radio or other communication between on-board crewmembers and the control center; and (6) options for assistance from other trains...

iii. Other operating considerations

When applicable, the railroad's emergency preparedness plan shall address passenger train emergency procedures involving operations on elevated structures, including drawbridges, and in electrified territory.

Liaison with Emergency Responders

Each railroad to which this part applies shall establish and maintain a working relationship with the on-line emergency responders by, as a minimum:

(i) Developing and making available a training program for all on-line emergency responders who could reasonably be expected to respond during an emergency situation. The training program shall include an emphasis on access to railroad equipment, location of railroad facilities, and communications interface, and provide information to emergency responders who may not have the opportunity to participate in an emergency simulation. Each affected railroad shall either offer the training directly or provide the program information and materials to state training institutes, firefighter organizations, or police academies;
(ii) Inviting emergency responders to participate in emergency simulations; and
(iii) Distributing applicable portions of its current emergency preparedness plan at least once every three years, or whenever the railroad materially changes its plan, in a manner that could reasonably be expected to affect the railroad's interface with the online emergency responders, whichever occurs earlier, including

documentation concerning the railroad's equipment and the physical characteristics of its line, necessary maps, and the position titles and telephone numbers of relevant railroad officers to contact. . . .

The plan must provide information on how the railroad and, if applicable, any host railroad develops and makes available a training program for all emergency responders who reasonably might be called upon to respond to a passenger train emergency. This plan should also identify who will conduct the actual training—the railroad, the host railroad, the emergency responders themselves, or all three parties. All training must include and emphasize access to railroad equipment, location of railroad facilities, and communications interface. Railroads and, if applicable, any host railroads are required to invite emergency responders to participate in any passenger train emergency simulation; however, a railroad's plan must also address how the railroad will provide information to emergency responders who have not had the opportunity to participate in a passenger train emergency simulation.

The plan must describe how applicable portions of the plan will be distributed to emergency responders, at least once every three years, or when a material alteration of the emergency preparedness plan occurs, whichever comes first. Certain documentation must accompany the plan when distributed, and the plan should also describe and state what documentation in addition to the plan is provided to the emergency responders (e.g., railroad equipment diagrams and manuals, right-of-way maps, information on physical characteristics such as tunnels, bridges, and electrified territory).

Passenger Safety Information

(i) General. Each railroad's emergency preparedness plan shall provide for passenger awareness of emergency procedures, to enable passengers to respond properly during an emergency.

(ii) Passenger awareness program activities. Each railroad shall conspicuously and legibly post emergency instructions inside all passenger cars (e.g., on car bulkhead signs, seatback decals, or seat cards) and shall utilize one or more additional methods to provide safety awareness information including, but not limited to, one of the following:

(A) On-board announcements;
(B) Laminated wallet cards;
(C) Ticket envelopes;
(D) Timetables;
(E) Station signs or video monitors;
(F) Public service announcements; or
(G) Seat drops. (pp. 5-16)

Potential areas of future discussion

- The Rail Safety Committee may consider evaluating the extensive lessons learned, contained herein, relative to the Unit Train Derailment Study, and the after-action reports arising from the Mosier and Lynchburg incidents, and compare to the current status of related issues within Ecology and UTC, as well as any other Washington State administrative departments that may have planning, and/or response responsibilities for rail transportation of hazardous materials.
- The Rail Safety Committee may want to consider reviewing hazmat team development and sustainability and provide an updated status.

Chapter 18: Public information during major incidents

Key questions

- What are the public information procedures that the Washington Department of Ecology currently has in place?

Takeaways

- Through the Department of Ecology, Washington State has well-established procedures for public information during oil spills and other hazmat emergencies.

The response community in Washington places a high value on communicating with the public. The following sections provide a more in-depth look at the public information techniques used in major responses, as well as ways to use public information to enhance safety and reduce the risk of spills.

Current Washington State public information procedures

The Department of Ecology has staff standing watch to receive spill calls 24 hours a day, 365 days a year. This roster includes a communications manager who is able to distribute rapid, real-time communication with stakeholders and the public during a response. After a unified command is formed, the Incident Command System (ICS) is used to manage responses, which include positions for a Public Information Officer (PIO) that will serve as lead of the Joint Information Center (JIC). While communications with the media is done through the PIO, agencies, elected officials, tribes and other groups get information through a Liaison officer. It is state policy that the spiller or responsible party not act as the lead Public Information Officer or Liaison Officer for oil spills.

During an incident, in accordance with the Northwest Area Contingency Plan (NWACP) (RRT and NWAC 2019; Washington State Dept. of Ecology 2019b), the federal and state response agencies plan public information communications together. Even prior to the formation of a unified command, the responding agencies connect with their counterparts, share information, and release a joint statement to the media. It is policy that the first release be issued within 30 minutes of the initial notification and not longer than two hours after notification is received. That first release is more likely to be through social media (Twitter, e.g.) rather than a press release.

The area plan contains a strategic level “96-hour plan” for major incidents. It includes guidance and best practices for crisis communication, with tools and checklists. Agencies in Washington are users of social media including Twitter, Facebook, Instagram, YouTube, and others. The plan has extensive information about use of social media during a response with best practices, tools and templates.

Public information is practiced routinely through drills. The Department of Ecology is responsible for implementing a drill and exercise program with railroad and other regulated plan holders. JIC and Liaison functions are routinely demonstrated during drills with live action role playing under spill scenarios. This often includes elected official briefing, mock press conferences, and VIP tours.

Ecology has established a public website as an education and communication tool before and during incidents.[382] It can become a public information platform during an incident, with a live webpage, neutrally branded for a unified command.

Potential areas of future discussion

- The Rail Safety Committee may consider working with Ecology to develop an engagement plan with Washington communities before a spill occurs to facilitate effective public information during an incident and enhance community trust in the plans that are in place.
- The Rail Safety Committee may consider working with the Area Committee to develop a work group dedicated to social engagement before, during and after incidents. The “oilspills101” site should be utilized as a neutral platform for the response community to engage with citizens on oil spill issues.

[382] Washington State Oil Spills 101 website. https://www.oilspills101.wa.gov/.

Chapter 19: FRA Railroad Safety Advisory Committee & Rail Safety Committees

Key questions

- What is the role of the FRA and the Railroad Safety Advisory Committee (RSAC) in working at the federal and regional levels to enhance rail safety?
- How would a Rail Safety Committee differ from the RSAC?
- What elements of the RSAC model might inform the development of Washington State Rail Safety Committee?

Takeaways

- States active in rail safety regulation have formed the Association of State Rail Safety Program Managers (Association), an FRA-supported federal organization. Washington is a member of the Association. A principal motivation for forming the Association was to attain greater uniformity among states in the conduct of rail regulatory activities, and to enable states to speak with a collective voice on rail safety topics.
- The Association shall promote railroad safety in the United States by encouraging consistent and uniform application and enforcement of railroad safety regulations and the promulgation of effective federal regulations.
- The USCG Harbor Safety Committees have a record of accomplishments in fostering communications between local maritime stakeholders and the USCG in the various Captains of the Port (COTPs). Communication is a two-way street which the Harbor Safety Committees help to facilitate, especially around local navigational, operational, and safety concerns. This allows the maritime industry and the COTP to work together to find solutions outside of the overarching Federal programs.
- A Washington State Railroad Safety Committee could function like a harbor safety committee, addressing national policies and procedures and local issues of concern.

This chapter reviews the various Federal agency organizations and their activities. There are also recommendations for a Washington State Rail Safety Committee similar to the USCG Harbor Safety Committees that promote communications with local stakeholders. A state Rail Safety Committee could have similar attributes and functions

The following sections provide a more in-depth look at roles of various types of safety committees in enhancing rail safety.

Role of Federal Railroad Administration (FRA)

According to the GAO's report*, Improved Human Capital Planning Could Address Emerging Safety Oversight Challenges* (GAO 2013b):

> The FRA's rail-safety oversight framework relies on inspections to ensure railroads comply with federal safety regulations. FRA inspects railroad

infrastructure and operations, identifies safety defects, and may, if warranted, cite the railroads for violations of federal safety regulations. The agency estimates that its inspectors may annually inspect less than 1 percent of the railroad activities covered in regulation. As a result, railroads have the primary responsibility for safety of the railroad system. To formulate regulations, FRA instituted the Railroad Safety Advisory Committee, a forum for FRA, the railroads, rail labor organizations, and other stakeholders to arrive at a consensus on proposed rules. Thirty states partner with FRA in providing FRA-certified railroad safety inspectors who are also authorized to enforce federal safety regulations. Finally, many railroads have additional safety programs, rules, and technologies to ensure safety beyond the required federal standards.

FRA has developed a risk-based approach to direct its inspection efforts, but the agency has been slow to implement broader risk reduction planning. FRA has two tools to help direct its inspection efforts—the National Inspection Plan (NIP) and the Staffing Allocation Model (SAM). The NIP process uses past accident and other data to target FRA's inspection activities, and the SAM estimates the best allocation of the different types of inspectors across FRA regions in order to minimize damage and casualties from rail accidents. However, all eight FRA regional administrators expressed concerns about FRA's staffing process that relies primarily on the SAM to predict appropriate regional inspector needs, and that does not allow the flexibility needed to accommodate the regions' changing resource needs. (GAO Highlights)

Railroads are required to comply with the safety standards set in federal safety regulations. When railroads do not comply or identified defects are serious, FRA may cite violations and assess civil penalties, either against railroads or individuals. Thus, FRA's approach is compliance-oriented and does not holistically assess safety problems across a railroad's system. (p. 10)

FRA supplements oversight of Class I railroads through the Railroad System Oversight program, established in October 2005. In addition to addressing safety compliance issues, this program addresses safety issues not subject to regulation, such as aspects of worker fatigue. Under this program, the agency assigns an FRA manager to work with each Class I railroad on identifying and resolving safety issues. According to FRA officials, these managers analyze accident and inspection data for their assigned railroad, and support FRA's inspection and enforcement efforts. Under this program, FRA has begun annual meetings with the leadership of each Class I railroad to discuss its safety performance. (pp. 12-13)

The GAO report, *Preliminary Observations on Federal Rail Safety Oversight and Positive Train Control Implementation*[383] stated (GAO 2013a):

> The FRA primarily monitors railroads' compliance, with federal safety regulations, through routine inspections by individual inspectors at specific sites on railroads' systems. Thirty states also employ railroad safety inspectors, who participate in a partnership program with FRA to conduct supplemental safety oversight activities based on FRA rail safety regulations and enforce state railroad safety laws. FRA applies a quantitative, risk-based approach, the National Inspection Plan, to inform its rail safety oversight efforts using analyses of past accident and inspection data and other information to target inspections in each region.... (GAO Highlights)
>
> FRA provides regulatory oversight of the safety of U.S. railroads, both passenger and freight. FRA develops and enforces regulations for the railroad industry that include numerous requirements related to safety, including requirements governing track; signal and train control systems; grade-crossing warning device systems; mechanical equipment, such as locomotives and tank cars; and railroad-operating practices. FRA also enforces hazardous materials regulations that relate to the safe transportation of such materials by rail.... (p. 3)
>
> [FRA's] inspection approach focuses on direct observations of train components, related equipment, and railroad property—including the track and signal systems—as well as operating practices to determine whether they meet FRA's standards. Inspectors also examine railroads' inspection and maintenance records. FRA's inspectors generally specialize in one of five areas, called inspection disciplines: (1) operating practices, (2) track, (3) hazardous materials, (4) signal and train control, and (5) motive power and equipment. Inspectors typically cover a range of standards within their discipline during inspections. FRA's policy is for inspectors to encourage railroads to comply with federal rail safety regulations voluntarily. When railroads do not comply voluntarily or identified problems are serious, FRA may cite violations and in certain instances take enforcement actions, including the assessment of civil penalties, to ensure compliance. (p. 6)
>
> FRA trains and certifies state inspectors and includes them in its inspection planning efforts. However, FRA's relationship and coordination with each state is unique. According to FRA officials, while state inspectors ensure compliance with state requirements, state inspectors are also responsible for ensuring compliance with federal safety regulations.
>
> In addition to federal and state inspectors, the railroads have their own inspectors who are responsible for ensuring that railroad equipment, track, and operations meet federal rail safety standards. Each railroad has its own inspectors or contracts with third parties to conduct the required inspections depending on the railroad's resources and FRA-mandated inspection responsibilities. (pp. 6-7)

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[383] GAO, Preliminary Observations on Federal Rail Safety Oversight and Positive Train Control Implementation, GAO-13-679T: Published: Jun 19, 2013

Railroad Safety Advisory Committee (RSAC) organization

RSAC history

As stated on the Rail Safety Advisory Committee website:

> In 1996, the FRA established the [RSAC] process, with all segments of the rail community working together to fashion mutually satisfactory solutions on safety regulatory issues.

The FRA implemented this collaborative approach to developing and issuing rail safety rules and regulations by creating the Railroad Safety Advisory Committee (RSAC). The RSAC includes stakeholders in the rail community such as government entities, railroads, rail labor organizations, trade associations, suppliers, and others that work with FRA to develop solutions to railroad safety and regulatory issues. FRA develops and issues rail safety rules and regulations while involving RSAC members in the rulemaking process. The RSAC recommendations are advisory, and FRA may deviate from them, if it so chooses.

RSAC purpose

As stated on the Rail Safety Advisory Committee website:

> The Committee's purpose is to seek agreement on the facts and data underlying any real or perceived safety problems; identify cost effective solutions based on the agreed-upon facts; and identify regulatory options where necessary to implement those solutions.

RSAC regulatory philosophy

As stated on the Rail Safety Advisory Committee website:

> Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people. In deciding whether and how to regulate, agencies should assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires another regulatory approach.
>
> The resultant rules must be reasonable, clear, effective, and enforceable; impose as small a burden as is practicable; and shall, to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt.

> The RSAC will provide advice and recommendations to the Federal Railroad Administration (FRA) regarding the development of the railroad safety regulatory program, including issuance of new regulations, review and revision of existing regulations, and identification of non-regulatory alternatives for improvement of railroad safety. Of course, the RSAC's own resource limitations will not permit FRA to refer every safety regulatory task to the RSAC. Moreover, on occasion, the need to address a safety issue in a very expedited way will preclude such a referral.
>
> It is FRA's policy to utilize consensus recommendations of the RSAC as the basis of proposed and final agency action, whenever possible, consistent with applicable law, including guidance from the President. In considering whether to adopt RSAC recommendations, the Administrator weighs the interests of the public at large and the ability of the agency to administer, and, if necessary, to enforce, any requirements that would result from final agency action.
>
> FRA will consult with the RSAC on a periodic basis regarding the development of its regulatory program, advising the RSAC of emerging issues, statutory requirements, and other identified needs. It is the intent of the FRA to consider the views of RSAC members in determining regulatory priorities.
>
> The RSAC provides advice and recommendations on specific tasks assigned to it by FRA. Whenever possible, FRA will consult with the RSAC prior to assigning a task to the committee. As each task is assigned, the RSAC may elect to accept or reject the task, or to recommend that the task be restructured. When a task is assigned, FRA sets a target date for the presentation of the RSAC's recommendations to the Administrator. The target date is based on consultation with the RSAC and may be adjusted by FRA based on further consultation. FRA may withdraw a task from the RSAC at any time. FRA will provide the RSAC an explanation when it does so.

RSAC task process

As stated in the FRA RSAC fact sheet[384]:

> RSAC Background
>
> As a Federal Advisory Committee, RSAC provides input to the FRA regarding the development of new regulations, the review and revision of existing regulations, statutory requirements, and identification of non-regulatory alternatives for the improvement of railroad safety in the United States. RSAC also provides advice and recommendations on specific tasks assigned to it by FRA, which the agency utilizes as the basis for some proposed and final regulatory actions.
>
> RSAC Process
>
> - FRA identifies a problem that may be solved through regulatory action. FRA sends a written problem statement to RSAC in the form of a "formal task."

[384] https://www.fra.dot.gov/eLib/details/L17340#p1_z5_gD_krsac

- RSAC may accept or reject the task or ask that it be restructured.
- Once accepted RSAC establishes a working group with the necessary expertise to define the safety problem presented, gather relevant facts, develop a range of options, and decide upon a recommended option.
- When a task is assigned, FRA sets a target date for the presentation of the RSAC's recommendations to the FRA Administrator. FRA may withdraw a task from the RSAC at any time and promulgate a rule through traditional rulemaking.
- RSAC receives the working group report and considers whether to adopt the recommendations.
- Once adopted, RSAC makes recommendations to the FRA Administrator for action. Following the FRA Administrator's approval, FRA publishes proposed and final rulemaking actions.

Selected RSAC tasks, 2010–2019

Major tasks that the RSAC has addressed, or is currently addressing, are listed in the RSAC website[385] under the RSAC Task tab. Some examples of these tasks are shown below and the more extensive listing and descriptions of the tasks can be found on the website.

- Speed Enforcement Wayside Warning Signs
- Hazardous Materials Issues/2015-5
- Rail Integrity III/2015-03
- Track Geometry/2015-02
- Track Subpart F Inspection/2015-01
- Rail Integrity/2014-02
- Train Crew Size/2013-05
- Operational Testing for Securement/2013-03
- Hazardous Materials Issues/2013-02
- Rail Failure/2012-01
- Risk Reduction/2011-04
- Fatigue Management Plans/2011-03
- Minimum Training Standards and Plans/2010-01

Association of State Railroad Safety Managers

States active in rail safety regulation have formed the Association of State Rail Safety Program Managers, a FRA-supported state organization committed to safe rail transportation. The purpose of this organization, as outlined in its Articles of Association,[386] are to "…support, encourage, develop, and enhance railroad safety, especially through the Federal/State Railroad Safety

[385] Federal Railroad Administration website. Railroad Safety Advisory Committee. RSAC Tasks. https://rsac.fra.dot.gov/tasks
[386] Association of State Rail Safety Program Managers. Articles of Association. https://railsafety.idaho.gov/Docs/articles%20of%20association.doc

Programs as established and defined by the Federal Railroad Safety Act of 1970, as amended, and other laws relative to railroad safety."

As stated in *The State Rail Safety Participation Program*[387]:

> A principle motivation for establishing a formal organization of State managers was to attain greater uniformity among States in conducting rail regulatory activities and to enable States to speak with a collective voice on rail safety topics and develop unified positions in its dealings with FRA. (p. 73)

As stated in the Articles of Association:

> The Association shall support, encourage, develop, and enhance railroad safety, especially through the Federal/State Railroad Safety Programs as established and defined by the Federal Railroad Safety Act of 1970, as amended, and other laws relative to railroad safety.
>
> The Association shall promote railroad safety in all United States by encouraging consistent and uniform application and enforcement of railroad safety regulations and the promulgation of effective federal regulations.
>
> The objectives of the Association are as follows:
>
> - To enhance the exchange of ideas and encourage teamwork within the State Rail Safety Participation Program;
> - To promote professionalism within the State Rail Safety Participation Program;
> - To facilitate the exchange of information among the states and to aid all states in meeting their individual safety goals;
> - To ensure the interests of State Rail Safety Participation Program are effectively represented in all venues;
> - To encourage the growth and vitality of the State Rail Safety Participation Program; and
> - To formulate consensus policy positions on state rail safety concerns and effectively communicate those positions. (p. 1)

The State of Washington, Region 8, is a participant in this Association.

United States Coast Guard advisory committees

The Federal Advisory Committee Act (FACA) of 1972 (Public Law 92-463, October 6, 1972), allows the federal government to seek the advice of citizens on a range of issues affecting policies and programs. Approximately 1,000 advisory committees are in existence at any given

[387] http://www.railsafety.idaho.gov/Docs/managers%20hand%20book.pdf

time. Each advisory committee must adhere strictly with FACA requirements, the Freedom of Information Act, and related regulations.

As stated on the USCG website[388]:

> The U.S. Coast Guard uses Federal Advisory Committees as advisors on a range of topics.[389] Each Committee has its own charter, and as a result, committees may be different from one another. Under the authority of FACA, the Secretary of the Department of Homeland Security, through the Commandant of the Coast Guard, has delegated the Assistant Commandant for Marine Safety and Environmental Protection the responsibility to oversee and utilize the Towing Safety Advisory Committee (TSAC). The Committee serves in an advisory capacity to the Secretary of Department of Homeland Security, via the Commandant, U.S. Coast Guard, on matters relating to the safety of the offshore mineral and energy industries.

Examples of USCG Safety Advisory Committees are:

- Towing Safety Advisory Committee
- Great Lakes Pilotage Advisory Committee
- National Maritime Security Advisory Committee
- National Mariner Medical Advisory Committee
- Merchant Marine Personnel Advisory Committee
- Lower Mississippi River Waterway Safety Advisory Committee
- Houston/Galveston Navigation Safety Advisory Committee
- National Offshore Safety Advisory Committee
- Chemical Transportation Advisory Committee
- Commercial Fishery Safety Advisory Committee

Using the Towing Safety Advisory Committee (TSAC) as an example, as stated on TSAC section of the USCG website:[390]

> The Committee consists of 18 members with expertise, knowledge and experience regarding shallow draft inland and coastal waterway navigation in the commercial towing industry. The Army Corps of Engineers and the Maritime Administration may also designate a representative to serve a three-year term, except that members appointed to fill a vacancy, which is not caused by the end of a term, may also serve the remainder of that individual's term. In addition to the members of TSAC, numerous other persons with equal experience and experience serve on TSAC's various subcommittees. All the TSAC members are volunteers, entitled to receive compensation for one public meeting per year. Committee members may

[388] US Coast Guard website. National Offshore Safety Advisory Committee. https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Commercial-Regulations-standards-CG-5PS/Office-of-Operating-and-Environmental-Standards/vfos/NOSAC/
[389] US Coast Guard website. Partnerships. https://www.work.uscg.mil/Partnerships/
[390] US Coast Guard website. National Offshore Safety Advisory Committee. https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Commercial-Regulations-standards-CG-5PS/Office-of-Operating-and-Environmental-Standards/vfos/NOSAC/

> serve up to two, 3-year terms. Two Committee members are elected as Chairman and Vice-Chairman to serve as the presiding officers on the Committee. The Committee also has a Designated Federal Officer, who is a full-time Coast Guard official. This individual furnishes administrative and staff support to the Committee. The DFO or Assistant Designated Federal Officer (ADFO) must be present at each Committee meeting.

United States Coast Guard Harbor Safety Committees

Harbor Safety Committees (HSCs) are local port/area committees that address issues that may include the safety, security, mobility, and environmental protection of a port or waterway. Membership in these advisory committees are typically composed of representatives of governmental agencies, maritime labor, industry organizations, and public interest groups. The participants in these committees work together to achieve mutual benefits for all port users primarily focusing on the need to ensure internal communications amongst all stakeholders within the port (USCG 2000).

As stated in the *USCG Harbor Safety Committee Desk Reference*[391] (USCG 2008):

> The US Coast Guard (USCG) long ago recognized the importance of local advisory committees as one of the keys to safe, efficient, and environmentally sound port/navigable waterway operations. Port complexes, along with their associated waterways and shoreside terminals are diverse in infrastructure, management, function, and markets served. Local Harbor Safety Committees are often the only venue available to owner/operators and other port stakeholders that enables these wide ranging port activity and interests to organize in a coordinated way to evaluate and resolve issues that affect port operations. Harbor Safety Committees become involved in all facets of port activities, including safety and navigation (including the maintenance and focus on aids to navigation), port congestion, traffic management, commercial issues and recreational issues, dredging, establishing a Vessel Traffic System (VTS), port competitiveness, and overall port and waterway management.
>
> The following list of Harbor Safety Committee participants, as shown in the *Harbor Safety Committee Desk Reference*, is not all-inclusive and one must be cognizant that each region's membership can be different (many include Environmental NGOs, Tribes, Public at Large, Ferries, and Recreational Boating interests), the participants within the Harbor Safety Committees are relatively consistent across all port areas and include most of these port stakeholder entities:
>
> - Port Authorities
> - Vessel owners and operators (tankers, dry cargo, barges, ferries)
> - Harbor pilots and pilot associations
> - Marine Exchanges

391 https://homeport.uscg.mil/Lists/Content/Attachments/14272/Harbor%20Safety%20Committee%20Desk%20Reference.pdf

> - Docking pilots
> - Tug and tow operators
> - Shipping agents
> - Terminal operators
> - Industry associations (national, state, and local)
> - Organized Labor
> - Commercial Fishing Industry Associations
> - State / Local Government agencies:
>   - Environmental Agencies
>   - Maritime Administrations
>   - Regional Development Agencies
>   - Emergency Management Agencies
>   - LEPC (fire and police departments, harbor masters)
> - Federal Government representatives:
>   - U.S. Coast Guard (USCG)
>   - National Oceanographic and Atmospheric Administration (NOAA) Hydrographic Group
>   - U.S. Army Corps of Engineers (USACE)
>
> The Harbor Safety Committee fulfills the USCG's need to establish partnerships that ensure that the port is effectively, safely, and securely, managed; and members of the port community are communicating with the USCG and with one another. (pp. 1-3)

In *A Word on Vessel Traffic Service*, Captain John Denham helps explain the purpose of a VTS (February 2008):

> The purpose of a (VTS) is to provide active monitoring and navigational advice for vessels in particularly confined and busy waterways. There are two main types of VTS, surveilled and non-surveilled. Surveilled systems consist of one or more land-based sensors (i.e. radar, AIS and closed-circuit television sites), which output their signals to a central location where operators monitor and manage vessel traffic movement. Non-surveilled systems consist of one or more reporting points at which ships are required to report their identity, course, speed, and other data to the monitoring authority. They encompass a wide range of techniques and capabilities aimed at preventing vessel collisions, rammings, and groundings in the harbor, harbor approach and inland waterway phase of navigation. They are also designed to expedite ship movements, increase transportation system efficiency, and improve all-weather operating capability.

Harbor Safety Committee meetings are open to the public. Industry stakeholders have expressed the need to provide input on decisions that affect their industry and livelihood. Industry stakeholders have an extensive knowledge of the waterway and their experiences, which allows them to suggest measures to reduce risks and offer valuable advice on related issues. Industry stakeholders believe that it is important for the Captain of the Port (COTP) to maintain a non-regulatory role within the Harbor Safety Committee thus within the scope of the local HSCs, the USCG works with industry as a partner versus a regulator which leads to a more open and honest dialog.

Potential framework for Washington State Rail Safety Committee

In February and March 2019, a draft framework was developed for a Washington State Rail Safety Committee (RSC).[392] It should be noted that Washington State does not yet have a formalized functioning Washington State Rail Safety Committee — the purpose is to establish a Washington State Rail Safety Committee. The following is the draft framework, drafted by the Department of Ecology in May 2019.

Purpose

The purpose of a Washington State Rail Safety Committee would be to proactively address, identify, assess, plan, communicate, and employ operational measures and best practices beyond — but not in conflict with — existing laws and regulations to promote safety, security, and environmental stewardship, allowing industry, regulators, and stakeholders to address issues of significant importance while avoiding preemption issues.

The Committee could be formed and chartered to:

- Provide a proactive forum for identifying, assessing, planning, communicating and implementing operational and environmental measures that promote safe and efficient use of rail in the State of Washington.
- Act as an education and resource network through which ideas, materials and procedures can be provided to persons interested in rail safety and operations.
- Develop Standards of Care and guidelines that promote improved operational and environmental safety.
- Act as a resource at the request of governmental bodies and individual legislators regarding issues related to rail operations, safety, security and environmental issues.
- Promote and sustain the goals of rail safety and environmental programs.
- Ensure that rail safety and environmental measures are coordinated with security initiatives.

Membership

General membership would be responsible for providing direction and support in all areas of the Committee's work. General membership could consist of one representative from each of the following groups:

- Two Mainline seats, with one representative from BNSF Railway and one from Union Pacific Railroad.
- One Short Line seat.
- Two Rail Labor seats, with one rep from Brotherhood of Locomotive Engineers and Trainmen and one from International Association of Sheet Metal, Air, Rail and Transportation Workers.
- One Emergency Response seat.

[392] Note this is subject to change.

- Two Tribal seats.
- One Public at Large seat.
- One Environmental seat.
- One City seat.
- One County seat.
- Three State seats, with one representative from the Department of Transportation, one from the Utilities and Transportation Commission, and one from the Department of Ecology.
- One Federal seat, with a representative from the Federal Rail Administration.

Governance

A Board of Directors could be formed to govern the Washington State Rail Safety Committee. The Board could consist of a Chair, Vice Chair, and Secretary. Each Board member could serve a two-year term and should be nominated and elected by the General Membership at the last meeting of each two-year term.

Duties of the Chair might include:

- Set dates and locations for meetings.
- Establish and distribute the agenda.
- Chair meetings.
- Act as a liaison between the Committee and other entities.
- Appoint Sub-Committee chairs.

Duties of the Vice Chair might include:

- Preside at the request of, or in the absence of, the Chair.
- Ensure that work done by Sub-Committees is documented and tracked such that issues are resolved in an appropriate and timely manner.
- Assist the Chair as required.

Duties of the Secretary might include:

- Manage, record, and publish records of the business of the Committee.
- Conduct correspondence for the Committee.

Sub-committees

Sub-committees could be established by the General Membership as needed for specific tasks. The Committee Chair could appoint a Sub-committee Chair who would determine committee membership appropriate to the subject matter. Sub-committee Chairs would be responsible for populating their committees with individuals who could provide expertise, perspective, and a diversity of viewpoints. Sub-committees could submit their findings and recommendations to the full Rail Safety Committee during regular meetings for action. Sub-committees could terminate at the completion of the project, time allotted, or other as determined by the Rail Safety Committee.

Meetings

A minimum of two regular meetings could be considered to be held annually, although it is anticipated that quarterly meetings could be held as the Committee develops and matures over time. The location of the two regular meetings could alternate between Spokane and Seattle, and quarterly meeting locations would ideally rotate through locations in Spokane, the Tri-Cities, Vancouver, and Seattle.

The location and date of the two regular meetings could be set by the Board of Directors and announced to the membership and general public at least two weeks in advance of the meeting.

Meetings could be open to all interested representatives of rail user groups and other interested members of the public. Any person may approach Committee Members or the Board of Directors to propose agenda items or topics for consideration at a regular meeting.

Potential considerations for an RSC

Some of the points that the RSC Implementation Workgroup may consider in the development of the RSC are:

- **The Right Approach.** Governmental agencies often rely on a regulatory approach to redress public risks and environmental issues, but this approach requires a high level of familiarity and understanding of the regulated community. With the rail industry, federal preemption has served to limit state and local agencies' ability to interact with the rail industry. This long-standing arrangement makes it difficult for agencies to develop appropriate regulatory requirements that offer further protection of public safety and the environment without impeding rail operations, freight mobility, and commerce in unforeseen or inequitable ways. Since an RSC is not a regulatory body or an Advisory Committee but is voluntary in all aspects, it offers a safe environment to collaborate on improving safety.
- **The Right Forum.** An open dialogue between industry, agencies, and public stakeholders requires a "safe place" for groups on both sides to advocate concerns and priorities. An RSC will serve as an open forum to facilitate communication and foster common understanding among all parties.
- **The Harbor Safety Committee Model.** The maritime community employs a Harbor Safety Committee (HSC) model to address issues of national and local importance without dealing with similar preemption issues. HSCs have been recognized as a leading cause of increasing safety in the maritime community, with the NTSB using those groups to identify safety risks, and where necessary, develop mitigation practices to address identified risks, such as voluntary standards of care, or emphasis on existing regulations/standards. It is common for state legislatures to ask these committees to deliberate on certain applicable issues with an eye on a possible voluntary safety standard.
- **Voluntary Safety Standards / Standards of Care for Rail.** The RSC would be charged with development of voluntary safety standards for identified risks and areas of concern to include, but not be limited to, hurdles and issues surrounding the adoption and implementation of positive train control, inspection standards for track, bridges, trestles and equipment, the benefits and hurdles of drone technology in industry inspections,

impact of training and qualifications on rail safety, preparedness, and emergency response practices.

- **Flexibility for Industry and State of Washington.** The voluntary safety standards can be tailored to fit Washington's unique needs and culture, while acknowledging the inherent need for some level of national standardization across state boundaries.
- **A System of Peers.** Under the HSC model, instances of non-compliance with the Standards of Care are identified, investigated, and discussed by the committee members, which include industry peers. The results of this process uncover underlying cause and inform an appropriate response, whether it be educational outreach or written admonishment or improvements through revisions to the Standards of Care. It is anticipated that the RSC would follow a similar arc. A peer-driven system can better understand and manage non-compliance issues within the industry, while still allowing for enforcement of federal regulations.
- **Benefits for the Industry.** A regulatory framework tends to approach compliance enforcement through penalties, but the RSC can offer a potential for benefits to industry, through compliance with voluntary safety standards, like the HSCs' Harbor Safety Plan Standards of Care approach. These benefits include partnerships and positive relationships with the public, federal/state/local governments, tribes, environmental organizations, industry, and others as applicable and would foster economic benefits associated with reduced accidents, injuries, and lawsuits. Again, the RSC would in no way preclude enforcement of federal regulations when needed.
- **This is the Right Time for the Rail Safety Committee.** UTC and Ecology are presently writing this rail safety technical paper to assist in the development and implementation of a Washington RSC and development of a rail risk/safety model and GIS spatial component. The project is a timely opportunity for the new committee to collaborate on safety concerns, and could even be used to help develop a Washington Rail Safety Plan with strong voluntary Safety Standards/Standards of Care right out of the gate.

The RSC Implementation Workgroup envisions that the WA RSC will:

- Provide a proactive forum for identifying, assessing, planning, communicating, and implementing voluntary operational measures and practices that promote efficient use of rail in Washington State while ensuring public safety and environmental protection.
- Act as an education and resource network through which ideas, materials, and procedures can be provided to people interested in rail safety and operations.
- Develop written, voluntary Safety Standards/Standards of Care and guidelines that promote improved operational and environmental safety.
- Act as a resource at the request of governmental bodies and individual legislators regarding issues related to rail operations, safety, security, and environmental issues.
- Promote and sustain the goals of rail safety and environmental programs.
- Ensure that rail safety and environmental measures are coordinated with security initiatives.

Potential areas of future discussion

- Washington State should consider developing a charter for a Washington State Railroad Safety Committee (RSC). This committee would consist of invited volunteers enlisted from a wide range of associated railroad transportation-related stakeholders. The charter should state specifically the purpose and mission of the RSC.
- The UTC, which has the broadest experience in interstate and intrastate rail transportation monitoring and issues, may be best positioned initially to chair the Committee. The chair position would involve other members to include industry and labor as it matures. The chair is a rotating position after a one- or two-year voluntary/elected appointment.
- The Committee, as a whole, in addition to development of potential various sub-committees, may wish to invite appropriate BNSF and UP personnel (operating, maintenance, signal, etc.) to meet with each or various sub-committees for a question and answer session. Railway personnel participation may require time and expense compensation.
- One member of the RSC should be the current Washington State representative to the Association of State Railroad Safety Managers (ASRSM). The ASRSM is a member of the Railroad Safety Advisory Committee (RSAC) of the FRA. The WSRSC member would then be the liaison between the WSRSC and the ASRSM, which would provide the communication and partnership link between Washington State and the RSAC/FRA. This partnership would provide the linkage for Washington State to gather in-state rail expertise and in-state rail issues for the purpose of ensuring local and regional interests are placed on the RSAC/FRA agenda for discussion/evaluation and vice versa. This would ensure that FRA/RSAC activities are adequately communicated and evaluated by the local/regional rail interests in Washington State.
- Based on stakeholder interests, individual committees be formed to consider particular concerns, but with the understanding of the regulatory restrictions.
- The RSC would presumably be composed of a wide range of stakeholders with varying concerns, as well as different degrees of knowledge about railroads. Based on the experience of the authors of this report, there are a few perspectives that might prove to be helpful to formulating the mission of the committee, including:
    - Railroads serve a vital purpose in the economy and society of Washington State by transporting a wide variety of commodities for industry and consumers, as well as transporting passengers to work and other destinations.
    - Railroads do not benefit from derailments, and, in fact, experience significant consequences from these incidents due to the economic effect on bottom line costs and adverse public reaction, whether they are self-insured or not.
    - Interstate railroads are regulated by the Surface Transportation Board (STB), under the ICC Act, as amended, and the FRA. As a result, Washington State and the UTC has limited regulatory authority to govern Class I railroads as federal regulations prevail.

Washington State and the UTC have greater regulatory authority over intrastate (short line) railways — railways whose operations do not extend past the state. The Committee would need to recognize and understand federal regulatory oversight of interstate transportation, including railroads.

Chapter 20: Insurance Standards & Practices for Railroads Moving Hazardous Materials

Key questions

- How are railroads insured for accidents involving hazardous materials?
- What standards and practices are currently in place in Washington after the *2014 Marine and Rail Oil Transportation Study*?
- Do standards and practices in Washington differ from those in other states?
- What are the liability limits of railroads that are involved in major hazmat spills?

Takeaways

- Shoreside facilities, rail tank cars, pipelines and marine tank vessels that produce, transport or store large volumes of oil have the potential to cause significant environmental and economic damage to resources if an oil spill were to occur. The federal government and certain states require owner/operators, e.g., responsible parties, to meet spill prevention and response standards. These owner/operators must meet minimum financial standards to mitigate damages from an oil spill incident. This requirement is termed "proof of financial responsibility." An owner/operator's access to funds can be a key component in being authorized to operate in U.S. waters or in certain state territorial waters.
- Owner/operators of the following types of facilities and equipment could be required to offer proof of financial responsibility in order to be legally able to operate in the U.S. and in certain states:
    - Oil tank farms
    - Crude oil transmission pipelines
    - Offshore oil platforms
    - Oil and gas exploration projects
    - Oil production facilities
    - Refineries
    - Oil tankers
    - Oil barges
    - Nontank vessels
    - Railroad tank car operators
    - Underground storage tanks
- Proof of financial responsibility may include:
    - Oil pollution insurance
    - Self-insurance
    - Surety bond
    - Letter of credit
    - Certificate of deposit
    - Financial guaranty
    - Protection and indemnity (P&I) coverage

- Both Alaska and California have implemented the financial responsibility requirements for rail carriers, and the courts seemed to have resolved the legal issue of state versus federal authority pursuant to this issue.
- As of September 2018, not all railroads mention insurance in their Washington State oil spill contingency plans.

The following sections provide a more in-depth look at insurance and financial issues associated with the movement of hazardous materials by rail.

Recommendation from *2014 Marine & Rail Study*

The *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015) included a recommendation to modify statutory authority to extend financial responsibility requirements to rail and mobile facilities and enable Ecology to modify the regulations on financial responsibility requirements. By requiring Certificates of Financial Responsibility (COFR), Ecology can ensure that companies transporting oil through the state can pay for cleanup costs and damages from oil spills.

Washington State has not yet established a level of financial responsibility for oil handling facilities, including rail.

The United States has established a spill response framework based on the premise that the "polluter pays" for oil spills and that the polluter — also known as the responsible party — is required to clean up the consequences of that oil spill. Both the federal government and Washington State have laws and rules that require certain oil handlers to demonstrate evidence of their financial ability to pay for the removal of oil spills, for natural resource damages, and for other expenses related to spill responses.

"Financial responsibility" refers to the proof or demonstration that a responsible party has the financial resources to pay for the costs and damages of a spill, up to a specified amount. Typically, financial responsibility is evidenced by an insurance policy or Protection and Indemnity (P&I) club documents, but it also may involve surety bonds, guarantees, letters of credit, or qualification for self-insurance. Washington State has not established financial responsibility levels for facilities, which include fixed, mobile facilities, and rail while train is stopped and transferring oil.

Tank cars are mostly owned by shippers and leasing corporations, not railroads. By law, the operator of any railroad in the U.S. cannot refuse to transport any cargo, no matter how hazardous, provided it conforms to applicable regulations.

Marine carriers can limit their liability as a condition of carriage. But, uniquely in the case of rail, the railroad operator cannot insist on an agreement sharing the risk with the shipper. The railroad operator is liable for all costs in the event of an accident up to an unlimited amount.

Smaller, local railroads carry relatively small liability limits. For example, MMA (Montreal Maine & Atlantic) had only $25 million in liability coverage with XL Insurance Co. Ltd. in the Lac-Mégantic incident.

In contrast, the eight U.S. and Canadian Class I railroads generally carry more than $1 billion in liability coverage. Class I railroads buy available market limits up to $1.5 billion excess of retentions of $25 million to $50 million or more.

Class II regional railroads typically buy $25 million to $50 million in limits, with some buying up to $100 million, while short-lines may buy as little as $5 million to $10 million.

Railroads have a common carrier obligation to transport all goods offered for transportation, including hazardous materials. This obligation ensures that railroads do not unreasonably discriminate between shippers. Therefore, railroads may not refuse shipment based on inconvenience or lack of profitability. Multiple parties are involved in the preparation, bulk packaging, handling and transportation of crude oil, yet the liability for an incident largely falls upon the transporter/responsible party (e.g., the railroad).

The impacts of a catastrophic incident can be high in cleanup costs, natural resources damages, damages to real and personal property, claims from personal injuries, and fatalities. These costs may exceed the ability for the responsible party to fully compensate and or pay for. Sufficient insurance coverage for these potential incident costs may not be available to the responsible party. There is no requirement for rail carriers to provide any level of financial guarantees concerning ability to cover potential incident costs.

Current Washington State requirements

Engrossed Substitute House Bill 1449, Chapter 274, Laws of 2015, adopted financial responsibility reporting requirements that railroads hauling crude oil must include in the annual reports they submit to the Washington Utilities and Transportation Commission (UTC).

The Washington State law requires that:

> Railroads that transport oil as bulk cargo must provide information to the UTC regarding their ability to pay for a reasonable worst-case spill of oil, an amount that is to be calculated by multiplying the reasonable anticipated per-barrel cleanup costs by the reasonable worst-case spill volume. This information is to be provided to the UTC as part of railroad's annual report, and the UTC may not use this information to economically regulate or penalize a railroad.

Requirements in other states

Alaska

Alaska statutes 46.04.040 and 46.04.055, which address financial responsibility and non-tank vessels, respectively, require proof of an operator's financial ability to respond to damage claims resulting from an oil discharge. This is termed “proof of financial responsibility.” The statutes and their defining regulations described on the Division of Spill Prevention and Response website and in the Alaska Administrative Code (18 AAC 75, Article 2):

> Prior to operating in Alaska, the following operations need approved proof of financial responsibility.

For rolling stock (railroad tank cars) used to transport oil or petroleum products in bulk as cargo, the following regulations apply:

- Application Deadline: At least 15 days prior to operation in Alaska, "*under specific conditions the department will consider applications received in shorter timeframes, see 18 AAC 75.205b (3),"* for a railroad tank car, by the owner or operator of the railroad tank car.
- Types of Proof of Financial Responsibility: Insurance, Self-insurance, Surety bond, Guaranty, Letter of Credit, Certificate of Deposit, P&I Certificate of Entry
- Dollar Amounts for Evidence of Financial Responsibility (October 1, 2017–September 30, 2020) for Non-Tank Vessel or Railroad Tank Cars:
    - Predominantly Persistent Product: $561.30 per incident, per barrel multiplier, with a $9,355,000 minimum
    - Predominantly Non-Persistent Product: $187.10 per incident, per barrel multiplier, with a $1,871,000 minimum.

For both Non-tank Vessels and Railroad Tank Cars:

- A person may not transport oil by railroad tank car or cause or permit the transfer of oil to or from a railroad tank car unless the person has furnished to the department and the department has approved proof of financial ability to respond to damages meeting the requirements of AS 46.04.040. Proof of financial responsibility required under this subsection is subject to adjustment of dollar amounts which are established at:
    - $300 per incident for each barrel of persistent product based on the maximum amount of persistent product storage capacity of any train on the railroad; and
    - $100 per incident for each barrel of non-persistent product based upon the maximum amount of non-persistent product storage capacity of any train on the railroad or $1 million, whichever is greater.

Response planning standards apply to non-tank vessels and railroad tank cars as follows:

For a railroad tank car:

- Containment and control of 15 percent of the maximum oil capacity of a train on the railroad within 48 hours; and
- Cleanup of the discharge within the shortest possible time consistent with minimizing damage to the environment."
- "An applicant may provide evidence of financial responsibility by proof of entry of the non-tank vessel in a protection and indemnity association or proof of coverage with another insurer that:
- Is financially solvent and has a favorable history of claim handling;
- Provides coverage against pollution risks in at least the amount of the financial responsibility required under (a) of this section without any requirement for a special endorsement;
- Does not agree to be subject to direct action in court or to appointment of an agent for service of process; and

- In the case of a protection and indemnity association or group of insureds, is not authorized by the Department of Commerce, Community, and Economic Development to sell insurance in the state so long as it is not listed by the Department of Commerce, Community, and Economic Development as being disapproved for use in the state.[393]

California

For railroads transporting oil as cargo, the product of the reasonable worst-case scenario volume measured in barrels (as determined in the applicant's oil spill contingency plan) multiplied by $10,000 up to a $100 million maximum.

Per the law as stated by the California Fish & Wildlife[394]:

> Insurance, self insurance, guaranty, letter of credit, certificate of deposits, surety bonds, Protection and Indemnity Club membership, a combination of methods, or other methods acceptable to the administrator. In order to maintain a COFR, the applicant (for most demonstrating methods of F.R.) is required to annually provide evidence of renewed F.R. Additionally, prior to the expiration of the COFR a renewal application must be submitted. During the time the COFR is valid, changes to the method of demonstrating F.R., or changes to the operation of the vessel or facility must be reported to the Oil Spill Prevention and Response Program.

As per Title 14-Subchapter 3, Section 817.04, Oil Spill Contingency Plans:

> C. Railroad. The reasonable worst case spill volume for a railroad is based on the railroad's maximum speed in California as stated in the most recent timetable the railroad has filed with the (FRA), and the amount of oil in bulk transported. Regardless of speed or track class, the minimum reasonable worst-case spill (RWCS) volume for a railroad is the largest single tank car the railroad may include in a consist. If a railroad moves more than one tank car in a consist then the reasonable worst-case spill volume is based on the larger of either the volume of one tank car or a percentage of the total oil in bulk transported, as (in Table 123).

Table 123: California Railroad Reasonable Worst-Case Spill (RWCS) Volumes[395]

Maximum Speed per Timetable	RWCS Volume
10 mph	Greater of: One tank car or 1% of all oil in bulk
25 mph	Greater of: One tank car or 5% of all oil in bulk
Greater than 25 mph	Greater of: One tank car or 20% of all oil in bulk

Based on these values, the RWCS volume for a typical CBR unit train traveling at speeds greater than 25 mph and consisting of 118 cars would be 16,850 bbl. The calculated cost at $10,000 per

[393] https://dec.alaska.gov/spar/ppr/contingency-plans/financial-responsibility/apply-for-fr/
https://www.akleg.gov/basis/statutes.asp#46.03.100
https://www.akleg.gov/basis/statutes.asp#46.04.055
[394] https://www.wildlife.ca.gov/OSPR/Financial-Responsibility/Requirements
[395] California Department of Fish and Wildlife.

bbl. times the volume would come to $168.5 million. However, with the $100 million cap, the financial responsibility requirement would be $100 million.

Railroad liability for oil spills

Liability under the Oil Pollution Act (OPA) of 1990 results from the risk of an oil spill reaching the "navigable waters of the United States." This includes oil that is spilled from rail tank cars or locomotives.

While the federal Resource Conservation and Recovery Act (RCRA) is a federal hazardous waste act, some of RCRA's provisions extend beyond chemical waste regulation. RCRA does prohibit the dumping of any waste EPA determines to be hazardous and imposes substantial administrative, civil and criminal penalties for the open dumping of such waste.

The EPA has determined by regulation that wastes having a flash point of 60ºC (140ºF) are to be considered "hazardous" for regulatory purposes. Thus, a determination of open dumping of these hazardous wastes, in violation of federal law, can be found, if oil exhibiting the threshold flash point is spilled from a rail car and contaminates soil or water.

Terrence M. Fay states in his write up in the Liability Under Federal Law from Crude Oil Spills from Rail Cars, (Thomson Hines, Oil & Gas Monitor, 2015):[396]

> However, even if the hazardous waste material generated by a crude oil spill does not have the requisite flash point, RCRA still affords a mechanism, both to the government and to private citizens impacted by such a spill, to seek redress. Section 7003 of RCRA allows EPA to seek injunctive (cleanup) relief against any person who contributes to the past or present handling, transportation or disposal of solid or hazardous waste if an "imminent and substantial endangerment" to the public health, safety or environment is created thereby. Oil-contaminated soil, at least, will likely be a "solid waste" for purposes of RCRA Section 7003. RCRA Section 7002 provides a tandem citizen suit remedy for private parties to seek injunctive (cleanup) relief if the government declines to act against the responsible party after receiving proper notice. In either case, "liability will fall upon any person found to have "contributed" to the disposal of the solid waste posing the imminent and substantial endangerment, in this instance the soil and, possibly, the water contaminated with oil from the spill…
>
> In addition to the OPA and RCRA, liability for oil spills can be triggered under Section 112 of the federal Clean Air Act (CAA). Section 112(r) was originally intended to protect against the accidental emission of air pollutants, including volatile hydrocarbon emissions that might accompany a crude oil spill, from what is referred to as a "stationary source" (as distinguished from a "mobile source," such as a locomotive). Section 112(r)(1) is known as the General Duty Clause, and it requires owners and operators to identify hazards, design and maintain a

[396] Fay, Terrence, Liability Under Federal Law from Crude Oil Spills from Rail Cars, (Thomson Hines, Oil & Gas Monitor, 2015)

safe facility, and minimize the consequences of accidental emissions when they occur.

As interpreted by USEPA, the CAA's definition of stationary source does not include air pollution sources used in "transportation, including storage incident to transportation, of any regulated substance" governed by regulations adopted by the U.S. Department of Transportation (USDOT). EPA recognizes that containers used in transportation or under active shipping papers are subject to exclusive regulation by USDOT under the Interstate Commerce Act. That recognition notwithstanding, it is EPA's position that a rail car may become a "stationary source" subject to Section 112(r) during loading, unloading, or when the container is being stored at a facility not incident to transportation (i.e., not under active shipping papers).

In the event of a crude oil spill from a rail car, not under active shipping papers, CAA Section 112(r) may impose strict (no fault) liability and allows EPA to file an action seeking civil penalties of not more than $37,500 for each day an owner or operator of a leaking rail car violates the General Duty Clause, as well as injunctive relief to prevent further violations. In addition, in the 1990 amendments to the CAA, Congress gave the EPA Administrator an additional mechanism to enforce compliance with the CAA: the power to assess an administrative penalty of up to $25,000 per day of violation.

Whether under the OPA, RCRA, CAA or any combination of those acts, EPA and parties impacted by crude oil spills from rail cars have ample authority to compel responsible parties to remediate crude oil spills and to impose significant monetary penalties to deter future spills. (p. 6)

Potential areas of future discussion

- The Rail Safety Committee may consider working with Washington State to put in place state financial responsibility requirements for rail transportation. Like the recommendations made in the 2*014 Washington State Marine & Rail Oil Transportation Study* (Etkin et al. 2015), Washington State should again attempt to pass legislation and then promulgate regulations requiring rail transportation companies to provide "Evidence of Financial Responsibility." This evidence can be provided by insurance, self-insurance, guaranty, letter of credit, certificate of deposits, surety bonds, Protection and Indemnity Club membership, a combination of methods, or other methods acceptable to the jurisdictional authority within the State of Washington.
- The level of evidence should be based upon a reasonable worse case spill as determined by Ecology/UTC in a dollar amount based upon a multiplier of the potential barrels involved in the reasonable worse case spill.
- Oil spill costs are greatly affected by oil type (persistence, toxicity, and adherence factors), as well as location. A model for calculating these costs could be based on work previously conducted for the Washington State Joint Legislative Audit and Review Committee (JLARC) (State of Washington JLARC 2009; Etkin et al. 2009; French-McCay et al. 2009), as described in detail in Chapter 23 of this report. It would need to be adapted to spill cleanup costs and potential damages.

Chapter 21: Lessons Learned from Major Rail Accidents 2013–2018

Key questions

- What were the circumstances of the major crude-by-rail accidents and other accidents with hazardous material releases that occurred during the last seven years?
- What are the important lessons learned that can be derived from these accidents to help in reducing the likelihood or severity of these types of accidents in the future?
- What were the major passenger train accidents that occurred in this time period?
- What are the lessons learned from these incidents?

Takeaways

- Previous rail accidents provide opportunities to investigate "lessons learned" to develop measures to prevent such accidents in the future.
- The NTSB in the U.S. and the Transportation Safety Board (TSB) in Canada have investigated rail accidents, as well as other rail accidents, to determine the causes and develop recommendations for prevention of future accidents.
- Train accidents, as with almost all rail incidents in U.S., are caused by a variety of factors. Human error remains a significant contributor to most accidents. Equipment failures also remain a significant contributor. Track condition has a lesser role in causing accidents/incidents.
- During the years 2013 through 2018, there were 21 accidents involving crude-by-rail (CBR) trains in the U.S. and Canada. The most serious of these accidents occurred in July 2013 in Lac-Mégantic, Quebec, Canada. This accident resulted in the deaths of 47 people. While several of the other CBR accidents involved fire or explosions, there were no further fatalities or serious injuries.
- The CBR accidents were attributed to the same types of causes as other accidents, such as derailments due to track defects, broken axles, and collisions. The difference in the severity of these accidents was the fact that the trains were carrying Bakken crude oil, which spilled. In some cases, the oil burned or exploded.
- The results of investigations into the circumstances of CBR accidents have led to the federal government passing legislation requiring certain safety measures to reduce the likelihood and severity of future CBR accidents. These safety measures include requirements for safer tank cars that are less likely to burst open and spill flammable oil and other hazardous substances.
- In the last several years, there have also been several passenger train accidents that have resulted in fatalities and serious injuries. These collisions and derailment accidents have mainly been caused by human error.
- There are many serious highway-rail grade crossing accidents that occur each year. The majority of these accidents are caused by human error on the part of the vehicle driver. (This is discussed in greater detail in Chapter 13.)

- One of the prevention measures that has received a great deal of public attention is Positive Train Control (PTC). NTSB investigations have concluded that PTC may have prevented a number of these accidents. However, PTC will not eliminate certain accidents/incidents from occurring, such as highway-rail grade crossing accidents and accidents involving slow speed train operations (as discussed in Chapter 9).

The following sections provide a more in-depth look at recent crude-by-rail (CBR) and other notable rail accidents with regard to "lessons learned" that may help in the prevention or reduction of the frequency or severity of future rail accidents.

Major crude-by-rail (CBR) accidents

There were a spate of crude-by-rail (CBR) accidents in the U.S. and Canada during 2013 through this past year. The causes of the accidents were not necessarily related to the fact that the trains were carrying crude oil in key trains or unit trains, but due to rail defects, human error, equipment failure, and other factors that cause derailments and other accidents in all types of freight trains regardless of cargo. The consequences and impacts of a CBR accident with the release of oil were noteworthy, however.

The lessons learned from these CBR accidents with regard to risk reduction measures have already, to a large extent, been implemented in response to these accidents, particularly the mandated use of safer tank car designs (DOT-117 and others) that reduce the chance of punctures or thermal tears in the cars in an impact accident. Other measures to reduce the chances of an accident and to reduce the severity of a CBR accident have also been implemented, such as reduced speed in densely-populated areas, conditioning of Bakken crude oil to reduce its volatility, and emergency response planning.

The most noteworthy accident, and the one that was the main impetus for the safety measures put into place, was the July 2013 accident in Lac-Mégantic, Quebec, Canada.

Lac-Mégantic incident

As noted in the 2017 Environmental Impact Statement for a proposed oil terminal in Vancouver, Washington (Etkin et al. 2017):

> On 5 July 2013, an unattended 74-car train carrying Bakken crude rolled down a 1.2 percent grade and derailed in downtown Lac-Mégantic, Quebec, resulting in the fire and explosion of several tank cars (Figure 86 and Figure 87). The fire and explosion destroyed more than 30 buildings and resulted in the death of 47 people.

Figure 85: Fire after Derailment and Explosion of CBR Train at Lac-Mégantic, Quebec[397]

Figure 86: Downtown Lac-Mégantic in Aftermath of July 2013 CBR Accident[398]

[397] TSB Canada photo.
[398] TSB Canada photo.

The incident at Lac-Mégantic, Quebec represented a "perfect storm" of human error failures that contributed to the accident and its consequences. This particular set of circumstances would not be expected to occur in the U.S. due to regulations and railroad operating practices in place, most importantly:

- A train would not be left unattended in this manner.
- The locomotive conditions in this incident would not be considered acceptable.
- A train with hazardous cargo would not be operated by a single person.

The use of safer tank cars (as per DOT-117 specifications) and the lower volatility of conditioned Bakken crude would also significantly reduce the probability that this series of events could recur in this manner. A synopsis of the event and an analysis of the spillage is presented here so that the volumes applied in the impacts modeling can be benchmarked against it.

For the Lac-Mégantic incident, the volume of oil can be accounted for in three phases. There were 72 DOT-111 cars loaded with a reported 7.7 million liters (48,432 bbl) of Bakken crude with each car holding about 672.66 bbl (28,252 gallons) (Etkin et al. 2017). Sixty-three tank cars derailed (holding about 42,378 bbl) 87.5 percent of the train's tank cars. About 37,739 bbl of oil were reported to have been released from the tank cars (TSB Canada 2014c).[399] Only four cars released no oil (2,961 bbl). An additional 1,964 bbl of oil were removed from damaged cars that did not entirely release their contents. About 100,000 liters (629 bbl) ended up in Mégantic Lake and the Chaudière River by way of surface flow, underground infiltration, and sewer systems. An undetermined amount of oil saturated nearly 77 acres of land.

Of the 63 derailed cars, 37 cars (holding approximately 24,888 bbl) had a breached shell due to impact damage. Of these, 21 cars had "large" breaches, 12 had "medium" breaches, and four had "small" breaches. The remaining 26 cars had no breach, although 22 of the non-breached cars had at least some denting. Only four derailed cars had no discernible damage (Figure 88).

There appeared to be three types of releases from the derailed tank cars:

- **Phase 1A (Instantaneous Derailment-Damage-Related Releases):** Twenty-one cars nearly instantaneously released their entire contents (14,126 bbl) due to the size of the breaches (of a large size commensurate with car diameter).
- **Phase 1B (Subsequent Derailment-Damage-Related Releases):** An additional 12,177 bbl of oil were subsequently released from about 18 cars with lesser degrees of damage.
- **Phase 2 (Burn-Through- and Thermal-Tear-Related Releases):** Four cars released 2,691 bbl of oil due to thermal tears that occurred as a result of the fire 20 minutes or longer after the initial releases; 13 cars later experienced localized loss of contents due to burn-through[400] (8,745 bbl).

[399] Note that with approximations and rounding in the TSB Canada report and conversions from liters to gallons to barrels, there are some rounding discrepancies.
[400] Burn-through is a perforation of the tank shell caused by fire damage.

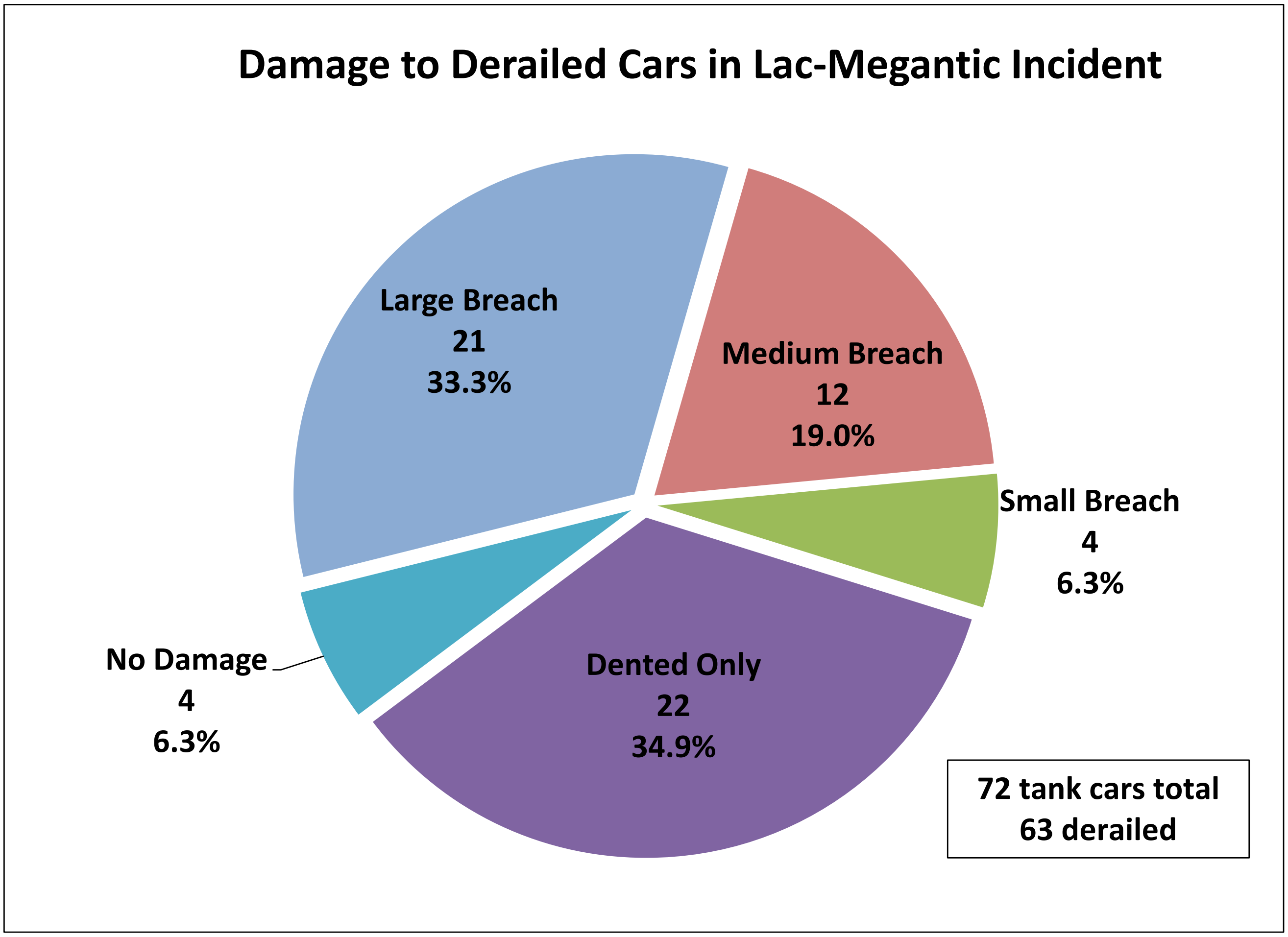

Figure 87: Damage to Derailed Cars in Lac-Mégantic Incident[401]

During the response operations, 740,000 liters (4,654 bbl) of crude oil were recovered from the derailed tank cars, of which 2,691 bbl were removed from the four non-damaged cars. About 1,963 bbl that remained in damaged cars (nearly three cars-worth of oil) were also removed. The "mass balance" of the contents of the train is illustrated in Figure 89 (Etkin et al. 2017).

[401] Graph produced by Environmental Research Consulting based on data in TSB Canada 2014b. Used with permission.

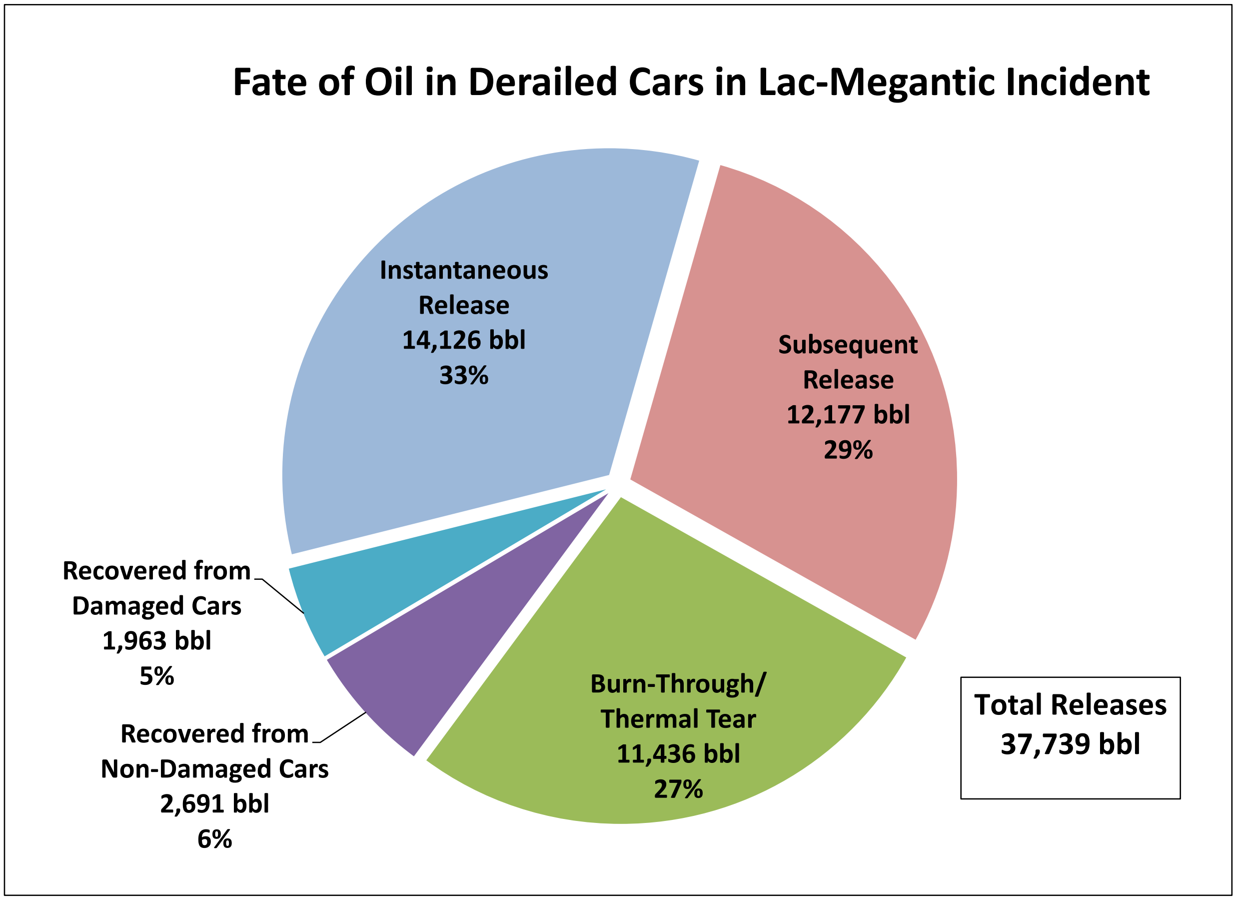

Figure 88: Fate of Oil in Derailed Cars (Mass Balance) in Lac-Mégantic Incident[402]

While about 37,739 bbl of oil were ultimately lost from Train MMA-002, the sequence of releases should be considered with respect to the likelihood of all of the events occurring in the future. The initial and subsequent releases were likely due to damages from the derailment itself (26,303 bbl). The burn-through and thermal-tear releases (11,436 bbl) were secondarily caused by the fire. The former releases may have been reduced by better tank car designs. The latter releases would likely have been reduced by the improved thermal protection in DOT-117 cars.

The accident investigation for the Lac-Mégantic incident revealed several key factors that caused and ultimately affected the outcome, and which have a bearing on the analysis of potential future incidents that may occur with regard to Washington State CBR traffic:[403]

- The train (MMA-002) had been under the control of a sole operator;
- The train was parked unattended on a mainline on a descending grade with the securement of the train reliance on a locomotive that was not in proper operating condition;

[402] Graph produced by Environmental Research Consulting based on data in TSB Canada 2014b. Used with permission.
[403] For a thorough analysis, refer to TSB Canada 2014b.

- There were significant braking failures (e.g., seven hand brakes that were applied to secure the train were insufficient to hold the train with the additional braking force from the locomotive's independent brakes; and the hand brakes had not been properly tested for effectiveness);
- The train was left unattended despite its abnormal condition (i.e., there had been significant indications of mechanical problems with the lead locomotive);
- The lead locomotive had a non-standard repair that allowed oil to accumulate in the turbocharger and exhaust manifold, resulting in a fire; the fire precipitated the locomotive's engine being shut down, which removed the braking ability of the locomotive; no additional locomotive was started to provide braking power;
- DOT-111 tank cars did not withstand shell damage and had inadequate thermal protection; and
- The volatility of the oil (unconditioned Bakken crude) contributed greatly to the fire, which caused the damages, including fatalities and injuries (the oil had been improperly classified with regard to hazard). (Etkin et al. 2017)

Other CBR accidents

Just prior to the Lac-Mégantic accident, there were two other considerably less severe CBR accidents, one in the U.S. and one in Canada. Thereafter, there were a series of CBR accidents, some with fires and some without fires. A synopsis of those accidents is shown in Table 124.

Table 124: Synopsis of Major US and Canadian Crude-by-Rail Accidents Including Features of the Accidents[404]

Location	Date	Derailed Cars	Cars with Release	Oil Spilled	Fire or Explosion	Speed	Cause
Parkers Prairie, MN	27 March 2013	14	1	714 bbl	No	40 mph	Broken axle
Calgary, AB	3 April 2013	7	2	640 bbl	Yes	Not known	Not known
Lac-Mégantic, QC	5 July 2013	63	54	37,719 bbl	Yes	Not known	Not known
Gainford, AB[405]	19 October 2013	12	3	0 bbl	Yes	Not known	Not known
Aliceville, AL	7 November 2013	30	12	10,846 bbl	Yes	39 mph	Rail defect

[404] Environmental Research Consulting data.
[405] The train included both crude oil and propane. Nine propane cars and four crude oil cars derailed. Three propane cars burned.

Location	Date	Derailed Cars	Cars with Release	Oil Spilled	Fire or Explosion	Speed	Cause
Casselton, ND	30 December 2013	20	18	9,524 bbl	Yes	42 mph	Collision related to broken axle
New Augusta, MS[406]	31 January 2014	11	7	1,190 bbl	Yes	47 mph	Rail defect
Plaster Rock, NB	7 February 2014	5	5	3,000 bbl	Yes	Not known	Not known
Vandergrift, PA	13 February 2014	19	4	108 bbl	No	31 mph	Track or roadbed problem
Lynchburg, VA	30 April 2014	15	3	1,190 bbl	Yes	24 mph	Rail defect
LaSalle, CO	9 May 2014	6	1	155 bbl	No	Not known	Not known
Mount Carbon, WV	16 February 2015	27	14	9,800 bbl	Yes	33 mph	Internal rail defect
Gogama, ON	14 February 2015	35	7	4,900 bbl	Yes	Not known	Not known
Gogama, ON	7 March 2015	69	7	4,709 bbl	Yes	Not known	Not known
Heimdal, ND	6 May 2015	6	5	2,295 bbl	Yes	24 mph	Not known
Culbertson, MT	17 July 2015	22	4	833 bbl	No	44 mph	Rail defect
Watertown, WI	8 November 2015	13	1	<24 bbl[407]	No	Not known	Not known
Mosier, OR	3 June 2016	11	Not known	1,000 bbl	Yes	26 mph[408]	Rail Defect
Money, MS	29 April 2017	12	Not known	>476 bbl	Yes	Not known	Collision[409]

[406] Methanol was also released in this accident.
[407] Listed originally in gallons. "Preliminary reports indicate less than 1,000 gallons of product spilled…" https://fox6now.com/2015/11/08/breaking-crews-on-scene-of-train-derailment-in-watertown/
[408] https://www.chicagotribune.com/nation-world/ct-oregon-oil-train-derailment-20160611-story.html
[409] Listed originally in gallons. "The Greenwod Commonwealth reports a tank car leaked more than 20,000 gallons of crude oil…"https://www.usnews.com/news/best-states/tennessee/articles/2017-05-01/railroad-reopens-after-fiery-crash-in-mississippi-delta

Location	Date	Derailed Cars	Cars with Release	Oil Spilled	Fire or Explosion	Speed	Cause
Plainfield, IL	1 July 2017	20	2	1,071 bbl	No	mph	Not known
Doon, IA	22 June 2018	32	14	5,476 bbl	Not known	48 mph[410]	Not known

The CBR accidents (other than Lac-Mégantic) that involved the release of crude oil and a synopsis of their outcomes follow.

March 2013 Parkers Prairie, Minnesota

On 27 March 2013, a mixed-manifest Canadian Pacific train transporting several tank cars of Alberta crude oil derailed in rural Parkers Prairie, Minnesota. Of the 14 tank cars that derailed, one ruptured and released about 700 bbl of oil.[411] There was no fire. Damage was reported to be minimal due to the frozen ground. The derailment was caused by a broken axle while the train was running at 40 mph. NTSB did not conduct an investigation. This accident caused the first major spill since the boom in North American CBR transport. However, the tank car did not contain Bakken crude oil.

April 2013 White River, Ontario

On 3 April 2013, a Canadian Pacific train carrying seven cars of crude oil, as well as other commodities derailed in White River, Ontario. Two of the Class-111 (the Canadian equivalent of DOT-111) tank cars released about 640 bbl of crude oil. Another 113 bbl of canola oil were also spilled. The fire was extinguished by local firefighters. There were no casualties.

The Transportation Safety Board of Canada (TSB Canada 2014b) attributed the accident to a broken wheel on one of the tank cars that fractured one of the rails (Figure 90). The damaged cars in this incident were Class 111 tank cars. The TSB said those cars were built before regulations were in place to ensure they could withstand a rollover, and therefore leaked oil. The report also noted that old valve handles contributed to the leak, as they were not designed to ensure they remained closed in the event of an accident.

[410] https://www.ntsb.gov/investigations/AccidentReports/Reports/HMD18LR002-preliminary-report.pdf
[411] Reuters website. 2013. *Train Hauling Canadian Oil Derails in Minnesota*. https://www.reuters.com/article/us-oil-train-derailment/train-hauling-canadian-oil-derails-in-minnesota-idUSBRE92Q13U20130328. March 27.

Figure 89: Broken Wheel on Tank Car in White River Derailment (April 2013)[412]

According to investigators, an electronic sensor known as a wheel impact load detector (WILD) had identified an issue with a set of wheels on one train car before the accident, but CP's own guidelines did not require that car to be taken out of service. By contrast, they said, an Association of American Railroads (AAR) guideline would have removed the car from service. The TSB report said the railway's guidelines “may not be sufficiently robust” when it comes to analyzing data from wheel impact load detectors.

This case clearly demonstrates the value of wayside detection systems and the guidelines for train car removal when defects are detected.

November 2013 Aliceville, Alabama

On 7 November 2013, a unit train hauling 90 DOT-108 cars derailed in Aliceville, Alabama, while traveling at 29 mph. Thirty tank cars derailed and twelve cars spilled a total of 10,846 bbl, some of which burned. There were no injuries, but there were impacts to an adjacent wetland area.

This accident is noteworthy in that when it occurred it was the largest CBR accident in the US with respect to spilled oil volume. The volume of 10,846 bbl (455,532 gallons) is often used as a benchmark with respect to determining reasonable worst-case discharge spill volumes. (In the

[412] TSB Canada 2014b.

following month, another accident occurred in Casselton, North Dakota, which resulted in slightly more spillage.) As discussed in Chapter 17, PHMSA opted to set 300,000 gallons (about 10 cars of oil) as the worst-case discharge volume for which railroads need to prepare contingency plans.

December 2013 Casselton, North Dakota

On 30 December 2013, a unit train carrying 104 tank cars of Bakken crude oil collided with the derailed cars from a previous freight train accident. The freight train was carrying 112 cars loaded with grain, 13 of which derailed due to a broken axle on one of the grain cars.

Two head-end locomotives and 20 tank cars derailed in the collision. About 11,333 bbl of crude oil spilled from 18 of the DOT-111 cars. The oil was released from cars that were punctured, or had damaged bottom valves and top fittings from the collision and derailment impacts. Other tank cars ruptured due to thermal tears (Figure 91) as pool fires weakened the tank steel and increased internal pressure. Thirteen of the cars had torn or punctured heads and shells, three had thermal tears, 10 had damaged valves and fittings, and three released product from bottom outlet valves.

Figure 90: Thermal Tear in DOT-111 Tank Car in Casselton, North Dakota Accident[413]

There were no injuries in the fire. One-thousand-four hundred residents were evacuated as a precaution.

One of the lessons learned from this accident is the importance of buffer cars to protect the train crew when transporting hazardous and flammable materials (Figure 92)

[413] Photo: NTSB

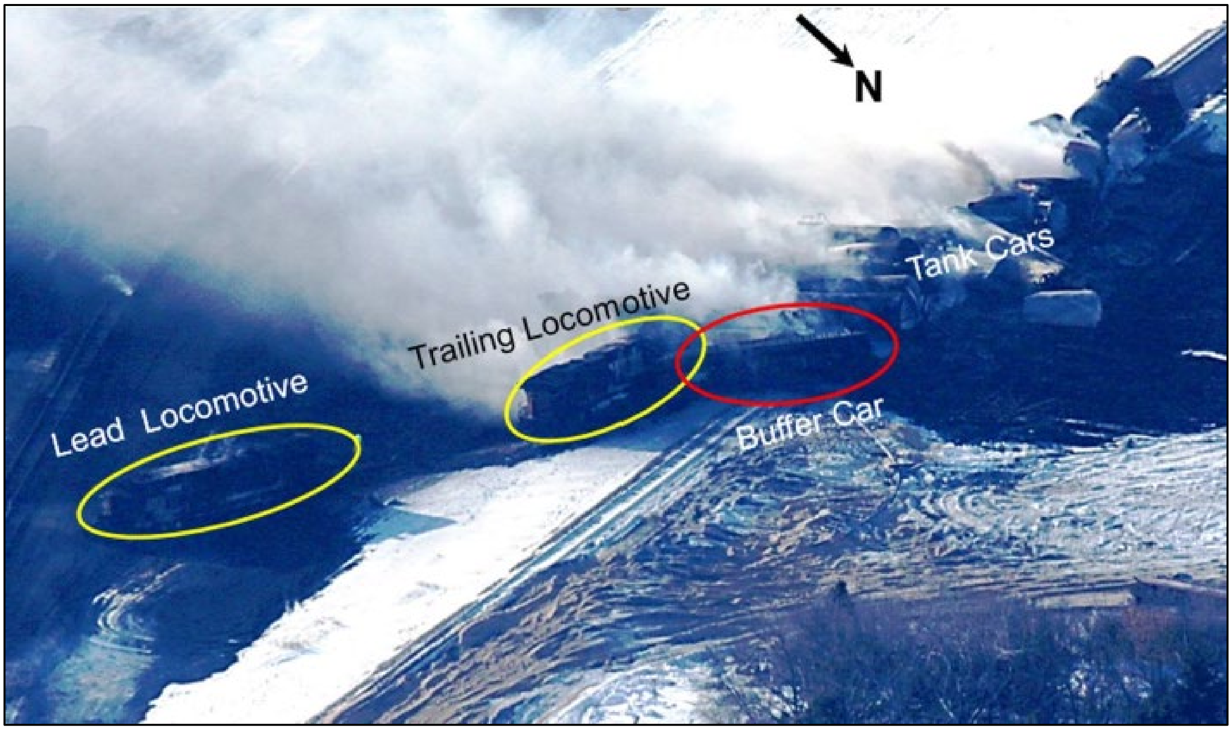

Figure 91: Buffer Car in Casselton, North Dakota CBR Accident[414]

Specifically, the NTSB report (NTSB 2017a) states:

> The placement requirement of hazardous material cars (placarded cars) in trains is contained in 49 CFR 174.85. The regulation specifies that "when train length permits, [a] placarded car may not be nearer than the sixth car from the engine or occupied caboose," meaning: that if there are enough cars in the train, put five cars between a placarded car and the locomotive or occupied caboose. However, when the train is not long enough to allow for a five-car buffer, trains may move with only a single buffer car. Railroads commonly use this exception to operate unit trains carrying hazardous materials with only one no-placarded (buffer) car separating placarded cars from locomotives and occupied cabooses, in contrast to the requirement for five buffer cars separating placarded cars from locomotives and occupied cabooses on mixed-freight trains. In the Casselton accident, the placement of cars in the oil train consist complied with the current PHMSA interpretation of § 174.85.
>
> Although unit trains transporting nonhazardous commodities such as coal and grain have existed for many years, 49 CFR 174.85 does not specifically address unit trains containing a single hazardous materials commodity. The FRA, PHMSA, and the railroads have recognized that buffer cars should be required on unit trains transporting hazardous materials to comply with the intent of 49 CFR 174.85. Since a hazardous materials unit train is composed of cars loaded with the same hazardous commodity, additional non-placarded cars must be added to the train to provide a buffer between occupied railcars

[414] NTSB 2017a (PHMSA photo).

> and locomotives and the hazardous materials. The FRA, PHMSA, and the railroads have interpreted the regulation to allow use of a single buffer car between the locomotives and the first placarded car, and those trains may travel across the country with only one buffer car required. (p. 19)

Besides the Lac-Mégantic accident, none of the CBR accidents listed in Table 124 involved casualties (fatalities or injuries). However, railroad personnel, emergency responders, and others in the vicinity of the fires and spills did face dangers and hazards, and there was great concern about the potential for greater consequences.

The same lessons learned that came from other CBR accidents applied. The accident itself was due to situations that could cause an accident on any other type of train. However, the consequences were considerably greater with the potential for fire and explosion with the spillage of highly-volatile crude oil. The lessons learned from the consequences side were that the release of oil cargo needed to be prevented through the use of safer tank cars. Older DOT-111 and similar tank cars needed to be phased out, which has occurred. The volatility of the crude oil also needed to be addressed, which was done, at least in part, by the end of 2015.

June 2016 Mosier, Oregon

On 3 June 2016, a Union Pacific CBR train derailed in Mosier, Oregon, along the Columbia River (Figure 93. Sixteen tank cars derailed, of which four released oil and burned. An estimated 1,119 bbl of oil was spilled, most of which burned (Figure 93), and a small amount of which entered the Columbia River causing a sheen. There were no injuries. Rail and roadway traffic were blocked for some time. Washington State officials and responders, including Ecology, were involved in the response. The Wasco County Sheriff evacuated about 100 residents within a quarter-mile around the incident. About one acre of an adjacent woodland burned. The wildfire was controlled within 24 hours. The effectiveness of the emergency response operations and lessons learned in the Mosier incident are discussed in Chapters 17 and 18.

Figure 92: Tank Cars Burning in Mosier, Oregon CBR Accident July 2016

This accident was of great concern to residents of both Washington and Oregon. The incident led Oregon's senators to contact the NTSB. In a response letter, the NTSB stated that it "recognized the impact of this accident on your constituents and understands the concerns of those affected."[415] However, NTSB chose not to investigate the Mosier incident further because early information gathered from the Union Pacific Railroad and the FRA "indicated that the circumstances of this accident did not pose any new significant safety issues." Union Pacific had identified the cause of the accident as a failed lag bolt that fastened the rail to the railroad ties on a curve. FRA determined that inadequate maintenance caused the failed lag bolt to remain in place.

In response to the derailment, and lack of investigation by the NTSB, Oregon Senators Jeff Merkley and Ron Wyden introduced the Mandate Oil Spill Inspections and Emergency Rules (Mosier) Act which calls for a moratorium on oil train traffic after major wrecks and require the Department of Transportation to reduce the amount of volatile gases in the crude oil those trains have been hauling. The bill died in committee.

Of the 1,119 bbl of oil that were released into the environment from four rail cars, 381 bbl burned or were vaporized, 429 bbl went into the soil, and 310 bbl went into the local wastewater treatment plant. A few gallons were reported to have entered the Columbia River causing a slight sheen. There were no observed effects on wildlife or the environment. One unexpected issue in the aftermath of the spill was that oil from the accident rendered the Mosier Wastewater Treatment Plant inoperable for several days. This required the use of portable toilets and the

[415] Oregon Public Broadcasting website. 2016. *Why Feds Chose Not to Investigate Oil Train Derailment in Columbia Gorge*. https://www.opb.org/news/series/oil-trains/feds-explain-why-they-chose-not-to-investigate-oil-train-derailment-in-columbia-gorge/. July 8.

creation of a temporary bypass system. No drinking water wells were contaminated (Franklin 2016).

Other recent freight train accidents with hazmat releases

A number of freight rail accidents involving the transport of commodities other than crude oil also provide valuable insights and lessons learned.

October 2011 ethanol train derailment, Tiskilwa, Illinois

On 7 October 2011, a freight train carrying 128 loaded cars of which a number of cars contained ethanol, a Class 3 flammable liquid, derailed. Ten of the derailed cars contained ethanol. Nine of the derailed ethanol tank cars were damaged, releasing ethanol, which ignited and burned (Figure 94). The intense fire caused three of the tank cars to fail and erupt in massive fireballs.

Figure 93: October 2011 Ethanol Train Derailment, Tiskilwa, Illinois[416]

NTSB (2013) determined the probable cause of the derailment was a broken rail. Contributing to the large release of ethanol was the inadequate puncture resistance of the DOT-111 tank cars and the failure of the draft sill attachments.

[416] NTSB 2013.

This accident is similar to accidents involving Bakken crude oil. Like Bakken crude, ethanol, also classified as a Class 3 flammable liquid, must now be transported in safer DOT-117 cars. The lesson learned from this case is that ethanol is also very volatile and flammable and can necessitate the same types of emergency response procedures as Bakken crude spills.

November 2012 derailment, vinyl chloride release, Paulsboro, New Jersey

On 30 November 2012, a Conrail freight train stopped on a main track at a moveable bridge (NTSB 2014a):

> A red signal aspect was displayed and did not change to green when the radio signal command was executed by the train crew, indicating that the bridge was not prepared for train movement. One of two conditions was required before the train could safety begin movement over the bridge: (1) Signal aspect changed to green, indicating that the running rails were aligned and locked to the fixed track and both ends of the bridge, or (2) The bridge was visually inspected by a qualified employee to ascertain that the running rails were aligned and locked to the fixed track at both ends of the bridge, and permission was granted by the train dispatcher for the train to pass the red signal.
>
> Despite multiple attempts by the train crew to remotely execute a radio signal command to align and lock the bridge, the signal aspect remained red and did not turn green. The conductor inspected the bridge and erroneously concluded it was properly locked to prevent movement. The engineer informed the dispatcher of the conductor's findings. The dispatcher then gave permission for the train to pass the red signal aspect and cross the bridge, as allowed by Consolidated Rail Corporation operating rules and procedures.
>
> . . . as the train traveled over the bridge, 7 cars derailed, the 6th through the 12th cars. Physical evidence indicated that the swing span locking mechanism was not engaged at the east end of the bridge. The bridge span rotated under the moving train, misaligned the running rails, and caused the train to derail. The bridge was structurally sound and did not collapse. Four tank cars that derailed on the bridge came to rest partially in Mantua Creek. Three of the derailed tank cars that entered the creek contained vinyl chloride and one contained ethanol. One tank car was breached and released about 20,000 gallons of vinyl chloride. Eyewitnesses reported a vapor cloud engulfed the scene immediately following the accident.
>
> On the day of the accident, 28 area residents sought medical attention for possible vinyl chloride exposure. The train crew and numerous emergency responders were also exposed to vinyl chloride. . .
>
> [NTSB] determines that the probable cause of the derailment was the operator allowing the train to proceed past the red signal aspect with the rail slide locks not fully engaged, which allowed the bridge to rotate and misalign the running rails as the train moved across it. Relying on a training and qualification program that did not prepare the train crew to examine the bridge lock system.

> Contributing to the accident was the lack of a comprehensive safety management program that would have identified and mitigated the risks associated with the continued operation of the bridge despite multiple bridge malfunctions of increasing frequency.
>
> Contributing to the consequences of the accident was the failure of the incident commander to implement established hazardous materials response protocols for worker protection and community exposure to the vinyl chloride release. (pp. viii - ix)

The lessons learned in this case are the importance of familiarity of emergency responders to procedures to protect workers and the community from toxic exposure.

2017 derailment of propane tank car, Hyndman, Pennsylvania

On 2 August 2017, a 178-car, five-locomotive mixed-manifest freight train derailed in Hyndman, Pennsylvania. Thirty-two cars derailed, including fifteen cars transporting hazardous materials, including three tank cars with liquefied petroleum gas (propane), eight tank cars with molten sulfur, two tank cars with liquid asphalt, and two tank cars with phosphoric acid residue (empty). One pressurized DOT-112 tank car released propane that burned, one DOT-111 car released molten sulfur that burned, and one DOT-111 car released asphalt. The sulfur burned for more than 48 hours. The accident occurred on tracks that ran adjacent to several residential houses (Figure 95). There were about 1,000 residents in a one-mile radius. There were no injuries or fatalities (NTSB 2017b):

> Two train crews were involved in the movement of the train before the accident. The first crew stopped the train on a descending grade after encountering suspected air brake problems. The crew applied 58 hand brakes while inspecting and recharging the air brake system. The conductor of this first crew found an air leak on a railcar about 20 railcars from the rear of the train. A CSX mechanical employee arrived to repair the air leak. However, by the time this issue was resolved, the crew did not have enough remaining duty time to complete the trip. Therefore, CSX relieved them with a new train crew.
>
> The second crew, thinking the train may still have air brake problems, kept all 58 handbrakes applied and unsuccessfully tried to pull the train down the hill. The conductor of the second crew then released the first 25 hand brakes, leaving 33 hand brakes still applied. The engineer applied a minimum air brake application and started the train with locomotive power down the grade. The train speed varied from 20 to 30 mph. The engineer transitioned from locomotive power to dynamic braking three times before the train derailed.
>
> . . . (NTSB) investigators determined that the 35th railcar derailed one set of wheels on a curve 1.7 miles before the location of the general derailment and fire. When the derailed railcar reached a highway-railroad grade crossing, the railcar moved further off the rail, initiating the derailment of the other railcars. NTSB investigators discovered that several railcar wheels east and west of the derailed cars had flat spots and built-up tread from the hand brakes not allowing the wheels to rotate, and bluing due to brake pad friction. (p. 2)

Figure 94: Derailment Scene in Hyndman, Pennsylvania[417]

This incident is noteworthy in that the molten sulfur ignited (likely from the burning propane) and burned for more than 48 hours. This would be important to consider in planning responses to sulfur spills.

March 2017 derailment with ethanol spill, Graettinger, Iowa

On 10 March 2017, a Union Pacific unit train transporting ethanol derailed in a rural area near Graettinger, Iowa, due to a broken rail (NTSB 2017c). Twenty loaded tank cars in the middle of a 98-car train with three locomotives and two sand-filled buffer cars derailed. Fourteen of the derailed DOT-111 tank cars released about 322,000 gallons (7,667 bbl) of undenatured ethanol, which burned for more than two and half days. There were no injuries and three nearby homes were evacuated as a precaution.

NTSB (2017c) attributed the derailment to a broken rail. NTSB further noted that the inadequacy of the railroad's track maintenance and inspection program and the inadequacy of the FRA's oversight contributed to the track condition.

In addition, NTSB found that the transport of ethanol without the use of volatile organic compound (VOC) denaturants, in addition to the continued use of DOT-111 cars (prior to the mandated phase-out) contributed to the intensity of the fire.

[417] NTSB 2017b.

This accident demonstrates further the safety concerns with the DOT-111 cars, which are no longer in use, but also the need for proper denaturing of ethanol before transport. Again, track maintenance and inspection programs can significantly reduce accidents due to broken rails.

Recent major passenger train accidents

There have been a number of passenger train accidents in the last several years, including collisions and derailments, for which the NTSB investigations have concluded that they likely would have been prevented or lessened in severity with PTC. The lessons learned from these incidents is that PTC will likely prevent similar types of accidents in the future. However, each incident had human error factors involved that should also be addressed so as not to rely solely on PTC.

September 2008 Chatsworth, Los Angeles, California collision

On 12 September 2008, a Union Pacific freight train collided head-on with a Metrolink commuter train in the Chatsworth District of Los Angeles, California. The accident occurred on a curved section of single track. The accident resulted in 102 injuries and 25 fatalities including the Metrolink engineer.

The NTSB concluded that the head-on collision was due to (NTSB 2010):

> "…the failure of the Metrolink engineer to comply with a red signal at a control point because he was text messaging on his personal wireless device, in violation of company policy. Distracted from his duties, he did not stop the train and collided head-on with the approaching freight train (Figure 96). He did so, despite earlier track signals and radio calls indicating he would need to stop. Contributing to the accident was the lack of a positive train control (PTC) system that would have stopped the train short of the red signal and thus prevented the collision." (p. 69)

This accident is generally referenced as the impetus for the push to implement PTC.

Figure 95: September 2008 Chatsworth, Los Angeles, California Collision[418]

December 2013 Metro-North derailment, Bronx, New York

In this incident, in Spuyten Duyvil, Bronx, New York, on 1 December 2013, a Metro-North commuter train was traveling at an estimated speed of 82 mph in a six-degree left hand curve where the speed was limited to 30 mph. All seven passenger cars and the locomotive (pushing the train from the rear) derailed (Figure 97). Four passengers were killed and 61 persons were injured. The NTSB determined that the probable cause of the accident was the engineer's noncompliance with the speed restriction because he had fallen asleep due to an undiagnosed medical condition (severe obstructive sleep apnea). "Also contributing to the accident was the absence of a (PTC) system that would have automatically applied the brakes to enforce the speed restriction" (NTSB 2014b). In its report, NTSB faulted both Metro-North for not screening its employees in sensitive positions for sleep disorders, and faulted the FRA for not requiring that railroads do such screening (NTSB 2014b). A contribution to the severity of the accident was the loss of the window glazing that resulted in the ejection of four passengers from the train and ultimately their deaths.

[418] Source: NTSB 2010.

Figure 96: December 2013 Metro-North Derailment, Bronx, New York[419]

May 2015 Amtrak derailment Philadelphia, Pennsylvania

In this accident, an Amtrak passenger train entered a curve at 106 mph where the speed is restricted to 50 mph. The train derailed after the engineer applied the emergency brakes. Eight passengers were killed and 185 were injured. The NTSB determined that "the probable cause of the accident was the engineer's acceleration to 106 mph as he entered a curve with a 50-mph speed restriction due to his loss of situational awareness" (NTSB 2016).[420] There had been radio communications about an emergency situation on another train (a person had thrown a rock through the windshield of a nearby commuter train, blinding the operator, who then accelerated that train), and there were two curves in succession that the engineer apparently confused. "Contributing to the accident was the lack of a (PTC) system. Contributing to the severity of the injuries were the inadequate requiremetns for occupant protection in the event of a train overturning" (NTSB 2016).

[419] Source: NTSB - https://twitter.com/NTSB/status/407329136735027200/photo/1, Public Domain, https://commons.wikimedia.org/w/index.php?curid=29965913

[420] Situational awareness is defined as "the perception of the elements in the environment with a volume of time and space, comprehension of their meaning, and the projection of their status in the near future." Informally, it is "knowing what's going on" (NSTB 2016).

Figure 97: May 2015 Amtrak Derailment, Philadelphia, Pennsylvania[421]

September 2016 New Jersey transit crash in Hoboken Station

In this accident, a New Jersey Transit train failed to stop, overriding a bumping post at the end of a track in the terminal in Hoboken, New Jersey (99). "The train was traveling about 21 mph at the time of the accident" (NTSB 2018e). One person on the passenger platform was killed, and 110 passengers and crewmembers were injured. The NTSB determined that the engineer's failure to stop was attributable to fatigue due to an undiagnosed medical condition (severe obstructive sleep apnea). Also contributing to the accident was the absence of a safety system that could have slowed down or stopped the train before the collision (NTSB 2018e).

[421] Source: NTSB 2016.

Figure 98: September 2016 New Jersey Transit Allision Accident in Hoboken Terminal[422]

December 2017 Amtrak derailment DuPont, Washington

In December 2017, an Amtrak train with twelve passenger cars and two locomotives derailed on the Lakewood Subdivision from a bridge near DuPont, Washington. The train was on its first service run on a single track from Tacoma when it derailed. The train was traveling at a speed of 78 mph through a curve restricted to 30 mph. Several of the train's passenger cars fell onto Interstate 5, hitting several highway vehicles. The accident resulted in the deaths of three passengers, injuries to 62 passengers and crew on the train, and injuries to eight persons in highway vehicles. The NTSB concluded that "[i]n this accident, PTC would have notified the engineer… about the speed reduction for the curve; if the engineer did not take appropriate action to control the train's speed, PTC would have applied the train brakes to maintain compliance with the speed restriction and to stop the train" (NTSB 2018a).

[422] NTSB 2018e.

February 2018 Amtrak Collision with CSX Freight Train, South Carolina

In February 2018, an Amtrak train, operating on a track warrant,[423] was diverted from the main track through a hand-thrown switch into a siding and collided head-on with a stationary CSX freight train in Cayce, South Carolina (Figure 100). The engineer and conductor of the Amtrak train died in the collision and 116 passengers and crewmembers were injured. In addition, 5,000 gallons (119 bbl) of diesel fuel were spilled.

In this rail subdivision, the "normal method of train operation was a traffic control system with wayside signals. Signal indications authorized movement in either direction. On the day before the accident, . . . CSX signal personnel suspended the traffic control signal system to install updated traffic control system components for implementing PTC on the subdivision. During this time… dispatchers would use track warrants to move trains through absolute blocks in the work territory" (NTSB 2018d).

[423] Track warrant is a method of authorizing movements or protecting employees or on-track equipment in signaled or non-signaled territory on controlled track within specified signals. These movements are under the jurisdiction of the train dispatcher.

Figure 99: February 2018 Collision: Amtrak Train and CSX Train, Cayce, South Carolina[424]

Highway-rail crossing accidents

Highway-rail accidents at grade crossings occur all too frequently.[425] Two examples of grade crossing accidents are presented herein to demonstrate some of particular issues with crossings that can be addressed to prevent future accidents.

February 2015 highway-rail crossing accident, Valhalla, New York

On 3 February 2015, a Metro-North commuter train struck a passenger car at a grade crossing near Valhalla, New York, killing the driver of the vehicle and five passengers on the train, and injuring 15 other train passengers. This incident is of note due to unusual circumstances that led to a high fatality rate on the train rather than just in the vehicle, which is more typical of crossing accidents. However, there are also lessons learned about driver actions in a rail crossing situation, visibility, and the potential ineffectiveness of warning devices.

Witnesses reported that the driver of the vehicle crossed onto the grade crossing and the crossing gate hit the rear of her vehicle. She “calmly” got out of her car to examine the damage to the vehicle and then got back into the car to drive forward over the tracks (Figure 101). It appeared that she was unaware that she was in a rail crossing. The train engineer saw the vehicle on the track and sounded the horn and applied the brake but was unable to avoid hitting the vehicle. The train traveled an additional 700 feet during which time it impacted and unhinged the third rail.[426] The third rail pierced the head rail car (electric trains have no locomotive), which caused serious damage, five fatalities, and 15 injuries of passengers in the first car. The fuel in the passenger vehicle also burned.

[424] NTSB 2018d.
[425] See Chapter 13.
[426] The third rail provides electric power to operate the train, which contacts the third rail with a special “shoe” on each wheel.

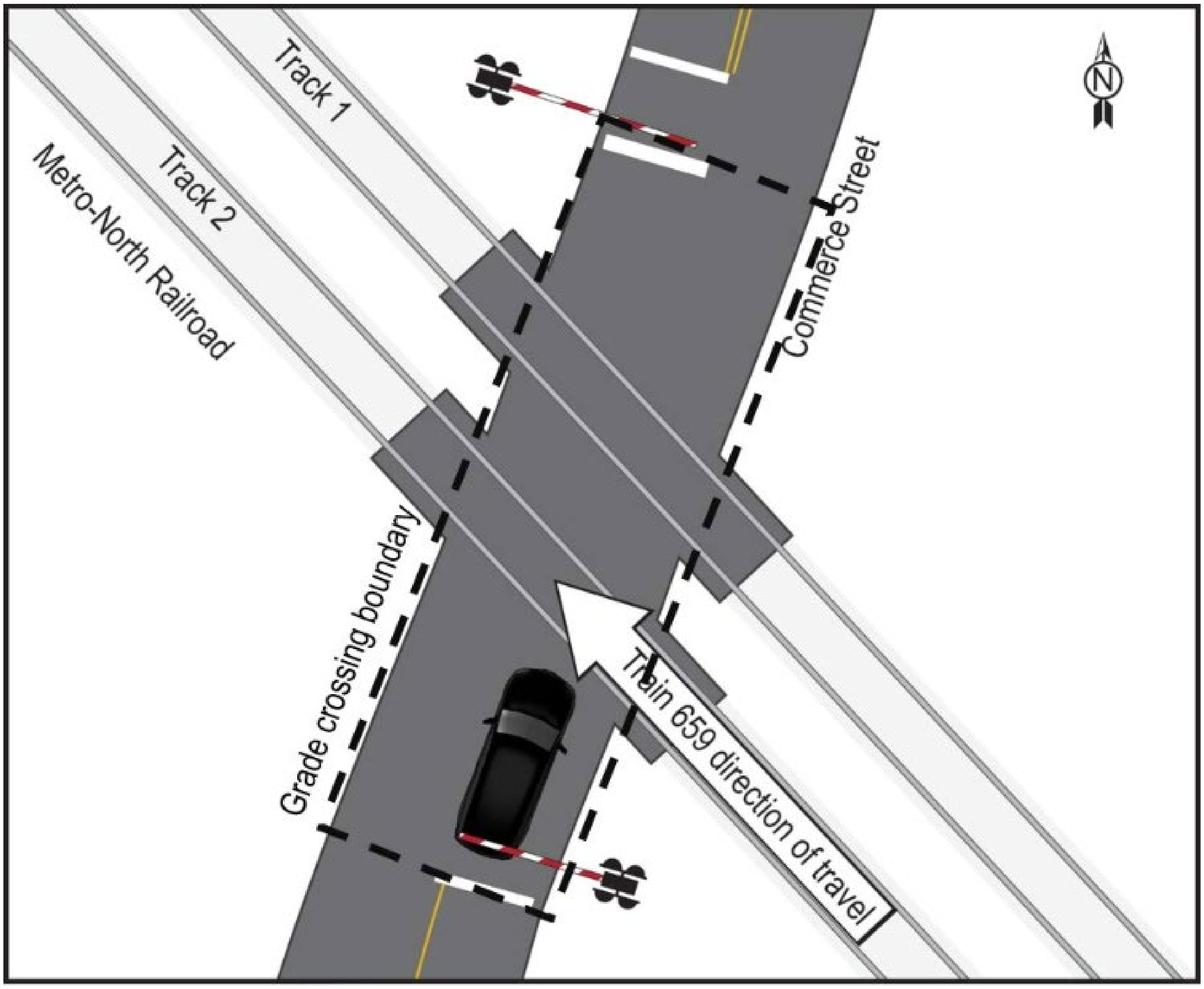

Figure 100: February 2015 Valhalla, New York, Grade Crossing Gate on Rear of Vehicle[427]

The atypically high number of fatalities and injuries of train passengers was due to the unusual occurrence with the third rail. Investigators concluded that there were defects in the third rail that came loose. The cause of the accident was attributed to the actions of the driver (NTSB 2017d). Note that NTSB does not typically investigate highway-rail crossing accidents, but the high number of fatalities and the third-rail factor made it an unusual case. The investigators looked carefully at a broad range of factors regarding visibility, warning devices, and driver awareness.

The crossing had a several warnings in advance of the crossing, although darkness may have prevented the driver from seeing them clearly (Figure 102). The curved approach to the crossing may also have hindered clear viewing of the crossing in advance, especially in the dark. The crossing warning system was found to be functioning properly.

[427] NTSB 2017d.

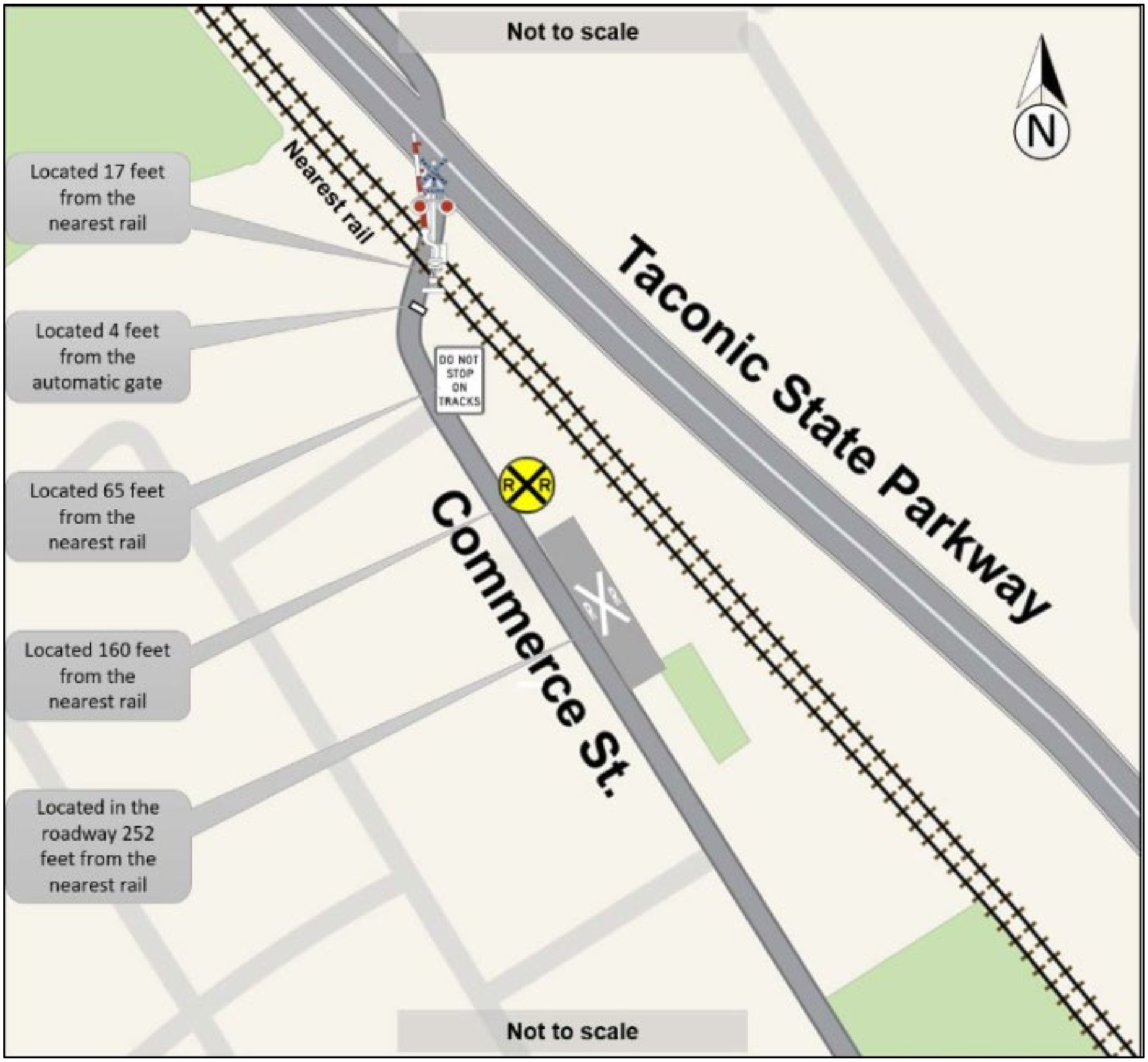

Figure 101: Warning Sign Locations on Approach to Crossing (Valhalla, NY)[428]

One additional factor at this crossing is the use of a traffic preemption system. Because traffic needs to stop before entering the parkway, there is the possibility of cars backing up, potentially onto the tracks. The traffic lights before and after the crossing are timed to allow enough room for cars to queue up without being on the tracks. The NTSB recommended checking the timing of traffic preemption systems associated with grade crossings.

The driver was not familiar with this particular crossing and had been re-routed due to a traffic accident on an adjacent road. However, grade crossing signals should be clear to any driver regardless of experience with a particular crossing. This accident demonstrates the need for further study of grade crossings with angled approaches and traffic preemptions, as well as the general need for further improvement of the visibility of warning devices, and driver education.

[428] NSTB 2017d.

In this case, the driver did not appear to be trying to "beat the train," as is the case in many other accidents.

2017 March Highway-Rail Crossing Accident, Biloxi, Mississippi

Another issue that arises in some highway-rail crossings is low ground clearance. Tractor-trailer trucks, buses, and other low-clearance vehicles may become caught while crossing the tracks and be unable to dislodge and move to avoid an oncoming train. One example of this is an accident that occurred in March 2017 in Biloxi, Mississippi, in which a bus became stuck on the "high-profile" grade crossing and was hit by a freight train. The accident caused four fatalities and 38 injuries of people on the bus.

The NTSB concluded that the cause of the accident was the failure of the railroad and the city "to coordinate and take action to improve the safety of the [grade crossing involved], a high vertical profile crossing on which motor vehicles were known to ground frequently (NTSB 2018b). The NTSB also concluded that "[c]ontributing to the circumstances of the crash was the inadequate guidance from the Federal Highway Administration on how to mitigate the risks posed by grade crossings with high vertical profiles" (NTSB 2018b). In the aftermath of the accident, the city posted a sign prohibiting buses, trucks and recreational vehicles from going through the crossing (Figure 103).

The lessons learned from this accident would be that high-profile, low-clearance grade crossings should be properly designated as prohibited to larger vehicles that may ground. However, the likelihood that this warning would be disregarded should be considered. Reconstructing the crossing to reduce the high profile would assist in preventing future groundings.

Figure 102: Low-Clearance High-Profile Crossing with Prohibition Sign in Biloxi, Mississippi[429]

[429] NTSB 2018b.

Lessons learned from recent passenger train accidents

- Human error remains too high of a contributor to passenger train accidents.
- PTC, in conjunction with other advanced signal systems, should mitigate many human error-caused incidents.
- No system is fail-safe, however, as other incident causes contribute to passenger train incidents (defects in equipment, track, etc.).

Potential areas of future discussion

- The Rail Safety Committee may want to consider reviewing past rail accidents for potential "lessons learned."
- Many of the prevention measures that have been developed in the aftermath of these accidents have already been implemented in Washington State, including safer tank cars (discussed in Chapter 15) and Positive Train Control (PTC) (discussed in Chapter 9). However, there are safety measures, particularly those that may prevent highway-rail crossing accidents (discussed in Chapter 13) that the Rail Safety Committee may want to consider including in a future voluntary rail safety plan.

Chapter 22: Factors that Affect Rail Accident Risk

Key questions

- Understanding that "risk" involves both the likelihood of accidents and the severity or impact of accidents, what specific factors increase or decrease the risk of rail accidents?
- How do these factors affect rates, and severity of rail accidents: track geometry (track configuration, curves, grades), train length (particularly for unit trains), physical properties of commodities being shipped (toxicity, flammability), car placement (position of cars with hazmats in train), train speeds (actual and mandated speed limits), and land management conflicts (proximity of high-consequence areas, populated areas, schools, residences to rail lines)?

Takeaways

- There are many factors that affect the likelihood of rail accidents. The more trains that pass through a rail corridor, the more likely that there will be an accident.
- Track geometry, or the three-dimensional layout of railroad track, affects the likelihood of an accident. Just as with highways, there are some features that make railroad tracks more prone to accidents. Track alignment, condition, curves, grades (up- or downhill slopes), crossings, and switches or turnouts can affect accidents. Often train speeds are restricted in locations that may cause accidents, such as curves.
- Track condition also plays an important role in determining the likelihood of accidents. Track that is not well maintained will have more accidents. Areas that are frequently washed out in floods or have falling trees or rocks that cause obstructions on tracks may also be more prone to accidents.
- Increased train speed and speed that is inappropriate for the track geometry, especially curves and grades, can increase the likelihood of an accident. Similar to motor vehicle accidents, train speed can also affect the severity of an accident by increasing the impact. Tank cars are more likely to break open in accidents at higher speeds. In addition, the faster the train speed, the greater the number of tank cars that will derail and potentially break open.
- Train length can affect accident rates. A train that is 100-cars long has about twice the likelihood of an accident than a ten-car train.
- Human operator factors can also affect the likelihood of an accident. Human error is a continuing cause of rail accidents, particularly when fatigue is involved. This is similar to automobile accidents.
- The human health and safety environment consequences of a rail accident with the release of a hazardous material are clearly higher when the accident occurs in a densely-populated area where more people are exposed.
- Some people are more vulnerable to the health effects of a toxic release, including the elderly, children, and people with certain health conditions, such as asthma or other respiratory ailments. For this reason, accidents that occur near hospitals, schools, day-care centers, and nursing homes are of particular concern.

The following sections provide a more in-depth look at the factors that have the greatest effect on the frequency and severity of rail accidents.

Factors that affect rail accident probability

There are various factors that may affect the likelihood of an accident.

Track-related factors that affect accident rates

The term “track geometry” means the three-dimensional layout of track. Track geometry includes the type of track, alignment of the track, turnouts or switches, curves, grades, crossings, and other features. The complex layout of track allows trains to transit to different locations across the varying geographic landscape. The condition of the various track geometry features also may affect the likelihood of different types of accidents.

Track alignment

Railway routes consist of straight (tangent) track, and curves. The elevation of rail routes also increases and decreases to pass over hills or mountains and through valleys.

Tangent track creates the least problem for railway operations because a moving rail car tends to be balanced over the two rails. There is little lateral force between the wheels and the rail, so unless there is a flaw in the rail or a mechanical part fails on the car, a derailment is unlikely.

Tangent track and curves are connected by spirals. A spiral is a section of track that transitions from straight to the full curvature of the curve. A spiral allows a train to enter a curve without putting jarring lateral forces on the rail or track structure. There are spirals on both ends of curves to help the transition into and out of the curve.

Curves are measured in degree of curvature. On mainline routes, a 12-degree curve (12°00’) is the maximum curvature that is found, and that is usually in an area that features some type of geography that requires such a sharp curve. In most cases, railroads prefer to not exceed a nine and a half degree (9°30’) curve. Car and locomotive wheel assemblies and vehicle length dictate the preferred maximum curvature.

Railroad curves are banked like highway curves to allow higher speeds around the curve. Banking on a railroad curve is called super elevation. The spiral at each end of the curve also assists the transition from level track at the tangent end to full super elevation at the beginning of the curve.

The degree of curvature and the amount of super elevation applied to the curve determines the speed that trains can safely traverse a curve (49 CFR Appendix A to Part 213, Maximum Allowable Curving Speeds). For example, a freight train can traverse a 3°00” curve at 62 mph if there are five inches of super elevation on the high rail. If there is only one inch of super elevation on that same three-degree curve, the maximum speed that a train can operate is 44 mph.

If a train is running at the prescribed speed for a curve and its super elevation, the force the train exerts on the rail is relatively balanced between the two rails. Like tangent track, this means a flaw in the track or a mechanical issue would be necessary for a derailment to occur.

If a train is operating above the prescribed speed through a curve, there are excessive lateral forces exerted on the outside (high) rail of the track structure. If the forces are severe, multiple potential derailing conditions are possible.

The first condition is related to poor track maintenance. If the rail is not securely attached to the ties, the rail can roll over and the train will derail. Poor maintenance of ties can sometimes cause this situation to occur. In poorly maintained wood ties, the spikes holding the rail to the ties loosen, and eventually can be vibrated out. This leaves little or no force holding the rail to the ties; when excessive lateral force is applied in that area, the rail can turn over.

Additionally, if the rail is not properly attached to the ties, the outside rail can actually be shoved away from the inside rail by the wheels of a train. This increases the distance between rails, which is called the gauge of the track. Correct gauge is set at 4 feet, 8 ½ inches to match the distance between wheels. If gauge greatly exceeds this distance because of unwanted rail movement, it is possible that a wheel can derail by falling between the rails.

It should also be noted that as wheels move around a curve, the metal at the top of the outside rail (called the ball of the rail) is minutely worn away. As more and more wheels traverse the curve, more metal is removed and the distance between the rails increases. If enough metal is worn away before the rail is replaced, a wide gauge situation can occur, and that can again lead to a wheel derailing.

Another potential derailing event associated with over speed through a curve is if enough lateral force is exerted, a car wheel can climb the rail causing the car to derail. Again, if the lateral force exceeds the downward vertical force of gravity, something has to give. If the rail is tightly attached to the ties, it is unlikely to turn over, or be spread away from the low rail. Therefore, the resultant action is the wheel pushes hard on the side of the rail, which can lead to the wheel riding up and over the rail. This potential result is exacerbated if the ball of the high rail has been worn over time.

If a train proceeds around a curve more slowly than the prescribed speed, there is a higher crushing force exerted on the inside (low) rail of the curve, as the downward gravitation force is greater than the lateral force created by the car moving through the curve. While that is unlikely to cause a derailment, it can damage the rail and ties over time, which can weaken the track structure. The force running on the low rail may introduce flaws into the steel of the rail, which may ultimately lead to a broken rail. This type of incident is described more thoroughly in the Rail section below.

Based on these observations, it is critical to match the track speed with the degree of curvature and the super elevation for the preponderance of trains using the route. If the curve is under elevated or poorly maintained, a light fast train has the potential to derail over the high side. If the curve is designed for fast speeds, but many of the trains are heavy slow trains that cannot reach the prescribed speed, damage can be done to the low rail.

Elevation changes (grade) also contribute to forces through curves. Grade elevation is measured in 100-foot increments. A rise of two feet per 100 feet is considered 2 percent grade. Grade is shown as positive when going uphill; it is shown as negative if going downhill. 2.2 percent grade (2 feet, 2 ½ inches rise per 100 feet) is usually the steepest grade found on mainline tracks for heavily traveled rail routes.

Grade adds additional forces within a train, and those forces are transmitted to the wheel/rail contact point. As a train pulls up a grade and around a curve, there is additional lateral force applied to the inside rail of a curve. If some action “jerks” the train (such as a locomotive slipping on wet or greasy rail), that sudden introduction of additional force is capable of creating a spike to the lateral force between the wheel and the rail on the inside of the curve. When this happens, a lighter car may be jerked up and over the rail. Placement of empty cars within a train must be considered on routes with heavy curvature and grades.

An additional impact of grade is how it affects train speed. Obviously, a train moving up a grade will likely operate at a slower speed than the same train on a flat piece of track. Conversely, a train operating down a grade will try to operate faster than the maximum track speed, unless the train is controlled by proper braking application. When braking is not applied correctly, there is a possibility of over speeding, which can lead to the potential derailment scenarios in curves that has been previously discussed.

In summary, curvature can contribute to derailments if the track is not properly super elevated, if the rails and ties are not properly maintained, if speed around a curve is too great or if a sudden force along the line of the train is introduced. Grade can contribute to train speed issues, exacerbating issues with curvature. However, curves with grades are just one aspect of track structure that can contribute to derailments.

Turnouts or switches

Turnouts (commonly referred to as switches) are where one track diverges from another track. A turnout has several important parts, including the switch points, the switch machine (or switch stand) and the frog (Figure 104).

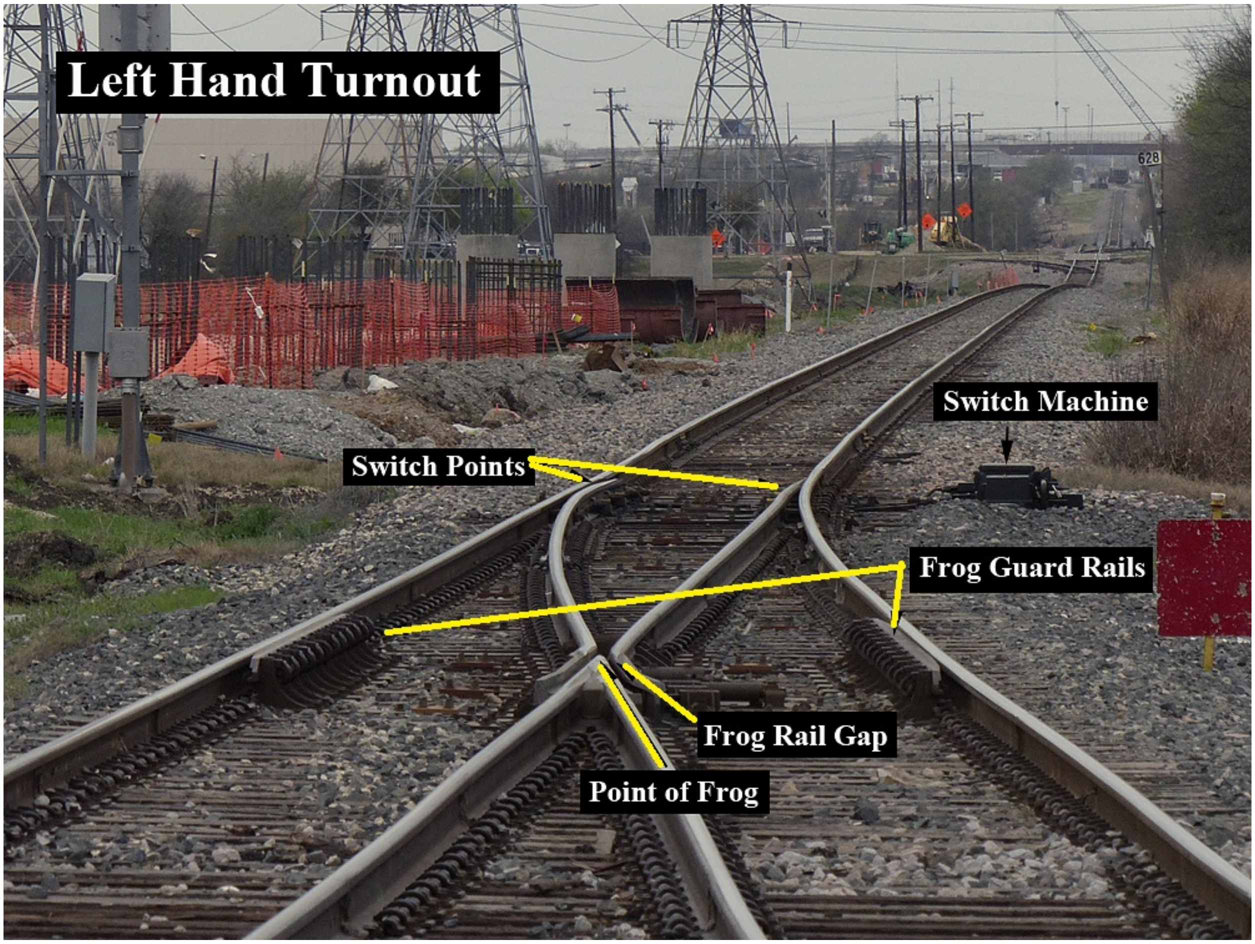

Figure 103: Left Hand Turnout Showing Switch Points, Frog, and Switch Machine[430]

Turnouts are used to provide access to:

- Sidings where trains meet.
- Crossovers where trains move from one track to a second track where there are multiple main tracks or junctions.
- Yard entrances and exits.
- Industry tracks.

The switch points (points) are the moveable pieces at the end of a turnout that direct the train wheels down one track or the other (Figure 108). Assuming an observer is standing on the single track looking towards the turnout, the diverging track goes to the left of the straight through track for a left-hand turnout (Figure 105). A right-hand turnout would have the diverging track going to the right of the straight track.

[430] Image credit: Eric Lyman. Used with permission.

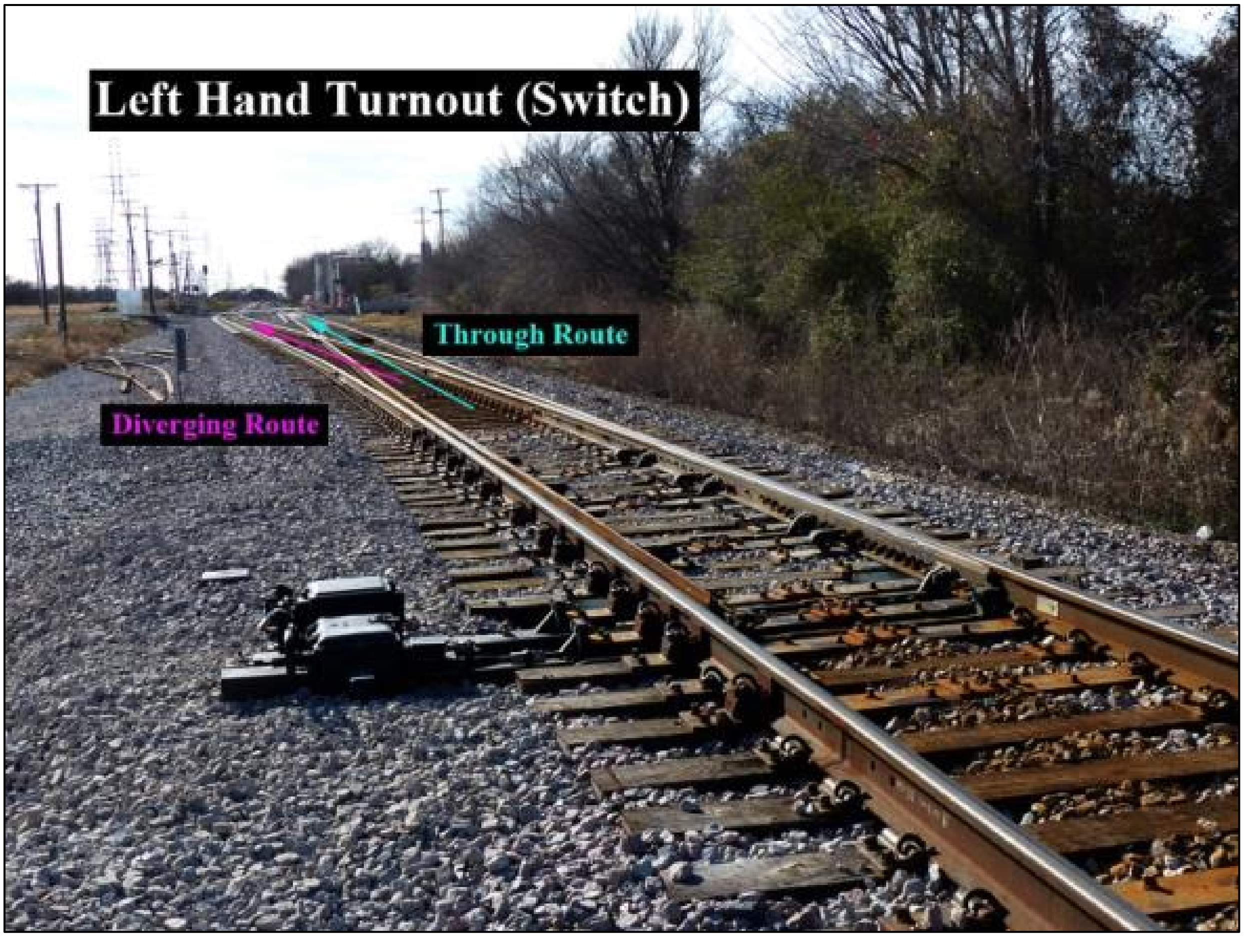

Figure 104: Diverging and Through Routes on Left Hand Turnout (Switch)[431]

Using a left-hand turnout, as an example, the left rail point would be positioned against the rail and the right point would be separated from the rail for a movement down the through track. For a diverging movement, the right point would shift over against the right rail and the left point would separate from the left rail, directing the train wheels onto the track that diverges to the left (Figure 106).

[431] Image credit: Eric Lyman. Used with permission.

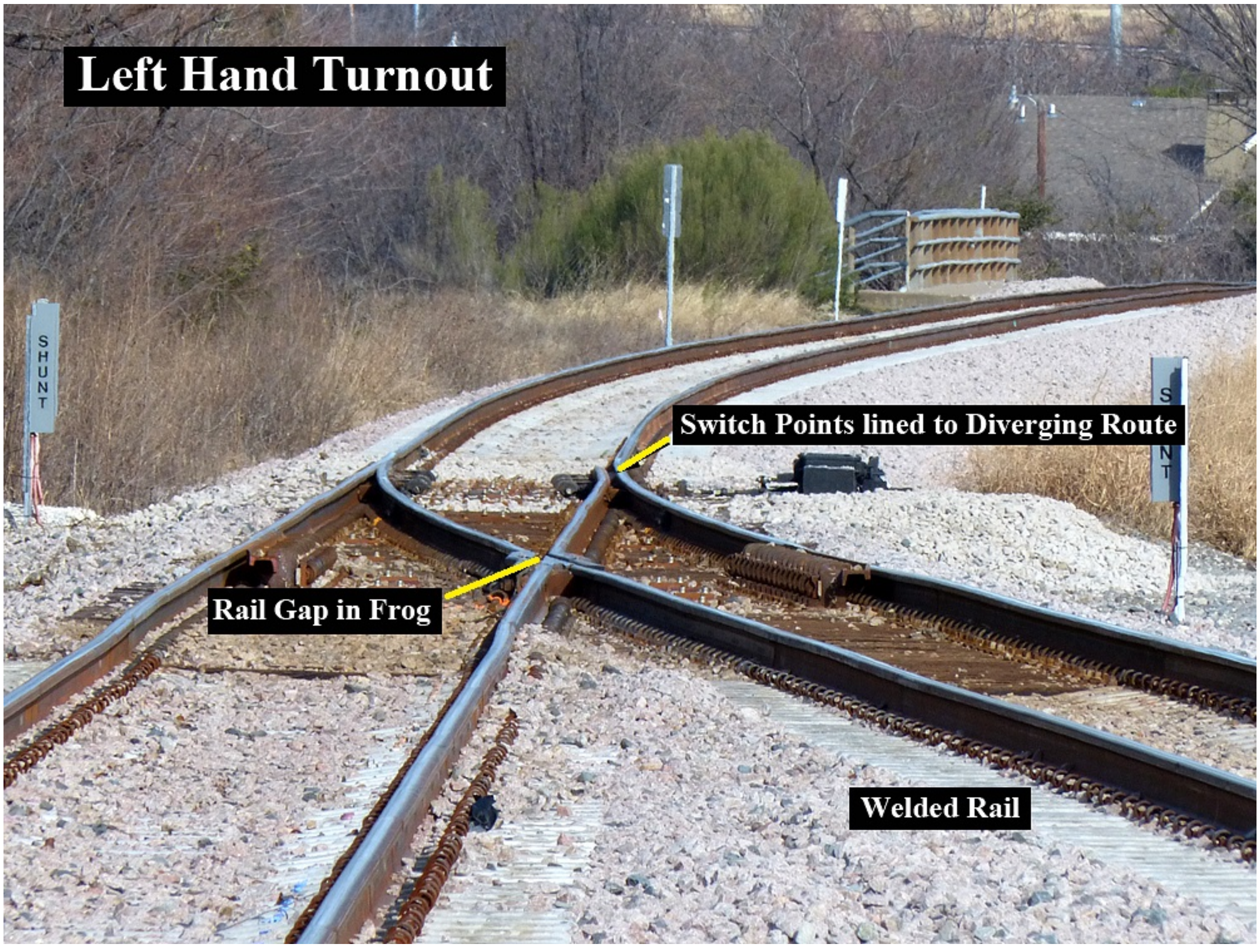

Figure 105: Left Hand Turnout with Switch Point Lined to Diverging Route[432]

The switch machine (used for automatic switch point movements) or switch stand (for manual movement of the points) is located along the side of a turnout near the tip of the points of the switch. A switch machine moves the switch points through a series of rods connected to the points (Figure 107).

[432] Image credit: Eric Lyman. Used with permission.

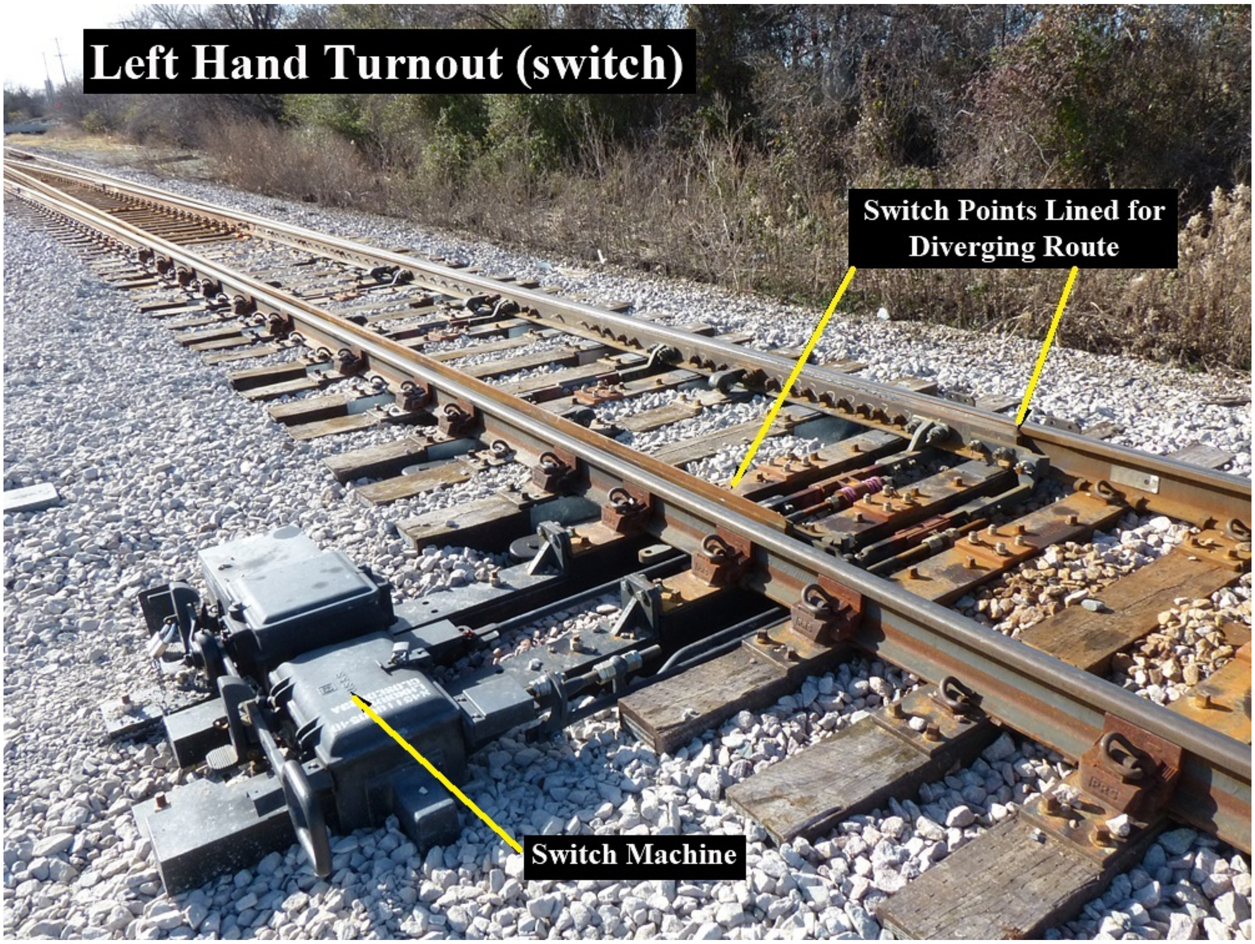

Figure 106: Left Hand Turnout (Switch) Showing Switch Machine and Switch Points[433]

A frog is a piece of the track where two rails cross. For the left-hand turnout described above, the left rail of the through route connects with the right rail of the diverging route at the switch frog. Standard frogs are machined with a gap where the wheel rolling on one route crosses the rail from the other route. There are guardrails on both sides of the point of the frog to keep the wheels in alignment so the car's wheels from one route do not accidently twist and start down the other route.

Turnouts present multiple scenarios that may contribute to a derailment. Turnouts are more susceptible to derailments than continuous rails because turnouts have interruptions in the track.

If the points of the switch are not properly aligned (with one point tight to one of the rails), it is possible for a wheel to climb over the improperly lined point and send a set of wheels down the route that the rest of the train is not moving along. With the force of the coupler pulling the car down one route while the wheels move down the diverging route, the car will derail.

A similar type of derailment can occur if the switch points are not properly maintained. As wheels roll over the switch points, the tips become worn. If enough metal is worn away, the pair

[433] Image credit: Eric Lyman. Used with permission.

of points may no longer direct the wheels on the proper route, which can lead to the same misrouting of a car as previously described.

If a switch is left lined towards the incorrect track in non-signal control territory, a train moving along that track may derail because of the speed it is traveling through the turnout. The curve of a turnout is relatively sharp, and the turnout route has no super elevation. Therefore, speeds through the diverging route of a turnout are usually noticeably reduced from the speed through the straight route. If the train does stay on the rails through an inadvertently lined turnout, it may collide with another train or car that has been left in the siding or industry track.

When a wheel from a car rolls through the gap in the rail at a turnout's frog, the wheel impacts the point of the frog. If the point of the frog is worn down through repetitive usage and not properly maintained, a larger gap forms. With a larger gap at the frog, it becomes possible for the wheel to leave the rail it is rolling on (Figure 108).

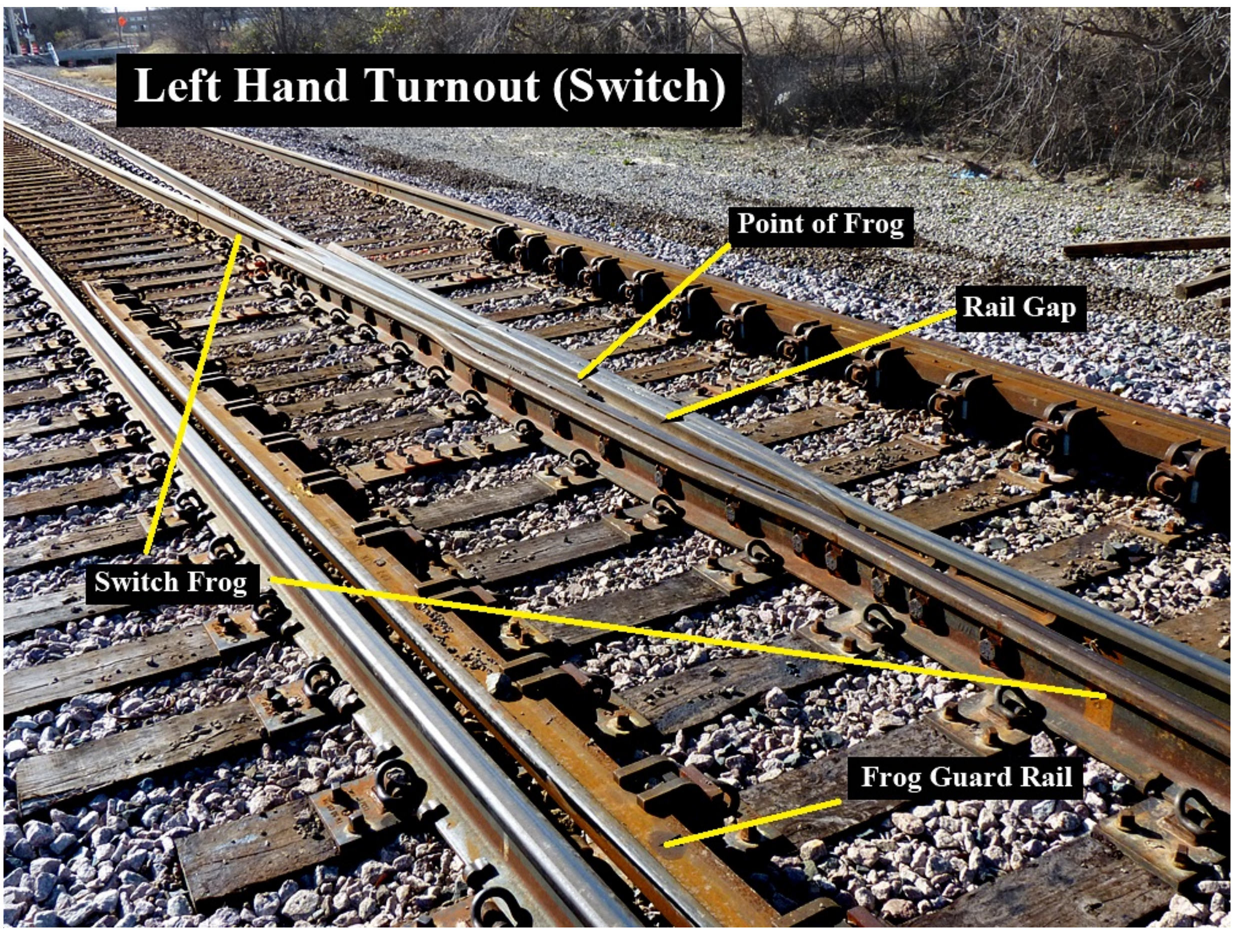

Figure 107: Left Hand Turnout (Switch) Showing Rail Gap and Frog Guard Rail[434]

[434] Image credit: Eric Lyman. Used with permission.

Finally, because a turnout has a rail of the diverging route crossing between the two rails of the through route, if something is dragging from a car, the dragging equipment may catch the rail between the two running rails and lift and derail the entire car.

These descriptions explain why large derailments frequently occur at turnouts. If the integrity of a continuous rail is affected by misaligned or worn switch points or a damaged frog, or some dragging equipment on a car catches the diverging rail between the rails of a turnout, wheels can be derailed at a turnout. If the train is moving at a relatively high rate of speed, following cars then derail and pile up as well.

Diamonds (rail crossings)

Diamonds are where two railroad tracks cross each other at grade (Figure 109). This occurs when one railway's track crosses a second railway's track (or two routes of the same railway cross). Trains on one route cannot access the second route at a diamond — a connection track with turnouts on both ends would be needed for trains to move from one route to the other.

Figure 108: Railroad Crossing Diamond Showing Guard Rails and Crossing Frog[435]

[435] Image credit: Eric Lyman. Used with permission.

Diamonds also have frog sections where the two rails from one route cross the two rails from the second route. Like turnouts, diamonds have gaps where the rails intersect, and they have guard rails bolted to the rails to prevent wheels from a train on one route from twisting towards the second route.

A diamond does not have the same issue with moveable points, so a diamond will not cause that type of derailment. However, dragging equipment can catch the cross rails at a diamond, so cars can derail similarly to what can happen at a turnout. Wear on the frog points through a diamond can also create a situation where it is possible that a wheel will derail because the gap is larger than it should be, or the rail may break because of excessive pounding by heavy locomotive or rail car wheels.

Rail conditions

Wheel loads and temperature subject rail to stresses. If there is a flaw in the rail, these stresses can lead to a sudden failure of the rail or a misalignment of the track. Broken rails and track misalignments can derail trains.

Railroads use two types of rail: jointed and continuously welded rail (CWR) (Figure 110). Jointed rails are shorter and are connected together by pieces called joint bars that attach along the side (web) of the rail. The joint bars are held together with bolts. Continuously welded rail is usually much longer, typically one quarter of a mile in length. The rail is usually welded at a foundry and then shipped to locations where it is laid to replace worn rail. Once multiple strings of CWR are laid, the joints between the strings are field welded to remove the joint between those strings.

Figure 109: Welded Rail on Concrete Ties[436]

[436] Image credit: Eric Lyman, Used with permission.

Joints create weaknesses in continuous rail. First, as trains roll over the joints, the ends of the rails become battered by the wheels (Figure 111). Over time, the integrity of the rail can be damaged. Additionally, the joint bars and bolts themselves (Figure 112) can become damaged or broken, also affecting the integrity of the continuous rail.

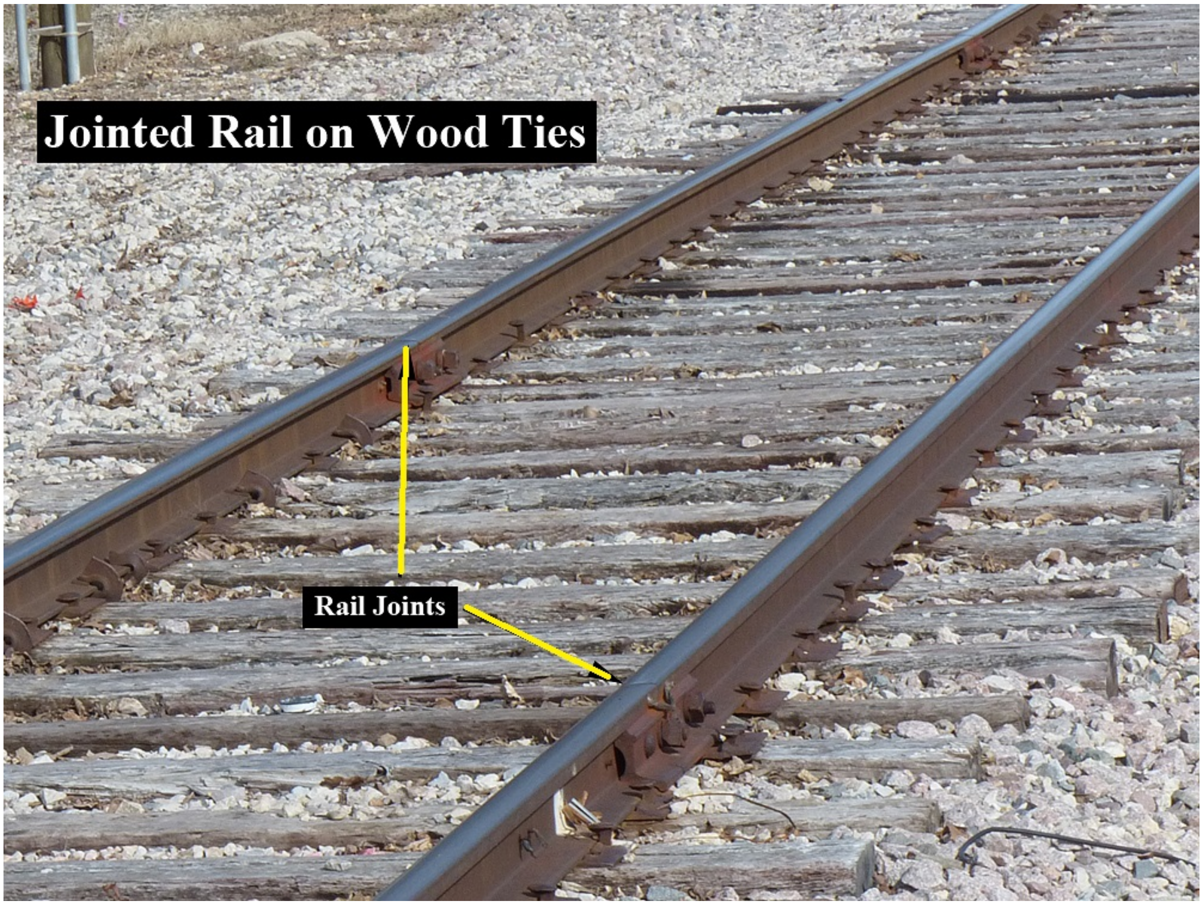

Figure 110: Jointed Rail on Wood Ties Showing Rail Joints[437]

[437] Image credit: Eric Lyman. Used with permission.

Figure 111: Jointed Rail Joint Bar[438]

Railroads are converting most of their mainlines that have jointed rail to continuously welded rail. CWR has proven to be more effective over time with less potential issues that cause derailments. However, even CWR has issues as discussed below.

From the perspective of the track structure, the ties act as supports for a very short bridge of suspended rail. As wheel loads move over the rail, there is force applied to the rail and it slightly deforms in a downward direction. If the rail and ties are in good condition, the rail returns to its normal alignment after the load is removed until the next wheel rolls over it.

Heavier wheel loads and higher train velocities impart higher forces to the rail, creating more deflection and recovery. Bad sub-grade, ballast and tie condition, also allow the rail to flex more than a well-supported rail.

A rail subjected to this constant flexing can lead to a failure. This is much like bending a paper clip many times, until the wire snaps in two. If the composition of the rail already has a flaw in it, the rail can fail more quickly under the constant repetitive flexing.

Temperature also places stresses on rail. During high temperature periods, as the rail heats up, it expands along its length. The ties, spikes and a track component called a rail anchor hold the rail in place within the ballast. A rail under this stress attempts to de-stress itself, and the only

[438] Image credit: Eric Lyman. Used with permission.

possible alternative is a side-to-side movement. If the lateral stresses within a heated rail exceed the holding force of the ties and ballast, the rail will displace the entire track structure (rail, tie plates, ties, spikes and rail anchors) laterally, allowing the rail to buckle. This displacement is commonly called a sun kink or thermal misalignment, and it can derail a train.

A thermal misalignment is particularly dangerous to trains because the signal system for the section of track continues to work normally. Since the rail remains intact, albeit severely out of alignment, the signals do not recognize there is an issue for an approaching train.

Once the rail has buckled laterally, the misalignment creates a set of very short, sharply reversing curves within the track alignment. A train that hits this misalignment acts the same as if it were over speeding through a curve — an excessive lateral force is created between the wheels and the point they contact the rail. This excessive lateral force will cause cars to derail and may even cause the locomotives to derail if the kink is severe enough.

Rail in cold weather locations also is affected by temperature. Conversely to thermal misalignments, a rail subjected to cold will tend to shrink along its length. Again, the ties, rail fasteners and rail anchors will hold the rail in place within the ballast. However, if forces are severe enough, particularly if there is a flaw in the composition of the rail steel, the rail can be prone to breaking in cold weather.

A train running over the rail will exacerbate this issue. In cold weather, the rail becomes more brittle, so a force such as a wheel rolling over it accentuates any flaw in the metal of the rail. If the rail breaks cleanly, and stays in alignment on both sides of the break, a train can make it over a break without derailing. However, if the fracture removes a portion of the head and web of the rail, or the rail becomes misaligned by the break, it is likely a wheel will derail moving over the break.

Broken rails are easier to detect because if the break cleanly separates the two pieces of a continuous rail, the signal system will recognize a break in the circuit and signals on both sides of the break will turn red. This will either force an approaching train to stop until it gets permission to proceed, or it will instruct the train to slow to a speed that allows the train to be stopped within the engineer's sight distance.

If, however, the rail breaks under a train's wheels, or if the fracture is not clean and leaves some of the rail intact, the train will have no warning that there is a broken rail. Under that situation, it is possible that a train will derail while passing over the break.

Grade crossings

Another area susceptible to accidents and derailments are grade crossings. Grade crossings have concrete or wooden planks located between the rails to create a smooth surface for the highway traffic to cross. With the planks or concrete sections between the rails, a piece of equipment dragging from a car is susceptible to catching on the planks and derailing the car (along with subsequent cars) in the same manner that occurs with a turnout or diamond.

Additionally, grade crossings bring highway traffic into contact with rail traffic. Even crossings with active warning devices like flashing lights and gates are susceptible to accidents, because drivers will occasionally ignore the warnings. If the vehicle is small that is hit by a train, such as a passenger car, it is unusual for the train to derail. This is because the locomotives have much more mass than the car, which results in the car being shoved out of the way of the train. However, if the train hits a heavier vehicle such as a loaded truck, it is much more likely that forces occurring during the impact will lift the locomotives, which will cause them to derail.

Location of the grade crossing also plays an important role in the likelihood of a grade crossing accident. Crossings in flat areas with good visibility in both directions are less likely to experience an accident compared to crossings with limited visibility in one or both directions. Crossings near the intersection of two roads are also more susceptible to accidents than those along a single road.

When a crossing is near an intersection, traffic crossing the railroad tracks can be stopped by the intersecting highway traffic or a traffic light. Cars waiting in line will sometimes ignore the grade crossing and park on the track while waiting to proceed. If a train comes along, those cars can be trapped on the grade crossing.

Long trucks waiting at the intersection can also extend back onto the grade crossing. Truck drivers that are not aware of where the end of their trailer is located may accidently leave the trailer foul of the tracks, where it can be struck by a passing train.

Curves

Rail tracks inevitability have sharp curves as they are restricted to the landform. “Tight” curves are defined as those with a radius of 500 to 1,000 meters (1,640 to 3,280 feet). The degree to which curves contribute to derailments or other accidents is tied in with train speed.

When a heavy-haul rail car is negotiating curved tracks with low speeds, the phenomenon of the “hunting motion” (also called “hunting oscillation”) occurs. Hunting motion or hunting oscillation is the back and forth swaying of the train on the rails as it “hunts” for equilibrium. Due to the hunting motion on the curved tracks, the interaction force between the wheel and the rail is significantly enhanced, the performance of the negotiation is severely deteriorated, the rail is sharply worn, and the rail life is clearly shortened, which may cause the vehicle to derail on curved track. For this reason, hunting motion on curved track has been studied extensively (Lee and Cheng 2005; Cheng and Lee 2005; Dukkipati and Swamy 2001).

One analysis resulted in the conclusion that the maximum speed on a curve with a radius of 600 meters (1,968.5 feet) is 47.5 mph (Wang and Liu 2012). This result reiterates the importance of speed reductions in curvy areas. The overall maximum speed of 45 mph for CBR trains (or 40 mph in high-threat urban areas or HTUAs) would cover the problem. But even slightly higher speeds could cause significant lateral shifts.

Track upgrades and operating speeds

In a series of studies conducted at the Rail Transportation and Engineering Center at the University of Illinois at Urbana-Champaign (Liu et al. 2010, 2013a, 2013b; 2014), the following conclusions were reached on reductions of rail accidents, primarily derailments, with safety enhancements:

- Track upgrades significantly reduce derailment rates.

- Broken wheel and accident rate down by 20 percent since 2004 due to wayside detectors.
- Integrated risk management systems that focus on reducing broken rails and broken wheels can significantly reduce derailments.

Improvements or upgrades to railroad track are likely to prevent or reduce the occurrence of certain types of track-related derailment accidents. At the same time, because these upgrades will allow for trains to travel at higher speeds, they may also increase the risk of certain types of equipment failures that are more likely to occur at higher speeds. Derailments at higher speeds also tend to involve more cars (Etkin et al. 2017, Liu et al. 2011a, 2011b).

Train derailments are less likely to occur on higher FRA track classes (Anderson and Barkan 2004 and Liu et al. 2011a), as shown in Table 125. FRA track classes are defined as follows:

- **FRA Class 1 Track:** track classified by FRA with respect to maximum speed for track condition as 10 mph for freight, 15 mph for passenger. Much yard, branch line, short-line, and industrial spur trackage falls into category.
- **FRA Class 2 Track:** track classified by FRA with respect to maximum speed for track condition as 25 mph for freight, 30 mph for passenger; Branch lines, secondary mainlines, many regional railroads, and some tourist operations frequently fall into this class.
- **FRA Class 3 Track:** track classified by FRA with respect to maximum speed for track condition as 40 mph for freight, 60 mph for passenger. This commonly includes regional railroads and Class 1 secondary mainlines.
- **FRA Class 4 Track:** track classified by FRA with respect to maximum speed for track condition as 60 mph for freight, 80 mph for passenger. This is the dominant class for main-line track used in passenger and long-haul freight service.
- **FRA Class 5 Track:** track classified by FRA with respect to maximum speed for track condition as 80 mph for freight, 90 mph for passenger. This is the standard for most high-speed track in the US.
- **FRA Class 6 Track:** track classified by FRA with respect to maximum speed for track condition as 110 mph for freight, 110 mph for passenger. This is found in the US exclusively on Amtrak's Northeast Corridor between New York and Washington, DC.

Table 125: Derailment Rates by FRA Track Class for Freight Trains Including the Average Speed at Time of Derailment, Derailment per Million Train Miles and Derailments per Billion Freight Car Miles[439]

FRA Track Class	Maximum Train Speed for Class	Average Speed at Time of Derailment	Derailments per Million Freight Train Miles	Derailments per Billion Freight Car Miles[440]
X and 1	10 mph	7.7 mph	48.54	720.1
2	25 mph	16.9 mph	6.06	92.7
3	40 mph	25.0 mph	2.04	31.5
4	60 mph	33.2 mph	0.53	7.8
5	80 mph	37.4 mph	0.32	4.9
All Classes	**-**	**25.7 mph**	**1.00**	**14.8**

Equipment-related accidents increase somewhat in FRA track classes 4 and 5. However, the end result is that with track class upgrades, there is an overall risk reduction, though the severity does increase with track class. This means that in the less likely event that there is a derailment, the actual number of cars derailed would be expected to be higher. However, this may be due to the higher speed rather than track condition (Etkin et al. 2017).

Train-related factors that affect accident rates

Besides track geometry and train velocity factors affecting the likelihood of accidents, there are also factors related to the condition and features of train equipment that may affect accident rates.

Effect of train length

The trend in the railroad industry is to increase the length of all trains. There are several reasons for this trend. One involves cost and the other involves capacity.

Longer trains reduce costs because fewer crews are used to move the same amount of freight. Longer trains also reduce the number of trains on a given corridor.

Distributed power units (DPU) have made longer trains possible. DPUs are locomotives that are placed in the middle or on the end of a train, with those locomotives being controlled by the engineer at the front of the train. The advancements in digital communications and electronics have made DPU possible, whereas 20 years ago, there was little talk of expanding trains from 7,000 feet to 12,000 or more feet.

DPU allow the railways to increase train length because they reduce the forces between cars. When all the locomotives are on the head end of a train, the couplers between cars near the front of the train carry all the force of the locomotives pulling one way and the entire weight of the train pulling the other way. Since couplers are rated for a limited number of pounds of force that

[439] Anderson and Barkan 2004 and Liu *et al.* 2011a.
[440] Freight car mile = freight car traveling one mile. Train-miles treat whole trains with multiple cars as one unit.

they can withstand without breaking apart, a train with all power on the head end was limited by a finite amount of tonnage that kept the couplers within their ratings.

DPU at the rear (or the middle) of a train reduce the stress forces on the couplers by shoving a portion of the train. With the reduction in forces in the couplers, more cars (additional weight) can be added and the couplers remain within their rating. The reduction of forces along the line of the train is a positive for the movement of trains and can actually reduce the chances of some types of derailments.

However, DPU can create other potential derailment issues. When a train is moving uphill on a territory with high curvature, if the DPU loses power (through a mechanical or communications issue), the sudden change of force throughout the train can create conditions that can lead to a derailment. As discussed previously about empty cars moving through curves that receive a sudden “jerk,” an empty or group of empties can be pulled off the track.

DPU have made train make up critical, particularly when running longer trains over territories that include grades and curves. If a train is incorrectly made up with large groups of empty cars surrounded by heavy loads, the train may be more susceptible to derailment than trains where the loads and empties are correctly spaced.

A commonly-cited concern about CBR trains is that, with 100 to as many as 120 cars, they are longer than other freight trains, and that this length increases the likelihood of an accident. The maximum length of a freight train is determined by the capacity of the locomotives, weight limitations, and coupler strength. Typically, U.S. Class 1 railroad freight trains range from 80 to 120 cars, though they can be as long as 200 cars (Furtado 2013; FRA 2005). The average freight car number for trains involved in main line accidents during 1975–2015 was 74.5, and from 2000–2015 was 77.6 cars, based on analysis of FRA accident data.

Train length does have, however, an effect on the probability of accidents, according to at least one study (Schafer and Barkan 2008). Table 126 shows the results of an analysis of freight trains that vary from 10 to 150 rail cars with respect to accident rates. In the end, the study conclusions were that running fewer, longer trains would reduce the overall number of accidents as opposed to running a higher number of shorter trains. The increase in accidents with a 100-car (or 102-car) train compared with a more standard 80-car freight train of the past amounts to 12.4 percent.

Table 126: Probability of Accidents for a Train Based on Train Length (Number of Cars) as Modeled[441]

Train Length (Number of Cars)	Corresponding Probability of Accident for Individual Train
10	0.00193
20	0.00214
30	0.00235
40	0.00256
50	0.00277
60	0.00298
70	0.00319
80	0.00340
90	0.00361
100	0.00382
110	0.00403
120	0.00424
130	0.00445
140	0.00466
150	0.00487

Mechanical failures

Mechanical issues can also create situations that can lead to derailments. Dragging equipment, roller bearing failures, hot wheels and even air line and brake issues can potentially derail a car or train.

As has been discussed, dragging equipment such as brake rigging, can catch on track components or grade crossing planking. Additionally, loose chains or strapping from loads can drag along the ground, with the potential to wrap around switch stands or other appliances along the side of a track. When one train meets an opposing train in a siding, a crew member from the stopped train is required to watch the moving train pass by from the opposite side to determine if any dragging equipment can be observed. Additionally, mainline railways install dragging equipment detectors at key locations to identify if equipment of some sort is dragging alongside the train.

Rail wheel sets roll within a component called a roller bearing. A bearing that is failing becomes hot with friction. If the bearing becomes hot enough, it can lock up or can cause an axle to actually melt and fail. Brake shoes that have been applied but failed to release can also heat a wheel sufficiently that the wheel becomes prone to failure. Both examples can lead to the derailment of a car.

Wheel flat spots can develop on one or more wheels when brakes stop the wheel from turning but the train continues to move. If the flat spot is severe enough, once the wheel resumes turning there is a potential to create broken rails as the flat spot impacts the rail. In some cases, the wheel itself can shatter, which will also derail a car.

[441] Schafer and Barkan 2008.

In rare instances, a failure in the air brake line on a train can cause an accident, particularly on a grade. Trains use air pressure transmitted from car to car to apply and release each cars' brakes. A disruption of the ability to transmit air from car to car can cause a brake failure.

When a train's air line has become kinked or blocked, the blockage prevents the brakes from setting up from that car through the end of the train. On grades, losing that percentage of brakes for the train can lead to the train not being able to control its speed, which can lead to a potential runaway situation.

Locomotives failing or slipping on wet or greasy rail can also cause forces that can potentially derail a train as described previously. Similarly, loss of communication with a DPU can cause those locomotives to shut down, which may also create forces to derail a portion of a train.

Lateral stability with crude-by-rail unit trains

Regarding CBR unit trains, Etkin et al. reported on a study conducted by TÜV Rheinland Mobility Rail Sciences that:

> ...unit trains are different from mixed cargo (manifest) trains in that all of the cars are relatively identical in size and shape. Unit trains are believed to have a greater lateral stability than manifest trains. This hypothesis was tested in a study conducted by TÜV Rheinland Mobility Rail Sciences for the Port of Vancouver, Washington. The Port of Vancouver requested that TÜV Rheinland evaluate the derailment risk of a proposed route exiting BNSF Railway Fallbridge Subdivision at MP 10.69 into the port. (TÜV Rheinland Mobility Rail Sciences Division 2014; Etkin et al. 2015, 2017).

And also:

> As part of this study, the researchers analyzed the derailment probability for a 120-car CBR unit train with three locomotives at the head end and two at the rear end. The in-train force analysis indicated that the maximum in-train longitudinal forces observed in all nominal and braking simulation scenarios were well within industry and AAR-recommended limits. The lateral-to-vertical ratio (L/V) is the lateral (side-to-side) force pushing outward against the rail compared to the vertical force pushing downward on the top of the rail. The tendency for the rail to tip and/or move laterally, or for the wheel to climb the rail increases as the L/V ratio increases so that:
>
> - L/V = 1.29, wheel may climb new rail;
> - L/V = 0.82, wheel lift impending;
> - L/V = 0.75, wheel may climb worn rail; and
> - L/V = 0.64, rail overturn force starts (unrestrained rail may overturn).
>
> The results of the analyses of the CBR unit train, as shown in [Table 127] indicate that all individual wheel L/V ratios were well under the maximum allowable values for the industry. Overall, TÜV Rail Sciences concluded that the proposed operation and track configuration was well within industry safety standards, and thus represented a low risk of derailment. (Etkin et al. 2017)

Note that the industry standards for maximum individual wheel L/V ratios are 0.82 (as recommended by industry) and 1.0 (as recommended by AAR). The industry standard for minimum percent wheel unloading standard is 10.0 percent. The maximum axle sum L/V ratio is 1.50. The industry standard for maximum truck side L/V ratio is 0.60.

Table 127: Vehicle Dynamic Results for Loaded Tanker Cars Based on Lateral and Vertical Parameter and In-Train Force on Train Car Couplers on Track as Designed and Class 1 and 2 Cross Level Dips[442]

Parameter	In-Train Force on Train Car Couplers	As-Designed Track	Class 1 Cross Level Dip	Class 2 Cross Level Dip
Maximum Individual Wheel L/V Ratio	300 Kips Buff	0.43	0.59	0.57
Maximum Individual Wheel L/V Ratio	300 Kips Draft	0.34	0.52	0.50
Maximum Individual Wheel L/V Ratio	None	0.39	0.56	0.54
Minimum % Wheel Unloading	300 Kips Buff	83.86	56.96	59.42
Minimum % Wheel Unloading	300 Kips Draft	90.60	68.37	70.75
Minimum % Wheel Unloading	None	90.87	62.09	64.75
Maximum Axle Sum L/V Ratio	300 Kips Buff	0.76	0.91	0.89
Maximum Axle Sum L/V Ratio	300 Kips Draft	0.67	0.84	0.83
Maximum Axle Sum L/V Ratio	None	0.73	0.88	0.86
Maximum Truck Side L/V Ratio	300 Kips Buff	0.32	0.39	0.38
Maximum Truck Side L/V Ratio	300 Kips Draft	0.33	0.32	0.31
Maximum Truck Side L/V Ratio	None	0.30	0.36	0.35

Note that a *kip* is a U.S. customary measure of force that is the equivalent of 1,000 pounds of force.

In draft mode, the yoke straps are placed in tension as the gear is compressed between the rear of the yoke and the striker. The striker is part of the car body structure and the path of the force is through the follower. In the buff mode, the coupler, which acts through the follower, places the gear in compression against the car body's rear stops.

There are no specific studies on lateral stability of mixed-manifest trains. The degree to which the results of the study on CBR trains can be extrapolated to other trains is unknown.

Sloshing of partially-filled rail tank cars

The sloshing of liquid cargo in tank cars has been brought up by some groups as an issue of concern for CBR transport. The concern is that the oil in partially-filled cars moves back and forth in waves causing more lateral (side-to-side) strain on tracks, both harming the tracks and increasing the likelihood for derailment (Ashtiani et al. 2015). Longitudinal (in the direction of

442 TÜV Rheinland Mobility Rail Sciences Division 2014.

the train movement or track, not from side to side) sloshing has also been an issue of concern under certain circumstances, particularly with regard to braking.

Slosh in tank cars has been identified as a potential issue during transport at slower speeds. In particular, if a train were to stop quickly, there may be some longitudinal sloshing that could cause braking issues. This concern has led to the consideration of advanced brake signal propagation systems in unit trains carrying Class 3 flammable liquids.[443] In its May 2015 USDOT/PHMSA Final Rule, Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains,[444] longitudinal sloshing (liquid movement in the direction the train is moving along the track) is mentioned as a potential contributing factor for derailments during the application of conventional air brakes (as opposed to ECP brakes). In addition to concerns about braking problems with longitudinal sloshing, there have been concerns about longitudinal sloshing causing undue wear on tracks, which may increase accidents.

A comprehensive review of existing engineering studies on sloshing was conducted for this analysis. According to various media reports, the FRA had been studying the sloshing effect in crude oil tank cars, including increases in sloshing due to required slower speeds, since early 2015.[445] An even earlier 2009 study conducted for the FRA (Jeong et al. 2009) concluded that the movement or sloshing of the fluid in tank cars during an impact event plays a significant role in force-time behavior, meaning it could increase the force involved in a collision. The study did not address the issue of whether sloshing would *cause* derailments or other accidents.

Partially-filled tanks in tank cars are prone to violent sloshing under certain motions. The large liquid movement creates highly localized impact pressure on tank walls that may in turn cause structural damage and may even create sufficient moment to affect the stability of the vehicle that carries the container. When a tank is partially filled with fluid, a free surface is present. Then, rigid body acceleration of the tank produces a subsequent sloshing of the fluid (Celebi and Akyildiz 2002).

Structural and fatigue analyses on tank cars have indicated that fluid sloshing exerts pressure on head walls, end walls, and side walls within the tanks themselves (Jimin et al. 2009). There are no quantitative assessments of the degree to which this might increase the likelihood of a release from tank cars upon impact. Other studies on sloshing have focused on the effects of liquid movement within tank cars with respect to pressure build-up and internal forces on parts of the tank car shells, but not in reference to any increased risk of derailment or other accidents (Tang et al. 2008a; Tang et al. 2008b; Barkan et al. 2000).

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[443] Federal Register Vol. 80 No. 89, 8 May 2015, Pipeline and Hazardous Materials Safety Administration 49 CFR Parts 171, 172, 173, *et al.* Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains; Final Rule.

[444] 49 CFR Parts 171, 172, 173, 174, and 179: DOT Pipeline and Hazardous Materials Safety Administration Docket No. PHMSA-2012-0082 (HM-251) ROM 2137-AE91

[445] For example: http://www.bloomberg.com/news/articles/2015-03-13/speed-limits-may-not-stop-fiery-oil-spills-u-s-rail-chief-says; Railway Age website. 2015. Thomas, David. *FRA Freezes on Tank Car Sloshing; DOE Oil Volatility Bombshell drops like a dud.* http://www.railwayage.com/index.php/blogs/david-thomas/fra-freezes-on-tank-car-sloshing-doe-oil-volatility-bombshell-drops-like-a-dud.html?channel= .

There have been no definitive conclusions on the degree to which sloshing may increase the likelihood of derailments. In fact, there have been conflicting results. One technical engineering study indicated that sloshing tends to increase the possibility of wheel/rail separation, thereby *increasing* the probability of derailments (Wang et al. 2014). This study found that the normal contact force of the wheelset of the rear bogie[446] becomes irregular with sloshing.

According to this same study, the speed at which a rigid-body (non-fluid-containing) car would derail on tangent track is 201 mph. For a fluid-containing car, the derailment speed is 134 mph. If the track is curved, the derailment speed for the fluid-containing car is 78 mph. (Note that these speeds exceed the typical and recommended speeds for CBR unit trains.)

A different engineering study (Gialleonardo et al. 2013) evaluated the running dynamic effects for partially-filled tank cars by modeling the various curve geometries, train speeds, and fill levels to analyze derailment and rollover (overturning) risks. This included longitudinal, lateral, and yaw[447] sloshing. The researchers concluded that sloshing can "significantly increase" the risk of *tanker truck* rollover, whereas its influence on the risk of derailment was "minor," because the running safety against flange climb derailment is only marginally affected by fluid sloshing even on "S-curves." Note that most of the past research studies on sloshing effects have been conducted on *tanker trucks*, not specifically on rail tank cars, which behave differently on tracks than tanker trucks do on roadways.

Another older study on partially-filled tanks indicated that neglecting fluid slosh in a partially-filled tank car could lead to an under-estimation of derailment potential by 18 to 25 percent (Abramson 1966). The fluid slosh movements may affect wheel-rail contact loads, according to one group of researchers (Ashtiani et al. 2015). This research team's study, however, concluded that the fluid slosh in partially filled tank cars yield an additional *dampening* effect on the lateral dynamics of the tank car (Table 128).

Table 128: Change in Critical Speed in Lateral Hunting with Liquid Sloshing Based on Tank Car Load State and Type of Cargo[448]

Tank Car Load State	Cargo	Specific Gravity	Total Cargo Mass (tons)	Solid Rigid Cargo with Speed (mph)	Liquid Cargo with Speed (mph	Increase in Critical Speed with Slosh
97% Full	**Fuel**	0.80	71.8	66.0	66.0	0
76% Full	**Water**	1.00	74.3	66.4	68.5	1.03
46% Full	**Sulfuric Acid**	1.80	74.5	74.9	80.5	1.07
Empty	**n/a**	n/a	n/a	51.4	51.4	0

The net effect is that the train is actually *more stable* on the tracks due to lateral sloshing. The 97 percent filled tank car containing fuel essentially acted the same as a car with rigid cargo. There was a negligible effect of liquid slosh in high-fill levels. Lateral liquid cargo movement within a partially-filled tank car could thus yield a *beneficial* influence on the wheelset hunting, thereby

[446] A bogie on a train car is the chassis. It bears the load of the freight car, transmits the traction and braking forces, steers the car in a safe manner, and smooths out track irregularities.
[447] Yaw movements are twists or oscillations around a vertical axis (relative to the track).
[448] Ashtiani *et al.* 2015.

stabilizing the cars on the track. Consequently, a partially-filled tank car can result in a relatively higher critical hunting velocity compared to that of a car with an equivalent rigid cargo. In other words, the fluid slosh within a tank of a railway wagon essentially acts as an absorber against the lateral hunting motions.

With respect to CBR tank cars, it is unlikely that the tank cars would be transported only partially filled, as this would not be cost efficient. While there would always be some room in the car for liquid expansion and to accommodate the different densities of the oils (e.g., very light Bakken crude vs. much denser diluted bitumen), it would not be less than 90 percent full.

Tank cars do not have baffles in them that are analogous to liquid tanks on ships.

Position in train

Research has shown that cars in front of the middle of a train are more likely to derail in a broken-rail-caused derailment than the cars at the very front or towards the end (Liu et al. 2014). An understanding of the likelihood of different cars derailing can be used to determine the safest location for tank cars carrying particularly hazardous commodities. The reasons that the cars in the middle of the train are more likely to derail than the cars at either end of the train are based on physics, that is, the forces to which the cars in the middle are subjected.

The degree to which the results of this study on an 82-car train can be extrapolated to a train of 100 to 120 cars is unknown. There are no specific studies on 100- to 120-car trains.

Human operator factors affecting rail accident rates

Human factors can also affect the frequency of accidents.[449] The knowledge, competence, and condition of train engineers and other train personnel have a major effect on getting trains safely from one location to another. More information on crew training is presented in Chapter 12.

Human error

Human error is a reoccurring cause for derailments. Some of the main causes of human error derailments can include fatigue, distraction, and repetitive routine, improper train handling,and loss of situational awareness.[450]

Train crews are on call 24 hours per day. While there are restrictions on how many hours can be worked prior to mandated rest time, there are no defined shifts for over the road train crews. This means that the working and rest hours change day to day. The inconsistency of when a person is called to work and rest can contribute to fatigue.

Railway crew fatigue is similar to driver fatigue; while operating the vehicle, the driver falls asleep and causes an accident. With railway fatigue, the accidents often occur when the crew that is controlling the train fails to respond to a restrictive signal, and the train proceeds onto track

[449] https://www.transportation.gov/testimony/role-human-factors-rail-accidents
[450] For more information on crew fatigue, see Chapter 12, Fatigue.

that it is not authorized to occupy. This can lead to collisions with other trains, which usually result in major incidents.

Another cause of human error derailment is distraction (NTSB 2010, 2016). Crew members on their cell phones or other devices may not be paying attention to the signal system or where they are relative to track segments with restricted speed limits. Railways normally restrict the use of personal communication devices by crew members while on duty.

Repetitive routines are also a cause of human error that leads to derailments.[451] Doing the same thing over and over each day leads to complacency regarding the task.[452]

Improper train handling is another human error that can cause derailments (Liu et al. 2012). Improper application of air brakes can create in-train forces that can potentially derail a car. Using too much braking air and then not having enough for further braking can also cause speed issues, which can lead to derailments.

Loss of situational awareness can also cause derailments (NTSB 2016). Loss of situational awareness is when an engineer and any other crew members in the control compartment of a train basically forget where they are relative to the route they are moving over. This can lead to overlooking track speed restrictions or track work restrictions, which can put trains into situations where they are moving faster than a safe track speed. This may lead to the potential for collisions or derailments.

Fatigue

Combating fatigue and assuring the train crews are properly rested is vital to insuring safety. The railroad industry views combating fatigue as a shared responsibility. Employers should provide an environment that allows employees to rest during off-duty hours, and employees should set aside time when off duty to obtain the rest they need (AAR 2018b).

Work hour regulations

AAR attributes the continual reductions in accidents and injuries, in part, to efforts to reduce fatigue issues, especially through the Hours of Service Act (HSA), first enacted in 1907 to limit railroad employee hours, which was amended several times over the years, most recently by the Rail Safety Improvement Act (RSIA) in 2008. Under these regulations, freight rail engineers and conductors (AAR 2018b):

- Must go off duty after 12 consecutive hours on the job and then must have at least 10 consecutive hours off duty before the railroad can notify them of their next assignment.
- May not remain or go on duty unless they have had at least 10 consecutive hours off duty during the prior 24 hours.
- If they work for six consecutive days, they must have at least two days off before they can work again. Working seven consecutive days is acceptable if the seventh

[451] http://www.hse.gov.uk/construction/lwit/assets/downloads/human-failure.pdf
[452] https://www.newsday.com/long-island/transportation/lirr/metro-north-derailment-reignites-engineer-fatigue-debate-1.6573072

day is required to return employees to their home terminal. However, if employees work seven consecutive days, they must have at least three consecutive days off before they can return to duty.

- On duty time and limbo time, in aggregate, cannot exceed 276 hours per month. (The vast majority of rail employees does not come close to this limit, and in fact are on duty for periods comparable to employees in most other industries.)
- For train dispatchers, a workday is limited to nine hours in a 24-hour period where two shifts are used, or 12 hours over the same period when there is only one shift. Signal employees can work a maximum of 12 consecutive hours on duty followed by at least 10 hours off duty.

For various reasons, a train crew may be unable to reach its destination within the allotted 12 hours. When this happens, the crew must stop the train and wait for replacements. Transportation of the crew from the stopped train to its destination terminal where the employees are released from duty is called "deadhead" transportation. (The mandatory rest period does not begin until an employee is released from duty.) For purposes of the HSA, time that the crew spends waiting for deadhead transportation after 12 hours of service, as well as the time they spend being transported to where they are released from duty, counts as neither time on duty nor time off duty. Instead, this time is considered "limbo time." Limbo time cannot exceed 30 hours per month. Employees receive additional rest after a duty tour where time on duty and limbo time exceed 12 hours. (p. 2)

Set work schedules

One of the ways in which many industries and workplaces alleviate fatigue is to set specific work schedules for employees. While many rail employees do work set schedules, some rail employees, such as some train crews, work flexible schedules that vary based on a variety of factors, including business levels, the time of the year, and the day of the week.

Overall, the more rail traffic there is, the more rail employees are needed. According to AAR (2018a):

> …because many different factors affect rail traffic, volume can vary by tens of thousands of carloads from one day to the next, much less one week or month to the next. Railroads have no control over the external forces that drive most of these variances, such as the state of the overall economy; the size and timing of grain harvests; factory ramp-ups and shutdowns; commodity prices; the timing and frequency of ocean vessel arrivals and departures; the status of export markets; and more.
>
> In many cases, collective bargaining agreements with railroad unions allow rail employees, especially those with the most seniority, to largely self-determine their work schedules (subject to the HSA limitations). These employees' actions, in turn, affect how many hours, and when, less senior employees work. This greatly complicates railroads' ability to schedule crew assignments. For example, if an employee suddenly decides to take a day off just before being called to work, it would cause an employee next in line to unexpectedly move up in the calling chain.

> Weather conditions, track maintenance, accidents, an unexpected employee illness, and dozens of other factors can affect an employee's work schedule, thus impacting the time other crews will be needed. For example, when a motor vehicle goes around crossing gates and is hit by a train, not only might that train be delayed for several hours, but trains behind it, other trains approaching from the opposite direction, and trains at terminals elsewhere on the railroad's system might be delayed as well. (p. 3)

Railroad efforts to alleviate fatigue

Some of the ways in which railroads are addressing the complex issue of fatigue are through some scientifically-based fatigue countermeasures (AAR 2018b), such as:

> - Increasing the minimum number of hours off duty and providing more predictable calling assignments and rest opportunities between shifts;
> - Focusing on returning crews home rather than lodging them away from home and making away-from-home lodging more rest-inducing;
> - Devising systems (including web sites, e-mails, and automated telephone systems) to improve communication between crew callers and employees;
> - Allowing employees who have been off work more than 72 hours (e.g., on vacation) to begin their first shift in the morning rather than the middle of the night;
> - Encouraging confidential sleep disorder screening and treatment; and
> - Offering fatigue education programs for employees and their families. Education is critical, since the effectiveness of fatigue initiatives depends on the actions of employees while off duty. Employees must make appropriate choices regarding how they spend their off-duty time, and education is important in encouraging sound decision making. (p. 3)

Complexity of fatigue

Fatigue is an issue that has been discussed for many years without resolution. While everybody agrees that something should be done to combat fatigue, neither the carriers nor labor agree on how it should be accomplished.

Railways do not want fatigued employees, because fatigued employees make mistakes, which can lead to accidents. However, the railroads operate 24 hours per day, seven days a week and therefore need employees available at any time, day or night, to take a train from one location to the next. The railways would like all their trains to run precisely like airlines, but the reality is even good schedule adherence leads to variations in the times trains run each day. Additionally, bulk commodity trains like coal, grain, and oil vary day-to-day, leading to a different crew demand each day.

The railways want to keep as few employees on the roster as possible because of cost. The only way to protect against fatigue currently would be to have a large number of on call personnel available to relieve regular employees that believe it would be unsafe to operate a train for that particular call because they are not rested.

Based on current pay rules, the on-call employees would only be paid when they actually ran a train. However, there would still be a large cost to the railways because training and benefits would still have to be paid for the pool employees. Additionally, there would likely also have to be some minimum salary that was paid whether the on-call employees worked or did not work, because no person could be expected to take a job where you were only paid when somebody else did not work on a random basis.

Labor unions have supported increasing the pool of employees to battle fatigue issues. Rather than use employees in the way they are currently called, the unions have advanced a concept that limits the hours current employees can be called to come to work. This would replace the current system where the first in crew is first to be called out after their rest period. Under this system, a crew can be called at any time during a 24-hour cycle, as long as they have had the mandatory rest time since they last ran a train.

Following is a simple example of the crew window proposal. An employee could be called to run a train from 7:00 am until 3:00 pm, but could not be called during any other hours. That employee would know that as long as he/she were not called by 3:00 pm, there would be no chance for a call until the next day at 7:00 am. This would make each employee's work hours more consistent, which should reduce fatigue.

This concept would require a larger pool of employees that are available each 24 hours to cover the randomness of daily rail operations. Each call window would have to be supported by enough employees to accommodate the highest possible number of trains that might be run. There would also have to be extra employees that are available to cover for vacations, sickness, and other time off work for the employees.

Railways have reviewed this type of concept and it has been discussed in negotiations. However, that concept has been met resistance by some individuals in the current labor force. There are some employees that want to be called for as many trains as they can operate within the current rest rules, because it leads to bigger paychecks. They are not willing to accept lesser pay to receive a more consistent work life. Therefore, there is an internal battle within the unions in addition to the added costs to the railway companies.

Crew numbers

In April 2014, the FRA announced its intention to issue a proposed rulemaking requiring two-person crews on CBR trains.[453] Currently, over 99 percent of U.S. trains operate with two federally-certified crew members, but this regulation would make this mandatory. FRA issued a Notice of Proposed Rulemaking (NPRM) in November 2015. The NRPM had the support of the Railroad Workers United,[454] United Transportation Union, and the Brotherhood of Locomotive Engineers and Trainmen (Etkin et al. 2015), though some railroads were lobbying against this regulatory change, citing advancements with automated safety systems (*e.g.*, PTC).[455] At an FRA hearing on 15 July 2016, the agency heard two sharply contrasting arguments on the

[453] USDOT. Federal Railroad Administration website. https://www.fra.dot.gov/eLib/details/L04999
[454] Railroad Workers United website. Kaminkow, Ron. *What's Wrong with Single Employee Train Operations?* http://railroadworkersunited.org/whats-wrong-with-single-employee-train-operations/.
[455] Union Pacific website. Union Pacific Statement Regarding Train Crew Size. https://www.up.com/media/train-crew/index.htm.

proposed two-person crew mandate — one from freight management and the other from labor (Vantuono 2016).

The most common issue referenced regarding reducing a crew from two people to one person is "safety." The argument is that a second person in the cab of the locomotive will likely see an unsafe condition if the engineer misses that condition.

The second most common argument for a second person in the cab is if something happens to the train such as a broken air hose — if there is only one person on the train, who is going to repair it? One solution that has been suggested is to have "roving conductors." Those would be employees, assigned to a geographic area, that have the responsibility to assist any train operating through that area.

PTC could possibly facilitate the reduction of a crew member from the perspective that if the technology continues to be developed, it could at some point actually operate the train without any input from an engineer. If that did occur, then the single individual on the train would be a conductor, and would be responsible for resolving any in route issues. The conductor would also be trained on PTC to correct any minor issues that occurred with the technology.

The industry group AAR reported that a review of FRA train accident data found no evidence that trains with one-person crews had accidents at a higher rate than with two-person crews. AAR supports a position of "continued flexibility in determining minimum crew size.[456] A 2015 study conducted for AAR concluded that PTC rather than crew size would significantly reduce accidents (ICF Incorporated 2015). Their fault tree analysis results are summarized in Table 129.

Table 129: Results of Annual Accident Frequency Analysis on Positive Train Control Tracks without PTC and with PTC and One- and Two-Person Crews Based on Accident Scenario[457]

Train Accident Scenario	Expected Annual Accidents with Two-Person Crew w/o PTC	Expected Annual Accidents with One-Person Crew + PTC	Expected Annual Accidents with Two-Person Crew + PTC
Accidents due to Violations	11	0.1	0.1
Accidents due to Selected Route Integrity Failures	13	2.5	2.4
Accidents due to Rollaways	3	0.3	3.0
Grade Crossing Accidents with Failure to Sound Horn	2	0.2	0.2
Accident Totals	**29**	**3.1**	**5.7**

Their analysis did not include evaluating the effect of one- or two-person crews *without* PTC. The study makes a noteworthy conclusion that, "Train accidents due to rollaways decrease by a factor of 10 with the removal of a second person from the cab due to fewer potential situations

[456] Association of American Railroads website. Freight Rail & Crew Size Regulations. https://www.aar.org/policy/crew-size-regulations.
[457] ICF Incorporated 2015.

and additional care taken when the sole operator leaves the cab" (ICF Incorporated 2015). The researchers explained:

> Two particular accident scenarios [for rollaway accidents] were identified that would be different for traditional operations today versus under the future cases. These involved instances in which: 1) the train was intentionally stopped to either move a hand operated switch or 2) to inspect the train after an emergency brake or detector stop. Regardless of why the train was stopped, the concern is if the train starts to roll away and the engineer in the cab must stop the train before an accident occurs. In general, this will only happen if the train has not been properly secured and the slope is sufficient for the train to start to roll. In the future one-person crew case, there is no engineer in the cab, so the operator on the ground must get back into the cab to stop the train or the onboard system must stop the train. (p. 3)

This conclusion is counter to that of the Canadian Transportation Safety Board and others that analyzed the Lac-Mégantic accident in which the train became a rollaway after the single operator left.[458] The Sheet Metal, Air, Rail, and Transportation Workers Union (SMART) has stated that, in the experience of its members, two-person crews are vital to safe operations.[459]

Given that two-person crews are already the predominant operating practice in the U.S., and because this is likely to become part of rulemaking, it is assumed in this study that two-person crews will be part of future CBR operating practice in Washington State. Since this has already been standard practice for some time, it will likely not affect accident rates in the future.

Factors affecting accident severity (amount of release)

The "severity" of an accident can have several different meanings. If severity is taken to mean the amount of damage to the environment or the degree of effects of human health and safety, then the amount of hazardous material released in a freight train accident will affect both. In this section, the severity is defined as the number of cars derailed or damaged and the amount of hazardous material released, as that would have the greatest effect on both environmental damages and human impacts. For passenger train accidents, the factors that would generally cause greater damage to rail tank cars would also tend to cause more damage to passenger cars.

The degree of damage or health and safety effects will also be affected by the type of material released and its behavior in the environment, as well as the sensitivity of the environment to that substance. Other factors will affect the degree to which environmental damage and human casualties occur, including access to the accident site for rescue and response operations. These factors are addressed in subsequent sections.

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[458] See Chapter 10.
[459] SMART Local 60 website. 2013. Kehoe, Jim. Two Person Train Crews. http://utulocal60.com/2013/11/25/two-person-train-crews/.

Numbers of cars derailing in accidents

When a rail accident occurs in transit, there are varying numbers of freight cars that may be involved. The more cars that derail, the greater the potential severity of the accident. An analysis of the numbers of freight cars involved in derailments and other accidents was conducted. Based on the FRA accident data,[460] probability distributions of numbers of cars involved per event are shown by accident type in Table 130. Accidents in all accident categories in which no freight cars are involved are assumed to be those in which only locomotives derail.

Table 130: Numbers of Damaged or Derailed Freight Cars Involved in National Rail Accidents Based on Accident Type Including Percentages of Accidents with No Car Damage (1975–2015)[461]

Percentile	Collision	Derailment	Hwy-Rail	Fire/Explosion	Misc.	All Accidents
% Accidents with 0 Freight Cars Involved[462]	**50.1%**	**2.5%**	**85.6%**	**97.2%**	**82.9%**	**17.1%**
10th Percentile	0	1	0	0	0	0
20th Percentile	0	2	0	0	0	1
25th Percentile	0	2	0	0	0	1
30th Percentile	0	3	0	0	0	1
40th Percentile	0	4	0	0	0	3
50th (Median)	0	5	0	0	0	4
60th Percentile	2	7	0	0	0	6
70th Percentile	3	9	0	0	0	8
75th Percentile	4	10	0	0	0	9
80th Percentile	5	12	0	0	0	11
90th Percentile	8	18	3	0	2	16
95th Percentile	13	24	10	0	6	22
99th Percentile	27	37	23	7	21	36
Worst Case	58	122	80	43	66	122

There are many factors that determine the number of rail cars involved. The issue of numbers of cars released in derailments has been studied extensively by various rail technology researchers (Glickman et al. 2007; Bagheri 2009; Bagheri et al. 2011; Liu et al. 2014).

[460] This follows the methodology in Etkin et al. 2015.
[461] FRA accident data on freight trains of at least 20 freight cars on mainline track (54,480 accidents).
[462] The percent accidents with zero (0) freight cars involved are those accidents (e.g., collisions or derailments) in which no cars were damaged or derailed. In derailment cases, this would mean that the locomotive derailed but no freight cars (empty or laden with cargo) derailed. In collisions or other accidents, it means that an accident occurred, but no freight cars derailed or were damaged. The car numbers shown for the percentile and worst-case situations indicate the numbers of freight cars involved if there were cars involved. In other words, the 49.9 percent of collision cases in which there were freight cars that were derailed and/or damaged.

Train velocity effect on accident severity

It is not unexpected that derailments that occur at higher speed do more damage than those which occur at lower speeds. The reason is a simple law of physics: conservation of energy. A moving train that derails has to dissipate the kinetic energy of the moving train — the faster the train was moving, the more energy that has to be dissipated. In most cases, a mainline derailment that occurs at 60 mph is going to be much more severe than a yard derailment that occurs at 10 mph.

The conundrum with that fact is that railroads are more efficient running at higher speeds. If there were no difference between running trains at 60 mph and 30 mph, it is likely railroads would choose to run them at 30 mph because of the reduced risk associated with slower speeds. However, capacity and customer commitments are not the same at widely varying speeds.

The impact of train velocity on customer commitments is straight forward: A train running at 30 mph takes twice the time a train running at 60 mph does to get from one terminal to another. While that may be acceptable for some commodities like coal or grain, it is not acceptable for high priority freight like trailers or containers of domestic consumer goods. Therefore, trains carrying those types of products must be run at higher speeds to meet commitments or to be able to compete for market share.

The impact of train velocity on capacity is also significant. The ability to minimize the time to run between points where trains can pass each other is a key component of capacity. Train velocity defines the time it takes to get between two points. A line where the average train speed is 50 mph will have approximately double the capacity of a line where the average speed is 25 mph.

It does not matter whether the track alignment dictates the average speed of the route, or whether the type of trains on the route dictate the average speed. A high curvature, high grade route that has a maximum track speed of 25 mph has approximately the same capacity that a flat, straight route that runs heavy slow unit trains at 25 mph, assuming the sidings where trains can meet are spaced at the same distance for both routes.

As rail freight traffic continues to grow, the ability to handle as many trains as possible over a line segment is extremely important for the rail industry. Expansion of the rail structure to accommodate more trains is expensive and is becoming more difficult with local, state and federal regulations. To compensate for that, railways are continually trying to boost the speed of their routes to increase the number of trains that can be accommodated.

These two sets of facts create conflicting goals. On one hand, risk is reduced by dropping the maximum speed, while on the other hand, the growth of business and the ability to handle that business is dictated by increasing speeds and train sizes. Railways have attempted to balance the two issues.

One way the railroads do this is by restricting the speeds of some train types. For example, loaded coal or grain trains will have maximum authorized speeds of 45 or 50 mph. This reduces the wheel impact on bridges and the track structure, which reduces the risk of those components failing under this type of train. Additionally, loaded unit trains operate with train cars that exceed 100 tons per operable brake, which makes these types of trains difficult to stop. By reducing their maximum allowable speed, the stopping distance can be reduced which potentially could reduce the impact of a derailment.

Other train types, such as priority container movements, are allowed to operate at a maximum speed of 70 mph. This allows them to meet transit time commitments and lets the railway compete for the business against trucking companies and other railway companies. The lighter, faster trains do not impact bridges or track structures like the heavier bulk commodity trains, so 70 mph is acceptable for the railroad. They also operate with less than 100 tons per operative brake, which means controlling their stopping distance from higher speeds is easier than controlling loaded unit trains.

Speed is an important factor in determining the number of train cars that derail in an accident. One study (Anderson and Barkan 2005) examined the average numbers of train cars that derail based on track class and speed, as summarized in Table 131 for FRA Class 4 Track.[463]

Table 131: Percent Track Derailment Accidents by Derailed Car Number and Train Speed[464]

Speed	1–5 Derailed Cars	6–10 Derailed Cars	11–15 Derailed Cars	16–20 Derailed Cars	21–25 Derailed Cars	>25 Derailed Cars	Average Number Derailed Cars
1–10 mph	71.1%	19.9%	5.7%	1.4%	0.5%	1.4%	**4.8**
11–25 mph	50.9%	25.3%	15.0%	5.8%	1.7%	1.4%	**6.9**
26–40 mph	41.7%	15.1%	16.9%	11.3%	7.2%	7.9%	**10.2**
> 40 mph	44.6%	10.9%	11.2%	8.9%	6.8%	17.7%	**10.9**
Total	**48.7%**	**16.0%**	**12.6%**	**7.9%**	**5.0%**	**9.7%**	**9.7**

Several studies indicate that in a highway-rail crossing accident, the speeds of the vehicle (automobile or truck) and train are important factors with derailments more likely to occur at higher vehicle speeds and lower train speeds (Chadwick et al. 2011, 2013).

Train speed also affects the probability that a derailment will result in spillage from tank cars. The greater the speed of the train, the higher the percentage of tank cars that release material. Train speed has a particular effect on release from tank car heads and shells, and to a lesser extent on releases from top fittings. Releases from bottom fittings are not greatly affected by train speed (Kawprasert and Barkan 2010).

In another study (Liu et al. 2014), the researcher showed that the numbers of tank cars that released material in a derailment at 50 mph were greater than those that derailed at 40 mph.

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[463] Track classified by FRA with respect to maximum speed for track condition as 60 mph for freight, 80 mph for passenger. This is the dominant class for main-line track used in passenger and long-haul freight service.
[464] Anderson and Barkan 2005.

Factors affecting degree of health and safety effects

If an accident is not prevented, that is the accident occurs, and a hazardous material is released, there are certain factors that would increase the severity of the outcome, including:

- The location of the accident in proximity to densely-populated areas, as well as the specific configurations of the location (tall buildings, etc.).
- The physical properties of the spilled or released substance.
- Ambient environmental conditions at the time of the incident and in its immediate aftermath.

Another factor that could affect the degree of effect is the timing of the incident. Timing could affect the number of people that are in the vicinity, traffic in the area that would hinder access of emergency vehicles, and other factors. Timing from a seasonal perspective could determine weather conditions that affect the behavior of the released substance.

High-consequence areas

A major hazardous material release in a high-consequence area (HCA) is of the greatest concern. Generally, HCAs are densely populated areas. As discussed in Chapter 4, railroads often run through many populated areas for both historical and economic reasons. Therefore, there is a certain likelihood that an accident may occur in a city or town. Many densely populated areas have rail speed restrictions to reduce the chances of an accident occurring.

If the accident occurs in a populated area, there is clearly a greater risk of human exposure and injury. The hazard zone modeling presented in Chapter 7 provides a perspective on the distances of exposure that may be involved in the event of a release.

Ambient weather conditions (temperature, humidity, wind speed and direction) will all influence the behavior of the released substance in the environment.

The physical layout of the city or town will also have a major effect on the dispersion of vapor clouds. The presence of taller buildings and other barriers will affect the spread of vapor clouds and can act as heat shields in the event of a fire.

In Washington State, there are long distances of rail lines that run through relatively unpopulated areas where an accident might also occur. In these areas, there may be less risk for human health and safety environment effects.

Tribal lands

As shown in Chapter 4, railroads also pass through a number of tribal lands, some of which are more densely populated than others. These impacts are largely ones that would affect any populated area in Washington State. The potential for human health and safety environment effects from a major rail accident with a release of a hazardous material is also high in these areas. Again, the effects will depend on the substance released, ambient conditions, and the numbers of people involved. Elderly people, people with certain pre-existing health conditions (e.g., asthma or other respiratory ailments) and young children will suffer the greatest health effects from exposure.

The effects of railroads more specifically related to tribal lands were discussed in the *2014 Marine & Rail Oil Transportation Study* (Etkin et al. 2015).

Crude oil trains and other trains present potential risks to tribal culture, tribal community subsistence harvest, and tribal treaty rights. With spills and potential fires associated with crude-by-rail transport, there are potential impacts to tribes on lands used for cultural and traditional practices, and lands associated with treaty resources, including usual and accustomed (U&A),[465] tribal ceded areas,[466] and tribal fisheries habitat areas.

Risks to tribal areas from spills already exist in all areas of the state. Changes associated with increased marine and rail transport of crude and associated facilities may increase and/or change the types of risks.

In addition to the potential health impacts of oil contamination of fish and shellfish, damages to fisheries affect cultural, traditional, and economic uses of fish for many tribes. Nearly all of the 29 tribes of Washington and several bordering tribes have traditional use areas, ceded lands, or treaty U&As. These tribes could be impacted by either rail and/or marine incidents associated with the crude-by-rail marine and rail transport and associated facilities.

Fires associated with rail accidents in inland areas could have short- and long-term impacts on U&A fishing, hunting, and culturally important tribal lands. Oil spill damages to these lands could also have short-term or long-term impacts for tribes.

Prolonged spill responses, safety evacuations, fires, and the aftermath of an event could reduce access to U&A fishing, hunting, and culturally important tribal lands.

Land management conflicts

With railroads, passing through cities and towns, there is a likelihood that the rails will pass by particularly high-consequence sites, such as buildings where large numbers of people congregate. Elderly people, people with certain pre-existing health conditions (e.g., asthma or other respiratory ailments) and young children will suffer the greatest health effects from exposure. For this reason, hospitals, schools, day-care centers, and nursing homes are particularly vulnerable.

If it is not possible to re-route trains from densely populated areas, consideration should be given to the proximity of these vulnerable populations near rail lines, or at least to give particular concern to contingency planning for emergency situations.

Grade crossings

The presence of large numbers of grade crossings increases the likelihood of accidents involving vehicles being hit by trains. Grade crossing issues are covered in depth in Chapter 13.

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[465] U&A is a treaty term from the 1854–1855 Stevens' Treaties used extensively in U.S. v. Washington, referring to an area where a particular tribe traditionally fished and over which the tribe has a territorial use claim under the provisions of the treaty. Treaty tribes retained their right to take fish in their "usual and accustomed" areas. These treaties are legally-binding contracts and are the supreme law of the land under the U.S. Constitution.
[466] Areas over which tribes by treaty relinquished control to the federal government in return for compensation in the form of livestock, merchandise, and annuities.

Physical properties of commodities

The physical properties of the released substance, as described in Chapter 6, as well as the amount released and ambient conditions, will affect its behavior when released. The toxicity and human health effects from exposure vary with the substance. The properties of the substance also determine the distances that it may spread. For a single-car ammonia release, the toxic exposure hazard distance is typically two miles in all directions. For an improbable 10-car release of ammonia, the toxic exposure distance would be nearly ten miles in all directions.

For flammable liquids, such as Bakken crude oil or ethanol, there is also a possibility of a fire or explosion if there is an ignition source. The explosion hazard distance from a single-car release of Bakken crude oil is about 400 to 500 feet in all directions. With a 10-car release, the hazard distance increases to over 1,300 feet in all directions.

Potential areas of future discussion

- The Rail Safety Committee and others with an interest in mitigating the risk of rail accidents in Washington State may want to develop an understanding and appreciation of the factors that affect the risk of rail accidents, both with respect to the likelihood of accidents, and the potential severity of the effects. This understanding will assist in making effective decisions on risk reduction.
- Many of the factors that contribute to increasing the risk of rail accidents are not ones that can be addressed directly by Washington State officials or the Rail Safety Committee because of jurisdictional issues. However, the Rail Safety Committee might consider including some of the following issues in recommendations for voluntary safety measures, such as:
    - Restrictions on train speed to reduce the likelihood of accidents and the severity of accidents. This is already being addressed by the railroads to some extent.
    - Inspections to assure optimal track condition.
    - Programs to address crew fatigue.

Chapter 23: Geographic Analysis of Rail Accident Risk for Washington

Key questions

- How does the risk of rail accidents (likelihood and impacts) differ in the various geographic zones of Washington State?

Takeaways

- The term "geography" includes the study of all of the physical features of a location — the land forms, waterways, vegetation, animals, and habitats, as well as the ways in which the land is inhabited and used by humans — cities and towns, tribal-use areas, industry, and transportation (including railroads).
- Geography affects the risk of rail accidents in a number of important ways:
    - Railroad accidents are more likely to occur in some locations because of track conditions that present greater challenges for rail operations, such as curves, flash flood areas, higher speed, and fewer wayside detectors that can identify anomalies on train wheels and other defects.
    - Railroad accidents are more likely to occur when there is more rail traffic.
    - Human health and safety environment effects, as well as environmental impacts will depend on the types and quantities of oil and hazardous substances that are transported by rail through different geographic regions.
    - Human health and safety environment effects from rail accidents, especially fires, explosion, and vapor clouds, are more likely and are more severe in more densely-populated areas.
    - Environmental effects of spills of oil and other hazardous materials are more severe in locations with waterways and particularly sensitive natural resources.
    - Reducing the effects of spills through response operations is more challenging in some types of geographic locations because of access issues and remoteness.
- When the likelihood of accidents, the potential severity, and the potential consequences or impacts are considered, the Lakeside subdivision appears to present a particularly high risk, followed by the Bellingham, Fallbridge, Seattle, and Spokane subdivisions.
- The risk scoring in this study was conducted only on a railroad subdivision basis. There are many variations within each subdivision.
- The geographic analysis only considers rail accidents involving oil and other hazardous materials as these could have a significant effect on human health and safety, as well as the environment. Highway-rail grade crossing accidents present a very high risk. The geographic factors for these types of accidents are the population density and levels of vehicular and pedestrian traffic that go through these crossings. These accidents can be reduced by crossing safety measures, including signs and gates, as well as education programs, as discussed in Chapter 13.

The following sections provide a more in-depth look at the geographic aspects of rail risk in Washington State, i.e., the way in which risk differs based on the probability and consequences of rail accidents, and how they differ, along the various rail corridors based on:

- The likelihood of accidents due to track conditions.
- The likelihood of accidents due to the rail traffic.
- The types of commodities that are transported by rail.
- The proximity to high-consequence areas (densely-populated cities and towns, tribal lands, and environmentally-sensitive areas).
- The potential consequences of a spill or release of a hazardous commodity.

Overview of geographic factors for rail risk

There are a large number of complex and inter-related factors that determine the risk of a rail accident in Washington State. The general concepts of "risk" for rail accidents are discussed in Chapter 3. The current chapter delves into some of the most important geographic considerations.

The geographic factors that affect the overall risk are divided into three categories:

- Factors that affect the likelihood of an accident occurring by geographic location.
- Factors that affect the severity of an accident occurring by geographic location.
- Factors that affect the consequences or impacts of an accident occurring by geographic location.

In any geographic analysis, the resolution or granularity of the geographic area considered is of great importance. One can consider risk on the basis of each mile (or less) of rail track in Washington — the most granular and specific approach. At the other end of the spectrum, one can consider the risk on a statewide basis — the least granular and most general approach.

The likelihood of an accident at a particular curved section of track on the outskirts of Spokane, or the specific effects of a certain type of hazardous material release in downtown Bellingham are outside the scope of this analysis. The analysis is conducted on a rail corridor or subdivision basis to the extent possible, drawing on previously conducted studies and other data and metrics that are available.

However, with advanced types of modeling, such as OILMAPL and (2-dimensional overland and downstream trajectory and fate model) and SIMAP (3-dimensional in-water trajectory, fate, and effects model) for oil spill simulations (as demonstrated in this chapter), plume modeling, and other tools, it is possible to go to that level of detail, if desired. This geographic analysis, and the WA-RRisk tool presented in Chapter 24, it is possible to do higher-level screening to determine which areas might merit a more careful analysis.

The geographic zones are divided by rail subdivision as shown in Figure 113 and Figure 114 to the extent practical and based on data availability.

Figure 112: BNSF Pacific Northwest Mainline Rail Network (with Subdivisions)[467]

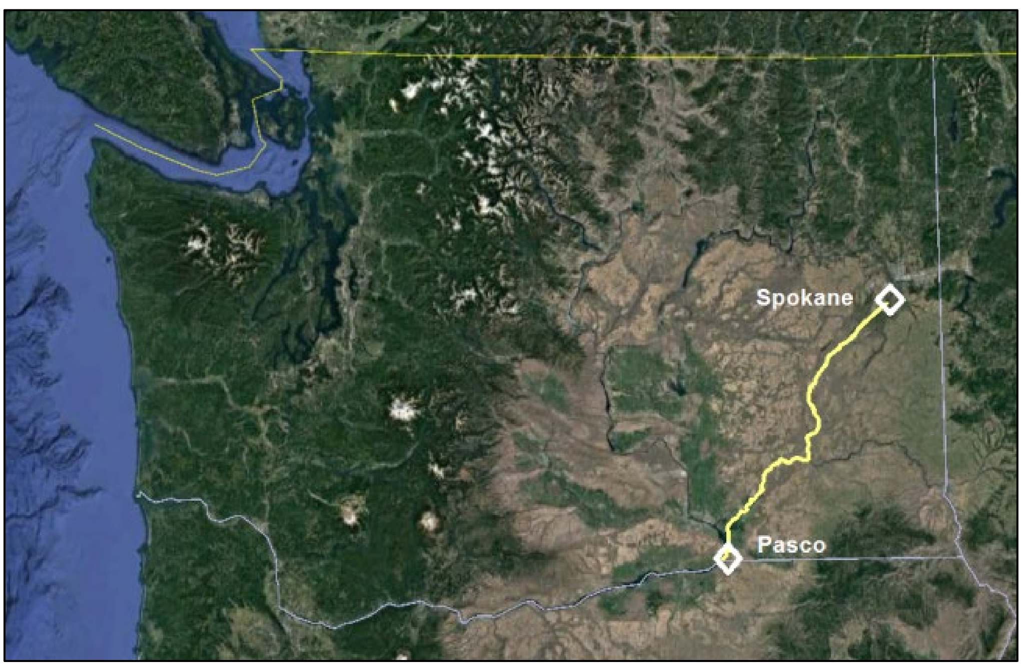

Figure 113: Union Pacific (UP) Mainline Rail between Spokane and Pasco[468]

[467] Map prepared by Environmental Research Consulting based on WSDOT data.
[468] Map prepared by Environmental Research Consulting based on WSDOT data.

Geographic analysis of likelihood of rail accidents

As discussed in Chapter 22, there are a number of factors that affect the likelihood of a rail accident. Assuming that operator training and competency are equal for all rail subdivisions, one can focus on the rail traffic (numbers or frequency of trains) and track conditions to determine the relative probability that a rail accident will occur.

The geographic analysis is limited to the risk related to derailments that involve train operation and rail-related factors, as well as the commodities being transported. (As shown in Table 26 in Chapter 5, derailments are the predominant accident type.) The likelihood of a passenger train being involved in a derailment or other accident is affected by many of the same track and rail operation conditions. There is no particular geographic component to the outcome of the accident. The number of human casualties is determined by the nature of the accident, the number of passengers aboard the train, and other non-geographic factors.

Highway-rail grade crossing accidents are more dependent on the characteristics of crossings, safety measures at crossings, and driver behavior. The more vehicular traffic and grade crossings, the more likely an accident may occur. There are no geographic differences with respect to the outcome if an accident occurs in which a vehicle is struck by a train. The geographic issues related to highway-rail crossings accidents are discussed in Chapter 13.

Derailment factors on Washington rail subdivisions

The factors that were selected to characterize the track conditions by rail subdivision are:

- Mileage (length of mainline track).
- General profile (grades and slopes).
- Curvature (numbers and degrees of curves).
- Number of flash flood warning areas.
- Numbers of wayside detectors per track mile.
- Maximum freight train speed.

Data for the various subdivisions were available in BNSF Timetables (BNSF 2003; 2018a) and UP Timetables provide detailed route and track conditions for railroad employees to assure that all operators have the most up-to-date and accurate information to safely transit each mile of track. Specific locations on tracks are referenced by “milepost” (MP).

BNSF subdivisions used for loaded CBR traffic

For this analysis, focus was placed on track curvature and flash flood warning areas, which present the greatest hazards. Table 132 and Table 133 provide a summation by subdivision of the geometric profiles that might affect safe train operations. BNSF's engineering standard for track curvature in new construction main line track (or for realignment of existing track) allows a maximum of 7 degrees 30 minutes of curvature. The standard for industry or lead track is a maximum curvature of maximum of 9 degrees 30 minutes. However, BNSF will grant a waiver for up to 12 degrees 30 minutes if it does not affect other rail operations. (Note that track locations are identified by “mileposts,” abbreviated as “MP.” These are analogous to mileposts that are often indicated by signs on federal and state highways.)

Table 132: Characteristics of BNSF Rail Subdivisions for Loaded CBR Traffic Including Profile, Curvature, Flash Flood Warnings, Wayside Detectors, and Maximum Freight Train Speed[469]

Feature	Spokane	Lakeside	Fallbridge	Seattle	Bellingham
Length	71 miles	146.4 miles	229.7 miles	136.5 miles	119.6 miles
Profile	Generally undulating with maximum ascending grade westbound of 0.98 percent MP 18 to 20; eastbound 0.64 percent MP66-64	Generally undulating with maximum ascending grade 1.15 percent westbound MP 4 to 10; westbound in Providence/ Connell area 1.0 eastbound (3 locations)	River grade ascending Pasco to Vancouver	Mildly undulating with minimum grades, except over Napavine Hill;0.97 percent northbound and 1.20 percent southbound	Mildly undulating, with greatest grade in 1.2 percent northbound near Bellingham
Curvature	10 curves ≥4 degrees; no curves ≥6 degrees; maximum curve 5 degrees, 15 minutes at MP 71.7 (Spokane)	55 curves ≥4 degrees; 19 curves ≥6 degrees; no curves ≥7 degrees, 30 minutes	No curves exceed 4 degrees	No curves that exceed 7 degrees, 30 minutes	1 curve at 9 degrees; all other at 7 degrees, 30 minutes or less

[469] Data sources: BNSF Timetable No. 7, Effective November 5, 2014, Updated through January 16, 2018; BNSF System Special Instructions No. 3, Effective July 18, 2012; BNSF Railway Northwest Division Track Charts, BNSF System Maintenance and Planning.

Feature	Spokane	Lakeside	Fallbridge	Seattle	Bellingham
Flash Flood Warning Areas	MP 7.8: Algoma; MP 51.3: Hauser Junction; MP 58: Otis Orchards	MP 2.5: Empire; MP 3.3: Empire; MP 19.9 to 20.5: Babb; MP 60: Essig; MP 82.3: Lind and Sand; MP 97 to 98: Cunningham; MP 107 to 108.7: Connell	MP 204.85 to 204.75: Berrian; MP 190.65 to 190.55: Plymouth; MP 174.95 to 174.85: Patterson and Whitcomb; MP 167.95 to 167.85: Whitcomb; MP 161.85 to161.75: McCredie; MP 147.5 to 146.95: Roosevelt; MP 141.15 to 1415: Roosevelt and Bates; MP 133.75 to 133.65: Bates; MP 42.75 to 42.70: Skamania	MP 17.7X: flash flood/bridge; MP 24.3X: flash flood/bridge; MP 29.4X: flash flood/bridge; MP 34.1X: flash flood/bridge; MP 5.2 to 5.7: flash flood; MP 7.3 to 8.2: flash flood; MP 15 to 19: flash flood; MP 21 to 23: flash flood; MP 24.3 to 25.5: flash flood; MP 36.1: flash flood/bridge; MP 47 to 49.5: flash flood	MP 105 to 104: flash flood; MP 100.3 to 98.7: flash flood MP 93 to 83: flash flood; MP 75.63: flash flood/bridge; MP 70: flash flood/bridge; MP 63 to 49: flash flood; MP 5.5 to 6: flash flood (Anacortes Spur)
Wayside Detectors	17 wayside detectors, averaging 4.18 miles apart; longest gap: 7.7 miles	29 wayside detectors, averaging 55 miles apart; longest gap: 8.2 miles	28 wayside detectors, averaging 8.2 miles apart; longest gap 25 miles: (MP 177.2 to 152.2)	16 wayside detectors, averaging 9.75 miles apart; longest gap 29.5 miles (MP 57.9 to 87.4)	20 wayside detectors, averaging 4.24 miles apart; longest gap 16 miles (MP 94.3 to110.3)
Maximum Freight Train Speed	60 mph	60 mph	60 mph	60 mph	60 mph

The Lakeside Subdivision features the most conspicuous area of curvature over the entire route between Sand Point and Vancouver, the area known as Hatton Canyon between MP 90 and MP 110. The area features multiple reverse curves, but track speed is generally limited to 35 mph to 50 mph. In addition, the track in the area crosses a dry wash in a number of locations. The wash is normally without water but every so often, enough rain falls above the run off to cause flooding and wash out concerns. Maximum curvature through the canyon is 6 degrees 50 minutes at MP 101.4 with 6 degree 30 minutes curves at MP 104.6, MP 103.7 and MP 88.9.7.

Table 133: Derailment Factors of BNSF Rail Subdivisions Including Curvature, Flash Flood Warnings, Wayside Detectors, and Maximum Freight Train Speed[470]

Feature	Spokane	Lakeside	Fallbridge	Seattle	Bellingham
Curves ≥7°30'	None	None	None	None	1
Curves ≥6°	None	19	None	None	None
Flash Flood Warning Areas	3	7	9	11	7
Average Wayside Detector Spacing	4.18 miles	5.05 miles	8.2 miles	9.75 miles	4.24 miles
Wayside Detectors Longest Gap	7.7 miles	8.2 miles	25 miles	29.5 miles	16.0 miles
Maximum Freight Train Speed	60 mph	60 mph	60 mph	60 mph	60 mph

The derailment factors were given relative scores in Table 133. The relative scores were derived by assigning a five-point scale (lowest, low, medium, high, highest) to the values for the factors shown in Table 134. The scoring scale applied one point for lowest and five points for highest. Curvature was given the highest weight (0.40), followed by the two wayside detector factors (0.15 and 0.15 each), and then flash flood areas (0.25), and maximum train speed (0.05). These weighting factors were based on expert judgement of the degree to which these factors would contribute to derailment probability. The total scores were derived by adding the weighted point scores for each subdivision. These scores were then normalized to derive relative probabilities by adding the total points for all subdivisions and dividing each subdivision by the grand total. The final result is a relative probability.

Table 134: Scores for Derailment Probability by BNSF Rail Subdivision Based on Rail Features[471]

Feature	Spokane	Lakeside	Fallbridge	Seattle	Bellingham
Curvature	Lowest (1 pt.)	Medium (3 pts.)	Lowest (1 pt.)	Lowest (1 pt.)	Medium (3 pts.)
Flash Flood Warnings	Low (2 pts.)	Medium (3 pts.)	Medium (3 pts.)	High (4 pts.)	Medium (3 pts.)
Wayside Detector Spacing	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	High (4 pts.)	Low (2 pts.)
Wayside Detector Gap	Low (2 pts.)	Medium (3 pts.)	High (4 pts.)	High (4 pts.)	High (4 pts.)
Maximum Train Speed	Medium (3 pts.)	Medium (3 pts.)	Medium (3 pts.)	Medium (3 pts.)	Medium (3 pts.)
Total Score	**1.65**	**3.00**	**2.50**	**2.75**	**3.00**

[470] Data sources: BNSF Timetable No. 7, Effective November 5, 2014, Updated through January 16, 2018; BNSF System Special Instructions No. 3, Effective July 18, 2012; BNSF Railway Northwest Division Track Charts, BNSF System Maintenance and Planning.
[471] Analysis by Environmental Research Consulting.

Feature	Spokane	Lakeside	Fallbridge	Seattle	Bellingham
Relative Derailment Probability	**0.13**	**0.23**	**0.19**	**0.21**	**0.23**

Note that the risk score for Lakeside increased due to the most conspicuous area of curvature over the entire route. The area features multiple reverse curves, but track speed is generally limited to 35 to 50 mph. Also, the track crosses dry wash in several locations.

Derailment analyses on the Stampede and Yakima Valley subdivisions were excluded from the CBR traffic analysis as those rails would generally only carry empty cars back to North Dakota through Spokane. However, the derailment probability was previously calculated in another study (Etkin et al. 2017). The total score for Stampede was calculated as 4.4, and for Yakima Valley as 3.9. If these scores are added to the ones in Table 134, the relative derailment probabilities change to those shown in Table 135.

The relative derailment probabilities can be viewed as the probability that *if a derailment were to occur*, it would have a greater likelihood of occurring in one of the subdivisions that had a higher relative derailment probability value.

Table 135: Relative Derailment Probability by BNSF Rail Subdivision with Stampede/Yakima Based on Rail Feature Scoring[472]

Subdivision	Total Score	Relative Derailment Probability
Spokane	1.65	0.08
Lakeside	3.00	0.14
Fallbridge	2.50	0.12
Seattle	2.75	0.13
Bellingham	3.00	0.14
Stampede	4.40	0.21
Yakima	3.90	0.18

The data for the Union Pacific (UP) Subdivision were not available. Therefore, it was not possible to derive a relative derailment probability for these tracks.

Geographic analysis of severity of rail accidents

As discussed in Chapter 22, the severity of an accident is determined by the amount of the release and the relative hazard (toxicity, flammability, propensity for dispersion, etc.) from a commodity.

The amount of the release from a derailed train depends on the number of cars that derail and the probability that the tank cars will be punctured or otherwise release some or all of their contents. Since all trains transporting hazardous materials are using safer tank cars (e.g., DOT-117 cars for Class 3 flammable liquids), the probability of rupture would generally be the same for all the

[472] Analysis by Environmental Research Consulting.

cars. The likelihood of a release of a particular material is then dependent on the number of carloads transported through a rail subdivision, and the relative hazard from each commodity.

Patterns of rail transport of commodities by geographic region

Rail corridors used by specific commodities are described below, based on analysis of STB Public Use Waybill Sample data. Waybill data is subject to non-disclosure rules, which sometimes results in origins or destinations of commodities being listed as "Not Specified."[473]

Sodium alkalies (or caustic soda, STCC code 28122) is primarily used for manufacturing pulp and paper. The commodity both originates and terminates in the Pacific Northwest. Where destinations are known, the Spokane and Richland BEAs account for most terminating traffic. A large share of this originates in the Portland BEA, which includes all ports in Washington and Oregon on the Lower Columbia River. Routing of most of this cargo is likely through the Columbia River Gorge, either on the BNSF or UP. In addition, there are small amounts that move between the PNW and Houston, Baton Rouge, and Los Angeles.

Sodium compounds except sodium alkalies (or soda ash, STCC code 28123), is almost exclusively moved from Wyoming to Portland by the Union Pacific, on the Oregon side of the Columbia River Gorge.

Potassium compounds (excluding potassium alkalies) (or potash, STCC code 28125) is almost exclusively moved from Saskatchewan to Portland. This traffic moves on the UP route from Eastport, Idaho, through Pasco to Hinkle, Oregon, and along the Oregon side of the Columbia River Gorge to Portland.

Sulfuric acid (STCC code 28193) terminates in the Portland BEA and originates in the Chicago, San Francisco, and Los Angeles BEAs. The precise termination location in the Portland BEA is unknown. If it is in Washington, the routing is along the BNSF I-5 mainline.

Anhydrous ammonia (STCC 28198) terminates in the Spokane and Richland BEAs. Origin data is not available for most shipments. Where it is known, the Alberta and San Francisco BEAs are the most common origins. Exact routing is unknown. Alberta traffic likely moves via the UP Eastgate Idaho to Hinkle, Oregon, while San Francisco traffic may move on either BNSF or UP.

Liquefied gases, coal or petroleum (STCC 29121) primarily originate in Canada (Alberta, Saskatchewan, and British Columbia), and North Dakota. Two-thirds terminates in the Seattle BEA, likely at the refineries north of Seattle. Portland accounts for approximately one-quarter of terminating traffic, and Richland less than 10 percent. This traffic may be routed over the border from Canada near Bellingham, or may move via Spokane, Pasco, Hinkle Oregon, Portland/Vancouver then on the BNSF I-5 corridor. The North Dakota traffic would likely move on BNSF over the Spokane, Lakeside, Fallbridge, Seattle, Scenic, and Bellingham subdivisions for refineries north of Seattle.

The corridors through which these hazardous commodities are primarily transported are more likely to have an accidental release of the specific substances.

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[473] For more information on the commodities transported by rail in Washington, including STCC numbers, see Chapter 6.

The most commonly-transported commodities that were considered in this analysis are:

- Crude petroleum
- Ethanol
- Propane
- Sulfuric acid
- Anhydrous ammonia

The annual carloads of these commodities were estimated by subdivision (Table 136). Note that a single carload may pass through multiple subdivisions before getting to its destination.

Table 136: Rail-Transported Hazardous Commodities by Subdivision (Annual Carloads)[474]

Commodity	Total	Spokane	Lakeside	Fallbridge	Seattle	Bellingham	UP
Crude Oil	78,687	74,685	74,685	74,685	74,685	45,135	4,002
Propane	19,955	19,955	19,955	19,955	19,955	0	0
Ethanol	13,209	13,209	13,209	13,209	13,209	0	0
Ammonia	3,319	3,319	2,720	0	0	0	0
Sulfuric Acid	853	853	853	853	0	0	0

Severity of accidents based on commodity properties

The sheer numbers of carloads of commodities being transported do not completely define the potential severity of accidents. A single carload of one commodity may have a much greater effect if released than ten carloads of another commodity.

Relative toxicities and different types of human health and safety environment effects are complex topics outside of the scope of this analysis. A relatively simple approach to defining release severity was based on the geographic extent of hazard zones in the event of a release, as discussed in detail in Chapter 7 (modeling of hypothetical releases) and Chapter 17 (emergency response issues). These hazard zones differ by the properties of the commodities and the typical ambient environmental conditions in each geographic area.

Referring to the data in Table 63 through Table 69 in Chapter 7, the commodities were ranked by severity by commodity, as shown in Table 137 with larger numbers being the highest.

Table 137: Ranking of Relative Severity of Releases of Hazardous Liquids Shipped by Rail Based on Lower Flammable Limit, Thermal Radiation, Explosion Overpressure, and Zone for Immediately Dangerous to Life and Health[475]

Hazardous Liquid	Lower Flammable Limit	Thermal Radiation at 12.5 kW/m^2	Explosion Overpressure at 2 psi	Radius for Immediately Dangerous to Life and Health Zone	Relative Severity Ranking
Anhydrous Ammonia	28 ft	7 ft	-	11,167 ft	10
Bakken Crude Oil	227 ft	-	441 ft	-	6

[474] Surface Transportation Board data.
[475] Analysis conducted by Risknology, Inc.

Hazardous Liquid	Lower Flammable Limit	Thermal Radiation at 12.5 kW/m^2	Explosion Overpressure at 2 psi	Radius for Immediately Dangerous to Life and Health Zone	Relative Severity Ranking
Diluted Bitumen	80 ft	168 ft	173 ft	-	3
Ethanol	33 ft	350 ft	44 ft	-	4
Propane	86 ft	26 ft	569 ft	-	5
Sulfuric Acid	-	-	-	23 ft	1

The severity by geographic region depends on the specific ambient conditions and the commodity. Certain insights can be gained on the comparative hazard distances associated with individual rail corridors and their geographic locations. The primary driver for the differences in hazard distances by geography is the weather associated with that region (wind speed, temperature and relative humidity).

For dispersion, the maximum distances for all hazardous chemicals were obtained for the Stampede location, which has the greatest wind speed. Dispersion hazard distances are insensitive to weather conditions for ammonia and ethanol. The maximum hazard distance is determined for Bakken crude oil, and the variability from minimum to maximum across regions is approximately 100 percent.

The variability for fire hazard distances across geographic regions is negligible.

Explosion hazard distances are determined uniquely for the chemical and weather conditions. For both Bakken crude oil and diluted bitumen, the maximum explosion distances are produced for the Scenic (Inland) region, which has the lowest characteristic wind speed. Explosion hazard distances do not vary significantly for ethanol. However, for propane, which is a heavier-than-air gas, the greatest hazard distances are determined for the Fallbridge, Lakeside, and Sumas regions, which all have 95th percentile wind speeds in the top 20 percent of all regions. This is not the maximum wind speed. Maximum explosion hazard distances are determined by a competitive effect between the wind speed driving the vapor cloud downwind, and the effect of turbulence, which disperses the vapor cloud along its drift path. This balance between physical effects results in wind speeds of approximately 14 mph generating the maximum hazard zone.

Combining the relative numbers of hazardous material carloads and the relative severity rankings, the subdivisions were ranked with regard to potential severity, as shown in Table 138.

Table 138: Relative Hazard Spill Severity by Rail Subdivision and Commodity[476]

Commodity	Spokane	Lakeside	Fallbridge	Seattle	Bellingham	UP
Crude Oil	Very High	Very High	Very High	Very High	High	Low
Propane	High	High	High	High	Very Low	Very Low
Ethanol	Medium	Medium	Medium	Medium	Very Low	Very Low
Ammonia	Medium	Medium	Very Low	Very Low	Very Low	Very Low
Sulfuric Acid	Low	Low	Low	Very Low	Very Low	Very Low

[476] Analysis by Environmental Research Consulting.

Accident release consequences by geographic region

The greatest concern with rail accidents involving hazardous materials is for human health and safety environment impacts, which would be highest in areas with the greatest number of people. Environmental impacts of spills are also important concerns. They also can vary by geographic location. This has been studied extensively in Washington State.

High-consequence areas for fire and explosion

As discussed in Chapter 4, railroads in Washington State pass through many densely-populated urban and suburban areas and tribal U&A areas that could potentially suffer significant consequences in the event of a major accident with the release of hazardous materials that may burn, explode, or form vapor clouds (Figure 115).

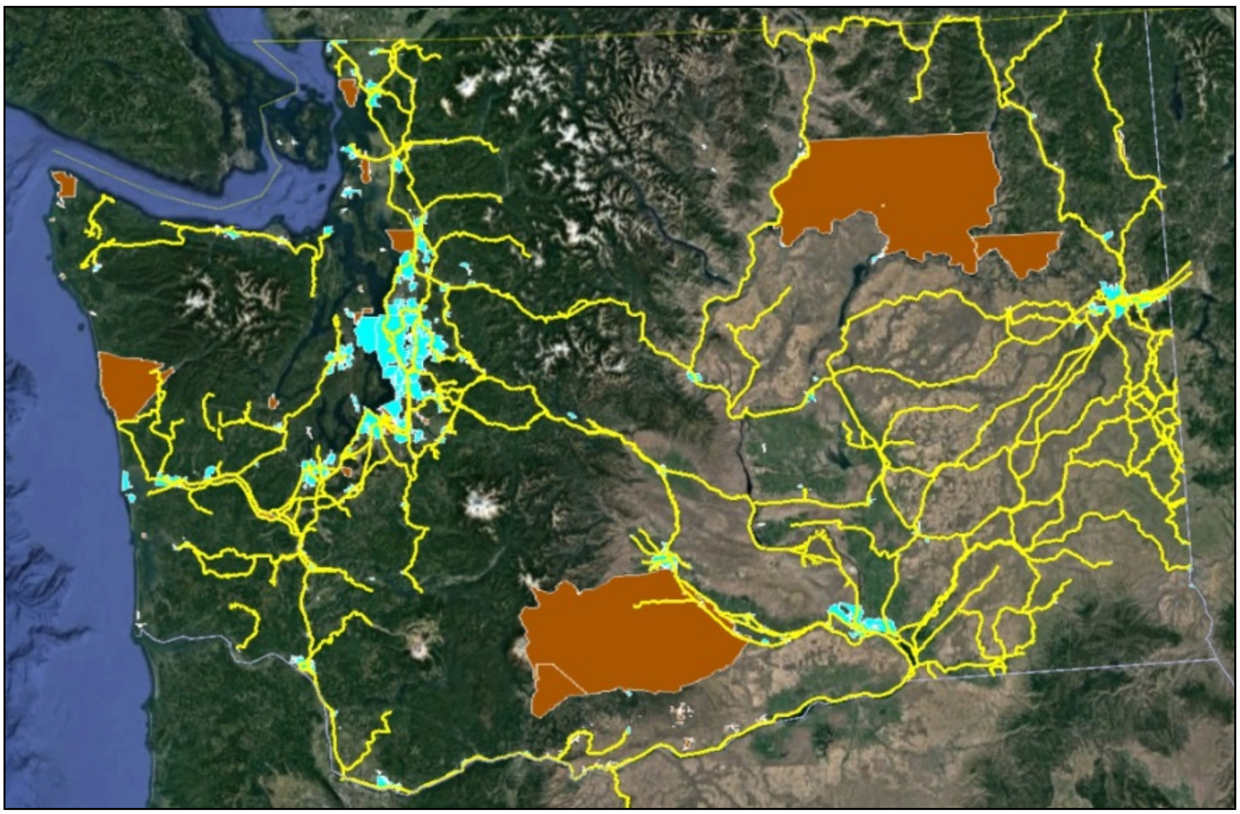

Figure 114: Intersection of Railroads, Populated Areas, and Tribal Lands (railroads in yellow, populated areas in aqua, and tribal lands in brown)[477]

There are also higher probabilities of highway-rail grade crossing accidents in locations that have higher vehicular traffic and train traffic. There are likely to be more highway-rail grade crossings in more densely-populated areas.

[477] Map created by Environmental Research Consulting based on WSDOT data.

The term "High-Consequence Area" (HCA) has been used by the pipeline industry and others to classify certain areas to be of particularly high concern in the event of a hazardous material accident. HCAs can also include locations where drinking water may be affected in the event of a spill, or locations with unusually sensitive ecological resources, such as endangered species or areas where migratory birds congregate.

In this analysis, HCAs are considered to be densely-populated areas. Environmental sensitivity is noted separately.

The rail corridors (by rail subdivisions) throughout Washington State are ranked by the prevalence of densely populated areas in Table 139.[478] Note that the entire rail corridor goes through densely populated areas. There are often wide expanses of open land or low-density smaller towns. The corridors were ranked with regard to the numbers of cities and towns, total population, and the rates of these per rail route mile. (1 = highest, 10 = lowest). The Seattle and Bellingham subdivisions have the highest rankings for all measures. The Eastgate-Hinkle (UP corridors) and Columbia River subdivisions have the lowest rankings. The Spokane subdivision has a relatively short mileage, but a high density per route mile. In this geographic analysis, the relative population by route mile was considered the most important metric determining HCA classification.

Table 139: Relative Ranking of High Consequence (Population Density) Areas in Washington State Rail Corridors by Subdivision Including Numbers of Cities and Population per Rail Route Mile[479]

Subdivision	Cities	Total Pop. in High-Density Cities	Rail Route Miles	Cities per Route Mile	Pop. per Route Mile	Rank by Cities	Rank by Total Pop.	Rank by Cities per Mile	Rank by Pop. Per Mile
Bellingham	11	458,480	119.6	0.092	3,833	2	2	2	3
Columbia River	2	39,714	171.3	0.012	232	9	9	9	9
Fallbridge	4	204,904	219.8	0.018	932	5	4	7	6
Lakeside	2	141,571	146.4	0.014	967	8	5	8	5
Scenic	6	57,938	155.7	0.039	372	4	8	5	8
Seattle	21	1,417,363	136.5	0.154	10,384	1	1	1	1
Spokane	2	301,834	38.3	0.052	7,881	7	3	4	2
Stampede	4	68,697	102.6	0.039	670	6	7	6	7
UP Corridor[480]	1	11,251	308.7	0.003	36	10	10	10	10
Yakima Valley	7	124,644	125.1	0.056	996	3	6	3	4

Geographic environmental sensitivity to oil spills

The potential environmental impacts of an oil spill are dependent on a large number of factors, but most particularly:

- Type of oil (chemical and physical properties, toxicity, adherence, persistence).

[478] For more specific information about communities in the rail corridors, refer to Table 15 in Chapter 4.
[479] Population data from Wikipedia; analyses conducted by Environmental Research Consulting.
[480] Eastgate to Hinkle, Oregon.

- Spill location (habitat types, species present).
- Time of year (nesting season, reproductive cycles, migration patterns).

These three factors play into the type of impact that might be expected from an oil spill. In a 2009 study conducted for the Washington Joint Legislative Audit and Review Committee (JLARC) and Ecology (State of Washington JLARC 2009; Etkin et al. 2009; French-McCay et al. 2009), these three factors were analyzed by mapping the state's marine, estuarine, and inland areas for sensitivity to different types of oils in different seasons.

The sensitivity mapping was heavily based on Ecology's Washington Compensation Schedule methodology (Chapter 173-183 WAC). The sensitivity mapping included:

- Habitat vulnerability to oil's propensity to cause impact by acute toxicity, mechanical injury, and persistence.
- Marine bird vulnerability.
- Marine mammal vulnerability.
- Marine fish vulnerability.
- Shellfish vulnerability.
- Salmon vulnerability.
- Recreation vulnerability.
- Freshwater vulnerability.
- Barriers to natural fish movement.
- Urbanization.
- Condition of riparian (river bank) vegetation.
- Streambed condition.
- Condition of floodplains.
- Land use of watersheds.
- Flow alteration of water due to impoundment.
- Water quality.

The study results indicated that the impact risk was highest for the heavy fuels, followed by crude oil. Impact risk was lower for light oils and gasoline, which are similar for a given zone. Impact risk was lowest for jet fuel and non-petroleum oils. This trend is related to the higher persistence and mechanical injury scores (measuring propensity to coat and foul organisms) of the heavier oils, which therefore have more impact on birds, mammals, habitats, and recreation then the non-persistent oils.

The seasonal variation of the impact risk scores was relatively small, because seasonal highs for some resources are balanced by different seasonal patterns for other resources. However, the scores are higher in spring and summer than in fall or winter (Etkin et al. 2015).

Marine and estuarine waters

The normalized impact scores of different oil types on marine and estuary waters (Figure 116) are shown by season in Table 140. From north to south and west to east the water regions are:

- Rosario Strait and vicinity
- Strait of Juan de Fuca

- Inner Straits
- Whidbey Basin
- North Puget Sound
- Hood Canal
- Central Puget Sound
- South Puget Sound
- Grays Harbor
- Willapa Bay
- West Columbia River
- Washington Outer Coast

The normalization of the scores shows the relative impacts of the oils and seasons compared to each other. The lowest impact would be for jet fuel or organic oils in fall and winter. The impacts of a spill of heavy oil in spring would be three times as high.

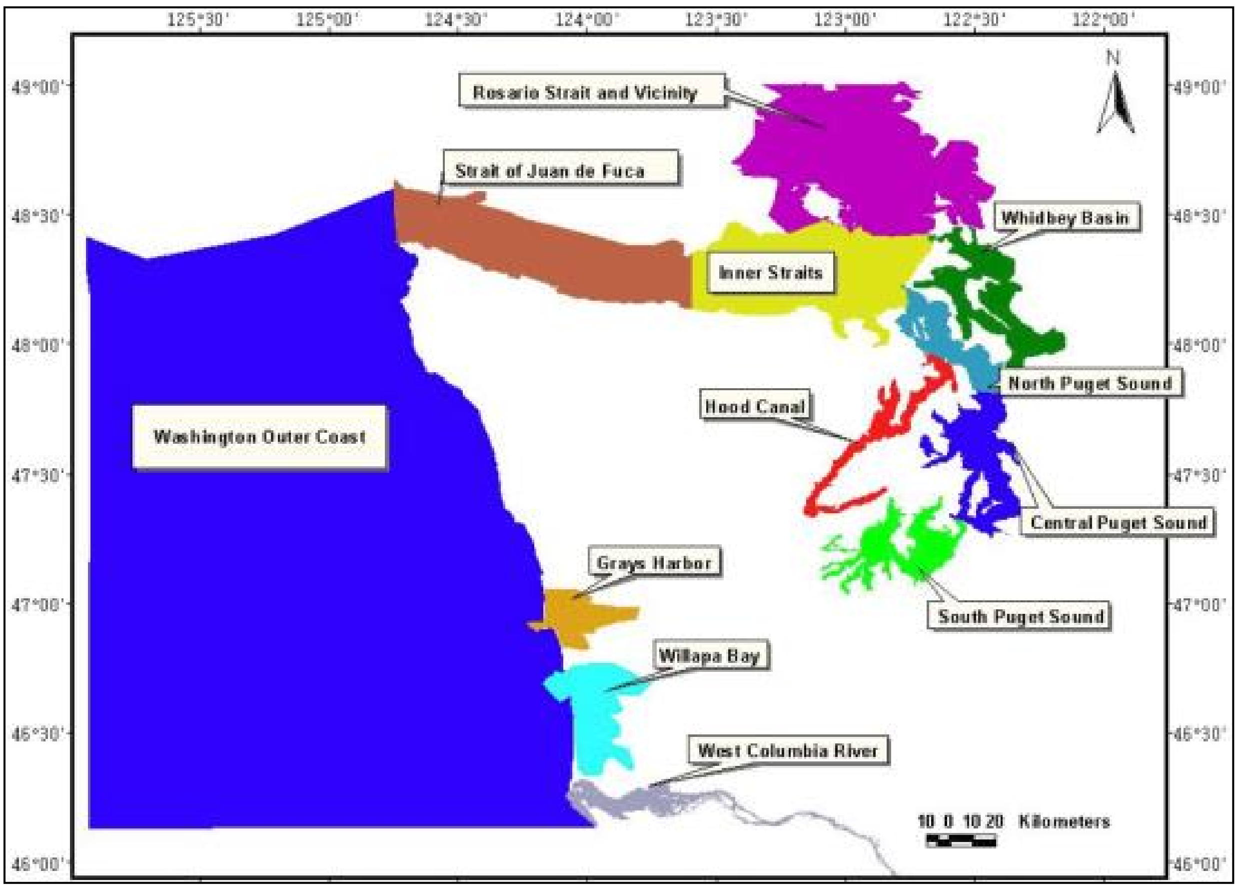

Figure 115: Estuarine and Marine Zones of Washington State[481]

[481] French-McCay et al. 2009. Used with permission.

Table 140: Normalized Estuarine/Marine Impact Risk Scores by Oil Category and Season[482]

Oil Category	Spring	Summer	Fall	Winter
Crude Oils	2.30	2.16	2.02	2.03
Heavy Oils	3.01	2.82	2.63	2.65
Light Oils	1.82	1.71	1.59	1.59
Gasoline	1.73	1.62	1.51	1.52
Jet Fuel	1.15	1.07	1.00	1.00
Non-Petroleum Oils	1.15	1.07	1.00	1.00

Averaged across the four seasons, the impacts of different oil categories by marine and estuarine zone are shown in Table 141. Again, the numbers have been normalized.

Table 141: Normalized Impact Risk Scores for Estuarine and Marine Zones by Oil Category[483]

Zone	Crude Oils	Heavy Oils	Light Oils	Gasolin e	Jet Fuel	Non-Petroleum
Outer Coast	2.92	3.87	2.33	2.33	1.48	1.48
Grays Harbor	3.09	4.01	2.42	2.27	1.51	1.51
Willapa Bay	3.55	4.63	2.79	2.62	1.74	1.74
Strait of Juan de Fuca	2.16	2.82	1.66	1.50	1.00	1.00
Inner Straits	3.83	5.00	3.08	2.96	1.91	1.91
Rosario Strait	3.08	4.04	2.46	2.37	1.55	1.55
Whidbey Basin	3.24	4.24	2.57	2.44	1.63	1.63
Northern Puget Sound	3.52	4.58	2.81	2.66	1.77	1.77
Central Puget Sound	2.41	3.17	1.88	1.78	1.19	1.19
South Puget Sound	3.04	3.96	2.38	2.28	1.51	1.51
Hood Canal	2.44	3.20	1.91	1.80	1.18	1.18
West Columbia River	3.22	4.16	2.54	2.37	1.63	1.63

Inland areas

The five individual Water Resource Inventory Areas, from west to east, are:

- Olympic Peninsula
- West of Cascades
- Lake Union / Lake Washington
- East Columbia River / Snake River
- East of Cascades (Figure 117)

"The highest impact risk for the inland zones is in the Olympic Peninsula zone, followed by West of Cascades and then East of Cascades. The Columbia-Snake River and Lake Union-

[482] French-McCay et al. 2009.
[483] French-McCay et al. 2009.

Washington have lower scores due to urbanization, fish barriers,[484] and impoundments in the watershed" (Etkin et al. 2015). Averaged across the four seasons, the normalized risk scores for impacts of different oil types by inland zone are shown in Table 142.

Figure 116: Washington Inland Zones with Individual Water Resource Inventory Areas[485]

Table 142: Normalized Impact Risk Scores for Inland Zones by Oil Category[486]

Zone	Crude Oils	Heavy Oils	Light Oils	Gasoline	Jet Fuel	Non-Petroleum Oils
Lake Union/ Lake Washington	1.98	2.56	1.56	1.46	1.00	1.00
East Columbia River/Snake River	2.46	3.19	1.94	1.81	1.24	1.24
Olympic Peninsula	5.29	6.85	4.18	3.90	2.67	2.67
West of Cascades	4.85	6.28	3.83	3.57	2.45	2.45
East of Cascades	3.79	4.91	3.00	2.79	1.92	1.92

Geographic analysis of oil spill behavior and effects

There are numerous factors including geographic and environmental variability that have the potential to influence the potential movement and behavior of an oil spill and its consequences.

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484 Screens installed to protect endangered species of fishes that would otherwise be harmed or killed when passing through industrial facilities such as steam electric power plants, hydroelectric generators, petroleum refineries, chemical plants, farm irrigation water and municipal drinking water treatment plants.
485 French-McCay et al. 2009. Used with permission.
486 French-McCay et al. 2009.

Because a rail corridor passes through so many regions and the exact location of a future release is never known, an assessment can be conducted to investigate hypothetical releases along an entire rail corridor.

Known as an "interval approach," hypothetical release modeling is conducted at an interval (e.g. 100 meter spacing) and at other points of interest (e.g. crossings of waterways). Each hypothetical worst case discharge, modeled at each point along the corridor, can then be tabulated to investigate the total number of resources that could potentially be affected should there be a release at any point. Understanding that release volume, river flow conditions, and other environmental factors may influence overland and downstream movement and behavior of oil then necessitates multiple overarching scenarios.

For modeling in Washington State, the interval approach was applied under low and high river flow conditions for a light (Bakken crude oil) and heavy (Cold Lake Winter Blend diluted bitumen) oil for a total of four parent scenarios (Horn et al. 2017; EFSEC 2017).

To conduct an assessment of potential rail accidents that could occur anywhere along the rail corridor, the two-dimensional OILMAPL and trajectory and fate model was used to predict the downslope movement and behavior of an oil release on land and downstream movement and behavior of oil on water, should the release enter a watercourse or waterbody. Using site-specific geographic, environmental, and hydrodynamic conditions, this modeling was conducted for one hypothetical release volume (22,830 bbl) for each of two oil types (conditioned Bakken Crude oil and Cold Lake Winter Blend diluted bitumen) over a range of river flow rates (e.g., high and low river flow conditions) and associated location-specific geographic and environmental conditions. Rather than focusing on specific deterministic locations, which may or may not be truly representative of all of the environments along the rail corridor, and to address each stakeholder concern, this system-wide analysis focused on an interval-based approach that would model numerous releases at a fixed interval of 1 km along the rail corridor, as well as every stream crossing along the rail corridor. In total, 999 individual releases were modeled along the rail corridor from the Washington-Idaho border to the planned facility for each of the four modeled scenarios (two crude oil types under two different river flow conditions).

This approach assessed the spectrum of environments along the rail line, resulting in a range of predicted spill trajectories based on the actual geographic and environmental variability that is present along the rail corridor. This provided trajectory modeling at a high spatial resolution that could be used to determine a system-wide understanding of regions that could potentially be affected based upon combinations of oil type, release volume, and environmental conditions (i.e. river flow conditions). Results were quantified including tabular summaries of the number of releases on land and entering specific waterways, as well as mass balance information such as evaporation statistics. The total number of high consequence areas (HCAs) and resources of interest were also quantified for each release scenario, including unique streams, lakes, and populated areas that may be intersected by a release.

Based upon two oil types, one release volume, and two modeled river flow seasons, a total of four system-wide assessments (i.e. scenarios) were conducted. This analysis provided the realistic range in predicated spatial extent of releases along the rail corridor based upon the variability within each of the 999 individually modeled releases per scenario.

The scenario for each hypothetical release involved 22,830 bbl of either conditioned Bakken crude oil or diluted bitumen. The release volume was based on the 90th percentile spill volume as determined by analyses conducted in another study for the Vancouver Energy Terminal EIS, as described in the report *Crude-by-Rail Spill Risk Analysis for the Proposed Vancouver Energy Terminal* (Etkin et al. 2017). The release represents about 35 tank cars, or about 29 percent of a 120-car train. This is the volume that is the most credible or "realistic" worst-case-discharge (WCD) with respect to the likelihood of the largest number of cars involved in a derailment (or other accident) and the likelihood of the cars releasing all of their contents. The 90th percentile discharge volume as described in Etkin et al. 2017:

> The 90th percentile discharge volume of 22,830 bbl from rail tank cars represents a highly unlikely scenario that has a probability of occurrence of about once in 480 years for Vancouver Energy, or an annual probability of about 0.0021. While it is theoretically possible for a spill of 85,260 bbl to occur (representing the entire unit train derailing and releasing all oil), as specified by the Washington Planning Standard, the 22,830-bbl scenario represents what may be termed an "effective worst-case discharge." It is more than twice the volume of the largest CBR spill incident to occur in the U.S. (10,846 bbl spilled in the November 2013 Aliceville, Alabama, incident). The 22,830-bbl scenario is 60 percent of the volume of the Lac-Mégantic, Quebec, incident. That incident, however, involved a number of factors that are highly unlikely to occur in the U.S. (p. 136)

An interval approach was used with OILMAPLand to conduct an assessment of rail accidents along the entire rail corridor. The modeling provides spill plume trajectories consisting of the overland and surface water pathway of the released product at 999 release locations along the rail corridor. In total 3,996 individual releases were modeled for the four modeled scenarios. Along each spill trajectory, the minimum travel time was estimated as well as a complete mass balance of the released product. The following points describe the types of summaries and figures produced through the modeling process and the information they portray. Summary figures of trajectory and minimum travel time from all releases along the rail corridor were provided for each modeled scenario.

- **Count of releases reaching specific locations:** A tabular summary to compare the 4 release scenarios. Of the 999 individual releases simulated, counts are provided for the number of simulations: Reaching the Pacific Ocean, entering the Columbia River (either from a tributary or directly), and the number reaching surface water lakes or streams versus the number terminating on land without reaching any water. Also, the count of unique lakes reached by all simulations is provided.
- **Evaporation statistics:** The quantity of oil evaporating for each of the release simulations was analyzed for each model scenario. The minimum and maximum quantity evaporated from any individual simulation was tallied along with the mean quantity evaporated for all 999 simulations. These quantities are presented as both a volume as well as a percentage of the total released volume.
- **Lists of sites reached by model scenario:** For each model scenario, lists of specific sites reached by any of the 999 release simulations were tallied. The sites tallied include: unique named streams, unique named lakes reached, and populated areas. Named streams and lakes were defined by the model input hydrology data from the USGS NHD product (USGS 2014). Populated areas were established based on the United States Department

of Transportation (USDOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) designated High Population Areas (HPA) and Other Populated Areas (OPA).

- **Maps of release trajectories and minimum travel time:** A map for each model scenario is provided to show the 999 release simulation trajectories. The plume trajectories are displayed in a way that shows the minimum estimated travel time at any given location. These maps are at a scale that shows the entire extent of all 999 release simulation trajectories for the entire rail corridor. An example of the individual spill plume trajectories from the conditioned Bakken high flow scenarios is in Figure 118 with gray circles representing release sites and subsequent spill tracks colored by travel time moving through watercourses. Differences in travel speed are evident with some rivers transporting oil faster than others. Minimum time to reach areas along the waterways increases as rivers flow away from the spill site.

In general, conditioned Bakken crude is a light oil with low density and viscosity while Cold Lake Winter Blend is denser with a higher viscosity. Both oils predominantly remain on the surface of the water forming extensive slicks and oiling shorelines. Once released, conditioned Bakken evaporates more rapidly than Cold Lake Winter Blend. On average, approximately 55 percent of the conditioned Bakken is predicted to evaporate while only 30 percent of the Cold Lake Winter Blend is predicted.

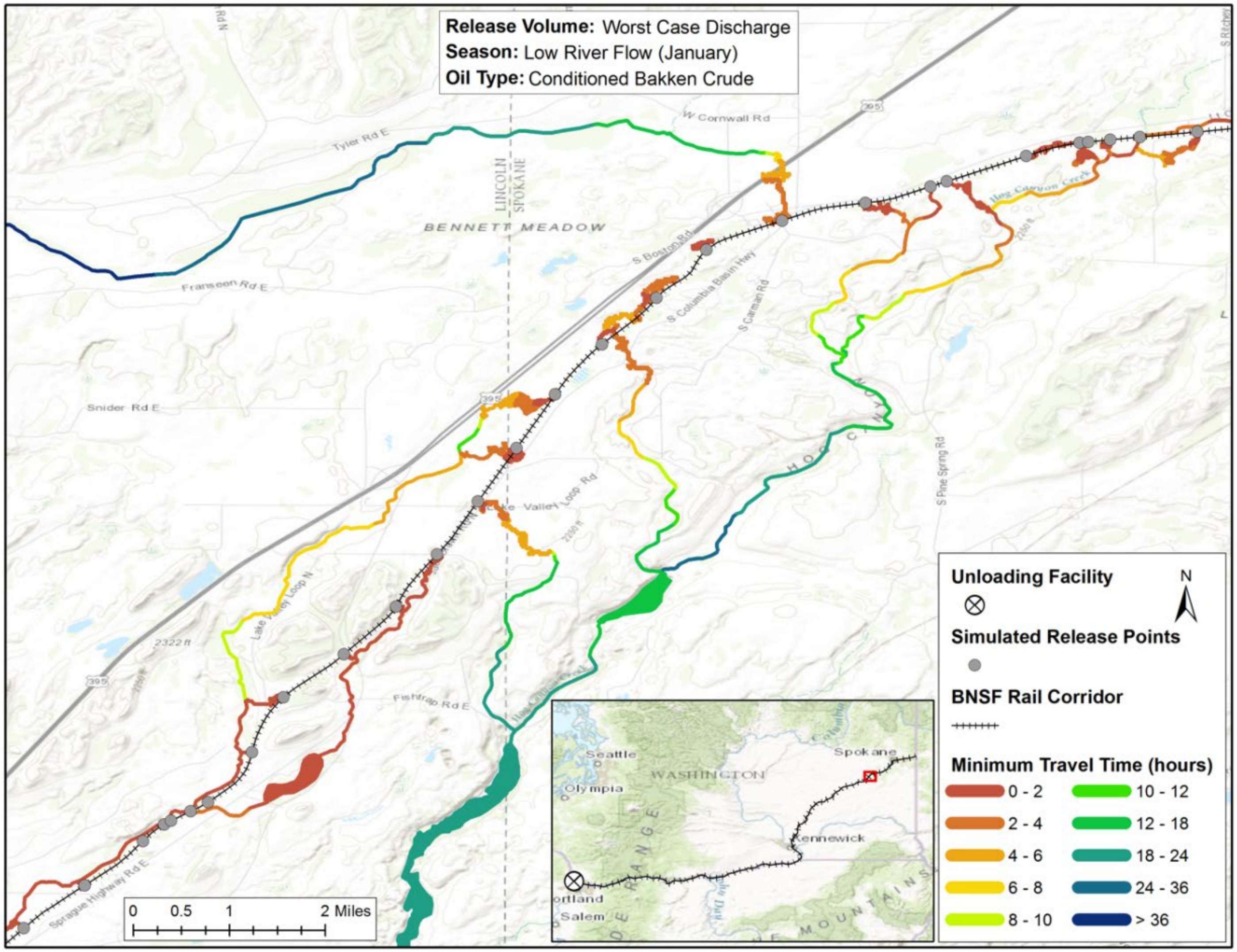

Figure 117: Spill Plume Minimum Travel Time for Conditioned Bakken Crude (High River Flow)[487]

[487] Map by RPS Group, Inc. Used with permission.

Figure 118 portrays 28 different hypothetical releases along the rail corridor to the southwest of Spokane, WA as part of a scenario investigating the worst-case discharge of conditioned Bakken crude oil under January (winter) low river flow conditions. Each of the simulated release points (interval approach with watercourse crossings) is depicted by a grey circle. The predicted plume of oil from the OILMAPLand model is provided, originating at each release point, ultimately flowing downhill, pooling on the land surface, moving down creeks and rivers, and spreading across lake surfaces. The colors depict the minimum travel time that is predicted for each potentially oiled region. As an example, if one release reached a waterway at hour 8, the lime green color would denote this. However, if a second release reached the same waterway at hour 3, the lime green would be covered by orange. Therefore, this map depicts the minimum time predicted for oil to reach each point from all 28 modeled simulations within this scenario. This map highlights several points of interest. In some cases, releases may:

- Adhere to land cover, fill local depressions, and remain on land without impacting waterways.
- Move over the land surface and intersect a waterway where they will move downstream.
- Enter waterways where oil may reach a waterbody (i.e. pond or lake), spread over its surface, and continue downstream.
- Be transported in similar or quite different directions based upon the exact location of the hypothetical release.

Figure 118 is shown at higher relative resolution than Figure 119 through Figure 122 to depict the level of detail built into the OILMAPL and simulation. For the interval approach, assessing consequence along the entire rail corridor, 999 releases were modeled in OILMAPL and for each combination of two river flows and two oil types for a grand total of 3,996 modeled releases. While some releases were predicted to remain on land, a large number were predicted to enter watercourses, where they are transported downstream in tributaries, rivers, and onto lakes (Figure 118). A greater number of conditioned Bakken model runs reached water compared with Cold Lake Winter Blend diluted bitumen. This is mainly a function of the viscosity of the oils and the resulting retention of oil on the land surface and along shorelines. Because conditioned Bakken is a lighter and less viscous oil, when compared to the Cold Lake Winter Blend, a relatively smaller amount of Bakken is retained on land and along shorelines. Therefore, Bakken oil shorelines further downstream, while Cold Lake Winter Blend oils shorelines, to a greater extent (more mass per unit area). The minimum travel time for modeled releases of both oil types and river flow conditions are presented to highlight the variability and timing of the maximum extent of each modeled releases (Figure 119 and Figure 122). In addition, higher river flow conditions result in decreased times for arrival of oil at each downstream point.

Figure 119 through Figure 122 portray the minimum travel time for oil to be reached at each point from all 999 modeled releases. Along the rail corridor, (dashed line) oil is predicted to have the potential to impact the environment immediately following a release. In general, most releases are contained within a few kilometers of the rail corridor. However, when oil has the potential to reach waterways (>80 percent of the scenarios) it has the potential to be transported great distances (>100 miles). Under low river flow conditions, colors are typically “cooler” trending towards green and blues as low river flow results in low river velocities, which transport oil more slowly through the environment and minimum times are therefore longer. Under higher river flow conditions, oil may reach the same point in less time, due to the higher river velocities.

These are observed in the warmer (yellows and reds predicted under high river flow conditions). Conditioned Bakken crude oil is a light and low viscosity oil, when compared to the heavier and more viscous Diluted Bitumen. Therefore, Conditioned Bakken will have less oil adhering to shorelines (thinner) when oil strands, when compared to Diluted Bitumen, which will have thicker oil on the shoreline when it strands. This results in a higher potential for Conditioned Bakken to move further within a given waterway, when compared to the diluted bitumen (shorter regions of potential contamination). In general, the Columbia River has a high potential for oil contamination following a release from a rail accident as the rail corridor is essentially along the river for hundreds of miles.

For the low river flow case simulating conditioned Bakken crude releases, trajectories showed potential impacts extending about 50–150 miles into five watercourses other than the Columbia River, branching out between Spokane and Kennewick. Minimum travel time increased for a spill in the Columbia River as it travelled west past the unloading facility, into the Pacific Ocean. For the low river flow case simulating diluted bitumen releases, trajectories showed a similar pattern with shorter trajectories extending about 50 miles into four watercourses other than the Columbia River, branching out between Spokane and Kennewick. For the high river flow case simulating conditioned Bakken crude releases, trajectories showed potential for spills extending about 25-100 miles into five watercourses branching out between Spokane and Kennewick. For the high river flow case simulating diluted bitumen releases, trajectories showed potential for spills extending about 50 miles into four watercourses, other than the Columbia River, between Spokane and Kennewick.

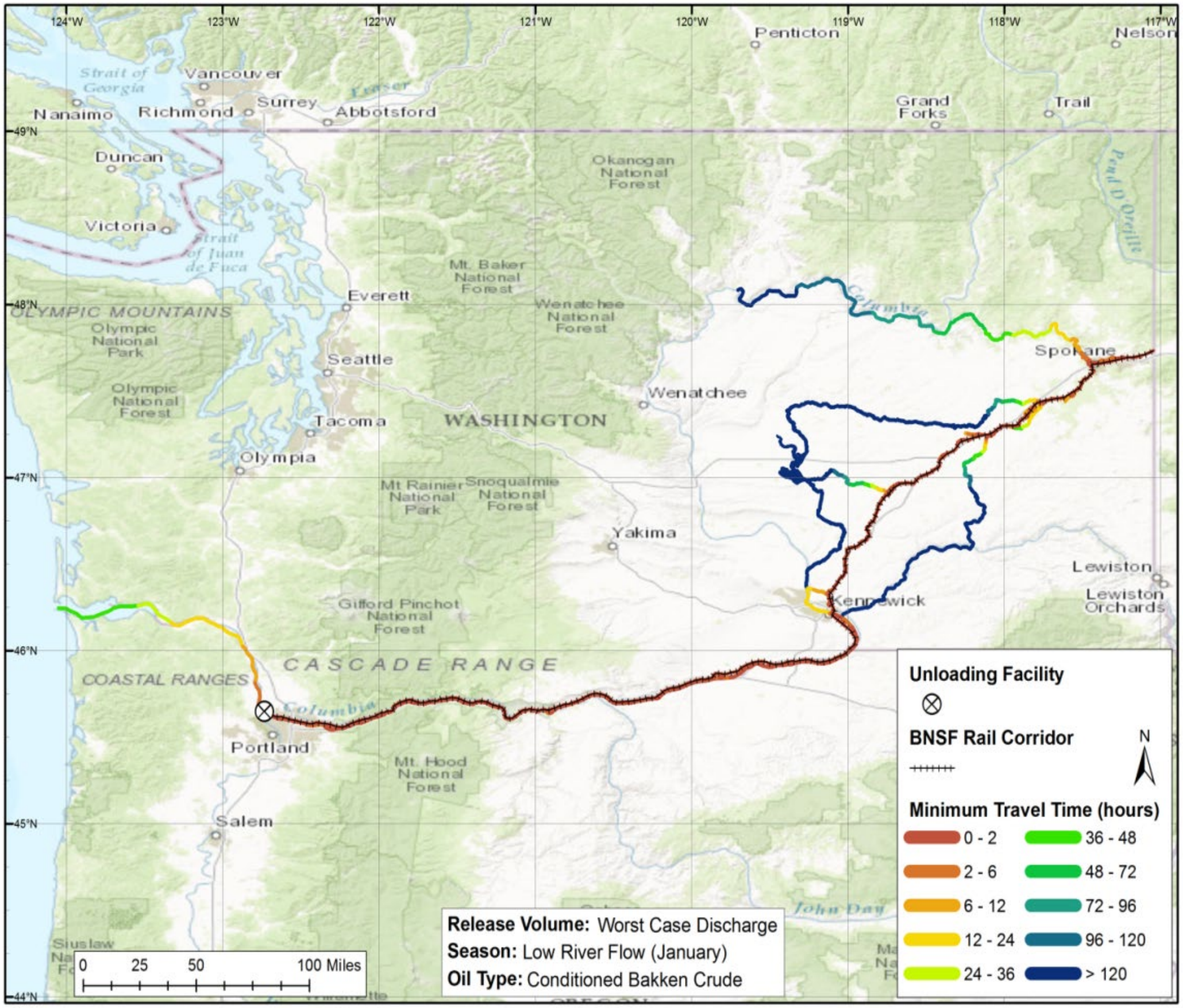

Figure 118: Spill Plume Minimum Travel Time for Conditioned Bakken Crude (Low River Flow)[488]

488 Map by RPS Group, Inc. Used with permission.

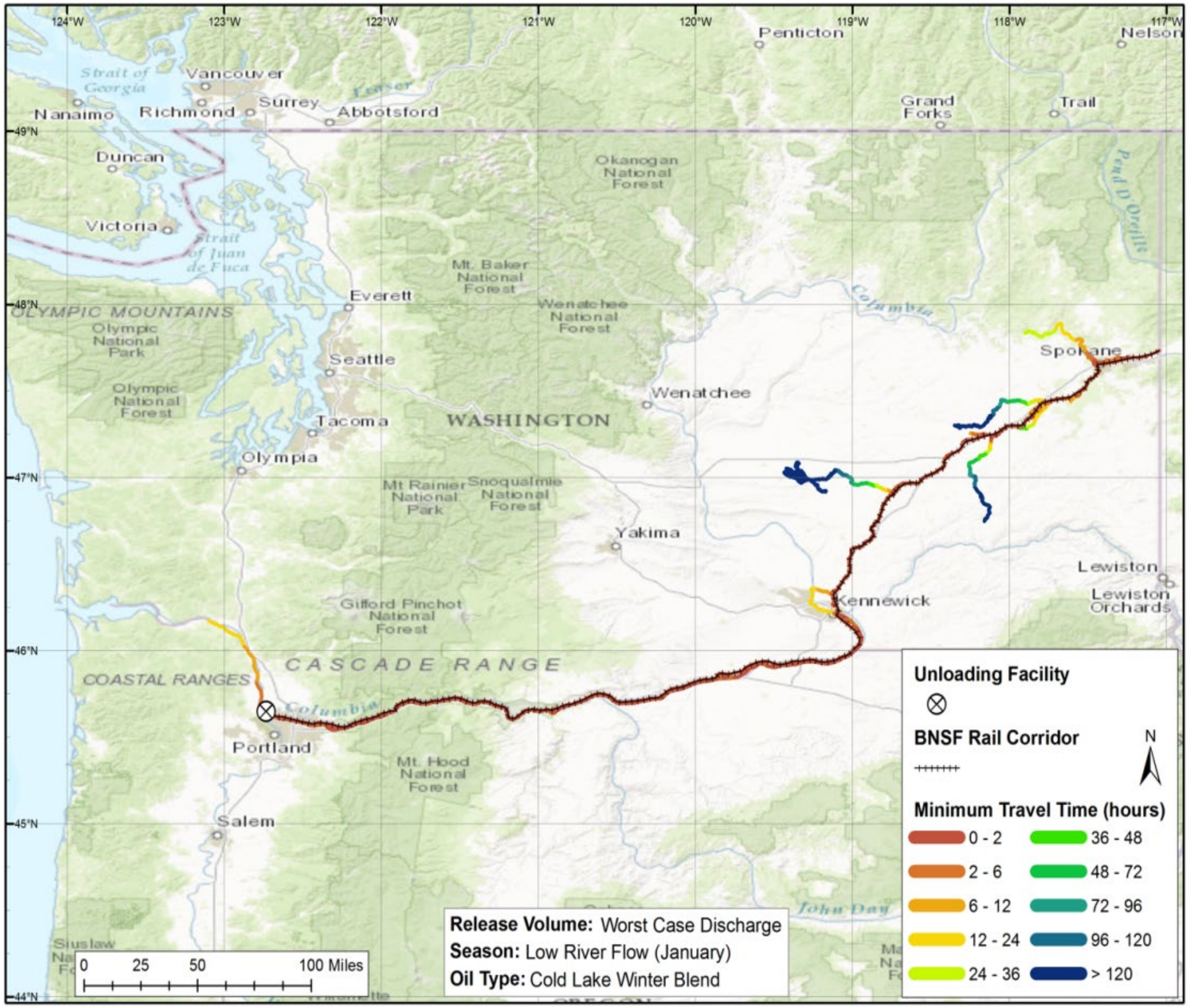

Figure 119: Spill Plume Minimum Travel Time for Diluted Bitumen (Low River Flow)[489]

[489] Map by RPS Group, Inc. Used with permission.

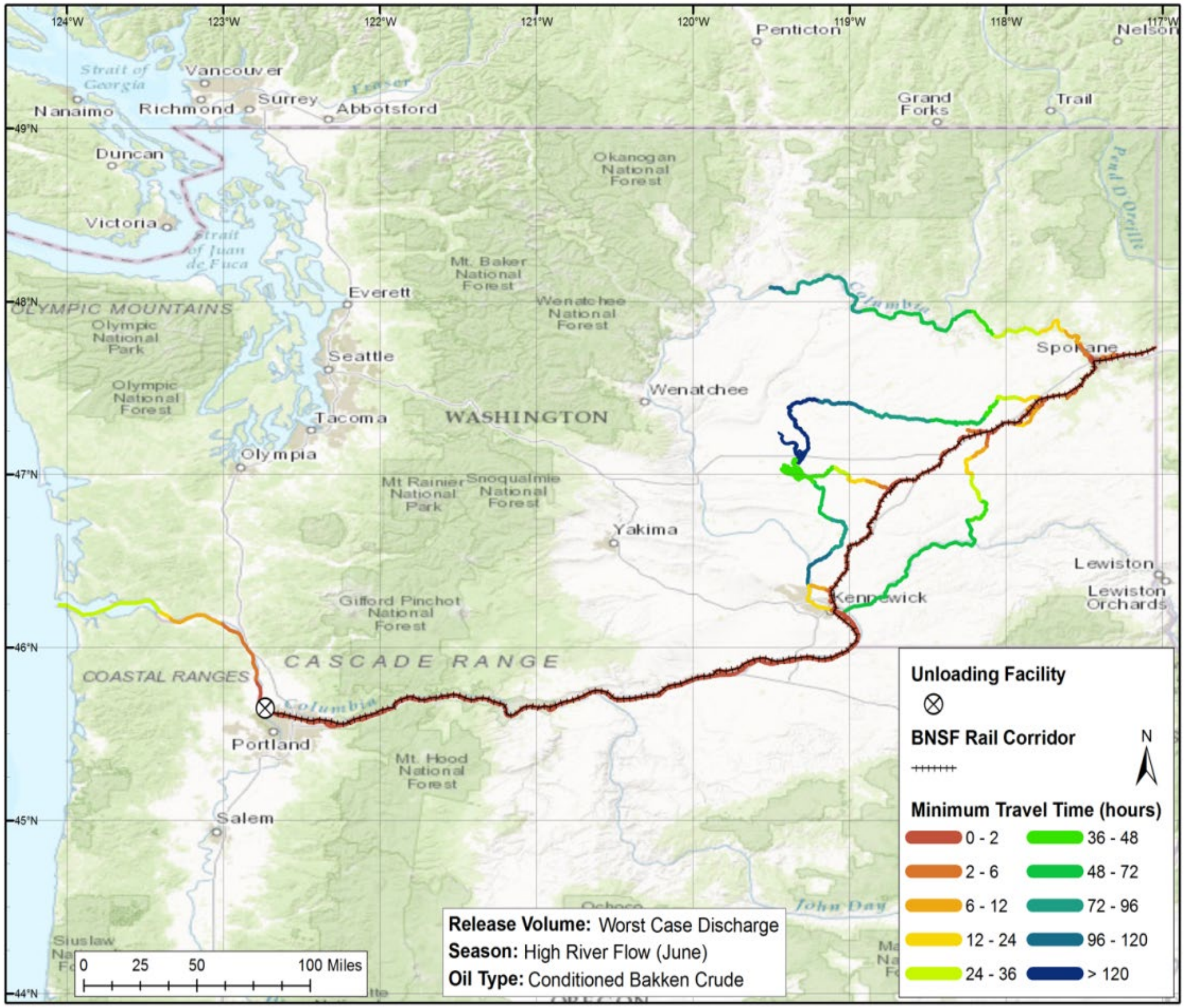

Figure 120: Spill Plume Minimum Travel Time for Conditioned Bakken Crude (High River Flow)[490]

[490] Map by RPS Group, Inc. Used with permission.

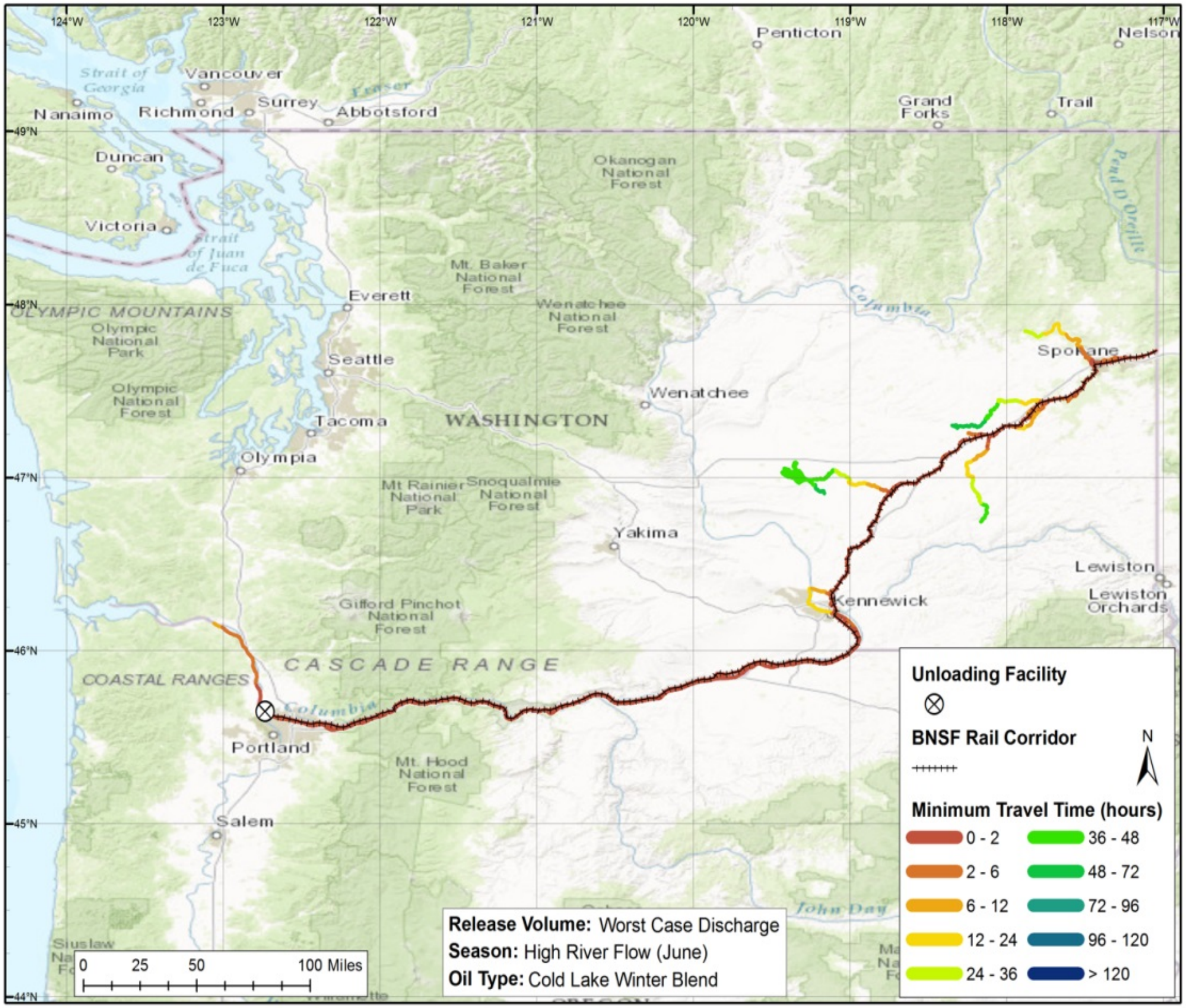

Figure 121: Spill Plume Minimum Travel Time for Diluted Bitumen (High River Flow)[491]

[491] Map by RPS Group, Inc. Used with permission.

Table 143: Percentage of Sites from Which Spilled Oil Reaches Different Waterways for Conditioned Bakken Crude and Diluted Bitumen for High and Low River Flow[492]

Waterways Reached	Conditioned Bakken Crude High River Flow	Conditioned Bakken Crude Low River Flow	Diluted Bitumen High River Flow	Diluted Bitumen Low River Flow
Reaching the Pacific Ocean	18.9 %	22.2%	0.0%	0.0%
Reaching the Columbia River	76.7%	76.8%	56.0%	56.8%
Reaching Water (Lake/River)	81.2%	81.2%	80.6%	80.6%
Not Reaching Water	18.8%	18.8%	19.4%	19.4%
Unique Lakes Reached[493]	5.4%	5.4%	4.2%	4.1%

In total, 36 named creeks and rivers, 23 ponds, lakes, and reservoirs, and 73 High Population Areas (HPA), as defined by the Pipeline and Hazardous Materials Safety Administration (PHMSA), were predicted to be affected by the modeled releases. Of those simulations that reached water, conditioned Bakken crude traveled further and therefore had a higher likelihood of reaching the Columbia River and Pacific Ocean when compared to the Cold Lake Winter Blend diluted bitumen. Within oil types, the distance traveled downstream was very similar between low and high flow conditions, with the difference mainly being in the amount of time it took to reach the furthest downstream point. The timing was a function of the river velocity, whereby low river current velocity resulted in longer times for downstream transport. The number of unique streams, lakes, and populated areas were generally similar among flow conditions and oil types, with conditioned Bakken predicted to affect slightly more resources due to the further predicted downstream extent.

While any specific release cannot be predicted, the interval approach can be very useful in ascertaining the potential extent of oil movement through the environment should a release occur. These results can be very helpful in understanding the spatial extent of potential risk and can be very important in oil spill response planning. Rather than planning for response activities in a narrow band along the rail corridor (e.g., an arbitrary band of 1 km on either side), these results suggest that there is the potential for significant downstream movement of oil and response capabilities may be necessary much further away from the rail corridor.

Emergency and spill response challenges

In the event of a major rail accident with the release of a hazardous material, there will be challenges in emergency response and spill response that are affected by the geography of the area, including:

- Accident site accessibility for emergency rescue operations (access roads, topography).
- Availability and proximity of rescue and fire-fighting equipment.

For responses, there are challenges in both rural areas where equipment and rescue personnel may be located at some distance from an accident site, and in densely populated urban areas

[492] Analysis by RPS Group, Inc.
[493] Does not include "lakes" that were treated as rivers (i.e., lakes along Columbia River above dams).

where there may be sufficient equipment and personnel, but traffic and other obstructions may delay operations. In all locations, weather, particularly snow and ice, can interfere with response times and access.

For this analysis, no particular rankings were given to the rail corridors, although the value of this should be considered by the Rail Safety Committee and others. In general, emergency response and spill response operations are quite carefully planned, including the location of equipment caches and training of personnel. Response plans for spills and emergency operations take into account response and accessibility issues.

Summary of geographic analysis

The three categories of rail accident risk factors — probability, severity, and consequences were evaluated on a rail subdivision basis and given relative rankings on a five-point scale of very high, high, medium, low, and very low. The rankings of the individual factors within probability, severity, and consequences are summarized in Table 144 through Table 146. The overall risk is summarized in Table 147.

Table 144: Geographic Analysis of Rail Accident Probability Factors by Rail Subdivision Based on Rail Traffic Density and Derailment Factors[494]

Subdivision	Daily Rail Traffic	Route Miles	Rail Traffic per Mile	Rail Traffic Density	Derailment Factors	Probability Ranking
Bellingham	26	119.6	0.22	High	Medium	High
Columbia River	24	171.3	0.14	Low	Low	Low
Fallbridge	42	219.8	0.19	Medium	Low	Medium
Lakeside	42	146.4	0.29	High	Medium	High
Scenic	23	155.7	0.15	Low	No Info	-
Seattle	60	136.5	0.44	High	Low	Medium
Spokane	66	38.3	1.72	Very High	Very Low	Medium
Stampede	6	102.6	0.06	Very Low	Very High	Medium
UP Corridor	No Info	308.7	No Info	No Info	No Info	-
Yakima Valley	8	125.1	0.06	Very Low	High	Medium

[494] Analysis by Environmental Research Consulting.

Table 145: Geographic Analysis of Rail Accident Severity Factors by Rail Subdivision for Different Hazardous Materials[495]

Subdivision	Crude Oil	Propane	Ethanol	Ammonia	Sulfuric Acid	Overall Severity Ranking
Bellingham	High	Very Low	Very Low	Very Low	Very Low	Medium
Columbia River	Very Low	Very Low	Very Low	Very Low	Very Low	Low
Fallbridge	Very High	High	Medium	Very Low	Low	High
Lakeside	Very High	High	Medium	Medium	Low	Very High
Scenic	Very Low	Very Low	Very Low	Very Low	Very Low	Low
Seattle	Very High	High	Medium	Very Low	Very Low	High
Spokane	Very High	High	Medium	Medium	Low	Very High
Stampede	Very Low	Very Low	Very Low	Very Low	Very Low	Low
UP Corridor	Low	Very Low	Very Low	Very Low	Very Low	Low
Yakima Valley	Very Low	Very Low	Very Low	Very Low	Very Low	Low

Table 146: Summary of Geographic Analysis of Rail Accident Consequence Factors by Rail Subdivision Including Rankings for High-Consequence Areas, Environmental Sensitivity, and Oil Spill Behavior[496]

Subdivision	High-Consequence Areas	Environmental Sensitivity	Oil Spill Behavior[497]	Overall Consequences Ranking
Bellingham	High	Very High	Very High	Very High
Columbia River	Low	Medium	High	Medium
Fallbridge	Medium	High	Very High	High
Lakeside	Medium	Medium	High	High
Scenic	Low	High	Medium	Medium
Seattle	Very High	Very High	Very High	Very High
Spokane	Very High	Medium	Low	High
Stampede	Medium	Very High	Medium	High
UP Corridor	Very Low	Medium	Low	Low
Yakima Valley	High	Medium	Low	Medium

[495] Analysis by Environmental Research Consulting.
[496] Analysis by Environmental Research Consulting.
[497] Generally based on likelihood of spreading.

Table 147: Summary of Geographic Analysis of Rail Accident Risk by Rail Subdivision Based on Probability Ranking, Severity Ranking, and Consequence Ranking[498]

Subdivision	Probability Ranking	Severity Ranking	Consequences Ranking	Overall Risk Score
Bellingham	High	Medium	Very High	High
Columbia River	Low	Low	Medium	Low
Fallbridge	Medium	High	High	High
Lakeside	High	Very High	High	Very High
Scenic	Medium	Low	Medium	Low
Seattle	Medium	High	Very High	High
Spokane	Medium	Very High	High	High
Stampede	Medium	Low	High	Medium
UP Corridor	Medium	Low	Low	Low
Yakima Valley	Medium	Low	Medium	Low

The risk scoring in this study was conducted only on a railroad subdivision basis. There are many variations within each subdivision.

Potential areas of future discussion

- The Rail Safety Committee may want to consider further analyses of the subdivisions that present relatively high risk for the likelihood of accidents (probability ranking), the severity of potential accidents (severity ranking), and the potential impacts of accidents (consequences ranking).
- That the risk scoring in this study was conducted only on a railroad subdivision basis. There are many variations within each subdivision that the Rail Safety Committee and/or state officials may want to consider evaluating in greater detail.

[498] For the subdivisions for which there were no data, the rankings were assumed to be "medium." Analysis by Environmental Research Consulting.

Chapter 24: Washington Rail Risk Assessment Tool (WA-RRisk)

Key questions

- What is the Washington Rail Risk Assessment Tool (WA-RRisk)?
- What are the inputs and assumptions inherent in the WA-RRisk Tool, and how might different inputs or assumptions, change the assessment of risk?
- How might the tool be used by the Rail Safety Committee, Ecology, and/or UTC, to evaluate potential effects of changes in risk factors, such as the introduction of more trains, changes in the implementation of safety measures, changes in assumptions on the effectiveness of various safety measures (e.g., effectiveness of PTC or ECP), or changes in the availability and use of DOT-117 cars?

Takeaways

- The WA-RRisk tool is a means to evaluate the potential effects of different types of safety measures and estimating the potential numbers of rail accidents under varying scenarios.
- The algorithm and inputs can easily be changed to incorporate different types of scenarios other than the hypothetical CBR explosion example.

The following sections provide a more in-depth look at a model, the Washington Rail Risk Assessment Tool (WA-RRisk), that can be used to evaluate rail risk reduction measures. The WA-RRisk tool is intended for use as a broad screening method to highlight areas of potential concern for more in-depth evaluation or to roughly quantify the potential variations in risk based on hypothetical developments or changes, such as fluctuations in rail traffic or implementation of safety measures. The WA-RRisk model is demonstrated with the example of crude-by-rail (CBR) unit trains laden with Bakken crude oil.

Purpose of WA-RRisk

Assessing the risk of rail transportation in Washington State requires pulling together a large array of different types of information that address the following issues:

1. Identifying the types of rail accidents that might occur with current and rail traffic.
2. Determining the likelihood or expected frequency of different types of rail accidents.
3. Determining the likelihood that different types of rail accidents will have consequences that could potentially affect human health and safety environment and/or impact the environment.
4. Determining the extent to which the likelihood or frequency of accidents can be reduced.
5. Determining the extent to which the consequences or impacts of accidents can be reduced.

The basic aspects of risk (numbers 1 through 3 in the list above) are summarized in Figure 123. The risk reduction measures (numbers 4 and 5 in the list above) are incorporated into the schematic diagram in Figure 124.

Note that the WA-RRisk model focuses on hazardous material releases and not the consequences of passenger train accidents or highway-rail crossing accidents.

With rail traffic in Washington State, there are most likely going to be occasional accidents that occur. The nature of the rail traffic — the numbers and types of trains going through different rail corridors — will affect the expected frequency of accidents. Factors that may affect the likelihood of accidents include: track geometry (i.e., the general layout of the tracks, the curves, slopes, and track connections and crossings), environmental conditions (e.g., weather), and human factors (decisions made by rail operators and drivers of vehicles that cross tracks at highway-rail crossings). Accident prevention measures will act to reduce the number and magnitude of accidents.

Once an accident has occurred, there is a possibility of human casualties (fatalities and injuries). These casualties may be prevented or reduced by various prevention measures. If the accident involves a car that contains oil or another hazardous material, there is a possibility that there would be a spill or release. Cargo release prevention measures (e.g., safer tank cars) may reduce the likelihood that a tank car or other car containing hazardous material would have a release.

If a release occurs, the properties of the hazardous material (i.e., its physical and chemical properties), as well as the amount released, in conjunction with the environmental conditions (e.g., wind), will affect the type of effects that may occur. In some cases, there may be a fire or explosion, or a vapor cloud release. In the event of a fire, explosion, or vapor cloud, the impacts will depend on the nature of the material, the environmental conditions, and the location of the accident. If the accident occurs in the vicinity of a high-consequence area (i.e., a highly-populated area), there may be human casualties or human health and safety environment effects. Emergency response operations, such as evacuations, may reduce the impacts of such an event.

If there is a fire or explosion some or all of the material may be consumed or released to the atmosphere without spilling onto the ground or into waterways.

If the oil or other hazardous material spills onto the ground or into waterways, the effects will be determined by the properties of the material as well as the properties and sensitivity of the receiving environment or habitats. There may be differences in effects based on season or other environmental conditions, such as weather.

The effects to the environment may be reduced to some extent with spill response measures. Spill response may prevent or reduce the amount of the spilled material that reaches sensitive environmental, socioeconomic, or cultural features. Response operations may also remove some of the material that has been spilled.

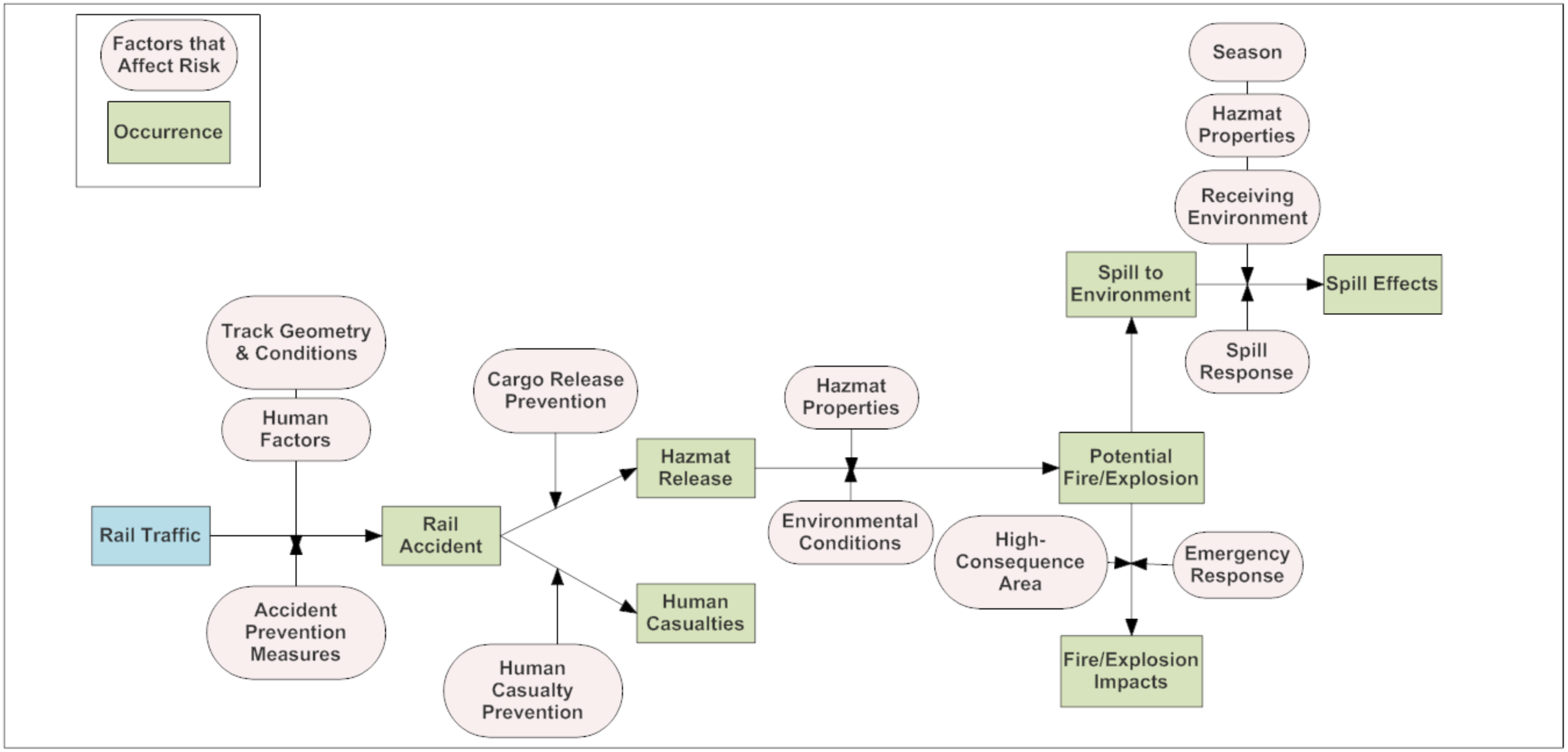

Figure 122: Factors that Affect the Degree of Risk in Rail Accidents[499]

[499] Figure prepared by Environmental Research Consulting. Used with permission.

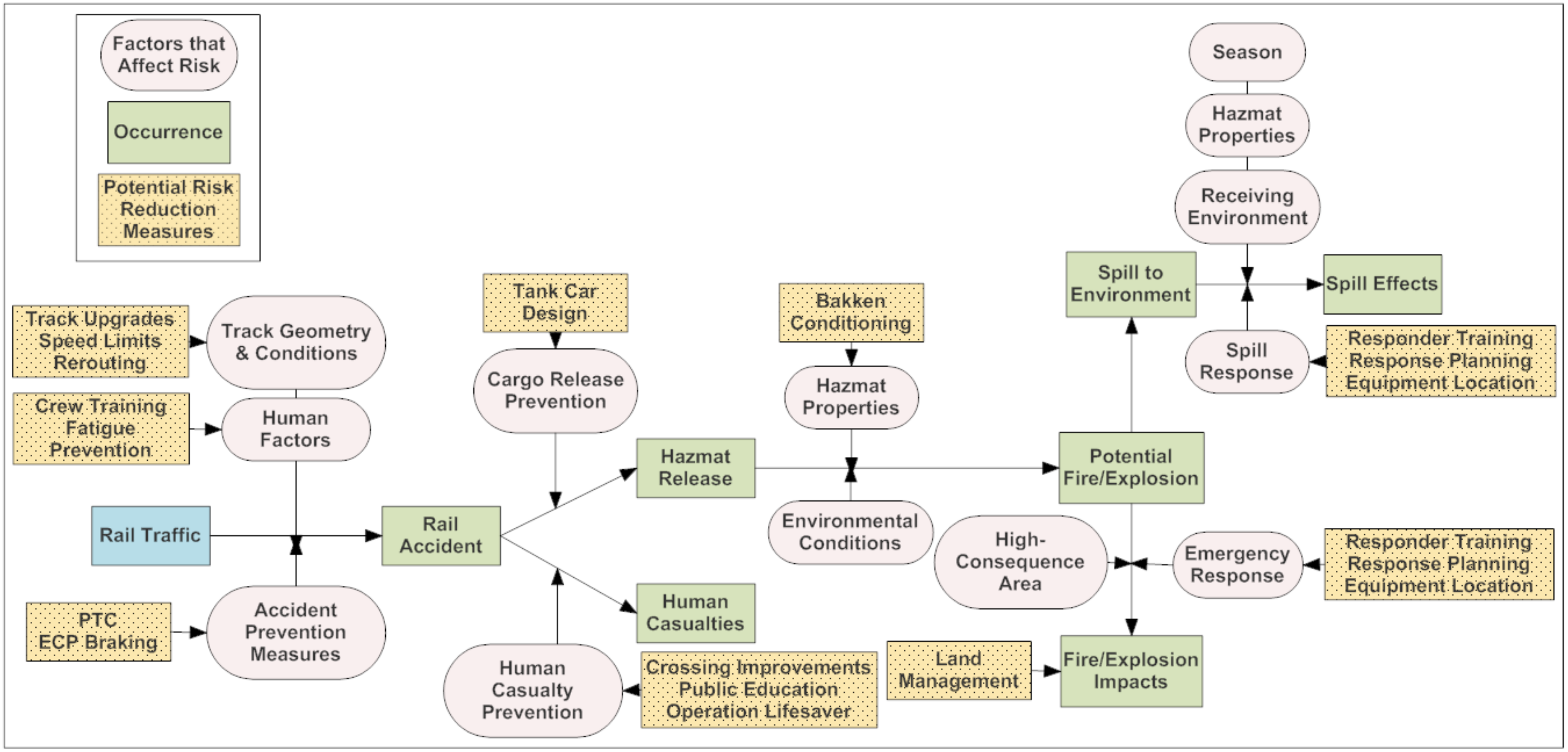

Figure 123: Risk Reduction or Mitigation Measures that Affect Rail Accident Risk[500]

[500] Figure prepared by Environmental Research Consulting. Used with permission.

In order to assist in evaluating the various risk factors that are discussed in this report, a model, the Washington Rail Risk (WA-RRisk) model was developed. WA-RRisk provides a simple tool that may be used to:

- Measure the relative effects of different factors in contributing to risk.
- Measure the relative effects of different risk reduction measures in reducing the probability and consequences of rail accidents in Washington State.

Note that "measuring (or quantifying) risk" with this tool is not going to predict the exact frequency of rail accidents nor their exact locations and impacts. WA-RRisk is merely a means for the Rail Safety Committee or officials at Ecology and UTC to evaluate the ways in which various changes in the existing railroad transportation system in Washington State may affect human health and safety, as well as effects to the environment.

Overview of WA-RRisk algorithm and event tree

An "algorithm" is a process or set of rules to be followed in completing a complex problem-solving operation or calculation. The algorithm for WA-RRisk is the set of mathematical equations that is used to calculate the risk metric. A series of steps is required:

1. Calculate the likelihood or expected frequency of a particular type of rail accident in a particular geographic zone (e.g., a rail subdivision or the whole state of Washington) based on the rail traffic level and any factors that may affect the likelihood (e.g., track conditions, accident prevention measures in place).

2. Calculate the likelihood that the accident will result in the release of a hazardous material based on the cargo being transported (i.e., the likelihood that a particular type of cargo is on a particular train) and prevention measures in place (e.g., tank car design).

3. Calculate the likelihood that there will be a fire, explosion, vapor cloud, and/or spill into the environment depending on the properties of the materials released and the environmental conditions.

4. If the rail accident results in a fire, explosion, and/or vapor cloud release, calculate the likelihood of effects based on the type of location (e.g., densely-populated or high-consequence area).

5. If the rail accident results in a spill, calculate the likelihood of effects of the spill based on the hazardous material properties, receiving environment, and season.

Note that the end result is a probability that there will be effects to humans and environmental resources. Determining the extent of those effects is beyond the scope of the model.

Steps 1 through 5 are performed with mathematical equations that are essentially a series of multiplications of different probabilities that form an "event tree." An event tree is essentially a series of events that need to occur for the final event to take place. First, the rail traffic needs to result in a rail accident. Then, the accident needs to result in the release of a hazardous material. Then, the release has to either result in a fire, explosion, or vapor cloud in order to cause human casualties and health effects, which are caused by exposure of the release of hydrocarbon to an ignition source — either early or late in the release process. The spill can also flow into a waterway or sensitive habitat to cause environmental impacts. The event tree is diagrammed in Figure 125. In the event tree diagram, there are a series of events shown at the top left of the diagram and the probabilities of these different events occurring are shown directly below them. In the diagram, a branch in the downward direction represents the event occurring and the downward direction represents the event occurring.

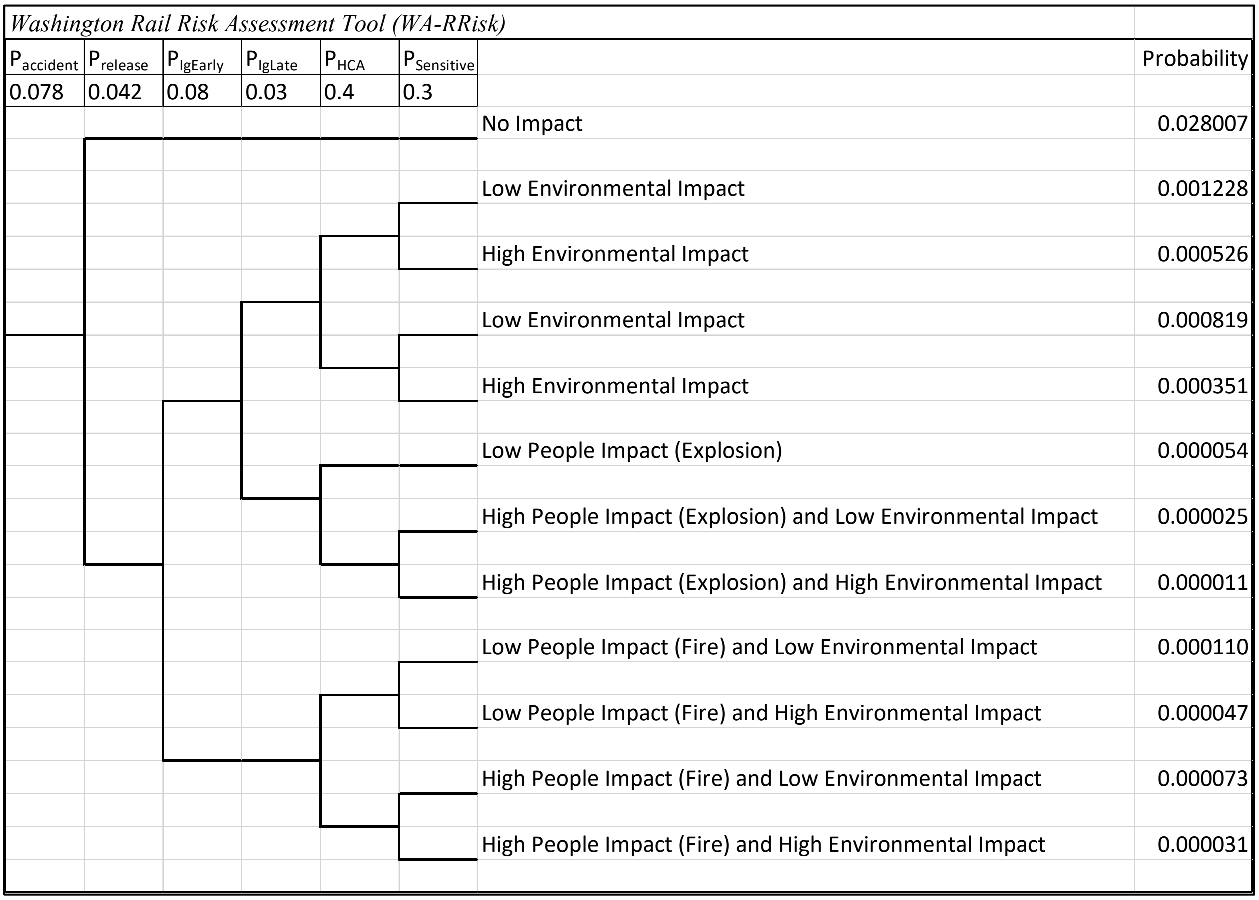

Figure 124: Simple Event Tree for Rail Accidents in WA-RRisk Model[501]

In an event tree in which all of the events need to occur in order to have the last event (e.g. a fire, explosion, or vapor cloud occurring in a high-consequence area), all of the probabilities are multiplied together.

As an example, an equation representing the path through the event tree resulting in high impact to people from an explosion and low environmental impact for a fire, explosion, or vapor cloud (FEV) occurring in a high-consequence area (HCA) and not in an environmentally sensitive area, where “P(x)” stands for the probability that the event “x” will occur is:

$$P=P(accident)*Prelease*(1-P(ignition)\ early)*P(ignition)\ late*P(HCA)*(1-P(sensitive)$$

[501] Figure created by Risknology, Inc. Used with permission.

The equation for a spill occurring in a waterway or sensitive resource area and having no ignition is:

$$P=P(accident)*Prelease*(1-P(ignition)\ early)*(1-P(ignition)\ late)*(1-P(HCA)*P(sensitive)$$

Note that the probability of a "release" turning into a "spill" depends on whether the spilled material burns, explodes, or vaporizes. For example, if there is a release of Bakken crude, it may burn and/or explode if there is an ignition source, or it may remain in liquid form in the absence of ignition. In an actual accident release scenario, there may be a combination of burning, exploding, vaporizing, and spilling into the environment.

WA-RRisk inputs and assumptions

For each of the probability components, the model user needs to make decisions on inputs:

- Probability of a rail accident.
- Probability of a release from the tank car in the event of an accident.
- Probability of an early ignition in the event of a release.
- Probability of a late ignition in the event of a release.
- Probability of the fire, explosion, or vapor cloud event occurring in a high-consequence area (HCA).
- Probability of the spill entering a waterway or other sensitive resource area.

Each of these probabilities differs by geography, commodity type (hazardous material such as Bakken crude oil), and other factors. The probabilities can also be affected by various factors that may decrease or increase the probabilities. Prevention measures would decrease the probability.

As an example, the WA-RRisk algorithm was applied for Bakken crude unit trains transiting through Washington State. The model could also be applied to other types of trains and cargoes.

Adjustments to probabilities by risk mitigation measures

Each of the probabilities in the event tree (Figure 125) and the formulae may be adjusted based on various types of risk reduction measures. Rail accident risk reduction measures act to reduce the likelihood, severity, or consequences of an accident.

The probability of an accident may be reduced by such measures as:

- A reduction in the number of trains;
- A reduction in the speed of trains;
- The use of Positive Train Control (PTC);
- Improvements to track and rail equipment maintenance; and/or
- Reductions in human error through efforts to reduce crew fatigue.

The probability of an accident resulting in the release of hazardous cargo (such as oil) may be reduced by such measures as safer tank car designs and/or a reduction in the speed of trains.

The probability of a release of hazardous cargo resulting in a fire, explosion, or vapor cloud may be reduced by such measures as:

- Changing the nature of the hazardous material before lading into tank cars (e.g., reducing the volatility of Bakken crude oil by conditioning).
- Using safer tank car designs that have better thermal protection.
- Reducing the number of cars of hazardous cargo in a mixed-manifest train (e.g., limiting the number of chlorine tank cars on a train).

The probability of an accident occurring in a high-consequence area (HCA), waterway, or sensitive resource area may be reduced by preventing of an accident or release in these types of locations in the first place. It may also be reduced by such measures as:

- Land management practices (e.g., not building schools or other highly-populated buildings near railroad tracks).
- Rerouting of trains along alternative routes, if at all possible and practicable. (Note that is often not an option.)

Example: Probability of a rail accident with Bakken crude oil

The accident probability or expected number of accidents involving a CBR train depends on the number of trains and the degree to which various safety measures may prevent or reduce the number of accidents.

There are various approaches to deriving a reasonable estimate of the probability of a CBR accident. One approach is to take the number of loaded CBR trains that pass through Wasington State (or through a particular location) and then determining the likelihood that those trains might experience an accident. Based on the data in Chapter 4 on Daily Trains through Washington State Cities and Towns (Table 15), there are about 2 trains daily or 730 CBR trains per year. These 730 trains each transit about 1,000 miles of track each. This comes to 730,000 train-miles per year.

Based on the accident rates for all freight trains for 2015 through 2018 in Washington State, as presented in Chapter 5,[502] there are expected to be about 1.07 accidents per one million train-miles. This would bring the expected number of CBR accidents per year to 0.78, or one accident every 1.3 years.

Note that this probability is based on overall freight train accident rates, and does not take into account any accident prevention measures that have been implemented specifically to prevent CBR accidents, such as reduced speeds. PTC, which has been fully implemented since the time period for the accident data is also likely to reduce accidents as well.

Applying an assumption of the probability that PTC might reduce CBR accidents is not straightforward. According to data presented in Chapter 9, the reduction in accidents with PTC due to violations and route integrity failures may be as high as about 90 percent (ICF Incorporated 2015). Some studies conducted in the early 2010s, provide less optimistic results, with accident reductions as low as less than 2 percent (Peters and Fritteli 2012). Based on these

[502] Table 15: Washington Freight Mainline Average Annual Accidents per Million Train-Miles.

divergent estimates, two different reduction probabilities were applied in the hypothetical example. The probabilities of the accidents would be multiplied by either 0.10 (for the 90 percent reduction) or 0.98 (for the 2 percent reduction).

Probability of release from tank car laden with Bakken crude oil

If the CBR rail accident involves laden (loaded rather than empty) tank cars of Bakken crude oil, one or more of the tank cars needs to break open or breach in order to release the oil to the environment.

The probability of release from one or more tank cars in CBR unit trains depends on a number of factors, as discussed in Chapter 15. The most important factors are tank car design and train speed at the time of the accident.

Since tank cars used in Washington State are now all safer DOT-117 cars, as discussed in Chapter 15, the probability of release from these types of cars can be applied in the WA-RRisk model calculation.

For this example, the probability of a release is assumed to be 4.2 percent, based on the data from a review of a variety of sources (API/AAR 2014; Treichel 2014; Barkan et al. 2015).[503]

Probability of fire, explosion, or spill with Bakken crude oil

If the release of Bakken crude oil occurs in such a way that there is a source of ignition and the ambient environmental conditions are conducive, there may be a fire and/or explosion that occurs. Ignition may occur from an outside source, such as a pilot light or match, static electricity, electrical shorts, or through sparks generated from scraping metal in the course of the accident. If there is no ignition, the Bakken crude oil would spill into the environment.

The probability of ignition varies considerably by location and the specific circumstances of the accident. A frequently applied estimate of ignition probability is 0.08 or 8 percent. If there is a release from a CBR tank car, there is a 30 percent probability that the release would result in a vapor cloud, which would be necessary for there to be an explosion (Cox et al. 1990). This is discussed in greater detail in Chapter 7.

Probability of accident in high-consequence area (HCA)

If the Bakken crude oil release results in a fire and/or explosion, the most severe consequences would occur if the accident occurs in a high-consequence area (HCA). An HCA is usually defined as a high-density population area. An accident in such a location has the greatest likelihood of causing human casualties — fatalities and serious injuries.

The precise location of the incident, the ambient environmental conditions at the time, and the numbers of people in the hazard zone will all determine the extent of the casualties. The ability of emergency responders to evacuate areas around the accident site will prevent casualties if explosions happen later in the accident. Later explosions may occur when there is a fire

[503] Based on Table 95: Feature Description and Conditional Probability of Release (Chapter 15).

immediately after the accident occurs that creates enough heat to affect other tank cars that have not broken open yet.

The probability that an accident with a release and subsequent fire or explosion will occur in a HCA depends on the percentage of track along the route that runs through HCAs, such as cities and towns.

Assuming that the likelihood of the accident occurring is equal across the entire route that a CBR train might travel, the probability of it occurring in an HCA would be the mileage of track going through highly-populated areas. Note that the assumption that the accident is just as likely to occur, in a particular mile in an HCA, as in any other mile in a less-populated area is questionable. CBR trains move more slowly in highly-populated areas. In addition, the track running through cities and towns is generally less likely to have steep slopes or curves that contribute to accidents.

In Chapter 4, there are maps and tables showing the intersection of railroad tracks through cities, towns, and tribal lands, as well as the numbers of trains going through densely-populated areas. A rough estimate is that 40 percent of the track mileage that CBR trains transit go through densely-populated areas.[504]

Probability of accident near waterways or sensitive resource areas

If the Bakken crude oil does not burn or explode, or if not all of it is consumed by fire, it will be released to the environment. The severity of the consequences of the release will depend on the location of the spill. The topography, environmental conditions, and proximity to waterways and sensitive resources will determine the severity of the effects. Prompt and effective spill response operations may help to reduce the ecological effects by reducing or redirecting the spread of the spilled oil (i.e., keeping it out of waterways and the most sensitive areas) and removing oil.

The probability that an oil spill from a CBR train will end up affecting waterways or sensitive resources is likely very high. Based on the large numbers of lakes, rivers, and streams that run throughout Washington State, as well as the presence of sensitive natural, tribal lands, and cultural resources, most spills, unless relatively small, might end up having some degree of impact.

For simplicity, it is assumed that there is a 0.90 probability that a spill will affect some type of waterway or sensitive resource.

Application of WA-RRisk to CBR example

The various inputs for the hypothetical CBR example of a Bakken crude oil accident with an explosion in a high-consequence area are summarized in Table 148.

[504] Based on Map of BNSF Train Routes through Washington State Showing Populated Areas in Chapter 4.

Table 148: Data Inputs for WA-RRisk for Hypothetical CBR Example[505]

Probability	Estimated Value
CBR Accident (with High PTC Effectiveness)	0.078 (per year)
CBR Accident (with Low PTC Effectiveness)	0.764 (per year)
Release of Crude Oil with Accident	0.042 (per accident)
Probability of Late Ignition	0.03 (per release)
Probability of High-Consequence Area	0.40 (per release)

Based on these hypothetical inputs, for the high-effectiveness assumption for PTC effectiveness in preventing accidents with CBR trains, the probability of an accident somewhere in a high-consequence area is 0.000025 or 1 in 40,000 per year. With the more pessimistic estimate of PTC effectiveness, the probability increases to 0.000248 or 1 in 4,032 per year.

Varying the inputs would result in different outcomes. For example, if the numbers of trains were doubled, the probabilities would increase by two, so that the probabilities with high PTC effectiveness would be 0.00005 or 1 in 20,000 per year. For the lower PTC effectiveness, the probability would be 0.0005 or 1 in 2,000 per year.

If yet other assumptions and inputs are incorporated into the calculation, there would be different outcomes. For example, if the estimate of high-consequence areas was too high (as it was based on a rough visual estimate from a map) and if more precise estimates are provided (e.g., with the use of GIS mapping), the value would change. If the HCA areas transited by CBR trains is really only 0.25, and one assumed that PTC was highly effective, the outcome would change to 0.000016 or 1 in 61,728 per year.

Recommendations for use of WA-RRisk

The WA-RRisk tool can be used to test the potential effectiveness of different types of safety measures by evaluating the effect that altering various components of the basis event tree would have on the overall safety picture. The most important point is that there are a series of probabilities, for the series of events, that need to occur in order for there to be the final event of concern, such as the fire, explosion, or spill. Varying the component factors will have different effects on the outcome.

It is important to remember that these are estimates based on a number of assumptions. These are not predictions.

Potential areas of future discussion

- The Rail Safety Committee may want to consider using the WA-RRisk tool (or other similar fault-tree models) to assess rail accident risk and the ways in which various risk reduction measures or other changes (such as changes in rail traffic) may affect that risk. The WA-RRisk tool or any other event tree-based model should always be used with caution. It is a

[505] Analysis by Environmental Research Consulting.

tool that may be used to initiate discussion and potential further research. It would not predict accidents.

Chapter 25: Summary of Discussion Areas

2014 Marine & Rail Study Recommendations

The Rail Safety Committee might consider reviewing the safety recommendations from the *2014 Marine & Rail Oil Transportation Study*, which were divided into those that could conceivably be administered or legislated by Washington State, as well as those that could be influenced by state officials at the federal level. Recommendations from this list that have not yet been implemented but that may be topics of relevance to the work of the Rail Safety Committee include the following.

Recommendation: "Modify the state's railroad regulatory fee structure. It should allow the UTC to fund additional inspector positions, including FRA-certified inspectors, and to increase state inspections in the areas of track, hazardous materials, operating practices, motive power and equipment, and crossing signals" (Etkin et al. 2015).

Recommendation: "Amend statutory authority to allow UTC inspectors to enter a private shipper's property to conduct hazardous material inspections related to rail operations" (Etkin et al. 2015).

Recommendation: "Amend Chapter 81.53 RCW to allow designated "first-class cities"[506] to opt-in to the UTC's railroad crossing inspection and enforcement program. Give the UTC jurisdiction to require first class cities to inform the UTC when crossings are opened or closed" (Etkin et al. 2015).

Recommendation: "Amend Chapter 81.53 RCW to give UTC jurisdiction over private road crossings on the primary routes for the transportation of crude oil and to establish and enforce minimum safety standards, including appropriate safety signage" (Etkin et al. 2015)

Result: ESHB 1449 incorporates the UTC recommendations from the *2014 Marine & Rail Oil Transportation Study (*Etkin et al. 2015). The bill was submitted on 1 March 2015 and makes several improvements to the UTC program, including:

1. Hire Additional Rail Inspectors

The UTC Rail Program is funded by fees paid for by the railroad industry. The legislation increases the railroad fee from 1.5 percent to 2.5 percent. Class III railroads that do not haul crude oil will continue to pay the fee of 1.5 percent. This increase allows the UTC to hire eight (8) additional inspectors at the state level and in the areas of track, hazardous materials, motive power and equipment, signal and train control and operating practices.

The increase in the railroad regulatory fee, to 2.5 percent of gross intrastate operating revenues, allows the UTC to hire five (5) additional FRA certified inspectors and three (3) state inspectors.

The UTC will be able to conduct the necessary inspections of public and private crossings, process petitions and work with the public on concerns surrounding crossing safety.

[506] Cities with 10,000 or more population.

2. Access to Private Shipper Property

The UTC currently conducts inspections of rail cars at private shipper property (for example at a refinery). This legislation allows the UTC to conduct these inspections without being accompanied by the FRA. This provision allows the UTC to continue to conduct hazardous materials inspections on private shipper property without FRA escort. Since 2010 there have been approximately 134 defects discovered during these inspections.

3. Rail Road Crossing in First Class Cities

First-class cities are exempt from the UTC's railroad safety jurisdiction. However, the influx of hazardous materials and train traffic has overwhelmed the resources of some first-class cities. This legislation allows first-class cities to opt in to the UTC's grade crossing inspection program. There is also a requirement that first-class cities inform the UTC when crossing are opened or closed. The UTC inspects approximately 1,000 crossings per year and issues around 200 defects.

4. Private Crossings

Neither the state nor federal government have authority over private crossings. This legislation allows the UTC to adopt minimum safety language, probably requiring a sign, at private crossings and gives UTC authority to inspect the crossings. There are approximately 3,000 private crossings in Washington State with 350 along the oil routes. The safety measures prescribed for private crossings could be funded, in part, by the Grade Crossing Protective Fund.

Recommendation: Work with BNSF Railway,[507] Union Pacific (UP) Railroad, "and other railroads operating in Washington to establish voluntary agreement(s), to operate loaded high-hazard flammable trains (HHFT)/Key Trains at a maximum speed of no more than 45 mph" (Etkin et al. 2015). High-hazard flammable trains are trains that carry flammable commodities. A "key train" is any train with:

- One or more carloads of spent nuclear fuel or high-level nuclear waste.
- Five or more loaded tank cars that require the phrase "POISON/TOXIC-INHALATION HAZARD" on shipping papers.
- Five or more loaded tank cars with anhydrous ammonia or ammonia solutions.
- 20 or more carloads or intermodal portable tank loads of any combination of hazardous materials considered to be "environmentally-sensitive chemicals."

Result: BNSF implemented a voluntary speed restriction for ethanol and crude: 50 mph max speed limit on Key Trains.

Recommendation: "Provide authority and funding for UTC to conduct Railroad and Road Authority Diagnostic reviews of the road crossings most at risk, to determine whether each crossing has sufficient protective devices" (Etkin et al. 2015).

Result: The UTC provided input and technical expertise on the *2014 Marine and Rail Oil Transportation Study* (Etkin et al. 2015), as was directed in the 2014 Supplemental Operating Budget, regarding the transportation of volatile crude oil within Washington State. On 11 June

[507] BNSF was formerly the Burlington Northern and Sante Fe Railway, but formally changed its name to BNSF. This is not an acronym.

2014, Governor Inslee issued Directive 14-06, which asked the UTC, in part, for risks along rail lines and to identify, prioritize and estimate costs to mitigate those risks:

> One specific area of risk that commission staff identified is public railroad-highway grade crossings along oil routes. As a result of its review, commission staff identified 347 public grade crossings along routes used by BNSF and UP to transport crude oil across the state.
>
> Commission staff's analysis of these crossings relied on information contained in commission and the FRA databases, along with reference documents, site visits, and other research tools. Staff reviewed each crossing for a variety of elements that may indicate that a particular crossing was at a higher risk than another crossing for an incident involving crude oil. In particular, staff looked at the following risk factors:
>
> - Crossings protected only by passive traffic control devices, such as crossbucks and/or stop or yield signs.
> - Crossings protected only by train-activated flashing lights.
> - Crossings with limited sight distance down the tracks, in one or both directions, and not protected by automatic gates.
> - Crossings with a significant grade or slope approaching the crossing and not protected by automatic gates.
> - Crossings with nearby roadway intersections that may cause traffic to queue over the tracks and not protected by automatic gates.
> - Roadways that cross the tracks at an acute angle at a crossing not protected by automatic gates.
> - More than one mainline track intersects the roadway at a crossing not protected by automatic gates.
> - The crossing exposure factor (i.e., the number of trains per day times the average number of vehicles using the crossing per day) is at a level that poses a higher risk. The number of vehicles using a crossing each day is called "Average Daily Traffic" or ADT.
>
> Commission staff analyzed the selected risk factors for crossings along oil routes and identified 14 of the 347 crossings that are under-protected and would benefit from investments in protection. These crossings were selected based on the identified risk factors and the existing levels of protection. Commission staff also conducted on-site diagnostic reviews and held meetings at each crossing with representatives from the respective railroad, state agencies and local government. As a team, the participants reviewed the crossing characteristics, discussed possible solutions to improve safety, and generally agreed on a future course of action to improve the crossing.[508]
>
> The 14 identified crossings may not represent the crossings with the highest overall risk factors in the state. There are crossings with greater risk potential, such as those in high population density areas. These crossings are already protected with active warning

[508] Information regarding this process and the crossing locations are available upon request from UTC.

> devices and there are few remaining risk reduction measures available. There were 10 additional crossings considered in this review process and a determination was made that no further action was needed.[509]
>
> ...Commission staff expects that interim upgrades can be completed within one year and that long-term recommendations may take up to three years. Both interim and long-term projects will require the support and cooperation of the railroad and the road authority. (UTC 2015)

Recommendation: "FRA, in conjunction with state and local governments, should review and improve usability of existing databases to include the ability to sort data by state and incident type. This would save time and improve the ability to search and retrieve accident and incident information" (Etkin et al. 2015).

Result: The UTC has developed an improved railroad safety database related to inspections and information tracked. The FRA has not, at this time, initiated, a review of its database.

Recommendation: "Following full implementation of the Bakken Crude Oil Conditioning Standard [North Dakota] on April 1, 2015, the Northwest Area Committee should conduct sampling of Bakken crude oil transported through Washington and perform analysis to characterize the hazards presented to first responders. The results and potential health/environmental threats should be communicated to Washington response organizations" (Etkin et al. 2015).

Result: Bakken crude oil sampling and analysis processes in Washington State are under consideration.

Recommendation: "The Washington Office of Financial Management and the state fire marshal should develop state funding options for the legislature to provide statewide coordinated training. The state fire marshal should also work with the railroad companies for expansion of the current centralized system for hazardous material training to address the unique hazards presented by CBR. The state fire marshal should review rail tank car training needs for first responders, develop a specific training program with mandatory requirements, and implement a coordinated training program for first responders" (Etkin et al. 2015).

Result: This has not been implemented due to cost issues.

Recommendation: "Direct Ecology and the fire marshal's office to analyze the continued need for hazardous materials response teams, their composition, how they should be equipped and trained, where they should be located, funding mechanisms, and how they will mutually assist statewide. This analysis should include development of a startup and estimates of recurring cost for such teams" (Etkin et al. 2015).

Result: The status of this action is undetermined.

Recommendation: "Consider funding options to adequately fund Washington's Spill Prevention, Preparedness, and Response Program [SPPR]" (Etkin et al. 2015). The 2015 legislation passed several recommendations from the 2014 Marine and Rail Oil Transportation Study and 2018

[509] There is additional information about the results of this study in Chapter 13.

legislation addressed new safety and environmental risks from non-floating oil spills. To help fund this work, the Legislature added oil imported by rail and pipeline to the barrel tax in 2015 and 2018, respectively. However, this helped compensate for loss of revenue due to decreased vessel imports over time, but it was not enough to cover the new and ongoing work assigned by legislation. Therefore, since the 2015-17 biennium, almost $8 million in revenue have been transferred from the Oil Spill Response Account to help cover shortfalls in the Oil Spill Prevention Account and support other agencies.

Result: The status of this action is still ongoing.

Recommendation: "Permitting agencies should require CBR facility permit applicants to conduct a thorough evaluation of specific locations of risk for train and/or vessel incidents related to the proposal. This should include inland and coastal areas, as determined by the lead agency" (Etkin et al. 2015).

Result: This is already being done to some extent. For example, UTC's Energy Facility Site Evaluation Council (EFSEC) oversaw an analysis of this type for proposed Vancouver Energy Distribution Terminal.[510] In another example, Ecology and Skagit County oversaw this for the proposed, but now cancelled, Shell Anacortes Rail Unloading Facility.[511]

Additional issues for rail safety committee consideration

After the members of the Rail Safety Committee familiarize themselves with the safety issues for Washington rail transportation, as presented in this report, they may also want to consider working together to develop voluntary best practices to increase rail transportation safety.

Accident database review

- The FRA accident database is an invaluable tool for analyzing trends and noting issues in specific rail subdivisions or for particular types of trains. The Rail Safety Committee might consider familiarizing itself with the database and utilize it for analyses that might provide useful information for developing voluntary safety standards.
- UTC, Ecology, and/or the Rail Safety Committee may consider regularly reviewing the data for Washington State. It may help in identifying issues and documenting the success of intervention and safety enhancement measures.
- As per recommendations from UTC in the *2014 Washington State Marine & Rail Study* (Etkin et al. 2015), Ecology and UTC might consider working with FRA, in conjunction with other state and local governments (i.e., other states and communities that have railroads passing through them), to review and improve the usability of existing FRA accident databases. Such improvements might include the ability to sort data by state and incident type in a more user-friendly manner than is currently available online. This would save time for the people doing the research and conducting the relevant analyses, as well as improve the ability to search and retrieve accident and incident information.

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[510] Note that EFSEC unanimously voted to reject the application for this terminal in November 2017 and the Governor subsequently rejected it.
[511] Note that Shell opted to withdraw its application for economic reasons in October 2016 after the issuance of the Draft Environmental Impact Statement.

Understanding hazardous commodities

- The Rail Safety Committee might consider developing a common understanding of the types of the hazardous commodities transported in Washington by rail, as well as their general properties. This could be essential for the Rail Safety Committee, as well as local emergency responders and decision-makers at the state and local levels.
- The Rail Safety Committee and emergency responders might consider familiarizing themselves with the labeling of the various types of hazardous materials, as presented in Appendix A.

Emergency response operations

- The Rail Safety Committee, local emergency responders, and spill cleanup responders may consider familiarizing themselves with the behavior of oil and other hazardous substances when they spill. While the behavior and consequences of oil spills may be more commonly understood and there will likely be more experience in dealing with spilled oil, there are specific safety hazards with more flammable oil, such as Bakken crude.
- The Rail Safety Committee, local emergency responders, and spill cleanup responders may wish to consider ensuring that there is effective training in emergency response for fires, explosions, and vapor cloud releases for Bakken crude and for other hazardous substances transported by rail, such as ethanol, propane, anhydrous ammonia, and sulfuric acid. Emergency response measures for releases of oil and other hazardous materials are explored in Chapter 17.

Approaches to accident reduction

- The Rail Safety Committee and Washington State officials might want to familiarize themselves with the different approaches to reducing the risk of rail accidents and consider appropriate measures to support the accident prevention measures currently in place, as described in Chapters 9 through 17.
- The Rail Safety Committee and Washington State officials might want to consider measures to reduce highway-rail crossing accidents, as discussed in greater detail in Chapter 13.
- The Rail Safety Committee and Washington State officials might want to consider looking closely at ways to reduce rail risk and develop voluntary safety measures that can be supported by the Rail Safety Committee for infrastructure and operations in the State.

Positive train control

- Implementation and training are keys to successful PTC operations. In Washington State those components are virtually complete for BNSF and UP freight operations and passenger operations. The Rail Safety Committee may consider working with the railroad industry to support PTC operations.

ECP braking systems

- The members of the Rail Safety Committee may wish to familiarize themselves with the different types of train braking systems, including ECP brakes. The committee needs to understand the value, application and benefit of ECP usage, including how it is best employed, if at all, to maximize rail operating safety.
- The Rail Safety Committee may wish to consider the various opinions and analyses that have been performed and invite discussion from the involved parties in order to develop an informed opinion of the value and practicality of ECP operations within the state.
- As with PTC, there is likely no clear and easy solution to the ECP implementation question, nationwide or within the state. The Committee may wish to endeavor to assess the various studies and come to a consensus on what is practical and what is not, within federal guidelines.
- The Rail Safety Committee may wish to work with railroad regulators and the railroad industry to better understand and evaluate the benefits of ECP braking, including the types of accidents that could and could not be prevented by ECP brakes.

Inspections

- UTC has an important role to play in monitoring Class 1 compliance with 49 CFR track and equipment requirements, safe operation of Intrastate rail operations, and road/rail crossing conflict issues. The future Rail Safety Committee may wish to consider supporting UTC in its programs to enhance inspection of railroad track and equipment as appropriate.
- Future use of drones to inspect difficult areas of access to rail will increase, as will increased use of track inspection vehicles that are unmanned. The future Rail Safety Committee may wish to consider supporting UTC in its use of drones as part of its inspection regime.

Crew training and qualifications

- The Rail Safety Committee might consider inviting railroad representatives to present more detailed information about training and certification programs.

Highway-rail crossing safety

- The Rail Safety Committee may wish to work closely with UTC to improve safety at any of the more dangerous grade crossings that have yet to be addressed.
- The Rail Safety Committee may wish to work with UTC in tracking the data maintained by the FRA on grade crossing accidents.
- The Rail Safety Committee may wish to support and expand on the efforts of Washington Operation Lifesaver in its education efforts.

Maintenance and infrastructure

- The Rail Safety Committee may wish to consider to invite a rail engineering representative, perhaps from BNSF's Regional Engineering office in Seattle, to participate in a presentation/question/answer forum discussing infrastructure maintenance, standards, daily maintenance practices and capital expenditure planning.

- The Rail Safety Committee may wish to consider to invite a Pacific Northwest Regional operating manager representative to discuss operational and capacity impacts of slow orders, derailments and other mainline disruptions.
- The Rail Safety Committee may wish to consider that a similar forum be held with a representative of a railroad's public affairs department to discuss the regulatory and public issues that a railroad has to be aware of in an on-going manner and how railroad's out-reach to involved stakeholders.

Tank car design

- Since tank car design regulations are under the jurisdiction of the federal government, state officials have no authority to make any regulations regarding tank car safety. This would be unnecessary since all railroads are all now required to use DOT-117 and safer tank cars. The Class I railroads that transport Class 3 flammables in Washington are in full compliance with these regulations.
- The Rail Safety Committee and Washington State officials may wish to consider supporting training programs and inspection programs that would increase safety and reduce non-accidental releases (NARs).
- It is unclear whether Washington State has the authority to conduct its own safety inspections on tank cars. It may be feasible for UTC to develop an additional "best achievable practice" program on tank car inspections and safety procedures.

Emergency response planning

- The Rail Safety Committee may consider evaluating the extensive lessons learned, contained herein, relative to the Unit Train Derailment Study, and the after-action reports arising from the Mosier and Lynchburg incidents, and compare to the current status of related issues within Ecology and UTC, as well as any other Washington State administrative departments, that may have planning and or response responsibilities for rail transportation of hazardous materials.
- The Rail Safety Committee may want to consider reviewing the hazmat team development and sustainability and provide and updated status.

Public information and engagement

- The Rail Safety Committee may consider working with Ecology to engage with Washington communities before a spill occurs to enhance community trust in the plans that are in place.
- The Rail Safety Committee may consider working with the NW Area Committee to develop a work group dedicated to public engagement before, during, and after incidents. The www.oilspills101.wa.gov website could be utilized as a neutral platform for the response community to engage with citizens on oil spill issues.

Rail Safety Committee development

- Washington State may want to consider developing a charter for a Washington State Railroad Safety Committee (RSC). This committee may consist of invited volunteers enlisted from a wide range of associated railroad transportation-related stakeholders. The charter may state specifically the purpose and mission of the RSC.

- The UTC, with the broadest experience in interstate and intrastate rail transportation monitoring and issues, may be best positioned to chair initially the Committee. The chair position may involve other members to include industry and labor as it matures. The chair would be a rotating position after a one- or two-year voluntary/elected appointment.
- The Committee, as a whole, in addition to development of potential various sub-committees, may wish to invite appropriate BNSF and UP personnel (operating, maintenance, signal, etc.) to meet with each or various sub-committees for a question and answer session. Railway personnel participation may require time and expense compensation.
- One member of the RSC may be the current Washington State representative to the Association of State Railroad Safety Managers (ASRSM). The ASRSM is a member of the Railroad Safety Advisory Committee (RSAC) of the FRA. The WSRSC member may then be the liaison between the WSRSC and the ASRSM, which would provide the communication and partnership link between Washington State and the RSAC/FRA. This partnership may provide the linkage for Washington State to gather in-state rail expertise and in-state rail issues for the purpose of ensuring local and regional interests are placed on the RSAC/FRA agenda for discussion/evaluation and vice versa. This may ensure that FRA/RSAC activities are adequately communicated and evaluated by the local/regional rail interests in the State of Washington.
- Based on stakeholder interests, individual committees may be formed to consider particular concerns, but with the understanding of the regulatory restrictions.

Financial responsibility

- The Rail Safety Committee may consider working with Washington State to put in place state financial responsibility requirements for rail transportation. Like the recommendations made in the 2*014 Washington State Marine and Rail Oil Transportation Study* (Etkin et al. 2015), Washington State should again attempt to pass legislation and then promulgate regulations requiring rail transportation companies to provide evidence of financial responsibility. This evidence can be provided by insurance, self-insurance, guaranty, letter of credit, certificate of deposits, surety bonds, Protection and Indemnity Club membership, a combination of methods, or other methods acceptable to the jurisdictional authority within the state of Washington.
- The level of evidence should be based upon a reasonable worse case spill as determined by Ecology/UTC in a dollar amount based upon a multiplier of the potential barrels involved in the reasonable worse case spill.
- Oil spill costs are greatly affected by oil type (persistence, toxicity, and adherence factors), as well as location. A model for calculating these costs could be based on work previously conducted for the Washington State Joint Legislative Audit and Review Committee (JLARC) (State of Washington JLARC 2009; Etkin et al. 2009; French-McCay et al. 2009), as described in detail in Chapter 23 of this report. It would need to be adapted to spill cleanup costs and potential damages.

Lessons learned from past rail accidents

- The Rail Safety Committee and others with an interest in mitigating the risk of rail accidents in Washington State should develop an understanding and appreciation of the factors that affect the risk of rail accidents, both with respect to the likelihood of accidents, and the potential severity of the effects. This understanding will assist in making effective decisions on risk reduction.
- Many of the factors that contribute to increasing the risk of rail accidents are not ones that can be addressed directly by Washington State officials or the Rail Safety Committee because of jurisdictional issues. However, the Rail Safety Committee might consider including some of the following issues in recommendations for voluntary safety measures, such as:
    - Restrictions on train speed to reduce the likelihood of accidents and the severity of accidents. This is already being addressed by the railroads to some extent.
    - Inspections to assure optimal track condition.
    - Programs to address crew fatigue.

Factors that affect rail accident risk

- The Rail Safety Committee and others with an interest in mitigating the risk of rail accidents in Washington State may want to develop an understanding and appreciation of the factors that affect the risk of rail accidents, both with respect to the likelihood of accidents, and the potential severity of the effects. This understanding will assist in making effective decisions on risk reduction.
- Many of the factors that contribute to increasing the risk of rail accidents are not ones that can be addressed directly by Washington State officials or the Rail Safety Committee because of jurisdictional issues. However, the Rail Safety Committee might consider including some of the following issues in recommendations for voluntary safety measures, such as:
    - Restrictions on train speed to reduce the likelihood of accidents and the severity of accidents. This is already being addressed by the railroads to some extent.
    - Inspections to assure optimal track condition.
    - Programs to address crew fatigue.

Geographic risk considerations

- The Rail Safety Committee may want to consider further analyses of the subdivisions that present relatively high risk for the likelihood of accidents (probability ranking), the severity of potential accidents (severity ranking), and the potential impacts of accidents (consequences ranking).
- That the risk scoring in this study was conducted only on a railroad subdivision basis. There are many variations within each subdivision that the Rail Safety Committee and/or state officials may want to consider evaluating in greater detail.

Washington Rail Risk tool

- The potential Rail Safety Committee may want to consider further analyses of the subdivisions that present relatively high risk for the likelihood of accidents (probability ranking), the severity of potential accidents (severity ranking), and the potential impacts of accidents (consequences ranking).

- That the risk scoring in this study was conducted only on a railroad subdivision basis. There are many variations within each subdivision that the Rail Safety Committee and/or state officials may want to consider evaluating in greater detail.

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Glossary

AAR Specification Tank Car: A tank car built, altered, or converted in accordance with the tank car specifications of the Association of American Railroads.

AAR: Association of American Railroads.

AB brakes: In 1873 George Westinghouse invented what has become the standard for rail air brake systems since. Simply, the original AB system involved putting compressed air into a brake pipe from front of train to end. As the brake pipe "charged" a brake valve on each car caused the brakes to release. Train brakes were applied by reducing the pressure in the brake pipe system. Previous brake systems were the opposite in that brake systems were not charged enroute and a brake application occurred by putting air into the system (or by handbrakes), which did not help if a break in two occurred.

ABDW brakes: The Westinghouse braking system has developed and improved over the last 100+ years. The latest generation of the system is the ABDW brakes, which were originally introduced in the late 1960's and early 1970's and has been subsequently improved since. The system uses the same basic air into brake pipe to each car that the original system devised. The enhancements have involved improvements to the brake valves on each car, both on the brake application side and on the brake line recharge side. The modern ABDW series brake valve detects as little as a one-and-a-half pound in brake pipe reduction to initiate a brake application, resulting in a reasonably uniform brake application throughout a train. Similarly, the modern ABDW brake valve can sense a minimal increase in brake pipe pressure during recharge, causing the brakes to release on each car. The modern ABDW brake system works particularly well on unit trains with complimentary equipment.

ABS: Automatic Block System.

Acoustic bearing detector (TADS-ABD): Type of wayside detector that uses acoustic signatures to evaluate the sound of internal bearings and identify those likely to fail in the near term.

ACP: Area Contingency Plan.

Acute toxicity: The adverse effects of a substance that result from a single exposure or over the course of a relatively short period of time (usually less than 24 hours).

Adhesiveness: The degree to which oil sticks to surfaces.

Advance Notice of Proposed Rulemaking (ANPRM): A document that an agency may chooses to issue before it is ready to issue an NPRM, used as a vehicle for public participation in the formulation of the regulatory change before the agency has done significant research or investigation on its own.

Advance Notice of Transfer (ANT): Ecology's oil transfer rules to prevent spills when oil is transferred over water that require submission of an Advance Notice of Oil Transfer (ANT) by the delivering facility (fixed or mobile) or vessel which is transferring over 100 gallons of bulk oil to a non-recreational vessel or facility; the ANT must be submitted 24 hours prior to the transfer for facilities, and as required by local USCG Captain of the Port requirements for vessels; smaller fueling stations that deliver oil to non-recreational vessels with an oil capacity of less than 10,500 gallons are not required to submit the ANT form; instead they must submit bi-annual reports detailing cumulative types and amounts of oil. (See WAC chapters 173-184-100, 173-180-215, and 173-180-210 for details.).

AFFF: Aqueous film forming foams.

AFPM: American Fuel & Petrochemical Manufacturers.

Alaska North Slope (ANS): The region of northern Alaska that includes Prudhoe Bay. ANS crude oil produced in this area is pumped down the Trans-Alaska Pipeline System (TAPS) to Valdez Terminal for transport by tankers.

Alkane: A simple saturated hydrocarbon contained in petroleum, the simplest of which is methane.

ALOHA: Areal Locations of Hazardous Atmospheres. ALOHA is the air hazard modeling program developed jointly by NOAA and the Environmental Protection Agency (EPA).

American Association of Railroads (AAR): Representing North America's freight railroads and Amtrak, it strives to help make the rail industry increasingly safe, efficient and productive.

American Fuel and Petrochemical Manufacturers (AFPM): A trade association representing high-tech American manufacturers of virtually the entire U.S. supply of gasoline, diesel, jet fuel, other fuels and home heating oil, as well as the petrochemicals used as building blocks for thousands of vital products in daily life.

American Petroleum Institute (API): The largest U.S. trade association for the oil and natural gas industry, representing about 400 corporations involved in production, refinement, distribution, and many other aspects of the petroleum industry.

Anhydrous ammonia: A colorless, highly irritating gas or liquid with a sharp, suffocating odor commonly used to make fertilizers.

ANPRM: Advance Notice of Proposed Rulemaking.

ANS: Alaska North Slope crude oil.

ANT: Advance Notice of Transfer.

API: American Petroleum Institute.

API Gravity: (written as °API), a measure of the density of an oil used by the petroleum industry. °API is inversely related to density, the higher the °API, the less dense the oil.

Aqueous film forming foams (AFFF): Fire-fighting foam is a foam used for fire suppression. Its role is to cool the fire and to coat the fuel, preventing its contact with oxygen, resulting in suppression of the combustion. Low-expansion foams such as AFFF are low-viscosity, mobile, and able to quickly cover large areas.

Aromatic: A more complex hydrocarbon that is composed of rings of benzene.

Association of American Railroads (AAR): Industry trade group representing primarily the major freight railroads of North America (Canada, Mexico and the United States). Amtrak and some regional commuter railroads are also members.

ASTM: American Society for Testing and Materials.

At-grade crossing: Railroad crossing with a roadway where the two transport axes intersect at the same level (also called "grade crossing").

ATP: Automatic Train Protection system.

ATV: All-terrain vehicle

Automatic Block System (ABS): Signal system that protects the movement of trains and the integrity of the track but does not authorize train movements.

Automatic Train Protection system (ATP): Type of train protection system which continually checks that the speed of a train is compatible with the permitted speed allowed by signaling. If it is not, ATP activates an emergency brake to stop the train. (This system is primarily used in Europe and Asia.).

Bakken crude oil: Form of light crude oil that originates from the Bakken Region or Formation in the Williston Basin located in northwestern North Dakota, northeastern Montana, southern Saskatchewan, and southwestern Manitoba.

Ball of rail: The top portion of a rail, where the wheel tread rides.

Ballast: Rock tamped around and below ties to support the track structure.

BAP: Best Achievable Protection. Training procedures, operational methods, and response technologies that are critical to successful oil spill responses.

Base of rail: The wider bottom portion of a rail that rests in the tie plate and is spiked or clipped to the tie.

Basic Active Warning System: An active warning system at a grade crossing that includes flashing lights and bells and may include gates that come down to block the highway.

bbl: barrel of oil, which is the equivalent of 42 gallons.

BC: British Columbia, Canada.

BEA: U.S. Bureau of Economic Analysis geographic district.

Benchwall: The narrow walkway that runs alongside a train track in a tunnel.

Biodegradation: The chemical dissolution of materials by bacteria or other biological means.

Biodiesel: A vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat (tallow) with an alcohol producing fatty acid esters. Biodiesel is meant to be used in standard diesel engines and is thus distinct from the vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be used alone, or blended with petrodiesel in any proportions.

Bitumen: A heavy asphalt-like form of petroleum.

BLEVE: Boiling Liquid Expanding Vapor Explosion.

BNSF: BNSF Railway Company. Official name of the railroad subsidiary of the Burlington Northern Santa Fe Corporation

Boiling Liquid Expanding Vapor Explosion (BLEVE): An explosion that results when a tank of liquefied gas is heated by fire to a point at which the pressure inside has increased and the strength of the tank has been reduced to the point that it ruptures.

Bottom outlet valve (BOV): a valve located in the bottom of a tank car for loading or unloading.

BOV: bottom outlet valve.

Brackish water: Water that has 0.05–3 percent dissolved salts compared with <0.05 percent for freshwater and 3–5 percent for seawater.

BTEX: benzene, toluene, ethylbenzene, and xylenes.

CAD: Computer Aided Dispatch.

CAMEO: Computer Aided Management of Emergency Operations. CAMEO is a suite of software contains several separate integrated software applications, including ALOHA and MARPLOT. ALOHA is the air hazard modeling program. MARLPOT is a mapping program. Both programs were developed jointly by NOAA and the Environmental Protection Agency (EPA). The programs can provide users with initial guidance on protective action decisions for chemical releases, and can model plumes to give users predictions of what level of contamination may exist. Data extrapolated from the model can then be used to make decisions regarding dose/exposure and any follow-on protective actions.

CanaPux: An alternative solid pellet form of bitumen or heavy crude for shipment by rail hopper cars.

Cant deficiency: cant deficiency is present when a vehicle's speed on a curve is greater than the speed at which the components of wheel to rail force are normal to the plane of the track. In that case, the resultant force (aggregated force of gravitational force and centrifugal force) exerts the outside rail more than the inside rails, in which it creates lateral acceleration toward outside of the curve. In order to reduce cant deficiency, the speed can be reduced or the super-elevation can be increased. The amount of cant deficiency is expressed in term of required super-elevation to be added in order to bring the resultant force into balance between the two rails.

Cant: The rate of change of elevation (height) between two rails or edges.

Carbon dioxide (CO_2): A naturally occurring chemical compound composed of two oxygen atoms each covalently double bonded to a single carbon atom..

Carload: The contents of one rail car of any type (e.g., hopper car, tank car).

CBR: crude-by-rail.

Centralized Traffic Control (CTC): A signal system that protects the movement of trains and the integrity of the track and also authorizes train movements. A dispatcher remotely controls the local interlockings and governs trains by signal indication.

CFR: Code of Federal Regulations.

Chemical Transportation Emergency Center (CHEMTREC): 24-hour emergency response service that provides assistance in the handling of incidents involving hazardous materials/dangerous goods.

CHEMTREC: Chemical Transportation Emergency Center.

Class 1 Hazardous Material: explosive.

Class 2 Hazardous Material: hazardous gas.

Class 3 Flammable Liquid: a liquid that has a flash point of not more than 60°C (140°F), or any material in a liquid phase with a flash point at or above 37.8°C (100°F) that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging. This includes liquids such as refined petroleum products, crude oil, and ethanol.

Class 4 Hazardous Material: flammable solid.

Class 5 Hazardous Material: oxidizing substance.

Class 6 Hazardous Material: toxic or infectious substance.

Class 7 Hazardous Material: radioactive material.

Class 8 Hazardous Material: corrosive substance.

Class 9 Hazardous Material: miscellaneous dangerous good.

Class I railroad: as per the Surface Transportation Board, a railroad "having annual carrier operating revenues of $250 million or more" after adjusting for inflation using the Railroad Freight Price Index developed by the Bureau of Labor Statistics.

Class II railroad: railroad that hauls freight and is mid-sized in terms of operating revenue (as of 2011, a railroad with revenues greater than $37.4 million but less than $433.2 million for at least three consecutive years). Switching and terminal railroads are excluded from Class II status. Railroads considered by the Association of American Railroads as "Regional Railroads" are typically Class II.

Class III railroad: also called a short-line railroad, which has an annual operating revenue of less than $20 million (1991 dollars). Typically local short-line railroads serving a small number of towns and industries or hauling cars for one or more larger railroads.

Class-111 tank car: Canadian term "Class 111" non-pressure tank car is the equivalent of the DOT-111 tank car. This type of tank car is also sometimes called the CTC-111A.

Classification bowl: section of a rail classification yard that contains tracks in which the various cars are assembled into trains bound for various destinations.

Clean Water Act (CWA): The laws that established the basic structure for regulating pollutant discharges into the waters of the U.S. It gave the EPA the authority to implement pollution control programs such as setting wastewater standards for industry. Also known as "Federal Water Pollution Control Act (FWPCA)."

Clips: Track appliances that hold the rail onto concrete ties.

CO_2: Carbon dioxide**.**

Code of Federal Regulations (CFR): An annual codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the Federal Government.

COFC: container on flat car (intermodal shipping).

Collision: An accident in which two moving objects strike each other.

Commodity: marketable item; a generic term for vessel or rail cargo.

Common Carrier Obligations: The obligation of railroads to transport all goods offered for transportation, including hazardous materials. This obligation is a common law doctrine, codified in the Interstate Commerce Act and recognized by the US Supreme Court in the early 1900s. The Interstate Commerce Commission Termination Act of 1995 (ICCTA) maintains the common carrier obligations of railroads and requires railroads to "provide the transportation or service on reasonable request." This obligation ensures that railroads do not unreasonably discriminate between shippers. Thus, railroads may not refuse shipment on the basis of inconvenience or lack of profitability.

Computer Aided Dispatch (CAD): A method of dispatching taxicabs, couriers, field service technicians, mass transit vehicles or emergency services assisted by computer**.**

Conditioning: a process by which the lighter, more volatile parts of an oil (such as Bakken crude) are removed (partially refined) to reduce volatility for safer shipping.

Consignee: company receiving the shipment at the destination.

Consist: the lineup or sequence of railroad carriages (cars), with or without a locomotive, that form a train unit.

Continuous Welded Rail (CWR): Long strings of rail (usually ¼ mile in length) that has been welded at a foundry to eliminate joints between rails.

Corrosivity: The degree to which an oil will corrode pipelines, tanks, or tank cars.

COSRP: Comprehensive Oil Spill Response Plan

CPC-1232 tank car: tank car that meets Transport Canada and AAR specifications with safety valve fittings with a capacity minimum of 27,000 standard cubic feet per minute, scfm, at 85 pounds per square inch, psi, discharge pressure.

Crossbuck: Railroad crossing sign made of two slats of wood or metal forming an X.

Crude: Crude oil.

Cryogenic liquid tank car: a vacuum-insulated tank car, consisting of an inner container (tank) enclosed with an outer steel shell (tank) designed for the transportation of refrigerated liquefied gases having a boiling point colder than minus 130°F.

CSX: CSX Transportation Class I railroad operating on the U.S. east coast.

CTC: Centralized Traffic Control.

CWA: Clean Water Act.

CWR: continuous welded rail.

Dark territory: A rail route without wayside signals.

DED: Dragging Equipment Detector.

Density: Mass or weight per unit volume; e.g., one pound of lead is much more dense than one pound of feathers.

Department of Homeland Security (DHS): Charged with the primary responsibilities of protecting the United States and its territories (including protectorates) from and responding to terrorist attacks, man-made accidents, and natural disasters.

DHS: Department of Homeland Security.

Diamond: A track appliance where two railroad tracks cross each other at grade. Diamonds also have frog sections where the two rails from one route cross the two rails from the second route (also called "crossing").

Dilbit: Another name for certain types of diluted bitumen.

Diluent: A diluting or thinning agent.

Diluted bitumen (Dilbit): A petroleum product produced by mixing bitumen (a highly viscous or solid asphaltic material) with light petroleum compounds (e.g., gas condensate or gas range oil), which are the diluent.

Dispersion: The breakup of oil into tiny droplets and subsequent spreading.

Dissolution: Dissolving.

Distributed Power Units (DPU): Locomotives placed in the middle or at the rear of a train that help push the train but are controlled by the engineer in the front of the train.

USDOT: United States Department of Transportation.

DOT-111 tank car: General characteristics of a DOT-111 tank car under existing regulations are as follows: DOT-111 cars are roughly 60 feet long, 11 feet wide and 16 feet high; the cars weigh approximately 80,000 pounds empty and 286,000 pounds when full; the cars can hold about 30,000 gallons or 715 barrels of oil depending on oil density; the tank is made of steel plate with a thickness of 7/16 of an inch; and the tank has a life span of approximately 50 years, with a 30–40 year economic lifespan.

DOT-117 tank car: Rail tank car that meets the specifications of PHSMA and FRA with regard to having a jacket, a wall thickness of 9/16 inch, thermal protection, a bottom outlet handles, top fittings protection, ECP brakes, and other features that reduces the likelihood of release on impact.

DOT-120 tank car: Rail tank car that includes the specifications of a DOT-117 except that it has a 19/32-inch tank head thickness, both insulation and high-flow pressure-relief valve, has a protected manway, and meets a test pressure of 200 psi.

DPS: Department of Public Safety (Minnesota)

DPU: distributed power unit.

Dragging equipment detector (DED): A device that detects dragging equipment on a railroad, which can damage the track and grade crossings.

DRPT: Department of Rail and Public Transportation (Virginia).

Ecology (ECY): Washington State Department of Ecology.

ECP: Electronically Controlled Pneumatic (brake).

ECY: Washington State Department of Ecology.

EDRC: Effective Daily Recovery Capacity.

EFSEC: Energy Facility Site Evaluation Council.

EGT: Export Grain Terminal.

EIA: environmental impact assessment or U.S. Energy Information Administration.

EIS: environmental impact statement.

Emergency Planning and Community Right-to-Know Act (EPCRA): Washington State legislation that protects public health, safety, and the environment from chemical hazards. This is done by requiring federal and state governments, local agencies, tribal nations, and industries to partner in implementing emergency planning and preparedness.

Emergency Response Assistance Plan (ERAP): A plan that describes what is to be done in the event of a transportation accident involving certain higher risk dangerous goods. The ERAP is required by the Transportation of Dangerous Goods Regulations (TDGR) for dangerous goods that require special expertise and response equipment to respond to an incident. The plan is intended to assist local emergency responders by providing them with technical experts and specially trained and equipped emergency response personnel at the scene of an incident.

Emulsion: Small droplets of oil suspended in water with a resultant frothy "mousse" appearance.

Energy Facility Site Evaluation Council (EFSEC): Council that provides a "one-stop" siting process for major energy facilities in the State of Washington. EFSEC coordinates all evaluation and licensing steps for siting certain energy facilities in Washington. EFSEC specifies the conditions of construction and operation. If approved, a Site Certification Agreement is issued in lieu of any other individual state or local agency permits. EFSEC also manages an environmental and safety oversight program of facility and site operations.

Entrainment: The process of oil going into the water column (below the water surface) due to winds or currents, including the process of oil going under a floating boom.

Environmental Impact Statement (EIS): Under U.S. environmental law, a document required by the National Environmental Policy Act (NEPA) for certain actions "significantly affecting the quality of the human environment." An EIS is a tool for decision making. It describes the positive and negative environmental effects of a proposed action, and it usually also lists one or more alternative actions that may be chosen instead of the action described in the EIS.

Environmentally-sensitive chemical: Any of the following substances: allyl chloride, carbon tetrachloride, chlorobenzene, chloroform, o-dichlorobenzene, dichloropropane (propylene dichloride), dichloropropane/dichloropropene mixture, dichloropropene, ethyl chloride, ethylene dibromide, ethylene dibromide and methyl bromide mixtures, ethylene dichloride, epichlorohydrin, methyl chloroform (1, 1, 1 trichloroethane), methylene chloride (dichloromethane), methylene chloride/chloroform mixture, perchloroethylene (tetrachloroethylene), perchloroethylene/trichloroethylene mixture, or trichloroethylene.

EOP: Emergency Operations Plan

EPA: U.S. Environmental Protection Agency.

EPCRA: Emergency Planning and Community Right-to-Know Act

ERAP: Emergency Response Assistance Plan.

ERG: Emergency Response Guide Book.

ERP: Emergency Response Plan.

ESF: Emergency Support Function

FAST Act: Fixing America's Surface Transportation Act of 2015**.**

Fecundity: Reproductive capacity.

Federal Energy Regulatory Commission (FERC): The United States federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, and oil pipeline.

Federal On-Scene Coordinator (FOSC): A designation in the U.S. for an individual that is responsible for providing access to federal resources and technical assistance and coordinates all federal containment, removal, and disposal efforts and resources during an oil or hazmat incident. For marine, coastal, and inland navigable waterway spills, the FOSC is the U.S. Coast Guard, and for inland spills, the FOSC is the EPA.

Federal Railroad Administration (FRA): An agency within the U.S. Department of Transportation that has jurisdiction over railroad safety at the federal level.

Federal Railroad Safety Act (FRSA): A Congressional act of 1970 that promotes the safety in all areas of railroad operations to reduce railroad-related accidents, and to reduce deaths and injuries to persons, and to reduce damage to property caused by accidents involving any carrier of hazardous materials (49 USC Part 20109).

Federal Water Pollution Control Act (FWPCA): The Clean Water Act (CWA), which are the laws that established the basic structure for regulating pollutant discharges into the waters of the U.S. It gave the EPA the authority to implement pollution control programs such as setting wastewater standards for industry.

FID: flame ionization detector.

First Responder: A general term for all trained emergency service personnel (as a firefighter, police officer, paramedic, etc.) who are expected to respond to emergencies or large-scale disasters.

First-class city: A city with 10,000 or more population.

Fish barrier: Screens installed to protect endangered species of fishes that would otherwise be harmed or killed when passing through industrial facilities such as steam electric power plants, hydroelectric generators, petroleum refineries, chemical plants, farm irrigation water and municipal drinking water treatment plants.

Flange: The portion of the wheel that rolls along the inside of the rail and allows the rail to guide the wheel.

Flash point: The lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a flash point requires an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed. The flash point is not to be confused with the auto-ignition temperature, which does not require an ignition source, or the fire point, the temperature at which the vapor continues to burn after being ignited. Neither the flash point nor the fire point is dependent on the temperature of the ignition source, which is much higher.

FOSC: Federal On-Scene Coordinator.

FRA Class 1 Track: track classified by FRA with respect to maximum speed for track condition as 10 mph for freight, 15 mph for passenger. Much yard, branch line, short-line, and industrial spur trackage falls into category.

FRA Class 2 Track: track classified by FRA with respect to maximum speed for track condition as 25 mph for freight, 30 mph for passenger. Branch lines, secondary mainlines, many regional railroads, and some tourist operations frequently fall into this class.

FRA Class 3 Track: track classified by FRA with respect to maximum speed for track condition as 40 mph for freight, 60 mph for passenger. This commonly includes regional railroads and Class 1 secondary mainlines.

FRA Class 4 Track: track classified by FRA with respect to maximum speed for track condition as 60 mph for freight, 80 mph for passenger. This is the dominant class for main-line track used in passenger and long-haul freight service.

FRA Class 5 Track: track classified by FRA with respect to maximum speed for track condition as 80 mph for freight, 90 mph for passenger. This is the standard for most high-speed track in the U.S.

FRA Class 6 Track: track classified by FRA with respect to maximum speed for track condition as 110 mph for freight, 110 mph for passenger. This is found in the U.S. exclusively on Amtrak's Northeast Corridor between New York and Washington, DC.

FRA: Federal Railroad Administration.

FRSA: Federal Railroads Safety Act.

Frog: A frog is a piece of the track where two rails cross. Standard frogs are machined with a gap where the wheel rolling on one route crosses the rail from the other route. There are guard rails on both sides of the point of the frog to keep the wheels in alignment. (Also called a "switch frog.").

FRSA: Federal Railroad Safety Act.

FWPCA: Federal Water Pollution Control Act.

Gallons per minute (gpm): A unit of volumetric flow rate.

Gauge: The distance between rails. Normal gauge is 4 feet, 8 ½ inches. Wide gauge is when the gauge is wider than 4 feet 8 ½ inches. Narrow gauge is when it is less than 4 feet 8 ½ inches.

GCOR: General Code of Operating Rules.

GDP: Gross Domestic Product.

General Code of Operating Rules (GCOR): A set of operating rules intended to enhance railroad safety for railroads in the United States. The GCOR is used by Class I railroads west of the Mississippi River, most of the Class II railroads, and many Short-line railroads.

Geographic Information System (GIS): A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

Geographic Response Plan (GRP): A geographically specific response plan for oil spills to water that includes response strategies tailored to a specific beach, shore, or waterway, and meant to minimize impact on sensitive resources threatened by the spill. GRPs are an important part of Washington State's oil spill programs. Each GRP has two main priorities: to identify natural, cultural and economic resources near vessel traffic routes, pipeline and rail corridors, highways, facilities or other potential pathways of spills to water; and to describe and prioritize response strategies in an effort to minimize injury from oil spills.

GIS: Geographic Information System

gpm: gallons per minute.

Grade crossing: Railroad crossing with a roadway where the two transport axes intersect at the same level. Also called "at-grade crossing."

Grade: The rise or fall of a track as measured over 100 feet. A two foot rise over 100 feet is called a 2 percent grade.

Gross Domestic Product (GDP): The total value of goods produced and services provided in a country or state during one year.

Group I oils: oils with a density of less than 0.80 g/cm^3, such as gasoline and kerosene. These oils evaporate readily. Also called "Volatile Distillates."

Group II oils: oils with a density of 0.80 to 0.85 g/cm^3, such as Bakken crude and diesel. These oils are not very persistent in the environment. Also called "Light Oils."

Group III oils: oils with a density of 0.85 to 0.95 g/cm^3, such as medium crude and diluted bitumen; these oils have moderate persistence. Also called "Medium Oils."

Group IV oils: oils with a density of over 0.95 to 1.0 g/cm^3, such as intermediate fuel oil and Bunker C. These oils are very persistent in the environment. Also called "Heavy Oils."

Group V oils: oils with a density of over 1.0 g/cm^3, such as Orimulsion and Boscan crude. These oils are heavier than fresh water. Also "Low API° Oils" (or "LAPIOs").

GRP: Geographic response plan.

Harbor Safety Committee: A proactive forum for identifying, assessing, planning, communicating, and implementing operational and environmental measures, beyond that which is in laws or regulations, that promote safe, secure, and efficient use of relevant waterways, harbors, or ports. The committee is generally made up of delegates appointed by broadly based organizations representing a span of interests with various governmental agencies formally supporting its work in advisory capacities.

Hazard Prediction and Assessment Capability (HPAC): HPAC is a computer model that predicts hazards and provides exposure information for populations in the vicinity of accidents involving releases from nuclear and chemical facilities, and facilities/transportation containers. HPAC models atmospheric dispersion of vapors, particles, or liquid droplets from multiple sources using pre-defined (not site-specific) release rates, using meteorological input that may range from wind speed and direction at only a single measurement location to 4-dimensional gridded wind and temperature fields.

Hazardous Materials Regulations (HMR): Federal regulations issued by the USDOT PHMSA (49 CFR Part 100–185) governing the transportation of hazardous materials by all modes of transport (air, highway, rail, and water).

Hazardous Materials Transportation Act (HMTA): The principal federal law in the U.S. regulating the transportation of hazardous materials. Its purpose is to "protect against the risks to life, property, and the environment that are inherent in the transportation of hazardous material in intrastate, interstate, and foreign commerce" under the authority of the U.S. Secretary of Transportation.

Hazmat: hazardous material.

HCA: High Consequence Area.

Head shield: Method of providing tank head puncture-resistance by mounting a metal shield on the end of a tank car.

Heavy oils: Crude oil and petroleum products that are persistent, though less toxic. This group includes heavy fuel oil, Bunker C, No. 5 or No. 6 fuel, most intermediate fuel oils, and heavy crude oils. This category would also include bitumen blends; in the US, these oils are classified as Group IV, having a specific gravity between 0.95 to and including 1.0 [API° ≤17.5 and >10.0]. In general, these heavy oils exhibit the following behavior: heavy oils with little or no evaporation or dissolution; heavy contamination likely; severe impacts to waterfowl and fur-bearing mammals through coating and ingestion; long-term contamination of sediments possible; weather slowly; and shoreline and substrate cleanup is difficult under all conditions. These oils are very persistent in the environment.

HHFT: high-hazard flammable trains.

HHFUT: highly hazardous flammable unit trains.

High Consequence Area (HCA): a geographic area in which a hazardous material release would affect a large number of people (i.e., a densely-populated area)

High Level Radioactive Waste (HLRW): waste generated in core fuel of a nuclear reactor, found at nuclear reactors or by nuclear fuel reprocessing.

High/Wide/Shifted Load Detector (SLD): device that detects significant shifts in cargo that may cause instability in a train.

HLRW: High Level Radioactive Waste.

HMR: Hazardous Materials Regulations

Hot box and dragging equipment detector: most commonly used types of wayside detector. A hot box detector is a heat-sensitive device used to measure the temperature of journal bearings on passing rail cars. A dragging equipment detector detects loose components and dragging under freight cars.

Hours of Service Act (HSA): the original federal statute limiting the hours of service of certain railroad employees was the Hours of Service Act, first enacted in 1907. It was intended to promote the safety of employees and travelers upon railroads by limiting the hours of service of certain railroad employees.

HPA: High Population Area.

HPAC: Hazard Prediction and Assessment Capability

HSA: Hours of Service Act.

HYSPLIT: Hybrid Single Particle Lagrangian Trajectory Model. HYSPLIT model is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. The program includes the integration of ALOHA, and advanced advection algorithms, updated stability and dispersion equations, and the option to include modules for chemical transformations. Without the additional dispersion modules, HYSPLIT computes the advection of a single pollutant particle, or simply its trajectory. Some of the applications include tracking and forecasting the release of radioactive material, volcanic ash, wildfire smoke, and pollutants (such as mercury) from various stationary emission sources.

IAFC: International Association of Fire Chiefs.

ICC: Interstate Commerce Commission.

ICCTA: Interstate Commerce Commission Termination Act of 1995.

ICS: Incident Command System.

Incident Command System (ICS): A management system designed to enable effective and efficient domestic incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure. ICS is normally structured to facilitate activities in five major functional areas: command, operations, planning, logistics, intelligence and investigations, finance and administration. It is a fundamental form of management, with the purpose of enabling incident managers to identify the key concerns associated with the incident — often under urgent conditions — without sacrificing attention to any component of the command system.

Intermodal freight transport: Transportation of intermodal shipping containers that can be transferred between trucks, vessels, and trains.

Intermodal: involving two or more different modes of transportation in conveying goods.

Interstate Commerce Commission Termination Act of 1995 (ICCTA): An act of Congress that maintains the common carrier obligations of railroads and requires railroads to "provide the transportation or service on reasonable request" (49 USC. Part 11101(a)). This obligation ensures that railroads do not unreasonably discriminate between shippers. Thus, railroads may not refuse shipment on the basis of inconvenience or lack of profitability.

Jacket: an outer protective covering for a tank car.

JIC: Joint Information Center.

JIS: Joint Information System.

JLARC: Joint Legislative Audit and Review Committee.

Joint Information Center (JIC): A central location that facilitates operation of the Joint Information System. A location where personnel with public information responsibilities perform critical emergency information functions, crisis communications, and public affairs functions.

Joint Information System (JIS): A system that provides the mechanism to organize, integrate, and coordinate information to ensure timely, accurate, accessible, and consistent messaging across multiple jurisdictions and/or disciplines with nongovernmental organizations and the private sector.

Joint bar: a connector between segments of track.

Joint Legislative Audit and Review Committee (JLARC): The Joint Legislative Audit and Review Committee (JLARC) works to make state government operations more effective, efficient, and accountable. The Committee is comprised of an equal number of House and Senate members, Democrats and Republicans. JLARC pursues its mission by conducting performance audits, program evaluations, sunset reviews, and other analyses. Assignments to conduct studies are made by the Legislature and the Committee itself. Based on these assignments, JLARC's non-partisan staff auditors, under the direction of the Legislative Auditor, independently seek answers to audit questions and issue recommendations to improve performance. Work by JLARC staff is conducted using Generally Accepted Government Auditing Standards. These standards ensure audit conclusions are independent, objective, and accurate. JLARC's authority is established in Chapter 44.28 Revised Code of Washington.

Jointed rail: Shorter rails that are connected by joint bars, which are bolted to the web of the rails.

Key train: Any train with: one or more carloads of spent nuclear fuel or high-level nuclear waste; five or more loaded tank cars that require the phrase "POISON/TOXIC-INHALATION HAZARD" on shipping papers; five or more loaded tank cars with anhydrous ammonia or ammonia solutions. 20 or more carloads or intermodal portable tank loads of any combination of hazardous materials considered to be "environmentally-sensitive chemicals."

Ladder track: Sometimes called the "lead track," is a track off which switches to yard tracks that are normally parallel to each other are contained, The switches provide access to the yard tracks from the ladder or lead track. Train/car movements arrive or depart from yard tracks by utilizing the ladder track to access the specific switch that allows movements to/from a particular yard track. The ladder or lead track is also often used as the "switching lead" when cars are pulled from a yard track and separated to other yard tracks for the purpose of combining cars with similar destinations together on one track.

LAPIOs: Low °API Oils." Oils that have specific gravities over 1.0 [°API ≤ 10.0]. In the U.S. these oils are classified as Group V. These oils are unique in that they can sink or remain submerged in the water column when spilled without needing aggregation with any sediment to otherwise increase their mass. Also "Low API° Oils" or "Group V Oils."

Large Diameter Hose (LDH): A hose for firefighting**.**

Lateral Force: The forces which push to the left or right of the direction of travel as a car is moving. The flanges of the wheel and the rail counter these forces by pushing against each other to keep the car on the rails.

LC_{50}: The concentration of a contaminant at which 50 percent of a particular species will experience mortality. The lower the LC_{50} of a species, the more sensitive the species. The higher the LC_{50} of a compound, the lower its toxicity, because it takes a higher concentration of the contaminant to cause mortality.

LD LMT: Load Limit — the maximum weight car and lading (in pounds, LB, and kilograms, KG).

LDH: large-diameter hoseline.

LEL: Lower Explosive Limit.

LEPC: Local Emergency Planning Commission.

LFL: Lower Flammable Limit.

Light oils: Crude oils and refined petroleum products that are quite toxic but also contain some persistent components. These oils do not evaporate as readily as volatile distillates. The category includes: No. 2 fuel, diesel fuel, light crude oil, gas oil, hydraulic oil, and catalytic feedstock. In the U.S., this category is called "Group II Oil", including crude oil and products that have a specific gravity less than 0.85 [API° >35.0]. In general, light fuels are: moderately toxic; will leave a residue of up to one-third of the spill amount after a few days; contain moderate concentrations of toxic soluble compounds; capable of oiling surface and subsurface resources with long-term contamination potential; and generally possible to clean up with effective response tools; also called "Group II oils."

Limbo time: The time railroad crewmembers spend being transported to where they are released from duty, which counts as neither time on duty nor time off duty.

Line-Haul: For carload service, line-haul represents the portion of a trip between yards where cars are sorted and/or staged for delivery or pick-up from line-side industries and transloading facilities. For trailer/container intermodal service, the line-haul portion of a trip comprises the segment between intermodal terminals at origin and destination.

Local Emergency Planning Committee (LEPC): Under the Emergency Planning and Community Right-to-Know Act (EPCRA), Local Emergency Planning Committees (LEPCs) must develop an emergency response plan, review the plan at least annually, and provide information about chemicals in the community to citizens. Plans are developed by LEPCs with stakeholder participation. The LEPC membership must include (at a minimum): elected state and local officials; police, fire, civil defense, and public health professionals; environment, transportation, and hospital officials; facility representatives; and representatives from community groups and the media.

Loop Track: Continuous track within a facility normally of sufficient length to allow a unit train to remain intact while loading or unloading a commodity. An example of loop tracks that allow unit train unloading while the train remains intact is the EGT export grain facility at Port of Longview. Many of the origin locations for unit grain and coal trains feature loop tracks that allow loading of a train without breaking it apart. If a loop track is not available at a loading or unloading facility, cars are spotted in smaller numbers then reassembled after the loading or unloading activity is completed to create the unit train.

Low API° Oils: Oils with a density of over 1.0 g/cm^3, such as Orimulsion and Boscan crude. These oils are heavier than fresh water. Also "LAPIOs" or "Group V Oils."

Lower Explosive Limit (LEL): The lowest concentration (by percentage) of a gas or vapor in air that is capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). Also called "Lower Flammable Limit."

Lower Flammable Limit (LFL): The lowest concentration (by percentage) of a gas or vapor in air that is capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). Also called "Lower Explosive Limit."

LT WT: Light Weight. The weight of the car without the lading (when empty) (in pounds, LB, and kilograms, KG).

Mainline: Track that is used for through trains or is the principal artery of the system from which branch lines, yards, sidings and spurs are connected. It generally refers to a route between towns, as opposed to a route providing suburban or metro services.

Manifest train: Freight train contains cars with various types of cargo. They may include rail tank cars that carry chemicals, refined oil products, and even crude oil. In some cases, manifest trains contain a "block" of as many as 20 crude oil tank cars.

Manual on Uniform Track Control Devices (MUTCD): Defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic.

Manway: A general term designating the circular-shaped opening located at the top of a tank car to allow access into the tank's interior for maintenance, inspection, and loading or unloading.

Material Safety Data Sheet (MSDS): a document that lists the occupational safety and health information for a hazardous substance.

Mechanical injury: An injury caused by coating, fowling or clogging of organisms and their appendages and apertures, such that movements and behaviors are mechanically inhibited; e.g., oiled birds suffer from mechanical injury.

Medium oils: Crude oils and refined petroleum products that are moderately toxic and moderately persistent, such as most crude oils, and lube oil. This category would also include synthetic crudes; in the US, these oils are considered "Group III Oils", having a specific gravity between 0.85 and less than 0.95 [API° ≤35.0 and >17.5]. In general, these medium oils exhibit the following behavior: about one-third will evaporate within 24 hours; oil contamination of can be severe and long-term; oil impacts to waterfowl and fur-bearing mammals can be severe; and cleanup is most effective if conducted quickly.

Meet Location: A point where two trains moving in opposing directions can safely pass each other.

MMA: Montreal Maine & Atlantic Railroad.

The Model Toxics Control Act (MTCA): Washington's environmental cleanup law**.** MTCA funds and directs the investigation, cleanup, and prevention of sites that are contaminated by hazardous substances. It funds work to protect people's health and the environment, and to preserve natural resources for the future.

Motion Sensor System (Crossing): A grade crossing protection system that has two approach circuits and an island circuit, similar to the basic active warning system. In a motion sensor system, however, the crossing signal's electronic circuitry measures the voltage in both approach circuits. Once a train has fouled or touched one of the circuits as it approaches the crossing, the voltage of the circuit drops and the grade crossing protection is activated. Once the train enters the island circuit, the circuit voltage becomes zero because the train is causing a dead short of the circuit. As the train clears the island circuit and moves away from the crossing in the opposite approach circuit, the voltage starts to climb again and the grade crossing protection is turned off.

MP: milepost (on railroad line).

MPCA: Minnesota Pollution Control Agency.

mph: miles per hour.

MRSA: Maine Revised Statutes Annotated.

MSDS: Material Safety Data Sheet.

MTCA: Model Toxics Control Act

MUTCD: Manual on Uniform Track Control Devices.

NAAQS: National Ambient Air Quality Standards

NAR: non-accident release.

National Contingency Plan (NCP): As found in 40 CFR Part 300 is the federal government's strategy for responding to both oil spills and hazardous substance releases.

National Environmental Policy Act (NEPA): A United States environmental law that established a U.S. national policy promoting the enhancement of the environment. The law was enacted on January 1, 1970.

National Incident Management System (NIMS): A systematic, proactive approach to guide departments and agencies at all levels of government, nongovernmental organizations, and the private sector to work together seamlessly and manage incidents involving all threats and hazards — regardless of cause, size, location, or complexity — in order to reduce loss of life, property and harm to the environment.

National Oceanic and Atmospheric Administration (NOAA): A scientific agency within the U.S. Department of Commerce focused on the conditions of the oceans and atmosphere. NOAA warns of dangerous weather, charts seas and skies, guides the use and protection of ocean and coastal resources, and conducts research to improve understanding and stewardship of the environment.

National Response Center (NRC): The sole federal point of contact for reporting all hazardous substances releases and oil spills.

National Transportation Safety Board (NTSB): independent federal agency that makes recommendations towards preventing future accidents based on its findings, but does not have any regulatory authority. Unlike the FRA, the NTSB is not required to factor costs, input from stakeholders or impacts on industry when making recommendations or issuing safety advisories.

NCP: National Contingency Plan.

NEC: not elsewhere classified.

NEPA: National Environmental Policy Act.

NFPA: National Fire Protection Association.

NGO: non-governmental organization

NIMS: National Incident Management System.

NOAA: National Oceanic and Atmospheric Administration.

Non-accident release (NAR): Release of a relatively small quantity of a hazardous material from a tank car due to the car not being properly secured after loading or unloading.

Nonene: An alkene with the molecular formula C_9H_{18}. Industrially, the most important nonenes are trimers of propene, which are used in the alkylation of phenol to produce nonylphenol, a precursor to detergents.

Non-persistent oil: Volatile oils that evaporate relatively rapidly, such as jet fuel, kerosene, and gasoline.

Non-tank vessel: A ship that does not carry oil as cargo, such as a container ship or a bulk carrier.

Nonylphenol ethoxylates (NPE): Widely used members of the larger alkylphenol and alkylphenol ethoxylate family of non-ionic surfactants. They are produced in large volumes, with uses that lead to widespread release to the aquatic environment.

Normalized impact risk score: A normalized score is derived by taking the lowest score and making that equal to 1.0, then comparing the other scores to that.

Northwest Area Contingency Plan (NWACP): A planning tool that provides for rapid, aggressive, and well-coordinated responses to reports of oil or hazardous substance spills.

Notice of Proposed Rulemaking (NPRM): Public notice issued by law when one of the independent agencies of the United States government wishes to add, remove, or change a rule or regulation as part of the rulemaking process. It is an important part of United States administrative law, which facilitates government by typically creating a process of taking of public comment.

NPE: Nonylphenol ethoxylates**.**

NPRM: Notice of Proposed Rulemaking.

NTSB: National Transportation Safety Board.

NWAC: Northwest Area Committee.

NWACP: Northwest Area Contingency Plan.

NYSDEC: New York State Department of Environmental Conservation.

ODOT: Oregon Department of Transportation.

OEM: Oregon Office of Emergency Management.

Oil Pollution Act of 1990 (OPA90): An act of Congress designed to mitigate and prevent civil liability from oil spills off the coast of the U.S., including provisions for spill contingency plans, liability limits and specifications for responsible parties, spill prevention measures (e.g., double hulls on tankers), and other measures.

Oil pour point: The lowest temperature at which the oil will still flow. Below this temperature, the oil begins to develop an internal yield stress and, in essence, solidifies. If the ambient temperature is above the pour point of the oil, it will behave as a liquid. If the ambient temperature is below the pour point, the oil will behave as a semi-solid.

Oil sands oil: Also called "tar sands oil." Oil extracted from bituminous (tar) sands.

Oil Spill Liability Trust Fund (OSLTF or Fund): A billion-dollar fund established as a funding source to pay removal costs and damages resulting from oil spills or substantial threats of oil spills to navigable waters of the U.S. The OSLTF is used for costs not directly paid by the polluter, referred to as the responsible party (RP).

Oil Spill Prevention Account (OSPA): Funds used for routine oil spill prevention and preparedness work. Funding for the OSRA comes from 80 percent of the 5 cents per bbl tax on oil transported by vessel, rail, and pipeline.

Oil Spill Response Account (OSRA): Funds used for oil spill response and cleanup when Washington State costs exceed $1,000. Funding for the OSRA comes from 20 percent of the 5 cents per bbl tax on oil transported by vessel, rail, and pipeline.

Oil Spill Response Plan (OSRP): Washington Administration Code (WAC) Chapter 173-182 requires larger oil handling facilities, pipelines and commercial vessels to have state approved oil spill contingency plans that describe their ability to respond to oil spills. A contingency plan is like a "game plan" that outlines what is necessary to ensure a rapid, aggressive and well-coordinated response to an oil spill. Critical elements of these plans include: notification and call out procedures to ensure response teams and resources are activated immediately; identification of spill management teams necessary to manage a spill or incident response; analysis of the planning standards and worst case spill volume to assess the necessary response needs; appropriate response equipment and personnel to respond to a worst case spill; identification of oil types and properties; contracts with primary response contractors to provide response equipment and personnel necessary to respond; and commitment for drills to test the plan.

Oil-mineral aggregate (OMA): A combination of oil mixed with sediment particles (e.g., sand in the surf zone of a beach). OMA may become heavier than water to cause sinking.

OLI: Operation Lifesaver**.**

OMA: oil-mineral aggregates.

OPA90: Oil Pollution Act of 1990.

OPA: Other Populated Area.

Operation Lifesaver (OLI): A nonprofit public safety education and awareness organization dedicated to reducing collisions, fatalities and injuries at highway-rail crossings and trespassing on or near railroad tracks. The organization was established in 1972 and now is active in all 50 states.

OPFC: Office of Fire Prevention and Control (New York State).

OSHA: Occupational Safety and Health Administration.

OSFM: Oregon Office State Fire Marshal.

OSPA: Oil Spill Prevention Account.

OSRA: Oil Spill Response Account.

OSRO: Oil Spill Removal Organization.

OSRP: Oil Spill Response Plan.

OSTLF: Oil Spill Liability Trust Fund.

Overheated journal bearings detector (HBD): Device that detects overheating in the trucks (or wheel axles) of a locomotive.

P&I: Protection and Indemnity.

Packing Group (PG): classification of cargoes with respect to flammability and other hazards.

Packing Group I: highest level of packing group (i.e., the most dangerous cargo). Includes toxic substances and preparations presenting a very severe risk for flammability, with an initial boiling point of less than 95°F.

Packing Group II: substances with a flash point of less than 73.4°F, and an initial boiling point of more than 95°F.

Packing Group III: substances with a flash point of between 73.4°F and 141.8°F, and an initial boiling point of more than 95°F.

PADD: Petroleum Administration for Defense Districts.

PAH: Polynuclear aromatic hydrocarbons or polycyclic aromatic hydrocarbons.

Pass or Overtake Location: A point where, for two trains moving in the same location, the faster train can overtake the slower train.

Passive System (Crossing): In a passive system the crossing is identified by a stop sign or crossbuck. The passive system approach relies on the vehicle driver or pedestrian to take the initiative to "stop, look, and listen" before proceeding safely. This type of crossing is generally used at very lightly used grade crossings, either by highway traffic or by rail traffic, or at private grade crossings (farm roads, driveways or business entrances).

Persistence: The degree to which heavier components of an oil linger in the environment before biodegrading.

Persistent oil: An oil for which at least some components tend to remain in the environment for an extended period of time after initial evaporation.

Petroleum Administration Defense Districts (PADD): The U.S. is divided into five Petroleum Administration for Defense Districts, or PADDs, as created during World War II under the Petroleum Administration for War to help organize the allocation of fuels derived from petroleum products, including gasoline and diesel (or "distillate") fuel; today, these regions are still used for data collection purposes. PADD 5 includes Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

PG: Packing Group.

PHMSA: Pipeline and Hazardous Material Safety Administration.

PID: photoionization detector.

PIH/TIH: Poison Inhalation Hazard/Toxic Inhalation Hazard**.**

PIO: Public Information Officer.

Pipeline and Hazardous Material Safety Administration (PHMSA): An agency within the U.S. Department of Transportation that is responsible for establishing and enforcing requirements for the safe transport of hazardous materials by all modes of transportation, including the design of railroad tank cars carrying crude oil. PHMSA was created in 2004 with the purpose of providing U.S. Department of Transportation a more focused research organization and establishing an operating administration for the inspection and enforcement of requirements for pipeline safety and hazardous materials transportation.

PNWR: Portland & Western Railroad.

Polluter Pays Principle: Principle 16 of the International Rio Declaration on Environment and Development, which is reflected in the national laws of each participant that require that the polluter or responsible party is, generally, responsible for the costs associated with pollution.

Polycyclic aromatic hydrocarbon (PAH): Also called "polynuclear aromatic hydrocarbons" (naphthalenes, phenanthrenes, fluorenes, dibenzothiophenes).

Pool Fire: a fire that burns from a pool of vaporizing fuel.

Positive Train Control (PTC): PTC is technology that overlays existing train hardware and software. As mandated by law, PTC is intended to prevent train-to-train collisions, derailments caused by excessive speed, unauthorized incursions by trains onto sections of track where maintenance activities are taking place and movement of a train through a track switch left in the wrong position. PTC enforces movement authorities, speed restrictions (signal and civil), and protection of roadway workers.

PPE: Personal protective equipment**.**

PRC: Primary Response Contractor.

Predictor System (Crossing): A crossing protection system in which the desired gate warning time is set to a constant time (for example, 30 seconds). Under this system, when a train enters the approach circuit, the crossing electronics calculate the slope of the decline of the voltage as the train approaches. Once the slope is acquired, the electronics can calculate how long the activation of the gates and flashers must be delayed to meet the desired activation time.

Pre-treated Bakken crude: Bakken crude oil that has been partially refined to remove the most volatile portions.

Private grade crossing (private crossing): Crossing between railroad tracks and privately owned roadways, such as on a farm or industrial area, and is intended for use by the owner or by the owner's licensees and invitees. A private crossing is not intended for public use and is not maintained by a public highway authority.

Protection and Indemnity (P&I): Liability insurance for practically all maritime liability risks associated with the operation of a vessel, other than that covered under a workers compensation policy and under the collision clause in a hull policy.

psi: pounds per square inch.

psia: pounds per square inch absolute.

PTC: positive train control.

Public grade crossings: crossings between railroads and roadways that are under the jurisdiction of, and maintained by, a public authority.

QI: Qualified Individual.

Qualified Individual (QI): The person identified in a spill contingency plan that has the authority to act on behalf of the plan holder (spiller or responsible party) to make decisions to order expenditures and actions in a spill response operation.

Quiet Zone: An area of railroad tracks that have a special designation that allows trains to pass through without whistles or horns to warn drivers and pedestrians at grade crossings.

Rail capacity: Maximum traffic flow a piece of infrastructure (in this case, railroad lines) can handle under specified operating conditions.

Rail crossing: Intersection of two railroad tracks or a railroad track and a highway or road.

Rail Safety Improvement Act (RSIA): A United States federal law, first enacted by Congress in 2008 to improve railroad safety. RSIA directs the FRA to, among other things, promulgate new safety regulations. These new regulations govern different areas related to railroad safety, such as hours of service requirements for railroad workers, positive train control implementation, standards for track inspections, certification of locomotive conductors, and safety at highway-rail grade crossings. Among its provisions, the most notable was the mandate requiring positive train control (PTC) technology to be installed on most of the U.S. railroad network by 2015. It also includes regulations related to combatting crew fatigue.

Railroad Safety Advisory Committee (RSAC): Develops new regulatory standards, through a collaborative process, with all segments of the rail community working together to fashion mutually satisfactory solutions on safety regulatory issues.

Railway bearing detector (RailBAMTM): type of wayside detector that detect faulty wheel bearings as trains pass by.

RCW: Revised Code of Washington.

Recurrence interval: same as “return period.”

Refined petroleum product: A material derived from crude oil (petroleum) as it is processed in oil refineries, such as fuel oils.

Refinery throughput capacity (or refinery capacity): The maximum amount of crude oil designed to flow into the distillation units, in other words, this is the amount of crude oil that a refinery can process on a daily basis; actual throughput may be less than this and may vary from day to day.

Reid Vapor Pressure (RVP): a measure of volatility.

Research and Special Programs Administration (RSPA): This sub-agency of the Department of Transportation focused on improving hazardous materials and pipeline safety; coordinating and advancing transportation research, technology and education activities to promote innovative transportation solutions; and managing the Department's transportation-related emergency response and recovery responsibilities. RSPA was abolished by act of Nov. 30, 2004 (118 Stat. 2424-2426) and certain duties and powers were transferred to both the Pipeline Hazardous Materials Safety Administration and the Administrator of the Research and Innovative Technology Administration, Department of Transportation.

Responsible party (RP): The entity that has the legal liability for an oil spill (the “spiller”).

Restricted speed: A speed where the train can stop within one half the distance of vision, not to exceed 20 mph.

Return period/return years: The expected period of time that would, on average, pass before a particular event might occur, which is calculated as the inverse of the annual frequency or probability. For example, a major flood may occur approximately every 100 years or so (the “100-year-flood”). This does not mean that the event will not occur before the time period is up or that it could not occur more frequently, or less frequently.

Revenue service demonstration (RSD): An advanced form of testing of positive train control (PTC) that occurs while trains operate in regular service.

Revised Code of Washington (RCW): The compilation of all permanent laws now in force.

Right-of-way (ROW): A type of easement granted or reserved over land for transportation purposes; for railroads, this is the narrow strip of land (typically 25 feet on either side of the railroad tracks).

Riparian: Pertaining to a river bank.

Risk mitigation: Reduction of risk by reducing the likelihood of an incident through prevention, or reducing the impacts of an incident by an effective response.

Risk: A term that encompasses both the likelihood, and probability, of an event occurring *and* the consequences or impacts of that event.

RMP: Risk Management Program.

Roller Bearing: A wheel component that houses the end of the axles of a wheel set. The roller bearing allows the axle (and wheels) to turn freely when the car is rolling.

Rolling stock: locomotives, carriages, railroad cars, wagons, coaches, or other vehicles that move on a railway.

ROW: right-of-way.

RP: Responsible party.

RSAC: Railroad Safety Advisory Committee.

RSC: Rail Safety Committee.

RSD: revenue service demonstration.

RSIA: Rail Safety Improvement Act.

RSPA: Research and Special Programs Administration.

RVP: Reid Vapor Pressure.

SARA: Superfund Amendment and Reauthorization Act.

SCBA: Self-contained breathing apparatus.

SCC: State Corporation Commission (Virginia).

SDS: Safety Data Sheet.

Self-contained Breathing Apparatus (SCBA): A device worn by rescue workers, firefighters, and others to provide breathable air in an "Immediately Dangerous to Life or Health" atmosphere.

SERC: State Emergency Response Commission.

Shale oil: An unconventional oil produced from oil shale rock fragments by pyrolysis (high temperature decomposition), hydrogenation (a reduction chemical reaction using hydrogen treatment), or thermal dissolution (another form of hydrogen treatment). Both hydrogenation and thermal dissolution are considered hydrogen-donor solvent refining processes. All four of these processes are liquid extraction processes that convert the organic matter within the rock (kerogen) into synthetic oil and gas.

Shale: A fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite.

Sheen: A very thin layer of oil on the water surface. Rainbow-colored sheens are generally 0.0003 mm thick. Silver sheens are usually about 0.0001 mm thick.

Shipper: The party that certifies and offers the hazardous material package for transportation.

Short-line: a local railroad. A small- or mid-sized railroad company that operates over a relatively short distance relative to larger national railroad networks.

Siding: A second track that diverges from a single track main line, then rejoins the main line some distance away (usually 1.5 to 2 miles). Sidings are used to meet opposing trains or overtake slower trains moving in the same direction. In some cases, a siding exists to serve an online industrial facility.

Single Track: A location, either on the mainline or within a facility that features only one track on which train operations can occur at any given time. For example, an unloading facility that features a loop track operation may only have one loop track for unloading. Consequently, only one train can be in the facility at any given time, unless the loop track has sufficient length to allow a train to be on either side of the unloading location at the same time. The second train can arrive short of the unloading location as the first train is completing its unloading. If the facility only features sufficient track length for one train to be on-site at any given time, following trains waiting to access the facility when the first train departs have to be staged on other tracks off the facility site, normally either in a yard or in mainline meet/pass sidings.

SMART: International Association of Sheet Metal, Air, Rail, and Transportation Workers.

SNF: Spent Nuclear Fuel.

Sorbent: Material used in a spill response to soak up oil.

SP&S: Spokane, Portland, Seattle Railway.

SPCC: Spill Prevention, Control, and Countermeasures.

Specific gravity: A measure of density based on grams per cubic centimeter. Fresh water has a specific gravity of 1.0.

Specific gravity: the density of a substance in relation to water.

Spent Nuclear Fuel (SNF): irradiated fuel or targets containing uranium, plutonium, or thorium that is permanently withdrawn from a nuclear reactor or other neutron irradiation facility following irradiation, the constituent elements of which have not been separated by reprocessing.

Spikes: Track appliances that hold the rail onto wooden ties.

Spill Prevention, Control, and Countermeasure (SPCC): Federal regulations administered under the EPA to help facilities prevent a discharge of oil into navigable waters or adjoining shorelines. The SPCC rule requires facilities to develop, maintain, and implement an oil spill prevention plan, called an SPCC plan. These plans help facilities prevent oil spill, as well as control a spill should one occur.

Spill Prevention, Preparedness, and Response Program (Spills Program) (SPPR): Focuses on preventing oil spills to Washington's waters and land, as well as planning for and delivering a rapid, aggressive, and well-coordinated response to oil and hazardous substance spills wherever they occur. A program of the Washington State Department of Ecology.

Spiral: A section of track that transitions from tangent to the full curvature of the curve. Spirals also transition the rails on a curve from flat at the tangent end to full super elevation in the curve.

SPPR: Spill Prevention, Preparedness, and Response Program.

SSU: Sabolt Seconds Universal, a measure of viscosity.

Staggers Rail Act: Federal legislation enacted in 1980 that deregulated the railroad industry and replaced the regulatory structure that had existed since the 1887 Interstate Commerce Act.

Standard Transportation Classification Code (STCC): Unique seven-digit codes that are used to classify commodities (cargo); the first two digits identify the major industry group of the commodity.

State Emergency Response Commission (SERC): A commission appointed by the Governor that is responsible for implementing Emergency Planning and Community Right-to-Know Act (EPCRA) provisions within the state.

STB: Surface Transportation Board.

STCC: Standard Transportation Classification Code.

Subgrade: Compacted dirt and rock under the ballast to support the track structure.

Sun kinks: Track alignment deformations that can occur because the rail heats up and expands, and the track and ballast section does not provide sufficient lateral resistance to keep the rail from buckling (also called “thermal misalignment”).

Super Elevation: Raising the outside rail of a curve to allow higher speeds through the curve; similar to banking a highway curve.

Supply chain: A system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials, and components into a finished product that is delivered to the end customer.

Surface Transportation Board (STB): An agency created by the ICC Termination Act of 1995 as the successor agency to the Interstate Commerce Commission. STB has jurisdiction over railroad rate and service issues and rail restructuring, such as mergers, sales and the construction and abandonment of rail lines. STB is an independent adjudicatory and economic regulatory agency, but administratively a part of U.S. Department of Transportation.

Sweet oil: Oil that has a low sulfur content.

Switch Frog: A frog is a piece of the track where two rails cross. Standard frogs are machined with a gap where the wheel rolling on one route crosses the rail from the other route. There are guard rails on both sides of the point of the frog to keep the wheels in alignment.

Switch Machine: Track appliance that moves the switch points through a series of rods connected to the points. Switch machines are powered and move the points automatically at the instruction of a control operator

Switch Points: The moveable pieces at the end of a turnout that direct the train wheels down one track or the other.

Switch Stand: Track appliance that moves the switch points through a series of rods connected to the points. Switch stands must be manually operated to move the switch points.

Switch: The section of track where one track diverges from another track (also called “turnout”).

Synbit: product made by diluting bitumen by using synthetic crude oil.

Syncrude: synthetic crude oil.

Synthetic crude: The output from a bitumen/extra heavy oil upgrader facility used in connection with oil sand production. It may also refer to shale oil, an output from an oil shale pyrolysis.

TADS-ABD: Acoustic bearing detector.

Tangent track: Straight track.

Tank Car Owner: The rail car owner, who often lease the cars to the shipper for use, is responsible for keeping the tank car in compliance with the Hazardous Materials Regulations (inspections/repairs, etc.).

Tar sands oil: See “oil sands oil.”

TBOGI: Truck bogie optical geometry inspection**.**

TC: Transport Canada.

TERC: Tribal Emergency Response Commission.

Thermal misalignment: Track alignment deformations that can occur because the rail heats up and expands, and the track and ballast section does not provide sufficient lateral resistance to keep the rail from buckling (also called “sun kinks”).

Tie Plate: Track appliances that sit on top of the tie and act as a cradle for the base of a rail. Spikes are driven through holes in the tie plates to hold a rail to a wooden tie. On concrete ties, the area where the rail sits is cast into the tie. These areas have metal pieces that hold the clips that attach the rail to the concrete ties.

Ties: Wooden or concrete track members that support the rails of a track. Ties are tamped into the ballast to create vertical and lateral support for the track.

Tight oil: a type of oil extracted from petroleum-bearing formations of low permeability (typically shale or tight sandstone). These formations produce oil through hydraulic fracturing; also called “shale oil.”

TIH: toxic inhalation hazard.

TOFC: trailer on flat car (intermodal shipping).

Ton-mile: Unit of measure the combines the tonnage of cargo or freight and the distance traveled; a single ton-mile is a ton of cargo being transported one mile.

Toxic Inhalation Hazard (TIH): Gases or liquids that are known or presumed to be toxic to humans so as to pose a hazard to health in the event of a release during transportation. Examples include chlorine gas, anhydrous ammonia, sulfur dioxide, ethylene oxide, and hydrogen fluoride.

TPD: Rail car truck performance detector. Rail car trucks are the wheel assemblies on each end of the car.

Track geometry car: An automated track inspection vehicle.

Track geometry: The three-dimensional track layout.

Track Warning Device (TWD): Device that inspects passing trains for defects or monitors for unusual trackside conditions that could adversely affect the safe and efficient movement of trains.

Track Warrant Control (TWC): TWC is a method of authorizing train movements over a territory where signals do not convey movement authority. TWC requires the issuing of a track warrant from a dispatcher to a train crew.

Track Warrant: A verbal method to authorize train movements in dark and ABS territory. The warrant identifies the territory the train can move over, normally between the starting point and destination location (for example a meet/pass siding), at which point the receiving train must receive further movement authorization for additional movement.

Trackage Agreement: One of a variety of agreements that allow carriers to operate on lines owned by other companies; where trackage rights do not exist the shipment continues to destination after transferring the material at an "Interchange Point."

Traditional use area: Lands that have been used historically for tribal fishing, hunting, and cultural activities.

Train-mile: Unit used in railroad accounting that is the equivalent of one mile traversed by a train.

Transporter (carrier): Entity that by federal law is required to transport from origin to destination hazardous materials that meet the USDOT requirements and as certified by the "shipper." Carriers are responsible for materials that are in transport on their system, and usually operate on their own lines but often have trackage agreements in areas they do not own the lines.

Trestle: A rigid frame used as a support for railroad tracks. A trestle may be in the form of a bridge or overpass across water or a valley.

Tribal ceded area: Area over which tribes by treaty relinquished control to the federal government in return for compensation in the form of livestock, merchandise, and annuities.

Truck bogie optical geometry inspection (TBOGI): type of wayside detector that is a laser-based monitoring system to measure performance of a rail car's axle and wheel suspension (commonly known as the "truck").

Truck performance detector (TPD): Type of wayside detector that assesses the performance of rail car suspension systems or trucks on curved track by measuring the wheel's lateral forces at major segments of track containing four to six degrees of curvature.

TSB: Transportation Safety Board (Canada).

Turnout (commonly called a switch): The section of track where one track diverges from another track (commonly called "switch").

TÜV Rail Sciences: TÜV Rheinland Mobility Rail Sciences Division**.**

TÜV Rheinland Mobility Rail Sciences Division (TÜV Rail Sciences): Provides analytical consulting services to the rail industry.

TWC: Track Warrant Control.

TWD: Track Warning Device.

U&A: Usual and Accustomed. This is a treaty term from the Stevens' Treaties used extensively in U.S. v. Washington, referring to an area where a particular tribe traditionally fished and over which the tribe has a territorial use claim under the provisions of the treaty. Treaty tribes retained their right to take fish in their "usual and accustomed" areas.

UC: Unified Command.

UDE: Undesired Emergency.

UEL: Upper Explosive Limit.

UFL: Upper Flammable Limit.

UN Number: four-digit number identifying a hazardous material**.**

UN: United Nations.

Unified Command (UC): An authority structure in which the role of incident commander is shared by two or more individuals, each already having authority in a different responding agency. Unified Command is one way to carry out command in which responding agencies and/or jurisdictions with responsibility for the incident share incident management. Unified Command may be needed for incidents involving multiple jurisdictions or agencies.

Unit train: Train in which all cars carry the same commodity and are shipped from the same origin to the same destination, without being split up or stored en route (also called "block train").

United States Department of Transportation (USDOT): Oversees federal highway, air, railroad, and maritime and other transportation administration functions.

UP: Union Pacific Railroad.

Upper Explosive Limit (UEL): highest concentration (percentage) of a gas or vapor in air capable of producing a flash of fire in presence of an ignition source (arch, flame, heat). Concentrations higher than UEL are "too rich" to burn. Also called "Upper Flammable Limit."

Upper Flammable Limit (UFL): highest concentration (percentage) of a gas or vapor in air capable of producing a flash of fire in presence of an ignition source (arch, flame, heat). Also called "Upper Explosive Limit."

U.S. Energy Information Administration (EIA): Principal agency of the U.S. Federal Statistical System responsible for collecting, analyzing, and disseminating energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA programs cover data on coal, petroleum, natural gas, electric, renewable and nuclear energy. EIA is part of the U.S. Department of Energy.

US: United States.

USCG: U.S. Coast Guard.

USDOT: U.S. Department of Transportation**.**

Usual and Accustomed (U&A): A tribal treaty term from the 1854–1855 Stevens' Treaties used extensively in U.S. v. Washington, referring to an area where a particular tribe traditionally fished and over which the tribe has a territorial use claim under the provisions of the treaty. Treaty tribes retained their right to take fish in their "usual and accustomed" areas. These treaties are legally-binding contracts and are the supreme law of the land under the U.S. Constitution.

UTC: Utilities and Transportation Commission.

Utilities and Transportation Commission (UTC): Created in 1905 by the Washington State Legislature as a three-member Railroad Commission, with regulatory authority to inspect and evaluate railroad company accounts, set rates, approve time schedules, monitor safety issues and enforce violations. However, in 1970 and again in 1980, the U.S. Congress passed legislation preempting states in all areas pertaining to economic regulation of railroads and limited the scope of state jurisdiction in regards to safety.[513].

Vapor Cloud Explosion: the result of a flammable gas or vapor mixture that is released into the atmosphere, at which point the resulting vapor cloud is ignited.

Vapor pressure: the pressure of a vapor exerted by its liquid or solid form.

VDEM: Virginia Department of Emergency Management.

VDEQ: Virginia Department of Environmental Quality.

VDFP: Virginia Department of Fire Programs.

VDH: Virginia Department of Health.

Vertical Force: Downward force applied to the rail by the wheels of a car or locomotive. This is essentially the weight of the car or locomotive divided amongst the number of wheels on the car or locomotive.

Viscosity: A measure of the resistance of oil to flowing once in motion. Liquids that flow very slowly, such as peanut butter or molasses, have high viscosities.

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[513] The Federal Railroad Safety and Hazardous Materials Transportation Control Act of 1970, the Interstate Commerce Commission Termination Act (ICCTA) and the Staggers Rail Act of 1980.

VOC: volatile organic compound.

Volatile distillates: Refined petroleum products that are highly toxic but evaporate relatively rapidly, such as gasoline, jet fuel, kerosene, crude condensate, and No. 1 fuel oil. In the U.S., this category is called "Group I Oil" that consists of hydrocarbon fractions at least 50 percent of which, by volume, distill at a temperature of 645ºF, and at least 95 percent of which, by volume, distill at a temperature of 700ºF. In general, volatile distillates exhibit the following behavior: highly volatile (evaporate completely within one to two days); contain high concentrations of toxic soluble compounds; capable of causing localized, severe impacts to surface and subsurface resources, and contaminating drinking water; and generally, because they evaporate so quickly, they are nearly impossible to clean up with conventional response tools. Also called "Group I Oils."

Volatile organic compound (VOC): An organic chemical that has a high vapor pressure at ordinary room temperature. Its high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air.

Volatilization: The process of turning from a liquid into a gas.

WAC: Washington Administrative Code.

WAOL: Washington Operation Lifesaver.

Washington Administrative Code (WAC): Codifies the regulations, a source of primary law, and arranges them by subject or agency.

Washington Operation Lifesaver (WAOL): A free public service education program dedicated to preventing and reducing fatalities and injuries at highway-railroad grade crossings and along railroad rights-of-way.

Washington State Department of Transportation (WSDOT): A governmental agency that constructs, maintains, and regulates the use of the state's transportation infrastructure. WSDOT is responsible for more than 20,000 lane-miles of roadway, nearly 3,000 vehicular bridges and 524 other structures. This infrastructure includes rail lines, state highways, state ferries (considered part of the highway system) and state airports.

Waybill: a shipping document prepared by a carrier at the point of origin showing the point of origin, destination, route, shipper, consignee, description of shipment, weight, charges and other data necessary to rate, ship, and settle.

Wayside detector: technology that allows railroads to prevent damage and accidents before they could happen. Positioned along 140,000 miles of railroad in the nation, seven kinds of wayside detectors monitor the wheels of passing trains and alert rail car owners to potential defects enabling them to schedule appropriate maintenance in a safe, timely, and cost-effective manner.

WBAPS: Web Accident Prediction System

WCD: Worst-Case Discharge.

WCS: Worst-Case Spill.

Weathering: The complex physical and chemical changes that occur after oil spills onto water or onto a substrate on land. Depending on the specific type of oil and its chemical makeup, and the environmental conditions (especially temperature) into which the oil spills, the various processes occur at different rates, including spreading on the water surface, evaporation, emulsification, oxidation, dissolution, dispersion, sedimentation, and biodegradation. Weathering affects the nature of the oil, including toxicity, and its behavior.

Web Accident Prediction System (WBAPS): a Federal Railroad Administration (FRA) model to calculate the probability of accidents at highway-rail crossings.

Web of rail: The middle portion of a rail that connects the ball of the rail to the base of the rail.

Wheel flange: The portion of the wheel that rolls along the inside of the rail and allows the rail to guide the wheel.

Wheel impact load detector (WILD): type of wayside detector that identifies rail wheels worn or damaged into an out-of-round shape before they can damage track.

Wheel profile measurement systems (WPMS): type of wayside detector that evaluates the complete rail profile by capturing laser images and detecting worn wheel treads or flanges.

Wheel tread: The portion of the wheel that rests on the top of the rail.

WILD: Wheel impact load detector.

Wireless Information System for Emergency Responders (WISER): A system designed to assist emergency responders in hazardous material incidents. WISER provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, health information (e.g., Material Safety Data Sheets and Emergency Response Guidelines), and containment and suppression advice. WISER is an emergency "look-up" resource and not a dispersion model.

WISER: Wireless Information System for Emergency Responders.

Worst-Case Discharge (WCD): A defined largest volume of an oil spill for response planning.

Worst-Case Spill (WCS): same as Worst-Case Discharge.

WRIA: Water Resource Inventory Area**.**

WRTSS: 2020 Washington Rail Transportation Safety Study.

WSDOT: Washington State Department of Transportation.

WTI: West Texas Intermediate crude oil, a grade of crude oil used as a benchmark in oil pricing. This grade is described as light because of its relatively low density, and sweet because of its low sulfur content.

Appendix A: Properties of Other Hazardous Commodities, Tank Car Labelling, and Hazard Classifications

Properties of other hazardous commodities

Hazardous materials can be grouped based on their major physical-chemical characteristics that determine fate: density, water solubility, and vapor pressure. The chemical quickly disperses in a dissolved state if water solubility is high, whereas it floats or sinks (depending on density) if solubility is low. Absorption to suspended particulate matter is proportional to its degree of insolubility. Volatilization rate is a function of vapor pressure. The classification of chemicals was based on the property ranges in Table 149 (Rowe et al. 2017) with the results in Table 150. Note that many of these commodities may be carried in Washington State in varying quantities.

Table 149: Classification of Physical Behavior of Chemicals[514]

Characteristic	High	Medium	Low
Buoyancy in Water	Floats (density <1.0 g/cm^3)	Neutral (density 1.01–1.03 g/cm^3)	Sinks (density >1.03 g/cm^3)
Solubility in Water[515]	Highly soluble (solubility >1,000 ppm)	Soluble (solubility 100–1,000 ppm)	Semi-soluble (solubility 1–100 ppm); insoluble (solubility <1 ppm)
Volatility	Highly volatile (vapor pressure >0.015 psi)	Semi- volatile (vapor pressure 0.00000015–0.015 psi)	Non-volatile (vapor pressure <0.00000015 psi)

Table 150: Properties of Common Chemicals[516]

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
(o-, p-) Nitrotoluene	1.163	Sink	0.002596	Semi-Volatile	651	Soluble
1,1-, 1,2-, or 1,3-Dichloropropane	1.159	Sink	0.9599	Highly Volatile	2,800	Highly Soluble
1,2-Dichloropropane	1.159	Sink	0.9599	Highly Volatile	2,800	Highly Soluble
1,3-Dichloropropene	1.211	Sink	2.99922	Highly Volatile	0	Insoluble
2,4-Dinitrotoluene	1.32	Sink	0.000019	Semi-Volatile	270	Soluble

[514] Rowe et al. 2017.
[515] Note “ppm” or “parts per million” is the same measure at mg/L or milligrams per liter.
[516] Rowe et al. 2017.

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
2,6-Dinitrotoluene	1.28	Sink	0.000005	Semi-Volatile	300	Soluble
Acetaldehyde	0.4528	Float	17.59	Highly Volatile	1 million	Highly Soluble
Acetic acid	1.05	Sink	0.301455	Highly Volatile	1 million	Highly Soluble
Acetic anhydride	1.08	Sink	0.096659	Highly Volatile	120,000	Highly Soluble
Acetone cyanohydrin	0.9	Float	0.94	Highly Volatile	1 million	Highly Soluble
Acrylonitrile	0.81	Float	1.6	Highly Volatile	75,500	Highly Soluble
Allyl alcohol	0.854	Float	0.54	Highly Volatile	1 million	Highly Soluble
Allyl chloride	0.9	Float	7.02	Highly Volatile	3,000	Highly Soluble
Ammonia, anhydrous	0.00076	Float	146.92	Highly Volatile	346,000	Highly Soluble
Ammonium sulfide solution (45% or less)	1	Float	9.68	Highly Volatile	999,999	Highly Soluble
Ammonium thiocyanate (<25%), Ammonium	1.31	Sink	0.020128	Highly Volatile	1 million	Highly Soluble
Amyl acetate	0.9	Float	0.08	Highly Volatile	1,700	Highly Soluble
Aniline	1.022	Neutrally Buoyant	0.009453	Semi-Volatile	36,070	Highly Soluble
Benzene	0.877	Float	1.84	Highly Volatile	1,780	Highly Soluble
Benzene hydrocarbon mixture (≥10% Benzene)	0.877	Float	1.84	Highly Volatile	1,780	Highly Soluble
Benzene/Acetylene mixture (≥10% Benzene)	0.877	Float	1.84	Highly Volatile	1,780	Highly Soluble
Benzyl chloride	1.1	Sink	0.025993	Highly Volatile	30	Semi-Soluble
Butyl acetate	0.883	Float	0.23	Highly Volatile	6,000	Highly Soluble
Butylamine (all isomers)	0.8	Float	1.98	Highly Volatile	1 million	Highly Soluble
Butyric acid	1	Float	0.01218	Semi-Volatile	1 million	Highly Soluble
Carbon disulfide	1.263	Sink	6.915583	Highly Volatile	2,200	Highly Soluble
Carbon tetrachloride	1.594	Sink	2.21125	Highly Volatile	800	Soluble

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
Caustic soda solution	2.13	Sink	0	Semi-Volatile	50 million	Highly Soluble
Chlorine	0.00316	Float	94.73	Highly Volatile	7,247	Highly Soluble
Chlorobenzene	1.107	Sink	0.2291	Highly Volatile	484	Soluble
Chloroform	1.483	Sink	3.80538	Highly Volatile	8,200	Highly Soluble
Chlorosulfonic acid	1.75	Sink	0.009997	Semi-Volatile	999,999	Highly Soluble
Crotonaldehyde	0.853	Float	0.69	Highly Volatile	180,000	Highly Soluble
Cyclohexane	0.778	Float	1.84	Highly Volatile	55	Semi-Soluble
Dichlorobenzenes (all isomers)	1.307	Sink	0.02842	Highly Volatile	118	Soluble
Diethylamine	0.71	Float	4.57	Highly Volatile	1 million	Highly Soluble
Dimethylamine	0.68	Float	29.9	Highly Volatile	1 million	Highly Soluble
Dinitrotoluene (molten)	1.32	Sink	0.000019	Semi-Volatile	270	Soluble
Epichlorohydrin	1.18066	Sink	0.348	Highly Volatile	65,800	Highly Soluble
Ethylamine	0.54632	Float	20.54	Highly Volatile	1 million	Highly Soluble
Ethylamine solution (40% or less)	0.54632	Float	20.54	Highly Volatile	1 million	Highly Soluble
Ethylamine solution (72% or less)	0.54632	Float	20.54	Highly Volatile	1 million	Highly Soluble
Ethylbenzene	0.865	Float	0.18	Highly Volatile	152	Soluble
Ethylene dibromide	2.172	Sink	1.508	Highly Volatile	4,152	Highly Soluble
Ethylene dichloride	1.25	Sink	1.5283	Highly Volatile	8,606	Highly Soluble
Ethylenediamine	0.9	Float	0.21	Highly Volatile	1 million	Highly Soluble
Formaldehyde (gas)	0.652	Float	0.88	Highly Volatile	1 million	Highly Soluble
Formaldehyde solution (37% to 50%)	0.652	Float	0.88	Highly Volatile	1 million	Highly Soluble
Formic acid	1.22	Sink	0.83375	Highly Volatile	1 million	Highly Soluble

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
Furfural	1.16	Sink	0.04495	Highly Volatile	79,400	Highly Soluble
Hydrochloric acid	1.16	Sink	0.470148	Highly Volatile	1 million	Highly Soluble
Isobutyl acetate	0.868	Float	0.39	Highly Volatile	6,000	Highly Soluble
Isoprene	0.681	Float	10.63	Highly Volatile	642	Soluble
Maleic anhydride	0.934	Float	0.02	Highly Volatile	163,000	Highly Soluble
m-Cresol	1.034	Sink	0.019394	Highly Volatile	235	Soluble
Methyl methacrylate	0.942	Float	0.74	Highly Volatile	15,600	Highly Soluble
Methylamine	0.693	Float	38.14	Highly Volatile	1,080,000	Highly Soluble
Methylamine solution (42% or less)	0.693	Float	38.14	Highly Volatile	1,080,000	Highly Soluble
m-Nitrophenol	1.485	Sink	0.009666	Semi-Volatile	11,550	Highly Soluble
m-Xylene	0.868	Float	0.16	Highly Volatile	160	Soluble
Naphthalene (molten)	1.162	Sink	0.001508	Semi-Volatile	31	Semi-Soluble
Naphthenic acid	1.05	Sink	0.000288	Semi-Volatile	2,010	Highly Soluble
n-Butyl acetate	0.883	Float	0.23	Highly Volatile	6,000	Highly Soluble
n-Butylamine	0.8	Float	1.98	Highly Volatile	1 million	Highly Soluble
Nitric acid	1.503	Sink	1.101909	Highly Volatile	1 million	Highly Soluble
Nitric acid (70% or less)	1.503	Sink	1.101909	Highly Volatile	1 million	Highly Soluble
Nitrobenzene	1.203	Sink	0.0029	Semi-Volatile	1,900	Highly Soluble
Nitrophenol (mixed isomers)	1.27	Sink	0.001933	Semi-Volatile	13,500	Highly Soluble
o-Cresol	1.048	Sink	0.00754	Semi-Volatile	26,000	Highly Soluble
o-Dichlorobenzene	1.307	Sink	0.02842	Highly Volatile	118	Soluble
o-Nitrophenol (molten)	1.49	Sink	0.003616	Semi-Volatile	1,080	Highly Soluble

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
o-Nitrotoluene	1.163	Sink	0.002596	Semi-Volatile	651	Soluble
o-Xylene	0.88	Float	0.17	Highly Volatile	220	Soluble
p-Cresol	1.035	Sink	0.002126	Semi-Volatile	20,000	Highly Soluble
p-Dichlorobenzene	1.458	Sink	0.013079	Semi-Volatile	83	Semi-Soluble
Phenol	1.132	Sink	0.006815	Semi-Volatile	88,360	Highly Soluble
Phosphoric acid	1.864	Sink	0.000551	Semi-Volatile	1 million	Highly Soluble
p-Nitrophenol	1.27	Sink	0.001933	Semi-Volatile	13,500	Highly Soluble
p-Nitrotoluene	1.299	Sink	0.000095	Semi-Volatile	254	Soluble
Propionic acid	0.993	Float	0.079837	Highly Volatile	170,700	Highly Soluble
Propionic anhydride	1.013	Neutrally Buoyant	0.026284	Highly Volatile	79,940	Highly Soluble
Propylene oxide	0.8287	Float	10.3	Highly Volatile	476,000	Highly Soluble
p-Xylene	0.861	Float	0.17	Highly Volatile	215	Soluble
Styrene	0.906	Float	0.13	Highly Volatile	300	Soluble
Sulfuric acid	1.84	Sink	0.000019	Semi-Volatile	1 million	Highly Soluble
tert-Butyl acetate	0.896	Float	0.73	Highly Volatile	14,410	Highly Soluble
tert-Butylamine	0.7	Float	6.96	Highly Volatile	80,150	Highly Soluble
Tetraethyl lead	1.659	Sink	0.005289	Semi-Volatile	2	Semi-Soluble
Toluene	0.8669	Float	0.55	Highly Volatile	515	Soluble
Trichloroethylene	1.465	Sink	1.4355	Highly Volatile	1,100	Highly Soluble
Triethylamine	0.729	Float	1.11	Highly Volatile	12,300	Highly Soluble
Trimethylamine solution (30% or less)	0.67	Float	32.59	Highly Volatile	475,000	Highly Soluble
Vinyl acetate	0.932	Float	2.04	Highly Volatile	20,000	Highly Soluble

Name	Density (g/cm^3)	Density Class	Vapor Pressure (psi)	Volatility Class	Solubility (ppm)	Solubility Class
Vinylidene chloride	1.218	Sink	11.6725	Highly Volatile	3,344	Highly Soluble
Xylenes	0.868	Float	0.16	Highly Volatile	160	Soluble
Xylenol	1.01	Neutrally Buoyant	0.002	Semi-Volatile	248	Soluble

Labeling and classification of hazardous commodities

There are federal regulations (CFR 49 Chapter I Pipeline and Hazardous Material Safety Administration, Department of Transportation, Subchapter A 100–110, Subchapter B 130, and Subchapter C 171–185) that stipulate the way in which hazardous materials should be handled, including regulations for classification and labeling. Hazardous materials or “dangerous goods” are classified as shown in Table 151. The corresponding hazardous material placards are shown in Figure 126.

Table 151: Hazardous Material Classifications[517]

Class	Material Type	Division	Material Description	Examples
Class 1	Explosive	1.1	Substances and articles that have a mass explosion hazard	Dynamite, TNT (2,4,6,-trinitrotoluene)
Class 1	Explosive	1.2	Substances and articles that have a projection hazard but not a mass explosion hazard	Detonating fuses
Class 1	Explosive	1.3	Substances and articles that have a fire hazard and either a minor blast hazard or a minor projection hazard or both	Flares, shotgun cartridges, display fireworks
Class 1	Explosive	1.4	Substances and articles that present no significant hazard; only a small hazard in the event of ignition or initiation during transport with any effects largely confined to the package	Safety fuses, ammunition, consumer fireworks
Class 1	Explosive	1.5	Very insensitive substances that have a mass explosion hazard	Blasting agents
Class 1	Explosive	1.6	Extremely insensitive articles that do not have a mass explosion hazard	Extemerly insensitive explosives
Class 2	Gas	2.1	Flammable gases	Acetylene, hydrogen, propane
Class 2	Gas	2.2	Non-flammable, non-toxic gases	Nitrogen, neon, carbon dioxide, oxygen

517 CFR 49 Chapter I Pipeline and Hazardous Material Safety Administration, Department of Transportation, Subchapter A 100–110, Subchapter B 130, and Subchapter C 171–185

Class	Material Type	Division	Material Description	Examples
Class 2	Gas	2.3	Toxic gases	Fluorine, chlorine, hydrogen cyanide
Class 3	Flammable Liquids	Packing Group I	Flammable liquids with an initial boiling point of 35°C or less and any flash point	Diethyl ether, carbon disulfide
Class 3	Flammable Liquids	Packing Group II	Flammable liquids with an initial boiling point of greater than 35°C and a flash point less than 23°C	Gasoline, acetone
Class 3	Flammable Liquids	Packing Group III	All other flammable liquids	Kerosene, diesel
Class 4	Flammable Solids	4.1	Flammable solids that are easily ignited and readily combustible	Nitrocellulose, magnesium, matches
Class 4	Flammable Solids	4.2	Substances liable to spontaneous combustion.	Aluminum alkyls, white phosphorus
Class 4	Flammable Solids	4.3	Substances that emit flammable gases when wet or react violently with water	Sodium, calcium, potassium, calcium carbide
Class 5	Oxidizing Substances and Organic Peroxides	5.1	Oxidizing substances	Calcium hypochlorites, ammonium nitrate, hydrogen peroxide, potassium permanganate
Class 5	Oxidizing Substances and Organic Peroxides	5.2	Organic peroxides	Benzoyl peroxide, cumene hydroperoxide
Class 6	Toxic Substances and Infectious Substances	6.1a	Toxic substances liable to cause death or serious injury to human health if inhaled, swallowed, or absorbed through skin	Potassium cyanide, mercuric chloride
Class 6	Toxic Substances and Infectious Substances	6.1b	Toxic substances harmful to human health	Pesticides, methylene chloride
Class 6	Toxic Substances and Infectious Substances	6.2	Infectious substances or biohazards	Virus cultures, medical waste
Class 7	Radioactive Material	None	Substances that are radioactive or that emit ionizing radiation	Enriched uranium, plutonium, radioactive ores, isotopes and some medical equipment or parts.
Class 8	Corrosive Substances	8.1	Corrosive acidic substances that can dissolve organic tissue or severely corrode metals	Sulfuric acid, hydrochloric acid
Class 8	Corrosive Substances	8.2	Corrosive alkali substances that can dissolve organic tissue or severely corrode metals	Potassium hydroxide, sodium hydroxide

Class	Material Type	Division	Material Description	Examples
Class 9	Miscellaneous Dangerous Goods	None	Substances and articles that during transport present a danger or hazard not covered by other 8 classes. This class encompasses, but is not limited to, environmentally hazardous substances, substances that are transported at elevated temperatures, miscellaneous articles and substances, genetically modified organisms and micro-organisms and (depending on method of transport) magnetized materials and aviation regulated substances.	Marine pollutants such as zinc oxide, lithium ion batteries, genetically modified organisms, air bag modules, asbestos, dry ice, and motor engines.

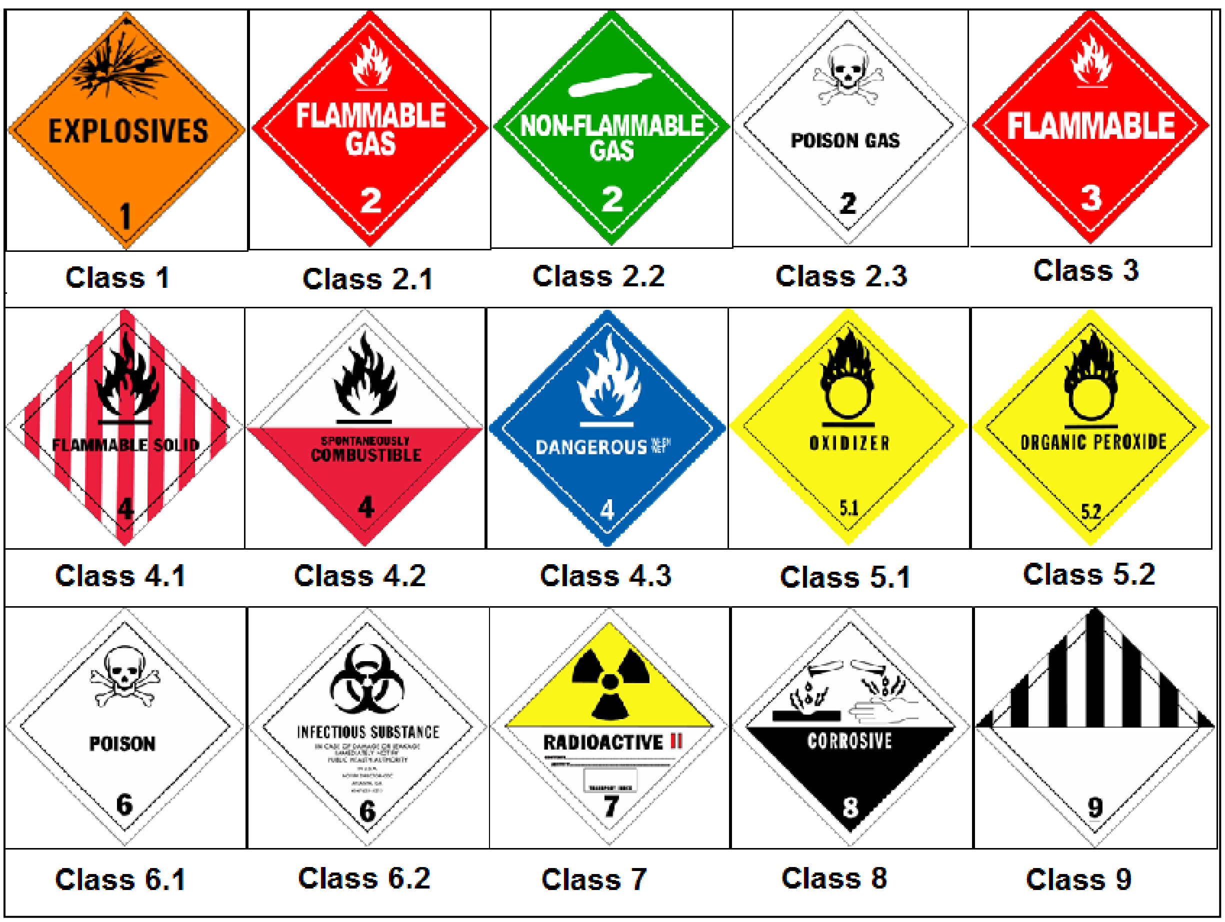

Figure 125: Hazardous Material Placards by Hazard Class[518]

[518] USDOT.

There is an additional type of placard that must be displayed for certain substances that are known to be inhalation hazards under "Special Provision 13" (Figure 127). Substances that would cause pollution if spilled into marine waters that would not otherwise require a hazardous material placard need to be labeled with a Marine Pollutant mark (Figure 128).

Figure 126: Inhalation Hazard Placard (Special Provision 13)[519]

Figure 127: Marine Pollutant Mark[520]

[519] USDOT.
[520] USDOT.

In addition to the placards on both the end and side of each tank car, there are requirements for identification numbers of certain substances to be included on trains. These four-digit numbers may appear on top of the diamond-shaped symbol or adjacent to it, as shown in Figure 129 (AAR 2011). The identification numbers are the United Nations (UN) Dangerous Goods Numbers. These numbers provide specific information on the contents of the tank cars.

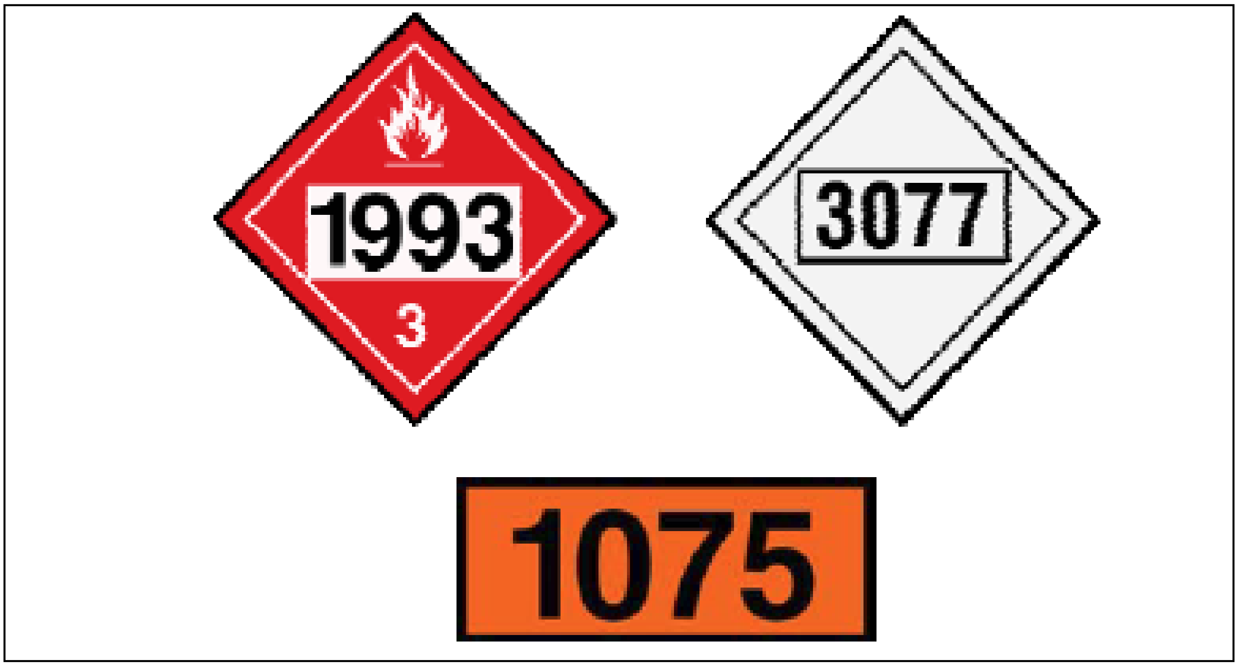

Figure 128: Identification Numbers on Hazardous Material Placards[521]

The identification numbers that are required to be displayed on placards with tank cars carrying Class 3 Flammable Liquids are shown in Table 152. The other hazardous substances that require placards on rail tank cars (AAR 2011), along with their identification numbers, are shown in Table 153. Note that some substances are considered to be "environmentally-sensitive" chemicals (designated as "ES"). Note that some substances have more than one classification. They may be Class 3 flammables, but also require a label as Poison (Class 6.1), as shown in Figure 126.

Information about the specific substances, including emergency response procedures, can be found in the National Oceanic and Atmospheric Administration (NOAA) CAMEO database, which can be readily searched online.[522] The easiest approach on this website is to enter the four-digit UN identification. Bakken crude oil and diluted bitumen would be classified as Petroleum Crude Oil with UN number 1267.

[521] USDOT.
[522] Cameo Chemicals website. Database of Hazardous Materials. https://cameochemicals.noaa.gov/.

Table 152: Labeling and Classification for Class 3 Flammable on Rail Cars[523]

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)	ES[524]
1090	Acetone		3	3	
1100	Allyl Chloride		3	3, 6.1	yes
1133	Adhesives (with Flammable Liquid)	Pyroxylin Cement	3	3	
1134	Chlorobenzene		3	3	yes
1170	Ethanol	Ethyl Alcohol or Ethanol Solutions	3	3	
1184	Ethylene Dichloride		3	3, 6.1	yes
1202	Diesel Fuel	Gas Oil, Light Heating Oil	3	3	
1203	Gasoline		3	3	
1230	Methanol	Methyl Alcohol	3	3	
1247	Methyl Methacrylate Monomer		3	3	
1263	Paint	Paint, lacquer, enamel, stain, shellac, varnish, polish, liquid filler, and liquid lacquer base	3	3	
1266	Perfumery Products (with Flammable Solvents)		3	3	
1267	Petroleum Crude Oil		3	3	
1268	Petroleum Distillates	Not otherwise specified (e.g., Naphtha, Raffinate, Petroleum Ether)	3	3	
1270	Petroleum Naphtha		3	3	
1279	Propylene Dichloride	1,2-Dichloropropane	3	3	yes
1288	Shale Oil		3	3	
1294	Toluene		3	3	
1863	Aviation Fuel	Jet Fuel, Turbine Engine Fuel	3	3	
1991	Chloroprene	Stabilized	3	3, 6.1	yes
1993	Flammable Liquid	Not otherwise specified[525]	3	3	
1987	Denatured Alcohol	Alcohols not otherwise specified	3	3	
1999	Liquid Tars	Road Asphalt, Bitumen, Cut Backs	3	3	
2047	Dichloropropene		3	3	yes
2055	Styrene Monomer Stabilized		3	3	
2762	Organochlorine Pesticide Liquid	Flammable, toxic, flash-point less than 23°C	3	3, 6.1	
3295	Octene	1-Octene	3	3	
3475	Ethanol and Gasoline Mixture		3	3	

523 USDOT.
524 ES = classified as "environmentally-sensitive" chemical.
525"Not otherwise specified" is generally abbreviated casinos."

Table 153: Labeling and Classification on Rail Cars for Additional Hazardous Materials[526]

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
1005	Anhydrous Ammonia	Liquefied	2.2	2.2, SP13	yes
1008	Boron Trifluoride		2.3	2.3, 8	
1009	Refrigerant Gas R-13B1	Bromotrifluoromethane	2.2	2.2	yes
1010	Butadienes		2.1	2.1	
1011	Butane		2.1	2.1	
1017	Chlorine		2.3	2.3, 5.1, 8	
1018	Refrigerant Gas R-22	Chlorodifluoromethane	2.2	2.2	yes
1020	Refrigerant Gas R-115	Chloropentafluoroethane	2.2	2.2	yes
1021	Refrigerant Gas R-124	Chlorotetrafluoroethane	2.2	2.2	yes
1022	Refrigerant Gas R-13	Chlorotrifluoromethane	2.2	2.2	yes
1026	Cyanogen		2.3	2.3. 2.1	
1028	Refrigerant Gas R-12	Dichlorodifluoromethane	2.2	2.2	yes
1030	Refrigerant Gas R-152a	Difluoroethane	2.1	2.1	yes
1032	Dimethylamine (Anhydrous)	Dimethyl Ether	2.1	2.1	
1035	Ethane		2.1	2.1	
1036	Ethylamine	Monoethylamine	2.1	2.1	
1037	Ethyl chloride		2.1	2.1	yes
1038	Ethylene	Refrigerated liquid	2.1	2.1	
1039	Ethyl Methyl Ether		2.1	2.1	
1040	Epoxyethane	Ethylene Oxide with Nitrogen, Oxirane	2.3	2.3, 2.1	
1041	Ethylene Oxide/Carbon Dioxide Mixture	More than 9 percent but not more than 87 percent ethylene oxide	2.1	2.1	
1045	Compressed Fluorine		2.3	2.3, 5.1, 8	
1048	Hydrogen Bromide	Anhydrous	2.3	2.3. 8	
1049	Compressed Hydrogen		2.1	2.1	
1050	Hydrogen Chloride	Anhydrous	2.3	2.3, 8	
1051	Hydrogen Cyanide	Stabilized, less than 3 percent water	6.1	6.1, 3	yes
1052	Hydrogen Fluoride	Anhydrous	8	8, 6.1	yes
1053	Hydrogen Sulfide		2.3	2.3, 2.1	
1055	Isobutylene	Isobutene, 2-Methylpropene	2.1	2.1	
1060	Methylactylene/Propadiene Mixture		2.1	2.1	
1061	Anhydrous Methylamine		2.1	2.1	
1062	Methyl Bromide	Not more than 2 percent Chloropicrin	2.3	2.3	

[526] USDOT.
[527] SP13 = Inhalation Hazard Special Provision 13.
[528] ES = classified as "environmentally-sensitive" chemical.

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
1063	Refrigerant Gas R-40	Methyl Chloride	2.1	2.1	yes
1064	Methyl Mercaptan		2.3	2.3, 2.1	
1067	Nitrogen Dioxide	Dinitrogen Tetroxide	2.3	2.3, 5.1, 8	
1069	Nitrosyl Chloride		2.3	2.3, 8	
1071	Compressed Oil Gas		2.3	2.3, 2.1	
1075	Liquefied Petroleum Gas (LPG)	Butane, LPG, Propane, Butylene, Isobutane, Isobutylene, Propylene	2.1	2.1	
1076	Phosgene		2.3	2.3, 8	
1077	Propene		2.1	2.1	
1078	Refrigerant Gas	Not otherwise specified, Dispersant gas not otherwise specified	2.2	2.2	yes
1079	Sulfur Dioxide		2.3	2.3	
1081	Tetrafluoroethylene		2.1	2.1	
1082	Refrigerant Gas R-1113	Chlorotrifluoroethylene, Trifluorochloroethylene	2.3	2.3, 2.1	
1085	Vinyl Bromide	Stabilized	2.1	2.1	
1086	Vinyl Chloride	Stabilized	2.1	2.1	
1092	Acrolein	Stabilized	6.1	6.1, 3	yes
1338	Phosphorus	Amorphous, Red Phosphorus	4.1	4.1	yes
1381	Phosphorus	White dry, white under water, white in solution, yellow dry, yellow under water, yellow in solution	4.2	4.2, 6.1	yes
1490	Potassium Permanganate		5.1	5.1	yes
1499	Potassium Nitrate/Sodium Nitrate Mixtures		5.1	5.1	yes
1581	Methyl Bromide/Chloropicrin Mixture		2.3	2.3	
1582	Methyl Chloride/Chloropicrin Mixture		2.3	2.3	
1589	Cyanogen Chloride	CK	2.3	2.3	
1591	o-Dichlorobenzene		6.1	6.1	
1593	Methylene Chloride	Dichloromethane	6.1	6.1	yes
1605	Ethylene Dibromide		6.1	6.1	yes
1612	Hexaethyl Tetraphosphate/ Compressed Gas Mixture		2.3	2.3	
1613	Hydrocyanic Acid	Aqueous solutions less than 20 percent hydrogen cyanide	6.1	6.1	yes
1647	Ethylene Dibromide/Methyl Bromide Mixture		6.1	6.1	yes
1660	Nitric Oxide		2.3	2.3, 5.1, 8	
1710	Trichloroethylene		6.1	6.1	yes

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
1741	Boron Trichloride		2.3	2.3, 8	
1744	Bromine/Bromine Solutions		8	8, 6.1	yes
1779	Formic Acid	More than 85 percent acid by mass	8	8, 3	yes
1790	Hydrofluoric Acid	Solution	8	8, 6.1	yes
1814	Potassium Hydroxide	Caustic Potash	8	8	
1823	Sodium Hydroxide	Caustic Soda	8	8, 6.1	
1829	Sulfur Trioxide	Stabilized or uninhibited	8	8	yes
1846	Carbon Tetrachloride		6.1	6.1	yes
1858	Refrigerant Gas R-1216	Hexafluoropropylene	2.2	2.2	yes
1859	Silicon Tetrafluoride		2.3	2.3. 8	
1860	Vinyl Fluoride	Stabilized	2.1	2.1	
1888	Chloroform		6.1	6.1	yes
1897	Perchloroethylene	Tetrachloroethylene	6.1	6.1	yes
1907	Soda Lime	Sodium Hydroxide/Calcium Oxide	8	8	
1911	Diborane		2.3	2.3, 2.1	
1912	Methyl Chloride/Methylene Chloride Mixture	Methylene Chloride/Chloroform Mixture	2.1	2.1	yes
1954	Compressed Gas (Flammable)	Not otherwise specified	2.1	2.1	
1957	Deuterium (Compressed)	Heavy Hydrogen	2.1	2.1	
1958	Refrigerant Gas R-114	1,2-Dichloro-1,1,2,2-Tetrafluoroethane	2.2	2.2	yes
1959	Refrigerant Gas R-1132a	1,1-Difluoroethylene	2.2	2.2	yes
1961	Ethane	Refrigerated liquid, Ethane-Propane Mixture	2.1	2.1	
1962	Ethylene		2.1	2.1	
1964	Compressed Hydrocarbon Gas Mixture	Not otherwise specified	2.1	2.1	
1965	Liquefied Hydrocarbon Gas Mixture	Not otherwise specified	2.1	2.1	
1966	Refrigerated Liquid Hydrogen		2.1	2.1	
1969	Isobutane		2.1	2.1	
1971	Compressed Methane	Compressed Natural Gas	2.1	2.1	
1972	Liquefied Natural Gas (LNG)	Refrigerated Methane Liquid	2.1	2.1	
1973	Refrigerant Gas R-502	Chlorodifluoromethane and Chloropentafluoroethane Mixture	2.2	2.2	yes
1974	Refrigerant Gas R-12B1	Chlorodifluorobromomethane	2.2	2.2	yes
1975	Nitric Oxide/Nitrogen Dioxide or Dinitrogen Tetroxide Mixture		2.3	2.3, 5.1, 8	
1976	Refrigerant Gas R-318	Octafluorocyclobutane	2.2	2.2	yes

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
1978	Propane		2.1	2.1	
1982	Refrigerant Gas R-14	Tetrafluoromethane	2.2	2.2	yes
1983	Refrigerant Gas R-133a	1-Chloro-2.2.2-Trifluoroethane	2.2	2.2	yes
1984	Refrigerant Gas R-23	Trifluoromethane	2.2	2.2	yes
2014	Hydrogen Peroxide	Aqueous solutions greater than 20 percent but not more than 60 percent Hydrogen Peroxide	5.1	5.1, 8	yes
2015	Hydrogen Peroxide	Aqueous solutions, stabilized, more than 60 percent hydrogen peroxide	5.1	5.1, 8	yes
2023	Epichlorohydrin		6.1	6.1, 3	yes
2031	Nitric Acid	Other than red fuming	8	8, 5.1	yes
2034	Compressed Hydrogen/Methane Mixture		2.1	2.1	
2035	Refrigerant Gas R-143a	1,1,1-Trifluoroethane	2.1	2.1	yes
2047	Dichloropropene		3	3	yes
2188	Hydrogen Arsenide	Arsine, SA	2.3	2.3, 2.1	
2189	Dichlorosilane		2.3	2.3, 2.1, 8	
2190	Compressed Oxygen Difluoride		2.3	2.3, 5.1, 8	
2191	Sulfuryl Fluoride		2.3	2.3	
2192	Germane or Germanium Hydride		2.3	2.3, 2.1	
2193	Refrigerant Gas R-116	Hexafluoroethane	2.2	2.2	yes
2194	Selenium Hexafluoride		2.3	2.3, 8	
2195	Tellurium Hexafluoride		2.3	2.3, 8	
2196	Tungsten Hexafluoride		2.3	2.3, 8	
2197	Hydriodic Acid	Hydrogen Iodide	2.3	2.3, 8	
2198	Phosphorus Pentafluoride		2.3	2.3, 8	
2199	Phosphine	Phosphoretted Hydrogen	2.3	2.3, 2.1	
2200	Allene	Propadiene	2.1	2.1	
2202	Hydrogen Selenide	Hydroselenic Acid	2.3	2.3, 2.1	
2203	Hydrogen Silicide	Silane	2.1	2.1	
2204	Carbon Oxysulfide	Carbonyl sulfide	2.3	2.3, 2.1	
2418	Sulfur Tetrafluoride		2.3	2.3, 8	
2420	Hexafluoroacetone		2.3	2.3. 8	
2421	Nitrogen Trioxide		2.3	2.3, 5.1, 8	
2422	Refrigerant Gas R-1318	Octafluorobut-2-ene	2.2	2.2	yes
2424	Refrigerant Gas R-218	Octafluoropropane	2.2	2.2	yes
2447	Phosphorus	White molten, White Phosphorus	4.2	4.2, 6.1	yes
2452	Ethylacetylene	Stabilized	2.1	2.1	

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
2453	Refrigerant Gas R-161	Ethyl Fluoride or Fluoroethane	2.1	2.1	yes
2454	Refrigerant Gas R-41	Methyl Fluoride or Fluoromethane	2.1	2.1	yes
2517	Refrigerant Gas R-142b	Difluorochloroethane, 1-Chloro-1,1-Difluoroethane	2.1	2.1	yes
2534	Methylchlorosilane		2.3	2.3, 2.1, 8	
2599	Refrigerant Gas R-503	Chlorotrifluoromethane and Trifluoromethane azetropic mixture	2.2	2.2	yes
2601	Cyclobutane		2.1	2.1	
2602	Refrigerant Gas R-500	Dichlorodifluoromethane and Difluoroethane azetropic mixture	2.2	2.2	yes
2676	Antimony Hydride	Stibine	2.3	2.3, 2.1	
2831	Methyl Chloroform	1,1,1-Trichloroethane	6.1	6.1	yes
2901	Bromine Chloride		2.3	2.3, 5.1, 8	yes
3057	Perfluoroacetylchloride	Trifluoroacetyl Chloride	2.3	2.3, 8	
3083	Perchloryl Fluoride		2.3	2.3, 5.1	
3138	Refrigerated Ethyl, Acetylene, Propylene Mixture	At least 71.5 percent Ethylene with not more than 22.5 percent Acetylene and not more than 6 percent Propylene	2.1	2.1	
3149	Hydrogen Peroxide/ Peroxyacetic Acid Mixtures	Not more than 5 percent Peroxyacetic Acid, stabilized	5.1	5.1, 8	yes
3153	Perfluoro Methyl Vinyl Ether		2.1	2.1	
3154	Perfluoro Ethyl Vinyl Ether		2.1	2.1	
3159	Refrigerant Gas R-134a	1,1,1,2-Tetrafluoroethane	2.2	2.2	yes
3160	Toxic Liquefied Gas (Flammable)	Not otherwise specified	2.3	2.3, 2.1	
3161	Liquefied Flammable Gas	Not otherwise specified	2.1	2.1	
3162	Toxic Liquefied Gas	Not otherwise specified	2.3	2.3	
3167	Non-Pressurized Flammable Gas	Not otherwise specified	2.1	2.1	
3220	Refrigerant Gas R-125	Pentafluoroethane	2.2	2.2	yes
3252	Refrigerant Gas R-32	Difluoromethane	2.1	2.1	yes
3296	Refrigerant Gas R-227	Heptafluoropropane	2.2	2.2	yes
3307	Toxic Liquefied Gas (Oxidizing)	Not otherwise specified	2.3	2.3, 5.1	
3308	Toxic Liquefied Gas (Corrosive)	Not otherwise specified	2.3	2.3, 8	
3309	Toxic Liquefied Gas (Flammable, Corrosive)	Not otherwise specified	2.3	2.3, 2.1, 8	
3310	Toxic Liquefied Gas (Toxic, Oxidizing, Corrosive)	Not otherwise specified	2.3	2.3, 5.1, 8	
3312	Refrigerated Liquid Flammable Gas	Not otherwise specified	2.1	2.1	

UN Number	Substance Name	Further Description or Alternate Name(s)	Hazard Class	Required Label(s)[527]	ES[528]
3318	Ammonia Solutions	More than 50 percent ammonia	2.3	2.3	yes
3337	Refrigerant Gas R-404A		2.2	2.2	yes
3338	Refrigerant Gas R-407A		2.2	2.2	yes
3339	Refrigerant Gas R-407B		2.2	2.2	yes
3340	Refrigerant Gas R-407C		2.2	2.2	yes
3354	Flammable Insecticide Gas	Not otherwise specified	2.1	2.1	
3374	Acetylene	Solvent free	2.1	2.1	
3412	Formic Acid	10 percent to 85 percent acid by mass	8	8	yes

The correct identification and labeling of the hazardous contents of rail tank cars (and other rail cars) are essential for four main reasons:

- Operators of trains that contain one or more cars with certain types of hazardous substances (called "key trains") need to follow additional precautionary operating procedures and regulations.
- In the event of an accident or emergency situation, first responders and rail crews need to be aware of the contents of the tank cars to plan for response operations and protect human health and safety.
- Railyard crews need to be aware of the contents of the cars in order to place them in the safest positions in the train consist (sequence of cars), because some substances should not be placed adjacent to cars carrying other substances that may react in the event of an accident or leak, and some cars require "buffer" cars.
- Some tank cars are used for multiple substances, but it is important to consider any residue that remains in the tank car from its previous load.

Other markings on outside of rail tank cars and other cars

In addition to any required hazardous material placards, tank cars have a large number of other markings stenciled onto the tanks including:

- Reporting mark or number, load limit, and load weight on the left side.
- USDOT and AAR specification numbers, commodity, and qualification panel on the right side.
- Reporting mark or number, and capacity in gallons and liters on the heads.

The reporting mark identifies the car's owner and the car itself (akin to a license-plate number on an automobile). The reporting mark is an alpha code of one to five letters for the car's owner followed by a one- to six-digit car identification number. If the last letter of the owner code is an "X," that indicates that the car is privately owned and not the property of the operating railroad company. The reporting mark appears on the left side of the car (while facing it) and on both ends.

The load limit markings, which appear under the reporting marks on the left side of the car, show:

- LD LMT (Load Limit)–the maximum weight car and lading in pounds (LB), and kilograms, (KG); and
- LT WT (Light Weight)–the weight of the car without the lading (when empty) in pounds, (LB) and kilograms (KG).

The tank capacity (in U.S. gallons, GAL, and liters, L) is shown on both ends of the tank cars. Note that the capacity does not necessarily indicate the amount of product in the car. The amount in the car, if laden, will be somewhat less. The amount is determined by the weight of the product and allowances made for air space.

The specification mark marking found on the right side of the car. It will be a string of letters and numbers, such as: DOT-111A100ALW1. This specification shows:

- Authorizing agency (e.g., USDOT, AAR, TC).
- Tank car class number (e.g., 111, 117).
- Delimiter letter (which has no significance unless it is: J, P, R, S, or T, or Class 113A, C, or D).
- Tank test pressure (in pounds per square inch gauge, psig).
- Material of construction when that material is anything other than carbon steel.
- Fusion welding (W) or PIH/TIH material (I).[529]
- Fittings, linings, and materials.

For the example DOT-111A100ALW1, the markings denote:

- Authorizing agency: USDOT
- Tank class: 111
- Delimiter: A
- Tank test pressure: 100 psig
- Material of construction Aluminum (AL)
- Fusion welding, W
- Fittings, linings, and materials: 1

Other rail cars also have load limit markings.

Shipping papers and waybills

For safety and practical purposes, freight rail carriers need to track a variety of information for each and every hazardous material car on every train, including:

- Contents of the car
- Emergency response information
- Car status (loaded or residue/empty)[530]
- Position in a train consist
- Origin, destination, and route

[529] PIH/TIH = Poison Inhalation Hazard/Toxic Inhalation Hazard
[530] An “empty” tank car or hopper car may still have some residue of its previous cargo that may present a hazard.

This is done with various types of shipping papers and waybills. Shipping papers are required to include the following information:

- Reporting mark (e.g., GATX 218668).
- Quantity notification (e.g., 1 T/C for one tank car, 1 C/L for one car load; or weight or volume).
- Proper shipping name (e.g., Chlorine or Sulfuric Acid), including any appropriate concentrations, and, if designated "NOS" or "not otherwise specified" in the Hazard Class or UN number, the actual name — e.g., "Corrosive Liquid, NOS (Capryl Chloride).
- If the tank car is empty, it must include phrase "Residue: Last contained:"
- Hazard Class.
- UN identification number.
- Packing group (PGI, PGII, PGIII).[531]
- Emergency response telephone number.
- Emergency response information (as in the *Emergency Response Guide*, USDOT PHMSA 2016).
- Position in train (may be in a separate document).

A "radio waybill" may take the place of a written document. The information is provided by radio or telephone to a dispatcher.

Key train identification

A key train is any train that falls under one of the following categories (AAR 2011):

- One or more loads of spent nuclear fuel or high-level radioactive waste.
- Five or more loaded tank cars containing materials that require the phrase "POISON/TOXIC-INHALATION HAZARD" on shipping papers (i.e., Class 2.3 or Class 6.1).
- Five or more loaded tank cars of anhydrous ammonia (Identification Number 1005) or ammonia solutions (Identification Number 3318), or twenty or more loaded tank cars or intermodal portable tank loads of flammable gas (Division 2.1), Division 1.1 or 1.2 explosives, or environmentally-sensitive chemicals.

[531] Exceptions: Classes 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 2.1, 2.2, 2.3, 4.1 (self-reactive liquids or solids, types B-F), 5.2, 6.2, 7, and ORM-D do not require the packing group notation. In addition, the following identification numbers from Classes 3, 4.2, 4.3, 5.1, 8 and 9 do not require the packing group notation:, NA1365, UN3121, UN3269, UN3343, N3477, UN2426, UN3127, UN3316, UN3363, UN2990, UN3166, UN3334, UN3473, UN3072, UN3171, UN3335, or UN3476.C.