Final
Engineering Design Report

Volume 1
(Text, Tables, Appendices)

September 9, 2014

Laurel Station
1009 East Smith Rd.
Bellingham, WA

Trans Mountain
Pipeline
(Puget Sound) LLC

URS

URS

FINAL
ENGINEERING DESIGN REPORT
LAUREL STATION
1009 EAST SMITH ROAD
BELLINGHAM, WASHINGTON

For

Trans Mountain Pipeline (Puget Sound) LLC
URS Job No.: 33764321

September 9, 2014

URS

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Mr. David South
Senior Engineer
Toxics Cleanup Program
Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008–5452

Final Engineering Design Report
Laurel Station
1009 East Smith Road
Bellingham, Washington
URS Job No.: 33764321

Dear Mr. South:

Presented herein is the final engineering design report for the above referenced property. This report was prepared in accordance with Consent Decree 14-2-01294-9, effective June 5, 2014. It was prepared by URS Corporation on behalf of Trans Mountain Pipeline (Puget Sound) LLC, which is operated by Kinder Morgan Canada. Please contact us if you have any questions or require additional information.

Sincerely,
URS Corporation

Karen Mixon
Project Manager

Cary Brown
Project Engineer

cc: Mike Droppo, Environmental Manager, Kinder Morgan Canada
Cris Matthews, Washington State Department of Ecology

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ABBREVIATIONS AND ACRONYMS

acfm	actual cubic feet per minute
ARAR	applicable or relevant and appropriate requirement
ARI	Analytical Resources, Inc.
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAP	cleanup action plan
CMP	Compliance Monitoring Plan
COCs	chemicals of concern
cleanup levels	CULs
cy	cubic yards
DPE	dual-phase extraction
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
EPH	extractable petroleum hydrocarbons
GAC	granulated activated carbon
gpm	gallons per minute
HCID	Hydrocarbon Identification
mg/kg	milligram per kilogram
MW	monitoring well
NPDES	National Pollutant Discharge Elimination System
PAHs	polycyclic aromatic hydrocarbons
PV	passive vent
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QC	quality control
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
ROI	radius of influence
SCB	soil, cement, and bentonite
Site	Laurel Station facility
SSR	Strategic Source Removal
TESC	temporary erosion and sediment control measures
TP	test pit
TPH	total petroleum hydrocarbons
TM	Trans Mountain
Trans Mountain	Trans Mountain Pipeline (Puget Sound) LLC
URS	URS Corporation
VPH	volatile petroleum hydrocarbons
WAC	Washington Administrative Code

1.0 INTRODUCTION

Presented herein is the final engineering design report (EDR) to support the implementation of the cleanup action to address petroleum-related contamination in soil and perched groundwater present at Trans Mountain Pipeline (Puget Sound) LLC's Laurel Station facility. The facility is located at 1009 East Smith Road in Bellingham, Washington (Site, **Drawing GA1010**). The Site is owned by Trans Mountain Pipeline (Puget Sound) LLC, hereafter referred to as Trans Mountain. It is currently operated by Kinder Morgan Canada.

The work to be performed is required under Consent Decree No. 14-2-01294-9 between Washington State Department of Ecology (Ecology) and Trans Mountain. The Cleanup Action Plan (CAP) is included as Exhibit A to the Consent Decree. The CAP provides a summary of site conditions, cleanup standards, and a description of the selected cleanup action. The cleanup action to be conducted at the site is based on the remedial investigation/feasibility study (RI/FS) completed for the site in 2013 (URS 2014a).

The cleanup is being overseen by Ecology. The Site is listed in Ecology's Integrated Site Information System under the following:

- Facility Site Name: Laurel Station (Alternate Names: Laurel Pump Station and Trans Mountain Oil Pipe Line)
- Facility Address: 1009 East Smith Road, Bellingham, Washington 98226-9765, Whatcom County
- Facility Site Identification Number (FSID): 2893
- Cleanup Site Identification Number (CSID): 102

The CAP, EDR, Engineering Specifications and associated plans (including the Compliance Monitoring Plan [CMP]) provide the information necessary to implement the selected cleanup action.

1.1 DOCUMENT PURPOSE AND CONTENT

The purposes of this document are to provide the engineering concepts and design criteria that provide the basis for the design of the cleanup action, and to summarize at an appropriate level of detail, administrative and technical procedures necessary to implement the cleanup action presented in the CAP. The remedial design package (and ancillary documents) consisting of the CAP, EDR (with drawings), specifications, and supplemental plans includes the detail to provide direction to selected contractors to implement the components of the cleanup action so that the cleanup goals are met, the work is performed using sound environmental practices and compliant with local, state, and federal laws, and the safety of contractors, facility personnel and the public is protected for the duration of the cleanup action.

To accomplish the above purposes, this document contains:

- The project objective and scope, summary of the cleanup action, and the organization and responsibility of primary parties involved/supporting the implementation of the cleanup action (Section 1.0)

- A summary of site conditions (Section 2.0)

- The basis of design, including cleanup levels and points of compliance as described in the CAP, substantive requirements and permits as associated with applicable local, state and federal laws, summary of affected media, chemicals of concern (COCs), nature and extent of contamination, and brief descriptions of the cleanup technologies that will be used during the cleanup action (Section 3.0)

- A description of individual design elements including site preparation/restoration, excavation methods and limits, material handling and disposal, installation of the dual-phase extraction (DPE) system, and sampling and analysis components to support field decisions during construction (Section 4.0)

- A summary of site management components including health and safety, access and staging areas, environmental protection and housekeeping requirements, documentation, and post-construction notifications and monitoring (Section 5.0)

- A description of how construction quality assurance will be addressed (Section 6.0)

- A preliminary schedule for field activities (Section 7.0)

- References (Section 8.0)

The RI/FS was conducted based on an approved work plan (URS 2010a) and work plan addenda (URS 2010b, 2011a, b, and c, 2012). The RI/FS was completed in 2013 and the final RI/FS report was approved by Ecology in June 2014 (URS 2014a). The CAP was based on the RI/FS report and was final as of June 5, 2014. The site history, environmental data collection and results, and the selection process and supporting detail for the cleanup action are presented in detail in these documents. To minimize unnecessary duplication of information, the detailed information in these documents is not repeated in the EDR, but the documents are referenced as needed. Brief descriptions of sampling and analyses to support the cleanup action are presented in the EDR, but details for sampling procedures, selected analyses, and associated quality assurance procedures are compiled in the CMP for the cleanup action. The CMP is presented as a stand-alone document as this document will support the construction period as well as post-construction monitoring.

Documents are available on Ecology's Laurel Station web site at https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=102.

Click on View Electronic Documents in the right sidebar.

1.2 PROJECT OBJECTIVE AND SCOPE

1.2.1 Objective

The purpose of the cleanup action is to remove or treat soil contaminated with petroleum-based constituents that are above site-specific cleanup levels for total petroleum hydrocarbons (TPH, gasoline-, diesel-, and heavy oil-range) in three areas located on the facility property – Pump Station Area, Tank 180 Area, and Material Storage Area – SU3-B7 (**Drawing GA1012**). Perched groundwater containing TPH and polycyclic aromatic hydrocarbons (PAHs) above groundwater cleanup levels is present in the Pump Station Area. The cleanup action is intended to address the affected perched groundwater in this area and reduce TPH and PAHs to below soil and groundwater cleanup levels specified in the CAP. At completion of the cleanup action, soil and perched groundwater in these three areas will meet the cleanup levels at the points of compliance as specified in the CAP or the areas (or portions of areas) will be placed under environmental restrictive covenants until such time that the contaminated media are accessible for removal or treatment. The methods that will be used to implement the cleanup action are described in this report.

1.2.2 Scope

The scope of the cleanup action includes:

- Preparation of the design package
- Procurement of contractors
- Construction management and engineering support
- Permitting and agency liaison
- Mobilization and preparation of access and staging areas
- Well abandonment within the excavation footprint (Pump Station Area only)
- Rerouting/protection of utilities and structures as needed and restoration following construction (Pump Station Area only)
- Excavation of accessible contaminated soil in the Pump Station Area and the Materials Storage Area
- Backfill of excavations with clean material
- DPE and passive vent well installation (Pump Station Area only)
- DPE system installation (Pump Station Area only)
- Installation of vapor and water treatment system for effluent from DPE system (Pump Station Area only)

- Installation of asphalt cap, expansion of storm drain system, addition of new drainage ditches/systems to reduce surface water infiltration (Pump Station Area only)

- Characterization, transport and disposal of excavated soil

- Restoration of access, staging, and work areas

- Demobilization

- Contractor reporting and closeout submittals (e.g., Record Drawings)

As described in the CAP, a field investigation to verify shallow soil contamination previously found in an area located in the southwest corner of the Pump Station Area associated with the former drain tile was completed in July 2014 (**Drawing GA1013,** locations TM-B11 and TP-9**)**. The results were reported to Ecology in a letter report dated August 26, 2014 (URS 2014c) and are summarized in Section 3.3.4. The report is provided in **Appendix A**.

1.3 SUMMARY OF CLEANUP ACTION

Three areas on the facility are identified for cleanup – Pump Station Area, Tank 180 Area, and the Material Storage Area – SU3-B7 (**Drawing GA1012**). The Pump Station Area is most complex as both soil and perched groundwater require cleanup in this area and these affected media are located within or adjacent to facility infrastructure. The Tank 180 Area and Material Storage Area – SU3-B7 only require cleanup of soil and are more limited in extent.

The cleanup action for each area is dictated by the conditions and extent of contamination in each.

1.3.1 Tank 180 Area and Material Storage Area – SU3-B7

The TPH-affected soil present under Tank 180 Area does not extend beyond the footprint of the tank (**Drawing GA1012**). The tank is permanent infrastructure and will be operational for the foreseeable future. This area will be placed under environmental restrictive covenant with no action until the tank is removed and the contaminated soil is accessible. The soil will be removed if TPH concentrations at the time of tank removal are above cleanup levels.

TPH-contaminated soil above cleanup levels in the Material Storage Area – SU3-B7 will be removed by excavation (**Drawings GA1012, GA1016**). Following excavation, soil samples will be collected from sidewalls and the base of the excavation and tested for TPH as indicated in the CMP. If soil is above cleanup levels following initial excavation, additional excavation will be conducted until cleanup levels are achieved as determined by analytical testing. The excavation will be backfilled with soil that has been tested and determined to be below soil cleanup levels for TPH and BTEX. Contaminated soil will be transported and disposed offsite at an appropriately licensed facility.

1.3.2 Pump Station Area

The soil cleanup action for the former oily water sump treatment area (former oily water sump and pump station building) within the Pump Station Area (**Drawing GA1012**) includes elements to reduce surface water infiltration to reduce perched groundwater beneath the area, removal of accessible soil using a combination of trench and slurry methods (referred herein as "Strategic Source Removal" or "SSR") and conventional excavation methods, and installation of a DPE system to treat remaining contaminated soil and perched groundwater. Soil in inaccessible locations under the piping manifold shelter secondary containment unit and the pump station building will be treated in situ using DPE. A low-permeability backfill will be used in the excavation to enhance the DPE system efficiency. Institutional controls will be placed on the portions of the Pump Station Area where residual COCs remain in place above cleanup levels because of access limitations. Vapor and groundwater removed with the DPE system will be treated to meet air emission and water discharge requirements.

Sampling and analysis to confirm the areas/concentrations of COCs in soil remaining post-excavation, to confirm best screen placement of DPE wells, to assess the effectiveness of the treatment system, and to monitor/confirm the progress of the cleanup action will be conducted as described in the CMP.

1.4 ORGANIZATION AND RESPONSIBILITY

The project team will consist of personnel from Trans Mountain, URS Corporation (URS), contractors to Trans Mountain and URS, and Analytical Resources Inc. (ARI, contract laboratory) as shown in **Table 1**. URS is the design lead and will serve Trans Mountain in the role of environmental consultant. Ecology will provide regulatory oversight of the cleanup action. Multiple contractors and subcontractors will be necessary to complete the components of the cleanup action. The various contractors and subcontractors will be selected after finalization of the design package. Contractor contact information will be provided to Ecology when available. The following paragraphs describe the major positions and responsibilities of the team for design and construction. Construction quality assurance is discussed in Section 6.0. Key project personnel and regulatory personnel and their responsibilities for Quality Assurance (QA) activities are described below.

1.4.1 Project Coordinator

The Project Coordinators are Mike Droppo for Trans Mountain and Cris Matthews for Ecology. The project coordinators are responsible for overseeing the implementation of the cleanup action per the Consent Decree and associated documents. To the maximum extent possible, all communications between Ecology and Trans Mountain and all documents should be directed through the Project Coordinators. These documents include but are not limited to reports, work plans, designs, and other correspondence concerning the activities performed pursuant to the consent decree. The project coordinator may designate, in writing, other staff contacts as necessary for all or parts of the work to be performed. If Ecology or Trans Mountain changes Project Coordinators, written notification will be provided to Ecology or Trans Mountain at least 10 calendar days prior to the change.

1.4.2 Project Manager

The Project Managers are Mike Droppo for Trans Mountain and Karen Mixon for URS. The project managers, with assistance from the Project Engineers, will be responsible for management and implementation of all aspects of the design and construction. Specific responsibilities include review and approval of work products, ensuring that appropriate design and construction procedures are followed, reporting of deviations from the Ecology-approved design to the Project Coordinators, and ensuring that the data collected will satisfy the cleanup action objectives. Trans Mountain will report substantive deviations from the design to the Ecology Project Coordinator in monthly or quarterly progress reports as indicated in the consent decree.

1.4.3 Project Engineer

The Project Engineers are Cary Brown for URS and Jennie McLeod for Trans Mountain. The URS project engineer is a professional engineer registered in the State of Washington responsible for the design and for observing and reviewing the construction for conformance to the design. The Project Engineer directs the design and construction management staff, interacts with the project Task Manager, and reports to the Project Manager. The URS Project Engineer will affix his PE stamp on the final design package.

The Trans Mountain project engineer works with the URS project engineer to ensure that the design and any field deviations are compliant with internal Trans Mountain standards and processes. She reports to the Trans Mountain Project Manager.

1.4.4 Design Staff

The design staff includes engineers and scientists from a variety of disciplines, including civil, structural, mechanical, electrical and geotechnical engineering, geology, and hydrogeology. The design staff works under the direction of the Project Manager and Project Engineer. The design staff will be available as needed to answer questions regarding the design during construction.

1.4.5 Construction Manager

The Construction Manager (CM) is yet to be identified but will be responsible for the following:

- Supervising the day-to-day performance of construction
- Directing/performing/documenting quality assurance activities (see Section 6.0)
- Overseeing sampling activities as specified in the CMP
- Communicating and documenting deviations from the approved plans.

1.4.6 Analytical Data QA/QC Manager

The URS Analytical Data QA/QC Manager, Christine Gebel, is responsible for developing and managing procedures described in the CMP, interfacing with the project laboratory and data quality assessment personnel, reviewing quality assurance/quality control (QA/QC) audit reports, coordinating audit procedures, implementing necessary corrective action procedures, reviewing and evaluating analytical laboratory results, reviewing data quality assessment reports, and submitting data to Ecology in accordance with the Consent Decree, including timely submittal for upload to Ecology's Environmental Information Management System. The URS Analytical Data QA/QC Manager reports to the URS Project Manager.

1.4.7 Analytical Laboratory Project Manager

The ARI analytical laboratory project manager, Kelly Bottem, is responsible for reviewing and reporting all analytical data generated during the project, responding to questions or concerns regarding the quality of the data that the URS project manager, analytical data QA/QC manager, or data quality assessment personnel may have, and implementing any corrective actions deemed necessary by these individuals with regards to laboratory operations.

1.4.8 Construction Contractor Superintendent

The construction contractor(s) for the cleanup action is yet to be determined. The selected firm(s) will be contracted directly to Trans Mountain and the contractor's job superintendent will be responsible for implementing the design and performing construction quality control per the approved plans and specifications (see Section 6.0).

2.0 SUMMARY OF SITE CONDITIONS

The general site description, geology, hydrogeology, surface water hydrogeology, release history, and operational history are provided in the RI/FS report (URS 2014a) and the CAP.

In summary, the Laurel Station facility is generally underlain by Bellingham Drift. The Bellingham Drift is a low permeability silty clay unit that is typically very stiff to hard. The Bellingham Drift restricts surface water infiltration across the site. In the area of the former oily water sump (Pump Station Area), the Bellingham Drift is not observed in soil borings and is interpreted to have been removed during grading for initial construction of the station. Based on data collected during the remedial investigation (RI) (URS 2014a), the perched shallow groundwater observed in the Pump Station Area is the result of surface water infiltration through the fill material where the Bellingham Drift was removed in the vicinity of the pump station and piping manifold. This perched water is detained by one or more lenses of low vertical permeability soils in the underlying glacial outwash. Contamination of the perched groundwater is due to contact with the contaminated soil in this area of the site. Groundwater was not encountered in the Tank 180 Area or the Material Storage Area where the Bellingham Drift is present.

The TPH found in the soil and groundwater is the result of historical releases of natural gas condensate and/or crude oil. No releases have been reported at the facility since October 2000.

The COCs at the Site are TPH in the gasoline-, diesel-, and heavy oil-ranges in soil and TPH (gasoline-, diesel-, and heavy oil-ranges) and PAHs in shallow perched groundwater. The areas and media that require cleanup at the Site are shown on **Drawings GA1012, GA1013, and GA1016** and include:

- Soil under the pump station building (Pump Station Area),
- Soil in proximity of the piping manifold (Pump Station Area) referred to as the former oily water sump area,
- A limited area of non-potable shallow perched groundwater that extends beneath, to the west and slightly east of the pump station and former oily water sump areas (Pump Station Area),
- Soil beneath Tank No. 180 (Tank 180 Area), and
- Soil within the Material Storage Area (SU3-B7).

Field verification of shallow soil contamination previously found in an area located in the southwest corner of the Pump Station Area associated with the former drain tile was conducted in July 2014 under an Ecology-approved work plan (URS 2014b). The area of concern is shown on **Drawing GA1013**. The results of the investigation were presented to Ecology in a letter report (URS 2014c) and are summarized in Section 3.3.4 and the report is provided in **Appendix A**. Based on the data, no cleanup action is warranted in this area.

3.0 BASIS OF DESIGN

3.1 CLEANUP LEVELS AND POINTS OF COMPLIANCE

Cleanup levels (CULs) have been established in the CAP for TPH and PAHs in soil and shallow perched groundwater at the Site. The development of the cleanup levels is discussed in Section 3.0 of the final RI/FS Report (URS 2014a). The cleanup standards (CULs and points of compliance) are presented in the CAP and summarized in **Table 2** of this EDR.

Cleanup levels were developed for TPH and PAHs as these are the COCs identified at the Site. Cleanup levels were developed also for benzene, toluene, ethylbenzene, and xylenes (BTEX) as these constituents have been detected at the Site and are associated with petroleum products. As site-specific cleanup levels are established for TPH, the analytical program will include analysis for volatile petroleum hydrocarbons (VPH), extractable petroleum hydrocarbons (EPH), gasoline-, diesel-, and oil-range petroleum hydrocarbons, BTEX, and PAHs so that the data can be used to determine if soils have achieved the cleanup levels for TPH. Analytical methods and associated project requirements for sampling and analysis are provided in the CMP.

3.2 APPLICABLE LOCAL, STATE, AND FEDERAL LAWS

Under Washington Administrative Code (WAC) 173-340-710, the Model Toxics Control Act requires that cleanup actions comply with all legally applicable state and federal laws and regulations and those requirements identified and determined to be applicable or relevant and appropriate requirement (hereinafter “ARARs”) for the site.

In accordance with WAC 173-340-710(9)(b), cleanup actions conducted under a consent decree are exempt from the procedural requirements of certain state and local laws. The cleanup action must still comply with the substantive requirements of the laws in accordance with WAC 173-340-710(9)(c). It is part of Ecology's role under a consent decree to ensure compliance with the substantive requirements. The applicable substantive requirements and permits for the Laurel Station cleanup action are listed in Exhibit D and Exhibit E of the Consent Decree. Persons conducting remedial actions have a continuing obligation to determine whether additional permits or approvals or substantive requirements are required. In the event that Ecology or Trans Mountain become aware of additional permits or approvals or substantive requirements, they shall promptly notify the other party of this knowledge (WAC 173-340-710[9][e]). At this time no additional permitting or substantive requirements have been identified beyond those indicated in Exhibits D and E of the Consent Decree.

3.3 AFFECTED MEDIA, CONSTITUENTS OF CONCERN, AND EXTENT OF CONTAMINATION

3.3.1 Pump Station Area

Soil containing TPH (gasoline-, diesel-, and heavy oil-range) and perched groundwater with TPH and PAHs above cleanup levels were identified in the Pump Station Area. The limits of contaminated soil associated with the former oily water sump and the pump station building and the limits of the affected perched groundwater are shown on **Drawing GA1013**. The surface at and surrounding the pump station building and former oily water sump area is capped with gravel or asphalt. Soil contamination above cleanup levels is present from approximately 4 feet to 15 feet below ground surface (bgs) beneath the pump station building and approximately 7 feet to 24 feet bgs in the former oily water sump area (**Drawing GA1014**). As described in the final RI/FS Report (URS 2014a), impacted shallow perched groundwater in the vicinity of the former oily water sump and pump station appears to be the result of surface water runoff infiltrating directly into the ground in this area due to removal of the Bellingham Drift. Contaminants present in the shallow perched groundwater are the result of direct contact of the groundwater with contaminated soil present beneath the pump station building and the former oily water sump area.

The mass of TPH present in the soil and groundwater volumes requiring cleanup were estimated in the RI/FS report (URS 2014a). Approximately 1,350 cubic yards (cy) of soil exceed the TPH CUL near the former oily water sump/pump station building with an estimated 29,500 pounds of TPH. Approximately 800,000 gallons of shallow perched groundwater exceed CULs with an estimated 33 pounds of TPH.

3.3.2 Tank 180 Area

A limited area of TPH-affected soil is present under Tank No. 180 (**Drawing GA1012**). Based on sampling conducted during the RI/FS, TPH contaminated soil is present on the north side beneath the tank footprint and does not extend beyond the footprint of the tank although the extent to the south is not delimited beneath the tank (see Figure 5 of the CAP). The tank is sitting on top of fill, which is on top of the Bellingham Drift. The TPH in the soil is not in direct contact with water, and any migration will be greatly retarded through the Bellingham Drift. As indicated previously, this area will be placed under environmental restrictive covenant.

3.3.3 Material Storage Area (SU3-B7)

This area currently has no surface capping. The lateral extent of petroleum contamination was not delimited during the RI; however the vertical extent was determined to be between 5 and 7 feet below ground surface (bgs, **Drawing GA1016**). Groundwater was not encountered and the COCs were TPH in soil. Boring SU3-B7 data indicates that the soil in this area is Bellingham Drift, which will limit vertical and lateral migration of COCs.

3.3.4 Field Verification – Southwest Corner of Pump Station Area

Two former locations, Test Pit TP-9 and boring TM-B11, associated with the former drain tile were not included for further investigation during the RI (**Drawing GA1013**). Previous data collected in November 1991 from TP-9 indicated field screening results for TPH of 2,000 mg/kg (milligram per kilogram) at 5 feet bgs, 900 mg/kg at 7 feet bgs, and 500 mg/kg at 10 feet bgs. At 15 feet bgs, field screening did not indicate presence of TPH. Affected soil was within a zone with water seepage through the soil at 5 feet bgs. The boring at TM-B11 was drilled in February 1992 to 65 feet bgs. TPH based on Ecology's Hydrocarbon Identification (HCID) method was 2,000 mg/kg at 5 feet bgs. Field screening at 15 feet bgs, 35 feet bgs, and 65 feet bgs did not indicate the presence of TPH. Groundwater was not encountered during drilling at TM-B11. Field verification of the historical results will be conducted as part of the site cleanup.

Field verification of shallow soil contamination previously found at locations TM-B11 and TP-9 was conducted in July 2014 under an Ecology-approved work plan (URS 2014b). The area of concern is shown on **Drawing GA1013**. The results of the investigation were presented to Ecology in a letter report (URS 2014c). Three direct-push borings (SB-1, SB-2, and SB-5) were advanced on July 29, 2014 to a depth of 15 feet bgs at the locations shown on **Drawing GA1015.** Field observations during drilling did not indicate presence of TPH-contamination. Soil samples collected from each boring at 5, 10, and 15 feet bgs were analyzed for gasoline-, diesel-, and heavy oil-range petroleum hydrocarbons and BTEX. TPH and BTEX were not detected above site cleanup levels. Based on these data, no cleanup action is warranted in the area of former locations TM-B11 and TP-9 and this area is not discussed further in this EDR.

3.4 CLEANUP METHODS

Multiple technologies will be used to conduct the cleanup action dependent upon the area.

3.4.1 Excavation Method – Strategic Source Removal

SSR excavation is a trench and slurry method that uses hydraulic pressure created from the addition of a slurry mix to an excavation to maintain the stability of the excavation walls. The slurry is added as the excavation proceeds and is then removed as the excavation is backfilled allowing continuous excavation with support of the excavation sidewalls. The backfill is a low permeability, high strength material consisting of a soil, cement, and bentonite (SCB) mixture.

The SSR method eliminates the need to install conventional shoring/support structure to stabilize the sidewalls of deep excavations.

The SSR excavation method will be used in the Pump Station Area near the Piping Manifold Shelter to provide structural support, on the perimeter of the excavation to support sidewalls, and in portions of the excavation where additional support will be required to continue excavation by conventional methods (**Drawing CE1011**). The excavation in this area is planned to a minimum depth of 20 feet to remove as much of the accessible contaminated soil as possible. The use of the SSR excavation method in this area results in less disruption to facility operations, reduction in schedule compared to conventional excavation, and flexibility in the excavation work flow around sensitive infrastructure. A description of locations where this method will be used and its application is presented in Section 4.4.2.

3.4.2 Excavation Method – Conventional

Conventional excavation methods will be used at the site to remove contaminated soil using an excavator in areas that do not require SSR methods. The soil removed will be transferred to truck or rail car for transport to an offsite disposal facility or the soil will be temporarily stockpiled prior to other use onsite or transfer offsite. The excavation will remain open until backfilled with soil that meets project requirements. All backfill sources will be sampled and tested for the site COCs. COCs, if present, must be below CULs.

Conventional excavation methods will be used in the Pump Station Area to remove the overburden on the hillside to accommodate space requirements for excavation of contaminated soil and to remove contaminated soil where the SSR excavation method is deemed unnecessary. Contaminated soil will also be removed by conventional excavation methods in the Material Storage Area. The areas where conventional excavation will be used are shown on **Drawings CE1011 and CE1012**. Locations and application of conventional excavation methods are described in Section 4.4.1.

3.4.3 Dual-Phase Extraction System

For the purposes of this EDR, DPE is an in situ treatment method that extracts both vapors and contaminated perched groundwater from soil using vacuum extraction. The extracted vapors and groundwater are separated and subsequently treated to remove COCs below threshold limits for air emission and discharge requirements for treated water.

One DPE system will be installed in the Pump Station Area to remove TPH constituents from two locations with contaminated soil that is not accessible for removal by excavation. The target areas are beneath the Pump Station Building and the Piping Manifold Shelter. The DPE system will also remove and treat perched groundwater within the treatment zone. The extent of DPE treatment is shown on **Drawing CE1015**.

The DPE system installation and performance are described in Section 4.5.

3.4.4 Reduction of Surface Water Infiltration

Surface water infiltration will be reduced in the former oily water sump treatment area within the Pump Station Area with the installation of hydraulic asphalt concrete and drainage structures associated with the new retaining wall. The low permeability hydraulic asphalt concrete will replace existing gravel surface surrounding the Piping Manifold Shelter. This will reduce surface water infiltration in the area where contaminated soil remains that could not be removed by excavation. Runoff from the hillslope above the newly constructed two tiered retaining wall will be captured in a surface swale and perforated drain pipe placed on an impervious geomembrane layer. Infiltrated flow behind the walls will be captured in a perforated drain pipe at the base of the lower tier of the retaining wall. The reduction of surface water infiltration reduces the amount of groundwater that could become contaminated if in contact with contaminated soil, reduces the volume of water that is introduced to the DPE system, and increases the overall efficiency of the DPE treatment of soil.

3.4.5 Institutional Controls

Institutional controls will be implemented for those areas where removal or treatment of petroleum affected media are not possible during the primary construction phase of the CAP and contamination above CULs remain. The areas where institutional controls are applied will be identified post-construction at the time the Completion Report is submitted to Ecology. The institutional controls will be documented in a draft Environmental (Restrictive) Covenant submitted to Ecology for approval. Once Ecology approval is obtained, the Environmental Covenant will be recorded and proof of recording will be submitted to Ecology.

4.0 DESIGN ELEMENTS

4.1 SURVEY AND BASE MAP DEVELOPMENT

Two land surveys were performed in January and May 2014 to refine the site base map. The additional surveys documented locations for natural and man-made site features, above ground and underground utilities, and provided topography with 1-foot intervals in the Pump Station Area. A utility locate was performed to mark traceable subsurface electrical, communication, water, sewer (storm and sanitary), and fuel lines prior to the land survey. The existing site conditions and utilities captured by the land survey are shown on **Drawing GA1013**.

The survey included the following natural and man-made features:

- Retaining wall
- Quarry spalls along hillside
- Building corners (Pump Station Building, Piping Manifold Shelter, Cold Storage Building, etc.)
- Road edge and centerline

- Monitoring well locations
- Limits of paved and/or gravel parking lots and driveways
- Catch basins
- Bollards and steel posts
- Fences
- Existing Trees
- Underground utilities (marked on the surface by the utility locator)

The survey and utility locate were performed by Larry Steele and Associates, Inc. Laurel Station employees also performed utility locates in the area in May 2014 prior to the second survey. Survey data were generated in U.S. Survey Foot coordinates in North American Datum of 1983, 2012A Correction, and North American Vertical Datum of 1988.

4.2 SITE PREPARATION

Subject to Ecology approval, the field work is expected to begin in September 2014 with the intent to conduct excavation work during the dry season. Based on current site conditions, site preparation will include the following in the Pump Station Area:

- Establish staging areas
- Identify access and haul road traffic routes
- Install temporary erosion and sediment controls
- Cut, cap, remove, and reroute utility connections
- Install physical barrier along the east end of the piping manifold structure to protect piping from construction equipment
- Remove select steel infrastructure and steel posts associated with the Piping Manifold Shelter and install temporary structural supports
- Remove bollards and concrete footings to clear the work area
- Abandon wells within the excavation footprint and as needed within the work area
- Remove the retaining wall

Site preparation activities and locations are shown on **Drawings GA1017 and CE1010**.

Site preparation activities necessary to complete excavation in the Material Storage Area will include the following:

- Establish staging areas
- Identify access and haul road traffic routes
- Install temporary erosion and sediment controls

Based on prior surveys, no utilities or structures are believed to be present in the planned excavation footprint in the Material Storage Area.

4.2.1 Work Limits and Staging Areas

Two staging areas will be established for storage of supplies and equipment during the construction phase. The selection of two staging areas is based on location of construction activities at the site. The facility construction entrance on East Smith Road and current road into the facility will be used to access the staging areas (**Drawing GA1012**).

The primary staging area is approximately 300 feet south of the Pump Station Area and is sized to accommodate equipment, facilities, and supply inventory to conduct all construction activities for both the Pump Station Area and the Material Storage Area (**Drawing GA1012**). A second staging area will be established closer to the excavation footprint in the Pump Station Area to locate equipment and supplies needed for a slurry processing plant used for SSR excavations and mixing SCB backfill.

All staging areas will be restored to pre-staging conditions following construction as these areas will not be needed once excavation work is completed and the DPE system is installed and operational.

Work limits encompass all of the areas where project activities are anticipated to occur. The work limits include areas where staging, excavation, well drilling, construction, and treatment will be performed as well as access and haul roads. No intrusive work or permanent changes will be made to the site outside of the construction limits without written approval from Trans Mountain.

The active work limits for the Pump Station Area are shown on **Drawing GA1017**. The active work limits include the excavation footprint, surrounding work area, and the area where subsurface and aboveground DPE system components will be installed. The Material Storage Area active work limits encompass the area where excavation of contaminated soil will be completed.

4.2.2 Utility Locate and Reroutes

Prior to conducting any intrusive work at the site, private utility locates will be conducted to identify locations of underground utilities. Utility locates will be conducted in all work areas where excavation, trenching and drilling will occur. The design requires that utilities in the pump station excavation area be disconnected, capped or rerouted per the Drawings. Shallow excavation work will be done around the utility locates to find the underground utilities prior to capping and rerouting. Utilities to be capped and rerouted are shown on **Drawing CE1010**. There are no known underground utilities at the Material Storage Area.

4.2.3 Site Clearing and Grubbing

No site clearing or grubbing will be required in the Pump Station Area or the Material Storage Area. In the Pump Station Area, grass and one foot of topsoil on the hillside that lies within the excavation limits will be removed, segregated and incorporated into a clean fill stockpile to be re-used as topsoil for hydroseeding once construction activities are completed. Trees on the hillside previously identified for removal in the CAP were removed in May 2014 by Trans Mountain during facility maintenance.

4.2.4 Temporary Erosion Controls

Erosion controls will be necessary to protect the environment during construction activities. Temporary erosion and sediment control measures (TESC) will comply with the substantive requirements of the Whatcom County Code Chapter 20.80.634 Stormwater Conformance and Stormwater Manual for Western Washington. Because of the potential for rainfall to cause erosion and transport eroded soil to stormwater, catch basins will be protected with filter baskets, and the downgradient perimeters of construction areas will be bordered by straw bales. Straw wattles may also be used immediately adjacent to individual excavation areas to further prevent eroded soil from reaching stormwater. The TESC requirements will also specify run-on controls to minimize the volume of precipitation entering open excavations. The locations of the required controls are shown on **Drawing GA1017**.

4.2.5 Demolition

Demolition activities in the Pump Station Area include relocation of utilities within the planned excavation area and removal of steel infrastructure from the Piping Manifold Shelter and steel bollards. The east portion of the Piping Manifold Shelter and concrete footing will be removed, as shown on **Drawings CE1010 and CS1011**. The concrete footing is associated with the steel posts supporting the overhead crane which services the piping manifold. Removal of these structures will provide direct access to contaminated soil adjacent to the east end of the Piping Manifold Shelter and allow better positioning of DPE well treatment components in this area. The overhead crane will be locked out and not used during excavation activities and the shelter and footing will be restored to their original condition during site restoration.

The fire water line that crosses the excavation area will be cut and removed from the area during intrusive activity. The fire water system in the excavation area consists of two cast iron pipes. The primary fire water line from the water tank is 8 inches and the loop (return) line is 6 inches. Both lines will need to be cut and temporarily capped/plugged at the east edge of the work limits to allow the system to remain in service to a portion of the site. While the lines are capped near the excavation area, the unaffected portion of the underground firewater system will be pressurized by alternate means (likely rental pump) to supply the fire hydrants associated with Tanks 170 and 180 and the facility entrance as directed by Trans Mountain's safety program requirements.

Bollards in the excavation area will be removed and stored; bollards will be re-installed during the site restoration phase of the work.

No demolition activities are planned for the Material Storage Area excavation work.

4.2.6 Retaining Wall Removal

The Ecology-block retaining wall and associated quarry spalls that bound the eastern side of the Pump Station Area will be removed and the hillside regraded to expand the work area for equipment access during excavation. A new retaining wall will be built from segmented concrete blocks manufactured by Redi-Rock following completion of the excavation work as part of the site restoration. The new wall will consist of two tiers between 3 and 4 feet tall and will include drainage in the form of a surface ditch and two subsurface drainpipes. The quarry spalls will be segregated for re-use during the installation of the new Redi-Rock retaining wall.

4.2.7 Structural Support for Piping Manifold Shelter

After demolition of the concrete footing and steel infrastructure on the east end of the Piping Manifold Shelter, structural supports to temporarily reinforce the shelter during excavation will be installed prior to the start of excavation work. Support and protection will include temporary kicker and crane stops to prevent the crane from moving towards the east end of the shelter near the excavation work. A temporary strut will be placed to support the east end of the structure and a steel plate will be placed in front of the Piping Manifold Shelter as a stop to prevent construction equipment from damaging piping inside the piping manifold shelter as shown on **Drawing CC1011**. Calculations used to determine deflection due to self-weight are provided in **Appendix B**.

4.3 WELL DECOMMISSIONING, PROTECTION AND INSTALLATION

Monitoring wells are located within the Pump Station Area. Wells within the excavation footprint or adjacent to it will be decommissioned prior to the start of excavation. Wells that will remain in place will be protected from damage during construction. New monitoring wells, DPE wells, and DPE passive vent (PV) wells will be installed as part of the DPE treatment system or to monitor the progress of the cleanup action after construction is completed. All well decommissioning and installation services will be performed by a Washington State licensed driller as required under WAC173-162.

4.3.1 Well Abandonment

Five monitoring wells (MW-1, MW-5, MW-7, SW-4, and SW-5) and 2 pilot test wells (MW-9 and MW-10) will be decommissioned as they are located within the excavation footprint or the retaining wall work zone (**Drawing CE1019**). Well and boring logs for each location are included in the final RI/FS report (URS 2014a).

Groundwater levels will be measured in all wells prior to decommissioning and the water levels will be documented in the well decommissioning records. The decommissioning of existing wells will be performed by a licensed driller by removing the top two feet of well casing that is below ground surface and then backfilling the well casing with a high solids bentonite grout mixture in accordance with requirements in WAC 173-160. The bentonite grout mixture will be pressure grouted at 50 pounds per square inch using a tremie hose. The top two feet will be completed with a concrete surface seal unless the well is located within the excavation footprint. A well abandonment record will be completed for each well decommissioned.

4.3.2 Well Protection

Wells not designated for decommissioning will be protected from damage during all site remediation activities. All wells within the work area are currently designated for decommissioning. The wells will be marked and barricaded when wells are located near active construction areas. If necessary for protection, above-ground well casings and monuments may require height adjustment or removal. If so, the wells will be restored to original condition or surface completions reconfigured following site work. The height of adjusted well casings will be surveyed following restoration. The locations of wells to be protected are shown on **Drawing CE1019**.

4.3.3 Well Installation

Four DPE wells, 2 DPE PV wells, and 4 groundwater monitoring wells will be installed in the Pump Station Area using sonic drilling methods after excavation and backfill is completed. A summary of the planned wells is provided in **Table 3** and the locations are shown on **Drawing CE1019**. The proposed well locations and construction details will be reviewed following completion of the excavation to confirm placement, screen depths, and number of DPE and monitoring wells to treat remaining contaminated soil and perched groundwater and monitor the effectiveness of the treatment.

The DPE and PV wells will be installed to a depth of approximately 25 feet bgs. Continuous soil sampling will be conducted in accordance with the CMP to determine the actual depth and screen interval of the DPE and PV wells. DPE and PV wells will be installed at a 30 degree angle to reach contaminated soils underneath the Piping Manifold Shelter (DPE-1 and DPE-2) and the Pump Station Building (DPE-3, DPE-4, PV-1, and PV-2). The length of combined well casing and screen will be longer than 25 feet because of the 30 degree angle. The design implements these placement considerations by requiring the use of angle sonic drilling methods and logging of the drill cores by a qualified person (engineer or geologist) during well installation. Logging of continuous soil cores during drilling of the 4 DPE and 2 PV wells will allow field selection of optimal placement of screen depth for each well. The DPE wells will be connected to the DPE system to extract vapors and groundwater from the subsurface. The PV wells provide a means to introduce air into the subsurface of the Pump Station Building and augment natural air flow through the contaminated zone to improve the efficiency of the DPE system. Without the PV wells, air flow through the contaminated soil would be limited due to the impermeability of the asphalt cap and building structure surrounding the DPE wells. The wells will be constructed with 4-inch diameter Schedule 40 PVC and 10 feet of 0.030-inch well screen. The wells will be screened approximately 15 to 25 feet bgs. Wells will be screened below the excavation limits into the remaining contaminated soil so the wells can effectively extract contaminated vapors and perched groundwater. The well construction details are shown on **Drawings CE1020 and CE1024**.

Four groundwater monitoring wells will be installed to monitor the progress of DPE treatment. Wells MW-15 and MW-16 will be located within the excavated area. Wells MW-17 and MW-18 will replace wells MW-5 and MW-7; however the locations will likely be moved toward the excavation area dependent upon the lateral limits of soil contamination found during excavation. Wells will be screened such that the well screen encompasses the historical perched groundwater zones. These wells will be used to verify that there is no recontamination of the clean backfill and to verify that surface modification measures are working as designed. It is possible that if all surface modifications are operating properly that the new wells will be dry. All of the wells installed in the new asphalted areas will be flush mounted surface completions. Wells installed on the hillside will be either stickup or flush mount completions at the discretion of facility personnel. The PV wells will be above ground completions and protected by steel bollards. If contamination remains in the soil below the excavation depth limits then two of the planned monitoring wells (MW-15 and MW-16) will be installed to serve as DPE wells and added to the DPE system.

All drilling activities used for subsurface installations will start the upper 8 feet using air knife technology to confirm that no utility is present before drilling begins.

4.4 SOIL EXCAVATION

This section describes the excavation approach and rationale. The design includes refinement of the lateral and vertical extent of the excavation. The remedial goal is to excavate and properly dispose of accessible petroleum contaminated soil above CULs in the Pump Station Area and Material Storage Area where practicable. It is not practicable to excavate petroleum contaminated soil underneath existing structures. SSR and conventional excavation methods will be used by the contractor to implement the design.

4.4.1 Conventional Soil Excavation

Conventional excavation methods will be used in the Pump Station Area and Material Storage Area. Conventional excavation methods will be used to move back the hillside prior to SSR excavation work in the Pump Station Area. Soil generated from hillside removal will be stockpiled for use as backfill. Following hillside removal, SSR excavation methods will primarily be used to remove contaminated soil from selected areas within the Pump Station Area. Once all areas that require SSR excavation are complete then conventional excavation will be used to finish the remaining excavation. The depth of the excavation in the Pump Station Area will be up to 25 feet.

In the Material Storage Area, all contaminated soil will be removed using conventional methods.

The contractor is responsible for means and methods of accomplishing the design per the plans and specifications. It is anticipated that the contractor will use a dozer, excavator or a combination of these during this excavation. The limits and depths of the excavation for the Pump Station Area are shown on **Drawing CE1011**. The limits and depths of the excavation for the Material Storage Area are shown on **Drawing CE1012**.

4.4.2 Strategic Source Removal Excavation

SSR excavation methods will only be used in the Pump Station Area. Once the hillside is removed, conventional or SSR excavation will be used during excavation of 3 exploratory trenches to refine the lateral limits of the contaminated soil to the north and east. The exploratory trenches will be attempted solely with conventional means but if the sidewalls cave, then slurry will be introduced to support the trench sidewalls. Once the extent of contamination is determined, this information will be used to set the limits of the excavation to either expand the excavation further into the hillside or reduce the footprint of the excavation. SSR excavation work will be completed adjacent to the Piping Manifold Shelter and shall be accomplished in 4 stages as shown on **Drawing CE1014**. This will be done to remove contaminated soil adjacent to the secondary containment of the Piping Manifold Shelter and to support the sidewalls around the shelter. The next stage will use SSR excavation along the perimeter of the limits of excavation to support the sidewalls and allow vertical slope cuts for conventional excavation methods. The SSR excavation along the piping manifold shelter, exploratory trenches and perimeter trenches will be backfilled with an SCB mix for stability. Geotechnical calculations for the SSR excavation and trenching will be provided by the contractor in charge of implementing SSR excavation technology.

The contractor will use an appropriately sized excavator to reach the desired excavation depths. The limits and depths of the SSR excavation work are shown on **Drawings CE1011 and CE1014**.

4.4.3 Material Handling and Disposal

Contaminated soils will be generated during excavation work at both the Pump Station Area and Material Storage Area. Contaminated soil will be loaded into trucks or rail cars and transported to a licensed offsite disposal facility. Contaminated material handling and disposal will be done in accordance with the project Waste Management Plan.

4.5 DUAL-PHASE EXTRACTION SYSTEM

This section describes the design, approach and treatment of contaminated soil using a DPE system after excavation work is completed. It is anticipated that residual soil contamination will remain beneath structures that cannot be excavated and within perched groundwater. The DPE system is designed to treat both soil and perched groundwater beneath the Piping Manifold Shelter and the pump station building where residual petroleum hydrocarbons remain (**Drawing CE1015**).

The depth anticipated to require treatment ranges from approximately 7 to 25 feet bgs. Assuming an average thickness in the contaminated zone requiring treatment of 11 feet over the entire area based on existing data, the treatment volume is approximately 388 bank cubic yards. The contaminated areas will be treated using a total of 4 DPE wells and 2 PV wells with the option of expanding the DPE system to include additional wells. The DPE wells are designed to treat soil and perched groundwater from approximately 10 to 25 feet bgs. The locations of the DPE and PV wells are shown on **Drawing CE1015**.

4.5.1 Treatment Requirements

The goal of DPE treatment is to reduce concentrations of COCs in soil and perched groundwater beneath the Piping Manifold Shelter and the Pump Station Area to below CULs (Section 3.1).

4.5.2 Duration of Treatment

The system will operate until groundwater sample data from the monitoring wells indicate COC concentrations are below CULs and vapor mass removal rates indicate decreasing trends. If the monitoring data indicate that continued operation would not likely further reduce residual contamination levels, the system will be shut down and a decision made as to whether confirmation soil sampling will be conducted in the treatment area. Estimates in the RI/FS were that the DPE treatment system will need to operate for approximately 2.5 years. Based on this estimate, the system will be designed to operate for a minimum of 5 years. Results obtained from groundwater and vapor sampling will determine the necessary duration of DPE system treatment.

4.5.3 Dual-Phase Extraction Equipment

The DPE system design includes a pre-fabricated DPE equipment container connected to subsurface and surface components. The DPE system will include high-vacuum pumps, sensors and operational controls. In situ pressure conditions will be monitored with direct reading pressure (vacuum) gauges. The DPE system enclosure will contain a liquid ring pump for high vacuum water and vapor extraction, a regenerative blower for low vacuum vapor only extraction, water transfer pumps for groundwater extraction, equalization tank, air treatment system and a water treatment system. The intent is for the high vacuum liquid ring pump to only operate when perched groundwater is present. The low vacuum blower will operate when DPE wells are dry because it is more energy efficient. A process flow diagram is shown on **Drawing GS1010**. A steel shipping container enclosure will be provided so that the DPE equipment can be pre-assembled and come as a complete package that is fully functional when it leaves the factory. This configuration will allow the manufacturer to conduct testing prior to shipment.

A piping and instrument diagram for the DPE treatment system is shown on **Drawing GS1008**.

The main subsurface components of the DPE system are the DPE and PV wells and associated underground piping. Each well will consist of a Schedule 40 polyvinyl chloride (PVC) screen attached to a Schedule 40 PVC riser pipe and a Schedule 40 PVC stinger pipe as shown on **Drawing CE1020**. The DPE pilot test conducted in 2011 showed a radius of influence (ROI) greater than 40 feet. The design parameters for the DPE system would have a conservative ROI of approximately 20 feet. Conservatively assuming a 20-foot ROI and a 20-foot overlap between DPE well points is expected to treat the areas of contaminated soil underneath the Piping Manifold Shelter and Pump Station Building.

Wellhead connections for each DPE well will include a custom well head, ball valves, flexible fittings, vacuum gauges (at stinger and well annulus), and all the necessary fittings to transition between the angled PVC riser pipe and stinger pipe heading to the piping manifold. The design details are shown in **Drawing MP1032**. The rationale for installing valves at each well point includes the following: (1) pressure checks can be made by closing the valve associated with the riser pipe, and (2) pressure checks of the stinger pipe can be made to assure adequate conditions are being made to allow for designed vapor and liquid extraction rates.

The vaults will be rectangular with dimensions of 2 feet by 3 feet, constructed from steel, AASHTO H20 rated and sized for the operator to easily access the wellheads. Each vault will have a 2-inch diameter PVC pipe installed in an underground trench that will be sloped at a 0.5 percent grade towards the piping manifold.

Trench details are shown in **Drawing CE1021**. Wellhead connection details are shown on **Drawing MP1032**.

The DPE system's surface components include the following:

- PVC piping manifold pipe (4 inch)
- DPE treatment equipment container
- DPE equipment inside shipping container
- Electrical connections
- Water treatment system
- Vapor treatment system

A liquid ring pump and a regenerative blower will generate the vacuum that will extract water and vapor. During periods of high water the liquid ring pump will be used and the regenerative blower will be turned off. The liquid ring pump is capable of producing high enough vacuum to lift water from the subsurface but uses more energy thus it is more expensive to operate. During most of the year, there is expected to be no water in the DPE wells and during this time the blower will operate extracting only vapors while the liquid ring pump will be turned off. Vapor and water treatment systems are discussed in Sections 4.5.4 and 4.5.6, respectively.

One equipment container that consists of a steel modular shipping container will be manufactured offsite by the vendor to contain the DPE system. The shipping container is specified as 8 feet wide by 20 feet long with 8.5 feet tall walls, with double doors on one end. Electrical connections for the DPE equipment, general purpose outlets, lighting, a heater, motorized louvers and motorized exhaust vents will also be provided inside the shipping container.

The shipping container will be located south of the piping manifold shelter at the base of the hillside.

The shipping container will have a wall-mounted, forced-air heater located approximately 2 feet above the floor. This heater is to keep the inside temperatures above 35°F, which should prevent freezing of extracted groundwater. In addition, the DPE equipment will generate heat during normal operation, and the typically moderate Puget Sound temperatures should only require heat for short periods of time. To keep the DPE equipment from overheating in the summer, two vents with motorized louvers will be installed on the walls to allow air from outside to enter the container in the summer. Two roof-mounted exhaust fans will be used to help promote air flow through the container. The two exhaust fans will be located on the roof on opposite corners from the wall vents. The locations of the louvers and the exhaust fans were designed to encourage cross air flow through the container. A temperature probe will be used to open the louvers and turn on the fans when temperatures exceed 80 degrees Fahrenheit.

4.5.4 Vapor Treatment Capture

Vapor treatment and capture will be performed using a traditional DPE system, which utilizes a vacuum to draw vapors from DPE wells. Results of DPE pilot testing on December 13 and 14, 2011 indicated that each extraction well would optimally operate at a flow rate of 20 actual cubic feet per minute (acfm) but could potentially reach 40 acfm. The current design includes 4 DPE wells. The vacuum pumps will be rated to operate at a minimum flow rate of 120 acfm at 28.5-inches mercury. The vacuum blowers are somewhat oversized to allow for potential future expansion if additional DPE wells are necessary. Vapors will be separated from the flow stream in a knockout tank and routed to the vapor treatment system. The vapor treatment system consists of a heat exchanger and a vapor liquid separator to further separate contaminated vapors prior to treatment by two granulated activated carbon (GAC) units. Treated vapors will be sampled according to the CMP and discharged to the atmosphere through a 10-foot stack. Discharged vapors must meet the air discharge concentrations allowed by the Northwest Clean Air Agency.

4.5.5 Material Handling and Disposal

Petroleum contaminated soils will be generated during the installation of the DPE, PV and monitoring wells for the DPE system. Contaminated soil should not be encountered during excavation trenching for system piping. It is anticipated drill cuttings and decontamination water will be containerized in 55 gallon drums and then transported off site to an approved disposal facility. Contaminated vapor and perched groundwater will be extracted from the subsurface during operation of the DPE system.

4.5.6 Extracted Groundwater Treatment and Discharge

Extracted groundwater treatment and discharge will be performed using a DPE system. During DPE pilot testing it was determined that each well produced groundwater at a flow rate between 0.6 to 0.8 gallons per minute (gpm), and this was only if the wells were operating at an extraction rate of approximately 40 acfm. According to historical groundwater levels, perched groundwater is not present in the wells year round and it is therefore likely that little or no groundwater will be extracted by the DPE system during the summer months. The design assumes an average sustained groundwater extraction rate of 1 gpm for the entire system per year. The maximum anticipated flow rate during the wet season is estimated to be 3 gpm. The system is designed to handle up to 5 gpm.

Groundwater will be separated from the flow stream in a knockout tank and then routed to the groundwater treatment system. The groundwater treatment system will consist of an equalization tank, bag filters and two GAC units. The equalization tank will be used to recover free product, if present, which will then be stored in an above ground storage tank prior to offsite disposal. Free product is not expected to be encountered and has not been observed in monitoring wells on the Site. Compliance monitoring will require that the presence/absence of free product and volume, if present, be documented as part of routine monitoring. Extracted groundwater will be pumped from the equalization tank through the bag filters and GAC units for subsequent discharge to the facility stormwater system. Treated water will be sampled according to the CMP. Discharged groundwater must meet discharge limits allowed by the facility NPDES permit and as noted in an Ecology-sponsored administrative order to the permit. If extracted groundwater exceeds the cleanup concentrations it will be re-routed back through the system.

4.6 SURFACE MODIFICATIONS

4.6.1 Surface Ditch and French Drain Systems

A drainage swale will be installed between the two tiers of the newly constructed retaining wall to redirect surface runoff away from the Pump Station Area. A high-density polyethylene geomembrane will be covered by quarry spalls and a perforated drainage pipe, which will redirect surface runoff to the north into an existing pipe. At the base of the lower tier, a perforated drainage pipe will be installed to capture water infiltrating below the wall. This water will be redirected below the lower tier of the wall into a new catch basin connected to the onsite storm water system. Refer to **Drawings CE1016 and CE1017**.

4.6.2 Modifications to Storm Drain System

During excavation activities, one existing catch basin and connecting storm drain lines will be removed. The three storm drain lines to be removed are (1) a portion of the storm drain line from the perimeter drain line surrounding the Piping Manifold Shelter; (2) the drain line from the sump in the Piping Manifold Shelter secondary containment area; and (3) storm drain line connecting the catchbasin to the manhole (**Drawing CE1010**). All connections to the manhole will be restored following excavation.

Three new catch basins will be installed to accommodate flow from the newly paved areas and runoff from adjacent areas (**Drawing CD1016**). Hydrologic calculations were completed to size the pipes (**Appendix B**). The new storm water pipes will connect into an existing manhole northeast of the main soil excavation area. The sump drain line will be replaced and connected to the new catch basin positioned near to the current catch basin. The valve attached to this sump drain line will also be replaced and installed in this catch basin.

4.6.3 Asphalt Cap

A hydraulic asphalt concrete cap will replace all gravel areas near the Piping Manifold Shelter. Heavy duty asphalt will be used in areas likely accessible by a large crane for servicing the shelter. The northeastern area will have light duty asphalt design for pick-up trucks. Any areas accessed only by pedestrians will utilize the lowest asphalt thickness. The new paving in the three areas will reduce surface water infiltration.

An asphalt berm will be installed along the existing concrete road to the west to reduce surface runoff into the area. An asphalt drainage swale will also be installed to redirect runoff around the western side of the Piping Manifold Shelter.

A two-foot gravel buffer will be installed around the ground surface at the two pipelines entering the southeastern corner of the Piping Manifold Shelter. The new asphalt berm will be installed approximately two feet from the pipelines to redirect surface runoff away from the pipes. The asphalt construction features are shown on **Drawing CE1023**.

4.7 SAMPLING AND ANALYSIS

The sampling and analysis plan for the project is presented in the CMP. The sampling methods, analytical program details, field quality control requirements, analytical quality assurance, and data review and management process are described in the CMP. Sampling will be conducted for multiple purposes from construction through post-construction monitoring. A brief summary of media and associated analyses is provided in the following sections.

4.7.1 Soil

Soil samples will be collected during construction to:

- Confirm backfill sources (whether offsite or onsite) meet the CULs before use
- Refine the excavation limits in the Pump Station Area to the north and east of the excavation area (from the exploratory trenches).
- Assess soil concentrations remaining in place post-excavation, (Pump Station Area and Materials Storage Building), and
- Support the placement of screen intervals for DPE, PV, and groundwater monitoring well installations (Pump Station Area, collected during drilling)

Samples will be analyzed for TPH using Ecology methods (Ecology, 1997) for VPH, EPH, and/or gasoline-, diesel-, and oil-range petroleum hydrocarbons. Samples may also be analyzed for BTEX and PAHs by EPA methods. The analytical program is based on the end data use for each sample. Samples collected to confirm CULs are met in capped areas will be analyzed for the full suite of analyses (VPH, EPH, BTEX, and PAHs) required for input to Ecology's MTCATPH 11.1 Workbook Tool so that the calculated TPH result can be compared to the TPH cleanup levels in **Table 2**. Samples collected in areas with no surface cap will be analyzed for gasoline-, diesel-, and oil-range petroleum hydrocarbons by Ecology methods Northwest total petroleum hydrocarbons – gasoline range (NWTPH-Gx) and Northwest total petroleum hydrocarbons – diesel range (NWTPH-Dx) and BTEX for direct comparison to the CULs in **Table 2**.

Soil samples will also be collected following shutdown of the DPE system to assess if CULs in soil are met. These samples will be collected via a drilling program in the treatment area. Samples will be analyzed as indicated above.

4.7.2 Groundwater

Groundwater samples will be collected from MW-2, MW-4, MW-6, MW-15, MW-16, MW-17, and MW-18 on a quarterly basis during DPE operation and for 2 years after the operation is shutdown. Samples will be analyzed for TPH (gasoline-, diesel-, and oil-range petroleum hydrocarbons) by Ecology methods NWTPH-Gx and NWTPH-Dx, BTEX, and PAHs. In addition, water levels will be collected during each sampling event at MW-2, MW-3, MW-4, MW-6, MW-11, MW-13, MW-14, MW-15, MW-16, MW-17, MW-18, SW-1, SW-2, and SW-3.

4.7.3 DPE Monitoring

Vapor will be monitored from the DPE system pre-treatment and post-treatment. Pre-treatment samples will be collected initially on a daily or weekly basis during startup and transition to monthly basis and then the frequency may be adjusted to longer intervals based on the data. These data will be used to assess mass removal. Samples will be analyzed for BTEX and TPH by modified EPA methods for air analysis. Post-treatment samples will be collected at a frequency and analyzed for constituents based on discharge monitoring requirements for Northwest Clean Air Agency.

Groundwater extracted by the DPE system will be monitored for free product, COCs and additional analyses as required by the Ecology-sponsored administrative order to the current facility NPDES permit. The frequency will be addressed in the administrative order, but no treated water will be discharged to the facility stormwater system until testing indicates that chemical constituents are below the discharge allowances.

4.7.4 Waste Characterization

Samples will be collected as needed to support waste characterization and disposal. Sampling may include, but not be limited to, soil, water from decontamination procedures, purge water from groundwater sampling, dewatering (if needed), and treatment system media (GAC, filters, etc.). The analytical testing will be selected based on requirements of the disposal facility, media, and process originating the waste.

4.8 WASTE MANAGEMENT

Waste generated during the construction activities will include:

- TPH-contaminated soil from excavation
- TPH-contaminated soil cuttings from drilling
- Potentially free product (not expected), TPH, BTEX, and PAH contaminated groundwater from purge and development activities following well installations
- Concrete/asphalt from demolition activities
- Groundwater from DPE system

- Vapor from DPE system
- General construction waste and PPE

A waste management plan with details on disposition of all waste materials will be prepared prior to the start of site activities. In general, contaminated soil from excavation will be direct-loaded to “rail car” containers for transfer to an appropriately licensed facility for petroleum contaminated material. A contingency plan to temporarily stockpile contaminated soil onsite will be in place in the event that “rail car” containers become limited and direct load and transfer to the rail facility is not available. All stockpiles will be placed on visqueen liner (10 millimeter thickness or greater) and covered to protect from the elements.

Drill cuttings and purge/development water will be containerized in 55-gallon Department of Transportation (DOT) approved drums and disposed at an appropriate facility based on the results of analytical testing. If dewatering becomes necessary during excavation, water will be collected in a temporary storage container, such as a Baker Tank, tested and disposed accordingly.

Concrete and asphalt removed will be recycled to the extent possible. All vapor and groundwater from the DPE system will be treated to meet discharge requirements via an onsite treatment unit and released to the atmosphere (vapor) and the facility storm drain system (groundwater). General construction waste and PPE will be containerized in a dumpster and disposed to local landfill.

Analytical testing for profiling and disposal considerations will be conducted per the CMP and based on the requirements of the disposal facilities. All waste characterization, transportation, and disposal will comply with federal, state, and local regulations. Records documenting chain of custody, soil profile information, final disposition of the material, and certification that the materials were properly disposed of will be maintained and provided in the project completion report.

4.9 SITE RESTORATION

4.9.1 Site Restoration Requirements

Utilities capped during excavation will be restored to pre-construction conditions. This includes, but is not limited to fire water, cathodic protection, and any capped and redirected storm drain lines.

The Piping Manifold Shelter steel infrastructure, concrete pad, and concrete footing will be restored to pre-construction conditions.

All post-excavation grading will be completed according to the Construction Drawings to allow proper drainage and maintain slope stability. Any disturbed area on the hillslope will have a layer of topsoil installed and will be hydroseeded.

Bollards removed and stored will be installed adjacent to the Piping Manifold Shelter at the pre-excavation locations. Bollards will be installed adjacent to one new catch basin and new monitoring wells.

4.9.2 Retaining Wall Reconstruction

The retaining wall will be replaced with a tiered segmented concrete block wall.

The terraced/benched sections will be constructed from pre-fabricated Redi-Rock blocks, which will have a natural looking cobblestone appearance, and be placed in a curved alignment. The upper segmented retaining wall will be approximately 115 feet in length and the lower segmented retaining wall will be 200 feet in length (**Drawings CE1016 and CE1017**). A quarry spall swale will be constructed in the terrace between the upper and lower wall sections as described in Section 4.2.6. The upper hillslope will be hydroseeded.

4.9.3 Demobilization

Following construction, the contractor will remove any equipment and materials from the site. Any remaining stockpiled material will be removed at the request of Trans Mountain. The site will be returned to a condition equivalent to or better than current conditions.

5.0 SITE MANAGEMENT

5.1 HEALTH AND SAFETY

Because of contaminant-related hazards, as well as traditional construction hazards on this project, the federal Occupational Safety and Health Administration (OSHA) standard for Hazardous Waste Operations and Emergency Response (29 CFR 1910.120) applies. The Contractor will be required to comply with OSHA and State of Washington regulations and site-specific requirements.

This project will require the Contractor to develop an Accident Prevention Plan (APP) with a Site Safety and Health Plan (SSHP). The Contractor has responsibility for implementation, oversight, and enforcement of the APP/SSHP.

The APP/SSHP will address the following:

- Description of work and phases of work anticipated (with an activity hazard analysis)
- Contractor’s safety and health policy
- Responsibility and lines of authority
- Subcontractors and suppliers

- Training
- Safety and health inspections
- Accident reporting

In particular, activity hazard analyses must be prepared for each activity, in a level of detail that includes task sequence descriptions.

The following safety concerns require planning and will need to be addressed in the APP/SSHP:

- Traffic/highway right-of-way and controls
- Extended work shifts
- Site access issues
- Potential contact with energized systems (electricity, pressurized water, etc.)
- Heavy equipment, including drilling equipment
- Use of power tools or powered equipment, crane, and rigging
- Manual lifting of heavy loads or repetitive motion
- Contact with hazardous animals, insects, plants, or other biohazards
- Heat or cold stress
- Exposure to high noise levels
- Hazardous waste work (contaminated sites)
- Use of hazardous materials/chemicals
- Dust control

5.2 ACCESS AND STAGING

Access to the work area will be through the gates at the main entrance or existing construction entrance located along East Smith Road at the north end of the Laurel Station facility **(Drawing GA1012**). Construction equipment and associated deliveries will use the existing construction entrance to access the staging areas. Passenger vehicles will use the main entrance and park at a designated location near the contractor trailer and Laurel Station office building. Contractor employees will be required to check in with Laurel Station management prior to work shifts. Temporary personnel such as delivery drivers need not check in with Laurel Station management as long as contractor escorts them while on site. Contractor personnel are not expected to need access to areas outside of the work areas and staging areas shown on **Drawing GA1012**. Procedures for contractor sign-in and entry control at gates will be developed once all contractors and project start date are determined.

5.3 SAFE WORK AROUND EXISTING UTILITIES

Underground utilities in the work area will be identified and marked using the following procedures:

- Notification to local utilities through the "one-call" telephone service at least 48 hours in advance of intrusive field activities

- Review of existing plans showing the locations of underground utilities

- Independent private utility locate prior to intrusive field activities

- Final check by Laurel Station facility staff

Excavation and drilling activities around known, marked underground utilities will be conducted using standard of practice safety precautions. All excavation and drilling will be performed with consideration that unknown, unmarked underground utilities may be present and will use safe work practices to identify and avoid such utilities whenever possible. Air knifing will be required up to 8 feet below ground surface prior to any drilling activities.

5.4 ENVIRONMENTAL PROTECTION AND HOUSEKEEPING

The general approach for environmental protection and housekeeping is to plan for and provide environmental protection measures to control pollution that develops during normal construction practice and maintain a neat, clean, and safe work site. For this project, environmental protection measures may include, but are not limited to:

- Stormwater management and control
- Spill Prevention and counter measures
- Control and disposal of waste derived from contractor operations
- Prevention of releases to the environment
- Dust control
- Noise control

Stormwater management and control includes protection of water resources, erosion control, and collection, storage, and treatment of construction dewatering water in accordance with all applicable laws and regulations. Temporary erosion control methods will include a minimum of straw wattles, straw bales, inlet protection for stormwater systems (**Drawing GA1018**), and daily (and immediately following rain events) monitoring by a temporary erosion control supervisor responsible for erosion control compliance.

Mobile fueling of equipment will be conducted at least 50 feet from the excavation and with secondary containment in place to prevent releases. A stabilized construction entrance will be provided at the location where construction equipment enters paved roadways, and roadway cleanup will be performed as needed. Further information and guidance is discussed in the construction SWPPP, Dust Control Plan, and Waste Management Plan that will be created per the project specifications (**Appendix D**).

5.5 RECORD DOCUMENTATION

The completion of the cleanup action and construction will be documented in a Completion Report. This report will include record drawings based on a land survey of the restored site, a narrative describing the cleanup action performed and results of sampling during construction, documentation of waste disposition, and plans for post action monitoring.

Specifically, the Completion Report will include:

- Vicinity map showing site access
- Final site topography
- Survey of new and replaced utilities and underground piping
- Drawings that shall clearly identify the boundaries of the site
- The boundaries, depth, and backfill material of all excavations
- The installed DPE system showing well and piping locations
- Photographs of the area taken during construction activities
- Locations of photograph reference points, sampling locations, and monitoring locations
- An analysis of any changes to the plan that occurred during construction.
- The types, levels, amounts, and locations of hazardous substances remaining on site and the measures that will be used to prevent migration and contact with those substances. This specification will include contamination beneath Tank 180. Maps will be included that clearly show the locations with respect to Washington State Plane coordinates. This information will be included in an Environmental Restrictive Covenant recorded for the site.

The Completion Report will be submitted to Ecology within 90 days of construction completion.

5.6 POST-CONSTRUCTION NOTIFICATIONS AND MONITORING

Within 14 calendar days of completion of site restoration and DPE system startup, the Project Engineer or his designee will notify Ecology. Notification will be by email or by telephone. Email or verbal notification will be followed in writing immediately afterwards.

Trans Mountain will own, operate, and maintain the DPE treatment system following acceptance of completed construction. The installation contractor will be required to warranty and maintain the DPE system for a period of 1 year or a time period agreed to upon by contract. Trans Mountain, or a separate contractor to Trans Mountain, will operate and maintain the DPE system following transfer of the system from the installation contractor.

Post construction monitoring will be specified in detail in the CMP, but will generally consist of groundwater sampling, vapor discharge sampling, treated water discharge sampling, and observations for free product. Operation and Maintenance of the DPE system will be specified in detail in the O&M plan.

6.0 CONSTRUCTION QUALITY ASSURANCE

Construction quality assurance will be conducted for this project per the requirements of a Quality Control (QC) Plan. Multiple contractors will be used to complete the cleanup action. Each will be responsible for a QC plan associated with the respective work to be performed. QA/QC for compliance sampling and analysis will be addressed through the CMP and the responsibility of URS. QC plans will outline means and methods to determine if the work completed complies with plans and specifications. The system will include inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed remedy.

The basic components of this QC program are the following:

- Preparation of a QC plan
- Field monitoring and confirmatory testing (when applicable) of construction materials
- Field monitoring of soil characteristics testing of materials when they are placed and compacted
- Review and approval of technical and laboratory data
- Preparation and review of daily reports
- Final inspection of all completed work
- Identification and documentation of material or construction defects and repairs
- Compilation of applicable data, logs, Contractor as-built documents, record drawings, and photographs into a remedy installation report

The QC process ensures that qualified people are monitoring the progress and quality of construction. The process will provide an objective overview of project progress and can help identify potential deficiencies or future problem areas during and after construction. The QC plan will identify the personnel involved in construction quality controls, their interrelationships, and their responsibilities

7.0 SCHEDULE

The estimated project schedule is presented in **Table 4**. Estimated durations of individual schedule elements are based on discussions with technology vendors and comparison to other similar projects. This schedule will be revised once the construction contractor has been selected, and will be updated throughout the project.

8.0 REFERENCES

URS Corporation. 2010a. *Supplemental Remedial Investigation/Feasibility Study Work Plan, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* May 2010.

———. 2010b. *Proposed Additional Data Gap Investigation Sampling Activities, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* August 2010.

———. 2011a. *Proposed Additional Data Gap Investigation Sampling Activities, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* January 2011.

———. 2011b. *Proposed Additional Data Gap Investigation Sampling and Pilot Testing Activities, Laurel Station, 1009 East Smith Road, Bellingham, Washington, Revision 1.0.* May 2011.

———. 2011c. *Dual-Phase Extraction and Bioventing Pilot Test Work Plan, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* November 2011.

———. 2012. *Work Plan Addendum, Proposed Shallow Perched Groundwater Evaluation, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* November 2012.

———. 2014a. *Final Remedial Investigation/Feasibility Study Report, Laurel Station, 1009 East Smith Road, Bellingham, Washington.* June 2014.

______. 2014b. Letter Work Plan – Revision 1.0, Additional Investigation – Pump Station Area, Laurel Station, 1009 East Smith Road, Bellingham, Washington. July 2014.

______. 2014c. Letter Report – Additional Investigation – Pump Station Area, Laurel Station, 1009 East Smith Road, Bellingham, Washington. August 2014.

Washington State Department of Ecology, 2014. Consent Decree 14-2-01294-9, Exhibit A Cleanup Action Plan, effective June 5, 2014.

TABLES

Table 1
Project Contacts

Key Role	Name	Telephone Numbers	Email Address	Mailing Address
Kinder Morgan				
Project Coordinator	Mike Droppo	(403) 514-6537	mike_droppo@kindermorgan.com	Kinder Morgan Canada, Inc. Ste. 2700, 300 5th Ave SW Calgary, AB T2P 5J2
Project Engineer	Jennie McLeod	(587-991)-7033	jennie_mcleod@kindermorgan.com	Kinder Morgan Canada, Inc. Ste. 2700, 300 5th Ave SW Calgary, AB T2P 5J2
Facility Contact	Patrick Davis	(360)-319-0800 (cell) (360)-398-1541 (facility main office)	patrick_davis@kindermorgan.com	Kinder Morgan Canada 1009 East Smith Road Bellingham, WA 98226-9765
Washington State Department of Ecology				
Project Coordinator	Cris Matthews, LHG	(360) 715-5232	cris.matthews@ecy.wa.gov	Department of Ecology-Bellingham Field Office 1440 10th Street, Suite 102, Bellingham, Washington 98225
URS Corporation				
Project Manager	Karen Mixon	(206) 438-2700 (Switchboard) (206) 438-2234 (Direct Line)	karen.mixon@urs.com	URS Corporation 1501 4th Avenue, Suite 1400 Seattle, WA 98101
Project Engineer	Cary Brown	(206) 438-2040 (Direct Line)	cary.brown@urs.com	
Field Task Manager	Demetrio Cabanillas	(206) 218-3206 (206)-734-2313 (cell) (206) 438-2066 (Direct Line)	demetrio.cabanillas@urs.com	
Data QA/QC Manager	Christine Gebel	(206)-438-2103 (Direct Line)	christine.gebel@urs.com	
Analytical Resources, Inc.				
Project Manager	Kelly Bottem	(206) 695-6200 (206) 695-6213 (Direct Line)	kellyb@arilabs.com	Analytical Resources, Inc. 4611 South 134th Place, Suite 100 Tukwila, WA 98168

Note:
This list will be updated throughout the project and distributed to all parties working on the project at time of update.

Table 2
Summary of Cleanup Levels and Points of Compliance

Chemical of Concern	Soil	Groundwater
Total Petroleum Hydrocarbons	***mg/kg***	***mg/L***
TPH - gasoline range	200[a]	0.8/1.0[b]
TPH - diesel range	460[a]	0.5
TPH - oil range	460[a]	0.5
TPH Direct Contact (by VPH/EPH Calc)	3,300	NA
VOCs	***µg/kg***	***µg/L***
Benzene	18,182	5
Toluene	6,400,000	640
Ethylbenzene	8,000,000	700
m,p-Xylene	16,000,000	1,600
o-Xylene	16,000,000	1,600
Total xylenes	16,000,000	1,600
PAHs	***µg/kg***	***µg/L***
1-Methylnaphthalene	34,500	1.51
2-Methylnaphthalene	320,000	32
Acenaphthene	4,800,000	960
Acenaphthylene	NE	NE
Anthracene	24,000,000	4,800
Benzo(g,h,i)perylene	NE	NE
Dibenzofuran	80,000	16
Fluoranthene	3,200,000	640
Fluorene	3,200,000	640
Naphthalene	1,600,000	160
Phenanthrene	NE	NE
Pyrene	2,400,000	480
cPAHs	***µg/kg***	***µg/L***
Benzo(a)pyrene	137	0.12
Benzo(a)anthracene	1,370	0.12
Benzo(b)fluoranthene	1,370	0.12
Benzo(k)fluoranthene	13,700	1.2
Dibenzo(a,h)anthracene	137	0.012
Chrysene	137,000	12
Indeno(1,2,3-c,d)pyrene	1,370	0.12
TTEC cPAHs[c]	137	0.12

Soil Point of Compliance: Soil cleanup levels based on human exposure via direct contact or ecological considerations, soil throughout the site from ground surface to 15 feet bgs (WAC 173-340-740[6][d] and WAC 173-340-7490[4][b])

Groundwater Point of Compliance: Throughout the site from the uppermost level of the saturated zone (shallow perched groundwater) extending vertically to the lowest depth (deep aquifer) that could potentially be affected by the site (WAC 173-340-720[8][b]

[a]MTCA TEE levels are from MTCA Table 749-2. These levels are used in areas where the surface is not capped and the depth is less than 15 feet below ground surface. Gasoline-range TPH is evaluated separately from diesel- and heavy oil-range TPH. Diesel- and heavy oil-range TPH measured by NWTPH-Dx are summed and compared to 460 mg/kg.

[b]Gasoline with benzene present/without benzene present

[c]cPAH cleanup levels under MTCA are based on the calculated total toxicity of the mixture using the Toxicity Equivalency Methodology in WAC 173-340-708(8). The mixture of cPAHs shall be considered a single hazardous substance and compared to the applicable MTCA Method B cleanup level for benzo(a)pyrene.

Notes:
cPAHs - carcinogenic PAHs
EPH - extractable petroleum hydrocarbon
µg/kg - microgram per kilogram
µg/L - microgram per liter
mg/kg - milligram per kilogram
mg/L - milligram per literv concentration
MTCA - Model Toxics Control Act
NE - not established
PAHs - polycyclic aromatic hydrocarbons
PQL - practical quantitation limit
TEE - terrestrial ecological evaluation
TPH - total petroleum hydrocarbons
VOCs - volatile organic compounds
VPH - volatile petroleum hydrocarbon

Table 3
New Well Details

Well ID	Well Type	Screened Interval[a] (feet bgs)	Diameter (Inch)	Well Casing Material	Screen Material	Screen Slot Size (Inch)	Sand Type
DPE-1	Dual Phase Extraction	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
DPE-2	Dual Phase Extraction	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
DPE-3	Dual Phase Extraction	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
DPE-4	Dual Phase Extraction	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
MW-15	Monitoring/ Compliance	5 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
MW-16	Monitoring/ Compliance	5 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
MW-17	Monitoring/ Compliance	5 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
MW-18	Monitoring/ Compliance	5 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
PV-1	Passive Vent	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12
PV-2	Passive Vent	15 to 25	4	Schedule 40 PVC	Schedule 40 PVC	0.030	#2/12

[a]Screened intervals for new wells will be revised as necessary, based on the boring logs obtained during well installation.

Notes:
Wells DPE-1, DPE-2, DPE-3, DPE-4, MW-15, MW-16, and MW-17 are planned as flush-mount monument installations to minimize the visual impact and interference with moving operation and maintenance equipment around the site.

Once excavation work has been completed, the well network will be reviewed to assess if any changes will be made to well locations or construction.

bgs - below ground surface
PVC - polyvinyl chloride

Table 4
Estimated Cleanup Action Plan Schedule

Task	Date
Contract award	August 25, 2014
Mobilization	September 2, 2014
Site Preparation	September 2014 (1 week)
Remove retaining wall and hillside, exploratory trenches and pipe rerouting.	September 2014 (1 week)
SSR Excavation, general excavation and grading	September and October 2014 (3 weeks)
Retaining wall construction, utility trenching and installation	October 2014 (1 week)
Hillside restoration and placing asphalt	October 2014 (1 week)
SSR contactor demobilization	October 20, 2014
Hydro-seeding, install new Monitoring, DPE and PV wells	October 2014 (1 week)
Deliver DPE equipment and install	October 2014 (1 week)
Start DPE system and testing	November 2014 (1 week)
Construction demobilization	November 2014 (2 weeks)
Initial DPE system start-up	November 2014 (2 weeks)
DPE system O&M and compliance monitoring	November 2014 through November 2019(5 years)

Notes:
DPE - dual phase extraction
O&M - operation and maintenance
SSR - strategic source removal

DRAWINGS

(Provided Separately)

APPENDIX A

Letter Report – Additional Investigation – Pump Station Area, August 28, 2014

URS

August 28, 2014

Mr. David South
Senior Engineer
Toxics Cleanup Program
Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, WA 98008–5452

Additional Investigation – Pump Station Area
Laurel Station
1009 East Smith Road
Bellingham, Washington

Dear Mr. South:

Presented herein is the documentation of the additional investigation conducted in the southwest portion of the Pump Station Area at Laurel Station. This work was performed in accordance with a Washington State Department of Ecology (Ecology) approved work plan, *Letter Work Plan – Revision 1.0, Additional Investigation – Pump Station Area, Laurel Station, 1009 East Smith Road, Bellingham, Washington* dated July 24, 2014. The purpose of the data collection was to assess current conditions at two historical locations where petroleum hydrocarbon contamination had been identified and determine if cleanup action is warranted for these locations.

This report was prepared by URS Corporation on behalf of Trans Mountain Pipeline (Puget Sound) LLC, which is operated by Kinder Morgan Canada, and is provided to support cleanup actions at the site. Please contact us if you have any questions or require additional information.

Sincerely,

URS Corporation

Karen Mixon
Project Manager

Tom Abbott, LG, LHG
Senior Project Hydrogeologist

State of Washington
Hydrogeologist
298
Licensed Geologist
Thomas A. Abbott

cc: Mike Droppo, Environmental Manager, Kinder Morgan Canada

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TABLE OF CONTENTS

1.0 INTRODUCTION

Presented herein is the documentation of the additional investigation conducted in July 2014 in the southwest portion of the Pump Station Area (**Drawing GA1012**) at Laurel Station located at 1009 East Smith Road in Bellingham, Washington (site). The work was performed in accordance with Washington State Department of Ecology (Ecology) approved work plan *Letter Work Plan – Revision 1.0, Additional Investigation – Pump Station Area, Laurel Station, 1009 East Smith Road, Bellingham, Washington* dated July 24, 2014 (URS 2014b).

During review of the Remedial Investigation/Feasibility Study (RI/FS) report for the site (URS 2014a), it was noted that two prior sample locations (test pit TP-9 and boring TM-B11) near the former drain tile in the southwest corner of the Pump Station Area where petroleum hydrocarbon contamination was identified in 1991 and 1992 were not evaluated during the remedial investigation conducted from 2010 to 2013 (**Drawing GA1013**). Subsequently, Ecology requested that assessment of the current conditions and if necessary, cleanup of these locations, be conducted as part of the Laurel Station cleanup action (Consent Decree 14-2-01294-9, June 2014, Exhibit A - Cleanup Action Plan).

Additional sample collection was completed at these former locations on July 29, 2014 to confirm the previous findings and to evaluate if these locations require cleanup action. This report documents the field activities, observations, sample collection and analytical results, and conclusions associated with the additional investigation.

This report was prepared by URS Corporation (URS) on behalf of Trans Mountain Pipeline (Puget Sound) LLC, which is operated by Kinder Morgan Canada (Kinder Morgan), and is provided to support cleanup actions at the site based on the findings.

2.0 BACKGROUND AND SCOPE

2.1 HISTORICAL DATA

The locations for test pit TP-9 and soil boring TM-B11 are shown on **Drawings GA1013 and GA1015**. Previous data collected in December 1991 and January 1992 from TP-9 indicated that oil-range petroleum hydrocarbons above the site cleanup level of 460 milligram/kilogram (mg/kg) for diesel and heavier oil-range petroleum hydrocarbons ranged from 500 mg/kg to 2,000 mg/kg from 5 to 10 feet below ground surface (bgs). At 15 feet bgs, oil-range petroleum hydrocarbons were reported at 25 mg/kg. The petroleum-affected soil was within a zone noted to have water seepage at 5 feet bgs. The boring TM-B11 was drilled in February 1992 to 65 feet bgs. TPH was detected at a concentration of 2,000 mg/kg at 5 feet bgs based on Ecology’s Hydrocarbon Identification (HCID) method. Field screening did not identify the presence of

TPH at 15 feet bgs, 35 feet bgs, and 65 feet bgs. Groundwater was not encountered during drilling at TM-B11.

2.2 FIELD ACTIVITIES

Utility clearance was performed by Kinder Morgan personnel prior to the start of drilling. Because of the proximity of the planned boring locations to the 16-inch Ferndale pipeline, Kinder Morgan located, uncovered, and flagged the pipeline so that the pipeline was visible during drilling. Kinder Morgan personnel were present and observed all work while borings were advanced.

Three direct-push borings were advanced on July 29, 2014 at the locations shown on **Drawing GA1015** using a direct push rig operated by Cascade Drilling, L.P. subcontracted to URS. Borings SB-1 and SB-2 were located adjacent to former locations TM-B11 and TP-9, respectively. Boring SB-5 was located between SB-1 and SB-2. Potential step-out borings SB-3 and SB-4 shown in the work plan (URS 2014b) were not drilled based on field observations at SB-1 and SB-2. Borings SB-1, SB-2, and SB-5 were advanced to a depth of 15 feet bgs. URS personnel monitored the drilling activities, conducted field screening with a photoionization detector (PID), logged the soil type, documented field observations, and collected soil samples. Soil cuttings were placed into a 5-gallon drum for later disposal. Each boring was backfilled with bentonite. Location coordinates for each boring location were recorded using Global Positioning Service (GPS).

A total of eighteen soil samples and one field duplicate were collected by URS and submitted to Analytical Resources, Incorporated (ARI), an Ecology-accredited laboratory located in Tukwila, Washington. Soil samples were collected from each boring at 3, 5, 7, 10, 12, and 15 feet bgs. Per the work plan (URS 2014b), samples from 5, 10, and 15 feet bgs were authorized for analysis as field observations did not indicate petroleum contamination in any of the borings. Samples collected from 5, 10, and 15 feet bgs were authorized for analysis for gasoline-, diesel-, and heavy oil-range petroleum hydrocarbons by Ecology methods NWTPH-Gx and NWTPH-Dx and benzene, toluene, ethylbenzene, and xylenes (BTEX) by EPA Method 8021B. The remaining samples were placed on hold at the laboratory.

2.3 FIELD OBSERVATIONS

Shallow soils encountered in the borings consisted of brown sand with gravel overlying light to dark brown and gray clay with varying amounts of silt, gravel, and sand. The gravelly sand is fill that overlies the clayey silty material which corresponds to the Bellingham Drift. No hydrocarbon odors, elevated PID readings or groundwater were noted in any of the three borings (SB-1, SB-2, and SB-5). Boring logs are provided in **Attachment A** and a cross section is presented on **Drawing GA1015**.

2.4 ANALYTICAL RESULTS

Soil samples were analyzed for gasoline-, diesel- and oil-range TPH and BTEX. The data were reviewed by a URS chemist. A copy of the laboratory report and data validation memorandum is provided in **Attachment B**. The data are summarized on **Table 1**.

BTEX and diesel and oil-range petroleum hydrocarbons were not detected in any of the samples. Gasoline-range petroleum hydrocarbons were detected in only one sample, SB-2 at 5 feet bgs, with a concentration of 5.5 mg/kg but well below the site cleanup level of 200 mg/kg. All laboratory reporting limits were well below site cleanup level criteria.

2.5 CONCLUSION

The current data collected in the vicinity of historical locations TP-9 and TM-B11 indicate that the petroleum hydrocarbon contamination previously documented is no longer present at these locations. Based on these data, no cleanup actions are warranted at these locations.

3.0 REFERENCES

URS Corporation, 2014a. Final Supplemental Remedial Investigation/Feasibility Study Report, Laurel Station, 1009 East Smith Road, Bellingham, Washington. June 2.

URS Corporation, 2014b. Letter Work Plan – Revision 1.0, Additional Investigation – Pump Station Area, Laurel Station, 1009 East Smith Road, Bellingham, Washington. July 24.

Washington State Department of Ecology, 2014. Consent Decree 14-2-01294-9, Exhibit A Cleanup Action Plan, effective June 5, 2014.

Table 1
Summary of Soil Analytical Results - Southwest Corner of Pump Station Area
Laurel Station
Bellingham, Washington

				Analyte											
	Sample		Depth	TPH (mg/kg)						VOCs (µg/kg)					
Location ID	**Date**	**Sample ID**	**(ft bgs)**	**Gasoline Range**	**Diesel Range**	**Oil Range**	**TPH Field Screen**	**Natural Gas Condensate (Field Screen)**	**Total TPH by 418.1**	**Benzene**	**Toluene**	**Ethylbenzene**	**m,p-Xylene**	**o-Xylene**	**Total Xylenes**
Cleanup Levels - Soil [a]				**200**	**460 (sum)**		**NE**	**NE**	**NE**	**18,182**	**6,400,000**	**8,000,000**	**16,000,000**	**16,000,000**	**16,000,000**
SB-1	7/29/2014	SB-1-5	5 ft	6.6 U	6.0 U	12 U	NA	NA	NA	17 U	17 U	17 U	33 U	17 U	33 U
SB-1	7/29/2014	SB-1-10	10 ft	5.8 U	5.8 U	12 U	NA	NA	NA	14 U	14 U	14 U	29 U	14 U	29 U
SB-1	7/29/2014	SB-DUP1	10 ft	6.0 U	5.9 U	12 U	NA	NA	NA	15 U	15 U	15 U	30 U	15 U	30 U
SB-1	7/29/2014	SB-1-15	15 ft	8.0 U	5.6 U	11 U	NA	NA	NA	20 U	20 U	20 U	40 U	20 U	40 U
SB-2	7/29/2014	SB-2-5	5 ft	**5.5**	5.8 U	12 U	NA	NA	NA	14 U	14 U	14 U	27 U	14 U	27 U
SB-2	7/29/2014	SB-2-10	10 ft	7.0 U	5.7 U	12 U	NA	NA	NA	18 U	18 U	18 U	35 U	18 U	35 U
SB-2	7/29/2014	SB-2-15	15 ft	6.2 U	5.6 U	11 U	NA	NA	NA	16 U	16 U	16 U	31 U	16 U	31 U
SB-5	7/29/2014	SB-5-5	5 ft	5.9 U	5.8 U	12 U	NA	NA	NA	15 U	15 U	15 U	30 U	15 U	30 U
SB-5	7/29/2014	SB-5-10	10 ft	5.9 U	5.7 U	11 U	NA	NA	NA	15 U	15 U	15 U	29 U	15 U	29 U
SB-5	7/29/2014	SB-5-15	15 ft	6.2 U	5.7 U	11 U	NA	NA	NA	15 U	15 U	15 U	31 U	15 U	31 U
TM-B11	2/18/1992	TM-B11X-5	5 ft	NA	**2,000**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TM-B11	2/24/1992	TM-B11-15	15 ft	NA	NA	NA	25 U	NA	NA	NA	NA	NA	NA	NA	NA
TM-B11	2/24/1992	TM-B11-35	35 ft	NA	NA	NA	25 U	NA	NA	NA	NA	NA	NA	NA	NA
TM-B11	2/24/1992	TM-B11-65	65 ft	NA	NA	NA	25 U	NA	NA	NA	NA	NA	NA	NA	NA
TP-9	12/20/1991	TP-9-2	5 ft	NA	NA	**900 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	1/8/1992	TP-9-2	5 ft	NA	NA	**2,000 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/3/1991	TP-9-3	7 ft	NA	NA	**95**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/10/1991	TP-9-3	7 ft	NA	NA	**70 J**	NA	NA	NA	NA	NA	NA	NA	NA	NA
TP-9	12/18/1991	TP-9-3	7 ft	NA	NA	**900 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/20/1991	TP-9-3	7 ft	NA	NA	**300 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	1/8/1992	TP-9-3	7 ft	NA	NA	**500 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/20/1991	TP-9-3-Dup	7 ft	NA	NA	**300 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/4/1991	TP-9-3X-7	7 ft	**180**	**170**	NA	**95**	NA	**1,000**	61 U	70 J	61 U	NA	NA	**510 J**
TP-9	12/19/1991	TP-9-4	10 ft	NA	NA	**500 J**	NA	25 U	NA	NA	NA	NA	NA	NA	NA
TP-9	12/4/1991	TP-9-5	15 ft	NA	NA	**25 J**	NA	25 UJ	NA	NA	NA	NA	NA	NA	NA

[a] This area does not have a surface cap. The cleanup levels shown were established in the Cleanup Action Plan for Trans Mountain Pipeline (Puget Sound) LLC, Laurel Station, Bellingham, Washington (Exhibit A, Consent Decree No. 14-2-01294-9 between Washington State Department of Ecology and Trans Mountain Pipeline (Puget Sound) LLC).

Notes:
Bolded value indicates the chemical was detected above the laboratory reporting limit.
Bold and highlighted value exceeds the selected cleanup level.
ft bgs - foot below ground surface
µg/kg - microgram per kilogram
mg/kg - milligram per kilogram
NA - not analyzed
NC - not calculated
TEE - terrestrial ecological evaluation
TPH - total petroleum hydrocarbons
U - not detected above reporting limit shown
VOCs - volatile organic compounds

NOTES:

1. AERIAL SOURCE: I–CUBED NFORMATION INTEGRATION & IMAGING LLC MAY 15, 2009.
2. COORDINATE GRID BASED ON WASHINGTON STATE PLANE, NORTH ZONE, NAD83.
3. SEE DOCUMENT NUMBERS GA1013, GA1017, AND CE1019 FOR A CLOSE–UP VIEW OF THE PUMP STATION AREA.
4. CONTRACTOR MAY REGRADE STORAGE AREAS WITH OWNER APPROVAL TO SUIT EQUIPMENT NEEDS.

LEGEND

1 LAUREL STATION OFFICE
2 MOTOR CONTROL CENTER BUILDINGS
3 MAINTENANCE SHOP
4 COLD STORAGE BUILDING
5 PUGET SOUND ENERGY SUBSTATION
6 PIPING MANIFOLD
7 RETENTION POND
8 PUMP STATION
PIPELINE
SITE BOUNDARY INDICATING AREAS DESIGNATED FOR REMEDIATION
STAGING AREA
STABILIZED CONSTRUCTION ENTRANCE

N

0 100 200

DRAFT DESIGN–
ISSUED FOR REVIEW

URS
1501 4TH AVENUE, SUITE 1400
SEATTLE, WA 98101-1616
(206) 438-2700

TRANSMOUNTAIN
TRANSMOUNTAIN PIPELINE (PUGET SOUND)

NO.	REFERENCE DRAWINGS	DRAWING NO.
4	WELL ABANDONMENT, PROTECTION, AND INSTALLATION PLAN	CE1019
3	EROSION SEDIMENT CONTROL DETAILS AND NOTES	GA1018
2	STAGING, WORK LIMITS, AND TEMPORARY EROSION CONTROL PLAN	GA1017
1	EXISTING CONDITIONS SITE PLAN–PUMP STATION AREA	GA1013

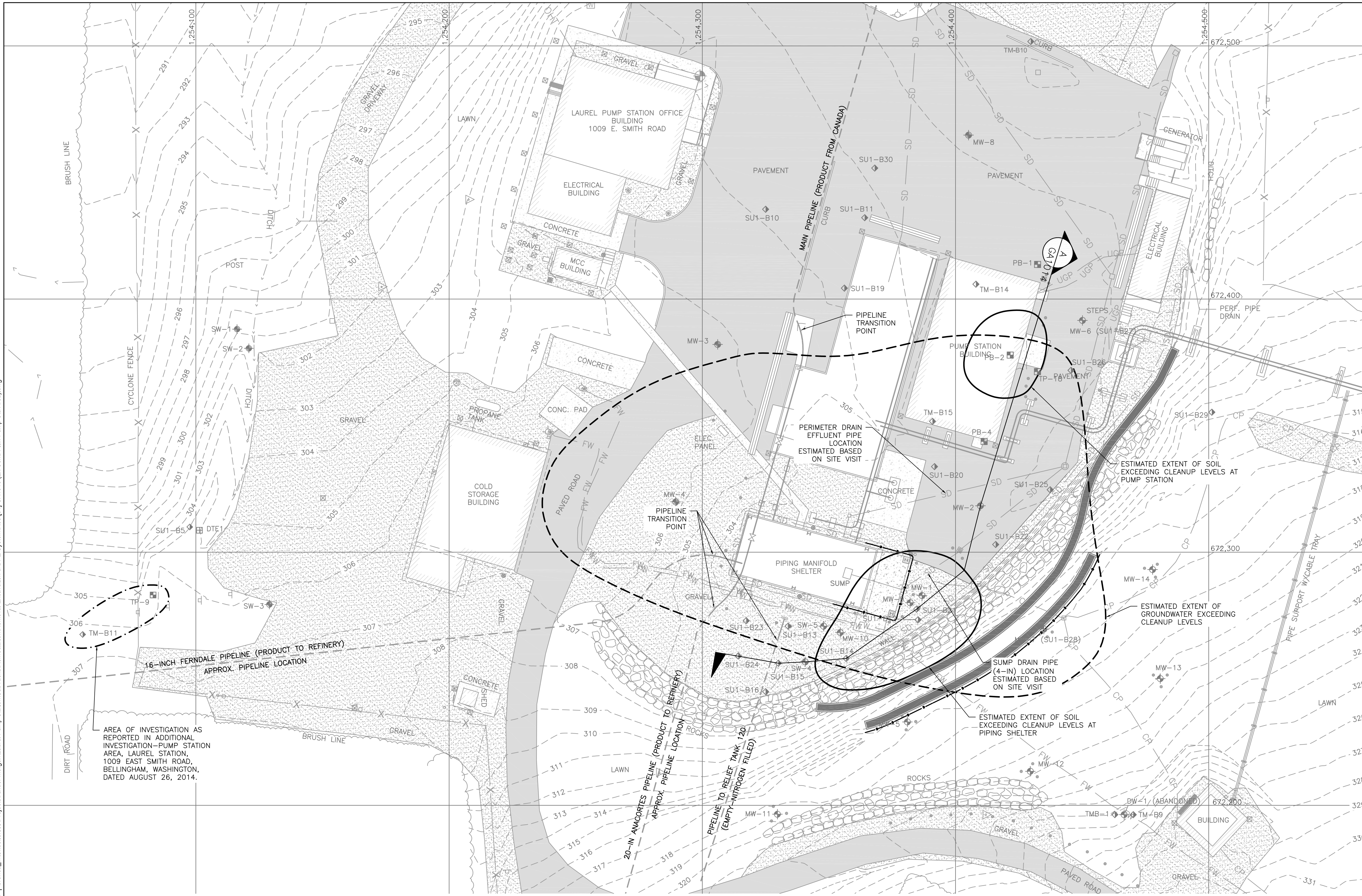
NO.	DATE	REVISION	DR.	CHK.	APPR.

NO.	DATE	REVISION	DR.	CHK.	APPR.

DRAWN L. JILES	FACILITY SITE PLAN WITH AERIAL PHOTO	SHEET SIZE D
CHECKED P. McCULLOUGH		SCALE AS NOTED
APPROVED C. BROWN	LAUREL STATION	DATE 07/11/14

DRAWING NUMBER

AFE	WBS	FACILITY ID.	DOCUMENT No.	SHT.No.	REV.
05–51041	C1A01	UL00	GA1012	3	A



EXISTING FEATURES

- FOUND IRON PIPE OR REBAR/CAP
- FOUND OR SET SPIKE
- SANITARY SEWER MANHOLE
- SANITARY SEWER CLEANOUT
- STORM MANHOLE
- STORM CATCH BASIN
- YARD DRAIN
- WATER METER
- WATER VALVE
- FIRE HYDRANT
- WATER VAULT
- UTILITY POLE
- GUY WIRE
- CP POWER BREAKER BOX
- GROUNDING ROD COVER
- YARD LIGHT
- MONITORING WELL
- BOLLARDS
- SIGN OR PIPELINE MARKER
- MAILBOX OR ELEC PANEL
- QUARRY SPALLS
- PAVEMENT
- CONCRETE
- GRAVEL
- FILL
- APPROX. LOCATION PIPELINE
- OHT — AERIAL TELEPHONE LINE
- DITCH
- X — FENCE LINE
- GAS — GAS LINE
- SD — STORM CULVERT
- SD — STORM DRAIN LINE
- UGP — UNDERGROUND POWER LINE (APPROX)
- FW — FIRE WATER LINE
- CP — CATHODIC PROTECTION (APPROX)
- AREA PENDING FIELD VERIFICATION OF PREVIOUS TPH CONTAMINATION
- ESTIMATED EXTENT OF SOIL EXCEEDING CLEANUP LEVELS
- ESTIMATED EXTENT OF GROUNDWATER EXCEEDING CLEANUP LEVELS

N

0 20 40

DRAFT DESIGN— ISSUED FOR REVIEW

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SEATTLE, WA 98101-1616
(206) 438-2700

TRANSMOUNTAIN
TRANSMOUNTAIN PIPELINE (PUGET SOUND)

DRAWN	L. JILES
CHECKED	P. McCULLOUGH
APPROVED	C. BROWN

EXISTING CONDITIONS SITE PLAN—PUMP STATION AREA

LAUREL STATION

SHEET SIZE: D
SCALE: AS NOTED
DATE: 07/11/14

DRAWING NUMBER

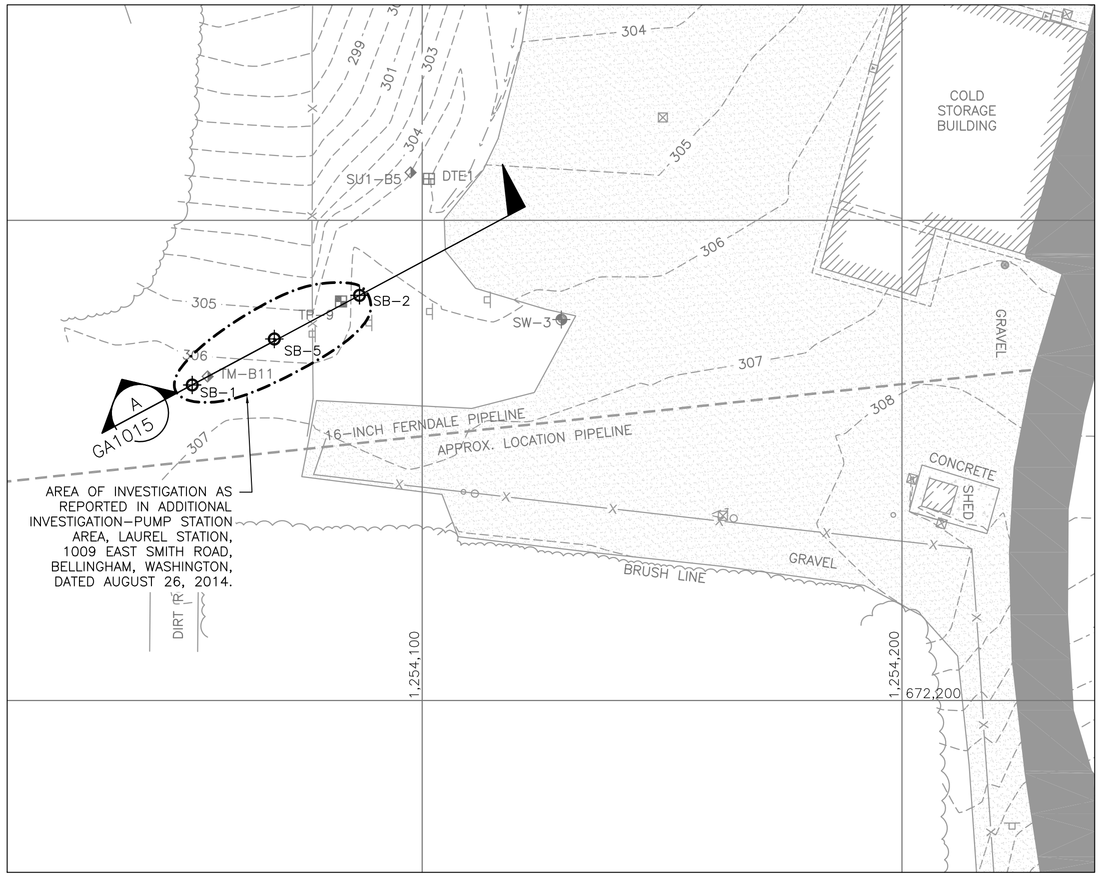
AFE	WBS	FACILITY ID.	DOCUMENT No.	SHT.No.	REV.
05–51041	C1A01	UL00	GA1013	4	A

NO.	REFERENCE DRAWINGS	DRAWING NO.	NO.	DATE	REVISION	DR.	CHK.	APPR.	NO.	DATE	REVISION	DR.	CHK.	APPR.
1	EXISTING CONDITIONS SECTION—PUMP STATION AREA	GA1014												

Mod: 08/27/2014, 09:51 | Plotted: 08/27/2014, 13:21 | brenda_mcintosh | \GIS\Projects\Kinder Morgan\Laurel Pump Station\SubTasks\Remediation\Removal Excavation & DPE System\R03\[04] GA1013 (Ex Cond Plan-Pump Sta Area).dwg

NOTES:

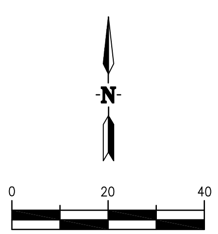
1. THE CROSS SECTION SHOWN IS BASED ON SURFACE TOPOGRAPHY DATA FROM THE JANUARY 2014 LAND SURVEY AND BORING LOGS FROM PREVIOUS INVESTIGATIONS. THE OFFSET DISTANCE FROM EACH BORING TO THE SECTION LINE IS SHOWN IN FEET. S INDICATES THE BORING IS SOUTH OF THE SECTION LINE; N INDICATES THE BORING IS NORTH OF THE SECTION LINE.
2. TP-9 AND TM-B11 WERE COMPLETED AND ASSOCIATED SAMPLES WERE COLLECTED IN 1991 AND 1992.
3. SB-1, SB-2 AND SB-5 WERE DRILLED AND ASSOCIATED SAMPLES WERE COLLECTED IN JULY 2014 TO VERIFY CURRENT CONDITIONS.

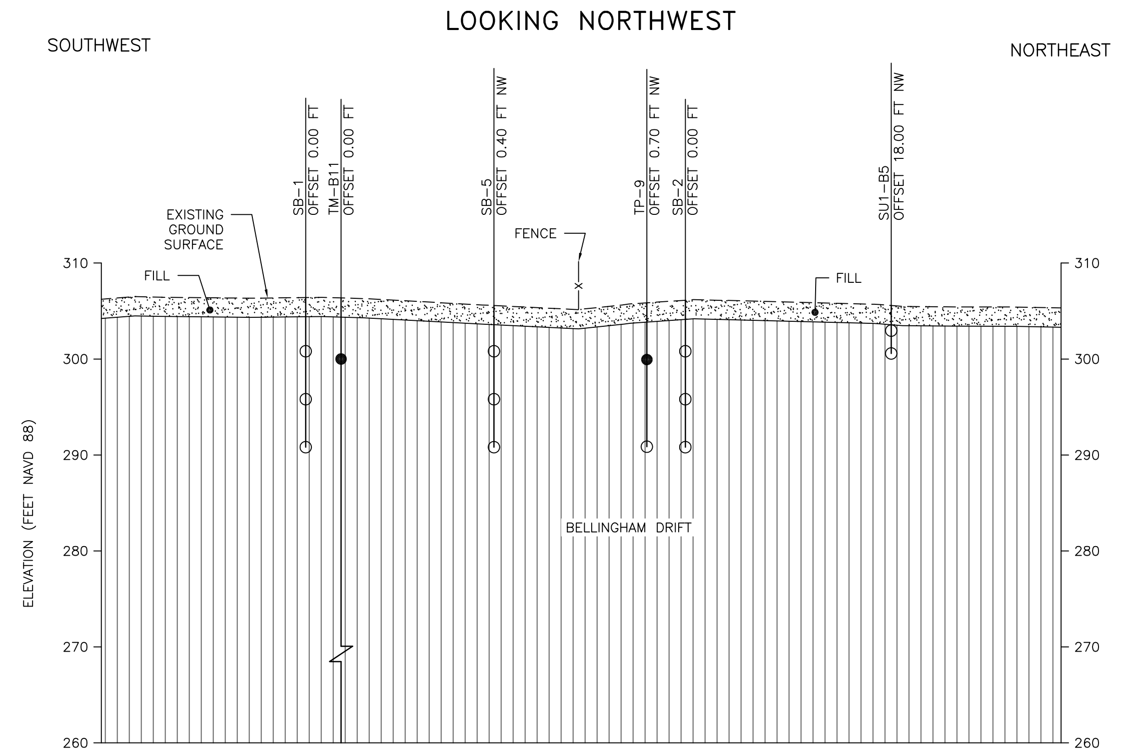


NOTE: SEE GA1013 FOR RELATIVE LOCATION.

EXISTING CONDITIONS AND INVESTIGATION SITE PLAN

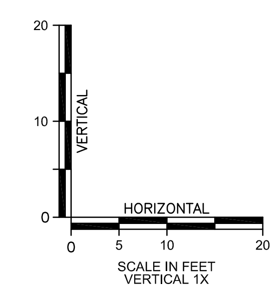
SCALE: 1-IN=20-FT





EXISTING CONDITIONS AND INVESTIGATION

A SECTION
GA1015
SCALE: AS SHOWN



LEGEND

- FILL
- BELLINGHAM DRIFT
- AREA OF INVESTIGATION OF PREVIOUS TPH CONTAMINATION
- ○ SOIL BELOW CLEANUP LEVELS
- ● SOIL EXCEEDS CLEANUP LEVELS
- SB-1 SOIL BORING LOCATIONS

SOIL BORING LOCATIONS

POINT NO.	NORTHING	EASTING
SB-1	672265.7	1254052.1
SB-2	672284.4	1254087.0
SB-5	672275.3	1254069.2

DRAFT DESIGN-
ISSUED FOR REVIEW

URS
1501 4TH AVENUE, SUITE 1400
SEATTLE, WA 98101-1616
(206) 438-2700

NO.	REFERENCE DRAWINGS	DRAWING NO.	NO.	DATE	REVISION	DR.	CHK.	APPR.	NO.	DATE	REVISION	DR.	CHK.	APPR.

TRANS MOUNTAIN
TRANSMOUNTAIN PIPELINE (PUGET SOUND)

DRAWN	TITLE	SHEET SIZE
L. JILES	EXISTING CONDITIONS AND INVESTIGATION PLAN AND SECTION -SW PUMP STATION AREA	D
CHECKED: P. McCULLOUGH		SCALE: AS NOTED
APPROVED: C. BROWN	LAUREL STATION	DATE: 07/11/14

DRAWING NUMBER

AFE	WBS	FACILITY ID.	DOCUMENT No.	SHT.No.	REV.
05-51041	C1A01	UL00	GA1015	6	A

Mod: 08/25/2014, 12:43 | Plotted: 08/27/2014, 13:21 | brenda_mcintosh\GIS\Projects\Kinder Morgan\Laurel Pump Station\SubTasks\Remediation\Removal Excavation & DPE System\R03\06] GA1015 (Ex Cond and Invest Sect-Pump Sta Area).dwg

ATTACHMENT A

Boring Logs

Project: Laurel Station Additional Investigation-Pump Station Area	**Log of Boring SB-1**
Project Location: Bellingham, Washington	Sheet 1 of 1
Project Number: 33764242	

Date(s) Drilled	**7/29/14**	Logged By	**IPV**	Checked By	**T. Abbott**
Drilling Method	**Direct Push**	Drilling Contractor	**Cascade Drilling, L.P.**	Total Depth of Borehole	**15 feet bgs**
Drill Rig Type	**Geoprobe 6600**	Drill Bit Size/Type	**2" x 5' Macro**	Ground Surface Elevation (feet)	
Groundwater Level (feet bgs)	**NA**	Sampling Method	**Macro Liner**	Hammer Data	**NA**
Borehole Backfill	**Bentonite Chips**	Location	**Southwest Corner of Pump Station Area**		

Elevation, feet	Downhole Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery (%)	PID/OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0							SP	Surface: grass Light brown fine to medium SAND, trace fine to coarse gravel (dry) (no odor)	
	2								Grading silty	
		■	SB-1-3		100	0.1		SM	Light brown to light gray sandy SILT, trace coarse gravel (moist to dry) (no odor)	1145
	4	■	SB-1-5			0.3				1155
	6	■	SB-1-7			0.1				1210
					100			CL	Light gray silty CLAY, trace fine to coarse gravel (dry) (low plasticity) (no odor)	
	8									
	10	■	SB-1-10			0.0				1215 SB-DUP1 @ SB-1-10
								SM	Light gray sandy SILT with fine to coarse gravel, fine to medium sand (dry) (no odor)	
	12	■	SB-1-12		100					1240
								CL	Light gray silty CLAY (dry) (no odor)	
								SP	Light brown fine to medium SAND (moist) (no odor)	
	14							ML	Light gray SILT with clay (dry) (no odor)	
		■	SB-1-15							1245
	16								Boring was completed to 15' bgs. Groundwater was not encountered. Boring was backfilled with bentonite.	
	18									
	20									

URS

ENV2 W/O WELL J:\PROJECTS\GRFX\ONEWORLD\33764242 KINDER MORGAN-LAUREL PUMP STATION\33764242LOGS.GPJ URSSEA3B.GLB URSSEA3.GDT 8/21/14

Project: Laurel Station Additional Investigation-Pump Station Area	**Log of Boring SB-2**
Project Location: Bellingham, Washington	Sheet 1 of 1
Project Number: 33764242	

Date(s) Drilled	**7/29/14**	Logged By	**IPV**	Checked By	**T. Abbott**
Drilling Method	**Direct Push**	Drilling Contractor	**Cascade Drilling, L.P.**	Total Depth of Borehole	**15 feet bgs**
Drill Rig Type	**Geoprobe 6600**	Drill Bit Size/Type	**2" x 5' Macro**	Ground Surface Elevation (feet)	
Groundwater Level (feet bgs)	**NA**	Sampling Method	**Macro Liner**	Hammer Data	**NA**
Borehole Backfill	**Bentonite Chips**	Location	**Southwest Corner of Pump Station Area**		

Elevation, feet	Downhole Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery (%)	PID/OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0							SP	Surface: gravel Dark brown fine to medium SAND with fine gravel (dry) (no odor)	Start: 1000
	2								Grading more silt	
		■	SB-2-3		100	0.2		ML	Light gray SILT with fine to medium sand (dry) (no odor)	1005
	4	■	SB-2-5			0.1				1010
	6	■	SB-2-7			0.1		SM	Light brown silty fine to medium SAND	1020
					100			CL	Light gray silty CLAY (dry) (low plasticity) (no odor)	
	8									
	10	■	SB-2-10			0.1				1030
								SM	Light gray sandy SILT with fine to coarse gravel, fine to medium sand (dry) (no odor)	
	12	■	SB-2-12		100	0.2				1040
	14	■	SB-2-15			0.5				1050
	15								Boring was completed to 15' bgs. Groundwater was not encountered. Boring was backfilled with bentonite.	
	16									
	18									
	20									

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Project: Laurel Station Additional Investigation-Pump Station Area **Project Location: Bellingham, Washington** **Project Number: 33764242**	**Log of Boring SB-5** Sheet 1 of 1

Date(s) Drilled	**7/29/14**	Logged By	**IPV**	Checked By	**T. Abbott**
Drilling Method	**Direct Push**	Drilling Contractor	**Cascade Drilling, L.P.**	Total Depth of Borehole	**15 feet bgs**
Drill Rig Type	**Geoprobe 6600**	Drill Bit Size/Type	**2" x 5' Macro**	Ground Surface Elevation (feet)	
Groundwater Level (feet bgs)	**NA**	Sampling Method	**Macro Liner**	Hammer Data	**NA**
Borehole Backfill	**Bentonite Chips**	Location	**Southwest Corner of Pump Station Area**		

Elevation, feet	Downhole Depth, feet	SAMPLES Type	SAMPLES Number	Blows/ 6in.	Recovery (%)	PID/OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0–3		SB-5-3		100	0.1		SP	Surface: grass Dark brown SAND with gravel (dry) (no odor)	1330
	3–7		SB-5-5			0.1		ML	Light gray to light brown SILT with trace fine to medium sand (dry) (no odor)	1335
			SB-5-7		100	0.1				1345
	7–8							CL	Light gray silty CLAY with sand (dry) (no odor)	
	8–9							ML	Light gray SILT with clay (moist) (no odor)	
	9–15		SB-5-10			0.2		CL	Light gray sandy CLAY (moist) (no odor)	1350
			SB-5-12		100	0.1				1400
			SB-5-15			0.0				1405
	15								Boring was completed to 15' bgs. Groundwater was not encountered. Boring was backfilled with bentonite.	

URS

ATTACHMENT B

Analytical Laboratory Reports and

Data Validation Memoranda

Memo

URS

Century Square
1501 4th Avenue, Suite 1400
Seattle, Washington 98101
206.438.2700 Telephone
206.438.2699 Fax

To:	Karen Mixon, Project Manager	**Info:**	**FINAL**
From:	Lucy Panteleeff, Chemist	**Date:**	August 19, 2014
RE:	Data Quality Review Southwest Corner of Pump Station Area – July 2014 Kinder Morgan – Laurel Station		

The data quality review of 19 soil samples and 1 trip blank collected on July 29, 2014 has been completed. The samples were analyzed by Analytical Resources, Incorporated (ARI) located in Tukwila, Washington for benzene, toluene, ethylbenzene, m,p-xylene, and o-xylene (BTEX) by EPA Method 8021B-modified, and/or total petroleum hydrocarbons (TPHs, gasoline-range, diesel-range, and/or oil-range) by Washington State Department of Ecology (Ecology) Methods NWTPH-Gx and NWTPH-Dx as indicated in the cross-reference below. Samples were analyzed for the chemical constituents as described in *Letter Work Plan Rev. 1.0, Additional Investigation–Pump Station Area, Laurel Station, Bellingham, Washington* dated July 24, 2014.

The analyses were performed in general accordance with methods specified in EPA's *Test Methods for Evaluating Solid Waste (SW-846)* and Ecology's *Analytical Methods for Petroleum Hydrocarbons*, June 1997. The laboratory provided a full data package containing sample results and associated QA/QC data. The following samples are associated with ARI group YU38:

Sample ID	Laboratory ID	Requested Analyses
SB-2-5	YU38A	NWTPH-Gx, BTEX, NWTPH-Dx
SB-2-10	YU38B	NWTPH-Gx, BTEX, NWTPH-Dx
SB-2-15	YU38C	NWTPH-Gx, BTEX, NWTPH-Dx
SB-1-5	YU38D	NWTPH-Gx, BTEX, NWTPH-Dx
SB-1-10	YU38E	NWTPH-Gx, BTEX, NWTPH-Dx
SB-1-15	YU38F	NWTPH-Gx, BTEX, NWTPH-Dx
SB-5-5	YU38G	NWTPH-Gx, BTEX, NWTPH-Dx
SB-5-10	YU38H	NWTPH-Gx, BTEX, NWTPH-Dx
SB-5-15	YU38I	NWTPH-Gx, BTEX, NWTPH-Dx
SB-DUP1 (Field Duplicate of SB-2-5)	YU38J	NWTPH-Gx, BTEX, NWTPH-Dx
Trip Blank	YU38K	NWTPH-Gx, BTEX
SB-2-3	YU38L	Placed on Hold
SB-2-7	YU38M	Placed on Hold
SB-2-12	YU38N	Placed on Hold
SB-1-3	YU38O	Placed on Hold
SB-1-7	YU38P	Placed on Hold
SB-1-12	YU38Q	Placed on Hold
SB-5-3	YU38R	Placed on Hold
SB-5-7	YU38S	Placed on Hold
SB-5-12	YU38T	Placed on Hold

The following comments refer to ARI's performance in meeting the quality control specifications described in the analytical methods. Data were qualified based on the method criteria and guidance provided in the EPA document *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, June 2008. Data qualifiers that may be assigned to data from this laboratory group include:

- U - The analyte was analyzed for, but was not detected above the reported sample quantitation limit.

- J - The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample. A '+' or '-' may be assigned to the 'J' flag to indicate high or low bias, respectively.

- UJ - The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

- R - The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

- DNR - Do Not Report. Multiple results reported from different analytical dates and/or dilutions. Value from another analysis should be used.

Sample Receipt

Upon receipt by ARI, the sample jar information was compared to the chain-of-custody (COC) and the cooler temperature was recorded. No discrepancies relating to sample identification were noted by ARI and the cooler was received at a temperature within the EPA-recommended limits of greater than 0 C and less than or equal to 6 C.

At the direction of URS, samples SB-2-3, SB-2-7, SB-2-12, SB-1-3, SB-1-7, SB-1-12, SB-5-3, SB-5-7 and SB-5-12 were placed on hold and not analyzed.

The laboratory noted that pea-sized (2-4 mm) air bubbles were present in the VOA vials submitted for the trip blank. Data were not qualified based on the presence of pea-sized air bubbles in the trip blank vials.

Organic Analyses

Samples were analyzed for BTEX and TPHs by the methods identified in the introduction to this report.

1. Holding Times – Acceptable

2. Initial and Continuing Calibrations – Acceptable except as noted below.

   <u>NWTPH-Dx</u> – The percent differences (%Ds) for the surrogate o-terphenyl exceeded the method limit of 15% in the continuing calibrations analyzed August 3, 2014 at 01:20 (15.1%, high) and 04:39 (17.4%, high). Data were not qualified based on the surrogate %Ds in these continuing calibrations.

3. Blanks – Acceptable

4. Surrogates – Acceptable

5. Laboratory Control Samples/Laboratory Control Sample Duplicates (LCS/LCSD) – Acceptable

6. Matrix Spike/Matrix Spike Duplicates (MS/MSDs) – Acceptable

   <u>NWTPH-Dx</u> – An MS/MSD was performed on SB-2-5 for diesel-range TPH. Results were acceptable.

   <u>NWTPH-Gx and BTEX</u>– A MS/MSD was not performed in association with the soil samples. Precision and accuracy were assessed using the LCS/LCSD results.

7. Field Duplicate – Acceptable

   <u>General</u> – A field duplicate was collected at SB-1-10 and identified as SB-DUP-1. Results were comparable.

8. Reporting Limits – Acceptable except as noted below.

General – The reporting limits for BTEX, gasoline-range TPH and diesel-range TPH in the samples were slightly elevated above the project requirements (Appendix G of the *Remedial Investigation Feasibility Study Work Plan,* URS 2010) due to the percent moisture content of the samples. The elevated reporting limits do not affect the comparison of data to the site cleanup levels.

9. Other Notes

The chromatograms were reviewed and no discrepancies were found in reported results. The samples were prepared without the use of acid and silica gel cleanup.

Overall Assessment of Data

The data reported in these laboratory groups are considered to be usable for meeting project objectives. The completeness for laboratory group YU38 is 100%.

Analytical Resources, Incorporated
Analytical Chemists and Consultants

August 7, 2014

Karen Mixon
URS Corporation
Century Square
1501 Fourth Avenue Suite 1400
Seattle, WA 98101

RE: Laurel Station/Kinder Morgan, 33764321
ARI Job: YU38

Dear Karen:

Please find enclosed the original Chain-of-Custody (COC) records, sample receipt documentation, and the final data package for the project referenced above.

Sample receipt information and analytical details are addressed in the Case Narrative.

An electronic copy of this data package will be kept on file at ARI. If you have any questions or require additional information, please contact me at your convenience.

Sincerely,
ANALYTICAL RESOURCES, INC.

Kelly Bottem
Client Services Manager
(206) 695-6211
kellyb@arilabs.com
www.arilabs.com

4611 South 134th Place, Suite 100 • Tukwila WA 98168 • **206-695-6200** • **206-695-6201** fax

Sample Receipt:

Analytical Resources, Inc. (ARI) received nineteen soil samples and a trip blank on July 30, 2014 logged under ARI Sample Delivery Group (SDG) YU38. The samples were analyzed for NWTPH-Gx plus BTEX and NWTPH-Dx, as requested. For details regarding sample receipt, please refer to the Cooler Receipt Form.

Diesel Range Organics by NWTPH-D Extended:

The samples were extracted on 7/31/14 and analyzed on 8/2/14 and 8/3/14 - within the method recommended holding time.

Initial calibration(s): All analytes of interest were within method acceptance criteria.

Continuing calibration(s): All analytes of interest were within method acceptance criteria.

Surrogates: Are in control.

Method Blank: The method blank was free of contamination.

Samples: There were no anomalies associated with these samples.

LCS/LCSD: The LCS and LCSD percent recoveries were within control limits.

Matrix spike/ Matrix spike duplicate: Are in control.

Gasoline Range Organics by NWTPH-Gx plus BTEX by 8021B Mod:

The samples were analyzed on 8/1/14 and 8/2/14 – within the method recommended holding time.

Initial calibration(s): All analytes of interest were within method acceptance criteria.

Continuing calibration(s): All analytes of interest were within method acceptance criteria.

Surrogates: The surrogate percent recoveries were within control limits.

Method Blanks: The method blanks were free of contamination.

Samples: There were no anomalies associated with these samples.

LCS/LCSD: The LCS and LCSD percent recoveries were within control limits.

Matrix spike/ Matrix spike duplicate: Are in control.

Chain of Custody Record & Laboratory Analysis Request

Analytical Resources, Incorporated
Analytical Chemists and Consultants
4611 South 134th Place, Suite 100
Tukwila, WA 98168
206-695-6200 206-695-6201 (fax)
www.arilabs.com

ARI Assigned Number:	Turn-around Requested: 1 WEEK	Page: 1	of 2
ARI Client Company: URS	Phone: 206 438 2234	Date: 7/29/14	Ice Present? Yes
Client Contact: KAREN MIXON		No. of Coolers: 2	Cooler Temps:
Client Project Name: LAUREL STATION			
Client Project #: 33764242	Samplers: IPV		

Sample ID	Date	Time	Matrix	No. Containers	% Solids	NWTPH-Gx BTEX	NWTPH-Dx	Sim PAHs					Notes/Comments
SB-2-3	7/29/14	1005	SOIL	4	X	X	X	X					HOLD ANALYSIS
SB-2-5	↓	1010	↓	↓	↓	↓	↓	↓					
SB-2-7	↓	1020	↓	↓	↓	↓	↓	↓					HOLD
SB-2-10	↓	1030	↓	↓	↓	↓	↓	↓					
SB-2-12	↓	1040	↓	↓	↓	↓	↓	↓					HOLD
SB-2-15	↓	1050	↓	↓	↓	↓	↓	↓					
SB-1-3	↓	1145	↓	↓	↓	↓	↓	↓					HOLD
SB-1-5	↓	1155	↓	↓	↓	↓	↓	↓					
SB-1-7	↓	1210	↓	↓	↓	↓	↓	↓					HOLD
SB-1-10	↓	1215	↓	↓	↓	↓	↓	↓					

Comments/Special Instructions	Relinquished by:	Received by:	Relinquished by:	Received by:
	(Signature) [signature]	(Signature) [signature]	(Signature)	(Signature)
	Printed Name: IAN VERMEEREN	Printed Name: Chris Atwell	Printed Name:	Printed Name:
	Company: URS	Company: ARI	Company:	Company:
	Date & Time: 7/29/14 1600	Date & Time: 7/30/14 1030	Date & Time:	Date & Time:

Limits of Liability: *ARI will perform all requested services in accordance with appropriate methodology following ARI Standard Operating Procedures and the ARI Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the Invoiced amount for said services. The acceptance by the client of a proposal for services by ARI release ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the Client.*

Sample Retention Policy: All samples submitted to ARI will be appropriately discarded no sooner than 90 days after receipt or 60 days after submission of hardcopy data, whichever is longer, unless alternate retention schedules have been established by work-order or contract.

YU38 : 00003

Chain of Custody Record & Laboratory Analysis Request

Analytical Resources, Incorporated
Analytical Chemists and Consultants
4611 South 134th Place, Suite 100
Tukwila, WA 98168
206-695-6200 206-695-6201 (fax)
www.arilabs.com

ARI Assigned Number:	Turn-around Requested: 1 WEEK	Page: 2	of 2
ARI Client Company: URS	Phone: 206438 2234	Date: 7/29/14	Ice Present? Yes
Client Contact: KAREN MIXON		No. of Coolers: 2	Cooler Temps:
Client Project Name: LAUREL STATION			
Client Project #: 33764242	Samplers: IN		

Sample ID	Date	Time	Matrix	No. Containers	% Solids	NWTPH-Gx BTEX	NWTPH-Dx	SIM PAH					Notes/Comments
SB-1-12	7/29/14	1210	SOIL	4	X	X	X	X					Hold
SB-1-15	↓	1245	↓	↓	↓	↓	↓	↓					
SB-5-3	↓	1330	↓	↓	↓	↓	↓	↓					Hold
SB-5-5	↓	1335	↓	↓	↓	↓	↓	↓					
SB-5-7	↓	1345	↓	↓	↓	↓	↓	↓					Hold
SB-5-10	↓	1350	↓	↓	↓	↓	↓	↓					
SB-5-12	↓	1400	↓	↓	↓	↓	↓	↓					Hold
SB-5-15	↓	1405	↓	↓	↓	↓	↓	↓					
SB-DUP1	↓		↓	↓	↓	↓	↓	↓					
TRIP BLANK	↓		↓	↓									

Comments/Special Instructions	Relinquished by:	Received by:	Relinquished by:	Received by:
	(Signature) [signature]	(Signature) [signature]	(Signature)	(Signature)
	Printed Name: Ian Vera	Printed Name: Chris Atwell	Printed Name:	Printed Name:
	Company: URS	Company: ARI	Company:	Company:
	Date & Time: 7/29/14 1600	Date & Time: 7/30/14 1030	Date & Time:	Date & Time:

Limits of Liability: *ARI will perform all requested services in accordance with appropriate methodology following ARI Standard Operating Procedures and the ARI Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the Invoiced amount for said services. The acceptance by the client of a proposal for services by ARI release ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the Client.*

Sample Retention Policy: All samples submitted to ARI will be appropriately discarded no sooner than 90 days after receipt or 60 days after submission of hardcopy data, whichever is longer, unless alternate retention schedules have been established by work-order or contract.

YL38 : 00001

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Cooler Receipt Form

ARI Client: URS

Project Name: LAUREL STATION

COC No(s): ______ NA

Delivered by: (Fed-Ex) UPS Courier Hand Delivered Other: ______

Assigned ARI Job No: YU38

Tracking No: ______ NA

Preliminary Examination Phase:

Were intact, properly signed and dated custody seals attached to the outside of to cooler?	(YES)	NO
Were custody papers included with the cooler?	(YES)	NO
Were custody papers properly filled out (ink, signed, etc.)	(YES)	NO

Temperature of Cooler(s) (°C) (recommended 2.0-6.0 °C for chemistry) 3.8 1.2
Time: 1030

If cooler temperature is out of compliance fill out form 00070F

Temp Gun ID#: 90877952

Cooler Accepted by: CA Date: 7/30/14 Time: 1030

Complete custody forms and attach all shipping documents

Log-In Phase:

Was a temperature blank included in the cooler?		YES	(NO)
What kind of packing material was used? ... (Bubble Wrap) (Wet Ice) Gel Packs (Baggies) Foam Block Paper Other: ______			
Was sufficient ice used (if appropriate)?	NA	(YES)	NO
Were all bottles sealed in individual plastic bags?		YES	(NO)
Did all bottles arrive in good condition (unbroken)?		(YES)	NO
Were all bottle labels complete and legible?		(YES)	NO
Did the number of containers listed on COC match with the number of containers received?		(YES)	NO
Did all bottle labels and tags agree with custody papers?		(YES)	NO
Were all bottles used correct for the requested analyses?		(YES)	NO
Do any of the analyses (bottles) require preservation? (attach preservation sheet, excluding VOCs)...	(NA)	YES	NO
Were all VOC vials free of air bubbles?	NA	~~YES~~	(NO) TB
Was sufficient amount of sample sent in each bottle?		(YES)	NO
Date VOC Trip Blank was made at ARI	NA	7-25-14	

Was Sample Split by ARI : (NA) YES Date/Time: ______ Equipment: ______ Split by: ______

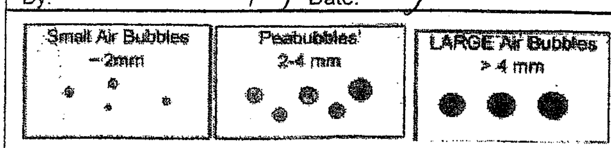
Samples Logged by: TB Date: 7-30-14 Time: 1030

***** Notify Project Manager of discrepancies or concerns *****

Sample ID on Bottle	Sample ID on COC	Sample ID on Bottle	Sample ID on COC

Additional Notes, Discrepancies, & Resolutions: TB 6 "pb"

By: TB Date: 7-30-14



Small → "sm" (< 2 mm)	
Peabubbles → "pb" (2 to < 4 mm)	
Large → "lg" (4 to < 6 mm)	
Headspace → "hs" (> 6 mm)	

Sample ID Cross Reference Report

ANALYTICAL RESOURCES INCORPORATED

ARI Job No: YU38
Client: URS
Project Event: 33764242
Project Name: Laurel Station

	Sample ID	ARI Lab ID	ARI LIMS ID	Matrix	Sample Date/Time	VTSR
1.	SB-2-5	YU38A	14-15555	Soil	07/29/14 10:10	07/30/14 10:30
2.	SB-2-10	YU38B	14-15556	Soil	07/29/14 10:30	07/30/14 10:30
3.	SB-2-15	YU38C	14-15557	Soil	07/29/14 10:50	07/30/14 10:30
4.	SB-1-5	YU38D	14-15558	Soil	07/29/14 11:55	07/30/14 10:30
5.	SB-1-10	YU38E	14-15559	Soil	07/29/14 12:15	07/30/14 10:30
6.	SB-1-15	YU38F	14-15560	Soil	07/29/14 12:45	07/30/14 10:30
7.	SB-5-5	YU38G	14-15561	Soil	07/29/14 13:35	07/30/14 10:30
8.	SB-5-10	YU38H	14-15562	Soil	07/29/14 13:50	07/30/14 10:30
9.	SB-5-15	YU38I	14-15563	Soil	07/29/14 14:05	07/30/14 10:30
10.	SB-DUP1	YU38J	14-15564	Soil	07/29/14	07/30/14 10:30
11.	Trip Blanks	YU38K	14-15565	Water	07/29/14	07/30/14 10:30
12.	SB-2-3	YU38L	14-15566	Soil	07/29/14 10:05	07/30/14 10:30
13.	SB-2-7	YU38M	14-15567	Soil	07/29/14 10:20	07/30/14 10:30
14.	SB-2-12	YU38N	14-15568	Soil	07/29/14 10:40	07/30/14 10:30
15.	SB-1-3	YU38O	14-15569	Soil	07/29/14 11:45	07/30/14 10:30
16.	SB-1-7	YU38P	14-15570	Soil	07/29/14 12:10	07/30/14 10:30
17.	SB-1-12	YU38Q	14-15571	Soil	07/29/14 12:40	07/30/14 10:30
18.	SB-5-3	YU38R	14-15572	Soil	07/29/14 13:30	07/30/14 10:30
19.	SB-5-7	YU38S	14-15573	Soil	07/29/14 13:45	07/30/14 10:30
20.	SB-5-12	YU38T	14-15574	Soil	07/29/14 14:00	07/30/14 10:30

ANALYTICAL RESOURCES INCORPORATED

TPHD SURROGATE RECOVERY SUMMARY

Matrix: Soil

QC Report No: YU38-URS
Project: Laurel Station
33764242

Client ID	OTER	TOT OUT
073114MBS	101%	0
073114LCS	99.5%	0
073114LCSD	94.7%	0
SB-2-5	95.2%	0
SB-2-5 MS	89.8%	0
SB-2-5 MSD	96.4%	0
SB-2-10	111%	0
SB-2-15	99.3%	0
SB-1-5	99.6%	0
SB-1-10	92.5%	0
SB-1-15	108%	0
SB-5-5	107%	0
SB-5-10	110%	0
SB-5-15	105%	0
SB-DUP1	97.4%	0

	LCS/MB LIMITS	QC LIMITS
(OTER) = o-Terphenyl	(50-150)	(50-150)

Prep Method: SW3546
Log Number Range: 14-15555 to 14-15564

FORM-II TPHD

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
TOTAL DIESEL RANGE HYDROCARBONS
NWTPHD by GC/FID
Extraction Method: SW3546
Page 1 of 2

QC Report No: YU38-URS
Project: Laurel Station
33764242

Matrix: Soil

Date Received: 07/30/14

Data Release Authorized: [signature]
Reported: 08/07/14

ARI ID	Sample ID	Extraction Date	Analysis Date	EFV DL	Range/Surrogate	LOQ	Result
MB-073114	Method Blank	07/31/14	08/02/14	1.00	Diesel Range	5.0	< 5.0 U
14-15555	HC ID: ---		FID3B	1.0	Motor Oil Range	10	< 10 U
					o-Terphenyl		101%
YU38A	SB-2-5	07/31/14	08/02/14	1.00	Diesel Range	5.8	< 5.8 U
14-15555	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		95.2%
YU38B	SB-2-10	07/31/14	08/03/14	1.00	Diesel Range	5.7	< 5.7 U
14-15556	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		111%
YU38C	SB-2-15	07/31/14	08/03/14	1.00	Diesel Range	5.6	< 5.6 U
14-15557	HC ID: ---		FID3B	1.0	Motor Oil Range	11	< 11 U
					o-Terphenyl		99.3%
YU38D	SB-1-5	07/31/14	08/03/14	1.00	Diesel Range	6.0	< 6.0 U
14-15558	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		99.6%
YU38E	SB-1-10	07/31/14	08/03/14	1.00	Diesel Range	5.8	< 5.8 U
14-15559	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		92.5%
YU38F	SB-1-15	07/31/14	08/03/14	1.00	Diesel Range	5.6	< 5.6 U
14-15560	HC ID: ---		FID3B	1.0	Motor Oil Range	11	< 11 U
					o-Terphenyl		108%
YU38G	SB-5-5	07/31/14	08/03/14	1.00	Diesel Range	5.8	< 5.8 U
14-15561	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		107%
YU38H	SB-5-10	07/31/14	08/03/14	1.00	Diesel Range	5.7	< 5.7 U
14-15562	HC ID: ---		FID3B	1.0	Motor Oil Range	11	< 11 U
					o-Terphenyl		110%
YU38I	SB-5-15	07/31/14	08/03/14	1.00	Diesel Range	5.7	< 5.7 U
14-15563	HC ID: ---		FID3B	1.0	Motor Oil Range	11	< 11 U
					o-Terphenyl		105%
YU38J	SB-DUP1	07/31/14	08/03/14	1.00	Diesel Range	5.9	< 5.9 U
14-15564	HC ID: ---		FID3B	1.0	Motor Oil Range	12	< 12 U
					o-Terphenyl		97.4%

FORM I

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
TOTAL DIESEL RANGE HYDROCARBONS
NWTPHD by GC/FID
Extraction Method: SW3546

QC Report No: YU38-URS
Project: Laurel Station
33764242

Matrix: Soil

Date Received: 07/30/14

Data Release Authorized:
Reported: 08/07/14

ARI ID	Sample ID	Extraction Date	Analysis Date	EFV DL	Range/Surrogate	LOQ	Result

Reported in mg/kg (ppm)

EFV-Effective Final Volume in mL.
DL-Dilution of extract prior to analysis.
LOQ-Limit of Quantitation

Diesel range quantitation on total peaks in the range from C12 to C24.
Motor Oil range quantitation on total peaks in the range from C24 to C38.
HC ID: DRO/RRO indicates results of organics or additional hydrocarbons in ranges are not identifiable.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
NWTPHD by GC/FID

Sample ID: SB-2-5
MS/MSD

Lab Sample ID: YU38A
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/07/14

QC Report No: YU38-URS
Project: Laurel Station
33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Extracted MS/MSD: 07/31/14

Date Analyzed MS: 08/02/14 23:14
MSD: 08/02/14 23:40
Instrument/Analyst MS: FID3B/VTS
MSD: FID3B/VTS

Sample Amount MS: 8.61 g-dry-wt
MSD: 8.59 g-dry-wt
Final Extract Volume MS: 1.0 mL
MSD: 1.0 mL
Dilution Factor MS: 1.00
MSD: 1.00
Percent Moisture: 14.3%

Range	Sample	MS	Spike Added-MS	MS Recovery	MSD	Spike Added-MSD	MSD Recovery	RPD
Diesel	< 5.8 U	149	174	85.6%	159	175	90.9%	6.5%

TPHD Surrogate Recovery

	MS	MSD
o-Terphenyl	89.8%	96.4%

Results reported in mg/kg
RPD calculated using sample concentrations per SW846.

FORM III

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
NWTPHD by GC/FID
Page 1 of 1

Sample ID: LCS-073114
LCS/LCSD

Lab Sample ID: LCS-073114
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/07/14

QC Report No: YU38-URS
Project: Laurel Station
33764242
Date Sampled: NA
Date Received: NA

Date Extracted LCS/LCSD: 07/31/14

Date Analyzed LCS: 08/02/14 21:58
LCSD: 08/02/14 22:24
Instrument/Analyst LCS: FID3B/VTS
LCSD: FID3B/VTS

Sample Amount LCS: 10.0 g-dry-wt
LCSD: 10.0 g-dry-wt
Final Extract Volume LCS: 1.0 mL
LCSD: 1.0 mL
Dilution Factor LCS: 1.00
LCSD: 1.00

Range	LCS	Spike Added-LCS	LCS Recovery	LCSD	Spike Added-LCSD	LCSD Recovery	RPD
Diesel	138	150	92.0%	135	150	90.0%	2.2%

TPHD Surrogate Recovery

	LCS	LCSD
o-Terphenyl	99.5%	94.7%

Results reported in mg/kg
RPD calculated using sample concentrations per SW846.

ANALYTICAL RESOURCES INCORPORATED

TPHG SOIL SURROGATE RECOVERY SUMMARY

ARI Job: YU38
Matrix: Soil

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242

Client ID	BFB	TFT	BBZ	TOT OUT
MB-080114	NA	92.7%	95.2%	0
LCS-080114	NA	94.1%	94.5%	0
LCSD-080114	NA	96.0%	96.9%	0
SB-2-5	NA	90.2%	92.7%	0
SB-2-10	NA	88.8%	91.7%	0
SB-2-15	NA	87.8%	90.8%	0
SB-1-5	NA	88.0%	92.3%	0
SB-1-10	NA	87.8%	90.1%	0
SB-1-15	NA	86.1%	90.2%	0
SB-5-5	NA	85.9%	89.7%	0
SB-5-10	NA	88.6%	93.4%	0
SB-5-15	NA	89.6%	93.8%	0
SB-DUP1	NA	86.5%	90.2%	0

	LCS/MB LIMITS	QC LIMITS
(TFT) = Trifluorotoluene	(80-120)	(65-128)
(BBZ) = Bromobenzene	(80-120)	(52-149)

Log Number Range: 14-15555 to 14-15564

FORM II TPHG

ANALYTICAL RESOURCES INCORPORATED

BETX SOIL SURROGATE RECOVERY SUMMARY

ARI Job: YU38
Matrix: Soil

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242

Client ID	TFT	BBZ	TOT OUT
MB-080114	92.8%	96.4%	0
LCS-080114	93.6%	96.7%	0
LCSD-080114	96.9%	99.1%	0
SB-2-5	89.8%	93.4%	0
SB-2-10	88.5%	92.5%	0
SB-2-15	86.9%	92.0%	0
SB-1-5	87.3%	93.2%	0
SB-1-10	87.2%	90.8%	0
SB-1-15	85.8%	90.9%	0
SB-5-5	85.1%	90.6%	0
SB-5-10	88.3%	94.2%	0
SB-5-15	89.2%	95.3%	0
SB-DUP1	86.1%	91.5%	0

	LCS/MB LIMITS	QC LIMITS
(TFT) = Trifluorotoluene	(80-120)	(69-126)
(BBZ) = Bromobenzene	(80-120)	(49-143)

Log Number Range: 14-15555 to 14-15564

FORM II BETX

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: MB-080114
METHOD BLANK

Lab Sample ID: MB-080114
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: NA
Date Received: NA

Date Analyzed: 08/01/14 22:40
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 100 mg-dry-wt

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	12	< 12 U	
108-88-3	Toluene	12	< 12 U	
100-41-4	Ethylbenzene	12	< 12 U	
179601-23-1	m,p-Xylene	25	< 25 U	
95-47-6	o-Xylene	12	< 12 U	
	Gasoline Range Hydrocarbons	5.0	< 5.0 U	---

BETX Surrogate Recovery

Trifluorotoluene	92.8%
Bromobenzene	96.4%

Gasoline Surrogate Recovery

Trifluorotoluene	92.7%
Bromobenzene	95.2%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

ANALYTICAL RESOURCES INCORPORATED

Sample ID: SB-2-5
SAMPLE

Lab Sample ID: YU38A
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/01/14 23:38
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 92 mg-dry-wt
Percent Moisture: 14.3%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	14	< 14 U	
108-88-3	Toluene	14	< 14 U	
100-41-4	Ethylbenzene	14	< 14 U	
179601-23-1	m,p-Xylene	27	< 27 U	
95-47-6	o-Xylene	14	< 14 U	
	Gasoline Range Hydrocarbons	**5.5**	**5.5**	**GRO**

BETX Surrogate Recovery

Trifluorotoluene	89.8%
Bromobenzene	93.4%

Gasoline Surrogate Recovery

Trifluorotoluene	90.2%
Bromobenzene	92.7%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

Sample ID: SB-2-10
SAMPLE

Lab Sample ID: YU38B
LIMS ID: 14-15556
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 00:07
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 72 mg-dry-wt
Percent Moisture: 13.2%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	18	< 18 U	
108-88-3	Toluene	18	< 18 U	
100-41-4	Ethylbenzene	18	< 18 U	
179601-23-1	m,p-Xylene	35	< 35 U	
95-47-6	o-Xylene	18	< 18 U	
	Gasoline Range Hydrocarbons	7.0	< 7.0 U	---

BETX Surrogate Recovery

Trifluorotoluene	88.5%
Bromobenzene	92.5%

Gasoline Surrogate Recovery

Trifluorotoluene	88.8%
Bromobenzene	91.7%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

Sample ID: SB-2-15
SAMPLE

Lab Sample ID: YU38C
LIMS ID: 14-15557
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 00:36
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 80 mg-dry-wt
Percent Moisture: 11.3%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	16	< 16 U	
108-88-3	Toluene	16	< 16 U	
100-41-4	Ethylbenzene	16	< 16 U	
179601-23-1	m,p-Xylene	31	< 31 U	
95-47-6	o-Xylene	16	< 16 U	
	Gasoline Range Hydrocarbons	6.2	< 6.2 U	---

BETX Surrogate Recovery

Trifluorotoluene	86.9%
Bromobenzene	92.0%

Gasoline Surrogate Recovery

Trifluorotoluene	87.8%
Bromobenzene	90.8%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

Sample ID: SB-1-5
SAMPLE

Lab Sample ID: YU38D
LIMS ID: 14-15558
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 01:06
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 75 mg-dry-wt
Percent Moisture: 16.0%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	17	< 17 U	
108-88-3	Toluene	17	< 17 U	
100-41-4	Ethylbenzene	17	< 17 U	
179601-23-1	m,p-Xylene	33	< 33 U	
95-47-6	o-Xylene	17	< 17 U	
	Gasoline Range Hydrocarbons	6.6	< 6.6 U	---

BETX Surrogate Recovery

Trifluorotoluene	87.3%
Bromobenzene	93.2%

Gasoline Surrogate Recovery

Trifluorotoluene	88.0%
Bromobenzene	92.3%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: SB-1-10
SAMPLE

Lab Sample ID: YU38E
LIMS ID: 14-15559
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 01:35
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 86 mg-dry-wt
Percent Moisture: 13.8%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	14	< 14 U	
108-88-3	Toluene	14	< 14 U	
100-41-4	Ethylbenzene	14	< 14 U	
179601-23-1	m,p-Xylene	29	< 29 U	
95-47-6	o-Xylene	14	< 14 U	
	Gasoline Range Hydrocarbons	5.8	< 5.8 U	---

BETX Surrogate Recovery

Trifluorotoluene	87.2%
Bromobenzene	90.8%

Gasoline Surrogate Recovery

Trifluorotoluene	87.8%
Bromobenzene	90.1%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: SB-1-15
SAMPLE

Lab Sample ID: YU38F
LIMS ID: 14-15560
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 03:02
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 62 mg-dry-wt
Percent Moisture: 11.8%

CAS Number	Analyte	RL	Result	
71-43-2	Benzene	20	< 20 U	
108-88-3	Toluene	20	< 20 U	
100-41-4	Ethylbenzene	20	< 20 U	
179601-23-1	m,p-Xylene	40	< 40 U	
95-47-6	o-Xylene	20	< 20 U	
				GAS ID
	Gasoline Range Hydrocarbons	8.0	< 8.0 U	---

BETX Surrogate Recovery

Trifluorotoluene	85.8%
Bromobenzene	90.9%

Gasoline Surrogate Recovery

Trifluorotoluene	86.1%
Bromobenzene	90.2%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

Sample ID: SB-5-5
SAMPLE

Lab Sample ID: YU38G
LIMS ID: 14-15561
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 03:31
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 85 mg-dry-wt
Percent Moisture: 13.5%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	15	< 15 U	
108-88-3	Toluene	15	< 15 U	
100-41-4	Ethylbenzene	15	< 15 U	
179601-23-1	m,p-Xylene	30	< 30 U	
95-47-6	o-Xylene	15	< 15 U	
	Gasoline Range Hydrocarbons	5.9	< 5.9 U	---

BETX Surrogate Recovery

Trifluorotoluene	85.1%
Bromobenzene	90.6%

Gasoline Surrogate Recovery

Trifluorotoluene	85.9%
Bromobenzene	89.7%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG

Sample ID: SB-5-10
SAMPLE

Lab Sample ID: YU38H
LIMS ID: 14-15562
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 04:01
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 85 mg-dry-wt
Percent Moisture: 13.0%

CAS Number	Analyte	RL	Result	
71-43-2	Benzene	15	< 15 U	
108-88-3	Toluene	15	< 15 U	
100-41-4	Ethylbenzene	15	< 15 U	
179601-23-1	m,p-Xylene	29	< 29 U	
95-47-6	o-Xylene	15	< 15 U	
				GAS ID
	Gasoline Range Hydrocarbons	5.9	< 5.9 U	---

BETX Surrogate Recovery

Trifluorotoluene	88.3%
Bromobenzene	94.2%

Gasoline Surrogate Recovery

Trifluorotoluene	88.6%
Bromobenzene	93.4%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: SB-5-15
SAMPLE

Lab Sample ID: YU38I
LIMS ID: 14-15563
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 04:30
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 81 mg-dry-wt
Percent Moisture: 12.3%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	15	< 15 U	
108-88-3	Toluene	15	< 15 U	
100-41-4	Ethylbenzene	15	< 15 U	
179601-23-1	m,p-Xylene	31	< 31 U	
95-47-6	o-Xylene	15	< 15 U	
	Gasoline Range Hydrocarbons	6.2	< 6.2 U	---

BETX Surrogate Recovery

Trifluorotoluene	89.2%
Bromobenzene	95.3%

Gasoline Surrogate Recovery

Trifluorotoluene	89.6%
Bromobenzene	93.8%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

ANALYTICAL RESOURCES INCORPORATED

Sample ID: SB-DUP1
SAMPLE

Lab Sample ID: YU38J
LIMS ID: 14-15564
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/02/14 04:59
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Sample Amount: 83 mg-dry-wt
Percent Moisture: 15.6%

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	15	< 15 U	
108-88-3	Toluene	15	< 15 U	
100-41-4	Ethylbenzene	15	< 15 U	
179601-23-1	m,p-Xylene	30	< 30 U	
95-47-6	o-Xylene	15	< 15 U	
	Gasoline Range Hydrocarbons	6.0	< 6.0 U	---

BETX Surrogate Recovery

Trifluorotoluene	86.1%
Bromobenzene	91.5%

Gasoline Surrogate Recovery

Trifluorotoluene	86.5%
Bromobenzene	90.2%

BETX values reported in µg/kg (ppb)
Gasoline values reported in mg/kg (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

Results corrected for soil moisture content per Section 11.10.5 of EPA Method 8000C.

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: LCS-080114
LAB CONTROL SAMPLE

Lab Sample ID: LCS-080114
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: NA
Date Received: NA

Date Analyzed LCS: 08/01/14 21:41
LCSD: 08/01/14 22:10
Instrument/Analyst LCS: PID1/PKC
LCSD: PID1/PKC

Purge Volume: 5.0 mL

Sample Amount LCS: 100 mg-dry-wt
LCSD: 100 mg-dry-wt

Analyte	LCS	Spike Added-LCS	LCS Recovery	LCSD	Spike Added-LCSD	LCSD Recovery	RPD
Gasoline Range Hydrocarbons	52.2	50.0	104%	51.6	50.0	103%	1.2%

Reported in mg/kg (ppm)

RPD calculated using sample concentrations per SW846.

TPHG Surrogate Recovery

	LCS	LCSD
Trifluorotoluene	94.1%	96.0%
Bromobenzene	94.5%	96.9%

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod

Sample ID: LCS-080114
LAB CONTROL SAMPLE

Lab Sample ID: LCS-080114
LIMS ID: 14-15555
Matrix: Soil
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: NA
Date Received: NA

Date Analyzed LCS: 08/01/14 21:41
LCSD: 08/01/14 22:10
Instrument/Analyst LCS: PID1/PKC
LCSD: PID1/PKC

Purge Volume: 5.0 mL

Sample Amount LCS: 100 mg-dry-wt
LCSD: 100 mg-dry-wt

Analyte	LCS	Spike Added-LCS	LCS Recovery	LCSD	Spike Added-LCSD	LCSD Recovery	RPD
Benzene	368	350	105%	376	350	107%	2.2%
Toluene	2760	2470	112%	2810	2470	114%	1.8%
Ethylbenzene	672	615	109%	682	615	111%	1.5%
m,p-Xylene	2180	2000	109%	2230	2000	112%	2.3%
o-Xylene	860	765	112%	874	765	114%	1.6%

Reported in µg/kg (ppb)

RPD calculated using sample concentrations per SW846.

BETX Surrogate Recovery

	LCS	LCSD
Trifluorotoluene	93.6%	96.9%
Bromobenzene	96.7%	99.1%

ANALYTICAL RESOURCES INCORPORATED

TPHG WATER SURROGATE RECOVERY SUMMARY

ARI Job: YU38
Matrix: Water

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242

Client ID	TFT	BBZ	TOT OUT
Trip Blanks	95.7%	94.6%	0

	LCS/MB LIMITS	QC LIMITS
(TFT) = Trifluorotoluene	(80-120)	(80-120)
(BBZ) = Bromobenzene	(80-120)	(80-120)

Log Number Range: 14-15565 to 14-15565

ANALYTICAL RESOURCES INCORPORATED

BETX WATER SURROGATE RECOVERY SUMMARY

ARI Job: YU38
Matrix: Water

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242

Client ID	TFT	BBZ	TOT OUT
Trip Blanks	94.9%	95.9%	0

		LCS/MB LIMITS	QC LIMITS
(TFT) = Trifluorotoluene	(5 mL PV)	(80-120)	(80-120)
(TFT) = Trifluorotoluene	(15 mL PV)	(79-120)	(80-120)
(BBZ) = Bromobenzene	(5 mL PV)	(80-120)	(77-120)
(BBZ) = Bromobenzene	(15 mL PV)	(79-120)	(80-120)

Log Number Range: 14-15565 to 14-15565

FORM II BETX

ANALYTICAL RESOURCES INCORPORATED

ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Sample ID: Trip Blanks
SAMPLE

Lab Sample ID: YU38K
LIMS ID: 14-15565
Matrix: Water
Data Release Authorized:
Reported: 08/04/14

QC Report No: YU38-URS
Project: Laurel Station
Event: 33764242
Date Sampled: 07/29/14
Date Received: 07/30/14

Date Analyzed: 08/01/14 23:09
Instrument/Analyst: PID1/PKC

Purge Volume: 5.0 mL
Dilution Factor: 1.00

CAS Number	Analyte	RL	Result	GAS ID
71-43-2	Benzene	0.25	< 0.25 U	
108-88-3	Toluene	0.25	< 0.25 U	
100-41-4	Ethylbenzene	0.25	< 0.25 U	
179601-23-1	m,p-Xylene	0.50	< 0.50 U	
95-47-6	o-Xylene	0.25	< 0.25 U	
	Gasoline Range Hydrocarbons	0.10	< 0.10 U	---

BETX Surrogate Recovery

Trifluorotoluene	94.9%
Bromobenzene	95.9%

Gasoline Surrogate Recovery

Trifluorotoluene	95.7%
Bromobenzene	94.6%

BETX values reported in µg/L (ppb)
Gasoline values reported in mg/L (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.

APPENDIX B

Design Data and Calculations

Stormwater Calculations

Calculations					
Client:	Trans Mountain	**Project No.:**	33764321		
Project:	Laurel Station Remediation	**Calculated by:**	e.dixon	**Date:**	6-3-14
Location:	Bellingham, WA	**Checked by:**		**Date:**	
Subject:	Stormwater Calculations		*Assumptions/Calculations*	**Rev:**	

1.0 OBJECTIVE

The objective of this calculation is to determine the necessary pipe size for the stormwater system additions at Laurel Station in Bellingham, WA. The pipe size will be calculated based on the peak flow rates from the 25-hr 24-hr and flooding checked for the 100-yr 24-hr storm. Calculations are completed using two different drainage areas due to drainage area uncertainty.

2.0 DATA

National Oceanic and Atmospheric Administration. "Precipitation-Frequency Atlas of the Western United States, Atlas 2, Volume IX-Washington." 1973.
NRCS. "National Engineering Handbook Part 630." 1967-2012, n.d.
URS. "Draft Remedial Investigation/Feasibility Study Report: Laurel Station." 2014.

3.0 ASSUMPTIONS

3.1 SOILS

Conservative curve number (CN) values are based on site conditions observed from aerial and site visit photos.

3.2 PRECIPITATION

The site location precipitation identified on the NOAA Atlas 2 isopluvial map provided the 2-yr, 10-yr, 25-yr and 100-yr 24-hr storm events.

3.3 DRAINAGE AREA

The first drainage area evaluated for the site (Attachment 3) assumed that an asphalt berm will be constructed along the paved western edge and will divert flow away from the drainage area. Any runoff from above the retention wall will be captured in the swale installed on the surface at the top of the wall. For this calculation, it was assumed that the area from the southern vegetated area above the road is diverted elsewhere. This area was included in the second drainage area evaluation to ensure the selected pipe could accommodate the additional flow.

The impervious area includes new asphalt, existing concrete/asphalt and existing piping manifold shelter. Pervious area includes the hillslope south of the new asphalt. Additional area calculations include the area above the paved road (Attachment 3).

3.4 PIPE SIZING

Ductile iron pipes were selected based on the shallow pipe depth. The slope was assumed to be 1%.

Calculations					
Client:	Trans Mountain	**Project No.:**	33764321		
Project:	Laurel Station Remediation	**Calculated by:**	e.dixon	**Date:**	6-3-14
Location:	Bellingham, WA	**Checked by:**		**Date:**	
Subject:	Stormwater Calculations		*Assumptions/Calculations*	**Rev:**	

4.0 METHODS AND RESULTS

4.1 SOILS

The hydrologic soil group of C/D for Bellingham soils was used and based on historic geologic site information (NRCS n.d.)(URS 2014). The selected CN for the pervious areas on site is 79 for open space, fair condition (grass cover 50-75%) (Attachment 5). This value is more conservative than assuming >75% cover following construction. Impervious areas for paved parking lots have a CN of 98 (Attachment 5).

4.2 PRECIPITATION

The precipitation values for Laurel Station are listed as follows (Attachment 4):

- 2-yr 24-hr: 1.9 inches
- 10-yr 24-hr: 2.8 inches
- 25-yr 24-hr: 3.4 inches
- 100-yr 24-hr: 4.2 inches

4.3 DRAINAGE AREA

The calculated drainage area was based on the site topography and Google maps. The impervious area was calculated as 0.47 acres. First drainage area calculations used a pervious area of 0.006 acres. Adding the pervious upper hillslope area increased the pervious area to 0.65 acres for the second drainage area calculation.

4.4 RUNOFF

The Santa Barbara Hydrologic Urban (SBUH) was used for the runoff calculations to determine the peak flow rate for each storm event. These calculations were completed for both drainage area calculations.

4.5 PIPE SIZING

The peak flow rates for the 25-yr 24-hr was used in FlowMaster to determine the pipe size for both drainage calculations. The assumptions described in Section 3.4 and the calculated runoff volumes (Attachment 1) were used.

Table 1. Summary of Peak Flow Rates

Storm Event	First Drainage Area Peak Flow Rate (cfs)	Second Drainage Area PeakFlow Rate (cfs)
25-yr 24-hr	0.40	0.62
100-yr 24-hr	0.50	0.83

5.0 CONCLUSIONS

A 6-in ductile iron pipe will accommodate surface runoff from both a 25-yr 24-hr storm and a 100-yr 24-hr storm based on the first drainage area calculations. When including the additional drainage area, a 6-in ductile iron pipe will accommodate a 25-yr 24-hr storm. The 100-yr 24-hr storm would require a pipe slightly larger than a 6-in, therefore flooding would be minimal. A 6-in ductile iron pipe is recommended.

Calculations

Client:	Trans Mountain	**Project No.:**	33764321		
Project:	Laurel Station Remediation	**Calculated by:**	e.dixon	**Date:**	6-3-14
Location:	Bellingham, WA	**Checked by:**		**Date:**	
Subject:	Stormwater Calculations		*Assumptions/Calculations*	**Rev:**	

6.0 ATTACHMENTS

Attachment 1: Pipe Sizing
Attachment 2: SBUH Method Runoff Volume Calculations
Attachment 3: Drainage Area Calculations
Attachment 4: Western Washington Isopluvial Maps
Attachment 5: Soils Information

Attachment 1

Pipe Sizing

Drainage Area 1
(without upper hillslope)

Laurel Station 25-yr 24-hr

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.012		Ductile Iron Pipe
Channel Slope	0.01000	ft/ft	Based on Stormwater Drawing
Normal Depth	0.43	ft	
Diameter	0.43	ft	
Discharge	0.40	ft³/s	See Attachment 2

Results

Recommended pipe diameter of 5.16" (round to 6")

Diameter	0.43	ft
Normal Depth	0.43	ft
Flow Area	0.14	ft²
Wetted Perimeter	1.34	ft
Hydraulic Radius	0.11	ft
Top Width	0.00	ft
Critical Depth	0.33	ft
Percent Full	100.0	%
Critical Slope	0.01094	ft/ft
Velocity	2.79	ft/s
Velocity Head	0.12	ft
Specific Energy	0.55	ft
Froude Number	0.00	
Maximum Discharge	0.43	ft³/s
Discharge Full	0.40	ft³/s
Slope Full	0.01003	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Laurel Station 25-yr 24-hr

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.43	ft
Critical Depth	0.33	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.01094	ft/ft

Laurel Station 100-yr 24-hr

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.012		Ductile Iron Pipe
Channel Slope	0.01000	ft/ft	Based on Stormwater Drawing
Normal Depth	0.46	ft	
Diameter	0.46	ft	
Discharge	0.50	ft³/s	See Attachment 2

Results

Diameter	0.46	ft
Normal Depth	0.46	ft
Flow Area	0.17	ft²
Wetted Perimeter	1.46	ft
Hydraulic Radius	0.12	ft
Top Width	0.00	ft
Critical Depth	0.37	ft
Percent Full	100.0	%
Critical Slope	0.01078	ft/ft
Velocity	2.95	ft/s
Velocity Head	0.13	ft
Specific Energy	0.60	ft
Froude Number	0.00	
Maximum Discharge	0.54	ft³/s
Discharge Full	0.50	ft³/s
Slope Full	0.00999	ft/ft
Flow Type	SubCritical	

Recommended pipe diameter of 5.52" (round to 6")

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Laurel Station 100-yr 24-hr

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.46	ft
Critical Depth	0.37	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.01078	ft/ft

Drainage Area 2
(with upper hillslope)

Laurel Station Additional Area: 25-yr 24-hr

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.012		Ductile Iron Pipe
Channel Slope	0.01000	ft/ft	Based on Stormwater Drawing
Normal Depth	0.50	ft	
Diameter	0.50	ft	
Discharge	0.62	ft³/s	See Attachment 2

Results

Diameter	0.50	ft	
Normal Depth	0.50	ft	Recommended pipe diameter of 6"
Flow Area	0.20	ft²	
Wetted Perimeter	1.58	ft	
Hydraulic Radius	0.13	ft	
Top Width	0.00	ft	
Critical Depth	0.40	ft	
Percent Full	100.0	%	
Critical Slope	0.01064	ft/ft	
Velocity	3.11	ft/s	
Velocity Head	0.15	ft	
Specific Energy	0.65	ft	
Froude Number	0.00		
Maximum Discharge	0.67	ft³/s	
Discharge Full	0.62	ft³/s	
Slope Full	0.00999	ft/ft	
Flow Type	SubCritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Laurel Station Additional Area: 25-yr 24-hr

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.50	ft
Critical Depth	0.40	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.01064	ft/ft

Laurel Station Additional Area: 100-yr 24-hr

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Diameter

Input Data

Roughness Coefficient	0.012		Ductile Iron Pipe
Channel Slope	0.01000	ft/ft	Based on Stormwater Drawing
Normal Depth	0.56	ft	
Diameter	0.56	ft	
Discharge	0.83	ft³/s	See Attachment 2

Results

Recommended pipe diameter of 6.72"

Diameter	0.56	ft
Normal Depth	0.56	ft
Flow Area	0.25	ft²
Wetted Perimeter	1.77	ft
Hydraulic Radius	0.14	ft
Top Width	0.00	ft
Critical Depth	0.45	ft
Percent Full	100.0	%
Critical Slope	0.01044	ft/ft
Velocity	3.34	ft/s
Velocity Head	0.17	ft
Specific Energy	0.74	ft
Froude Number	0.00	
Maximum Discharge	0.89	ft³/s
Discharge Full	0.83	ft³/s
Slope Full	0.00998	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Laurel Station Additional Area: 100-yr 24-hr

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.56	ft
Critical Depth	0.45	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.01044	ft/ft

Attachment 2

SBUH Method Runoff
Volume Calculations

Drainage Area 1
(without upper hillslope)

SBUH

2-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation
Basin:
Storm Event: 02-YEAR, 24-HOUR
Given:

Area = 0.48 acres
Pt = 1.90 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)		IMPERVIOUS AREA (Roads)	
Area =	0.01 acres	Area =	0.47 acres
CN =	79	CN =	98
S =	2.66	S =	0.20
0.2S =	0.53	0.2S =	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.22
Vol(cf)=	2,870

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	(6) Accumu-lated Runoff in.	(7) Incre-mental Runoff in.	(8) Accumu-lated Runoff in.	(9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
1	10	0.0040	0.0076	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
2	20	0.0040	0.0076	0.0152	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
3	30	0.0040	0.0076	0.0228	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
4	40	0.0040	0.0076	0.0304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
5	50	0.0040	0.0076	0.0380	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
6	60	0.0040	0.0076	0.0456	0.0000	0.0000	0.0001	0.0001	0.0001	0.0	0.00
7	70	0.0040	0.0076	0.0532	0.0000	0.0000	0.0007	0.0006	0.0006	0.0	0.00
8	80	0.0040	0.0076	0.0608	0.0000	0.0000	0.0018	0.0011	0.0011	0.0	0.00
9	90	0.0040	0.0076	0.0684	0.0000	0.0000	0.0033	0.0015	0.0015	0.0	0.00
10	100	0.0040	0.0076	0.0760	0.0000	0.0000	0.0052	0.0019	0.0019	0.0	0.00
11	110	0.0050	0.0095	0.0855	0.0000	0.0000	0.0080	0.0029	0.0028	0.0	0.01
12	120	0.0050	0.0095	0.0950	0.0000	0.0000	0.0114	0.0033	0.0033	0.0	0.01
13	130	0.0050	0.0095	0.1045	0.0000	0.0000	0.0151	0.0038	0.0037	0.0	0.01
14	140	0.0050	0.0095	0.1140	0.0000	0.0000	0.0193	0.0042	0.0041	0.0	0.01
15	150	0.0050	0.0095	0.1235	0.0000	0.0000	0.0238	0.0045	0.0044	0.0	0.01
16	160	0.0050	0.0095	0.1330	0.0000	0.0000	0.0287	0.0048	0.0048	0.0	0.01
17	170	0.0060	0.0114	0.1444	0.0000	0.0000	0.0349	0.0062	0.0061	0.0	0.02
18	180	0.0060	0.0114	0.1558	0.0000	0.0000	0.0414	0.0066	0.0065	0.0	0.02
19	190	0.0060	0.0114	0.1672	0.0000	0.0000	0.0483	0.0069	0.0068	0.0	0.02
20	200	0.0060	0.0114	0.1786	0.0000	0.0000	0.0555	0.0072	0.0071	0.0	0.02
21	210	0.0060	0.0114	0.1900	0.0000	0.0000	0.0630	0.0075	0.0073	0.0	0.02
22	220	0.0060	0.0114	0.2014	0.0000	0.0000	0.0707	0.0077	0.0076	0.0	0.02
23	230	0.0070	0.0133	0.2147	0.0000	0.0000	0.0800	0.0093	0.0091	0.0	0.02
24	240	0.0070	0.0133	0.2280	0.0000	0.0000	0.0895	0.0096	0.0094	0.0	0.03
25	250	0.0070	0.0133	0.2413	0.0000	0.0000	0.0994	0.0098	0.0096	0.0	0.03
26	260	0.0070	0.0133	0.2546	0.0000	0.0000	0.1094	0.0100	0.0099	0.0	0.03
27	270	0.0070	0.0133	0.2679	0.0000	0.0000	0.1196	0.0102	0.0101	0.0	0.03
28	280	0.0070	0.0133	0.2812	0.0000	0.0000	0.1300	0.0104	0.0102	0.0	0.03
29	290	0.0082	0.0156	0.2968	0.0000	0.0000	0.1424	0.0124	0.0122	0.0	0.03
30	300	0.0082	0.0156	0.3124	0.0000	0.0000	0.1550	0.0126	0.0124	0.0	0.04
31	310	0.0082	0.0156	0.3279	0.0000	0.0000	0.1678	0.0128	0.0126	0.0	0.04
32	320	0.0082	0.0156	0.3435	0.0000	0.0000	0.1808	0.0130	0.0128	0.0	0.04
33	330	0.0082	0.0156	0.3591	0.0000	0.0000	0.1939	0.0131	0.0129	0.0	0.04
34	340	0.0082	0.0156	0.3747	0.0000	0.0000	0.2072	0.0133	0.0130	0.0	0.04
35	350	0.0095	0.0181	0.3927	0.0000	0.0000	0.2227	0.0155	0.0153	0.0	0.04
36	360	0.0095	0.0181	0.4108	0.0000	0.0000	0.2384	0.0157	0.0154	0.0	0.04
37	370	0.0095	0.0181	0.4288	0.0000	0.0000	0.2543	0.0158	0.0156	0.0	0.04
38	380	0.0095	0.0181	0.4469	0.0000	0.0000	0.2702	0.0160	0.0157	0.0	0.05
39	390	0.0095	0.0181	0.4649	0.0000	0.0000	0.2863	0.0161	0.0158	0.0	0.05
40	400	0.0095	0.0181	0.4830	0.0000	0.0000	0.3025	0.0162	0.0159	0.0	0.05
41	410	0.0134	0.0255	0.5084	0.0000	0.0000	0.3255	0.0230	0.0226	0.1	0.05
42	420	0.0134	0.0255	0.5339	0.0000	0.0000	0.3487	0.0232	0.0228	0.1	0.06
43	430	0.0134	0.0255	0.5594	0.0003	0.0003	0.3721	0.0234	0.0230	0.1	0.07
44	440	0.0180	0.0342	0.5936	0.0014	0.0011	0.4037	0.0316	0.0311	0.1	0.08
45	450	0.0180	0.0342	0.6278	0.0034	0.0019	0.4355	0.0318	0.0313	0.1	0.09
46	460	0.0340	0.0646	0.6924	0.0092	0.0058	0.4961	0.0606	0.0597	0.2	0.13
47	470	0.0540	0.1026	0.7950	0.0237	0.0146	0.5935	0.0974	0.0960	0.3	0.22 Q peak
48	480	0.0270	0.0513	0.8463	0.0333	0.0096	0.6426	0.0491	0.0484	0.1	0.21
49	490	0.0180	0.0342	0.8805	0.0405	0.0072	0.6755	0.0328	0.0324	0.1	0.13
50	500	0.0134	0.0255	0.9059	0.0462	0.0057	0.7000	0.0245	0.0242	0.1	0.09
51	510	0.0134	0.0255	0.9314	0.0523	0.0061	0.7245	0.0246	0.0242	0.1	0.07
52	520	0.0134	0.0255	0.9568	0.0586	0.0064	0.7491	0.0246	0.0243	0.1	0.07
53	530	0.0088	0.0167	0.9736	0.0630	0.0044	0.7653	0.0162	0.0160	0.0	0.06
54	540	0.0088	0.0167	0.9903	0.0675	0.0045	0.7815	0.0162	0.0160	0.0	0.05
55	550	0.0088	0.0167	1.0070	0.0721	0.0046	0.7977	0.0162	0.0160	0.0	0.05
56	560	0.0088	0.0167	1.0237	0.0769	0.0048	0.8139	0.0162	0.0160	0.0	0.05
57	570	0.0088	0.0167	1.0404	0.0817	0.0049	0.8301	0.0162	0.0160	0.0	0.05
58	580	0.0088	0.0167	1.0572	0.0867	0.0050	0.8464	0.0162	0.0161	0.0	0.05
59	590	0.0088	0.0167	1.0739	0.0919	0.0051	0.8626	0.0163	0.0161	0.0	0.05
60	600	0.0088	0.0167	1.0906	0.0971	0.0052	0.8789	0.0163	0.0161	0.0	0.05
61	610	0.0088	0.0167	1.1073	0.1025	0.0054	0.8952	0.0163	0.0161	0.0	0.05
62	620	0.0088	0.0167	1.1240	0.1080	0.0055	0.9115	0.0163	0.0161	0.0	0.05
63	630	0.0088	0.0167	1.1408	0.1136	0.0056	0.9278	0.0163	0.0161	0.0	0.05
64	640	0.0088	0.0167	1.1575	0.1193	0.0057	0.9441	0.0163	0.0161	0.0	0.05
65	650	0.0072	0.0137	1.1712	0.1240	0.0048	0.9575	0.0134	0.0132	0.0	0.04

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	(6) Accumu-lated Runoff in.	(7) Incre-mental Runoff in.	(8) Accumu-lated Runoff in.	(9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0137	1.1848	0.1288	0.0048	0.9708	0.0134	0.0132	0.0	0.04
67	670	0.0072	0.0137	1.1985	0.1337	0.0049	0.9842	0.0134	0.0132	0.0	0.04
68	680	0.0072	0.0137	1.2122	0.1387	0.0050	0.9976	0.0134	0.0132	0.0	0.04
69	690	0.0072	0.0137	1.2259	0.1438	0.0050	1.0110	0.0134	0.0132	0.0	0.04
70	700	0.0072	0.0137	1.2396	0.1489	0.0051	1.0244	0.0134	0.0132	0.0	0.04
71	710	0.0072	0.0137	1.2532	0.1541	0.0052	1.0377	0.0134	0.0133	0.0	0.04
72	720	0.0072	0.0137	1.2669	0.1593	0.0053	1.0511	0.0134	0.0133	0.0	0.04
73	730	0.0072	0.0137	1.2806	0.1646	0.0053	1.0645	0.0134	0.0133	0.0	0.04
74	740	0.0072	0.0137	1.2943	0.1700	0.0054	1.0780	0.0134	0.0133	0.0	0.04
75	750	0.0072	0.0137	1.3080	0.1755	0.0055	1.0914	0.0134	0.0133	0.0	0.04
76	760	0.0072	0.0137	1.3216	0.1810	0.0055	1.1048	0.0134	0.0133	0.0	0.04
77	770	0.0057	0.0108	1.3325	0.1854	0.0044	1.1154	0.0106	0.0105	0.0	0.03
78	780	0.0057	0.0108	1.3433	0.1899	0.0045	1.1260	0.0106	0.0105	0.0	0.03
79	790	0.0057	0.0108	1.3541	0.1944	0.0045	1.1367	0.0106	0.0105	0.0	0.03
80	800	0.0057	0.0108	1.3650	0.1989	0.0045	1.1473	0.0106	0.0105	0.0	0.03
81	810	0.0057	0.0108	1.3758	0.2035	0.0046	1.1580	0.0106	0.0105	0.0	0.03
82	820	0.0057	0.0108	1.3866	0.2081	0.0046	1.1686	0.0106	0.0105	0.0	0.03
83	830	0.0057	0.0108	1.3975	0.2127	0.0046	1.1792	0.0106	0.0105	0.0	0.03
84	840	0.0057	0.0108	1.4083	0.2174	0.0047	1.1899	0.0106	0.0105	0.0	0.03
85	850	0.0057	0.0108	1.4191	0.2221	0.0047	1.2005	0.0106	0.0105	0.0	0.03
86	860	0.0057	0.0108	1.4299	0.2269	0.0048	1.2112	0.0107	0.0106	0.0	0.03
87	870	0.0057	0.0108	1.4408	0.2317	0.0048	1.2218	0.0107	0.0106	0.0	0.03
88	880	0.0057	0.0108	1.4516	0.2365	0.0048	1.2325	0.0107	0.0106	0.0	0.03
89	890	0.0050	0.0095	1.4611	0.2408	0.0043	1.2418	0.0093	0.0093	0.0	0.03
90	900	0.0050	0.0095	1.4706	0.2451	0.0043	1.2512	0.0094	0.0093	0.0	0.03
91	910	0.0050	0.0095	1.4801	0.2494	0.0043	1.2605	0.0094	0.0093	0.0	0.03
92	920	0.0050	0.0095	1.4896	0.2538	0.0044	1.2699	0.0094	0.0093	0.0	0.03
93	930	0.0050	0.0095	1.4991	0.2581	0.0044	1.2793	0.0094	0.0093	0.0	0.03
94	940	0.0050	0.0095	1.5086	0.2626	0.0044	1.2886	0.0094	0.0093	0.0	0.03
95	950	0.0050	0.0095	1.5181	0.2670	0.0044	1.2980	0.0094	0.0093	0.0	0.03
96	960	0.0050	0.0095	1.5276	0.2714	0.0045	1.3073	0.0094	0.0093	0.0	0.03
97	970	0.0050	0.0095	1.5371	0.2759	0.0045	1.3167	0.0094	0.0093	0.0	0.03
98	980	0.0050	0.0095	1.5466	0.2804	0.0045	1.3261	0.0094	0.0093	0.0	0.03
99	990	0.0050	0.0095	1.5561	0.2850	0.0045	1.3354	0.0094	0.0093	0.0	0.03
100	1000	0.0050	0.0095	1.5656	0.2895	0.0046	1.3448	0.0094	0.0093	0.0	0.03
101	1010	0.0040	0.0076	1.5732	0.2932	0.0037	1.3523	0.0075	0.0074	0.0	0.02
102	1020	0.0040	0.0076	1.5808	0.2969	0.0037	1.3598	0.0075	0.0074	0.0	0.02
103	1030	0.0040	0.0076	1.5884	0.3006	0.0037	1.3673	0.0075	0.0074	0.0	0.02
104	1040	0.0040	0.0076	1.5960	0.3043	0.0037	1.3748	0.0075	0.0074	0.0	0.02
105	1050	0.0040	0.0076	1.6036	0.3081	0.0037	1.3823	0.0075	0.0074	0.0	0.02
106	1060	0.0040	0.0076	1.6112	0.3118	0.0037	1.3898	0.0075	0.0074	0.0	0.02
107	1070	0.0040	0.0076	1.6188	0.3156	0.0038	1.3973	0.0075	0.0074	0.0	0.02
108	1080	0.0040	0.0076	1.6264	0.3193	0.0038	1.4048	0.0075	0.0074	0.0	0.02
109	1090	0.0040	0.0076	1.6340	0.3231	0.0038	1.4123	0.0075	0.0074	0.0	0.02
110	1100	0.0040	0.0076	1.6416	0.3269	0.0038	1.4198	0.0075	0.0074	0.0	0.02
111	1110	0.0040	0.0076	1.6492	0.3308	0.0038	1.4273	0.0075	0.0074	0.0	0.02
112	1120	0.0040	0.0076	1.6568	0.3346	0.0038	1.4348	0.0075	0.0074	0.0	0.02
113	1130	0.0040	0.0076	1.6644	0.3385	0.0039	1.4423	0.0075	0.0074	0.0	0.02
114	1140	0.0040	0.0076	1.6720	0.3423	0.0039	1.4498	0.0075	0.0074	0.0	0.02
115	1150	0.0040	0.0076	1.6796	0.3462	0.0039	1.4573	0.0075	0.0074	0.0	0.02
116	1160	0.0040	0.0076	1.6872	0.3501	0.0039	1.4648	0.0075	0.0074	0.0	0.02
117	1170	0.0040	0.0076	1.6948	0.3540	0.0039	1.4723	0.0075	0.0074	0.0	0.02
118	1180	0.0040	0.0076	1.7024	0.3580	0.0039	1.4798	0.0075	0.0074	0.0	0.02
119	1190	0.0040	0.0076	1.7100	0.3619	0.0039	1.4873	0.0075	0.0074	0.0	0.02
120	1200	0.0040	0.0076	1.7176	0.3659	0.0040	1.4948	0.0075	0.0075	0.0	0.02
121	1210	0.0040	0.0076	1.7252	0.3698	0.0040	1.5024	0.0075	0.0075	0.0	0.02
122	1220	0.0040	0.0076	1.7328	0.3738	0.0040	1.5099	0.0075	0.0075	0.0	0.02
123	1230	0.0040	0.0076	1.7404	0.3778	0.0040	1.5174	0.0075	0.0075	0.0	0.02
124	1240	0.0040	0.0076	1.7480	0.3819	0.0040	1.5249	0.0075	0.0075	0.0	0.02
125	1250	0.0040	0.0076	1.7556	0.3859	0.0040	1.5324	0.0075	0.0075	0.0	0.02
126	1260	0.0040	0.0076	1.7632	0.3899	0.0040	1.5399	0.0075	0.0075	0.0	0.02
127	1270	0.0040	0.0076	1.7708	0.3940	0.0041	1.5474	0.0075	0.0075	0.0	0.02
128	1280	0.0040	0.0076	1.7784	0.3981	0.0041	1.5550	0.0075	0.0075	0.0	0.02
129	1290	0.0040	0.0076	1.7860	0.4021	0.0041	1.5625	0.0075	0.0075	0.0	0.02
130	1300	0.0040	0.0076	1.7936	0.4062	0.0041	1.5700	0.0075	0.0075	0.0	0.02
131	1310	0.0040	0.0076	1.8012	0.4104	0.0041	1.5775	0.0075	0.0075	0.0	0.02
132	1320	0.0040	0.0076	1.8088	0.4145	0.0041	1.5850	0.0075	0.0075	0.0	0.02
133	1330	0.0040	0.0076	1.8164	0.4186	0.0041	1.5925	0.0075	0.0075	0.0	0.02
134	1340	0.0040	0.0076	1.8240	0.4228	0.0042	1.6001	0.0075	0.0075	0.0	0.02
135	1350	0.0040	0.0076	1.8316	0.4269	0.0042	1.6076	0.0075	0.0075	0.0	0.02
136	1360	0.0040	0.0076	1.8392	0.4311	0.0042	1.6151	0.0075	0.0075	0.0	0.02
137	1370	0.0040	0.0076	1.8468	0.4353	0.0042	1.6226	0.0075	0.0075	0.0	0.02
138	1380	0.0040	0.0076	1.8544	0.4395	0.0042	1.6301	0.0075	0.0075	0.0	0.02
139	1390	0.0040	0.0076	1.8620	0.4437	0.0042	1.6377	0.0075	0.0075	0.0	0.02
140	1400	0.0040	0.0076	1.8696	0.4480	0.0042	1.6452	0.0075	0.0075	0.0	0.02
141	1410	0.0040	0.0076	1.8772	0.4522	0.0042	1.6527	0.0075	0.0075	0.0	0.02
142	1420	0.0040	0.0076	1.8848	0.4565	0.0043	1.6602	0.0075	0.0075	0.0	0.02
143	1430	0.0040	0.0076	1.8924	0.4607	0.0043	1.6678	0.0075	0.0075	0.0	0.02
144	1440	0.0040	0.0076	1.9000	0.4650	0.0043	1.6753	0.0075	0.0075	0.0	0.02

Total Volume of Runoff[1] = 2,870 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH

10-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation
Basin:
Storm Event: 10-YEAR, 24-HOUR
Given:

Area = 0.48 acres
Pt = 2.80 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.01 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.33
Vol(cf)=	4,411

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distribution % of Pt	(4) Incremental Rainfall in.	(5) Accumulated Rainfall in.	Pervious Area (6) Accumulated Runoff in.	Pervious Area (7) Incremental Runoff in.	Impervious Area (8) Accumulated Runoff in.	Impervious Area (9) Incremental Runoff in.	(10) Total Runoff in.	(11) Instant hydrograph cfs	(12) design hydrograph cfs	
1	10	0.0040	0.0112	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0112	0.0224	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0112	0.0336	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0112	0.0448	0.0000	0.0000	0.0001	0.0001	0.0001	0.0	0.00	
5	50	0.0040	0.0112	0.0560	0.0000	0.0000	0.0011	0.0010	0.0010	0.0	0.00	
6	60	0.0040	0.0112	0.0672	0.0000	0.0000	0.0030	0.0020	0.0019	0.0	0.00	
7	70	0.0040	0.0112	0.0784	0.0000	0.0000	0.0058	0.0028	0.0028	0.0	0.01	
8	80	0.0040	0.0112	0.0896	0.0000	0.0000	0.0094	0.0036	0.0035	0.0	0.01	
9	90	0.0040	0.0112	0.1008	0.0000	0.0000	0.0136	0.0042	0.0041	0.0	0.01	
10	100	0.0040	0.0112	0.1120	0.0000	0.0000	0.0184	0.0048	0.0047	0.0	0.01	
11	110	0.0050	0.0140	0.1260	0.0000	0.0000	0.0251	0.0067	0.0066	0.0	0.02	
12	120	0.0050	0.0140	0.1400	0.0000	0.0000	0.0324	0.0074	0.0072	0.0	0.02	
13	130	0.0050	0.0140	0.1540	0.0000	0.0000	0.0404	0.0079	0.0078	0.0	0.02	
14	140	0.0050	0.0140	0.1680	0.0000	0.0000	0.0488	0.0085	0.0083	0.0	0.02	
15	150	0.0050	0.0140	0.1820	0.0000	0.0000	0.0577	0.0089	0.0088	0.0	0.02	
16	160	0.0050	0.0140	0.1960	0.0000	0.0000	0.0670	0.0093	0.0091	0.0	0.03	
17	170	0.0060	0.0168	0.2128	0.0000	0.0000	0.0787	0.0116	0.0114	0.0	0.03	
18	180	0.0060	0.0168	0.2296	0.0000	0.0000	0.0907	0.0121	0.0119	0.0	0.03	
19	190	0.0060	0.0168	0.2464	0.0000	0.0000	0.1032	0.0125	0.0122	0.0	0.03	
20	200	0.0060	0.0168	0.2632	0.0000	0.0000	0.1160	0.0128	0.0126	0.0	0.04	
21	210	0.0060	0.0168	0.2800	0.0000	0.0000	0.1291	0.0131	0.0129	0.0	0.04	
22	220	0.0060	0.0168	0.2968	0.0000	0.0000	0.1424	0.0134	0.0131	0.0	0.04	
23	230	0.0070	0.0196	0.3164	0.0000	0.0000	0.1583	0.0159	0.0156	0.0	0.04	
24	240	0.0070	0.0196	0.3360	0.0000	0.0000	0.1745	0.0162	0.0159	0.0	0.05	
25	250	0.0070	0.0196	0.3556	0.0000	0.0000	0.1910	0.0164	0.0162	0.0	0.05	
26	260	0.0070	0.0196	0.3752	0.0000	0.0000	0.2077	0.0167	0.0164	0.0	0.05	
27	270	0.0070	0.0196	0.3948	0.0000	0.0000	0.2245	0.0169	0.0166	0.0	0.05	
28	280	0.0070	0.0196	0.4144	0.0000	0.0000	0.2416	0.0171	0.0168	0.0	0.05	
29	290	0.0082	0.0230	0.4374	0.0000	0.0000	0.2618	0.0202	0.0199	0.1	0.05	
30	300	0.0082	0.0230	0.4603	0.0000	0.0000	0.2822	0.0204	0.0201	0.1	0.06	
31	310	0.0082	0.0230	0.4833	0.0000	0.0000	0.3028	0.0206	0.0202	0.1	0.06	
32	320	0.0082	0.0230	0.5062	0.0000	0.0000	0.3236	0.0208	0.0204	0.1	0.06	
33	330	0.0082	0.0230	0.5292	0.0000	0.0000	0.3444	0.0209	0.0205	0.1	0.06	
34	340	0.0082	0.0230	0.5522	0.0002	0.0002	0.3655	0.0210	0.0207	0.1	0.06	
35	350	0.0095	0.0266	0.5788	0.0008	0.0007	0.3900	0.0245	0.0241	0.1	0.06	
36	360	0.0095	0.0266	0.6054	0.0020	0.0012	0.4146	0.0247	0.0243	0.1	0.07	
37	370	0.0095	0.0266	0.6320	0.0036	0.0017	0.4394	0.0248	0.0244	0.1	0.07	
38	380	0.0095	0.0266	0.6586	0.0058	0.0021	0.4643	0.0249	0.0245	0.1	0.07	
39	390	0.0095	0.0266	0.6852	0.0084	0.0026	0.4894	0.0250	0.0246	0.1	0.07	
40	400	0.0095	0.0266	0.7118	0.0114	0.0030	0.5145	0.0251	0.0247	0.1	0.07	
41	410	0.0134	0.0375	0.7493	0.0165	0.0050	0.5500	0.0356	0.0351	0.1	0.09	
42	420	0.0134	0.0375	0.7868	0.0223	0.0059	0.5857	0.0357	0.0352	0.1	0.10	
43	430	0.0134	0.0375	0.8243	0.0290	0.0067	0.6216	0.0359	0.0354	0.1	0.10	
44	440	0.0180	0.0504	0.8747	0.0392	0.0102	0.6699	0.0484	0.0477	0.1	0.12	
45	450	0.0180	0.0504	0.9251	0.0507	0.0115	0.7185	0.0485	0.0479	0.1	0.14	
46	460	0.0340	0.0952	1.0203	0.0759	0.0252	0.8106	0.0921	0.0910	0.3	0.20	
47	470	0.0540	0.1512	1.1715	0.1241	0.0483	0.9578	0.1472	0.1456	0.4	0.33	Q peak
48	480	0.0270	0.0756	1.2471	0.1517	0.0276	1.0318	0.0739	0.0732	0.2	0.32	
49	490	0.0180	0.0504	1.2975	0.1713	0.0196	1.0811	0.0494	0.0489	0.1	0.19	
50	500	0.0134	0.0375	1.3350	0.1865	0.0152	1.1179	0.0368	0.0364	0.1	0.13	
51	510	0.0134	0.0375	1.3726	0.2021	0.0156	1.1548	0.0368	0.0365	0.1	0.11	
52	520	0.0134	0.0375	1.4101	0.2182	0.0161	1.1917	0.0369	0.0365	0.1	0.11	
53	530	0.0088	0.0246	1.4347	0.2290	0.0108	1.2159	0.0242	0.0240	0.1	0.09	
54	540	0.0088	0.0246	1.4594	0.2400	0.0110	1.2401	0.0242	0.0240	0.1	0.07	
55	550	0.0088	0.0246	1.4840	0.2512	0.0112	1.2644	0.0243	0.0240	0.1	0.07	
56	560	0.0088	0.0246	1.5086	0.2626	0.0114	1.2887	0.0243	0.0241	0.1	0.07	
57	570	0.0088	0.0246	1.5333	0.2741	0.0116	1.3129	0.0243	0.0241	0.1	0.07	
58	580	0.0088	0.0246	1.5579	0.2859	0.0117	1.3372	0.0243	0.0241	0.1	0.07	
59	590	0.0088	0.0246	1.5826	0.2978	0.0119	1.3615	0.0243	0.0241	0.1	0.07	
60	600	0.0088	0.0246	1.6072	0.3098	0.0121	1.3858	0.0243	0.0241	0.1	0.07	
61	610	0.0088	0.0246	1.6318	0.3221	0.0122	1.4101	0.0243	0.0241	0.1	0.07	
62	620	0.0088	0.0246	1.6565	0.3345	0.0124	1.4345	0.0243	0.0241	0.1	0.07	
63	630	0.0088	0.0246	1.6811	0.3470	0.0126	1.4588	0.0243	0.0241	0.1	0.07	
64	640	0.0088	0.0246	1.7058	0.3597	0.0127	1.4831	0.0243	0.0241	0.1	0.07	
65	650	0.0072	0.0202	1.7259	0.3702	0.0105	1.5031	0.0199	0.0198	0.1	0.06	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	(6) Accumu-lated Runoff in.	(7) Incre-mental Runoff in.	(8) Accumu-lated Runoff in.	(9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0202	1.7461	0.3808	0.0106	1.5230	0.0199	0.0198	0.1	0.06
67	670	0.0072	0.0202	1.7662	0.3915	0.0107	1.5429	0.0199	0.0198	0.1	0.06
68	680	0.0072	0.0202	1.7864	0.4024	0.0108	1.5629	0.0199	0.0198	0.1	0.06
69	690	0.0072	0.0202	1.8066	0.4133	0.0109	1.5828	0.0199	0.0198	0.1	0.06
70	700	0.0072	0.0202	1.8267	0.4243	0.0110	1.6028	0.0199	0.0198	0.1	0.06
71	710	0.0072	0.0202	1.8469	0.4353	0.0111	1.6227	0.0200	0.0198	0.1	0.06
72	720	0.0072	0.0202	1.8670	0.4465	0.0112	1.6427	0.0200	0.0198	0.1	0.06
73	730	0.0072	0.0202	1.8872	0.4578	0.0113	1.6626	0.0200	0.0198	0.1	0.06
74	740	0.0072	0.0202	1.9074	0.4692	0.0114	1.6826	0.0200	0.0198	0.1	0.06
75	750	0.0072	0.0202	1.9275	0.4806	0.0114	1.7025	0.0200	0.0198	0.1	0.06
76	760	0.0072	0.0202	1.9477	0.4922	0.0115	1.7225	0.0200	0.0198	0.1	0.06
77	770	0.0057	0.0160	1.9636	0.5013	0.0092	1.7383	0.0158	0.0157	0.0	0.05
78	780	0.0057	0.0160	1.9796	0.5106	0.0092	1.7541	0.0158	0.0157	0.0	0.05
79	790	0.0057	0.0160	1.9956	0.5199	0.0093	1.7700	0.0158	0.0157	0.0	0.05
80	800	0.0057	0.0160	2.0115	0.5292	0.0093	1.7858	0.0158	0.0157	0.0	0.05
81	810	0.0057	0.0160	2.0275	0.5386	0.0094	1.8016	0.0158	0.0157	0.0	0.05
82	820	0.0057	0.0160	2.0434	0.5481	0.0094	1.8174	0.0158	0.0157	0.0	0.05
83	830	0.0057	0.0160	2.0594	0.5576	0.0095	1.8332	0.0158	0.0157	0.0	0.05
84	840	0.0057	0.0160	2.0754	0.5671	0.0095	1.8491	0.0158	0.0157	0.0	0.05
85	850	0.0057	0.0160	2.0913	0.5767	0.0096	1.8649	0.0158	0.0157	0.0	0.05
86	860	0.0057	0.0160	2.1073	0.5864	0.0096	1.8807	0.0158	0.0157	0.0	0.05
87	870	0.0057	0.0160	2.1232	0.5961	0.0097	1.8966	0.0158	0.0157	0.0	0.05
88	880	0.0057	0.0160	2.1392	0.6058	0.0097	1.9124	0.0158	0.0157	0.0	0.05
89	890	0.0050	0.0140	2.1532	0.6144	0.0086	1.9263	0.0139	0.0138	0.0	0.04
90	900	0.0050	0.0140	2.1672	0.6230	0.0086	1.9402	0.0139	0.0138	0.0	0.04
91	910	0.0050	0.0140	2.1812	0.6317	0.0087	1.9541	0.0139	0.0138	0.0	0.04
92	920	0.0050	0.0140	2.1952	0.6403	0.0087	1.9680	0.0139	0.0138	0.0	0.04
93	930	0.0050	0.0140	2.2092	0.6491	0.0087	1.9819	0.0139	0.0138	0.0	0.04
94	940	0.0050	0.0140	2.2232	0.6578	0.0088	1.9958	0.0139	0.0138	0.0	0.04
95	950	0.0050	0.0140	2.2372	0.6666	0.0088	2.0097	0.0139	0.0138	0.0	0.04
96	960	0.0050	0.0140	2.2512	0.6754	0.0088	2.0236	0.0139	0.0138	0.0	0.04
97	970	0.0050	0.0140	2.2652	0.6843	0.0089	2.0375	0.0139	0.0138	0.0	0.04
98	980	0.0050	0.0140	2.2792	0.6932	0.0089	2.0514	0.0139	0.0138	0.0	0.04
99	990	0.0050	0.0140	2.2932	0.7021	0.0089	2.0653	0.0139	0.0138	0.0	0.04
100	1000	0.0050	0.0140	2.3072	0.7110	0.0090	2.0792	0.0139	0.0138	0.0	0.04
101	1010	0.0040	0.0112	2.3184	0.7182	0.0072	2.0903	0.0111	0.0111	0.0	0.04
102	1020	0.0040	0.0112	2.3296	0.7254	0.0072	2.1014	0.0111	0.0111	0.0	0.03
103	1030	0.0040	0.0112	2.3408	0.7327	0.0072	2.1125	0.0111	0.0111	0.0	0.03
104	1040	0.0040	0.0112	2.3520	0.7399	0.0072	2.1237	0.0111	0.0111	0.0	0.03
105	1050	0.0040	0.0112	2.3632	0.7472	0.0073	2.1348	0.0111	0.0111	0.0	0.03
106	1060	0.0040	0.0112	2.3744	0.7544	0.0073	2.1459	0.0111	0.0111	0.0	0.03
107	1070	0.0040	0.0112	2.3856	0.7617	0.0073	2.1570	0.0111	0.0111	0.0	0.03
108	1080	0.0040	0.0112	2.3968	0.7691	0.0073	2.1682	0.0111	0.0111	0.0	0.03
109	1090	0.0040	0.0112	2.4080	0.7764	0.0073	2.1793	0.0111	0.0111	0.0	0.03
110	1100	0.0040	0.0112	2.4192	0.7838	0.0074	2.1904	0.0111	0.0111	0.0	0.03
111	1110	0.0040	0.0112	2.4304	0.7912	0.0074	2.2016	0.0111	0.0111	0.0	0.03
112	1120	0.0040	0.0112	2.4416	0.7986	0.0074	2.2127	0.0111	0.0111	0.0	0.03
113	1130	0.0040	0.0112	2.4528	0.8060	0.0074	2.2238	0.0111	0.0111	0.0	0.03
114	1140	0.0040	0.0112	2.4640	0.8134	0.0074	2.2350	0.0111	0.0111	0.0	0.03
115	1150	0.0040	0.0112	2.4752	0.8209	0.0075	2.2461	0.0111	0.0111	0.0	0.03
116	1160	0.0040	0.0112	2.4864	0.8283	0.0075	2.2572	0.0111	0.0111	0.0	0.03
117	1170	0.0040	0.0112	2.4976	0.8358	0.0075	2.2684	0.0111	0.0111	0.0	0.03
118	1180	0.0040	0.0112	2.5088	0.8433	0.0075	2.2795	0.0111	0.0111	0.0	0.03
119	1190	0.0040	0.0112	2.5200	0.8509	0.0075	2.2906	0.0111	0.0111	0.0	0.03
120	1200	0.0040	0.0112	2.5312	0.8584	0.0075	2.3018	0.0111	0.0111	0.0	0.03
121	1210	0.0040	0.0112	2.5424	0.8660	0.0076	2.3129	0.0111	0.0111	0.0	0.03
122	1220	0.0040	0.0112	2.5536	0.8735	0.0076	2.3240	0.0111	0.0111	0.0	0.03
123	1230	0.0040	0.0112	2.5648	0.8811	0.0076	2.3352	0.0111	0.0111	0.0	0.03
124	1240	0.0040	0.0112	2.5760	0.8887	0.0076	2.3463	0.0111	0.0111	0.0	0.03
125	1250	0.0040	0.0112	2.5872	0.8964	0.0076	2.3574	0.0111	0.0111	0.0	0.03
126	1260	0.0040	0.0112	2.5984	0.9040	0.0076	2.3686	0.0111	0.0111	0.0	0.03
127	1270	0.0040	0.0112	2.6096	0.9117	0.0077	2.3797	0.0111	0.0111	0.0	0.03
128	1280	0.0040	0.0112	2.6208	0.9194	0.0077	2.3909	0.0111	0.0111	0.0	0.03
129	1290	0.0040	0.0112	2.6320	0.9271	0.0077	2.4020	0.0111	0.0111	0.0	0.03
130	1300	0.0040	0.0112	2.6432	0.9348	0.0077	2.4131	0.0111	0.0111	0.0	0.03
131	1310	0.0040	0.0112	2.6544	0.9425	0.0077	2.4243	0.0111	0.0111	0.0	0.03
132	1320	0.0040	0.0112	2.6656	0.9502	0.0077	2.4354	0.0111	0.0111	0.0	0.03
133	1330	0.0040	0.0112	2.6768	0.9580	0.0078	2.4466	0.0111	0.0111	0.0	0.03
134	1340	0.0040	0.0112	2.6880	0.9658	0.0078	2.4577	0.0111	0.0111	0.0	0.03
135	1350	0.0040	0.0112	2.6992	0.9736	0.0078	2.4689	0.0111	0.0111	0.0	0.03
136	1360	0.0040	0.0112	2.7104	0.9814	0.0078	2.4800	0.0111	0.0111	0.0	0.03
137	1370	0.0040	0.0112	2.7216	0.9892	0.0078	2.4911	0.0111	0.0111	0.0	0.03
138	1380	0.0040	0.0112	2.7328	0.9971	0.0078	2.5023	0.0111	0.0111	0.0	0.03
139	1390	0.0040	0.0112	2.7440	1.0049	0.0079	2.5134	0.0111	0.0111	0.0	0.03
140	1400	0.0040	0.0112	2.7552	1.0128	0.0079	2.5246	0.0111	0.0111	0.0	0.03
141	1410	0.0040	0.0112	2.7664	1.0207	0.0079	2.5357	0.0111	0.0111	0.0	0.03
142	1420	0.0040	0.0112	2.7776	1.0286	0.0079	2.5469	0.0111	0.0111	0.0	0.03
143	1430	0.0040	0.0112	2.7888	1.0365	0.0079	2.5580	0.0111	0.0111	0.0	0.03
144	1440	0.0040	0.0112	2.8000	1.0444	0.0079	2.5692	0.0111	0.0111	0.0	0.03

Total Volume of Runoff[1] = 4,411 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

V = SumQ x dt
V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH

25-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation
Basin:
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 0.48 acres
Pt = 3.40 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.01 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.40
Vol(cf)=	5,444

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs	
1	10	0.0040	0.0136	0.0136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0136	0.0272	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0136	0.0408	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0136	0.0544	0.0000	0.0000	0.0008	0.0008	0.0008	0.0	0.00	
5	50	0.0040	0.0136	0.0680	0.0000	0.0000	0.0032	0.0023	0.0023	0.0	0.00	
6	60	0.0040	0.0136	0.0816	0.0000	0.0000	0.0068	0.0036	0.0035	0.0	0.01	
7	70	0.0040	0.0136	0.0952	0.0000	0.0000	0.0114	0.0047	0.0046	0.0	0.01	
8	80	0.0040	0.0136	0.1088	0.0000	0.0000	0.0170	0.0055	0.0055	0.0	0.01	
9	90	0.0040	0.0136	0.1224	0.0000	0.0000	0.0233	0.0063	0.0062	0.0	0.02	
10	100	0.0040	0.0136	0.1360	0.0000	0.0000	0.0303	0.0070	0.0069	0.0	0.02	
11	110	0.0050	0.0170	0.1530	0.0000	0.0000	0.0398	0.0095	0.0094	0.0	0.02	
12	120	0.0050	0.0170	0.1700	0.0000	0.0000	0.0501	0.0103	0.0101	0.0	0.03	
13	130	0.0050	0.0170	0.1870	0.0000	0.0000	0.0610	0.0109	0.0108	0.0	0.03	
14	140	0.0050	0.0170	0.2040	0.0000	0.0000	0.0725	0.0115	0.0113	0.0	0.03	
15	150	0.0050	0.0170	0.2210	0.0000	0.0000	0.0845	0.0120	0.0118	0.0	0.03	
16	160	0.0050	0.0170	0.2380	0.0000	0.0000	0.0969	0.0124	0.0122	0.0	0.03	
17	170	0.0060	0.0204	0.2584	0.0000	0.0000	0.1123	0.0154	0.0151	0.0	0.04	
18	180	0.0060	0.0204	0.2788	0.0000	0.0000	0.1281	0.0158	0.0156	0.0	0.04	
19	190	0.0060	0.0204	0.2992	0.0000	0.0000	0.1444	0.0162	0.0160	0.0	0.05	
20	200	0.0060	0.0204	0.3196	0.0000	0.0000	0.1610	0.0166	0.0163	0.0	0.05	
21	210	0.0060	0.0204	0.3400	0.0000	0.0000	0.1779	0.0169	0.0166	0.0	0.05	
22	220	0.0060	0.0204	0.3604	0.0000	0.0000	0.1950	0.0172	0.0169	0.0	0.05	
23	230	0.0070	0.0238	0.3842	0.0000	0.0000	0.2154	0.0203	0.0200	0.1	0.05	
24	240	0.0070	0.0238	0.4080	0.0000	0.0000	0.2360	0.0206	0.0203	0.1	0.06	
25	250	0.0070	0.0238	0.4318	0.0000	0.0000	0.2569	0.0209	0.0205	0.1	0.06	
26	260	0.0070	0.0238	0.4556	0.0000	0.0000	0.2780	0.0211	0.0208	0.1	0.06	
27	270	0.0070	0.0238	0.4794	0.0000	0.0000	0.2993	0.0213	0.0210	0.1	0.06	
28	280	0.0070	0.0238	0.5032	0.0000	0.0000	0.3208	0.0215	0.0211	0.1	0.06	
29	290	0.0082	0.0279	0.5311	0.0000	0.0000	0.3462	0.0254	0.0249	0.1	0.07	
30	300	0.0082	0.0279	0.5590	0.0003	0.0003	0.3717	0.0256	0.0251	0.1	0.07	
31	310	0.0082	0.0279	0.5868	0.0011	0.0008	0.3975	0.0257	0.0253	0.1	0.07	
32	320	0.0082	0.0279	0.6147	0.0025	0.0014	0.4234	0.0259	0.0255	0.1	0.07	
33	330	0.0082	0.0279	0.6426	0.0044	0.0019	0.4494	0.0260	0.0256	0.1	0.07	
34	340	0.0082	0.0279	0.6705	0.0069	0.0024	0.4755	0.0262	0.0258	0.1	0.07	
35	350	0.0095	0.0323	0.7028	0.0104	0.0035	0.5060	0.0304	0.0300	0.1	0.08	
36	360	0.0095	0.0323	0.7351	0.0145	0.0041	0.5365	0.0306	0.0301	0.1	0.09	
37	370	0.0095	0.0323	0.7674	0.0192	0.0047	0.5672	0.0307	0.0303	0.1	0.09	
38	380	0.0095	0.0323	0.7997	0.0246	0.0053	0.5980	0.0308	0.0304	0.1	0.09	
39	390	0.0095	0.0323	0.8320	0.0305	0.0059	0.6289	0.0309	0.0305	0.1	0.09	
40	400	0.0095	0.0323	0.8643	0.0370	0.0065	0.6599	0.0310	0.0306	0.1	0.09	
41	410	0.0134	0.0456	0.9098	0.0471	0.0101	0.7038	0.0438	0.0433	0.1	0.11	
42	420	0.0134	0.0456	0.9554	0.0583	0.0112	0.7477	0.0440	0.0434	0.1	0.12	
43	430	0.0134	0.0456	1.0010	0.0704	0.0122	0.7918	0.0441	0.0436	0.1	0.13	
44	440	0.0180	0.0612	1.0622	0.0883	0.0178	0.8512	0.0594	0.0587	0.2	0.15	
45	450	0.0180	0.0612	1.1234	0.1077	0.0195	0.9108	0.0596	0.0589	0.2	0.17	
46	460	0.0340	0.1156	1.2390	0.1487	0.0409	1.0238	0.1129	0.1117	0.3	0.24	
47	470	0.0540	0.1836	1.4226	0.2236	0.0750	1.2039	0.1802	0.1784	0.5	0.40	Q peak
48	480	0.0270	0.0918	1.5144	0.2652	0.0416	1.2943	0.0904	0.0895	0.3	0.39	
49	490	0.0180	0.0612	1.5756	0.2944	0.0291	1.3546	0.0603	0.0598	0.2	0.23	
50	500	0.0134	0.0456	1.6211	0.3167	0.0224	1.3996	0.0449	0.0446	0.1	0.16	
51	510	0.0134	0.0456	1.6667	0.3396	0.0229	1.4445	0.0450	0.0446	0.1	0.13	
52	520	0.0134	0.0456	1.7122	0.3631	0.0235	1.4895	0.0450	0.0446	0.1	0.13	
53	530	0.0088	0.0299	1.7422	0.3788	0.0157	1.5191	0.0296	0.0293	0.1	0.11	
54	540	0.0088	0.0299	1.7721	0.3947	0.0159	1.5487	0.0296	0.0294	0.1	0.09	
55	550	0.0088	0.0299	1.8020	0.4108	0.0161	1.5783	0.0296	0.0294	0.1	0.09	
56	560	0.0088	0.0299	1.8319	0.4271	0.0163	1.6079	0.0296	0.0294	0.1	0.09	
57	570	0.0088	0.0299	1.8618	0.4436	0.0165	1.6375	0.0296	0.0294	0.1	0.09	
58	580	0.0088	0.0299	1.8918	0.4604	0.0167	1.6671	0.0296	0.0294	0.1	0.09	
59	590	0.0088	0.0299	1.9217	0.4773	0.0169	1.6968	0.0296	0.0294	0.1	0.09	
60	600	0.0088	0.0299	1.9516	0.4944	0.0171	1.7264	0.0296	0.0294	0.1	0.09	
61	610	0.0088	0.0299	1.9815	0.5117	0.0173	1.7560	0.0296	0.0294	0.1	0.09	
62	620	0.0088	0.0299	2.0114	0.5292	0.0175	1.7857	0.0297	0.0294	0.1	0.09	
63	630	0.0088	0.0299	2.0414	0.5468	0.0177	1.8154	0.0297	0.0295	0.1	0.09	
64	640	0.0088	0.0299	2.0713	0.5647	0.0178	1.8450	0.0297	0.0295	0.1	0.09	
65	650	0.0072	0.0245	2.0958	0.5794	0.0147	1.8693	0.0243	0.0241	0.1	0.08	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0245	2.1202	0.5942	0.0148	1.8936	0.0243	0.0241	0.1	0.07
67	670	0.0072	0.0245	2.1447	0.6092	0.0149	1.9179	0.0243	0.0241	0.1	0.07
68	680	0.0072	0.0245	2.1692	0.6242	0.0151	1.9422	0.0243	0.0241	0.1	0.07
69	690	0.0072	0.0245	2.1937	0.6394	0.0152	1.9665	0.0243	0.0241	0.1	0.07
70	700	0.0072	0.0245	2.2182	0.6547	0.0153	1.9908	0.0243	0.0241	0.1	0.07
71	710	0.0072	0.0245	2.2426	0.6700	0.0154	2.0151	0.0243	0.0242	0.1	0.07
72	720	0.0072	0.0245	2.2671	0.6855	0.0155	2.0394	0.0243	0.0242	0.1	0.07
73	730	0.0072	0.0245	2.2916	0.7011	0.0156	2.0637	0.0243	0.0242	0.1	0.07
74	740	0.0072	0.0245	2.3161	0.7167	0.0157	2.0880	0.0243	0.0242	0.1	0.07
75	750	0.0072	0.0245	2.3406	0.7325	0.0158	2.1123	0.0243	0.0242	0.1	0.07
76	760	0.0072	0.0245	2.3650	0.7484	0.0159	2.1366	0.0243	0.0242	0.1	0.07
77	770	0.0057	0.0194	2.3844	0.7610	0.0126	2.1559	0.0193	0.0191	0.1	0.06
78	780	0.0057	0.0194	2.4038	0.7737	0.0127	2.1751	0.0193	0.0191	0.1	0.06
79	790	0.0057	0.0194	2.4232	0.7864	0.0127	2.1944	0.0193	0.0191	0.1	0.06
80	800	0.0057	0.0194	2.4426	0.7992	0.0128	2.2136	0.0193	0.0192	0.1	0.06
81	810	0.0057	0.0194	2.4619	0.8120	0.0128	2.2329	0.0193	0.0192	0.1	0.06
82	820	0.0057	0.0194	2.4813	0.8249	0.0129	2.2522	0.0193	0.0192	0.1	0.06
83	830	0.0057	0.0194	2.5007	0.8379	0.0130	2.2714	0.0193	0.0192	0.1	0.06
84	840	0.0057	0.0194	2.5201	0.8509	0.0130	2.2907	0.0193	0.0192	0.1	0.06
85	850	0.0057	0.0194	2.5395	0.8640	0.0131	2.3100	0.0193	0.0192	0.1	0.06
86	860	0.0057	0.0194	2.5588	0.8771	0.0131	2.3292	0.0193	0.0192	0.1	0.06
87	870	0.0057	0.0194	2.5782	0.8903	0.0132	2.3485	0.0193	0.0192	0.1	0.06
88	880	0.0057	0.0194	2.5976	0.9035	0.0132	2.3678	0.0193	0.0192	0.1	0.06
89	890	0.0050	0.0170	2.6146	0.9151	0.0116	2.3847	0.0169	0.0168	0.0	0.05
90	900	0.0050	0.0170	2.6316	0.9268	0.0117	2.4016	0.0169	0.0168	0.0	0.05
91	910	0.0050	0.0170	2.6486	0.9385	0.0117	2.4185	0.0169	0.0168	0.0	0.05
92	920	0.0050	0.0170	2.6656	0.9502	0.0118	2.4354	0.0169	0.0168	0.0	0.05
93	930	0.0050	0.0170	2.6826	0.9620	0.0118	2.4523	0.0169	0.0168	0.0	0.05
94	940	0.0050	0.0170	2.6996	0.9739	0.0118	2.4693	0.0169	0.0168	0.0	0.05
95	950	0.0050	0.0170	2.7166	0.9857	0.0119	2.4862	0.0169	0.0168	0.0	0.05
96	960	0.0050	0.0170	2.7336	0.9976	0.0119	2.5031	0.0169	0.0168	0.0	0.05
97	970	0.0050	0.0170	2.7506	1.0095	0.0119	2.5200	0.0169	0.0168	0.0	0.05
98	980	0.0050	0.0170	2.7676	1.0215	0.0120	2.5369	0.0169	0.0168	0.0	0.05
99	990	0.0050	0.0170	2.7846	1.0335	0.0120	2.5538	0.0169	0.0168	0.0	0.05
100	1000	0.0050	0.0170	2.8016	1.0456	0.0120	2.5707	0.0169	0.0168	0.0	0.05
101	1010	0.0040	0.0136	2.8152	1.0552	0.0097	2.5843	0.0135	0.0135	0.0	0.04
102	1020	0.0040	0.0136	2.8288	1.0649	0.0097	2.5978	0.0135	0.0135	0.0	0.04
103	1030	0.0040	0.0136	2.8424	1.0746	0.0097	2.6114	0.0135	0.0135	0.0	0.04
104	1040	0.0040	0.0136	2.8560	1.0843	0.0097	2.6249	0.0135	0.0135	0.0	0.04
105	1050	0.0040	0.0136	2.8696	1.0940	0.0097	2.6384	0.0135	0.0135	0.0	0.04
106	1060	0.0040	0.0136	2.8832	1.1038	0.0098	2.6520	0.0135	0.0135	0.0	0.04
107	1070	0.0040	0.0136	2.8968	1.1136	0.0098	2.6655	0.0135	0.0135	0.0	0.04
108	1080	0.0040	0.0136	2.9104	1.1234	0.0098	2.6791	0.0135	0.0135	0.0	0.04
109	1090	0.0040	0.0136	2.9240	1.1332	0.0098	2.6926	0.0135	0.0135	0.0	0.04
110	1100	0.0040	0.0136	2.9376	1.1431	0.0098	2.7061	0.0135	0.0135	0.0	0.04
111	1110	0.0040	0.0136	2.9512	1.1529	0.0099	2.7197	0.0135	0.0135	0.0	0.04
112	1120	0.0040	0.0136	2.9648	1.1628	0.0099	2.7332	0.0135	0.0135	0.0	0.04
113	1130	0.0040	0.0136	2.9784	1.1727	0.0099	2.7468	0.0135	0.0135	0.0	0.04
114	1140	0.0040	0.0136	2.9920	1.1826	0.0099	2.7603	0.0135	0.0135	0.0	0.04
115	1150	0.0040	0.0136	3.0056	1.1926	0.0099	2.7738	0.0135	0.0135	0.0	0.04
116	1160	0.0040	0.0136	3.0192	1.2025	0.0100	2.7874	0.0135	0.0135	0.0	0.04
117	1170	0.0040	0.0136	3.0328	1.2125	0.0100	2.8009	0.0135	0.0135	0.0	0.04
118	1180	0.0040	0.0136	3.0464	1.2225	0.0100	2.8145	0.0135	0.0135	0.0	0.04
119	1190	0.0040	0.0136	3.0600	1.2325	0.0100	2.8280	0.0135	0.0135	0.0	0.04
120	1200	0.0040	0.0136	3.0736	1.2426	0.0100	2.8416	0.0135	0.0135	0.0	0.04
121	1210	0.0040	0.0136	3.0872	1.2526	0.0101	2.8551	0.0135	0.0135	0.0	0.04
122	1220	0.0040	0.0136	3.1008	1.2627	0.0101	2.8687	0.0135	0.0135	0.0	0.04
123	1230	0.0040	0.0136	3.1144	1.2728	0.0101	2.8822	0.0135	0.0135	0.0	0.04
124	1240	0.0040	0.0136	3.1280	1.2829	0.0101	2.8958	0.0135	0.0135	0.0	0.04
125	1250	0.0040	0.0136	3.1416	1.2930	0.0101	2.9093	0.0135	0.0135	0.0	0.04
126	1260	0.0040	0.0136	3.1552	1.3032	0.0101	2.9229	0.0135	0.0135	0.0	0.04
127	1270	0.0040	0.0136	3.1688	1.3133	0.0102	2.9364	0.0135	0.0135	0.0	0.04
128	1280	0.0040	0.0136	3.1824	1.3235	0.0102	2.9500	0.0135	0.0135	0.0	0.04
129	1290	0.0040	0.0136	3.1960	1.3337	0.0102	2.9635	0.0135	0.0135	0.0	0.04
130	1300	0.0040	0.0136	3.2096	1.3439	0.0102	2.9771	0.0136	0.0135	0.0	0.04
131	1310	0.0040	0.0136	3.2232	1.3542	0.0102	2.9906	0.0136	0.0135	0.0	0.04
132	1320	0.0040	0.0136	3.2368	1.3644	0.0103	3.0042	0.0136	0.0135	0.0	0.04
133	1330	0.0040	0.0136	3.2504	1.3747	0.0103	3.0177	0.0136	0.0135	0.0	0.04
134	1340	0.0040	0.0136	3.2640	1.3850	0.0103	3.0313	0.0136	0.0135	0.0	0.04
135	1350	0.0040	0.0136	3.2776	1.3953	0.0103	3.0448	0.0136	0.0135	0.0	0.04
136	1360	0.0040	0.0136	3.2912	1.4056	0.0103	3.0584	0.0136	0.0135	0.0	0.04
137	1370	0.0040	0.0136	3.3048	1.4159	0.0103	3.0719	0.0136	0.0135	0.0	0.04
138	1380	0.0040	0.0136	3.3184	1.4263	0.0104	3.0855	0.0136	0.0135	0.0	0.04
139	1390	0.0040	0.0136	3.3320	1.4366	0.0104	3.0990	0.0136	0.0135	0.0	0.04
140	1400	0.0040	0.0136	3.3456	1.4470	0.0104	3.1126	0.0136	0.0135	0.0	0.04
141	1410	0.0040	0.0136	3.3592	1.4574	0.0104	3.1261	0.0136	0.0135	0.0	0.04
142	1420	0.0040	0.0136	3.3728	1.4678	0.0104	3.1397	0.0136	0.0135	0.0	0.04
143	1430	0.0040	0.0136	3.3864	1.4783	0.0104	3.1532	0.0136	0.0135	0.0	0.04
144	1440	0.0040	0.0136	3.4000	1.4887	0.0104	3.1668	0.0136	0.0135	0.0	0.04

Total Volume of Runoff[1] = 5,444 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

V = SumQ x dt
V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH
100-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation
Basin:
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 0.48 acres
Pt = 4.20 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.01 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk} (hrs)=	7.83
T_c (min)=	6
Q_{pk} (cfs)=	0.50
Vol(cf)=	6,823

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step + Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs	
1	10	0.0040	0.0168	0.0168	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0168	0.0336	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0168	0.0504	0.0000	0.0000	0.0004	0.0004	0.0004	0.0	0.00	
4	40	0.0040	0.0168	0.0672	0.0000	0.0000	0.0030	0.0026	0.0025	0.0	0.00	
5	50	0.0040	0.0168	0.0840	0.0000	0.0000	0.0075	0.0045	0.0044	0.0	0.01	
6	60	0.0040	0.0168	0.1008	0.0000	0.0000	0.0136	0.0061	0.0060	0.0	0.01	
7	70	0.0040	0.0168	0.1176	0.0000	0.0000	0.0210	0.0074	0.0072	0.0	0.02	
8	80	0.0040	0.0168	0.1344	0.0000	0.0000	0.0294	0.0084	0.0083	0.0	0.02	
9	90	0.0040	0.0168	0.1512	0.0000	0.0000	0.0387	0.0093	0.0092	0.0	0.03	
10	100	0.0040	0.0168	0.1680	0.0000	0.0000	0.0488	0.0101	0.0099	0.0	0.03	
11	110	0.0050	0.0210	0.1890	0.0000	0.0000	0.0623	0.0135	0.0133	0.0	0.03	
12	120	0.0050	0.0210	0.2100	0.0000	0.0000	0.0767	0.0143	0.0141	0.0	0.04	
13	130	0.0050	0.0210	0.2310	0.0000	0.0000	0.0917	0.0151	0.0148	0.0	0.04	
14	140	0.0050	0.0210	0.2520	0.0000	0.0000	0.1074	0.0157	0.0154	0.0	0.04	
15	150	0.0050	0.0210	0.2730	0.0000	0.0000	0.1236	0.0162	0.0159	0.0	0.05	
16	160	0.0050	0.0210	0.2940	0.0000	0.0000	0.1402	0.0166	0.0163	0.0	0.05	
17	170	0.0060	0.0252	0.3192	0.0000	0.0000	0.1606	0.0204	0.0201	0.1	0.05	
18	180	0.0060	0.0252	0.3444	0.0000	0.0000	0.1815	0.0209	0.0206	0.1	0.06	
19	190	0.0060	0.0252	0.3696	0.0000	0.0000	0.2029	0.0213	0.0210	0.1	0.06	
20	200	0.0060	0.0252	0.3948	0.0000	0.0000	0.2245	0.0217	0.0213	0.1	0.06	
21	210	0.0060	0.0252	0.4200	0.0000	0.0000	0.2465	0.0220	0.0216	0.1	0.06	
22	220	0.0060	0.0252	0.4452	0.0000	0.0000	0.2688	0.0222	0.0219	0.1	0.06	
23	230	0.0070	0.0294	0.4746	0.0000	0.0000	0.2950	0.0262	0.0258	0.1	0.07	
24	240	0.0070	0.0294	0.5040	0.0000	0.0000	0.3215	0.0265	0.0261	0.1	0.07	
25	250	0.0070	0.0294	0.5334	0.0000	0.0000	0.3483	0.0268	0.0263	0.1	0.08	
26	260	0.0070	0.0294	0.5628	0.0004	0.0004	0.3753	0.0270	0.0265	0.1	0.08	
27	270	0.0070	0.0294	0.5922	0.0013	0.0010	0.4024	0.0272	0.0267	0.1	0.08	
28	280	0.0070	0.0294	0.6216	0.0029	0.0016	0.4298	0.0273	0.0269	0.1	0.08	
29	290	0.0082	0.0344	0.6560	0.0056	0.0026	0.4620	0.0322	0.0317	0.1	0.08	
30	300	0.0082	0.0344	0.6905	0.0090	0.0034	0.4944	0.0324	0.0319	0.1	0.09	
31	310	0.0082	0.0344	0.7249	0.0131	0.0041	0.5269	0.0325	0.0321	0.1	0.09	
32	320	0.0082	0.0344	0.7594	0.0180	0.0049	0.5596	0.0327	0.0322	0.1	0.09	
33	330	0.0082	0.0344	0.7938	0.0235	0.0056	0.5924	0.0328	0.0324	0.1	0.09	
34	340	0.0082	0.0344	0.8282	0.0298	0.0062	0.6253	0.0329	0.0325	0.1	0.09	
35	350	0.0095	0.0399	0.8681	0.0378	0.0080	0.6636	0.0383	0.0378	0.1	0.10	
36	360	0.0095	0.0399	0.9080	0.0467	0.0089	0.7020	0.0384	0.0379	0.1	0.11	
37	370	0.0095	0.0399	0.9479	0.0564	0.0097	0.7405	0.0385	0.0380	0.1	0.11	
38	380	0.0095	0.0399	0.9878	0.0668	0.0105	0.7791	0.0386	0.0381	0.1	0.11	
39	390	0.0095	0.0399	1.0277	0.0780	0.0112	0.8178	0.0387	0.0382	0.1	0.11	
40	400	0.0095	0.0399	1.0676	0.0899	0.0119	0.8566	0.0388	0.0383	0.1	0.11	
41	410	0.0134	0.0563	1.1239	0.1079	0.0180	0.9114	0.0548	0.0542	0.2	0.13	
42	420	0.0134	0.0563	1.1802	0.1272	0.0193	0.9663	0.0549	0.0543	0.2	0.15	
43	430	0.0134	0.0563	1.2365	0.1477	0.0205	1.0213	0.0550	0.0545	0.2	0.16	
44	440	0.0180	0.0756	1.3121	0.1771	0.0294	1.0954	0.0741	0.0733	0.2	0.18	
45	450	0.0180	0.0756	1.3877	0.2085	0.0314	1.1696	0.0742	0.0735	0.2	0.21	
46	460	0.0340	0.1428	1.5305	0.2728	0.0643	1.3102	0.1405	0.1393	0.4	0.30	
47	470	0.0540	0.2268	1.7573	0.3868	0.1140	1.5341	0.2239	0.2221	0.6	0.50	Q peak
48	480	0.0270	0.1134	1.8707	0.4486	0.0618	1.6463	0.1122	0.1113	0.3	0.48	
49	490	0.0180	0.0756	1.9463	0.4913	0.0428	1.7211	0.0749	0.0743	0.2	0.29	
50	500	0.0134	0.0563	2.0026	0.5240	0.0326	1.7769	0.0558	0.0554	0.2	0.20	
51	510	0.0134	0.0563	2.0588	0.5572	0.0333	1.8327	0.0558	0.0554	0.2	0.16	
52	520	0.0134	0.0563	2.1151	0.5911	0.0339	1.8885	0.0558	0.0555	0.2	0.16	
53	530	0.0088	0.0370	2.1521	0.6137	0.0226	1.9252	0.0367	0.0364	0.1	0.14	
54	540	0.0088	0.0370	2.1890	0.6365	0.0228	1.9618	0.0367	0.0364	0.1	0.11	
55	550	0.0088	0.0370	2.2260	0.6596	0.0231	1.9985	0.0367	0.0365	0.1	0.11	
56	560	0.0088	0.0370	2.2630	0.6829	0.0233	2.0352	0.0367	0.0365	0.1	0.11	
57	570	0.0088	0.0370	2.2999	0.7064	0.0235	2.0719	0.0367	0.0365	0.1	0.11	
58	580	0.0088	0.0370	2.3369	0.7301	0.0237	2.1086	0.0367	0.0365	0.1	0.11	
59	590	0.0088	0.0370	2.3738	0.7541	0.0240	2.1454	0.0367	0.0365	0.1	0.11	
60	600	0.0088	0.0370	2.4108	0.7783	0.0242	2.1821	0.0367	0.0365	0.1	0.11	
61	610	0.0088	0.0370	2.4478	0.8026	0.0244	2.2188	0.0367	0.0365	0.1	0.11	
62	620	0.0088	0.0370	2.4847	0.8272	0.0246	2.2556	0.0367	0.0365	0.1	0.11	
63	630	0.0088	0.0370	2.5217	0.8520	0.0248	2.2923	0.0367	0.0365	0.1	0.11	
64	640	0.0088	0.0370	2.5586	0.8770	0.0250	2.3290	0.0367	0.0366	0.1	0.11	
65	650	0.0072	0.0302	2.5889	0.8975	0.0206	2.3591	0.0301	0.0299	0.1	0.10	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

					Pervious Area		Impervious Area				
(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	(6) Accumu-lated Runoff in.	(7) Incre-mental Runoff in.	(8) Accumu-lated Runoff in.	(9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0302	2.6191	0.9182	0.0207	2.3892	0.0301	0.0299	0.1	0.09
67	670	0.0072	0.0302	2.6494	0.9390	0.0208	2.4193	0.0301	0.0299	0.1	0.09
68	680	0.0072	0.0302	2.6796	0.9600	0.0209	2.4494	0.0301	0.0299	0.1	0.09
69	690	0.0072	0.0302	2.7098	0.9810	0.0210	2.4794	0.0301	0.0299	0.1	0.09
70	700	0.0072	0.0302	2.7401	1.0022	0.0212	2.5095	0.0301	0.0299	0.1	0.09
71	710	0.0072	0.0302	2.7703	1.0234	0.0213	2.5396	0.0301	0.0299	0.1	0.09
72	720	0.0072	0.0302	2.8006	1.0448	0.0214	2.5697	0.0301	0.0299	0.1	0.09
73	730	0.0072	0.0302	2.8308	1.0663	0.0215	2.5998	0.0301	0.0300	0.1	0.09
74	740	0.0072	0.0302	2.8610	1.0879	0.0216	2.6299	0.0301	0.0300	0.1	0.09
75	750	0.0072	0.0302	2.8913	1.1096	0.0217	2.6600	0.0301	0.0300	0.1	0.09
76	760	0.0072	0.0302	2.9215	1.1314	0.0218	2.6901	0.0301	0.0300	0.1	0.09
77	770	0.0057	0.0239	2.9455	1.1487	0.0173	2.7140	0.0238	0.0237	0.1	0.08
78	780	0.0057	0.0239	2.9694	1.1661	0.0174	2.7378	0.0238	0.0237	0.1	0.07
79	790	0.0057	0.0239	2.9933	1.1836	0.0175	2.7616	0.0238	0.0237	0.1	0.07
80	800	0.0057	0.0239	3.0173	1.2011	0.0175	2.7855	0.0238	0.0237	0.1	0.07
81	810	0.0057	0.0239	3.0412	1.2187	0.0176	2.8093	0.0238	0.0237	0.1	0.07
82	820	0.0057	0.0239	3.0652	1.2363	0.0176	2.8332	0.0238	0.0237	0.1	0.07
83	830	0.0057	0.0239	3.0891	1.2540	0.0177	2.8570	0.0238	0.0237	0.1	0.07
84	840	0.0057	0.0239	3.1130	1.2718	0.0177	2.8809	0.0238	0.0237	0.1	0.07
85	850	0.0057	0.0239	3.1370	1.2896	0.0178	2.9047	0.0238	0.0237	0.1	0.07
86	860	0.0057	0.0239	3.1609	1.3074	0.0179	2.9286	0.0238	0.0237	0.1	0.07
87	870	0.0057	0.0239	3.1849	1.3254	0.0179	2.9524	0.0239	0.0238	0.1	0.07
88	880	0.0057	0.0239	3.2088	1.3433	0.0180	2.9763	0.0239	0.0238	0.1	0.07
89	890	0.0050	0.0210	3.2298	1.3591	0.0158	2.9972	0.0209	0.0208	0.1	0.06
90	900	0.0050	0.0210	3.2508	1.3750	0.0158	3.0181	0.0209	0.0208	0.1	0.06
91	910	0.0050	0.0210	3.2718	1.3909	0.0159	3.0390	0.0209	0.0208	0.1	0.06
92	920	0.0050	0.0210	3.2928	1.4068	0.0159	3.0600	0.0209	0.0208	0.1	0.06
93	930	0.0050	0.0210	3.3138	1.4228	0.0160	3.0809	0.0209	0.0208	0.1	0.06
94	940	0.0050	0.0210	3.3348	1.4388	0.0160	3.1018	0.0209	0.0208	0.1	0.06
95	950	0.0050	0.0210	3.3558	1.4548	0.0160	3.1227	0.0209	0.0208	0.1	0.06
96	960	0.0050	0.0210	3.3768	1.4709	0.0161	3.1437	0.0209	0.0208	0.1	0.06
97	970	0.0050	0.0210	3.3978	1.4870	0.0161	3.1646	0.0209	0.0209	0.1	0.06
98	980	0.0050	0.0210	3.4188	1.5032	0.0162	3.1855	0.0209	0.0209	0.1	0.06
99	990	0.0050	0.0210	3.4398	1.5194	0.0162	3.2065	0.0209	0.0209	0.1	0.06
100	1000	0.0050	0.0210	3.4608	1.5356	0.0162	3.2274	0.0209	0.0209	0.1	0.06
101	1010	0.0040	0.0168	3.4776	1.5486	0.0130	3.2441	0.0167	0.0167	0.0	0.05
102	1020	0.0040	0.0168	3.4944	1.5616	0.0130	3.2609	0.0167	0.0167	0.0	0.05
103	1030	0.0040	0.0168	3.5112	1.5747	0.0131	3.2776	0.0167	0.0167	0.0	0.05
104	1040	0.0040	0.0168	3.5280	1.5878	0.0131	3.2944	0.0167	0.0167	0.0	0.05
105	1050	0.0040	0.0168	3.5448	1.6009	0.0131	3.3111	0.0167	0.0167	0.0	0.05
106	1060	0.0040	0.0168	3.5616	1.6140	0.0131	3.3279	0.0167	0.0167	0.0	0.05
107	1070	0.0040	0.0168	3.5784	1.6271	0.0131	3.3446	0.0167	0.0167	0.0	0.05
108	1080	0.0040	0.0168	3.5952	1.6403	0.0132	3.3614	0.0168	0.0167	0.0	0.05
109	1090	0.0040	0.0168	3.6120	1.6535	0.0132	3.3781	0.0168	0.0167	0.0	0.05
110	1100	0.0040	0.0168	3.6288	1.6667	0.0132	3.3949	0.0168	0.0167	0.0	0.05
111	1110	0.0040	0.0168	3.6456	1.6799	0.0132	3.4116	0.0168	0.0167	0.0	0.05
112	1120	0.0040	0.0168	3.6624	1.6932	0.0132	3.4284	0.0168	0.0167	0.0	0.05
113	1130	0.0040	0.0168	3.6792	1.7064	0.0133	3.4451	0.0168	0.0167	0.0	0.05
114	1140	0.0040	0.0168	3.6960	1.7197	0.0133	3.4619	0.0168	0.0167	0.0	0.05
115	1150	0.0040	0.0168	3.7128	1.7330	0.0133	3.4786	0.0168	0.0167	0.0	0.05
116	1160	0.0040	0.0168	3.7296	1.7463	0.0133	3.4954	0.0168	0.0167	0.0	0.05
117	1170	0.0040	0.0168	3.7464	1.7597	0.0133	3.5122	0.0168	0.0167	0.0	0.05
118	1180	0.0040	0.0168	3.7632	1.7731	0.0134	3.5289	0.0168	0.0167	0.0	0.05
119	1190	0.0040	0.0168	3.7800	1.7864	0.0134	3.5457	0.0168	0.0167	0.0	0.05
120	1200	0.0040	0.0168	3.7968	1.7999	0.0134	3.5624	0.0168	0.0167	0.0	0.05
121	1210	0.0040	0.0168	3.8136	1.8133	0.0134	3.5792	0.0168	0.0167	0.0	0.05
122	1220	0.0040	0.0168	3.8304	1.8267	0.0134	3.5959	0.0168	0.0167	0.0	0.05
123	1230	0.0040	0.0168	3.8472	1.8402	0.0135	3.6127	0.0168	0.0167	0.0	0.05
124	1240	0.0040	0.0168	3.8640	1.8537	0.0135	3.6294	0.0168	0.0167	0.0	0.05
125	1250	0.0040	0.0168	3.8808	1.8672	0.0135	3.6462	0.0168	0.0167	0.0	0.05
126	1260	0.0040	0.0168	3.8976	1.8807	0.0135	3.6630	0.0168	0.0167	0.0	0.05
127	1270	0.0040	0.0168	3.9144	1.8942	0.0135	3.6797	0.0168	0.0167	0.0	0.05
128	1280	0.0040	0.0168	3.9312	1.9078	0.0136	3.6965	0.0168	0.0167	0.0	0.05
129	1290	0.0040	0.0168	3.9480	1.9214	0.0136	3.7132	0.0168	0.0167	0.0	0.05
130	1300	0.0040	0.0168	3.9648	1.9350	0.0136	3.7300	0.0168	0.0167	0.0	0.05
131	1310	0.0040	0.0168	3.9816	1.9486	0.0136	3.7468	0.0168	0.0167	0.0	0.05
132	1320	0.0040	0.0168	3.9984	1.9622	0.0136	3.7635	0.0168	0.0167	0.0	0.05
133	1330	0.0040	0.0168	4.0152	1.9758	0.0136	3.7803	0.0168	0.0167	0.0	0.05
134	1340	0.0040	0.0168	4.0320	1.9895	0.0137	3.7970	0.0168	0.0167	0.0	0.05
135	1350	0.0040	0.0168	4.0488	2.0032	0.0137	3.8138	0.0168	0.0167	0.0	0.05
136	1360	0.0040	0.0168	4.0656	2.0169	0.0137	3.8306	0.0168	0.0167	0.0	0.05
137	1370	0.0040	0.0168	4.0824	2.0306	0.0137	3.8473	0.0168	0.0167	0.0	0.05
138	1380	0.0040	0.0168	4.0992	2.0443	0.0137	3.8641	0.0168	0.0167	0.0	0.05
139	1390	0.0040	0.0168	4.1160	2.0581	0.0137	3.8808	0.0168	0.0167	0.0	0.05
140	1400	0.0040	0.0168	4.1328	2.0718	0.0138	3.8976	0.0168	0.0167	0.0	0.05
141	1410	0.0040	0.0168	4.1496	2.0856	0.0138	3.9144	0.0168	0.0167	0.0	0.05
142	1420	0.0040	0.0168	4.1664	2.0994	0.0138	3.9311	0.0168	0.0167	0.0	0.05
143	1430	0.0040	0.0168	4.1832	2.1132	0.0138	3.9479	0.0168	0.0167	0.0	0.05
144	1440	0.0040	0.0168	4.2000	2.1270	0.0138	3.9646	0.0168	0.0167	0.0	0.05

Total Volume of Runoff[1] = 6,823 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

V = SumQ x dt
V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Drainage Area 2
(with upper hillslope)

SBUH
2-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation - Additional Drainage Area
Basin:
Storm Event: 02-YEAR, 24-HOUR
Given:

Area = 1.12 acres
Pt = 1.90 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)		IMPERVIOUS AREA (Roads)	
Area =	0.65 acres	Area =	0.47 acres
CN =	79	CN =	98
S =	2.66	S =	0.20
0.2S =	0.53	0.2S =	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.26
Vol(cf)=	3,948

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step + Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs	
1	10	0.0040	0.0076	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0076	0.0152	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0076	0.0228	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0076	0.0304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
5	50	0.0040	0.0076	0.0380	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
6	60	0.0040	0.0076	0.0456	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00	
7	70	0.0040	0.0076	0.0532	0.0000	0.0000	0.0007	0.0006	0.0003	0.0	0.00	
8	80	0.0040	0.0076	0.0608	0.0000	0.0000	0.0018	0.0011	0.0005	0.0	0.00	
9	90	0.0040	0.0076	0.0684	0.0000	0.0000	0.0033	0.0015	0.0006	0.0	0.00	
10	100	0.0040	0.0076	0.0760	0.0000	0.0000	0.0052	0.0019	0.0008	0.0	0.00	
11	110	0.0050	0.0095	0.0855	0.0000	0.0000	0.0080	0.0029	0.0012	0.0	0.01	
12	120	0.0050	0.0095	0.0950	0.0000	0.0000	0.0114	0.0033	0.0014	0.0	0.01	
13	130	0.0050	0.0095	0.1045	0.0000	0.0000	0.0151	0.0038	0.0016	0.0	0.01	
14	140	0.0050	0.0095	0.1140	0.0000	0.0000	0.0193	0.0042	0.0018	0.0	0.01	
15	150	0.0050	0.0095	0.1235	0.0000	0.0000	0.0238	0.0045	0.0019	0.0	0.01	
16	160	0.0050	0.0095	0.1330	0.0000	0.0000	0.0287	0.0048	0.0020	0.0	0.01	
17	170	0.0060	0.0114	0.1444	0.0000	0.0000	0.0349	0.0062	0.0026	0.0	0.02	
18	180	0.0060	0.0114	0.1558	0.0000	0.0000	0.0414	0.0066	0.0028	0.0	0.02	
19	190	0.0060	0.0114	0.1672	0.0000	0.0000	0.0483	0.0069	0.0029	0.0	0.02	
20	200	0.0060	0.0114	0.1786	0.0000	0.0000	0.0555	0.0072	0.0030	0.0	0.02	
21	210	0.0060	0.0114	0.1900	0.0000	0.0000	0.0630	0.0075	0.0031	0.0	0.02	
22	220	0.0060	0.0114	0.2014	0.0000	0.0000	0.0707	0.0077	0.0032	0.0	0.02	
23	230	0.0070	0.0133	0.2147	0.0000	0.0000	0.0800	0.0093	0.0039	0.0	0.02	
24	240	0.0070	0.0133	0.2280	0.0000	0.0000	0.0895	0.0096	0.0040	0.0	0.03	
25	250	0.0070	0.0133	0.2413	0.0000	0.0000	0.0994	0.0098	0.0041	0.0	0.03	
26	260	0.0070	0.0133	0.2546	0.0000	0.0000	0.1094	0.0100	0.0042	0.0	0.03	
27	270	0.0070	0.0133	0.2679	0.0000	0.0000	0.1196	0.0102	0.0043	0.0	0.03	
28	280	0.0070	0.0133	0.2812	0.0000	0.0000	0.1300	0.0104	0.0044	0.0	0.03	
29	290	0.0082	0.0156	0.2968	0.0000	0.0000	0.1424	0.0124	0.0052	0.0	0.03	
30	300	0.0082	0.0156	0.3124	0.0000	0.0000	0.1550	0.0126	0.0053	0.0	0.04	
31	310	0.0082	0.0156	0.3279	0.0000	0.0000	0.1678	0.0128	0.0054	0.0	0.04	
32	320	0.0082	0.0156	0.3435	0.0000	0.0000	0.1808	0.0130	0.0055	0.0	0.04	
33	330	0.0082	0.0156	0.3591	0.0000	0.0000	0.1939	0.0131	0.0055	0.0	0.04	
34	340	0.0082	0.0156	0.3747	0.0000	0.0000	0.2072	0.0133	0.0056	0.0	0.04	
35	350	0.0095	0.0181	0.3927	0.0000	0.0000	0.2227	0.0155	0.0065	0.0	0.04	
36	360	0.0095	0.0181	0.4108	0.0000	0.0000	0.2384	0.0157	0.0066	0.0	0.04	
37	370	0.0095	0.0181	0.4288	0.0000	0.0000	0.2543	0.0158	0.0067	0.0	0.04	
38	380	0.0095	0.0181	0.4469	0.0000	0.0000	0.2702	0.0160	0.0067	0.0	0.05	
39	390	0.0095	0.0181	0.4649	0.0000	0.0000	0.2863	0.0161	0.0068	0.0	0.05	
40	400	0.0095	0.0181	0.4830	0.0000	0.0000	0.3025	0.0162	0.0068	0.0	0.05	
41	410	0.0134	0.0255	0.5084	0.0000	0.0000	0.3255	0.0230	0.0097	0.1	0.05	
42	420	0.0134	0.0255	0.5339	0.0000	0.0000	0.3487	0.0232	0.0097	0.1	0.06	
43	430	0.0134	0.0255	0.5594	0.0003	0.0003	0.3721	0.0234	0.0100	0.1	0.07	
44	440	0.0180	0.0342	0.5936	0.0014	0.0011	0.4037	0.0316	0.0139	0.1	0.08	
45	450	0.0180	0.0342	0.6278	0.0034	0.0019	0.4355	0.0318	0.0145	0.1	0.09	
46	460	0.0340	0.0646	0.6924	0.0092	0.0058	0.4961	0.0606	0.0288	0.2	0.14	
47	470	0.0540	0.1026	0.7950	0.0237	0.0146	0.5935	0.0974	0.0494	0.3	0.25	
48	480	0.0270	0.0513	0.8463	0.0333	0.0096	0.6426	0.0491	0.0262	0.2	0.26	Q peak
49	490	0.0180	0.0342	0.8805	0.0405	0.0072	0.6755	0.0328	0.0180	0.1	0.16	
50	500	0.0134	0.0255	0.9059	0.0462	0.0057	0.7000	0.0245	0.0136	0.1	0.11	
51	510	0.0134	0.0255	0.9314	0.0523	0.0061	0.7245	0.0246	0.0138	0.1	0.09	
52	520	0.0134	0.0255	0.9568	0.0586	0.0064	0.7491	0.0246	0.0140	0.1	0.09	
53	530	0.0088	0.0167	0.9736	0.0630	0.0044	0.7653	0.0162	0.0093	0.1	0.08	
54	540	0.0088	0.0167	0.9903	0.0675	0.0045	0.7815	0.0162	0.0094	0.1	0.07	
55	550	0.0088	0.0167	1.0070	0.0721	0.0046	0.7977	0.0162	0.0095	0.1	0.06	
56	560	0.0088	0.0167	1.0237	0.0769	0.0048	0.8139	0.0162	0.0096	0.1	0.06	
57	570	0.0088	0.0167	1.0404	0.0817	0.0049	0.8301	0.0162	0.0096	0.1	0.07	
58	580	0.0088	0.0167	1.0572	0.0867	0.0050	0.8464	0.0162	0.0097	0.1	0.07	
59	590	0.0088	0.0167	1.0739	0.0919	0.0051	0.8626	0.0163	0.0098	0.1	0.07	
60	600	0.0088	0.0167	1.0906	0.0971	0.0052	0.8789	0.0163	0.0099	0.1	0.07	
61	610	0.0088	0.0167	1.1073	0.1025	0.0054	0.8952	0.0163	0.0100	0.1	0.07	
62	620	0.0088	0.0167	1.1240	0.1080	0.0055	0.9115	0.0163	0.0100	0.1	0.07	
63	630	0.0088	0.0167	1.1408	0.1136	0.0056	0.9278	0.0163	0.0101	0.1	0.07	
64	640	0.0088	0.0167	1.1575	0.1193	0.0057	0.9441	0.0163	0.0102	0.1	0.07	
65	650	0.0072	0.0137	1.1712	0.1240	0.0048	0.9575	0.0134	0.0084	0.1	0.06	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0137	1.1848	0.1288	0.0048	0.9708	0.0134	0.0084	0.1	0.06
67	670	0.0072	0.0137	1.1985	0.1337	0.0049	0.9842	0.0134	0.0085	0.1	0.06
68	680	0.0072	0.0137	1.2122	0.1387	0.0050	0.9976	0.0134	0.0085	0.1	0.06
69	690	0.0072	0.0137	1.2259	0.1438	0.0050	1.0110	0.0134	0.0085	0.1	0.06
70	700	0.0072	0.0137	1.2396	0.1489	0.0051	1.0244	0.0134	0.0086	0.1	0.06
71	710	0.0072	0.0137	1.2532	0.1541	0.0052	1.0377	0.0134	0.0086	0.1	0.06
72	720	0.0072	0.0137	1.2669	0.1593	0.0053	1.0511	0.0134	0.0087	0.1	0.06
73	730	0.0072	0.0137	1.2806	0.1646	0.0053	1.0645	0.0134	0.0087	0.1	0.06
74	740	0.0072	0.0137	1.2943	0.1700	0.0054	1.0780	0.0134	0.0088	0.1	0.06
75	750	0.0072	0.0137	1.3080	0.1755	0.0055	1.0914	0.0134	0.0088	0.1	0.06
76	760	0.0072	0.0137	1.3216	0.1810	0.0055	1.1048	0.0134	0.0088	0.1	0.06
77	770	0.0057	0.0108	1.3325	0.1854	0.0044	1.1154	0.0106	0.0070	0.0	0.05
78	780	0.0057	0.0108	1.3433	0.1899	0.0045	1.1260	0.0106	0.0070	0.0	0.05
79	790	0.0057	0.0108	1.3541	0.1944	0.0045	1.1367	0.0106	0.0071	0.0	0.05
80	800	0.0057	0.0108	1.3650	0.1989	0.0045	1.1473	0.0106	0.0071	0.0	0.05
81	810	0.0057	0.0108	1.3758	0.2035	0.0046	1.1580	0.0106	0.0071	0.0	0.05
82	820	0.0057	0.0108	1.3866	0.2081	0.0046	1.1686	0.0106	0.0071	0.0	0.05
83	830	0.0057	0.0108	1.3975	0.2127	0.0046	1.1792	0.0106	0.0072	0.0	0.05
84	840	0.0057	0.0108	1.4083	0.2174	0.0047	1.1899	0.0106	0.0072	0.0	0.05
85	850	0.0057	0.0108	1.4191	0.2221	0.0047	1.2005	0.0106	0.0072	0.0	0.05
86	860	0.0057	0.0108	1.4299	0.2269	0.0048	1.2112	0.0107	0.0072	0.0	0.05
87	870	0.0057	0.0108	1.4408	0.2317	0.0048	1.2218	0.0107	0.0073	0.0	0.05
88	880	0.0057	0.0108	1.4516	0.2365	0.0048	1.2325	0.0107	0.0073	0.0	0.05
89	890	0.0050	0.0095	1.4611	0.2408	0.0043	1.2418	0.0093	0.0064	0.0	0.05
90	900	0.0050	0.0095	1.4706	0.2451	0.0043	1.2512	0.0094	0.0064	0.0	0.04
91	910	0.0050	0.0095	1.4801	0.2494	0.0043	1.2605	0.0094	0.0064	0.0	0.04
92	920	0.0050	0.0095	1.4896	0.2538	0.0044	1.2699	0.0094	0.0065	0.0	0.04
93	930	0.0050	0.0095	1.4991	0.2581	0.0044	1.2793	0.0094	0.0065	0.0	0.04
94	940	0.0050	0.0095	1.5086	0.2626	0.0044	1.2886	0.0094	0.0065	0.0	0.04
95	950	0.0050	0.0095	1.5181	0.2670	0.0044	1.2980	0.0094	0.0065	0.0	0.04
96	960	0.0050	0.0095	1.5276	0.2714	0.0045	1.3073	0.0094	0.0065	0.0	0.04
97	970	0.0050	0.0095	1.5371	0.2759	0.0045	1.3167	0.0094	0.0065	0.0	0.04
98	980	0.0050	0.0095	1.5466	0.2804	0.0045	1.3261	0.0094	0.0066	0.0	0.04
99	990	0.0050	0.0095	1.5561	0.2850	0.0045	1.3354	0.0094	0.0066	0.0	0.04
100	1000	0.0050	0.0095	1.5656	0.2895	0.0046	1.3448	0.0094	0.0066	0.0	0.04
101	1010	0.0040	0.0076	1.5732	0.2932	0.0037	1.3523	0.0075	0.0053	0.0	0.04
102	1020	0.0040	0.0076	1.5808	0.2969	0.0037	1.3598	0.0075	0.0053	0.0	0.04
103	1030	0.0040	0.0076	1.5884	0.3006	0.0037	1.3673	0.0075	0.0053	0.0	0.04
104	1040	0.0040	0.0076	1.5960	0.3043	0.0037	1.3748	0.0075	0.0053	0.0	0.04
105	1050	0.0040	0.0076	1.6036	0.3081	0.0037	1.3823	0.0075	0.0053	0.0	0.04
106	1060	0.0040	0.0076	1.6112	0.3118	0.0037	1.3898	0.0075	0.0053	0.0	0.04
107	1070	0.0040	0.0076	1.6188	0.3156	0.0038	1.3973	0.0075	0.0053	0.0	0.04
108	1080	0.0040	0.0076	1.6264	0.3193	0.0038	1.4048	0.0075	0.0053	0.0	0.04
109	1090	0.0040	0.0076	1.6340	0.3231	0.0038	1.4123	0.0075	0.0054	0.0	0.04
110	1100	0.0040	0.0076	1.6416	0.3269	0.0038	1.4198	0.0075	0.0054	0.0	0.04
111	1110	0.0040	0.0076	1.6492	0.3308	0.0038	1.4273	0.0075	0.0054	0.0	0.04
112	1120	0.0040	0.0076	1.6568	0.3346	0.0038	1.4348	0.0075	0.0054	0.0	0.04
113	1130	0.0040	0.0076	1.6644	0.3385	0.0039	1.4423	0.0075	0.0054	0.0	0.04
114	1140	0.0040	0.0076	1.6720	0.3423	0.0039	1.4498	0.0075	0.0054	0.0	0.04
115	1150	0.0040	0.0076	1.6796	0.3462	0.0039	1.4573	0.0075	0.0054	0.0	0.04
116	1160	0.0040	0.0076	1.6872	0.3501	0.0039	1.4648	0.0075	0.0054	0.0	0.04
117	1170	0.0040	0.0076	1.6948	0.3540	0.0039	1.4723	0.0075	0.0054	0.0	0.04
118	1180	0.0040	0.0076	1.7024	0.3580	0.0039	1.4798	0.0075	0.0054	0.0	0.04
119	1190	0.0040	0.0076	1.7100	0.3619	0.0039	1.4873	0.0075	0.0054	0.0	0.04
120	1200	0.0040	0.0076	1.7176	0.3659	0.0040	1.4948	0.0075	0.0055	0.0	0.04
121	1210	0.0040	0.0076	1.7252	0.3698	0.0040	1.5024	0.0075	0.0055	0.0	0.04
122	1220	0.0040	0.0076	1.7328	0.3738	0.0040	1.5099	0.0075	0.0055	0.0	0.04
123	1230	0.0040	0.0076	1.7404	0.3778	0.0040	1.5174	0.0075	0.0055	0.0	0.04
124	1240	0.0040	0.0076	1.7480	0.3819	0.0040	1.5249	0.0075	0.0055	0.0	0.04
125	1250	0.0040	0.0076	1.7556	0.3859	0.0040	1.5324	0.0075	0.0055	0.0	0.04
126	1260	0.0040	0.0076	1.7632	0.3899	0.0040	1.5399	0.0075	0.0055	0.0	0.04
127	1270	0.0040	0.0076	1.7708	0.3940	0.0041	1.5474	0.0075	0.0055	0.0	0.04
128	1280	0.0040	0.0076	1.7784	0.3981	0.0041	1.5550	0.0075	0.0055	0.0	0.04
129	1290	0.0040	0.0076	1.7860	0.4021	0.0041	1.5625	0.0075	0.0055	0.0	0.04
130	1300	0.0040	0.0076	1.7936	0.4062	0.0041	1.5700	0.0075	0.0055	0.0	0.04
131	1310	0.0040	0.0076	1.8012	0.4104	0.0041	1.5775	0.0075	0.0055	0.0	0.04
132	1320	0.0040	0.0076	1.8088	0.4145	0.0041	1.5850	0.0075	0.0056	0.0	0.04
133	1330	0.0040	0.0076	1.8164	0.4186	0.0041	1.5925	0.0075	0.0056	0.0	0.04
134	1340	0.0040	0.0076	1.8240	0.4228	0.0042	1.6001	0.0075	0.0056	0.0	0.04
135	1350	0.0040	0.0076	1.8316	0.4269	0.0042	1.6076	0.0075	0.0056	0.0	0.04
136	1360	0.0040	0.0076	1.8392	0.4311	0.0042	1.6151	0.0075	0.0056	0.0	0.04
137	1370	0.0040	0.0076	1.8468	0.4353	0.0042	1.6226	0.0075	0.0056	0.0	0.04
138	1380	0.0040	0.0076	1.8544	0.4395	0.0042	1.6301	0.0075	0.0056	0.0	0.04
139	1390	0.0040	0.0076	1.8620	0.4437	0.0042	1.6377	0.0075	0.0056	0.0	0.04
140	1400	0.0040	0.0076	1.8696	0.4480	0.0042	1.6452	0.0075	0.0056	0.0	0.04
141	1410	0.0040	0.0076	1.8772	0.4522	0.0042	1.6527	0.0075	0.0056	0.0	0.04
142	1420	0.0040	0.0076	1.8848	0.4565	0.0043	1.6602	0.0075	0.0056	0.0	0.04
143	1430	0.0040	0.0076	1.8924	0.4607	0.0043	1.6678	0.0075	0.0056	0.0	0.04
144	1440	0.0040	0.0076	1.9000	0.4650	0.0043	1.6753	0.0075	0.0056	0.0	0.04

Total Volume of Runoff[1] = 3,948 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH

10-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation - Additional Drainage Area
Basin:
Storm Event: 10-YEAR, 24-HOUR
Given:

Area = 1.12 acres
Pt = 2.80 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.65 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.47
Vol(cf)=	6,834

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step
+ Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distribution % of Pt	(4) Incremental Rainfall in.	(5) Accumulated Rainfall in.	Pervious Area (6) Accumulated Runoff in.	Pervious Area (7) Incremental Runoff in.	Impervious Area (8) Accumulated Runoff in.	Impervious Area (9) Incremental Runoff in.	(10) Total Runoff in.	(11) Instant hydrograph cfs	(12) design hydrograph cfs
1	10	0.0040	0.0112	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
2	20	0.0040	0.0112	0.0224	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
3	30	0.0040	0.0112	0.0336	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00
4	40	0.0040	0.0112	0.0448	0.0000	0.0000	0.0001	0.0001	0.0000	0.0	0.00
5	50	0.0040	0.0112	0.0560	0.0000	0.0000	0.0011	0.0010	0.0004	0.0	0.00
6	60	0.0040	0.0112	0.0672	0.0000	0.0000	0.0030	0.0020	0.0008	0.0	0.00
7	70	0.0040	0.0112	0.0784	0.0000	0.0000	0.0058	0.0028	0.0012	0.0	0.01
8	80	0.0040	0.0112	0.0896	0.0000	0.0000	0.0094	0.0036	0.0015	0.0	0.01
9	90	0.0040	0.0112	0.1008	0.0000	0.0000	0.0136	0.0042	0.0018	0.0	0.01
10	100	0.0040	0.0112	0.1120	0.0000	0.0000	0.0184	0.0048	0.0020	0.0	0.01
11	110	0.0050	0.0140	0.1260	0.0000	0.0000	0.0251	0.0067	0.0028	0.0	0.02
12	120	0.0050	0.0140	0.1400	0.0000	0.0000	0.0324	0.0074	0.0031	0.0	0.02
13	130	0.0050	0.0140	0.1540	0.0000	0.0000	0.0404	0.0079	0.0033	0.0	0.02
14	140	0.0050	0.0140	0.1680	0.0000	0.0000	0.0488	0.0085	0.0036	0.0	0.02
15	150	0.0050	0.0140	0.1820	0.0000	0.0000	0.0577	0.0089	0.0037	0.0	0.02
16	160	0.0050	0.0140	0.1960	0.0000	0.0000	0.0670	0.0093	0.0039	0.0	0.03
17	170	0.0060	0.0168	0.2128	0.0000	0.0000	0.0787	0.0116	0.0049	0.0	0.03
18	180	0.0060	0.0168	0.2296	0.0000	0.0000	0.0907	0.0121	0.0051	0.0	0.03
19	190	0.0060	0.0168	0.2464	0.0000	0.0000	0.1032	0.0125	0.0052	0.0	0.03
20	200	0.0060	0.0168	0.2632	0.0000	0.0000	0.1160	0.0128	0.0054	0.0	0.04
21	210	0.0060	0.0168	0.2800	0.0000	0.0000	0.1291	0.0131	0.0055	0.0	0.04
22	220	0.0060	0.0168	0.2968	0.0000	0.0000	0.1424	0.0134	0.0056	0.0	0.04
23	230	0.0070	0.0196	0.3164	0.0000	0.0000	0.1583	0.0159	0.0067	0.0	0.04
24	240	0.0070	0.0196	0.3360	0.0000	0.0000	0.1745	0.0162	0.0068	0.0	0.05
25	250	0.0070	0.0196	0.3556	0.0000	0.0000	0.1910	0.0164	0.0069	0.0	0.05
26	260	0.0070	0.0196	0.3752	0.0000	0.0000	0.2077	0.0167	0.0070	0.0	0.05
27	270	0.0070	0.0196	0.3948	0.0000	0.0000	0.2245	0.0169	0.0071	0.0	0.05
28	280	0.0070	0.0196	0.4144	0.0000	0.0000	0.2416	0.0171	0.0072	0.0	0.05
29	290	0.0082	0.0230	0.4374	0.0000	0.0000	0.2618	0.0202	0.0085	0.1	0.05
30	300	0.0082	0.0230	0.4603	0.0000	0.0000	0.2822	0.0204	0.0086	0.1	0.06
31	310	0.0082	0.0230	0.4833	0.0000	0.0000	0.3028	0.0206	0.0087	0.1	0.06
32	320	0.0082	0.0230	0.5062	0.0000	0.0000	0.3236	0.0208	0.0087	0.1	0.06
33	330	0.0082	0.0230	0.5292	0.0000	0.0000	0.3444	0.0209	0.0088	0.1	0.06
34	340	0.0082	0.0230	0.5522	0.0002	0.0002	0.3655	0.0210	0.0089	0.1	0.06
35	350	0.0095	0.0266	0.5788	0.0008	0.0007	0.3900	0.0245	0.0107	0.1	0.07
36	360	0.0095	0.0266	0.6054	0.0020	0.0012	0.4146	0.0247	0.0110	0.1	0.07
37	370	0.0095	0.0266	0.6320	0.0036	0.0017	0.4394	0.0248	0.0114	0.1	0.08
38	380	0.0095	0.0266	0.6586	0.0058	0.0021	0.4643	0.0249	0.0117	0.1	0.08
39	390	0.0095	0.0266	0.6852	0.0084	0.0026	0.4894	0.0250	0.0120	0.1	0.08
40	400	0.0095	0.0266	0.7118	0.0114	0.0030	0.5145	0.0251	0.0123	0.1	0.08
41	410	0.0134	0.0375	0.7493	0.0165	0.0050	0.5500	0.0356	0.0179	0.1	0.10
42	420	0.0134	0.0375	0.7868	0.0223	0.0059	0.5857	0.0357	0.0184	0.1	0.12
43	430	0.0134	0.0375	0.8243	0.0290	0.0067	0.6216	0.0359	0.0189	0.1	0.13
44	440	0.0180	0.0504	0.8747	0.0392	0.0102	0.6699	0.0484	0.0262	0.2	0.15
45	450	0.0180	0.0504	0.9251	0.0507	0.0115	0.7185	0.0485	0.0271	0.2	0.18
46	460	0.0340	0.0952	1.0203	0.0759	0.0252	0.8106	0.0921	0.0533	0.4	0.26
47	470	0.0540	0.1512	1.1715	0.1241	0.0483	0.9578	0.1472	0.0898	0.6	0.47 Q peak
48	480	0.0270	0.0756	1.2471	0.1517	0.0276	1.0318	0.0739	0.0471	0.3	0.46
49	490	0.0180	0.0504	1.2975	0.1713	0.0196	1.0811	0.0494	0.0321	0.2	0.29
50	500	0.0134	0.0375	1.3350	0.1865	0.0152	1.1179	0.0368	0.0243	0.2	0.20
51	510	0.0134	0.0375	1.3726	0.2021	0.0156	1.1548	0.0368	0.0245	0.2	0.17
52	520	0.0134	0.0375	1.4101	0.2182	0.0161	1.1917	0.0369	0.0248	0.2	0.17
53	530	0.0088	0.0246	1.4347	0.2290	0.0108	1.2159	0.0242	0.0165	0.1	0.14
54	540	0.0088	0.0246	1.4594	0.2400	0.0110	1.2401	0.0242	0.0166	0.1	0.11
55	550	0.0088	0.0246	1.4840	0.2512	0.0112	1.2644	0.0243	0.0167	0.1	0.11
56	560	0.0088	0.0246	1.5086	0.2626	0.0114	1.2887	0.0243	0.0168	0.1	0.11
57	570	0.0088	0.0246	1.5333	0.2741	0.0116	1.3129	0.0243	0.0169	0.1	0.11
58	580	0.0088	0.0246	1.5579	0.2859	0.0117	1.3372	0.0243	0.0170	0.1	0.11
59	590	0.0088	0.0246	1.5826	0.2978	0.0119	1.3615	0.0243	0.0171	0.1	0.12
60	600	0.0088	0.0246	1.6072	0.3098	0.0121	1.3858	0.0243	0.0172	0.1	0.12
61	610	0.0088	0.0246	1.6318	0.3221	0.0122	1.4101	0.0243	0.0173	0.1	0.12
62	620	0.0088	0.0246	1.6565	0.3345	0.0124	1.4345	0.0243	0.0174	0.1	0.12
63	630	0.0088	0.0246	1.6811	0.3470	0.0126	1.4588	0.0243	0.0175	0.1	0.12
64	640	0.0088	0.0246	1.7058	0.3597	0.0127	1.4831	0.0243	0.0176	0.1	0.12
65	650	0.0072	0.0202	1.7259	0.3702	0.0105	1.5031	0.0199	0.0145	0.1	0.11

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri- bution % of Pt	(4) Incre- mental Rainfall in.	(5) Accumu- lated Rainfall in.	Pervious Area (6) Accumu- lated Runoff in.	Pervious Area (7) Incre- mental Runoff in.	Impervious Area (8) Accumu- lated Runoff in.	Impervious Area (9) Incre- mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro- graph cfs	(12) design hydro- graph cfs
66	660	0.0072	0.0202	1.7461	0.3808	0.0106	1.5230	0.0199	0.0145	0.1	0.10
67	670	0.0072	0.0202	1.7662	0.3915	0.0107	1.5429	0.0199	0.0146	0.1	0.10
68	680	0.0072	0.0202	1.7864	0.4024	0.0108	1.5629	0.0199	0.0146	0.1	0.10
69	690	0.0072	0.0202	1.8066	0.4133	0.0109	1.5828	0.0199	0.0147	0.1	0.10
70	700	0.0072	0.0202	1.8267	0.4243	0.0110	1.6028	0.0199	0.0148	0.1	0.10
71	710	0.0072	0.0202	1.8469	0.4353	0.0111	1.6227	0.0200	0.0148	0.1	0.10
72	720	0.0072	0.0202	1.8670	0.4465	0.0112	1.6427	0.0200	0.0149	0.1	0.10
73	730	0.0072	0.0202	1.8872	0.4578	0.0113	1.6626	0.0200	0.0149	0.1	0.10
74	740	0.0072	0.0202	1.9074	0.4692	0.0114	1.6826	0.0200	0.0150	0.1	0.10
75	750	0.0072	0.0202	1.9275	0.4806	0.0114	1.7025	0.0200	0.0150	0.1	0.10
76	760	0.0072	0.0202	1.9477	0.4922	0.0115	1.7225	0.0200	0.0151	0.1	0.10
77	770	0.0057	0.0160	1.9636	0.5013	0.0092	1.7383	0.0158	0.0120	0.1	0.09
78	780	0.0057	0.0160	1.9796	0.5106	0.0092	1.7541	0.0158	0.0120	0.1	0.08
79	790	0.0057	0.0160	1.9956	0.5199	0.0093	1.7700	0.0158	0.0120	0.1	0.08
80	800	0.0057	0.0160	2.0115	0.5292	0.0093	1.7858	0.0158	0.0121	0.1	0.08
81	810	0.0057	0.0160	2.0275	0.5386	0.0094	1.8016	0.0158	0.0121	0.1	0.08
82	820	0.0057	0.0160	2.0434	0.5481	0.0094	1.8174	0.0158	0.0121	0.1	0.08
83	830	0.0057	0.0160	2.0594	0.5576	0.0095	1.8332	0.0158	0.0122	0.1	0.08
84	840	0.0057	0.0160	2.0754	0.5671	0.0095	1.8491	0.0158	0.0122	0.1	0.08
85	850	0.0057	0.0160	2.0913	0.5767	0.0096	1.8649	0.0158	0.0122	0.1	0.08
86	860	0.0057	0.0160	2.1073	0.5864	0.0096	1.8807	0.0158	0.0122	0.1	0.08
87	870	0.0057	0.0160	2.1232	0.5961	0.0097	1.8966	0.0158	0.0123	0.1	0.08
88	880	0.0057	0.0160	2.1392	0.6058	0.0097	1.9124	0.0158	0.0123	0.1	0.08
89	890	0.0050	0.0140	2.1532	0.6144	0.0086	1.9263	0.0139	0.0108	0.1	0.08
90	900	0.0050	0.0140	2.1672	0.6230	0.0086	1.9402	0.0139	0.0108	0.1	0.07
91	910	0.0050	0.0140	2.1812	0.6317	0.0087	1.9541	0.0139	0.0109	0.1	0.07
92	920	0.0050	0.0140	2.1952	0.6403	0.0087	1.9680	0.0139	0.0109	0.1	0.07
93	930	0.0050	0.0140	2.2092	0.6491	0.0087	1.9819	0.0139	0.0109	0.1	0.07
94	940	0.0050	0.0140	2.2232	0.6578	0.0088	1.9958	0.0139	0.0109	0.1	0.07
95	950	0.0050	0.0140	2.2372	0.6666	0.0088	2.0097	0.0139	0.0109	0.1	0.07
96	960	0.0050	0.0140	2.2512	0.6754	0.0088	2.0236	0.0139	0.0110	0.1	0.07
97	970	0.0050	0.0140	2.2652	0.6843	0.0089	2.0375	0.0139	0.0110	0.1	0.07
98	980	0.0050	0.0140	2.2792	0.6932	0.0089	2.0514	0.0139	0.0110	0.1	0.07
99	990	0.0050	0.0140	2.2932	0.7021	0.0089	2.0653	0.0139	0.0110	0.1	0.07
100	1000	0.0050	0.0140	2.3072	0.7110	0.0090	2.0792	0.0139	0.0110	0.1	0.07
101	1010	0.0040	0.0112	2.3184	0.7182	0.0072	2.0903	0.0111	0.0088	0.1	0.07
102	1020	0.0040	0.0112	2.3296	0.7254	0.0072	2.1014	0.0111	0.0089	0.1	0.06
103	1030	0.0040	0.0112	2.3408	0.7327	0.0072	2.1125	0.0111	0.0089	0.1	0.06
104	1040	0.0040	0.0112	2.3520	0.7399	0.0072	2.1237	0.0111	0.0089	0.1	0.06
105	1050	0.0040	0.0112	2.3632	0.7472	0.0073	2.1348	0.0111	0.0089	0.1	0.06
106	1060	0.0040	0.0112	2.3744	0.7544	0.0073	2.1459	0.0111	0.0089	0.1	0.06
107	1070	0.0040	0.0112	2.3856	0.7617	0.0073	2.1570	0.0111	0.0089	0.1	0.06
108	1080	0.0040	0.0112	2.3968	0.7691	0.0073	2.1682	0.0111	0.0089	0.1	0.06
109	1090	0.0040	0.0112	2.4080	0.7764	0.0073	2.1793	0.0111	0.0089	0.1	0.06
110	1100	0.0040	0.0112	2.4192	0.7838	0.0074	2.1904	0.0111	0.0089	0.1	0.06
111	1110	0.0040	0.0112	2.4304	0.7912	0.0074	2.2016	0.0111	0.0090	0.1	0.06
112	1120	0.0040	0.0112	2.4416	0.7986	0.0074	2.2127	0.0111	0.0090	0.1	0.06
113	1130	0.0040	0.0112	2.4528	0.8060	0.0074	2.2238	0.0111	0.0090	0.1	0.06
114	1140	0.0040	0.0112	2.4640	0.8134	0.0074	2.2350	0.0111	0.0090	0.1	0.06
115	1150	0.0040	0.0112	2.4752	0.8209	0.0075	2.2461	0.0111	0.0090	0.1	0.06
116	1160	0.0040	0.0112	2.4864	0.8283	0.0075	2.2572	0.0111	0.0090	0.1	0.06
117	1170	0.0040	0.0112	2.4976	0.8358	0.0075	2.2684	0.0111	0.0090	0.1	0.06
118	1180	0.0040	0.0112	2.5088	0.8433	0.0075	2.2795	0.0111	0.0090	0.1	0.06
119	1190	0.0040	0.0112	2.5200	0.8509	0.0075	2.2906	0.0111	0.0090	0.1	0.06
120	1200	0.0040	0.0112	2.5312	0.8584	0.0075	2.3018	0.0111	0.0091	0.1	0.06
121	1210	0.0040	0.0112	2.5424	0.8660	0.0076	2.3129	0.0111	0.0091	0.1	0.06
122	1220	0.0040	0.0112	2.5536	0.8735	0.0076	2.3240	0.0111	0.0091	0.1	0.06
123	1230	0.0040	0.0112	2.5648	0.8811	0.0076	2.3352	0.0111	0.0091	0.1	0.06
124	1240	0.0040	0.0112	2.5760	0.8887	0.0076	2.3463	0.0111	0.0091	0.1	0.06
125	1250	0.0040	0.0112	2.5872	0.8964	0.0076	2.3574	0.0111	0.0091	0.1	0.06
126	1260	0.0040	0.0112	2.5984	0.9040	0.0076	2.3686	0.0111	0.0091	0.1	0.06
127	1270	0.0040	0.0112	2.6096	0.9117	0.0077	2.3797	0.0111	0.0091	0.1	0.06
128	1280	0.0040	0.0112	2.6208	0.9194	0.0077	2.3909	0.0111	0.0091	0.1	0.06
129	1290	0.0040	0.0112	2.6320	0.9271	0.0077	2.4020	0.0111	0.0091	0.1	0.06
130	1300	0.0040	0.0112	2.6432	0.9348	0.0077	2.4131	0.0111	0.0092	0.1	0.06
131	1310	0.0040	0.0112	2.6544	0.9425	0.0077	2.4243	0.0111	0.0092	0.1	0.06
132	1320	0.0040	0.0112	2.6656	0.9502	0.0077	2.4354	0.0111	0.0092	0.1	0.06
133	1330	0.0040	0.0112	2.6768	0.9580	0.0078	2.4466	0.0111	0.0092	0.1	0.06
134	1340	0.0040	0.0112	2.6880	0.9658	0.0078	2.4577	0.0111	0.0092	0.1	0.06
135	1350	0.0040	0.0112	2.6992	0.9736	0.0078	2.4689	0.0111	0.0092	0.1	0.06
136	1360	0.0040	0.0112	2.7104	0.9814	0.0078	2.4800	0.0111	0.0092	0.1	0.06
137	1370	0.0040	0.0112	2.7216	0.9892	0.0078	2.4911	0.0111	0.0092	0.1	0.06
138	1380	0.0040	0.0112	2.7328	0.9971	0.0078	2.5023	0.0111	0.0092	0.1	0.06
139	1390	0.0040	0.0112	2.7440	1.0049	0.0079	2.5134	0.0111	0.0092	0.1	0.06
140	1400	0.0040	0.0112	2.7552	1.0128	0.0079	2.5246	0.0111	0.0092	0.1	0.06
141	1410	0.0040	0.0112	2.7664	1.0207	0.0079	2.5357	0.0111	0.0093	0.1	0.06
142	1420	0.0040	0.0112	2.7776	1.0286	0.0079	2.5469	0.0111	0.0093	0.1	0.06
143	1430	0.0040	0.0112	2.7888	1.0365	0.0079	2.5580	0.0111	0.0093	0.1	0.06
144	1440	0.0040	0.0112	2.8000	1.0444	0.0079	2.5692	0.0111	0.0093	0.1	0.06

Total Volume of Runoff[1] = 6,834 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH

25-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation - Additional Drainage Area
Basin:
Storm Event: 25-YEAR, 24-HOUR
Given:

Area = 1.12 acres
Pt = 3.40 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.65 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.62
Vol(cf)=	8,898

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step + Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

					Pervious Area		Impervious Area					
(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	(6) Accumu-lated Runoff in.	(7) Incre-mental Runoff in.	(8) Accumu-lated Runoff in.	(9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs	
1	10	0.0040	0.0136	0.0136	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0136	0.0272	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0136	0.0408	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
4	40	0.0040	0.0136	0.0544	0.0000	0.0000	0.0008	0.0008	0.0004	0.0	0.00	
5	50	0.0040	0.0136	0.0680	0.0000	0.0000	0.0032	0.0023	0.0010	0.0	0.00	
6	60	0.0040	0.0136	0.0816	0.0000	0.0000	0.0068	0.0036	0.0015	0.0	0.01	
7	70	0.0040	0.0136	0.0952	0.0000	0.0000	0.0114	0.0047	0.0020	0.0	0.01	
8	80	0.0040	0.0136	0.1088	0.0000	0.0000	0.0170	0.0055	0.0023	0.0	0.01	
9	90	0.0040	0.0136	0.1224	0.0000	0.0000	0.0233	0.0063	0.0027	0.0	0.02	
10	100	0.0040	0.0136	0.1360	0.0000	0.0000	0.0303	0.0070	0.0029	0.0	0.02	
11	110	0.0050	0.0170	0.1530	0.0000	0.0000	0.0398	0.0095	0.0040	0.0	0.02	
12	120	0.0050	0.0170	0.1700	0.0000	0.0000	0.0501	0.0103	0.0043	0.0	0.03	
13	130	0.0050	0.0170	0.1870	0.0000	0.0000	0.0610	0.0109	0.0046	0.0	0.03	
14	140	0.0050	0.0170	0.2040	0.0000	0.0000	0.0725	0.0115	0.0048	0.0	0.03	
15	150	0.0050	0.0170	0.2210	0.0000	0.0000	0.0845	0.0120	0.0050	0.0	0.03	
16	160	0.0050	0.0170	0.2380	0.0000	0.0000	0.0969	0.0124	0.0052	0.0	0.03	
17	170	0.0060	0.0204	0.2584	0.0000	0.0000	0.1123	0.0154	0.0065	0.0	0.04	
18	180	0.0060	0.0204	0.2788	0.0000	0.0000	0.1281	0.0158	0.0067	0.0	0.04	
19	190	0.0060	0.0204	0.2992	0.0000	0.0000	0.1444	0.0162	0.0068	0.0	0.05	
20	200	0.0060	0.0204	0.3196	0.0000	0.0000	0.1610	0.0166	0.0070	0.0	0.05	
21	210	0.0060	0.0204	0.3400	0.0000	0.0000	0.1779	0.0169	0.0071	0.0	0.05	
22	220	0.0060	0.0204	0.3604	0.0000	0.0000	0.1950	0.0172	0.0072	0.0	0.05	
23	230	0.0070	0.0238	0.3842	0.0000	0.0000	0.2154	0.0203	0.0085	0.1	0.05	
24	240	0.0070	0.0238	0.4080	0.0000	0.0000	0.2360	0.0206	0.0087	0.1	0.06	
25	250	0.0070	0.0238	0.4318	0.0000	0.0000	0.2569	0.0209	0.0088	0.1	0.06	
26	260	0.0070	0.0238	0.4556	0.0000	0.0000	0.2780	0.0211	0.0089	0.1	0.06	
27	270	0.0070	0.0238	0.4794	0.0000	0.0000	0.2993	0.0213	0.0090	0.1	0.06	
28	280	0.0070	0.0238	0.5032	0.0000	0.0000	0.3208	0.0215	0.0090	0.1	0.06	
29	290	0.0082	0.0279	0.5311	0.0000	0.0000	0.3462	0.0254	0.0107	0.1	0.07	
30	300	0.0082	0.0279	0.5590	0.0003	0.0003	0.3717	0.0256	0.0109	0.1	0.07	
31	310	0.0082	0.0279	0.5868	0.0011	0.0008	0.3975	0.0257	0.0113	0.1	0.08	
32	320	0.0082	0.0279	0.6147	0.0025	0.0014	0.4234	0.0259	0.0117	0.1	0.08	
33	330	0.0082	0.0279	0.6426	0.0044	0.0019	0.4494	0.0260	0.0121	0.1	0.08	
34	340	0.0082	0.0279	0.6705	0.0069	0.0024	0.4755	0.0262	0.0124	0.1	0.08	
35	350	0.0095	0.0323	0.7028	0.0104	0.0035	0.5060	0.0304	0.0148	0.1	0.09	
36	360	0.0095	0.0323	0.7351	0.0145	0.0041	0.5365	0.0306	0.0152	0.1	0.10	
37	370	0.0095	0.0323	0.7674	0.0192	0.0047	0.5672	0.0307	0.0156	0.1	0.10	
38	380	0.0095	0.0323	0.7997	0.0246	0.0053	0.5980	0.0308	0.0160	0.1	0.11	
39	390	0.0095	0.0323	0.8320	0.0305	0.0059	0.6289	0.0309	0.0164	0.1	0.11	
40	400	0.0095	0.0323	0.8643	0.0370	0.0065	0.6599	0.0310	0.0168	0.1	0.11	
41	410	0.0134	0.0456	0.9098	0.0471	0.0101	0.7038	0.0438	0.0243	0.2	0.14	
42	420	0.0134	0.0456	0.9554	0.0583	0.0112	0.7477	0.0440	0.0249	0.2	0.16	
43	430	0.0134	0.0456	1.0010	0.0704	0.0122	0.7918	0.0441	0.0256	0.2	0.17	
44	440	0.0180	0.0612	1.0622	0.0883	0.0178	0.8512	0.0594	0.0353	0.2	0.20	
45	450	0.0180	0.0612	1.1234	0.1077	0.0195	0.9108	0.0596	0.0363	0.2	0.24	
46	460	0.0340	0.1156	1.2390	0.1487	0.0409	1.0238	0.1129	0.0712	0.5	0.35	
47	470	0.0540	0.1836	1.4226	0.2236	0.0750	1.2039	0.1802	0.1192	0.8	0.62	Q peak
48	480	0.0270	0.0918	1.5144	0.2652	0.0416	1.2943	0.0904	0.0621	0.4	0.62	
49	490	0.0180	0.0612	1.5756	0.2944	0.0291	1.3546	0.0603	0.0422	0.3	0.38	
50	500	0.0134	0.0456	1.6211	0.3167	0.0224	1.3996	0.0449	0.0318	0.2	0.26	
51	510	0.0134	0.0456	1.6667	0.3396	0.0229	1.4445	0.0450	0.0322	0.2	0.22	
52	520	0.0134	0.0456	1.7122	0.3631	0.0235	1.4895	0.0450	0.0325	0.2	0.22	
53	530	0.0088	0.0299	1.7422	0.3788	0.0157	1.5191	0.0296	0.0215	0.1	0.19	
54	540	0.0088	0.0299	1.7721	0.3947	0.0159	1.5487	0.0296	0.0217	0.1	0.15	
55	550	0.0088	0.0299	1.8020	0.4108	0.0161	1.5783	0.0296	0.0218	0.1	0.15	
56	560	0.0088	0.0299	1.8319	0.4271	0.0163	1.6079	0.0296	0.0219	0.1	0.15	
57	570	0.0088	0.0299	1.8618	0.4436	0.0165	1.6375	0.0296	0.0220	0.1	0.15	
58	580	0.0088	0.0299	1.8918	0.4604	0.0167	1.6671	0.0296	0.0221	0.2	0.15	
59	590	0.0088	0.0299	1.9217	0.4773	0.0169	1.6968	0.0296	0.0223	0.2	0.15	
60	600	0.0088	0.0299	1.9516	0.4944	0.0171	1.7264	0.0296	0.0224	0.2	0.15	
61	610	0.0088	0.0299	1.9815	0.5117	0.0173	1.7560	0.0296	0.0225	0.2	0.15	
62	620	0.0088	0.0299	2.0114	0.5292	0.0175	1.7857	0.0297	0.0226	0.2	0.15	
63	630	0.0088	0.0299	2.0414	0.5468	0.0177	1.8154	0.0297	0.0227	0.2	0.15	
64	640	0.0088	0.0299	2.0713	0.5647	0.0178	1.8450	0.0297	0.0228	0.2	0.15	
65	650	0.0072	0.0245	2.0958	0.5794	0.0147	1.8693	0.0243	0.0187	0.1	0.14	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0245	2.1202	0.5942	0.0148	1.8936	0.0243	0.0188	0.1	0.13
67	670	0.0072	0.0245	2.1447	0.6092	0.0149	1.9179	0.0243	0.0189	0.1	0.13
68	680	0.0072	0.0245	2.1692	0.6242	0.0151	1.9422	0.0243	0.0189	0.1	0.13
69	690	0.0072	0.0245	2.1937	0.6394	0.0152	1.9665	0.0243	0.0190	0.1	0.13
70	700	0.0072	0.0245	2.2182	0.6547	0.0153	1.9908	0.0243	0.0191	0.1	0.13
71	710	0.0072	0.0245	2.2426	0.6700	0.0154	2.0151	0.0243	0.0191	0.1	0.13
72	720	0.0072	0.0245	2.2671	0.6855	0.0155	2.0394	0.0243	0.0192	0.1	0.13
73	730	0.0072	0.0245	2.2916	0.7011	0.0156	2.0637	0.0243	0.0192	0.1	0.13
74	740	0.0072	0.0245	2.3161	0.7167	0.0157	2.0880	0.0243	0.0193	0.1	0.13
75	750	0.0072	0.0245	2.3406	0.7325	0.0158	2.1123	0.0243	0.0194	0.1	0.13
76	760	0.0072	0.0245	2.3650	0.7484	0.0159	2.1366	0.0243	0.0194	0.1	0.13
77	770	0.0057	0.0194	2.3844	0.7610	0.0126	2.1559	0.0193	0.0154	0.1	0.12
78	780	0.0057	0.0194	2.4038	0.7737	0.0127	2.1751	0.0193	0.0154	0.1	0.11
79	790	0.0057	0.0194	2.4232	0.7864	0.0127	2.1944	0.0193	0.0155	0.1	0.10
80	800	0.0057	0.0194	2.4426	0.7992	0.0128	2.2136	0.0193	0.0155	0.1	0.11
81	810	0.0057	0.0194	2.4619	0.8120	0.0128	2.2329	0.0193	0.0155	0.1	0.11
82	820	0.0057	0.0194	2.4813	0.8249	0.0129	2.2522	0.0193	0.0156	0.1	0.11
83	830	0.0057	0.0194	2.5007	0.8379	0.0130	2.2714	0.0193	0.0156	0.1	0.11
84	840	0.0057	0.0194	2.5201	0.8509	0.0130	2.2907	0.0193	0.0156	0.1	0.11
85	850	0.0057	0.0194	2.5395	0.8640	0.0131	2.3100	0.0193	0.0157	0.1	0.11
86	860	0.0057	0.0194	2.5588	0.8771	0.0131	2.3292	0.0193	0.0157	0.1	0.11
87	870	0.0057	0.0194	2.5782	0.8903	0.0132	2.3485	0.0193	0.0157	0.1	0.11
88	880	0.0057	0.0194	2.5976	0.9035	0.0132	2.3678	0.0193	0.0158	0.1	0.11
89	890	0.0050	0.0170	2.6146	0.9151	0.0116	2.3847	0.0169	0.0139	0.1	0.10
90	900	0.0050	0.0170	2.6316	0.9268	0.0117	2.4016	0.0169	0.0139	0.1	0.09
91	910	0.0050	0.0170	2.6486	0.9385	0.0117	2.4185	0.0169	0.0139	0.1	0.09
92	920	0.0050	0.0170	2.6656	0.9502	0.0118	2.4354	0.0169	0.0139	0.1	0.09
93	930	0.0050	0.0170	2.6826	0.9620	0.0118	2.4523	0.0169	0.0139	0.1	0.09
94	940	0.0050	0.0170	2.6996	0.9739	0.0118	2.4693	0.0169	0.0140	0.1	0.09
95	950	0.0050	0.0170	2.7166	0.9857	0.0119	2.4862	0.0169	0.0140	0.1	0.09
96	960	0.0050	0.0170	2.7336	0.9976	0.0119	2.5031	0.0169	0.0140	0.1	0.09
97	970	0.0050	0.0170	2.7506	1.0095	0.0119	2.5200	0.0169	0.0140	0.1	0.10
98	980	0.0050	0.0170	2.7676	1.0215	0.0120	2.5369	0.0169	0.0140	0.1	0.10
99	990	0.0050	0.0170	2.7846	1.0335	0.0120	2.5538	0.0169	0.0141	0.1	0.10
100	1000	0.0050	0.0170	2.8016	1.0456	0.0120	2.5707	0.0169	0.0141	0.1	0.10
101	1010	0.0040	0.0136	2.8152	1.0552	0.0097	2.5843	0.0135	0.0113	0.1	0.09
102	1020	0.0040	0.0136	2.8288	1.0649	0.0097	2.5978	0.0135	0.0113	0.1	0.08
103	1030	0.0040	0.0136	2.8424	1.0746	0.0097	2.6114	0.0135	0.0113	0.1	0.08
104	1040	0.0040	0.0136	2.8560	1.0843	0.0097	2.6249	0.0135	0.0113	0.1	0.08
105	1050	0.0040	0.0136	2.8696	1.0940	0.0097	2.6384	0.0135	0.0113	0.1	0.08
106	1060	0.0040	0.0136	2.8832	1.1038	0.0098	2.6520	0.0135	0.0113	0.1	0.08
107	1070	0.0040	0.0136	2.8968	1.1136	0.0098	2.6655	0.0135	0.0114	0.1	0.08
108	1080	0.0040	0.0136	2.9104	1.1234	0.0098	2.6791	0.0135	0.0114	0.1	0.08
109	1090	0.0040	0.0136	2.9240	1.1332	0.0098	2.6926	0.0135	0.0114	0.1	0.08
110	1100	0.0040	0.0136	2.9376	1.1431	0.0098	2.7061	0.0135	0.0114	0.1	0.08
111	1110	0.0040	0.0136	2.9512	1.1529	0.0099	2.7197	0.0135	0.0114	0.1	0.08
112	1120	0.0040	0.0136	2.9648	1.1628	0.0099	2.7332	0.0135	0.0114	0.1	0.08
113	1130	0.0040	0.0136	2.9784	1.1727	0.0099	2.7468	0.0135	0.0114	0.1	0.08
114	1140	0.0040	0.0136	2.9920	1.1826	0.0099	2.7603	0.0135	0.0114	0.1	0.08
115	1150	0.0040	0.0136	3.0056	1.1926	0.0099	2.7738	0.0135	0.0115	0.1	0.08
116	1160	0.0040	0.0136	3.0192	1.2025	0.0100	2.7874	0.0135	0.0115	0.1	0.08
117	1170	0.0040	0.0136	3.0328	1.2125	0.0100	2.8009	0.0135	0.0115	0.1	0.08
118	1180	0.0040	0.0136	3.0464	1.2225	0.0100	2.8145	0.0135	0.0115	0.1	0.08
119	1190	0.0040	0.0136	3.0600	1.2325	0.0100	2.8280	0.0135	0.0115	0.1	0.08
120	1200	0.0040	0.0136	3.0736	1.2426	0.0100	2.8416	0.0135	0.0115	0.1	0.08
121	1210	0.0040	0.0136	3.0872	1.2526	0.0101	2.8551	0.0135	0.0115	0.1	0.08
122	1220	0.0040	0.0136	3.1008	1.2627	0.0101	2.8687	0.0135	0.0115	0.1	0.08
123	1230	0.0040	0.0136	3.1144	1.2728	0.0101	2.8822	0.0135	0.0115	0.1	0.08
124	1240	0.0040	0.0136	3.1280	1.2829	0.0101	2.8958	0.0135	0.0116	0.1	0.08
125	1250	0.0040	0.0136	3.1416	1.2930	0.0101	2.9093	0.0135	0.0116	0.1	0.08
126	1260	0.0040	0.0136	3.1552	1.3032	0.0101	2.9229	0.0135	0.0116	0.1	0.08
127	1270	0.0040	0.0136	3.1688	1.3133	0.0102	2.9364	0.0135	0.0116	0.1	0.08
128	1280	0.0040	0.0136	3.1824	1.3235	0.0102	2.9500	0.0135	0.0116	0.1	0.08
129	1290	0.0040	0.0136	3.1960	1.3337	0.0102	2.9635	0.0135	0.0116	0.1	0.08
130	1300	0.0040	0.0136	3.2096	1.3439	0.0102	2.9771	0.0136	0.0116	0.1	0.08
131	1310	0.0040	0.0136	3.2232	1.3542	0.0102	2.9906	0.0136	0.0116	0.1	0.08
132	1320	0.0040	0.0136	3.2368	1.3644	0.0103	3.0042	0.0136	0.0116	0.1	0.08
133	1330	0.0040	0.0136	3.2504	1.3747	0.0103	3.0177	0.0136	0.0116	0.1	0.08
134	1340	0.0040	0.0136	3.2640	1.3850	0.0103	3.0313	0.0136	0.0117	0.1	0.08
135	1350	0.0040	0.0136	3.2776	1.3953	0.0103	3.0448	0.0136	0.0117	0.1	0.08
136	1360	0.0040	0.0136	3.2912	1.4056	0.0103	3.0584	0.0136	0.0117	0.1	0.08
137	1370	0.0040	0.0136	3.3048	1.4159	0.0103	3.0719	0.0136	0.0117	0.1	0.08
138	1380	0.0040	0.0136	3.3184	1.4263	0.0104	3.0855	0.0136	0.0117	0.1	0.08
139	1390	0.0040	0.0136	3.3320	1.4366	0.0104	3.0990	0.0136	0.0117	0.1	0.08
140	1400	0.0040	0.0136	3.3456	1.4470	0.0104	3.1126	0.0136	0.0117	0.1	0.08
141	1410	0.0040	0.0136	3.3592	1.4574	0.0104	3.1261	0.0136	0.0117	0.1	0.08
142	1420	0.0040	0.0136	3.3728	1.4678	0.0104	3.1397	0.0136	0.0117	0.1	0.08
143	1430	0.0040	0.0136	3.3864	1.4783	0.0104	3.1532	0.0136	0.0117	0.1	0.08
144	1440	0.0040	0.0136	3.4000	1.4887	0.0104	3.1668	0.0136	0.0118	0.1	0.08

Total Volume of Runoff[1] = 8,898 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

SBUH
100-yr 24-hr

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

Project: Laurel Station Remediation - Additional Drainage Area
Basin:
Storm Event: 100-YEAR, 24-HOUR
Given:

Area = 1.12 acres
Pt = 4.20 inches
dt = 10 min.
Tc = 6 min.

PERVIOUS AREA (Interim Final Cover Area)			IMPERVIOUS AREA (Roads)		
Area	=	0.65 acres	Area	=	0.47 acres
CN	=	79	CN	=	98
S	=	2.66	S	=	0.20
0.2S	=	0.53	0.2S	=	0.04

SUMMARY	
T_{pk}(hrs)=	7.83
T_c (min)=	6
Q_{pk}(cfs)=	0.83
Vol(cf)=	11,760

Compute: Runoff Hydrograph

Column (3) = SCS Type IA Rainfall Distribution
Column (4) = Col. (3) x Pt
Column (5) = Accumulated Sum of Col. (4)
Column (6) = [If P <= 0.2S] = 0; Note, use PERVIOUS Area "S" value.
[If P > 0.2S] = (Col.(5) - 0.2S)^2/(Col.(5) + 0.8S); Using the PERVIOUS Area "S" value.
Column (7) = Col.(6) of Present Time Step - Col.(6) of Previous Time Step
Column (8) = Same method as for Col.(6), except use the IMPERVIOUS Area "S" value.
Column (9) = Col.(8) of the present time step - Col.(8) of the previous time step.
Column (10) = ((PERVIOUS area / Total area) x Col.(7)) + ((IMPERVIOUS area / Total area) x Col.(9))
Column (11) = (60.5 x Col.(10) x Total Area) / 10 (dt = 10 minutes)
Routing Constant, w = dt / (2Tc + dt) = 0.4545
Column (12) = Col.(12) of Previous Time Step + (w x [Col.(11) of Previous Time Step + Col.(11) of Present Time Step - (2 x Col.(12) of Previous Time Step)])

(1) Time Increment	(2) Time min.	(3) Rainfall distribution % of Pt	(4) Incremental Rainfall in.	(5) Accumulated Rainfall in.	Pervious Area (6) Accumulated Runoff in.	Pervious Area (7) Incremental Runoff in.	Impervious Area (8) Accumulated Runoff in.	Impervious Area (9) Incremental Runoff in.	(10) Total Runoff in.	(11) Instant hydrograph cfs	(12) design hydrograph cfs	
1	10	0.0040	0.0168	0.0168	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
2	20	0.0040	0.0168	0.0336	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.00	
3	30	0.0040	0.0168	0.0504	0.0000	0.0000	0.0004	0.0004	0.0002	0.0	0.00	
4	40	0.0040	0.0168	0.0672	0.0000	0.0000	0.0030	0.0026	0.0011	0.0	0.00	
5	50	0.0040	0.0168	0.0840	0.0000	0.0000	0.0075	0.0045	0.0019	0.0	0.01	
6	60	0.0040	0.0168	0.1008	0.0000	0.0000	0.0136	0.0061	0.0026	0.0	0.01	
7	70	0.0040	0.0168	0.1176	0.0000	0.0000	0.0210	0.0074	0.0031	0.0	0.02	
8	80	0.0040	0.0168	0.1344	0.0000	0.0000	0.0294	0.0084	0.0035	0.0	0.02	
9	90	0.0040	0.0168	0.1512	0.0000	0.0000	0.0387	0.0093	0.0039	0.0	0.03	
10	100	0.0040	0.0168	0.1680	0.0000	0.0000	0.0488	0.0101	0.0042	0.0	0.03	
11	110	0.0050	0.0210	0.1890	0.0000	0.0000	0.0623	0.0135	0.0057	0.0	0.03	
12	120	0.0050	0.0210	0.2100	0.0000	0.0000	0.0767	0.0143	0.0060	0.0	0.04	
13	130	0.0050	0.0210	0.2310	0.0000	0.0000	0.0917	0.0151	0.0063	0.0	0.04	
14	140	0.0050	0.0210	0.2520	0.0000	0.0000	0.1074	0.0157	0.0066	0.0	0.04	
15	150	0.0050	0.0210	0.2730	0.0000	0.0000	0.1236	0.0162	0.0068	0.0	0.05	
16	160	0.0050	0.0210	0.2940	0.0000	0.0000	0.1402	0.0166	0.0070	0.0	0.05	
17	170	0.0060	0.0252	0.3192	0.0000	0.0000	0.1606	0.0204	0.0086	0.1	0.05	
18	180	0.0060	0.0252	0.3444	0.0000	0.0000	0.1815	0.0209	0.0088	0.1	0.06	
19	190	0.0060	0.0252	0.3696	0.0000	0.0000	0.2029	0.0213	0.0090	0.1	0.06	
20	200	0.0060	0.0252	0.3948	0.0000	0.0000	0.2245	0.0217	0.0091	0.1	0.06	
21	210	0.0060	0.0252	0.4200	0.0000	0.0000	0.2465	0.0220	0.0092	0.1	0.06	
22	220	0.0060	0.0252	0.4452	0.0000	0.0000	0.2688	0.0222	0.0093	0.1	0.06	
23	230	0.0070	0.0294	0.4746	0.0000	0.0000	0.2950	0.0262	0.0110	0.1	0.07	
24	240	0.0070	0.0294	0.5040	0.0000	0.0000	0.3215	0.0265	0.0111	0.1	0.07	
25	250	0.0070	0.0294	0.5334	0.0000	0.0000	0.3483	0.0268	0.0112	0.1	0.08	
26	260	0.0070	0.0294	0.5628	0.0004	0.0004	0.3753	0.0270	0.0115	0.1	0.08	
27	270	0.0070	0.0294	0.5922	0.0013	0.0010	0.4024	0.0272	0.0120	0.1	0.08	
28	280	0.0070	0.0294	0.6216	0.0029	0.0016	0.4298	0.0273	0.0124	0.1	0.08	
29	290	0.0082	0.0344	0.6560	0.0056	0.0026	0.4620	0.0322	0.0151	0.1	0.09	
30	300	0.0082	0.0344	0.6905	0.0090	0.0034	0.4944	0.0324	0.0156	0.1	0.10	
31	310	0.0082	0.0344	0.7249	0.0131	0.0041	0.5269	0.0325	0.0161	0.1	0.11	
32	320	0.0082	0.0344	0.7594	0.0180	0.0049	0.5596	0.0327	0.0166	0.1	0.11	
33	330	0.0082	0.0344	0.7938	0.0235	0.0056	0.5924	0.0328	0.0170	0.1	0.11	
34	340	0.0082	0.0344	0.8282	0.0298	0.0062	0.6253	0.0329	0.0175	0.1	0.12	
35	350	0.0095	0.0399	0.8681	0.0378	0.0080	0.6636	0.0383	0.0207	0.1	0.13	
36	360	0.0095	0.0399	0.9080	0.0467	0.0089	0.7020	0.0384	0.0213	0.1	0.14	
37	370	0.0095	0.0399	0.9479	0.0564	0.0097	0.7405	0.0385	0.0218	0.1	0.15	
38	380	0.0095	0.0399	0.9878	0.0668	0.0105	0.7791	0.0386	0.0223	0.2	0.15	
39	390	0.0095	0.0399	1.0277	0.0780	0.0112	0.8178	0.0387	0.0227	0.2	0.15	
40	400	0.0095	0.0399	1.0676	0.0899	0.0119	0.8566	0.0388	0.0232	0.2	0.16	
41	410	0.0134	0.0563	1.1239	0.1079	0.0180	0.9114	0.0548	0.0334	0.2	0.19	
42	420	0.0134	0.0563	1.1802	0.1272	0.0193	0.9663	0.0549	0.0343	0.2	0.23	
43	430	0.0134	0.0563	1.2365	0.1477	0.0205	1.0213	0.0550	0.0350	0.2	0.23	
44	440	0.0180	0.0756	1.3121	0.1771	0.0294	1.0954	0.0741	0.0482	0.3	0.28	
45	450	0.0180	0.0756	1.3877	0.2085	0.0314	1.1696	0.0742	0.0494	0.3	0.33	
46	460	0.0340	0.1428	1.5305	0.2728	0.0643	1.3102	0.1405	0.0963	0.7	0.48	
47	470	0.0540	0.2268	1.7573	0.3868	0.1140	1.5341	0.2239	0.1602	1.1	0.83	Q peak
48	480	0.0270	0.1134	1.8707	0.4486	0.0618	1.6463	0.1122	0.0830	0.6	0.83	
49	490	0.0180	0.0756	1.9463	0.4913	0.0428	1.7211	0.0749	0.0563	0.4	0.50	
50	500	0.0134	0.0563	2.0026	0.5240	0.0326	1.7769	0.0558	0.0424	0.3	0.35	
51	510	0.0134	0.0563	2.0588	0.5572	0.0333	1.8327	0.0558	0.0427	0.3	0.29	
52	520	0.0134	0.0563	2.1151	0.5911	0.0339	1.8885	0.0558	0.0431	0.3	0.29	
53	530	0.0088	0.0370	2.1521	0.6137	0.0226	1.9252	0.0367	0.0285	0.2	0.25	
54	540	0.0088	0.0370	2.1890	0.6365	0.0228	1.9618	0.0367	0.0286	0.2	0.20	
55	550	0.0088	0.0370	2.2260	0.6596	0.0231	1.9985	0.0367	0.0288	0.2	0.20	
56	560	0.0088	0.0370	2.2630	0.6829	0.0233	2.0352	0.0367	0.0289	0.2	0.20	
57	570	0.0088	0.0370	2.2999	0.7064	0.0235	2.0719	0.0367	0.0291	0.2	0.20	
58	580	0.0088	0.0370	2.3369	0.7301	0.0237	2.1086	0.0367	0.0292	0.2	0.20	
59	590	0.0088	0.0370	2.3738	0.7541	0.0240	2.1454	0.0367	0.0293	0.2	0.20	
60	600	0.0088	0.0370	2.4108	0.7783	0.0242	2.1821	0.0367	0.0294	0.2	0.20	
61	610	0.0088	0.0370	2.4478	0.8026	0.0244	2.2188	0.0367	0.0296	0.2	0.20	
62	620	0.0088	0.0370	2.4847	0.8272	0.0246	2.2556	0.0367	0.0297	0.2	0.20	
63	630	0.0088	0.0370	2.5217	0.8520	0.0248	2.2923	0.0367	0.0298	0.2	0.20	
64	640	0.0088	0.0370	2.5586	0.8770	0.0250	2.3290	0.0367	0.0299	0.2	0.20	
65	650	0.0072	0.0302	2.5889	0.8975	0.0206	2.3591	0.0301	0.0246	0.2	0.19	

SANTA BARBARA URBAN HYDROGRAPH (SBUH) METHOD
RUNOFF VOLUME CALCULATION

(1) Time Increment	(2) Time min.	(3) Rainfall distri-bution % of Pt	(4) Incre-mental Rainfall in.	(5) Accumu-lated Rainfall in.	Pervious Area (6) Accumu-lated Runoff in.	Pervious Area (7) Incre-mental Runoff in.	Impervious Area (8) Accumu-lated Runoff in.	Impervious Area (9) Incre-mental Runoff in.	(10) Total Runoff in.	(11) Instant hydro-graph cfs	(12) design hydro-graph cfs
66	660	0.0072	0.0302	2.6191	0.9182	0.0207	2.3892	0.0301	0.0246	0.2	0.17
67	670	0.0072	0.0302	2.6494	0.9390	0.0208	2.4193	0.0301	0.0247	0.2	0.17
68	680	0.0072	0.0302	2.6796	0.9600	0.0209	2.4494	0.0301	0.0248	0.2	0.17
69	690	0.0072	0.0302	2.7098	0.9810	0.0210	2.4794	0.0301	0.0248	0.2	0.17
70	700	0.0072	0.0302	2.7401	1.0022	0.0212	2.5095	0.0301	0.0249	0.2	0.17
71	710	0.0072	0.0302	2.7703	1.0234	0.0213	2.5396	0.0301	0.0250	0.2	0.17
72	720	0.0072	0.0302	2.8006	1.0448	0.0214	2.5697	0.0301	0.0250	0.2	0.17
73	730	0.0072	0.0302	2.8308	1.0663	0.0215	2.5998	0.0301	0.0251	0.2	0.17
74	740	0.0072	0.0302	2.8610	1.0879	0.0216	2.6299	0.0301	0.0252	0.2	0.17
75	750	0.0072	0.0302	2.8913	1.1096	0.0217	2.6600	0.0301	0.0252	0.2	0.17
76	760	0.0072	0.0302	2.9215	1.1314	0.0218	2.6901	0.0301	0.0253	0.2	0.17
77	770	0.0057	0.0239	2.9455	1.1487	0.0173	2.7140	0.0238	0.0201	0.1	0.16
78	780	0.0057	0.0239	2.9694	1.1661	0.0174	2.7378	0.0238	0.0201	0.1	0.14
79	790	0.0057	0.0239	2.9933	1.1836	0.0175	2.7616	0.0238	0.0201	0.1	0.14
80	800	0.0057	0.0239	3.0173	1.2011	0.0175	2.7855	0.0238	0.0202	0.1	0.14
81	810	0.0057	0.0239	3.0412	1.2187	0.0176	2.8093	0.0238	0.0202	0.1	0.14
82	820	0.0057	0.0239	3.0652	1.2363	0.0176	2.8332	0.0238	0.0202	0.1	0.14
83	830	0.0057	0.0239	3.0891	1.2540	0.0177	2.8570	0.0238	0.0203	0.1	0.14
84	840	0.0057	0.0239	3.1130	1.2718	0.0177	2.8809	0.0238	0.0203	0.1	0.14
85	850	0.0057	0.0239	3.1370	1.2896	0.0178	2.9047	0.0238	0.0203	0.1	0.14
86	860	0.0057	0.0239	3.1609	1.3074	0.0179	2.9286	0.0238	0.0204	0.1	0.14
87	870	0.0057	0.0239	3.1849	1.3254	0.0179	2.9524	0.0239	0.0204	0.1	0.14
88	880	0.0057	0.0239	3.2088	1.3433	0.0180	2.9763	0.0239	0.0204	0.1	0.14
89	890	0.0050	0.0210	3.2298	1.3591	0.0158	2.9972	0.0209	0.0180	0.1	0.13
90	900	0.0050	0.0210	3.2508	1.3750	0.0158	3.0181	0.0209	0.0180	0.1	0.12
91	910	0.0050	0.0210	3.2718	1.3909	0.0159	3.0390	0.0209	0.0180	0.1	0.12
92	920	0.0050	0.0210	3.2928	1.4068	0.0159	3.0600	0.0209	0.0180	0.1	0.12
93	930	0.0050	0.0210	3.3138	1.4228	0.0160	3.0809	0.0209	0.0181	0.1	0.12
94	940	0.0050	0.0210	3.3348	1.4388	0.0160	3.1018	0.0209	0.0181	0.1	0.12
95	950	0.0050	0.0210	3.3558	1.4548	0.0160	3.1227	0.0209	0.0181	0.1	0.12
96	960	0.0050	0.0210	3.3768	1.4709	0.0161	3.1437	0.0209	0.0181	0.1	0.12
97	970	0.0050	0.0210	3.3978	1.4870	0.0161	3.1646	0.0209	0.0181	0.1	0.12
98	980	0.0050	0.0210	3.4188	1.5032	0.0162	3.1855	0.0209	0.0182	0.1	0.12
99	990	0.0050	0.0210	3.4398	1.5194	0.0162	3.2065	0.0209	0.0182	0.1	0.12
100	1000	0.0050	0.0210	3.4608	1.5356	0.0162	3.2274	0.0209	0.0182	0.1	0.12
101	1010	0.0040	0.0168	3.4776	1.5486	0.0130	3.2441	0.0167	0.0146	0.1	0.11
102	1020	0.0040	0.0168	3.4944	1.5616	0.0130	3.2609	0.0167	0.0146	0.1	0.10
103	1030	0.0040	0.0168	3.5112	1.5747	0.0131	3.2776	0.0167	0.0146	0.1	0.10
104	1040	0.0040	0.0168	3.5280	1.5878	0.0131	3.2944	0.0167	0.0146	0.1	0.10
105	1050	0.0040	0.0168	3.5448	1.6009	0.0131	3.3111	0.0167	0.0146	0.1	0.10
106	1060	0.0040	0.0168	3.5616	1.6140	0.0131	3.3279	0.0167	0.0146	0.1	0.10
107	1070	0.0040	0.0168	3.5784	1.6271	0.0131	3.3446	0.0167	0.0147	0.1	0.10
108	1080	0.0040	0.0168	3.5952	1.6403	0.0132	3.3614	0.0168	0.0147	0.1	0.10
109	1090	0.0040	0.0168	3.6120	1.6535	0.0132	3.3781	0.0168	0.0147	0.1	0.10
110	1100	0.0040	0.0168	3.6288	1.6667	0.0132	3.3949	0.0168	0.0147	0.1	0.10
111	1110	0.0040	0.0168	3.6456	1.6799	0.0132	3.4116	0.0168	0.0147	0.1	0.10
112	1120	0.0040	0.0168	3.6624	1.6932	0.0132	3.4284	0.0168	0.0147	0.1	0.10
113	1130	0.0040	0.0168	3.6792	1.7064	0.0133	3.4451	0.0168	0.0147	0.1	0.10
114	1140	0.0040	0.0168	3.6960	1.7197	0.0133	3.4619	0.0168	0.0147	0.1	0.10
115	1150	0.0040	0.0168	3.7128	1.7330	0.0133	3.4786	0.0168	0.0148	0.1	0.10
116	1160	0.0040	0.0168	3.7296	1.7463	0.0133	3.4954	0.0168	0.0148	0.1	0.10
117	1170	0.0040	0.0168	3.7464	1.7597	0.0133	3.5122	0.0168	0.0148	0.1	0.10
118	1180	0.0040	0.0168	3.7632	1.7731	0.0134	3.5289	0.0168	0.0148	0.1	0.10
119	1190	0.0040	0.0168	3.7800	1.7864	0.0134	3.5457	0.0168	0.0148	0.1	0.10
120	1200	0.0040	0.0168	3.7968	1.7999	0.0134	3.5624	0.0168	0.0148	0.1	0.10
121	1210	0.0040	0.0168	3.8136	1.8133	0.0134	3.5792	0.0168	0.0148	0.1	0.10
122	1220	0.0040	0.0168	3.8304	1.8267	0.0134	3.5959	0.0168	0.0148	0.1	0.10
123	1230	0.0040	0.0168	3.8472	1.8402	0.0135	3.6127	0.0168	0.0148	0.1	0.10
124	1240	0.0040	0.0168	3.8640	1.8537	0.0135	3.6294	0.0168	0.0149	0.1	0.10
125	1250	0.0040	0.0168	3.8808	1.8672	0.0135	3.6462	0.0168	0.0149	0.1	0.10
126	1260	0.0040	0.0168	3.8976	1.8807	0.0135	3.6630	0.0168	0.0149	0.1	0.10
127	1270	0.0040	0.0168	3.9144	1.8942	0.0135	3.6797	0.0168	0.0149	0.1	0.10
128	1280	0.0040	0.0168	3.9312	1.9078	0.0136	3.6965	0.0168	0.0149	0.1	0.10
129	1290	0.0040	0.0168	3.9480	1.9214	0.0136	3.7132	0.0168	0.0149	0.1	0.10
130	1300	0.0040	0.0168	3.9648	1.9350	0.0136	3.7300	0.0168	0.0149	0.1	0.10
131	1310	0.0040	0.0168	3.9816	1.9486	0.0136	3.7468	0.0168	0.0149	0.1	0.10
132	1320	0.0040	0.0168	3.9984	1.9622	0.0136	3.7635	0.0168	0.0149	0.1	0.10
133	1330	0.0040	0.0168	4.0152	1.9758	0.0136	3.7803	0.0168	0.0150	0.1	0.10
134	1340	0.0040	0.0168	4.0320	1.9895	0.0137	3.7970	0.0168	0.0150	0.1	0.10
135	1350	0.0040	0.0168	4.0488	2.0032	0.0137	3.8138	0.0168	0.0150	0.1	0.10
136	1360	0.0040	0.0168	4.0656	2.0169	0.0137	3.8306	0.0168	0.0150	0.1	0.10
137	1370	0.0040	0.0168	4.0824	2.0306	0.0137	3.8473	0.0168	0.0150	0.1	0.10
138	1380	0.0040	0.0168	4.0992	2.0443	0.0137	3.8641	0.0168	0.0150	0.1	0.10
139	1390	0.0040	0.0168	4.1160	2.0581	0.0137	3.8808	0.0168	0.0150	0.1	0.10
140	1400	0.0040	0.0168	4.1328	2.0718	0.0138	3.8976	0.0168	0.0150	0.1	0.10
141	1410	0.0040	0.0168	4.1496	2.0856	0.0138	3.9144	0.0168	0.0150	0.1	0.10
142	1420	0.0040	0.0168	4.1664	2.0994	0.0138	3.9311	0.0168	0.0150	0.1	0.10
143	1430	0.0040	0.0168	4.1832	2.1132	0.0138	3.9479	0.0168	0.0151	0.1	0.10
144	1440	0.0040	0.0168	4.2000	2.1270	0.0138	3.9646	0.0168	0.0151	0.1	0.10

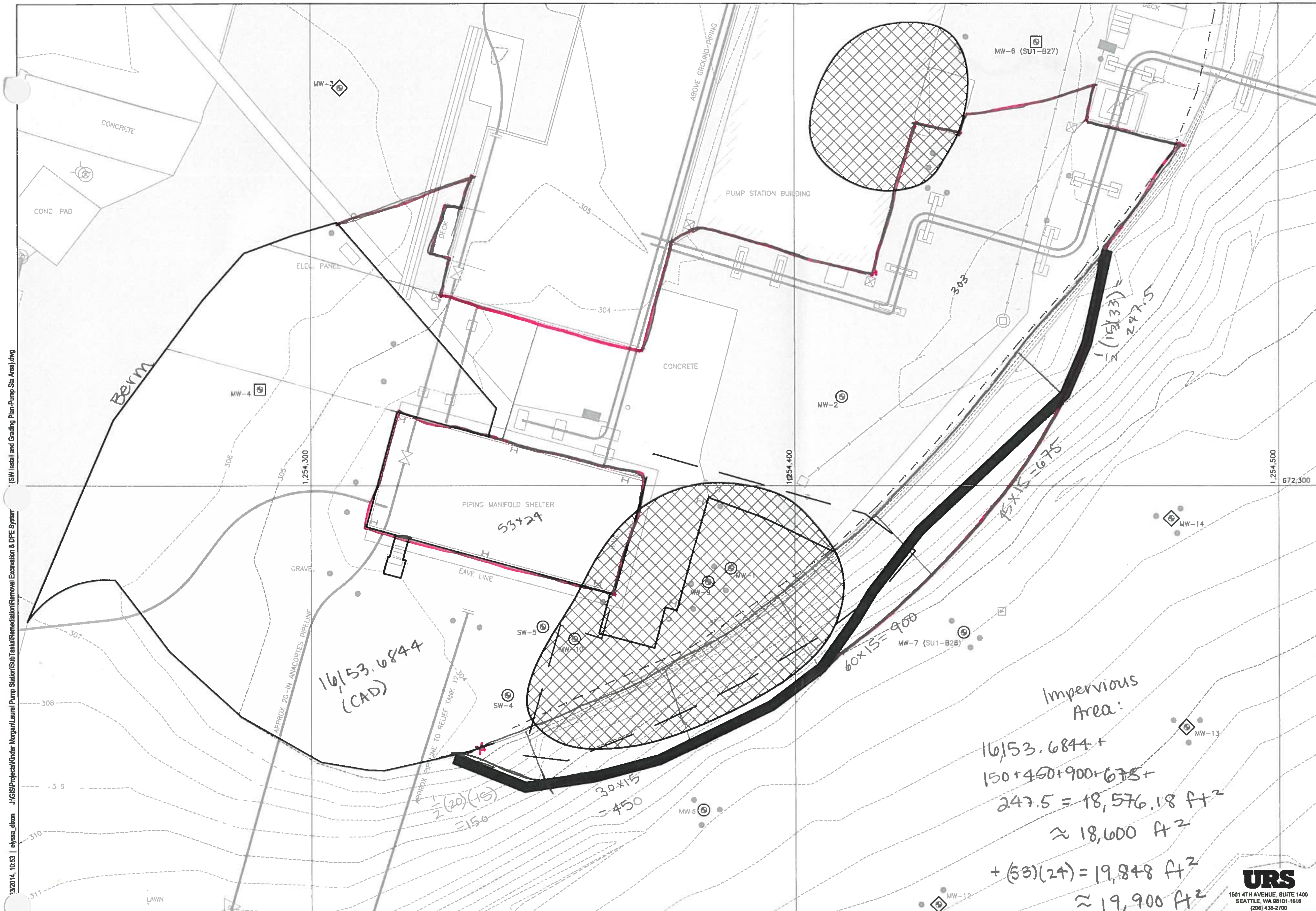
Total Volume of Runoff[1] = 11,760 cu. ft.

Notes:

1. Total Runoff Volume is found by summing column (12) and multiplying by the time step, dt as follows:

   V = SumQ x dt
   V(cu.ft.) = SumQ(cu.ft/s) x dt(min.) x (60 s/min.)

Attachment 3
Drainage Area Calculations



NOTES:

1. VERTICAL EXTENTS OF EXCAVATION OF CONTAMINATED MATERIAL WILL NOT BE ALTERED, BUT HORIZONTAL EXTENTS MAY CHANGE BASED ON SITE CONDITIONS AND SOIL CHARACTERIZATION.
2. METHOD USED TO REMOVE CONTAMINATED SOIL MUST PROTECT EXISTING PIPING AND EQUIPMENT FROM DAMAGE.
3. EXCAVATION WILL BE PERFORMED USING SLURRY METHODS TO SUPPORT EXCAVATION SIDEWALLS IN AREAS ADJACENT TO SENSITIVE STRUCTURES SUCH AS THE PIPING MANIFOLD SHELTER AND TRANSFER PIPING, ALONG LIMITED ACCESS BOUNDARIES AND IN AREAS THAT ARE DIFFICULT TO REMOVE CONTAMINATED SOIL TO DEPTH WITHOUT SIGNIFICANTLY IMPACTING THE SURROUNDING AREA. CONVENTIONAL EXCAVATION WILL BE USED TO REMOVE CONTAMINATED SOILS IN AREAS THAT ARE MORE READILY ACCESSIBLE.

LEGEND

- APPROXIMATE LIMITS OF SOIL EXCEEDING PCL
- EXCAVATION LIMITS
- NEW RETAINING WALL
- GROUNDWATER MONITORING WELL
- DECOMMISSION WELL (HISTORICALLY DRY)
- ABANDON WELL (EXCAVATION ACCESS)

100% SUBMITTAL
NOT FOR CONSTRUCTION

URS
1501 4TH AVENUE, SUITE 1400
SEATTLE, WA 98101-1616
(206) 438-2700

KINDER MORGAN
TRANSMOUNTAIN PIPELINE (PUGET SOUND)

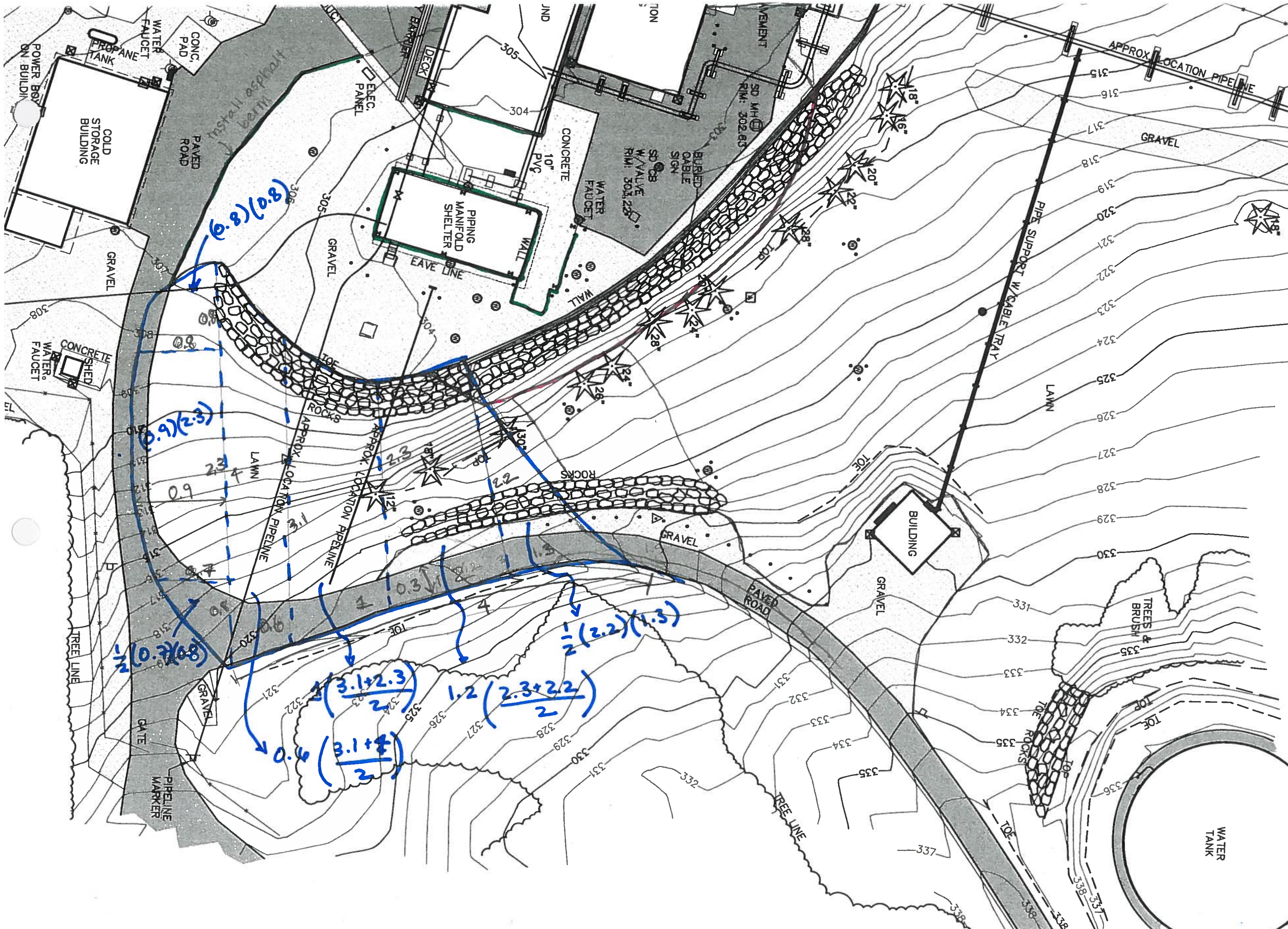
NO.	REFERENCE DRAWINGS	DRAWING NO.	NO.	DATE	REVISION	DR.	CHK.	APPR.	NO.	DATE	REVISION	DR.	CHK.	APPR.

DRAWN L. JILES CHECKED P. McCOLLOUGH APPROVED	STORMWATER INSTALLATION AND GRADING PLAN– PUMP STATION AREA LAUREL PUMP STATION	SHEET SIZE D SCALE AS NOTED DATE 05/30/14

DRAWING NUMBER

AFE	WBS	FACILITY ID.	DOCUMENT No.	SHT.No.	REV.
05-51041	–	UL00	C-7	15	

Mod: 05/23/2014, 09:51 | Plotted 5/23/2014, 10:53 | elyssa_dixon J:\GIS\Projects\Kinder Morgan\Laurel Pump Station\SubTasks\Remediation\Removal Excavation & DPE System\(SW Install and Grading Plan-Pump Sta Area).dwg



$\frac{1}{2}(1.3)(2.2) = 1.43$

$(1.2)\left(\frac{2.3+2.2}{2}\right) = 2.7$

$(1)\left(\frac{3.1+2.3}{2}\right) = 2.7$

$(2.3)(0.9) = 2.07$

$(0.7)(0.8)\frac{1}{2} = 0.28$ ← impervious

$(0.8)(0.8) = 0.64$

$0.6\left(\frac{3.1+4}{2}\right) = 2.13$

Pervious:

$11.67 - 4(0.3)$

$= 10.47 \cdot \frac{30}{0.9}$

$= 349\ ft^2$

Impervious:

$0.28 + 4(0.3) =$

$1.48 \cdot \frac{30}{0.9}$

$= 49.33$

$\Rightarrow 50\ ft^2$

Assume flow from above Paved road is diverted

Pervious: 0.008 acres
Impervious: 0.001 acres

Additional Drainage Area Calculations for Area above Paved Road

30" scale: 1.1" = 100 ft

(0.5)(4.5 in)(1.5 in) =
(0.5)(409 ft)(136 ft) =
27,812 sf = 0.64 acres
(pervious area)

Attachment 4

Western Washington

Isopluvial Maps

NOAA Atlas 2 Volume 9

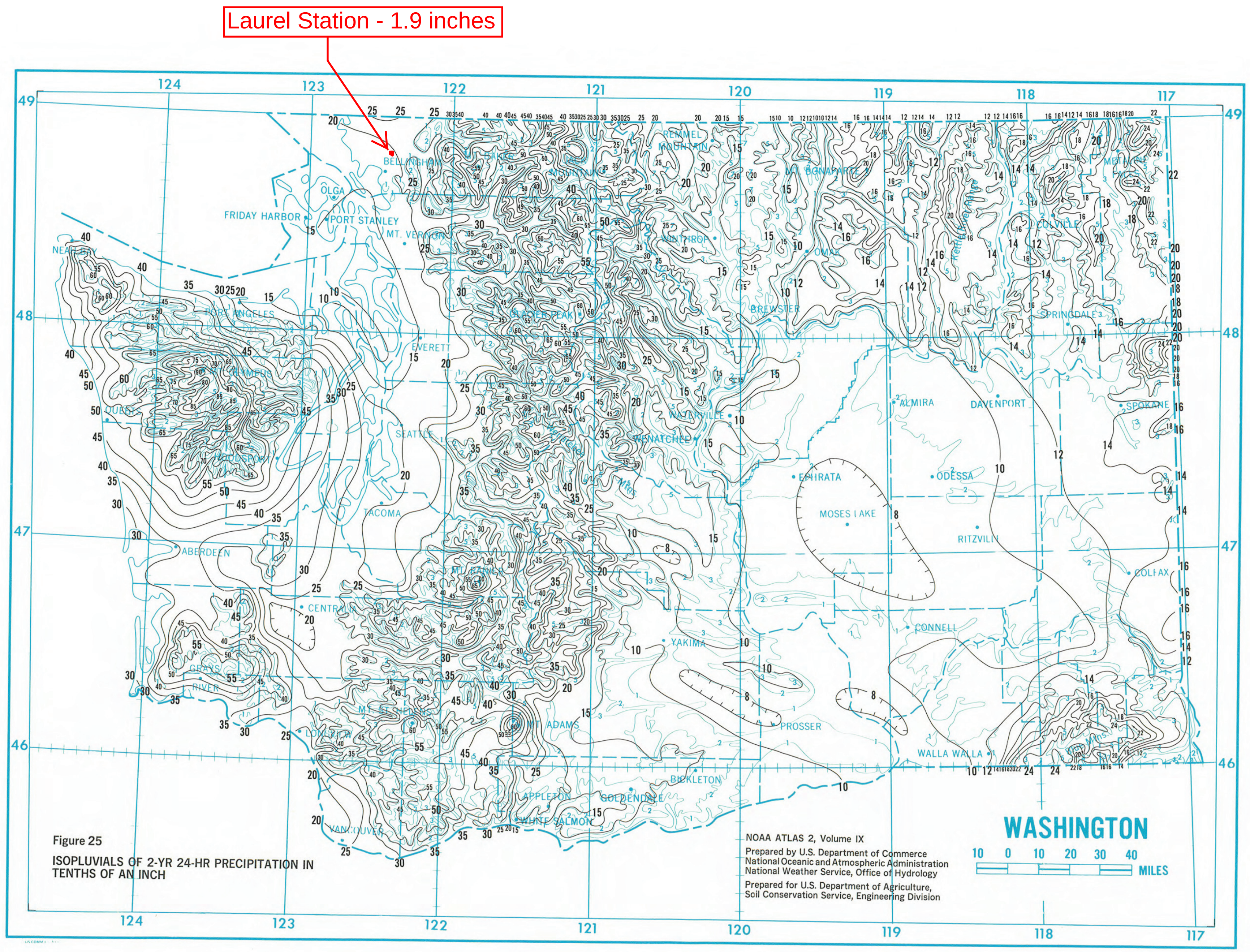


Figure 25

ISOPLUVIALS OF 2-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

Laurel Station - 2.8 inches

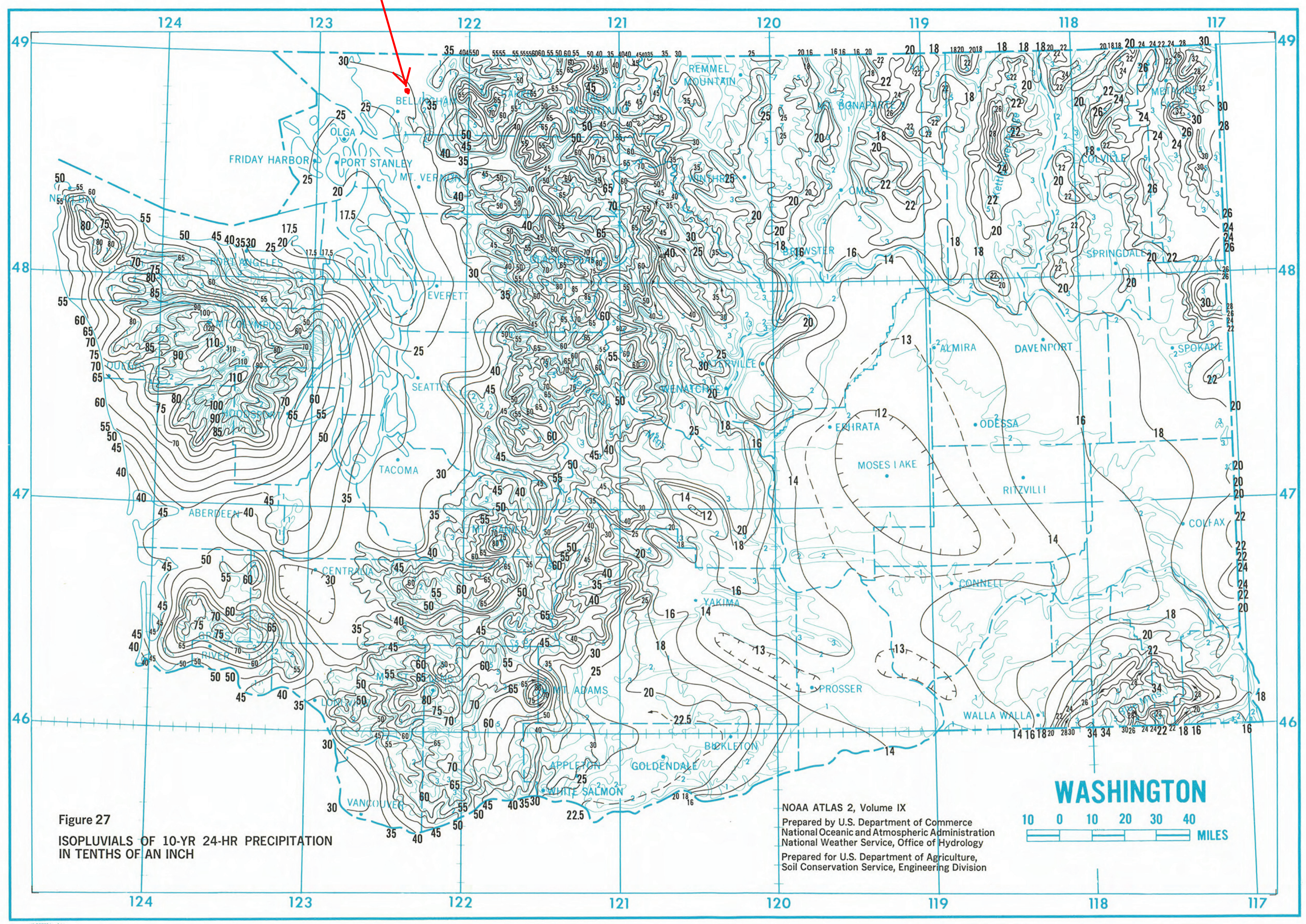


Figure 27

ISOPLUVIALS OF 10-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

NOAA ATLAS 2, Volume IX
Prepared by U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology
Prepared for U.S. Department of Agriculture,
Soil Conservation Service, Engineering Division

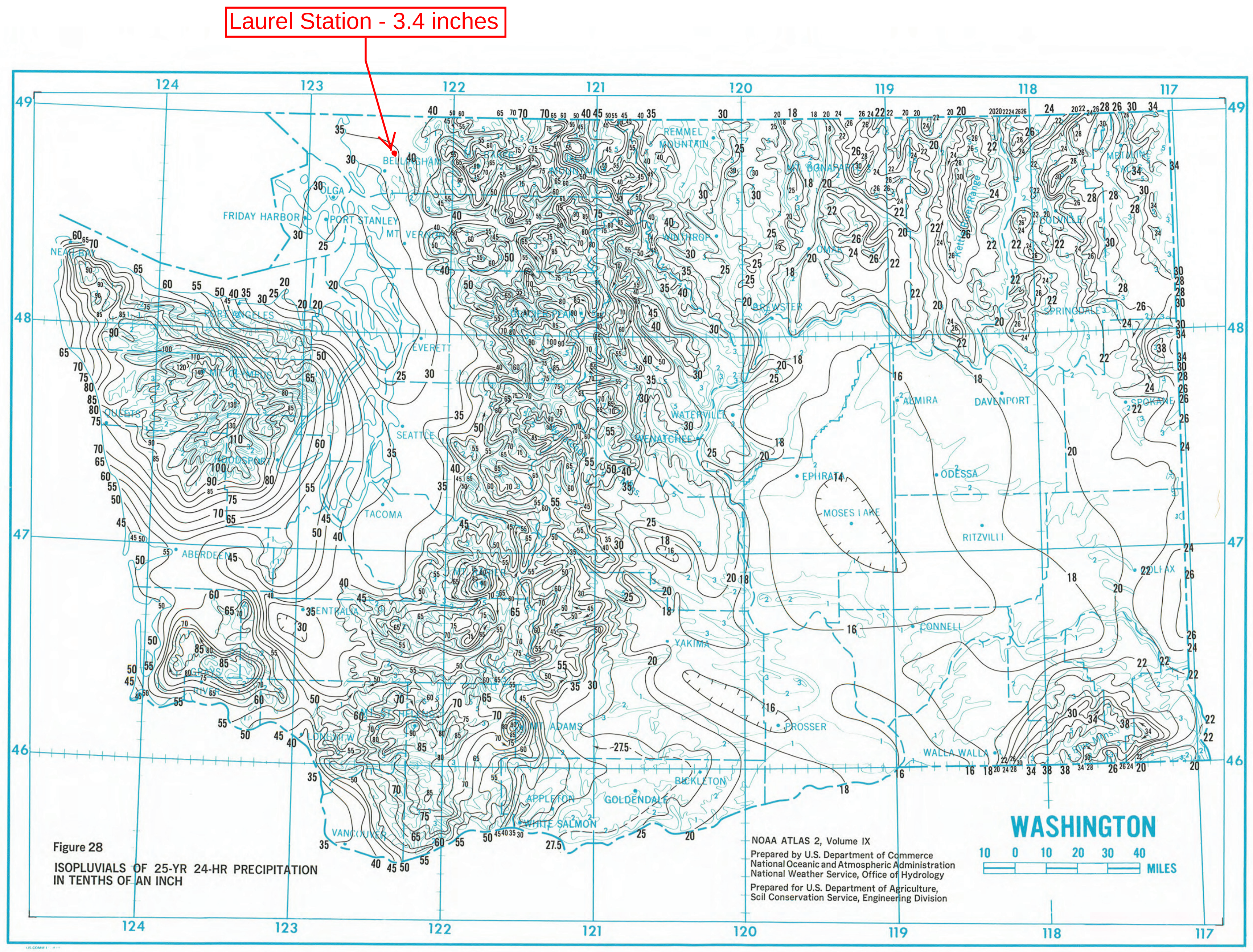


Figure 28

ISOPLUVIALS OF 25-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

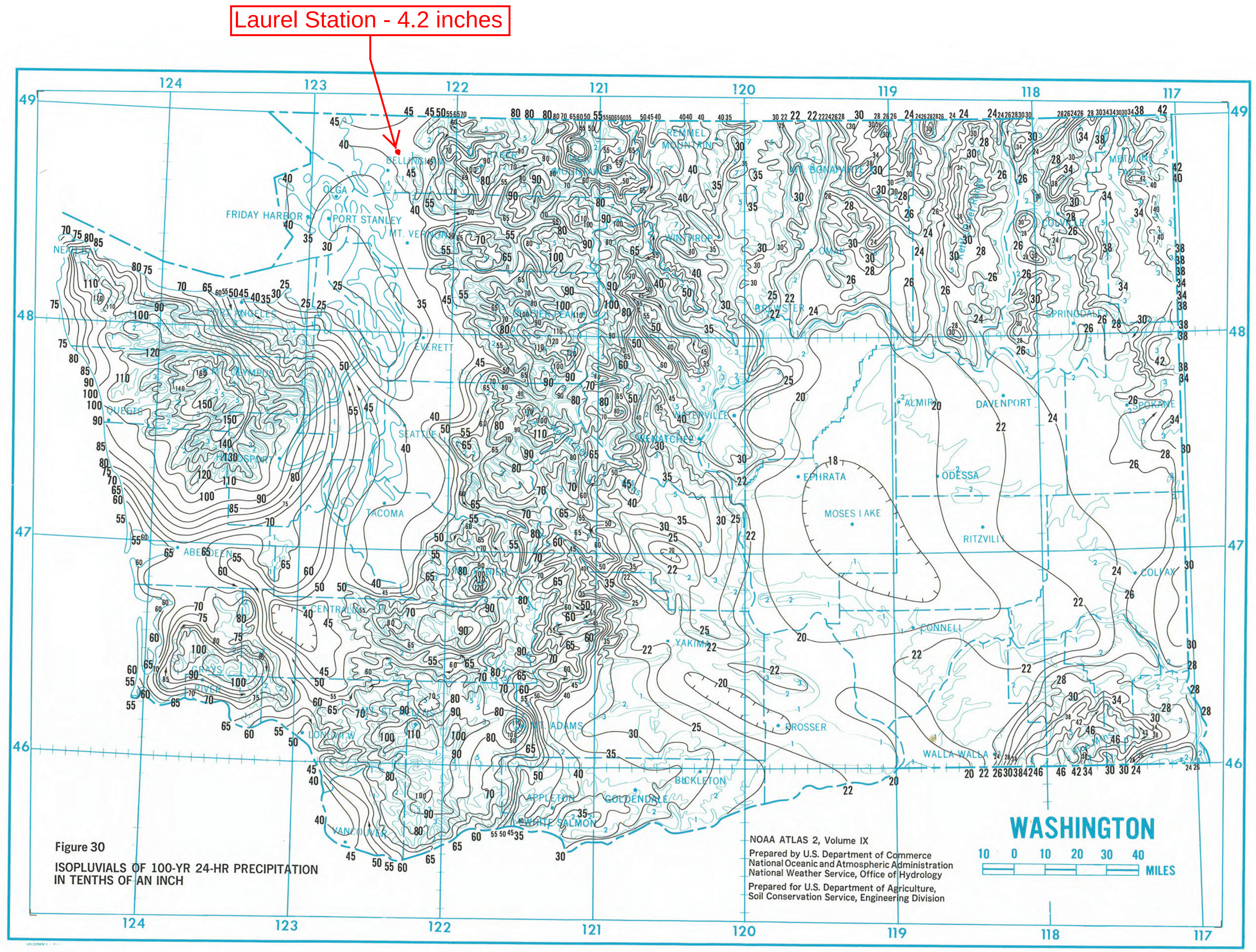


Figure 30

ISOPLUVIALS OF 100-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

☆ U.S. GOVERNMENT PRINTING OFFICE : 1974 O – 507-860

Attachment 5

Soils Information

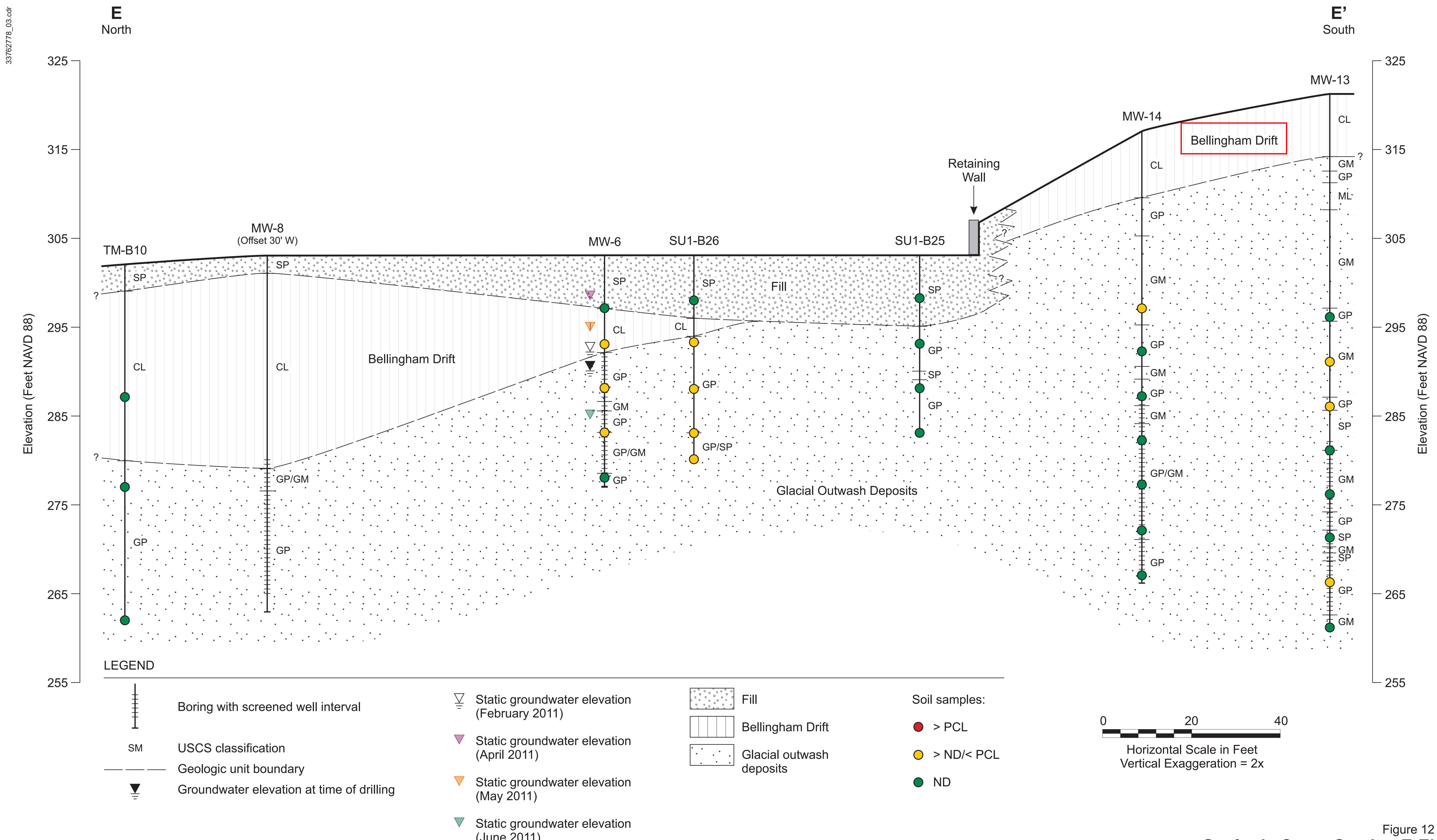


Figure 12
Geologic Cross Section E-E'

URS

Laurel Station
Bellingham, Washington

Exhibit A: Hydrologic Soil Groups for the United States

BEARVILLE	C
BEARWALLOW	C
BEASLEY	C
BEASON	C
BEATRICE	D
BEAUCOUP	B/D
BEAUFORD	D
BEAUGHTON	D
BEAUREGARD	C
BEAUSITE	C
BEAUVAIS	B
BEAVERCREEK	B
BEAVERDAM	C
BEAVERDUMP	B
BEAVERFLAT	B
BEAVERTAIL	D
BEBEEVAR	B
BECA	C
BECHTEL	B
BECHYN	D
BECKER	B
BECKHAM	B
BECKMAN	D
BECKS	C
BECKSTRAND	C
BECKVILLE	B
BECKWITH	D
BECRAFT	B
BEDEN	D
BEDFORD	C
BEDKE	B
BEDNER	C
BEDSTEAD	C
BEDWYR	D
BEDZEE	D
BEECH	C
BEECH GROVE	C
BEECHER	C
BEECHWOOD	C
BEELEM	D
BEENO	C
BEERBO	D
BEERSHEBA	B
BEESKOVE	B
BEEWON	D
BEEZEE	B
BEHEMOTOSH	C
BEHRING	D
BEIGLE	B
BEIRMAN	D
BEJUCOS	B
BELAIN	C
BELATE	B
BELCHER	D
BELDEN	C
BELDING	B
BELFON	B
BELGARRA	C
BELGRADE	B
BELINDA	D
BELK	D
BELKNAP	C
BELLA	D
BELLAMY	C
BELLAVISTA	C
BELLE	B
BELLECHESTER	A
BELLEHELEN	D
BELLENMINE	D
BELLEVILLE	B/D
BELLEVILLE, Ponded	D
BELLEVUE	B
BELLICUM	B
BELLINGHAM	C/D
BELLOTA	D
BELLPASS	D
BELLPINE	C
BELLSLAKE	D
BELLTOWER	B
BELLWOOD	D
BELMILL	B
BELPRE	C
BELRICK	B
BELROSE	B
BELSAC	B
BELTAVA	B
BELTON	C
BELTSVILLE	C
BELUGA	C/D
BELVOIR	C
BELZAR	C
BEMIDJI	B
BEMIS	C
BEMISHAVE	C
BEN LOMOND	B
BENADUM	C/D
BENCHLEY	D
BEND	B
BENDAHL	B
BENDAVIS	C
BENDER	B
BENDERLY	A
BENDOH	B
BENEMES	A
BENEVOLA	C
BENEWAH	D
BENFIELD	C
BENITO	D
BENKA	B
BENKELMAN	B
BENKLIN	C
BENMAN	C
BENNDALE	B
BENNING	B
BENRIDGE	B
BENSLEY	B
BENSON	D
BENSTOT	C
BENTAXLE	D
BENTEEN	C
BENTILLA	C
BENTONSPORT	B
BENZ	D
BEOR	D
BEOWAWE	B
BEQUINN	B
BERDA	B
BERDUGO	C
BEREA	C
BERGQUIST	B
BERGSTROM	B
BERGSVIK	D
BERLAND	D
BERLIN	C
BERMUDIAN	B
BERN	B
BERNALDO	B
BERNARD	D
BERNICE	A
BERNOW	B
BERON	D
BERRAY	B
BERRYHILL	D
BERRYMAN	C
BERTHAHILL	B
BERTHOUD	B
BERTOLOTTI	B
BERTRAND	B
BERVILLE	B/D
BERWOLF	B
BERZATIC	D
BESHERM	C
BESNER	B
BESS	C
BESSIE	D
BESSLEN	D
BESTPITCH	D
BESTROM	C
BETHALTO	B
BETHANY	C
BETHUNE	C
BETIS	A
BETRA	C
BETTERAVIA	C
BEULAH	B
BEVERIDGE	D
BEVERLY	A
BEVIER	C
BEVIL	D
BEVINGTON	B
BEW	C
BEWEARZE	B
BEWLEYVILLE	B
BEXAR	D
BEZO	D
BIAGGI	B
BICKERDYKE	D
BICKETT	D
BICKFORD	D
BICKLETON	B
BICONDOA	C/D
BIDDLE	C/D
BIDONIA	D
BIDRIM	D
BIEDELL	D
BIEDSAW	D
BIFFLE	B
BIG TIMBER	D
BIGA	C
BIGBEAVER	C
BIGBEE	A
BIGBOW	B
BIGBROWN	C
BIGCREEK	B
BIGDRAW	C
BIGDUTCH	B
BIGELOW	B
BIGFOOT	C
BIGFROG	D
BIGGSVILLE	B
BIGHAT	D
BIGHILL	B
BIGLAKE	A
BIGLICK	D
BIGLOST	B
BIGLOST, Wet	C
BIGPAW	B
BIGPOOL	C
BIGRIVER	B
BIGSAG	D
BIGSHEEP	B
BIGWIN	C
BIJORJA	C
BIKEN	D
BIKEYAH	C
BILGER	D
BILGRAY	C
BILHAUL	D
BILHIL	C
BILLMAN	C
BILLYBOY	B
BILLYCREEK	C
BILLYHAW	D
BILLYRIDGE	B
BILMOD	B
BILSON	B
BILTMORE	A
BIMINI	C
BIMMER	D
BINDLE	B
BINFORD	B
BINGER	B
BINGHAMPTON	B
BINGHAMVILLE	D
BINNSVILLE	D
BINS	B
BINTON, Reclaimed	B
BINTON	C
BINVAR	C
BIPLANE	D
BIPPUS	B
BIRCHBAY	C
BIRCHFIELD	D
BIRCHLAKE	C
BIRDSALL	D
BIRDSBEAK	D
BIRDSVIEW	A
BIRKBECK	B
BIRMINGHAM	B
BISBEE	A
BISCAY	D
BISCAYNE	B/D
BISCHOFF	B
BISCUIT	B/D
BISGANI	B
BISHOP	C
BISON	B
BISPING	B
BISSETT	D
BISSONNET	D
BIT	C
BITCREEK	B
BITCREEK LOAM	B
BITNER	C
BITTER	B
BITTERCREEK	D
BITTERROOT	C
BIVANS	D
BIWABIK	A
BIXBY	B
BJORKLAND	B/D
BLACK CANYON	C/D
BLACKBURN	B
BLACKCREEK	C
BLACKDOG	B
BLACKFOOT	B/C
BLACKHAMMER	B
BLACKHOOF	D
BLACKHORSE	D
BLACKLAKE	D
BLACKLEG	D
BLACKMORE	B
BLACKMOUNT	B
BLACKNEST	B
BLACKOAR	B/D
BLACKPIPE	C
BLACKRIVER	B
BLACKSAN	B
BLACKSPAR	D
BLACKSPOT	D
BLACKTOP	D
BLACKWATER	D
BLACKWOOD	B
BLAG	D
BLAGO	D
BLAINEGATE	D
BLAIR	C
BLAKABIN	C
BLAKENEY	D
BLALOCK	D
BLAMER	C
BLANCA	B
BLANCHE	B
BLANCHESTER	B/D
BLANCOVERDE	C
BLAND	C
BLANEY	B
BLANKET	C
BLANKOUT	A
BLANTON	B
BLAPPERT	D
BLAQUIRRE	C
BLASE	C
BLASHKE	A
BLAYDEN	D
BLAZEFORK	D
BLEAKHILL	C
BLEAKWOOD	C
BLEIBLERVILLE	D
BLEUMONT	C
BLEVINS	B
BLEVINTON	B
BLEWETT	D
BLICHTON	D
BLIMO	B
BLIND	B
BLINDSPRING	A
BLINN	C
BLINT	B
BLISSHILL	C
BLITZEN	C
BLIZZARD	D
BLOCKER	D
BLOCKHOUSE	D
BLOCKTOWN	C/D
BLOOMFIELD	A
BLOOMING	B
BLOOMINGDALE	D
BLOOR	D
BLOSSBERG	C

Table 9–5 Runoff curve numbers for urban areas [1/]

Cover description cover type and hydrologic condition	Average percent impervious area [2/]	- - CN for hydrologic soil group - - A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

1/ Average runoff condition, and $I_a = 0.2S$.

2/ The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

3/ CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space type.

4/ Composite CNs for natural desert landscaping should be computed using figures 9–3 or 9–4 based on the impervious area percentage (CN=98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

Asphalt Calculations

HEAVY DUTY FLEXIBLE PAVEMENT DESIGN

Objective: To design the heavy duty flexible pavement, for light (class 3) and heavy (class 8) loading (see Attachment 1). Assumed design life of the pavement is 20 years.

It is assumed that the heavy duty flexible pavement will see a peak daily vehicle traffic count of 100. The breakdown of the 100 vehicle count and their assumed truck load type are:

- 98 - Pickup Trucks - H-20 loading
- 2 - 250 Ton Demag Crane - Heavy, Class 8 (GVWR = 140,804 lbs)

An H-20 design vehicle has two single axles, front at 20% and rear at 80% (see Attachment 2). According to FHWA, passenger vehicles are negligible in determining Equivalent Single Axle Loads (ESALs); therefore, a Light, Class 3 Truck (14,000 lbs total gross vehicle weight rating) is assumed as the design passenger vehicle. The GVWR for the Class 8 Heavy Vehicle is shown on Attachment 3.

$t := 20$ years, design life of heavy duty flexible pavement

$p\_H20 := 98$ peak daily passes of H-20 loading

$p\_CL8 := 2$ peak daily passes of Class 8 Vehicle

$GVWR_{H20} := 14000$ lbs, gross vehicle weight rating for H-20 Vehicle

$LD_F := 0.2$ ratio of total load distributed to front axle, based on H-20 load distribution

$LD_R := 1 - LD_F$

$LD_R = 0.8$ ratio of total load distributed to rear axle, based on H-20 load distribution

$FAL := GVWR_{H20} \cdot LD_F$ $FAL = 2800$ lbs, front axle load

$RAL := GVWR_{H20} \cdot LD_R$ $RAL = 11200$ lbs, rear axle load

$GVWR_{CL8} := 140804$ lbs, gross vehicle weight rating for Class 8 Vehicle (see Attachment 3)

$FAL_{CL8} := 21935$ lbs, front axle load for Class 8 Vehicle

$R2AL_{CL8} := 21936$ lbs, single axle load for Class 8 Vehicle

$R3AL_{CL8} := 18781$ lbs, single axle load for Class 8 Vehicle

$R4AL_{CL8} := 18498$ lbs, single axle load for Class 8 Vehicle

$R5AL_{CL8} := 18287$ lbs, single axle load for Class 8 Vehicle

$R6AL_{CL8} := 20684$ lbs, single axle load for Class 8 Vehicle

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$R7AL_{CL8} := 20684$ lbs, single axle load for Class 8 Vehicle

Determine Axle Load Equivalency Factors for H-20 Load

Assuming an initial SN = 3 and Table 4.2 (See Attachment 4)

$ALEF_{F\_H20} := 0.003$ unitless, Axle Load Equivalency Factor for front axle at 4000 lbs (>2800 lbs)

$ALEF_{R\_H20} := 0.213$ unitless, Axle Load Equivalency Factor for rear axle at 12000 lbs (>11200 lbs)

Determine 18-kip Equivalent Single Axle Load (ESAL) for H-20 Load

$ESAL_{H20} := ALEF_{F\_H20} + ALEF_{R\_H20}$ $ESAL_{H20} = 0.216$ unitless, ESAL for H-20

$W_{18\_H20} := p\_H20 \cdot ESAL_{H20} \cdot 365 \cdot t$ $W_{18\_H20} = 154526$ 18-kip ESAL for H-20

Determine Axle Load Equivalency Factors for Class 8 Vehicle

Assuming an initial SN = 3 and Table 4.2 (See Attachment 4)

$ALEF_{F\_CL8} := 2.09$ unitless, Axle Load Equivalency Factor for front axle at 22000 lbs (>21935 lbs)

$ALEF_{R2\_CL8} := 2.09$ unitless, Axle Load Equivalency Factor for rear axle at 22000 lbs (>21936 lbs)

$ALEF_{R3\_CL8} := 1.47$ unitless, Axle Load Equivalency Factor for rear axle at 20000 lbs (>18781 lbs)

$ALEF_{R4\_CL8} := 1.47$ unitless, Axle Load Equivalency Factor for rear axle at 20000 lbs (>18498 lbs)

$ALEF_{R5\_CL8} := 1.47$ unitless, Axle Load Equivalency Factor for rear axle at 20000 lbs (>18287 lbs)

$ALEF_{R6\_CL8} := 2.09$ unitless, Axle Load Equivalency Factor for rear axle at 22000 lbs (>20684 lbs)

$ALEF_{R7\_CL8} := 2.09$ unitless, Axle Load Equivalency Factor for rear axle at 22000 lbs (>20684 lbs)

Determine 18-kip Equivalent Single Axle Load (ESAL) for Class 8 Truck

$$ESAL_{CL8} := ALEF_{F\_CL8} + ALEF_{R2\_CL8} + ALEF_{R3\_CL8} + ALEF_{R4\_CL8} + ALEF_{R5\_CL8} + ALEF_{R6\_CL8} \cdots + ALEF_{R7\_CL8}$$

$ESAL_{CL8} = 12.77$ unitless, ESAL for Class 8 Vehicle

$W_{18\_CL8} := p\_CL8 \cdot ESAL_{CL8} \cdot 365 \cdot t$

$W_{18\_CL8} = 186442$ 18-kip ESAL for Class 8 Vehicle

Total W_{18}

$W_{18} := W_{18\_H20} + W_{18\_CL8}$

$W_{18} = 340968$ 18-kip ESAL for all vehicles combined

Determine Structural Number, SN

$CBR := 40$ unitless, California Bearing Ratio. From boring logs in the RI-FS plan 2014, subgrade soil is an SP and GP soil type (see Attachment 5). This soil will be compacted before placing the heavy duty flexible pavement (compacted subgrade). Per Attachment 6, the CBR ranges from 10 to 60 between the two soils. 40 is selected as a resaonable value based on the material analyzed from the test pits.

$M_R := 1500 \cdot CBR$ psi, resilient modulus of the subgrade soil

$M_R = 60000$ psi

$Z_R := -1.645$ unitless, reliability (z from standard normal distribution) for 95% reliability (see Attachment 4)

$S_o := 0.45$ unitless, overall standard deviation (on reliability) (see Attachment 4)

$SN := 1$ unitless, structural number (initial guess to get root function started)

$\Delta PSI := 1.9$ design present serviceability loss (see Attachment 4)

$W_{18} = 340968$ 18-kip equivalent single axle load

$$SN := \mathrm{root}\left[\left[Z_R \cdot S_o + 9.36 \cdot (\log(SN+1)) - 0.20 + \left[\frac{\log\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{0.40 + \left[\frac{1094}{(SN+1)^{5.19}}\right]}\right] + 2.32 \cdot \log(M_R) - 8.07 - \log(W_{18})\right], SN\right]$$

$SN = 1.3$ unitless, required structural number say ===> $SN := 2$ unitless, required structural number

Determine thickness of wearing and base course layers (see Attachment 6)

$a_1 := 0.35$ unitless, structural layer coefficient for surface course of sand mix asphalt concrete (used this coefficient to be conservative)

$a_2 := 0.14$ unitless, structural layer coefficient for base course of crushed stone

$M_2 := 1$ unitless, drainage coefficient for the base course layer, 1 assumes good drainage characteristic due to it being an SP (see Attachment 4)

$D_1 := 4$ inches, thickness of wearing layer (TRY values till SN below is equal to required SN)

$D_2 := 6$ inches, thickness of base course layer (TRY values till SN below is equal to required SN)

$SN := a_1 \cdot D_1 + a_2 \cdot D_2 \cdot M_2$ $SN = 2.2$ WHICH IS EQUAL TO REQUIRED SN, THEREFORE DESIGN IS ADEQUATE

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ATTACHMENT 1

Light
(pickup trucks, vans, SUVs)

Medium
(delivery trucks)

Heavy
(tractor-trailer combinations)

Figure 2: Common Truck Categories

Vehicle manufacturers use more precise technical definitions and divide trucks into eight classes according to gross vehicle weight rating (GVWR). Table 1 shows vehicle manufacturer truck classifications. Figure 3 shows a basic breakdown of the truck and bus population in the U.S.

Table 1: Vehicle Manufacturer Truck Classification[1]

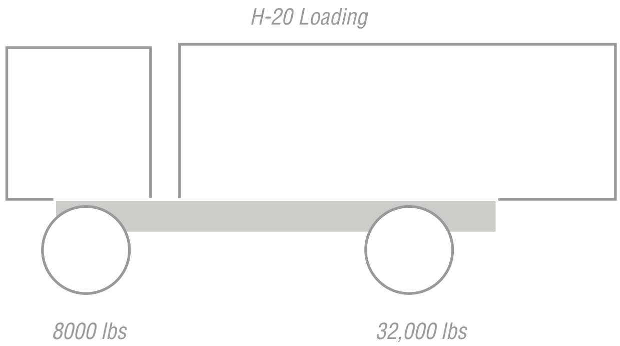
Category	Class	GVWR[2]	Representative Vehicles
Light	1	0 - 27 kN 0 - 6,000 lbs.	pickup trucks, ambulances, parcel delivery
	2	27 - 45 kN (6,001 - 10,000 lbs.)	
	3	45 - 62 kN (10,001 - 14,000 lbs.)	
Medium	4	62 - 71 kN (14,001 - 16,000 lbs.)	city cargo van, beverage delivery truck, wrecker, school bus
	5	71 - 87 kN (16,001 - 19,500 lbs.)	
	6	87 - 116 kN (19,501 - 26,000 lbs.)	
	7	116 - 147 kN (26,001 to 33,000 lbs.)	
Heavy	8	147 kN and over (33,000 lbs. and over)	truck tractor, concrete mixer, dump truck, fire truck, city transit bus

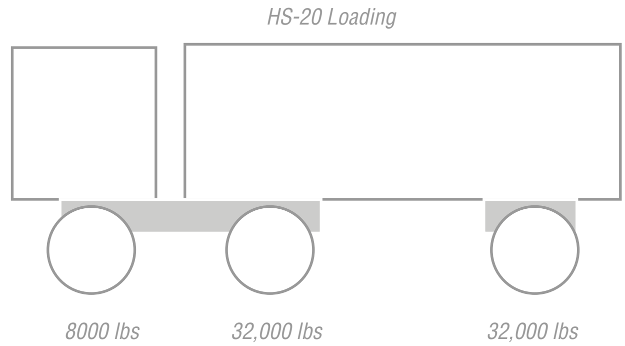
Notes:

1. The above classes are not the same as used by the FHWA
2. Gross Vehicle Weight Rating (GVWR): weight specified by manufacturer as the maximum loaded weight (truck plus cargo) of a single vehicle.

ATTACHMENT 2

H-20 and HS-20 loading





Dynamic Load Sample Calculation

Wheel load = W_L= 16,000 lbs (32,000 lb axle / 2)
Dynamic Force = F_d = 1.2 (20% greater than static force)
Spread Area = A = 1496 si (12" cover w/45 degree angle)
Weight of base = d_y = 0.97 psi (12" road base @ 140 lbs/cf)

$\sigma_{va} = (W_L \times F_d \ / A) + d_y$

σ_{va} = (16,000 lbs x 1.2 / 1496 si) + 0.97 lbs

σ_{va}= 13.8 psi

13.8 psi (95 kPa) on Rainstore3

Surface Pressure

32,000 for the rear axle

32,000 lbs / 2 tires per rear axle = 16000 lbs

200 square inches contact (20" x 10 ")*

16000 lbs / 200 sq inches = 80 psi

80 psi (552 kPa) static

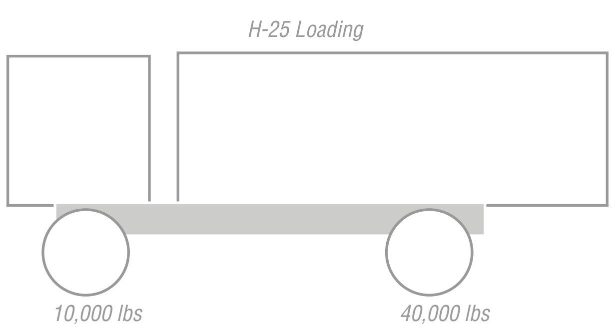
Rainstore3 has been independently field and labaratory tested to meet H-20 Bridge Loading.

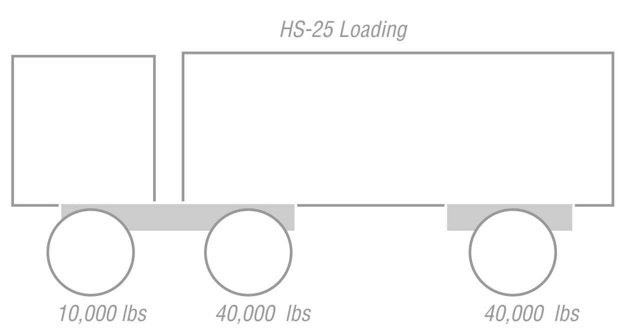
Grasspave2, Gravelpave2, Slopetame2, and Draincore2 can withstand 2,100 psi empty (14,470 kPa).

Grasspave2, Gravelpave2, and Slopetame2 can withstand 5,721 psi with fill material (39,273 kPa).

Invisible Structures, Inc.

invisiblestructures.com
800-233-1510





*AASHTO 3.30 Tire Contact Area

TEREX | DEMAG

AC 200-1 | All Terrain Crane 240 t Lifting Capacity

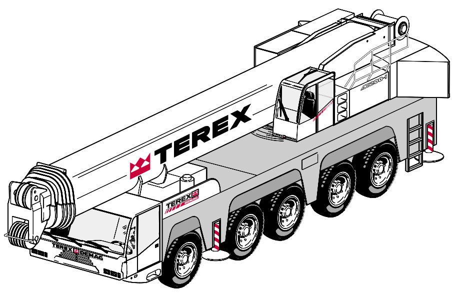
AC 200-1

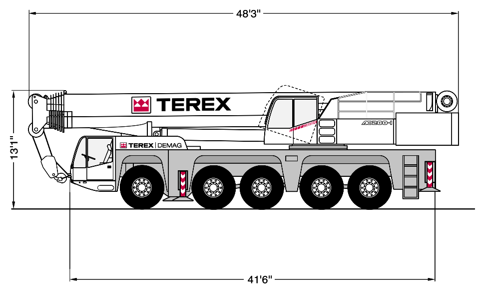
ALL TERRAIN CRANE

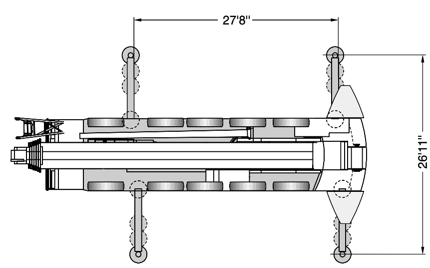
TEREX | DEMAG

AC 200-1 HIGHLIGHTS

- Shortest 200-tonner on 5 axles with 41.3 ft carrier length
- 7-section 223 ft boom with Unimec telescoping and pinning system giving unequalled 328.1 ft combined boom-and-jib length with the 108.3 ft boom extension fitted
- Speed-dependent rear axle steering for increased manoeuvrability and driving stability
- Innovative Demag IC-1 crane control system with touchscreen
- Carrier with modified axle arrangement available as an option







ALL TERRAIN CRANE

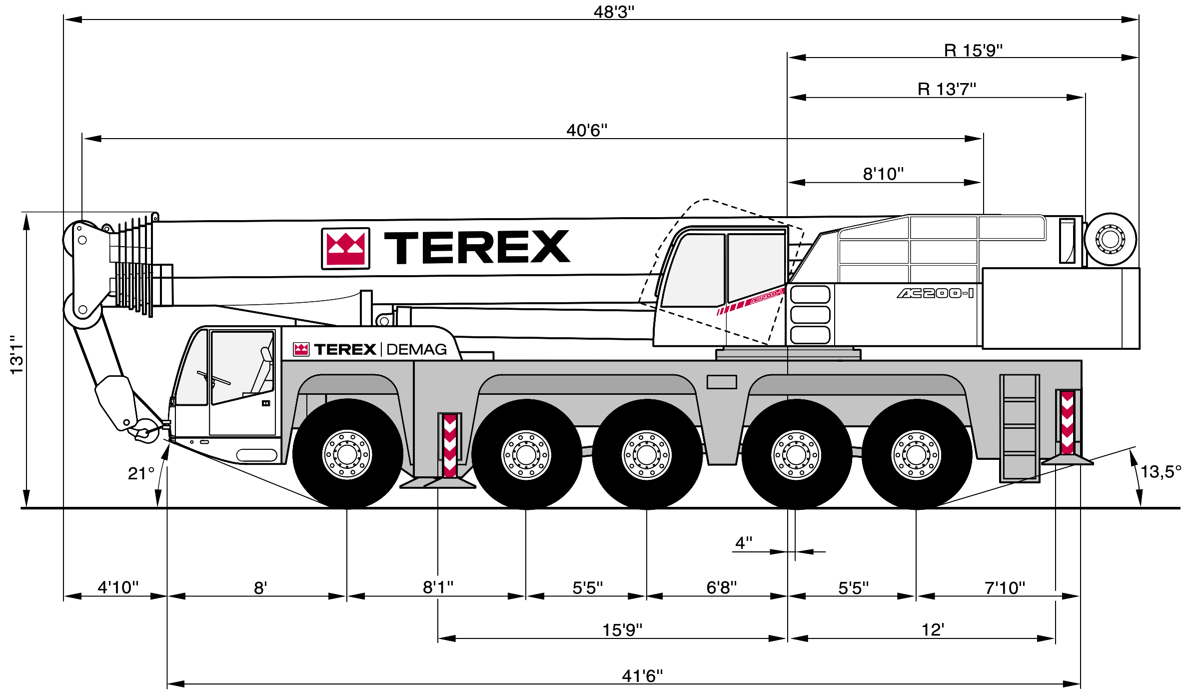
AC 200-1

CONTENTS

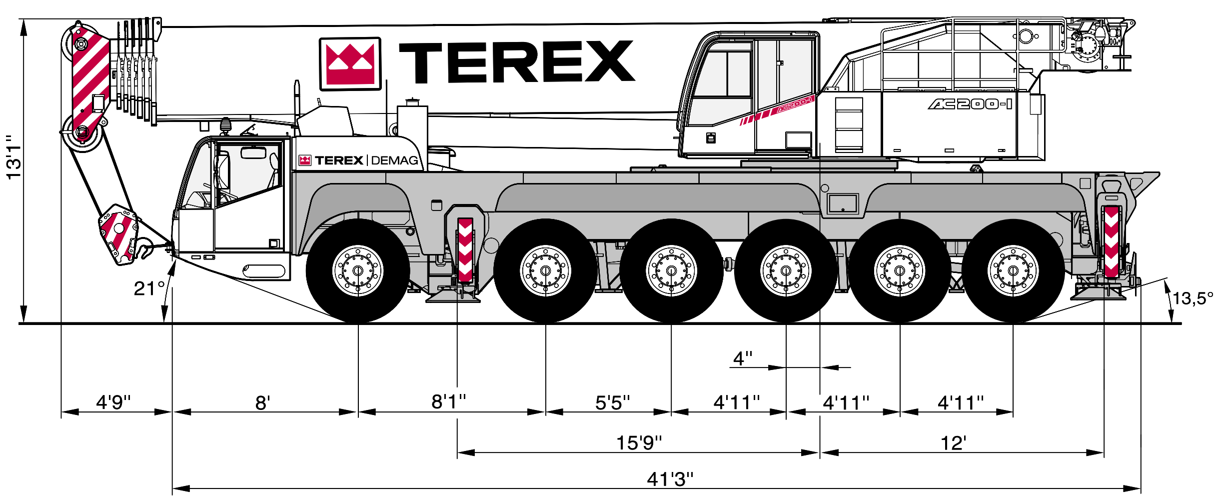
TEREX | DEMAG

DIMENSIONS

AC 200-1



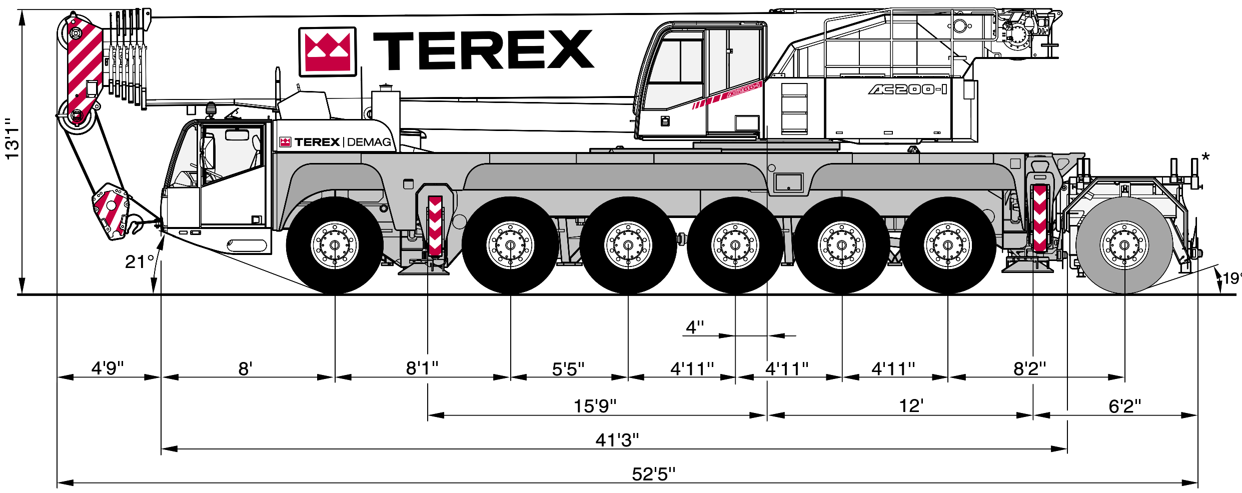
AC 200-1 P



ALL TERRAIN CRANE
AC 200-1

DIMENSIONS

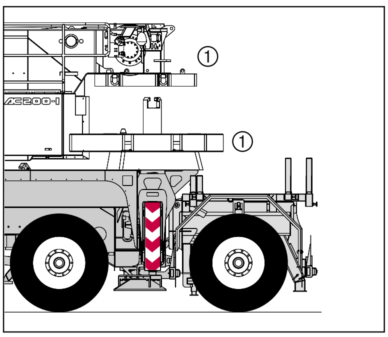
AC 200-1 TP

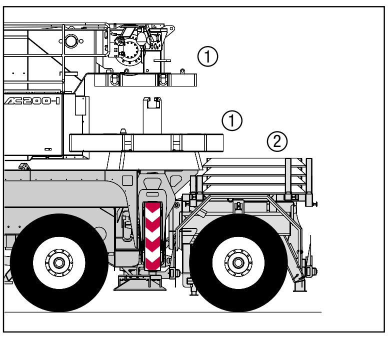


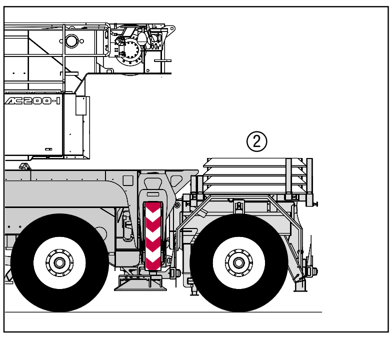
* with special attachment

OPTION: WITH MODULAR AXLE

Selection of configurations





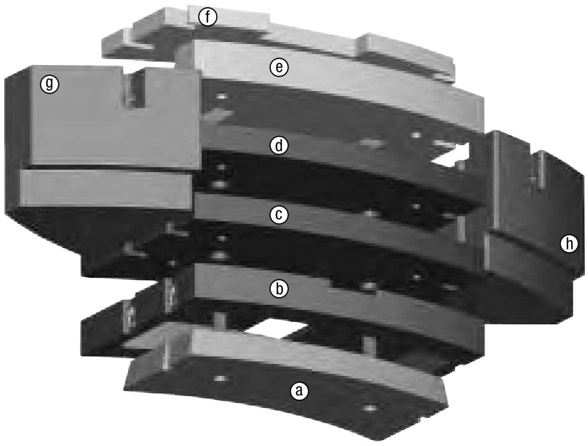


① Additional counterweight

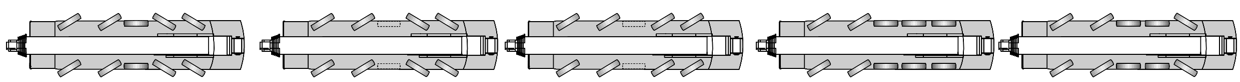
② Base plates

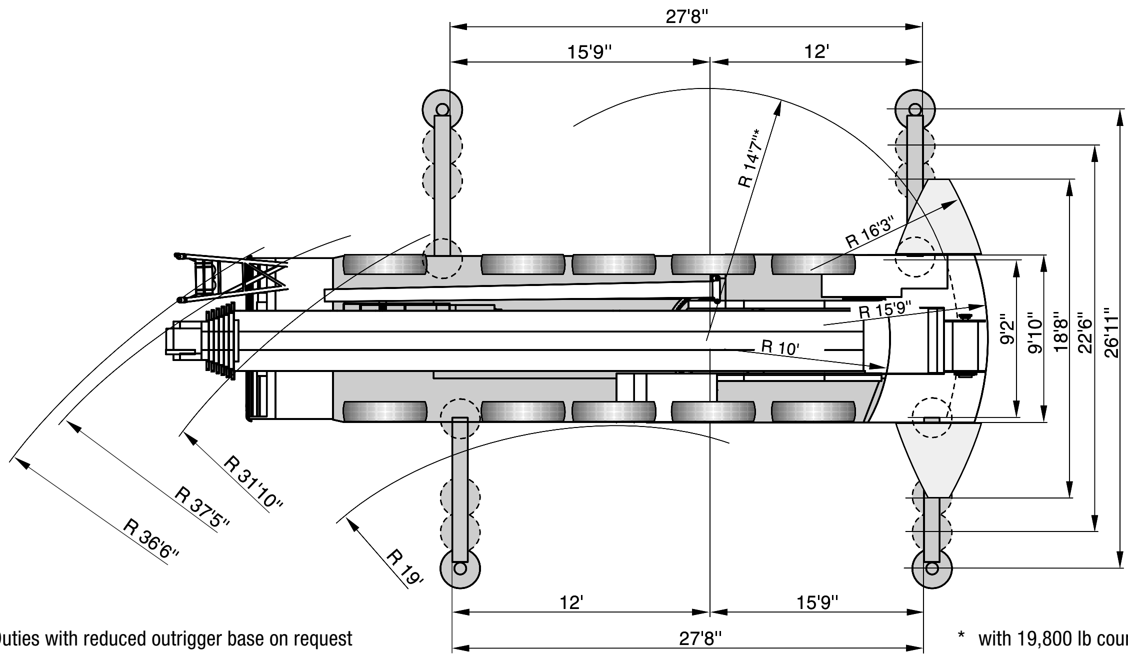
TEREX | DEMAG

DIMENSIONS



	ⓐ 12,600 lb	ⓑ 16,100 lb	ⓒ 19,800 lb	ⓓ 19,800 lb	ⓔ 20,100 lb	ⓕ 7,100 lb	ⓖ 28,200 lb	ⓗ 28,200 lb
19,600 lb	X					X		
28,700 lb	X	X						
32,600 lb	X		X					
35,900 lb	X	X				X		
39,700 lb	X		X			X		
48,700 lb	X	X	X					
55,800 lb	X	X	X			X		
68,600 lb	X	X	X	X				
75,800 lb	X	X	X	X		X		
88,600 lb	X	X	X	X	X			
95,700 lb	X	X	X	X	X	X		
132,100 lb	X	X	X	X		X	X	X
152,100 lb	X	X	X	X	X	X	X	X





Duties with reduced outrigger base on request

* with 19,800 lb counterweight

ALL TERRAIN CRANE
AC 200-1

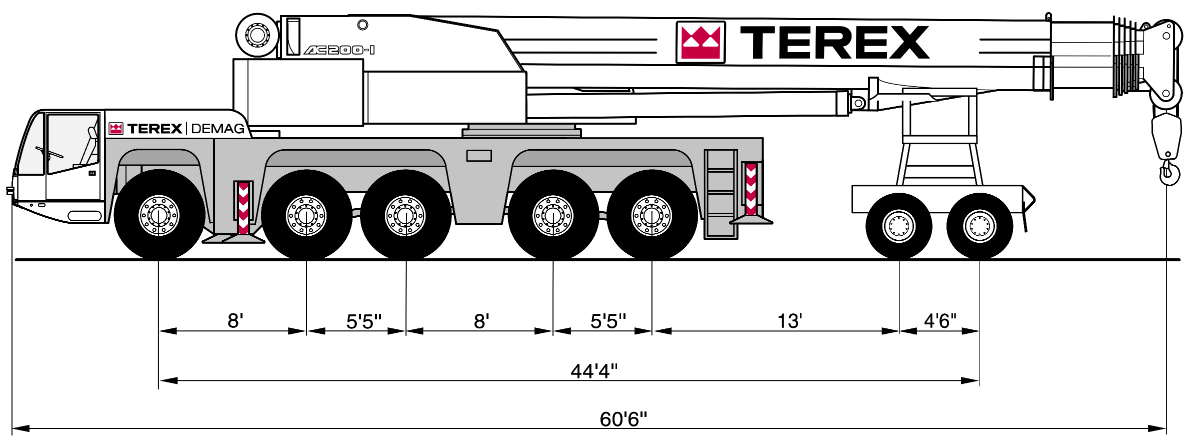
AXLE WEIGHT WITH DOLLY AC 200-1

CRANE CONFIGURATION

Drive	10 x 8 x 8
Tires	20.5 R 25
Outrigger front	
Outrigger rear	
Boom extended	3'3"
Hook block 3 sheaves	
2-axle boom dolly	5700 lb

AXLES

Axle	1	2	3	4	5	6	7	Total weight
Weight	21,935 lb	21,936 lb	18,781 lb	18,498 lb	18,287 lb	20,684 lb	20,684 lb	140,804 lb



TEREX | DEMAG

SPECIFICATIONS

AXLE LOADS

Basic machine with hook block

Axles	5 x 26,400 lb
Total weight	132,000 lb

WORKING SPEEDS (INFINITELY VARIABLE)

Mechanisms	Normal speed	High speed	Max. permissible line pull[1]	Rope diameter / Rope length
Hoist I	147.6 ft/min	410 ft/min	22,000 lb	0,83" / 1132 ft
Hoist II	147.6 ft/min	410 ft/min	22,000 lb	0,83" / 1132 ft
Slewing				max. 1.3 ^{1}/min
Boom elevation				–1,5° – +82°

CARRIER PERFORMANCE

Travel speed	0 . . 53 mph
Gradeability	max. 71 %

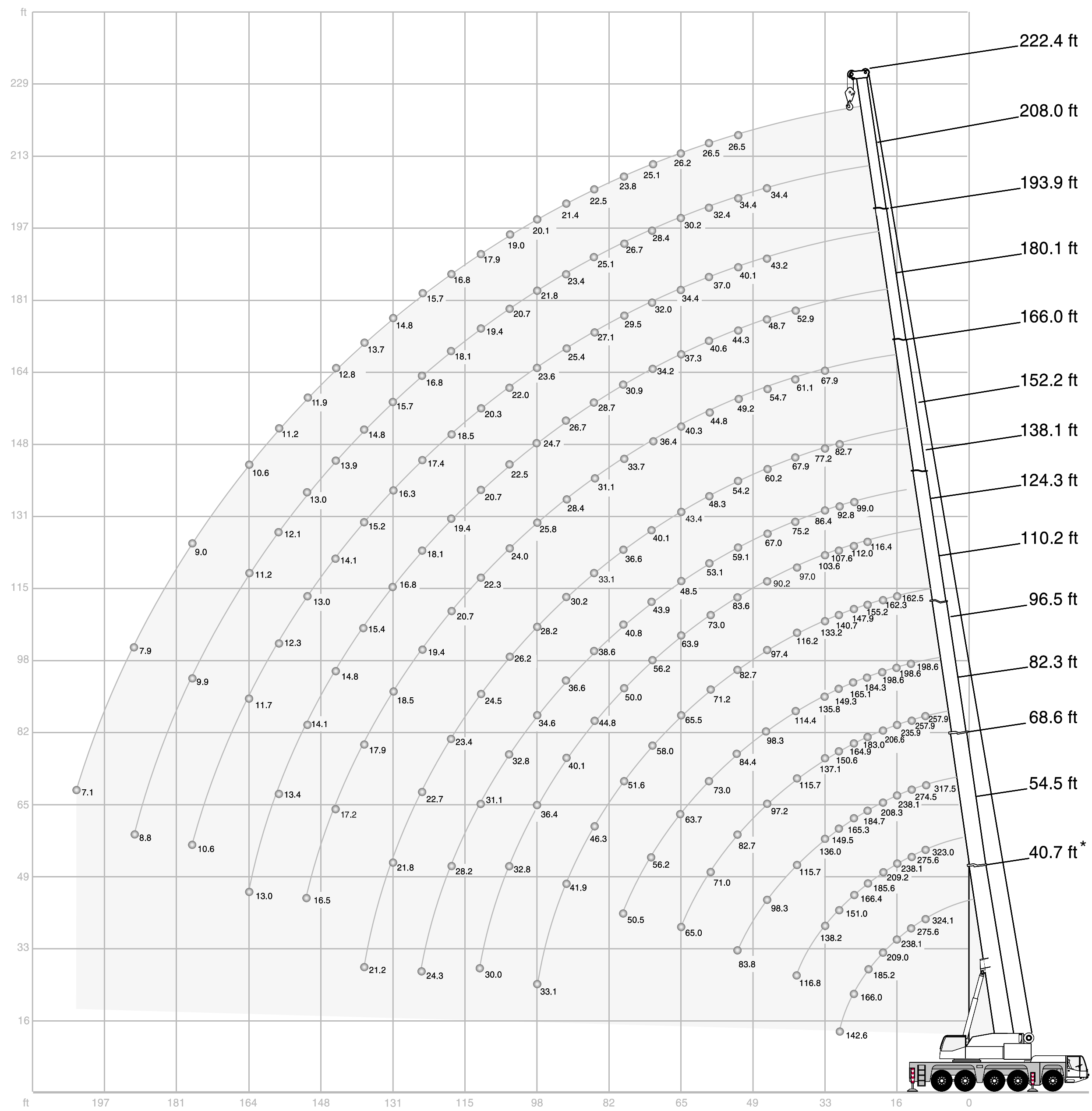
HOOK BLOCK / SINGLE LINE HOOK

Type	Possible load[1]	Number of sheaves	Weight	„D“	Number of lines
200	324,500 lb	9	3,860 lb	9.8 ft	16
160	305,800 lb	7	3,310 lb	9.8 ft	15
125	228,600 lb	5	2,480 lb	9.8 ft	11
80	148,400 lb	3	1,870 lb	9.8 ft	7
32	64,800 lb	1	1,320 lb	8.9 ft	3
12,5	21,800 lb	Single line hook	770 lb	6.6 ft	1

Remarks

[1] varies depending on national regulations

HA WORKING RANGES



TEREX | DEMAG

HA LIFTING CAPACITIES

152,100 lb | 360° | 85 %

Radius	40.7*	40.7	54.5	68.6	82.3	96.5	110.2	124.3	138.1	152.2	166.0	180.1	193.9	208.0	222.4	Radius
ft	Main boom (ft), 1,000 lb															ft
	480.0**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10	324.1	324.1	323.0	317.5	257.9	-	-	-	-	-	-	-	-	-	-	10
11	323.0	297.6	298.7	296.5	257.9	-	-	-	-	-	-	-	-	-	-	11
13	299.8	275.6	275.6	274.5	257.9	198.6	-	-	-	-	-	-	-	-	-	13
15	280.0	255.7	255.7	255.7	253.5	198.6	-	-	-	-	-	-	-	-	-	15
16	262.4	238.1	238.1	238.1	235.9	198.6	162.5	-	-	-	-	-	-	-	-	16
19	230.4	209.0	209.2	208.3	206.6	198.6	162.3	-	-	-	-	-	-	-	-	19
23	203.3	185.2	185.6	184.7	183.0	184.3	155.2	116.4	-	-	-	-	-	-	-	23
26	175.7	166.0	166.4	165.3	164.9	165.1	147.9	112.0	99.0	-	-	-	-	-	-	26
29	142.6	142.6	151.0	149.5	150.6	149.3	140.7	107.6	92.8	82.7	-	-	-	-	-	29
33	-	-	138.2	136.0	137.1	135.8	133.2	103.6	86.4	77.2	67.9	-	-	-	-	33
39	-	-	116.8	115.7	115.7	114.4	116.2	97.0	75.2	67.9	61.1	52.9	-	-	-	39
46	-	-	-	98.3	97.2	98.3	97.4	90.2	67.0	60.2	54.7	48.7	43.2	34.4	-	46
52	-	-	-	83.8	82.7	84.4	82.7	83.6	59.1	54.2	49.2	44.3	40.1	34.4	26.5	52
59	-	-	-	-	71.0	73.0	71.2	73.0	53.1	48.3	44.8	40.6	37.0	32.4	26.5	59
65	-	-	-	-	65.0	63.7	65.5	63.9	48.5	43.4	40.3	37.3	34.4	30.2	26.2	65
72	-	-	-	-	-	56.2	58.0	56.2	43.9	40.1	36.4	34.2	32.0	28.4	25.1	72
79	-	-	-	-	-	50.5	51.6	50.0	40.8	36.6	33.7	30.9	29.5	26.7	23.8	79
85	-	-	-	-	-	-	46.3	44.8	38.6	33.1	31.1	28.7	27.1	25.1	22.5	85
92	-	-	-	-	-	-	41.9	40.1	36.6	30.2	28.4	26.7	25.4	23.4	21.4	92
98	-	-	-	-	-	-	33.1	36.4	34.6	28.2	25.8	24.7	23.6	21.8	20.1	98
105	-	-	-	-	-	-	-	32.8	32.8	26.2	24.0	22.5	22.0	20.7	19.0	105
111	-	-	-	-	-	-	-	30.0	31.1	24.5	22.3	20.7	20.3	19.4	17.9	111
118	-	-	-	-	-	-	-	-	28.2	23.4	20.7	19.4	18.5	18.1	16.8	118
124	-	-	-	-	-	-	-	-	24.3	22.7	19.4	18.1	17.4	16.8	15.7	124
131	-	-	-	-	-	-	-	-	-	21.8	18.5	16.8	16.3	15.7	14.8	131
138	-	-	-	-	-	-	-	-	-	21.2	17.9	15.4	15.2	14.8	13.7	138
144	-	-	-	-	-	-	-	-	-	-	17.2	14.8	14.1	13.9	12.8	144
151	-	-	-	-	-	-	-	-	-	-	16.5	14.1	13.0	13.0	11.9	151
157	-	-	-	-	-	-	-	-	-	-	-	13.4	12.3	12.1	11.2	157
164	-	-	-	-	-	-	-	-	-	-	-	13.0	11.7	11.2	10.6	164
177	-	-	-	-	-	-	-	-	-	-	-	-	10.6	9.9	9.0	177
190	-	-	-	-	-	-	-	-	-	-	-	-	-	8.8	7.9	190
203	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.1	203
216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	216

Remarks

* over rear

** Exceptional load, additional measures required

ALL TERRAIN CRANE
AC 200-1

HA LIFTING CAPACITIES

95,700 lb | 360° | 85 %

Radius	Main boom (ft) 40.7	54.5	68.6	82.3	96.5	110.2	124.3	138.1	152.2	166.0	180.1	193.9	208.0	222.4	Radius
ft	1,000 lb														ft
10	318.6	318.6	316.4	257.9	-	-	-	-	-	-	-	-	-	-	10
11	292.1	292.1	291.0	257.9	-	-	-	-	-	-	-	-	-	-	11
13	269.0	269.0	267.9	257.9	198.6	-	-	-	-	-	-	-	-	-	13
15	249.1	249.1	248.0	246.9	198.6	-	-	-	-	-	-	-	-	-	15
16	231.5	231.5	230.4	229.3	198.6	162.5	-	-	-	-	-	-	-	-	16
19	202.6	202.8	201.9	200.4	198.6	162.3	-	-	-	-	-	-	-	-	19
23	179.7	180.1	179.0	180.1	178.8	155.2	116.4	-	-	-	-	-	-	-	23
26	160.7	161.6	160.3	161.4	160.1	147.9	112.0	99.0	-	-	-	-	-	-	26
29	140.4	143.1	142.9	141.8	139.8	140.7	107.6	92.8	82.7	-	-	-	-	-	29
33	-	126.1	126.1	124.8	125.2	125.2	103.6	86.4	77.2	67.9	-	-	-	-	33
39	-	101.0	101.0	99.9	102.1	100.1	97.0	75.2	67.9	61.1	52.9	-	-	-	39
46	-	-	84.7	85.5	84.4	86.2	84.4	67.0	60.2	54.7	48.7	43.2	34.4	-	46
52	-	-	70.5	70.1	70.5	70.5	68.3	59.1	54.2	49.2	44.3	40.1	34.4	26.5	52
59	-	-	-	59.5	60.2	58.6	56.4	53.1	48.3	44.8	40.6	37.0	32.4	26.5	59
65	-	-	-	52.0	51.1	49.6	47.6	47.0	43.4	40.3	37.3	34.4	30.2	26.2	65
72	-	-	-	-	44.1	42.5	40.8	42.3	38.4	36.4	34.2	32.0	28.4	25.1	72
79	-	-	-	-	38.6	37.0	38.6	36.8	34.4	33.1	30.9	29.5	26.7	23.8	79
85	-	-	-	-	-	33.1	34.0	32.0	30.4	29.1	28.7	27.1	25.1	22.5	85
92	-	-	-	-	-	31.5	30.0	28.2	28.7	26.2	25.1	25.4	23.4	21.4	92
98	-	-	-	-	-	28.2	26.7	25.4	25.6	23.8	23.4	22.3	21.8	20.1	98
105	-	-	-	-	-	-	23.8	24.0	22.5	22.7	20.7	20.5	20.7	19.0	105
111	-	-	-	-	-	-	21.4	22.0	20.1	20.3	19.4	19.0	18.1	17.9	111
118	-	-	-	-	-	-	-	19.6	19.0	17.9	17.6	17.0	15.9	15.7	118
124	-	-	-	-	-	-	-	17.6	17.9	16.1	16.1	15.0	13.7	13.7	124
131	-	-	-	-	-	-	-	-	15.9	15.2	14.3	13.2	11.9	11.9	131
138	-	-	-	-	-	-	-	-	14.3	13.9	12.8	11.5	10.4	10.4	138
144	-	-	-	-	-	-	-	-	-	12.3	11.5	10.1	8.8	8.8	144
151	-	-	-	-	-	-	-	-	-	11.0	10.1	8.8	7.7	7.5	151
157	-	-	-	-	-	-	-	-	-	-	9.0	7.7	6.4	6.4	157
164	-	-	-	-	-	-	-	-	-	-	7.9	6.6	5.3	5.3	164
177	-	-	-	-	-	-	-	-	-	-	-	4.9	3.5	3.3	177

2

TEREX | DEMAG

HA LIFTING CAPACITIES

35,900 lb 360° **85 %**

Radius	Main boom 40.7	54.5	68.6	82.3	96.5	110.2	124.3	138.1	152.2	166.0	180.1	193.9	208.0	222.4	Radius
ft	1,000 lb														ft
10	309.7	309.7	308.6	257.9	-	-	-	-	-	-	-	-	-	-	10
11	283.3	283.3	282.2	257.9	-	-	-	-	-	-	-	-	-	-	11
13	260.1	260.1	259.0	257.9	198.6	-	-	-	-	-	-	-	-	-	13
15	240.3	241.4	240.3	238.1	198.6	-	-	-	-	-	-	-	-	-	15
16	223.8	223.8	222.7	221.6	198.6	162.5	-	-	-	-	-	-	-	-	16
19	187.6	190.3	187.2	188.7	177.0	162.3	-	-	-	-	-	-	-	-	19
23	155.9	158.5	158.3	155.4	148.6	135.6	116.4	-	-	-	-	-	-	-	23
26	132.5	134.9	134.9	131.8	122.6	112.9	109.3	99.0	-	-	-	-	-	-	26
29	105.8	111.8	113.1	111.8	103.6	101.0	91.9	85.8	79.4	-	-	-	-	-	29
33	-	91.7	93.0	92.2	93.5	86.2	78.7	73.9	69.9	65.3	-	-	-	-	33
39	-	64.8	69.0	69.2	68.3	65.5	62.6	60.0	55.1	52.9	48.9	34.6	-	-	39
46	-	-	52.2	52.5	51.6	52.7	51.8	48.3	45.2	44.1	41.4	38.4	34.4	-	46
52	-	-	41.2	41.4	43.4	42.5	41.0	41.2	39.2	36.8	36.6	34.2	31.5	26.5	52
59	-	-	-	35.3	35.5	34.6	35.3	33.7	34.0	32.8	30.6	28.2	25.8	24.9	59
65	-	-	-	29.8	29.5	30.2	29.3	29.3	28.7	27.6	25.8	23.4	21.2	20.5	65
72	-	-	-	-	24.9	25.6	25.4	24.7	24.0	22.9	21.6	19.6	17.4	16.8	72
79	-	-	-	-	22.0	21.8	21.6	20.9	20.3	19.2	18.1	16.3	14.3	13.7	79
85	-	-	-	-	-	18.7	18.5	17.9	17.2	15.9	14.8	13.7	11.7	11.0	85
92	-	-	-	-	-	16.1	15.9	15.2	14.6	13.2	12.1	11.0	9.3	8.6	92
98	-	-	-	-	-	13.9	13.7	13.0	12.3	11.0	9.9	8.8	7.3	6.6	98
105	-	-	-	-	-	-	11.7	11.0	10.4	9.0	8.2	6.8	5.5	4.9	105
111	-	-	-	-	-	-	10.1	9.3	8.6	7.5	6.4	5.1	4.0	3.3	111
118	-	-	-	-	-	-	-	7.9	7.3	6.0	5.1	3.7	2.4	-	118
124	-	-	-	-	-	-	-	6.6	6.0	4.6	3.7	2.4	-	-	124
131	-	-	-	-	-	-	-	-	4.9	3.5	2.6	-	-	-	131
138	-	-	-	-	-	-	-	-	3.7	2.6	-	-	-	-	138
144	-	-	-	-	-	-	-	-	-	-	-	-	-	-	144

19,600 lb 360° **85 %**

Radius	Main boom 40.7	54.5	68.6	82.3	96.5	110.2	124.3	138.1	152.2	166.0	180.1	193.9	208.0	222.4	Radius
ft	1,000 lb														ft
10	306.4	306.4	306.4	257.9	-	-	-	-	-	-	-	-	-	-	10
11	280.0	281.1	280.0	257.9	-	-	-	-	-	-	-	-	-	-	11
13	257.9	257.9	256.8	255.7	198.6	-	-	-	-	-	-	-	-	-	13
15	238.1	239.2	238.1	235.9	198.6	-	-	-	-	-	-	-	-	-	15
16	219.8	220.5	219.4	218.9	196.0	162.5	-	-	-	-	-	-	-	-	16
19	176.8	179.2	179.2	165.6	156.5	141.1	-	-	-	-	-	-	-	-	19
23	146.6	149.3	142.6	136.5	124.1	119.5	107.6	-	-	-	-	-	-	-	23
26	111.6	118.4	119.3	109.8	106.9	97.4	89.5	81.4	-	-	-	-	-	-	26
29	86.4	93.0	94.6	95.7	88.8	81.1	76.5	72.5	66.6	-	-	-	-	-	29
33	-	74.5	79.1	79.6	75.2	69.2	67.7	62.8	58.4	54.2	-	-	-	-	33
39	-	51.6	55.8	56.0	55.1	56.9	52.0	50.5	47.2	45.0	43.9	-	-	-	39
46	-	-	41.7	43.2	44.1	43.0	43.0	40.8	39.9	37.5	34.6	31.7	28.9	-	46
52	-	-	34.0	34.8	34.6	35.5	34.8	34.6	32.8	30.2	27.8	25.1	22.5	21.4	52
59	-	-	-	28.2	28.9	28.7	28.4	27.8	26.9	24.5	22.5	20.1	17.6	16.8	59
65	-	-	-	23.1	23.8	23.6	23.4	22.9	22.0	20.1	18.1	15.9	13.7	13.0	65
72	-	-	-	-	19.8	19.8	19.4	18.5	17.9	16.5	14.6	12.6	10.4	9.9	72
79	-	-	-	-	16.5	16.5	15.9	15.2	14.6	13.2	11.7	9.7	7.7	7.1	79
85	-	-	-	-	-	13.7	13.2	12.3	11.7	10.4	9.3	7.5	5.5	4.9	85
92	-	-	-	-	-	11.5	10.8	10.1	9.5	8.2	7.1	5.5	3.5	2.9	92
98	-	-	-	-	-	9.5	9.0	8.2	7.5	6.2	5.3	3.7	-	-	98
105	-	-	-	-	-	-	7.5	6.6	6.0	4.6	3.7	2.2	-	-	105
111	-	-	-	-	-	-	6.2	5.3	4.4	3.3	2.2	-	-	-	111
118	-	-	-	-	-	-	-	4.0	3.3	-	-	-	-	-	118
124	-	-	-	-	-	-	-	3.1	2.2	-	-	-	-	-	124
131	-	-	-	-	-	-	-	-	-	-	-	-	-	-	131

ALL TERRAIN CRANE

AC 200-1

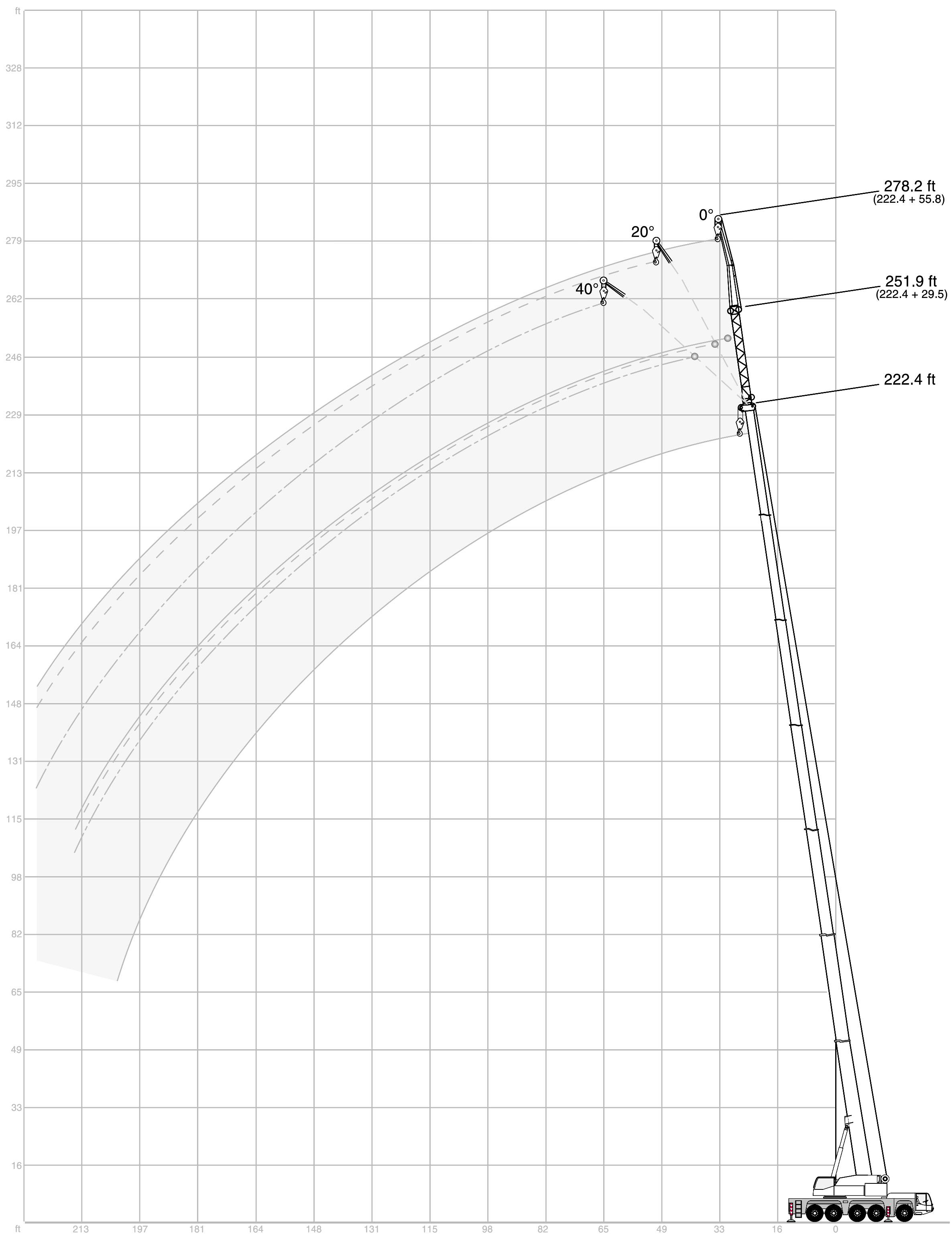
HA LIFTING CAPACITIES

0 lb | 360° | 85 %

Radius	Main boom ft: 40.7	54.5	68.6	82.3	96.5	110.2	124.3	138.1	152.2	166.0	180.1	193.9	205.7	Radius
ft							1,000 lb							ft
10	303.1	303.1	303.1	257.9	-	-	-	-	-	-	-	-	-	10
11	277.8	277.8	276.7	257.9	-	-	-	-	-	-	-	-	-	11
13	254.6	255.7	254.6	228.2	187.2	-	-	-	-	-	-	-	-	13
15	231.5	231.5	216.5	186.1	160.9	-	-	-	-	-	-	-	-	15
16	203.9	206.6	183.0	160.7	142.4	131.2	-	-	-	-	-	-	-	16
19	156.3	152.1	139.1	121.7	114.0	99.6	-	-	-	-	-	-	-	19
23	104.5	111.6	104.9	100.1	89.5	81.1	76.3	-	-	-	-	-	-	23
26	74.1	80.7	86.2	80.7	74.5	70.8	65.0	60.4	-	-	-	-	-	26
29	55.8	61.5	66.1	66.4	64.6	59.7	57.1	53.8	49.6	-	-	-	-	29
33	-	50.0	52.9	55.3	55.8	51.6	49.8	46.3	42.5	38.1	-	-	-	33
39	-	34.4	37.9	39.0	39.9	39.7	37.9	34.8	32.0	28.4	25.6	-	-	39
46	-	-	27.6	28.7	29.5	29.3	29.1	26.9	24.7	21.8	19.2	16.3	15.7	46
52	-	-	20.7	21.6	22.5	22.3	22.0	21.2	19.2	16.8	14.6	11.9	11.5	52
59	-	-	-	16.8	17.4	17.2	17.2	16.5	15.2	12.8	10.8	8.6	8.2	59
65	-	-	-	13.2	13.9	13.7	13.4	12.8	11.9	9.7	7.9	5.7	5.5	65
72	-	-	-	-	11.0	10.8	10.8	10.1	9.3	7.3	5.5	3.5	3.3	72
79	-	-	-	-	8.8	8.6	8.6	7.9	7.1	5.1	3.5	-	-	79
85	-	-	-	-	-	6.8	6.8	6.2	5.3	3.3	-	-	-	85
92	-	-	-	-	-	5.3	5.1	4.4	3.7	-	-	-	-	92
98	-	-	-	-	-	4.0	3.7	2.9	-	-	-	-	-	98
105	-	-	-	-	-	-	2.4	-	-	-	-	-	-	105

TEREX | DEMAG

HAV WORKING RANGES



ALL TERRAIN CRANE

AC 200-1

HAV LIFTING CAPACITIES

152,100 lb | 360° | 85 %

40.7 ft Main boom

Radius	Extension 29.5 ft 0°	20°	40°	Extension 55.8 ft 0°	20°	40°
ft	1,000 lb					
10	39.7	-	-	33.1	-	-
11	39.7	-	-	32.6	-	-
13	39.7	-	-	32.2	-	-
15	39.7	-	-	31.5	-	-
16	39.7	34.2	-	30.9	-	-
19	39.7	31.5	-	29.8	-	-
23	39.7	29.3	22.7	28.2	-	-
26	38.6	27.6	21.6	26.9	-	-
29	35.3	25.8	20.7	25.4	21.2	-
33	31.7	24.3	20.1	24.0	20.3	-
39	27.1	21.8	18.7	21.8	18.5	-
46	23.4	19.8	17.6	19.8	17.2	15.2
52	20.7	18.3	-	18.1	16.1	14.3
59	18.1	-	-	16.8	15.0	13.7
65	-	-	-	15.4	14.1	13.2
72	-	-	-	14.3	13.4	13.0
79	-	-	-	13.7	13.0	-
85	-	-	-	-	-	-
92	-	-	-	-	-	-
98	-	-	-	-	-	-
105	-	-	-	-	-	-
111	-	-	-	-	-	-
118	-	-	-	-	-	-

110.2 ft Main boom

Radius	Extension 29.5 ft 0°	20°	40°	Extension 55.8 ft 0°	20°	40°
ft	1,000 lb					
23	39.7	-	-	-	-	-
26	39.7	-	-	23.1	-	-
29	39.7	-	-	22.9	-	-
33	37.9	29.3	-	22.5	-	-
39	33.7	27.6	20.9	21.6	-	-
46	30.4	25.8	20.1	20.7	17.4	-
52	27.1	24.3	19.4	19.6	16.5	-
59	24.7	22.7	18.7	18.7	15.9	-
65	22.7	21.2	18.3	17.9	15.2	13.4
72	20.7	19.8	17.6	16.8	14.6	13.0
79	19.0	18.3	17.2	15.9	13.7	12.6
85	17.6	17.0	16.5	14.8	13.0	12.1
92	16.5	16.1	15.9	13.9	12.3	11.5
98	15.4	15.0	15.0	12.8	11.9	11.0
105	14.3	14.1	14.1	12.1	11.2	10.8
111	13.4	13.2	-	11.5	10.6	10.4
118	12.8	12.6	-	10.8	10.1	9.9
124	12.1	11.9	-	9.9	9.7	9.7
131	-	-	-	9.5	9.3	9.3
138	-	-	-	9.0	9.0	-
144	-	-	-	8.6	8.6	-
151	-	-	-	8.2	8.2	-
157	-	-	-	-	-	-

166.0 ft Main boom

Radius	Extension 29.5 ft 0°	20°	40°	Extension 55.8 ft 0°	20°	40°
ft	1,000 lb					
39	33.5	-	-	-	-	-
46	30.9	-	-	17.9	-	-
52	28.7	25.1	-	17.4	-	-
59	26.7	23.8	19.2	17.0	-	-
65	24.9	22.5	19.0	16.5	14.6	-
72	23.1	21.4	18.5	15.9	14.1	-
79	21.4	20.3	18.1	15.4	13.7	12.3
85	19.6	19.2	17.9	15.0	13.2	12.1
92	18.3	18.3	17.4	14.6	12.8	11.9
98	17.2	17.2	17.0	14.1	12.6	11.7
105	16.1	16.1	16.1	13.4	12.1	11.2
111	15.0	15.0	15.0	12.8	11.7	11.0
118	13.9	14.1	14.1	12.1	11.5	10.6
124	13.0	13.0	13.2	11.5	11.0	10.4
131	12.3	12.3	12.3	10.8	10.6	10.1
138	11.5	11.5	11.7	10.1	10.1	9.9
144	10.8	10.8	11.0	9.7	9.7	9.5
151	10.1	10.1	10.4	9.3	9.3	9.3
157	9.5	9.5	-	8.6	8.8	8.8
164	9.0	9.0	-	8.2	8.4	8.4
177	8.2	8.2	-	7.3	7.3	7.5
190	-	-	-	6.4	6.6	-
203	-	-	-	5.7	5.7	-

222.4 ft Main boom

Radius	Extension 29.5 ft 0°	20°	40°	Extension 55.8 ft 0°	20°	40°
ft	1,000 lb					
59	17.4	-	-	11.5	-	-
65	17.4	-	-	11.5	-	-
72	17.4	17.4	-	11.5	-	-
79	17.2	17.2	17.2	11.5	-	-
85	17.2	17.0	17.2	11.5	11.2	-
92	17.0	16.5	16.8	11.5	11.2	-
98	16.1	16.1	16.1	11.2	11.0	10.6
105	15.4	15.4	15.4	11.2	10.8	10.6
111	14.6	14.6	14.8	11.0	10.8	10.4
118	13.9	13.9	13.9	10.8	10.6	10.1
124	13.2	13.2	13.2	10.6	10.4	10.1
131	12.3	12.3	12.6	10.4	9.9	9.9
138	11.7	11.7	11.9	10.1	9.7	9.7
144	11.0	11.0	11.2	9.7	9.5	9.5
151	10.1	10.4	10.6	9.3	9.3	9.3
157	9.5	9.7	9.9	8.6	8.8	9.0
164	8.8	9.0	9.0	8.2	8.4	8.6
177	7.7	7.7	7.9	7.1	7.5	7.7
190	6.6	6.6	6.8	6.2	6.4	6.6
203	5.5	5.5	5.5	5.3	5.5	5.7
216	4.6	4.6	-	4.4	4.6	4.9
229	3.3	3.5	-	3.5	3.7	4.0
243	-	-	-	2.6	3.1	-

TEREX | DEMAG

HAV LIFTING CAPACITIES

95,700 lb | 360° | 85 %

40.7 ft Main boom

Radius	Extension 29.5 ft 0°	29.5 ft 20°	29.5 ft 40°	55.8 ft 0°	55.8 ft 20°	55.8 ft 40°
ft	1,000 lb					
10	39.7	-	-	33.1	-	-
11	39.7	-	-	32.6	-	-
13	39.7	-	-	32.2	-	-
15	39.7	-	-	31.5	-	-
16	39.7	34.2	-	30.9	-	-
19	39.7	31.5	-	29.8	-	-
23	39.7	29.3	22.7	28.2	-	-
26	38.6	27.6	21.6	26.9	-	-
29	35.3	25.8	20.7	25.4	21.2	-
33	31.7	24.3	20.1	24.0	20.3	-
39	27.1	21.8	18.7	21.8	18.5	-
46	23.4	19.8	17.6	19.8	17.2	15.2
52	20.7	18.3	-	18.1	16.1	14.3
59	18.1	-	-	16.8	15.0	13.7
65	-	-	-	15.4	14.1	13.2
72	-	-	-	14.3	13.4	13.0
79	-	-	-	13.7	13.0	-
85	-	-	-	-	-	-
92	-	-	-	-	-	-
98	-	-	-	-	-	-
105	-	-	-	-	-	-
111	-	-	-	-	-	-
118	-	-	-	-	-	-

110.2 ft Main boom

Radius	Extension 29.5 ft 0°	29.5 ft 20°	29.5 ft 40°	55.8 ft 0°	55.8 ft 20°	55.8 ft 40°
ft	1,000 lb					
23	39.7	-	-	-	-	-
26	39.7	-	-	23.1	-	-
29	39.7	-	-	22.9	-	-
33	37.9	29.3	-	22.5	-	-
39	33.7	27.6	20.9	21.6	-	-
46	30.4	25.8	20.1	20.7	17.4	-
52	27.1	24.3	19.4	19.6	16.5	-
59	24.7	22.7	18.7	18.7	15.9	-
65	22.7	21.2	18.3	17.9	15.2	13.4
72	20.7	19.8	17.6	16.8	14.6	13.0
79	19.0	18.3	17.2	15.9	13.7	12.6
85	17.6	17.0	16.5	14.8	13.0	12.1
92	16.5	16.1	15.9	13.9	12.3	11.5
98	15.4	15.0	15.0	12.8	11.9	11.0
105	14.3	14.1	14.1	12.1	11.2	10.8
111	13.4	13.2	-	11.5	10.6	10.4
118	12.8	12.6	-	10.8	10.1	9.9
124	12.1	11.9	-	9.9	9.7	9.7
131	-	-	-	9.5	9.3	9.3
138	-	-	-	9.0	9.0	-
144	-	-	-	8.6	8.6	-
151	-	-	-	8.2	8.2	-
157	-	-	-	-	-	-

166.0 ft Main boom

Radius	Extension 29.5 ft 0°	29.5 ft 20°	29.5 ft 40°	55.8 ft 0°	55.8 ft 20°	55.8 ft 40°
ft	1,000 lb					
39	33.5	-	-	-	-	-
46	30.9	-	-	17.9	-	-
52	28.7	25.1	-	17.4	-	-
59	26.7	23.8	19.2	17.0	-	-
65	24.9	22.5	19.0	16.5	14.6	-
72	23.1	21.4	18.5	15.9	14.1	-
79	21.4	20.3	18.1	15.4	13.7	12.3
85	19.6	19.2	17.9	15.0	13.2	12.1
92	18.3	18.3	17.4	14.6	12.8	11.9
98	17.2	17.2	17.0	14.1	12.6	11.7
105	16.1	16.1	16.1	13.4	12.1	11.2
111	15.0	15.0	15.0	12.8	11.7	11.0
118	13.9	14.1	14.1	12.1	11.5	10.6
124	13.0	13.0	13.2	11.5	11.0	10.4
131	12.3	12.3	12.3	10.8	10.6	10.1
138	11.5	11.5	11.7	10.1	10.1	9.9
144	10.8	10.8	11.0	9.7	9.7	9.5
151	10.1	10.1	10.4	9.3	9.3	9.3
157	9.5	9.5	-	8.6	8.8	8.8
164	8.6	9.0	-	8.2	8.4	8.4
177	6.6	6.8	-	7.3	7.3	7.5
190	-	-	-	5.7	6.2	-
203	-	-	-	4.4	4.6	-

222.4 ft Main boom

Radius	Extension 29.5 ft 0°	29.5 ft 20°	29.5 ft 40°	55.8 ft 0°	55.8 ft 20°	55.8 ft 40°
ft	1,000 lb					
59	17.4	-	-	11.5	-	-
65	17.4	-	-	11.5	-	-
72	17.4	17.4	-	11.5	-	-
79	17.2	17.2	17.2	11.5	-	-
85	17.2	17.0	17.2	11.5	11.2	-
92	17.0	16.5	16.8	11.5	11.2	-
98	16.1	16.1	16.1	11.2	11.0	10.6
105	15.4	15.4	15.4	11.2	10.8	10.6
111	14.6	14.6	14.8	11.0	10.8	10.4
118	13.9	13.9	13.9	10.8	10.6	10.1
124	13.2	13.2	13.2	10.6	10.4	10.1
131	11.5	12.3	12.6	10.4	9.9	9.9
138	9.7	10.8	11.5	10.1	9.7	9.7
144	8.4	9.3	9.9	8.8	9.5	9.5
151	7.1	7.9	8.6	7.5	9.3	9.3
157	5.7	6.6	7.1	6.4	7.9	9.0
164	4.6	5.5	6.0	5.3	6.8	7.9
177	2.9	3.5	3.7	3.3	4.6	5.5
190	-	-	-	-	2.9	3.5
203	-	-	-	-	-	-
216	-	-	-	-	-	-
229	-	-	-	-	-	-
243	-	-	-	-	-	-

ALL TERRAIN CRANE
AC 200-1

HAV LIFTING CAPACITIES

152,100 lb | 360° | 85 %

40.7 ft Main boom

	Extension					
	82.0 ft			108.3 ft		
Radius	0°	20°	40°	0°	20°	40°
ft	1,000 lb					
16	27.1	-	-	-	-	-
19	26.5	-	-	-	-	-
23	25.1	-	-	20.5	-	-
26	24.0	-	-	19.4	-	-
29	22.7	-	-	18.3	-	-
33	21.6	-	-	17.4	-	-
39	19.4	17.2	-	15.7	-	-
46	17.2	15.4	-	14.1	13.0	-
52	15.9	14.3	13.2	12.6	11.9	-
59	14.3	13.0	12.1	11.2	10.8	10.4
65	12.8	12.1	11.5	10.4	9.9	9.5
72	11.9	11.2	10.8	9.5	9.0	8.8
79	11.0	10.4	10.1	8.6	8.4	8.2
85	10.4	9.9	9.5	7.9	7.7	7.7
92	9.5	9.3	9.3	7.3	7.3	7.1
98	9.0	8.8	8.8	6.8	6.6	6.6
105	8.6	8.4	-	6.2	6.2	6.2
111	-	-	-	5.7	5.7	6.0
118	-	-	-	5.5	5.5	5.5
124	-	-	-	5.3	5.1	-
131	-	-	-	4.9	4.9	-
138	-	-	-	-	-	-
144	-	-	-	-	-	-
151	-	-	-	-	-	-
157	-	-	-	-	-	-
164	-	-	-	-	-	-

110.2 ft Main boom

	Extension					
	82.0 ft			108.3 ft		
Radius	0°	20°	40°	0°	20°	40°
ft	1,000 lb					
33	18.7	-	-	-	-	-
39	18.1	-	-	13.7	-	-
46	17.2	-	-	12.8	-	-
52	16.3	-	-	12.1	-	-
59	15.4	13.7	-	11.5	-	-
65	14.3	12.8	-	10.8	-	-
72	13.4	12.1	11.2	10.1	-	-
79	12.3	11.5	10.6	9.7	8.4*	-
85	11.7	10.6	10.1	9.0	7.9*	-
92	10.8	9.9	9.5	8.4	7.7*	7.3*
98	10.1	9.3	9.0	7.9	7.3*	7.1*
105	9.5	8.8	8.4	7.5	7.1*	6.8*
111	8.8	8.4	8.2	7.1	6.6*	6.4*
118	8.2	7.9	7.7	6.4	6.4*	6.2*
124	7.9	7.5	7.3	6.0	6.2*	6.0*
131	7.5	7.1	7.1	5.5	6.0*	5.7*
138	7.1	6.8	6.6	5.1	5.5*	5.5*
144	6.6	6.4	6.4	4.9	5.3*	5.3*
151	6.2	6.2	6.2	4.6	5.1*	5.1*
157	6.0	5.7	-	4.4	4.9*	4.9*
164	5.7	5.5	-	4.0	4.6*	4.6*
177	5.3	5.3	-	3.5	4.2*	4.2*
190	-	-	-	3.3	3.7*	3.7*
203	-	-	-	-	3.3*	3.3*
216	-	-	-	-	2.9*	-
229	-	-	-	-	2.4*	-

166.0 ft Main boom

	Extension					
	82.0 ft			108.3 ft		
Radius	0°	20°	40°	0°	20°	40°
ft	1,000 lb					
52	14.1	-	-	-	-	-
59	13.9	-	-	9.5	-	-
65	13.4	-	-	9.5	-	-
72	12.8	11.7	-	9.3	-	-
79	12.3	11.2	-	8.8	8.2	-
85	11.9	10.8	10.1	8.4	7.9	-
92	11.5	10.4	9.7	8.2	7.5	7.3
98	11.0	9.9	9.5	7.7	7.3	6.8
105	10.4	9.5	9.0	7.5	7.1	6.6
111	9.9	9.3	8.6	7.3	6.6	6.4
118	9.5	8.8	8.4	6.8	6.4	6.2
124	9.3	8.4	7.9	6.6	6.2	6.0
131	8.8	7.9	7.7	6.2	6.0	5.7
138	8.4	7.7	7.3	6.0	5.7	5.5
144	7.9	7.5	7.1	5.7	5.5	5.3
151	7.5	7.1	6.8	5.5	5.3	5.1
157	7.3	6.8	6.6	5.3	5.1	4.9
164	6.8	6.6	6.4	4.9	4.9	4.6
177	6.0	6.0	6.0	4.4	4.4	4.4
190	5.3	5.3	5.3	4.0	4.0	4.0
203	4.6	4.6	4.6	3.5	3.5	3.5
216	4.2	4.2	-	3.1	3.1	3.1
229	3.5	3.5	-	2.6	2.6	-
243	-	-	-	2.2	2.2	-

219.8 ft Main boom

	Extension					
	82.0 ft			108.3 ft		
Radius	0°	20°	40°	0°	20°	40°
ft	1,000 lb					
65	7.9	-	-	-	-	-
72	7.9	-	-	4.9	-	-
79	7.9	-	-	4.9	-	-
85	7.9	-	-	4.9	-	-
92	7.9	7.7	-	4.9	6.0**	-
98	7.9	7.7	-	4.9	6.0**	-
105	7.9	7.7	7.7	4.9	6.0**	-
111	7.9	7.7	7.7	4.9	6.0**	5.7**
118	7.7	7.7	7.7	4.9	5.7**	5.7**
124	7.7	7.7	7.5	4.9	5.7**	5.7**
131	7.7	7.5	7.3	4.9	5.5**	5.5**
138	7.5	7.3	7.3	4.6	5.5**	5.3**
144	7.5	7.1	7.1	4.6	5.3**	5.1**
151	7.5	7.1	6.8	4.6	5.1**	5.1**
157	7.3	6.8	6.6	4.6	4.9**	4.9**
164	6.8	6.6	6.4	4.6	4.9**	4.9**
177	6.2	6.0	6.2	4.4	4.4**	4.4**
190	5.3	5.5	5.5	4.0	4.2**	4.2**
203	4.6	4.9	4.9	3.5	4.0**	4.0**
216	4.0	4.2	4.4	3.1	3.5**	3.7**
229	3.1	3.5	3.5	2.6	3.1**	3.3**
243	2.4	2.6	2.9	-	2.6**	2.6**
256	-	-	-	-	-	-
269	-	-	-	-	-	-

Remarks: * Main boom 152.2 ft ** Main boom 208.0 ft

TEREX | DEMAG

HAV LIFTING CAPACITIES

95,700 lb 360° 85 %

40.7 ft Main boom

Radius (ft)	Extension 82.0 ft 0°	82.0 ft 20°	82.0 ft 40°	Extension 108.3 ft 0°	108.3 ft 20°	108.3 ft 40°
	1,000 lb					
16	27.1	-	-	-	-	-
19	26.5	-	-	-	-	-
23	25.1	-	-	20.5	-	-
26	24.0	-	-	19.4	-	-
29	22.7	-	-	18.3	-	-
33	21.6	-	-	17.4	-	-
39	19.4	17.2	-	15.7	-	-
46	17.2	15.4	-	14.1	13.0	-
52	15.9	14.3	13.2	12.6	11.9	-
59	14.3	13.0	12.1	11.2	10.8	10.4
65	12.8	12.1	11.5	10.4	9.9	9.5
72	11.9	11.2	10.8	9.5	9.0	8.8
79	11.0	10.4	10.1	8.6	8.4	8.2
85	10.4	9.9	9.5	7.9	7.7	7.7
92	9.5	9.3	9.3	7.3	7.3	7.1
98	9.0	8.8	8.8	6.8	6.6	6.6
105	8.6	8.4	-	6.2	6.2	6.2
111	-	-	-	5.7	5.7	6.0
118	-	-	-	5.5	5.5	5.5
124	-	-	-	5.3	5.1	-
131	-	-	-	4.9	4.9	-
138	-	-	-	-	-	-
144	-	-	-	-	-	-

110.2 ft Main boom

Radius (ft)	Extension 82.0 ft 0°	82.0 ft 20°	82.0 ft 40°	Extension 108.3 ft 0°	108.3 ft 20°	108.3 ft 40°
	1,000 lb					
33	18.7	-	-	-	-	-
39	18.1	-	-	13.7	-	-
46	17.2	-	-	12.8	-	-
52	16.3	-	-	12.1	-	-
59	15.4	13.7	-	11.5	-	-
65	14.3	12.8	-	10.8	9.9	-
72	13.4	12.1	11.2	10.1	9.5	-
79	12.3	11.5	10.6	9.7	8.8	8.4
85	11.7	10.6	10.1	9.0	8.4	7.9
92	10.8	9.9	9.5	8.4	7.9	7.5
98	10.1	9.3	9.0	7.9	7.5	7.3
105	9.5	8.8	8.4	7.5	7.1	6.8
111	8.8	8.4	8.2	7.1	6.6	6.4
118	8.2	7.9	7.7	6.4	6.2	6.0
124	7.9	7.5	7.3	6.0	6.0	5.7
131	7.5	7.1	7.1	5.5	5.5	5.5
138	7.1	6.8	6.6	5.1	5.1	5.1
144	6.6	6.4	6.4	4.9	4.9	4.9
151	6.2	6.2	6.2	4.6	4.4	4.4
157	6.0	5.7	-	4.4	4.2	4.2
164	5.7	5.5	-	4.0	4.0	4.0
177	5.3	5.3	-	3.5	3.5	3.5
190	-	-	-	3.3	3.3	-

166.0 ft Main boom

Radius (ft)	Extension 82.0 ft 0°	82.0 ft 20°	82.0 ft 40°	Extension 108.3 ft 0°	108.3 ft 20°	108.3 ft 40°
	1,000 lb					-
52	14.1	-	-	-	-	-
59	13.9	-	-	9.5	-	-
65	13.4	-	-	9.5	-	-
72	12.8	11.7	-	9.3	-	-
79	12.3	11.2	-	8.8	8.2	-
85	11.9	10.8	10.1	8.4	7.9	-
92	11.5	10.4	9.7	8.2	7.5	7.3
98	11.0	9.9	9.5	7.7	7.3	6.8
105	10.4	9.5	9.0	7.5	7.1	6.6
111	9.9	9.3	8.6	7.3	6.6	6.4
118	9.5	8.8	8.4	6.8	6.4	6.2
124	9.3	8.4	7.9	6.6	6.2	6.0
131	8.8	7.9	7.7	6.2	6.0	5.7
138	8.4	7.7	7.3	6.0	5.7	5.5
144	7.9	7.5	7.1	5.7	5.5	5.3
151	7.5	7.1	6.8	5.5	5.3	5.1
157	7.3	6.8	6.6	5.3	5.1	4.9
164	6.8	6.6	6.4	4.9	4.9	4.6
177	6.0	6.0	6.0	4.4	4.4	4.4
190	5.3	5.3	5.3	4.0	4.0	4.0
203	4.2	4.6	4.6	3.5	3.5	3.5
216	2.9	3.3	-	2.9	3.1	3.1
229	-	-	-	-	2.2	-

219.8 ft Main boom

Radius (ft)	Extension 82.0 ft 0°	82.0 ft 20°	82.0 ft 40°	Extension 108.3 ft 0°	108.3 ft 20°	108.3 ft 40°
	1,000 lb					
65	7.9	-	-	-	-	-
72	7.9	-	-	4.9	-	-
79	7.9	-	-	4.9	-	-
85	7.9	-	-	4.9	-	-
92	7.9	7.7	-	4.9	6.0**	-
98	7.9	7.7	-	4.9	6.0**	-
105	7.9	7.7	7.7	4.9	6.0**	-
111	7.9	7.7	7.7	4.9	6.0**	5.7**
118	7.7	7.7	7.7	4.9	5.7**	5.7**
124	7.7	7.7	7.5	4.9	5.7**	5.7**
131	7.7	7.5	7.3	4.9	5.5**	5.5**
138	7.5	7.3	7.3	4.6	5.5**	5.3**
144	7.5	7.1	7.1	4.6	5.3**	5.1**
151	7.3	7.1	6.8	4.6	5.1**	5.1**
157	6.2	6.8	6.6	4.6	4.9**	4.9**
164	5.3	6.6	6.4	4.6	4.9**	4.9**
177	3.3	4.9	6.0	2.9	4.4**	4.4**
190	-	3.1	4.0	-	3.3**	4.2**
203	-	-	-	-	-	2.6**
216	-	-	-	-	-	-
229	-	-	-	-	-	-
243	-	-	-	-	-	-
256	-	-	-	-	-	-

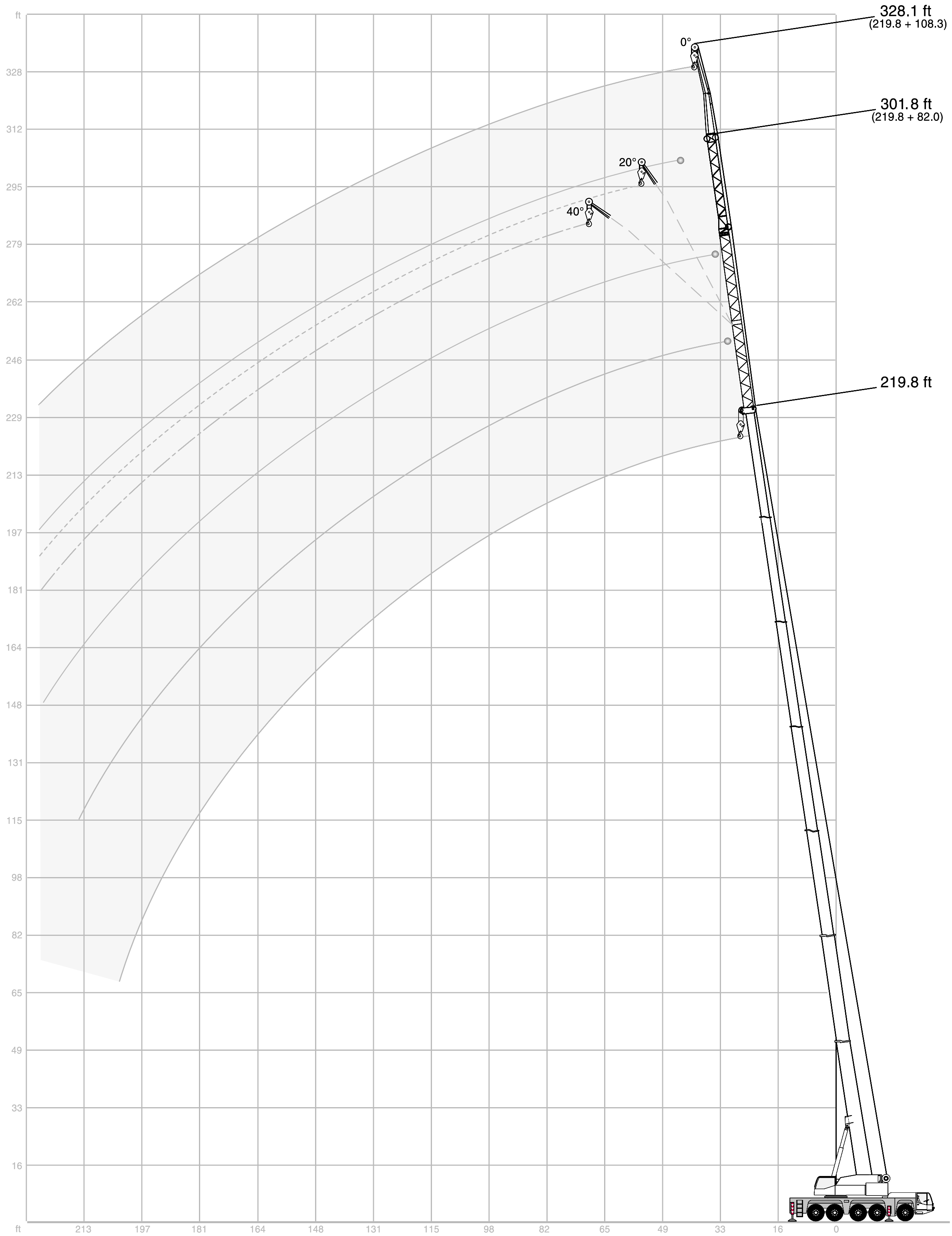
Remarks

** Main boom 208.0 ft

ALL TERRAIN CRANE

AC 200-1

HAV WORKING RANGES



3

TEREX | DEMAG

TECHNICAL DESCRIPTION

CARRIER

Drive / Steering	10 x 8 x 8.
Frame	Torsion-resistant box girder frame fabricated from high-strength fine grain structural steel.
Outriggers	4 telescopic outriggers, fabricated from fine grain structural steel, fully hydraulic horizontal and vertical extension.
Engine	Water-cooled 8 cylinder DaimlerChrysler diesel engine OM 502 LA, rating 390 kW (530 HP) at 1800 ^{1}/min, torque 2400 Nm at 1300 ^{1}/min, EUROMOT 3a. Fuel tank capacity: 132 gallons.
Transmission	ZF AS-Tronic, electronically automated transmission with automatic clutch, 16 forward and 2 reverse speeds with integrated retarder, 2-range transfer case, cruise control.
Axles	Axles 2, 3, 4, and 5: driven, 1, 2, 4, and 5: steering. Transverse differential lockout control on axles 2, 3, 4, and 5. Longitudinal lockout control on axles 3 and 4.
Suspension	Hydro-pneumatic suspension on all axles, hydraulically lockable for on-site travel.
Wheels and tires	10 wheels fitted with 14.00 R 25 tires (Michelin or Bridgestone).
Steering	10 x 8, axle 1+2: ZF dual-circuit semiblock mechanical steering with hydraulic booster and mechanical steering limiter. Axle 4+5: speed-depending steering for on-road drive, special steering programs to be selected off-road.
Brakes	To EC directives, sustained action brake: hydraulic retarder integrated into gearbox. Exhaust brake and constant choke valve.
Electrical equipment	24 V system.
Driver's cab	Highly comfortable ergonomic cab with clearly arranged dashboard, rubber mounted steel cab, corrosion-resistant powder coating with 2-pack top coat. 9.8 ft wide, 2 comfortable seats, with pneumatically sprung and heated driver's seat incl. head and arm rests, and three-point seat belts, vertically adjustable steering wheel, safety glass used throughout, electric windows, heated and electrically adjustable mirrors, windscreen defroster fans, engine-dependent hot water heater, electric windscreen washer and wiper, roller blinds, radio with CD player, stowage compartment, air-conditioning.

SUPERSTRUCTURE

Engine	Water-cooled 6 cylinder DaimlerChrysler diesel engine OM 906 LA, rating 170 kW (231 HP) at 2200 ^{1}/min, torque 810 Nm at 1200-1600 ^{1}/min. Fuel tank capacity: 132 gallons (on carrier).
Hydraulic system	Two variable displacement axial piston pumps with automatic power control enabling the operator to engage four independent working movements simultaneously, separate pump for slewing. Hydraulic oil cooler included as standard.
Hoist	Fixed displacement axial piston hydraulic motor, hoist drum with integrated planetary gear reducer, and spring-applied multi-disk brake. Hydraulic brake, drum rotation indicator.
Slew unit	Hydraulic motor with planetary gear reducer, pedal-operated brake, joystick-actuated free swing, spring-applied holding brake.
Boom elevation	1 differential cylinder with automatic lowering brake valve.
Crane cab	Highly comfortable cab with sliding door, roof window and large hinged windscreen, safety glass used throughout, sprung and hydraulically damped operator's seat with head and arm rests, wiper for windscreen and roof window, self-contained hot water heater with timer and 'Heizmatic' for sensitive heat flow control, dashboard with instrumentation and crane controls, e.g. drum rotation indicator for hoists I and II, load moment limiter, outrigger loading indicator, two working lights, air-conditioning. The crane cab can be tilted back hydraulically 18°.
Main boom	Boom base and 6 telescopic sections fabricated from fine grain structural steel, anti-deflection Demag Ovaloid profile.
Counterweight	152,100 lb hydraulically stowed on carrier.
Operator aids	Electronic load moment indicator with graphic display and touchscreen, digital readout for hook load, rated load, boom length and angle, radius, monitoring code to assist in trouble shooting, and analog display to indicate capacity utilization in %, integrated control system for boom telescoping, display for duty charts and theoretical and actual outrigger loading. Working range limitation to certain pre-defined slew angles, heights and radii („virtual walls") included as standard.

OPTIONAL EQUIPMENT

Runner	5.4 ft, 2-sheaves.
Twist arrestor	To prevent the hoist ropes from twisting.
Heavy-lift attachment	2 additional sheaves on boom head, max. lifting capacity 324,500 lb, 16 parts of line. The max. lifting capacity of the standard crane without heavy-lift attachment is 249,100 lb (6 sheaves on boom head).
Emergency control	Interface for emergency control to recover small loads, incl. transformer. With hydraulic motor and hydraulic pump available on request.
Warning light	For boom and attachments.
Rooster sheave	Sheave on boom head folding to the side of the boom, for single-line operation.
Wheels and tires	10 wheels fitted with 16.00 R 25 tires.
Main boom extension	Boom extension hydraulically offsetable under partial load up to 40°.

NOTES TO LIFTING CAPACITY

Ratings are in compliance with ISO 4305 and DIN 15019.2 (test load = 1.25 x suspended load + 0.1 x dead weight of boom head).
Weight of hook blocks and slings is part of the load, and is to be deducted from the capacity ratings.

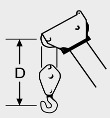
Consult operation manual for further details.

Note: Data published herein is intended as a guide only and shall not be construed to warrant applicability for lifting purposes.
Crane operation is subject to the computer charts and operation manual both supplied with the crane.

KEY

Counterweight

Lifting capacities on outriggers 360°

„D“ 

HA: Main boom

HAV: Main boom extension

TEREX | DEMAG

ALL TERRAIN CRANE
AC 200-1

The information contained in this brochure merely consists of general descriptions and a broad compilation of performance features which might not apply precisely as described under specific application conditions or which may change as a result of further product development.
The desired performance features only become binding once expressly agreed in the final contract.

Note: Data published herein is intended as a guide only and shall not be construed to warrant applicability for lifting purposes.
Crane operation is subject to the computer charts and operation manual both supplied with the crane.

Subject to change without notice.

02/06

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Mobile hydraulic and lattice-boom cranes
202 Raleigh St. · Wilmington, NC 28412 USA
Phone +1 910 395 8500 · Fax +1 910 395 8538
Email: american@american-crane.com

Bigge Crane and Rigging Co.
10700 Bigge Avenue
San Leandro, CA 94577
Phone: (888) 337-BIGGE or (510) 638-8100
Fax: (510) 639-4053
Email: info@bigge.com
Web site: www.bigge.com

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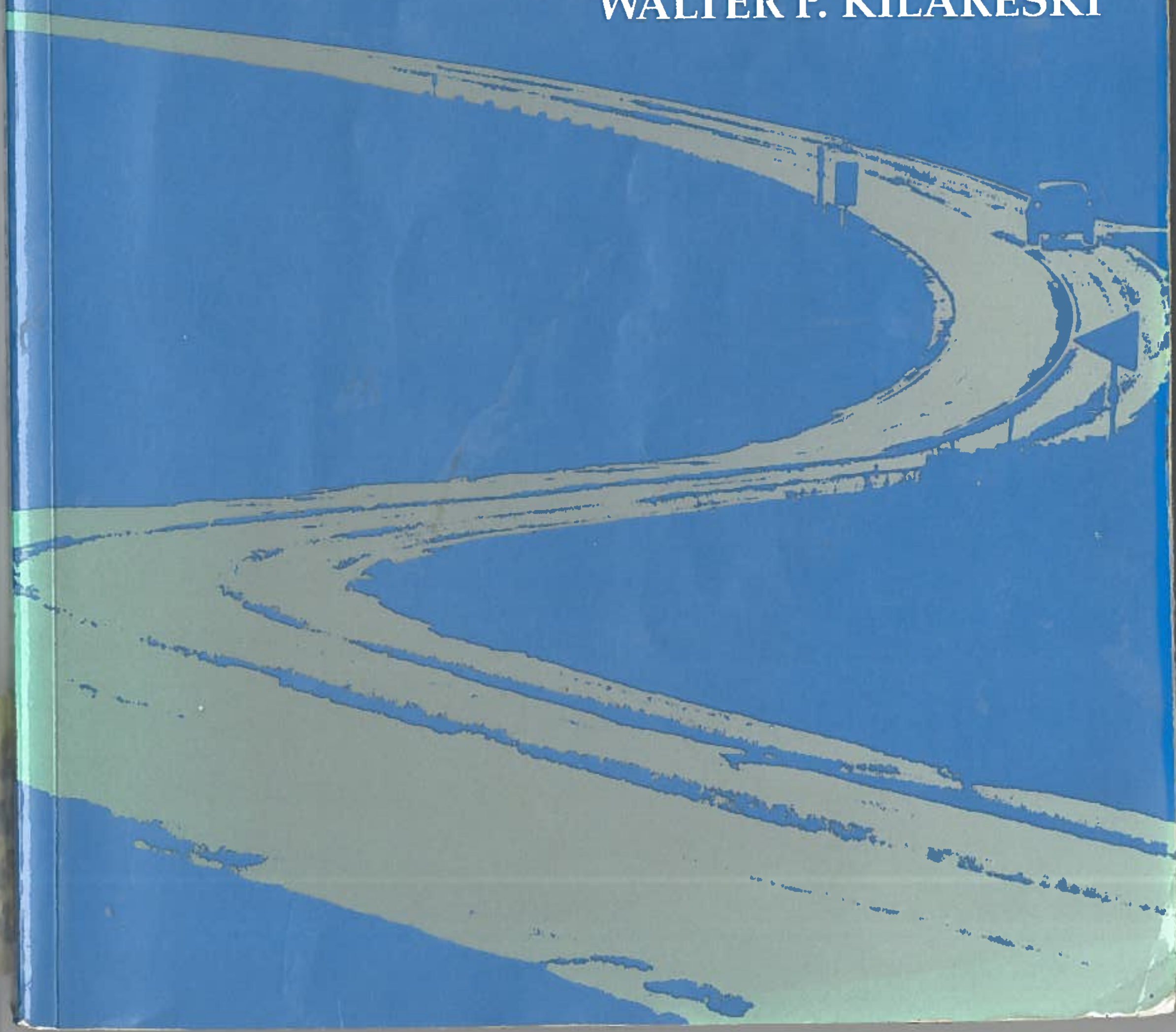
ATTACHMENT 4

PRINCIPLES OF HIGHWAY ENGINEERING *AND* TRAFFIC ANALYSIS

FRED L. MANNERING
WALTER P. KILARESKI



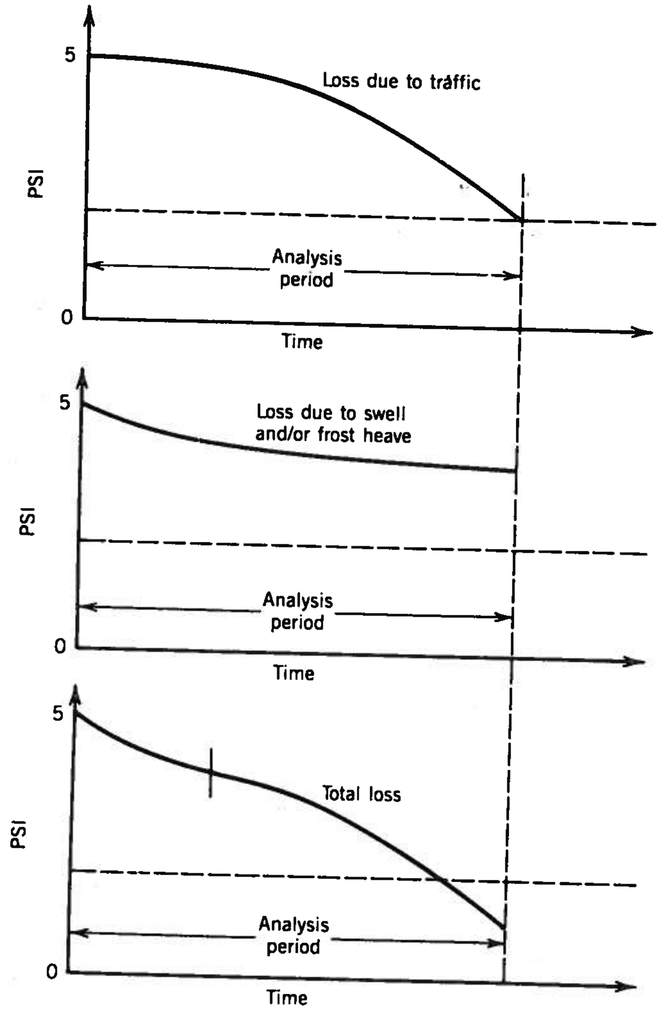


FIGURE 4.6
Pavement performance trends. Redrawn from "AASHTO Guide for Design of Pavement Structure," Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 1986. Used by permission.

terminal serviceability index (TSI) is reached. At this point, most raters feel that the pavement can no longer perform in a serviceable manner.

It should be obvious that it would be a tremendous job to have panels of raters evaluate all of the nation's highways on a continuous basis. Instead, correlations have been made between panel opinions and measured variables such as pavement roughness, rutting, and cracking. Consequently, mechanical devices are now used to determine PSI rather than with a panel of raters.

It has been found that new pavements usually have an initial PSI rating of approximately 4.2 to 4.5. As traffic is applied to the pavement and with the climate interaction with the pavement, the PSI will continue to drop to an unacceptable level. This level or terminal serviceability index, TSI, is selected on the basis of the highway function. A highway facility such as an interstate highway will usually have a TSI of 3.0 while a local road can have a TSI of 2.0.

Flexible Pavement Design Equation

At the conclusion of the AASHO Road Test a regression analysis (see Chapter 7 for a discussion on regression analysis) was performed to determine the interactions of traffic loadings, material properties, layer thickness, and climate. The relationship between axle loads and the thickness index of the pavement system is shown in Fig. 4.7. The thickness index represents a combination of layer thickness and strength coefficients. The term *thickness index* is the same as the term *structural number*, which will be discussed later.

The relationship shown in Fig. 4.7 can be used to determine the thickness of a flexible pavement. For example, assume that a new pavement must withstand 1 million applications of a 24-kip tandem axle load. Based on the curves, it can

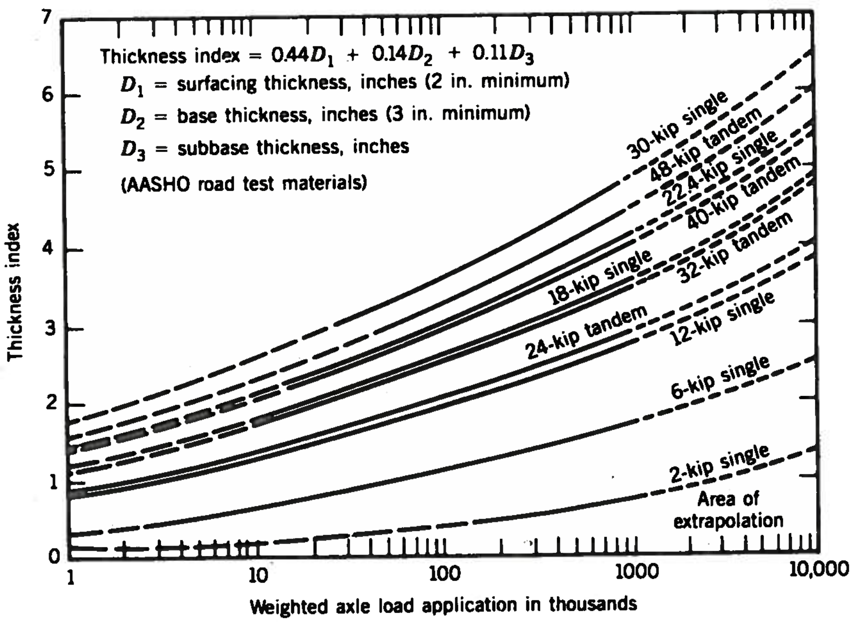


FIGURE 4.7
AASHO road test thickness index versus axle loads. Redrawn from "AASHO Road Test Report 5", Highway Research Board, Special Report 61E, Washington, D.C., 1962. Used by permission.

be seen that a thickness index of approximately 3.0 is needed to sustain that type of loading. There are many combinations of pavement materials and thickness that will provide an index value of 3.0; however, it is the responsibility of the pavement engineer to select a practical and economic combination of the materials to satisfy the design inputs. Since there is an infinite number of combinations of material properties and thicknesses, the graph shown in Fig. 4.7 can quickly lose its utility. Consequently, an equation was developed for flexible pavement design, which replaces the graph in Fig. 4.7.

The basic equation for flexible pavement design given in the 1986 Design Guide permits the engineers to determine a structural number required to carry the design traffic loading. The AASHTO equation is

$$\log_{10} W_{18} = Z_R S_o + 9.36(\log_{10}(\text{SN} + 1)) - 0.20 + \frac{\log_{10}[\Delta\text{PSI}/(4.2 - 1.5)]}{0.40 + [1094/(\text{SN} + 1)^{5.19}]} + 2.32\log_{10} M_R - 8.07 \tag{4.7}$$

where W_{18} = 18-kip equivalent single axle load
Z_R = reliability (z from standard normal distribution)
S_o = overall standard deviation
SN = structural number
ΔPSI = design present serviceability loss
M_R = resilient modulus of the subgrade soil

The variables that serve as input to Eq. 4.7 are discussed in the following paragraphs. The graphical solution to Eq. 4.7 is shown in Fig. 4.8. The inputs to the nomograph solution (or Eq. 4.7) include:

Reliability.

Overall standard deviation.

18-kip equivalent axle loads.

Soil resilient modulus.

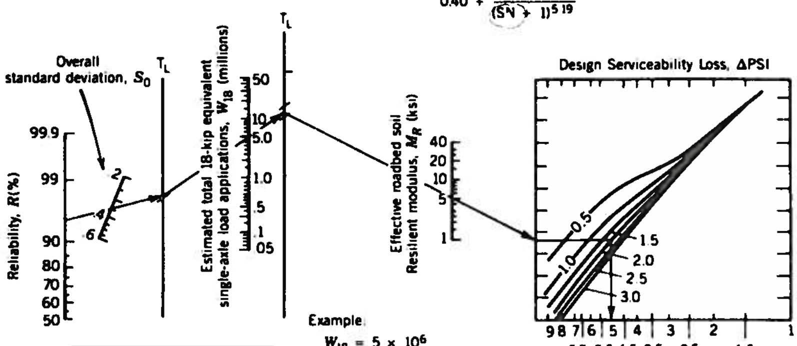
Serviceability loss.

Reliability is defined as "the probability that serviceability will be maintained at adequate levels from a user's point of view, throughout the design life of the facility." This factor insures that the pavement will perform at or above the TSI level during the design period. If the engineer would like to make sure that the pavement will not fail, a high reliability level is selected (90 percent, etc.).

The overall standard deviation factor takes into account the designers ability to estimate the variation in the ability to estimate future 18-kip equivalent axle loads. Typical values for the range of standard deviation for flexible pavement design are 0.4 to 0.5.

*Also, CERM 76-17

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$



Z_R's corresponding to R's

R	Z_R
99.5%	-2.576
99.0%	-2.326
97.5%	-1.960
95.0%	-1.645
90.0%	-1.282
80.0%	-0.842
70.0%	-0.524
60.0%	-0.253
50.0%	0.000

FIGURE 4.8
Design chart for flexible pavements based on using mean values for each input. Redrawn from "AASHTO Guide for Design of Pavement Structure," Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 1986. Used by permission.

There is a wide range of vehicle loadings on the highway system. Automobile and truck traffic provide a mixed spectrum of axle types and axle loads. To try and design for the mixed traffic loadings, this input variable would require a significant amount of data collection and design evaluation. Instead, the problem of handling mixed traffic loading was solved with the adoption of a standard 18-kip equivalent single-axle load, ESAL. With this method of traffic analysis, the various axle types and loadings can be related to one single-design load.

It was found at the AASHO Road Test that the 18-kip equivalent axle load was also a function of the Terminal Serviceability Index of the pavement structure. The axle load equivalency factors for flexible pavement design, with a TSI of 2.5, are presented in Tables 4.2 and 4.3.

The soil resilient modulus, M_R, is used to reflect the engineering properties of the subgrade. The resilient modulus can be determined by AASHTO Test Method T274. The M_R is important for the design, since it reflects the strength of the soil—which must ultimately support the load. The measurement of the resilient modulus is not performed by all transportation agencies, therefore, a relationship between M_R and the California Bearing Ratio, CBR, has been

TABLE 4.2
Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and TSI = 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.003	0.002	0.002
6	0.011	0.017	0.017	0.013	0.010	0.009
8	0.032	0.047	0.051	0.041	0.034	0.031
10	0.078	0.102	0.118	0.102	0.088	0.080
12	0.168	0.198	0.229	0.213	0.189	0.176
14	0.328	0.358	0.399	0.388	0.360	0.342
16	0.591	0.613	0.646	0.645	0.623	0.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

determined, since many agencies use the CBR test to determine the supporting characteristics of the subgrade. The relationship is

$$M_R = 1500 \times \text{CBR} \tag{4.8}$$

The amount of serviceability loss can be determined by the design engineer during the pavement selection process. The engineer must decide the final PSI level for the particular pavement. If the design is for a pavement with heavy traffic load, then the loss may only be 1.2 while a low volume road may have a total loss of 2.7.

TABLE 4.4
Structural Layer Coefficients

Pavement Component	Coefficient
Surface Course	
Hot mix asphalt concrete	0.44
Sand mix asphalt concrete	0.35
Base Course	
Crushed stone	0.14
Dense graded crushed stone	0.18
Soil cement	0.20
Emulsion/aggregate-bituminous	0.30
Portland cement/aggregate	0.40
Lime-pozzolan/aggregate	0.40
Hot mix asphaltic concrete	0.40
Subbase	
Crushed stone	0.11

Structural Number

After the input variables have been selected and applied to Fig. 4.8, a design structural number, SN, is selected. The SN represents the overall pavement system structural requirements needed to sustain the design traffic loadings for the design period. The structural number is similar to the Thickness Index as shown in Fig. 4.7. As stated earlier there is a number of pavement material combinations and thickness that will provide satisfactory service. The following equation can be used to relate individual material types and thickness to the structural number. Typical layer coefficients are shown in Table 4.4.

$$SN = a_1 D_1 + a_2 D_2 M_2 + a_3 D_3 M_3 \qquad (4.9)$$

where a_1, a_2, a_3 = layer coefficient of the wearing, base and subbase layer, respectively
D_1, D_2, D_3 = thickness of wearing, base and subbase, respectively
M_2, M_3 = drainage coefficient for the base and subbase, respectively
$M_2, M_3 \approx 0.4$ to 1.4 ($M > 1.0$ good/excellent drainage)

A drainage coefficient, M_i, is used to modify the thickness of the lower pavement layers to take into account drainage characteristics. A value of 1.0 for M_i represents good drainage characteristics. A soil such as clay will not drain very well; consequently, it will have a lower coefficient. Since there are many combinations of layer coefficient and thickness that solve Eq. 4.9, there are some guidelines that can be used to narrow the number of solutions. Experience has

ATTACHMENT 5

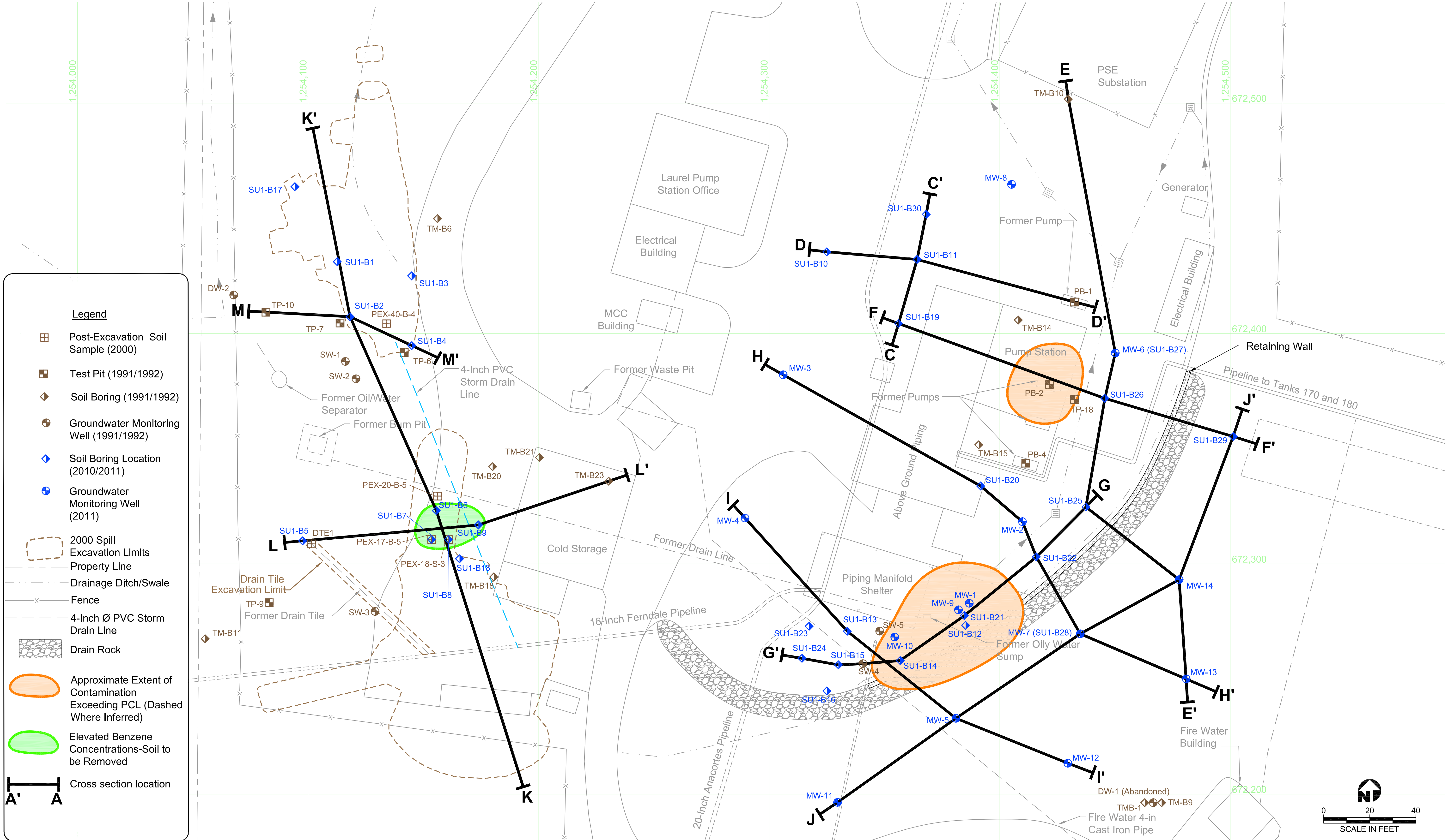
URS

DRAFT
REMEDIAL INVESTIGATION/
FEASIBILITY STUDY REPORT
Public Review Draft
LAUREL STATION
1009 EAST SMITH ROAD
BELLINGHAM, WASHINGTON

For

Trans Mountain Pipeline (Puget Sound) LLC
URS Job No.: 33764322

April 7, 2014



Coordinate grid based on Washington State Plane, North Zone, NAD83

J:\GIS\Projects\Kinder Morgan\Laurel Pump Station\SubTasks\RI-FS\Figure 9 (Unit 1 Samp Locs).dwg
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Figure 9
Soil Boring/Monitoring Well Locations (Study Unit 1)

URS

Laurel Station
Bellingham, Washington

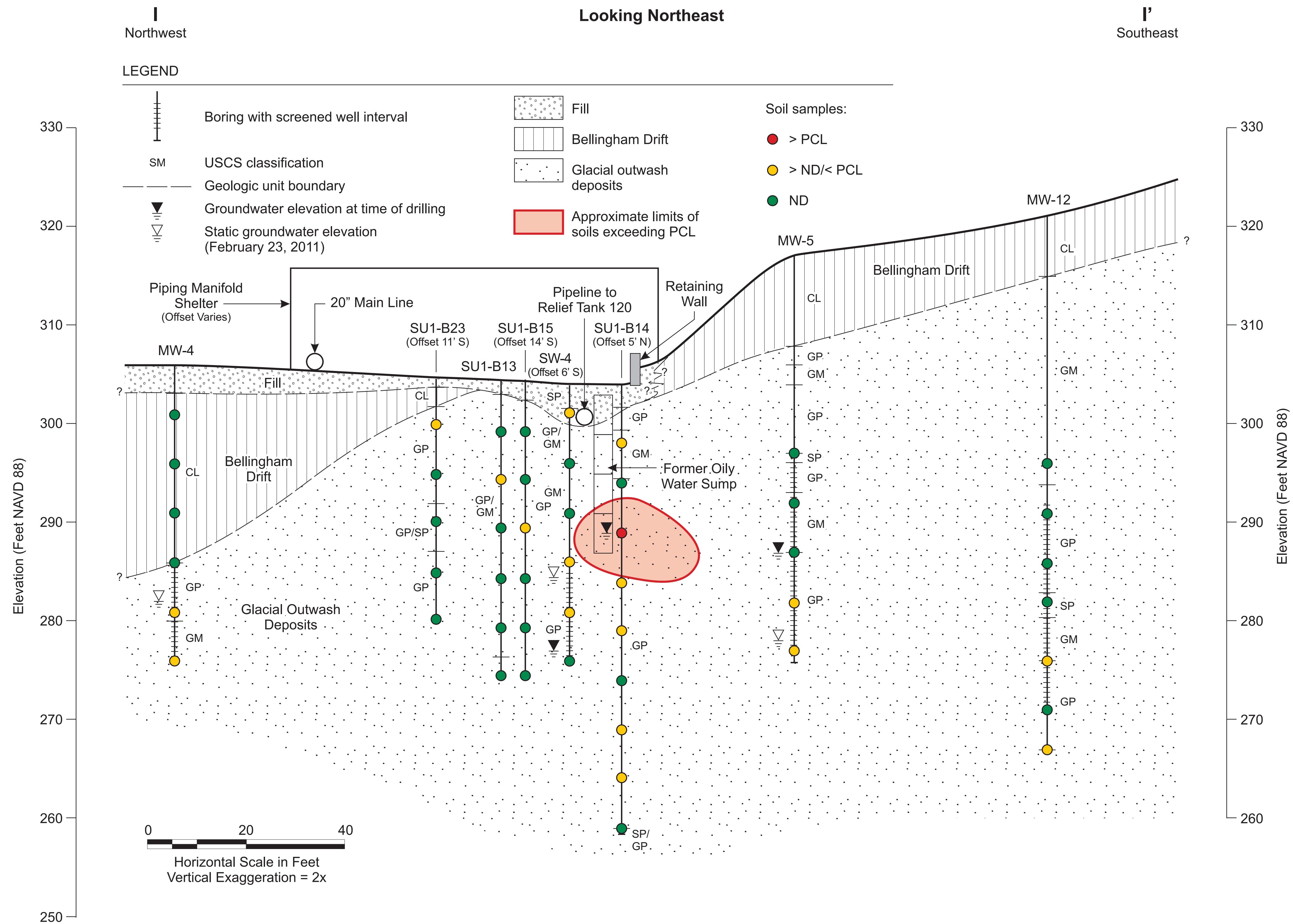

Figure 16

Geologic Cross Section I-I'

URS

Laurel Station
Bellingham, Washington

Project: Laurel Station Data Gap Investigation
Project Location: Bellingham, Washington
Project Number: 33762344

Log of Boring SU1-B14

Date(s) Drilled	**6/8/10**	Logged By	**IPV**	Checked By	**DRR**
Drilling Method	**Hollow Stem Auger**	Drilling Contractor	**Cascade Drilling Inc.**	Total Depth of Borehole	**45.5 feet bgs**
Drill Rig Type	**Limited Access HSA**	Drill Bit Size/Type	**8.25" OD**	Ground Surface Elevation	**N/A**
Groundwater Level (feet bgs)	**15 and 30 ft**	Sampling Method	**SPT**	Hammer Data	**140#**
Borehole Backfill	**Bentonite Chips**	Location	**Study Unit #1**		

Elevation, feet	Downhole Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Blows/ 6in.	SAMPLES Recovery (%)	SAMPLES OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0							GP	Gravel surface Cuttings are gravel	0800
				100/3	70	0.0		GM	Dark gray silty fine subrounded GRAVEL, fine to coarse sand (very dense) (moist) (no hydrocarbon odor)	
	5		SU1-B14-6	100/6		1.2			Grading (slight hydrocarbon odor)	
	10		SU1-B14-10	150/6	90	0.2		GP	Dark gray fine to medium subrounded GRAVEL with fine to coarse sand and silt (very dense) (moist to wet) (no hydrocarbon odor)	Sample moisture increasing
	15		SU1-B14-15	100/4	100	600			Grading dark gray fine to coarse subrounded GRAVEL with fine to coarse sand, trace silt (very dense) (wet) (slight hydrocarbon odor) 15 ft▼	Soil-Dup-1
	20		SU1-B14-20	100/6	80	450			Grading (moist) (strong hydrocarbon odor, staining?)	
	25		SU1-B14-25	120/4	70	100			Grading (strong hydrocarbon odor)	
			SU1-B14-30	100/4	100	15				0946
	30									

Project: Laurel Station Data Gap Investigation Project Location: Bellingham, Washington Project Number: 33762344	**Log of Boring SU1-B14** Sheet 2 of 2

Elevation, feet	Downhole Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery (%)	OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	30								Grading (wet) (slight to moderate hydrocarbon odor)	Take double volume for MS/MSD - cannot get triple volume
	35		SU1-B14-35	100/6	~~100~~	12.5			Grading sandy GRAVEL with increasing sand (moist to wet) (slight hydrocarbon odor)	
	40		SU1-B14-40	100/5	~~90~~	2.5			Grading gray sandy fine to coarse GRAVEL with silt, fine to coarse sand (very dense) (no hydrocarbon odor)	
			SU1-B14-45	100/5	~~100~~	2.2				
	45							SP/GP	Gray sandy fine to medium subrounded GRAVEL to gravelly fine to coarse SAND (very dense) (moist) (no hydrocarbon odor)	1035
									Boring was completed to 45 ft bgs. Groundwater was encountered at 15 and 30-35 ft bgs. Boring was backfilled with bentonite chips.	
	50									
	55									
	60									
	65									

H.Y. Fang
Foundation Engng Handbook
1991

ATTACHMENT 6

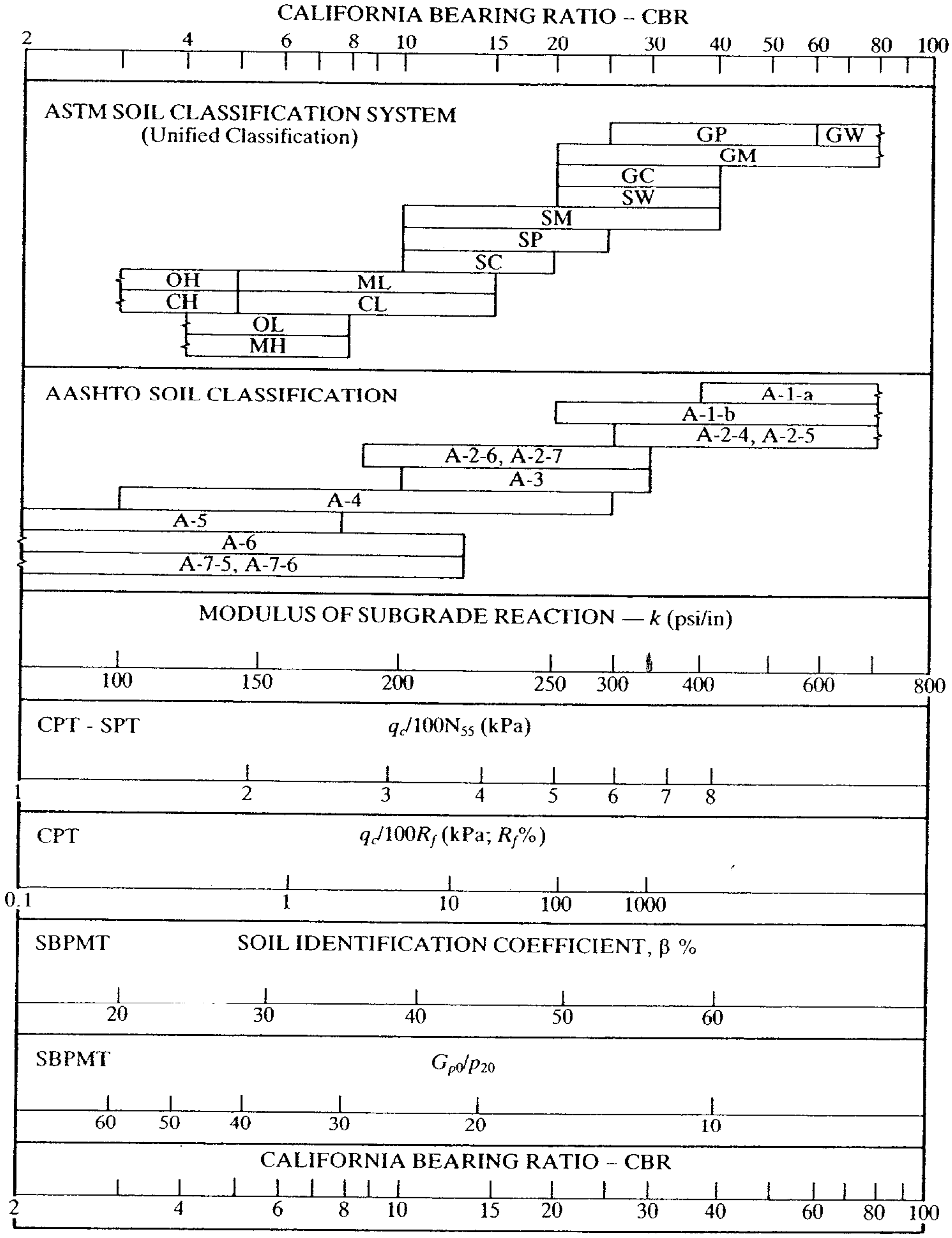

Fig. 3.37 Chart for approximate interrelationships between soil classification, bearing values, and some in-situ parameters: q_c, cone tip bearing; N_{55}, SPT blow count/ft; R_f, friction ratio (percent); G_{p0}, shear modulus at 0 percent strain; p_{20}, pressure at 20 percent strain; CBR, California Bearing Ratio. (*After Pamukcu and Fang, 1989.*)

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LIGHT DUTY FLEXIBLE PAVEMENT DESIGN

Objective: To design the light duty flexible pavement, for H-20 loading. Assumed design life of the pavement is 20 years.

It is assumed that this area will see a maximum daily vehicle traffic count of 100 vehicles per day.

According to FHWA, passenger vehicles are negligible in determining Equivalent Single Axle Loads (ESALs); therefore, a Light, Class 3 Truck (14,000 lbs total gross vehicle weight rating) is assumed as the design passenger vehicle using the light duty flexible pavement.

$p := 100$ number of passes in light duty flexible pavement area

$t := 20$ years, design life of flexible pavement before major maintenance (i.e. overlay) is required

$GVWR := 14000$ lbs (gross vehicle weight rating for light truck, class 3 (see Attachment 1))

$LD_F := 0.2$ ratio of total load distributed to front axle, based on H-20 distribution (see Attachment 2)

$LD_R := 1 - LD_F$

$LD_R = 0.8$ ratio of total load distributed to rear axle, based on H-20 distribution

$FAL := GVWR \cdot LD_F$ $FAL = 2800$ lbs, front axle load

$RAL := GVWR \cdot LD_R$ $RAL = 11200$ lbs, rear axle load

Determine Axle Load Equivalency Factors

Assuming an initial SN = 3 and Table 4.2 (see Attachment 3)

$ALEF_F := 0.004$ unitless, Axle Load Equivalency Factor for front axle at FAL at 4000 lbs (>2800 lbs)

$ALEF_R := 0.229$ unitless, Axle Load Equivalency Factor for rear axle at RAL at 12000 lbs (>11200 lbs)

Determine 18-kip Equivalent Single Axle Load (ESAL)

$ESAL := ALEF_F + ALEF_R$ $ESAL = 0.233$ unitless, ESAL for the light truck

$W_{18} := p \cdot ESAL \cdot 365 \cdot t$ $W_{18} = 170090$ 18-kip ESAL

URS CORP
By: G. Franco
06.09.14

LAUREL STATION
LIGHT DUTY
FLEXIBLE PAVEMENT DESIGN

Determine Structural Number, SN

$CBR := 40$ unitless, California Bearing Ratio. From boring logs in the RI-FS plan 2014, subgrade soil is an SP and GP soil type (see Attachment 4). This soil will be compacted before placing the light duty flexible pavement (compacted subgrade). Per Attachment 5, the CBR ranges from 10 to 60 between the two soils. 40 is selected as a resaonable value based on the material analyzed from the test pits.

$M_R := 1500 \cdot CBR$ psi, resilient modulus of the subgrade soil

$M_R = 60000$ psi

$Z_R := -1.645$ unitless, reliability (z from standard normal distribution) for 95% reliability (see Attachment 3)

$S_o := 0.45$ unitless, overall standard deviation (on reliability) (see Attachment 3)

$SN := 1$ unitless, structural number (initial guess to get root function started)

$\Delta PSI := 1.9$ design present serviceability loss (see Attachment 3)

$W_{18} = 170090$ 18-kip equivalent single axle load

$$SN := \text{root}\left[\left[Z_R \cdot S_o + 9.36 \cdot (\log(SN+1)) - 0.20 + \left[\frac{\log\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \left[\frac{1094}{(SN+1)^{5.19}}\right]}\right] + 2.32 \cdot \log(M_R) - 8.07 - \log(W_{18})\right], SN\right]$$

$SN = 1.178$ say ===> $SN := 1.5$ unitless, required structural number

Determine thickness of wearing and base course layers

$a_1 := 0.35$ unitless, structural layer coefficient for surface course of sand mix asphalt concrete (used this coefficient to be conservative)

$a_2 := 0.14$ unitless, structural layer coefficient for base course of crushed stone, most conservative coefficient

$M_2 := 1$ unitless, drainage coefficient for the base course layer, 1 assumes good drainage characteristic due to it being an SP

$D_1 := 3$ inches, thickness of wearing layer (TRY values till SN below is equal to required SN)

$D_2 := 6$ inches, thickness of base course layer (TRY values till SN below is equal to required SN)

$SN := a_1 \cdot D_1 + a_2 \cdot D_2 \cdot M_2$ $SN = 1.9$ WHICH IS GREATER THAN REQUIRED SN, THEREFORE DESIGN IS ADEQUATE

URS CORP
By: G. Franco
06.09.14

ATTACHMENT 1

Light (pickup trucks, vans, SUVs) **Medium** (delivery trucks) **Heavy** (tractor-trailer combinations)

Figure 2: Common Truck Categories

Vehicle manufacturers use more precise technical definitions and divide trucks into eight classes according to gross vehicle weight rating (GVWR). Table 1 shows vehicle manufacturer truck classifications. Figure 3 shows a basic breakdown of the truck and bus population in the U.S.

Table 1: Vehicle Manufacturer Truck Classification[1]

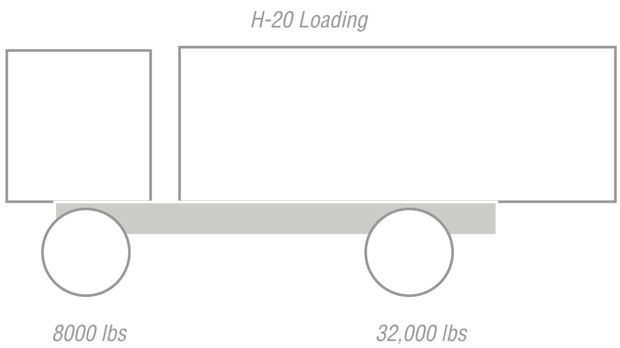
Category	Class	GVWR[2]	Representative Vehicles
Light	1	0 - 27 kN 0 - 6,000 lbs.	pickup trucks, ambulances, parcel delivery
	2	27 - 45 kN (6,001 - 10,000 lbs.)	
	3	45 - 62 kN (10,001 - 14,000 lbs.)	
Medium	4	62 - 71 kN (14,001 - 16,000 lbs.)	city cargo van, beverage delivery truck, wrecker, school bus
	5	71 - 87 kN (16,001 - 19,500 lbs.)	
	6	87 - 116 kN (19,501 - 26,000 lbs.)	
	7	116 - 147 kN (26,001 to 33,000 lbs.)	
Heavy	8	147 kN and over (33,000 lbs. and over)	truck tractor, concrete mixer, dump truck, fire truck, city transit bus

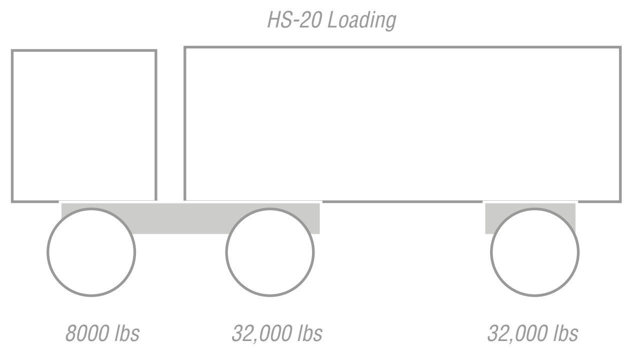
Notes:

1. The above classes are not the same as used by the FHWA
2. Gross Vehicle Weight Rating (GVWR): weight specified by manufacturer as the maximum loaded weight (truck plus cargo) of a single vehicle.

ATTACHMENT 2

H-20 and HS-20 loading





Dynamic Load Sample Calculation

Wheel load = W_L = 16,000 lbs (32,000 lb axle / 2)
Dynamic Force = F_d = 1.2 (20% greater than static force)
Spread Area = A = 1496 si (12" cover w/45 degree angle)
Weight of base = d_y = 0.97 psi (12" road base @ 140 lbs/cf)

$\sigma_{va} = (W_L \times F_d / A) + d_y$

$\sigma_{va} = (16{,}000 \text{ lbs} \times 1.2 / 1496 \text{ si}) + 0.97 \text{ lbs}$

$\sigma_{va} = 13.8 \text{ psi}$

13.8 psi (95 kPa) on Rainstore3

Surface Pressure

32,000 for the rear axle

32,000 lbs / 2 tires per rear axle = 16000 lbs

200 square inches contact (20" x 10 ")*

16000 lbs / 200 sq inches = 80 psi

80 psi (552 kPa) static

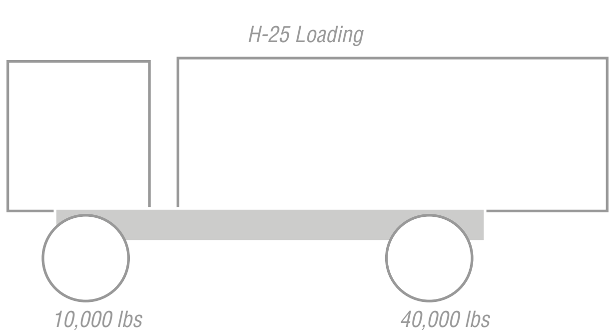
Rainstore3 has been independently field and labaratory tested to meet H-20 Bridge Loading.

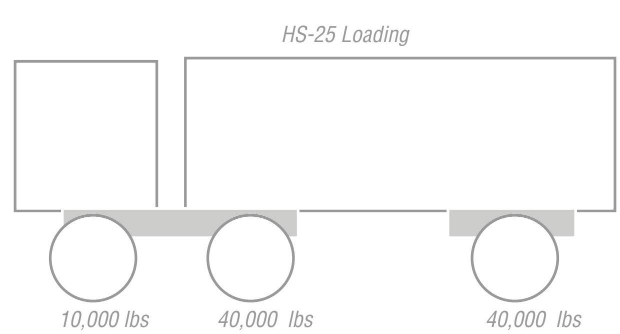
Grasspave2, Gravelpave2, Slopetame2, and Draincore2 can withstand 2,100 psi empty (14,470 kPa).

Grasspave2, Gravelpave2, and Slopetame2 can withstand 5,721 psi with fill material (39,273 kPa).

Invisible Structures, Inc.

invisiblestructures.com
800-233-1510



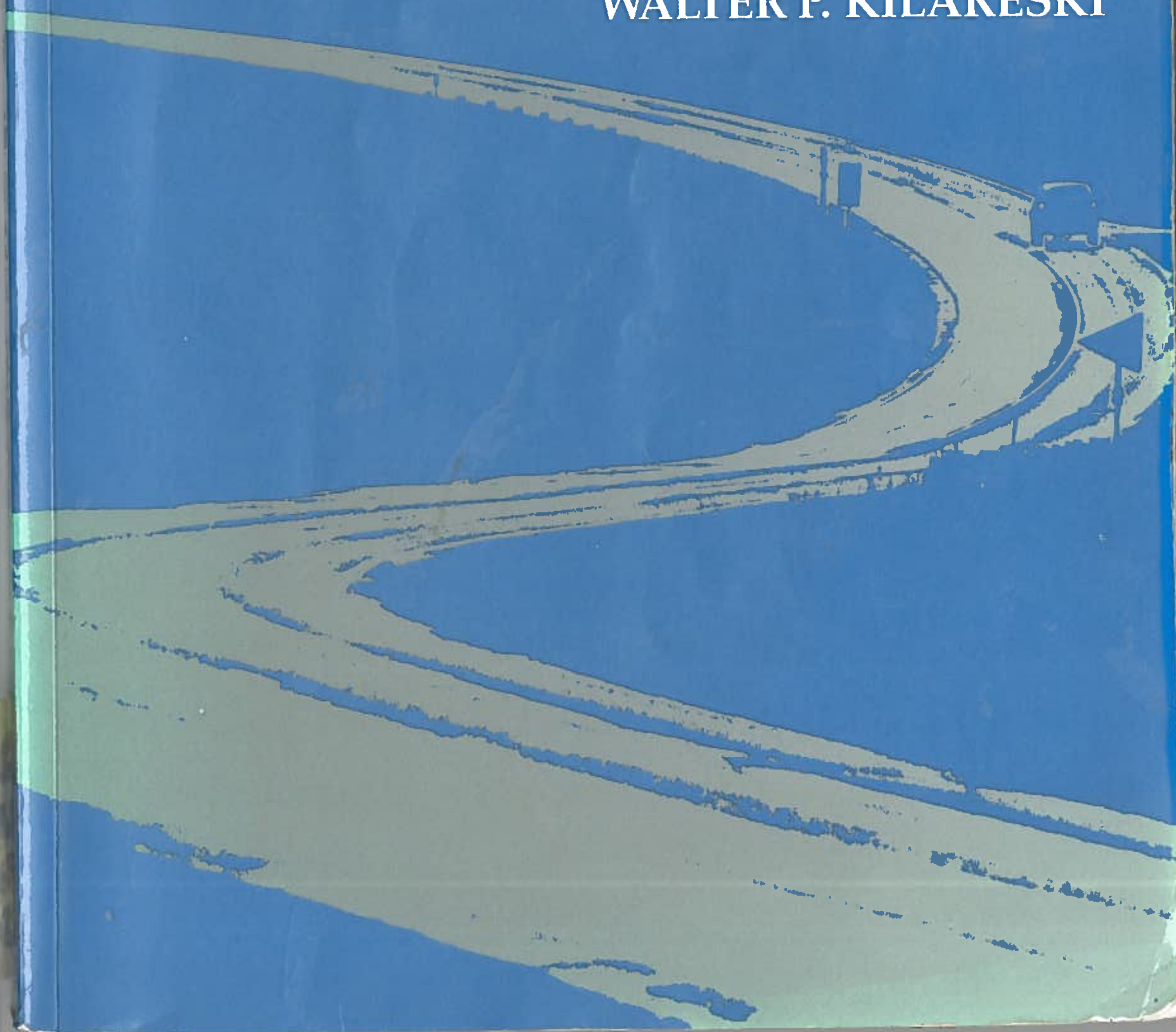


**AASHTO 3.30 Tire Contact Area*

ATTACHMENT 3

PRINCIPLES OF HIGHWAY ENGINEERING *AND* TRAFFIC ANALYSIS

FRED L. MANNERING
WALTER P. KILARESKI



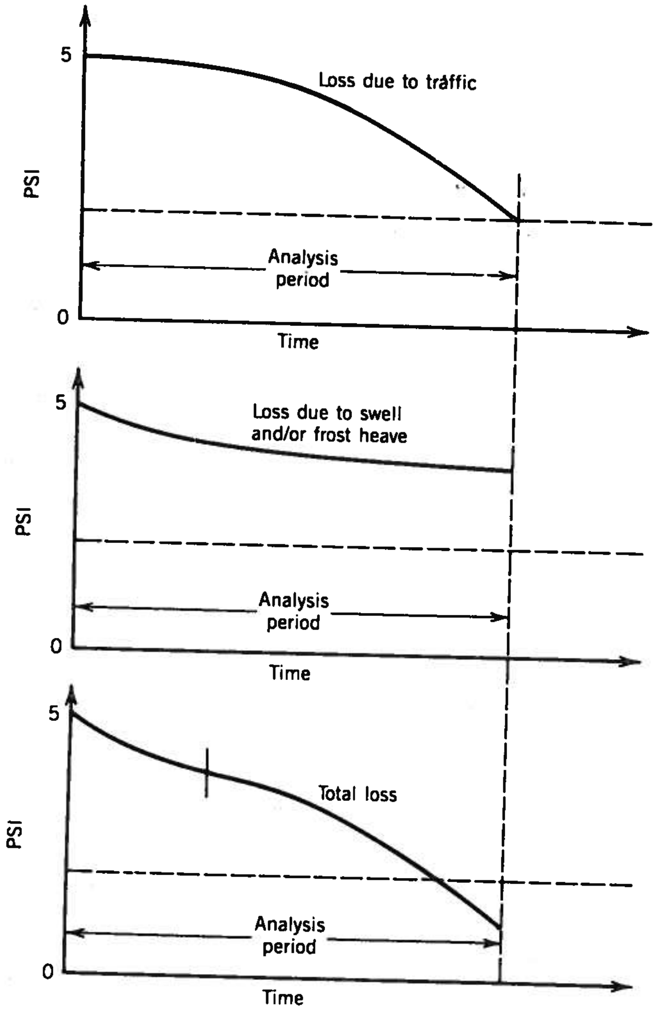


FIGURE 4.6
Pavement performance trends. Redrawn from "AASHTO Guide for Design of Pavement Structure," Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 1986. Used by permission.

terminal serviceability index (TSI) is reached. At this point, most raters feel that the pavement can no longer perform in a serviceable manner.

It should be obvious that it would be a tremendous job to have panels of raters evaluate all of the nation's highways on a continuous basis. Instead, correlations have been made between panel opinions and measured variables such as pavement roughness, rutting, and cracking. Consequently, mechanical devices are now used to determine PSI rather than with a panel of raters.

It has been found that new pavements usually have an initial PSI rating of approximately 4.2 to 4.5. As traffic is applied to the pavement and with the climate interaction with the pavement, the PSI will continue to drop to an unacceptable level. This level or terminal serviceability index, TSI, is selected on the basis of the highway function. A highway facility such as an interstate highway will usually have a TSI of 3.0 while a local road can have a TSI of 2.0.

Flexible Pavement Design Equation

At the conclusion of the AASHO Road Test a regression analysis (see Chapter 7 for a discussion on regression analysis) was performed to determine the interactions of traffic loadings, material properties, layer thickness, and climate. The relationship between axle loads and the thickness index of the pavement system is shown in Fig. 4.7. The thickness index represents a combination of layer thickness and strength coefficients. The term *thickness index* is the same as the term *structural number*, which will be discussed later.

The relationship shown in Fig. 4.7 can be used to determine the thickness of a flexible pavement. For example, assume that a new pavement must withstand 1 million applications of a 24-kip tandem axle load. Based on the curves, it can

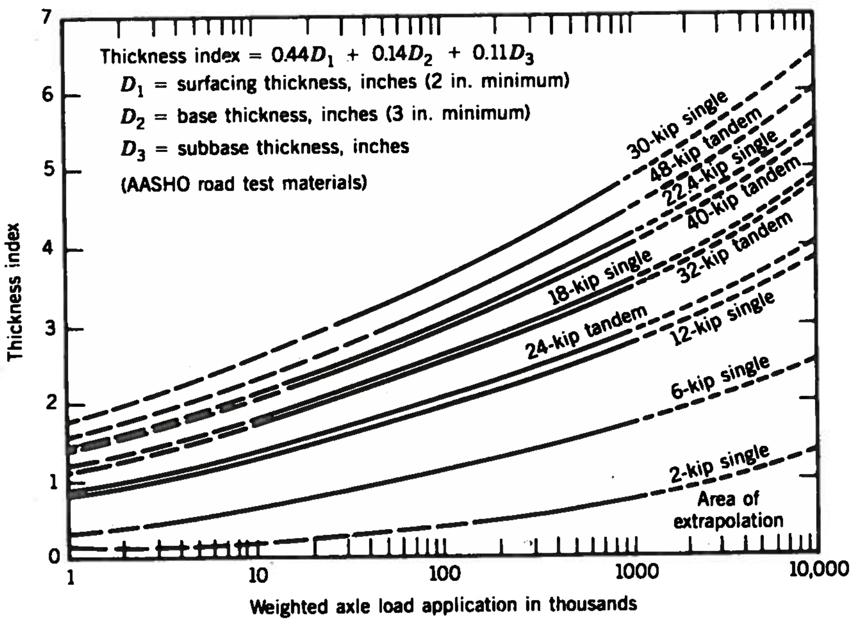


FIGURE 4.7
AASHO road test thickness index versus axle loads. Redrawn from "AASHO Road Test Report 5", Highway Research Board, Special Report 61E, Washington, D.C., 1962. Used by permission.

be seen that a thickness index of approximately 3.0 is needed to sustain that type of loading. There are many combinations of pavement materials and thickness that will provide an index value of 3.0; however, it is the responsibility of the pavement engineer to select a practical and economic combination of the materials to satisfy the design inputs. Since there is an infinite number of combinations of material properties and thicknesses, the graph shown in Fig. 4.7 can quickly lose its utility. Consequently, an equation was developed for flexible pavement design, which replaces the graph in Fig. 4.7.

The basic equation for flexible pavement design given in the 1986 Design Guide permits the engineers to determine a structural number required to carry the design traffic loading. The AASHTO equation is

decimal

$$\log_{10} W_{18} = Z_R S_o + 9.36(\log_{10}(\mathrm{SN}+1)) - 0.20 + \frac{\log_{10}[\Delta\mathrm{PSI}/(4.2-1.5)]}{0.40 + [1094/(\mathrm{SN}+1)^{5.19}]} + 2.32\log_{10} M_R - 8.07 \quad (4.7)$$

where W_{18} = 18-kip equivalent single axle load
Z_R = reliability (z from standard normal distribution)
S_o = overall standard deviation
SN = structural number
ΔPSI = design present serviceability loss
M_R = resilient modulus of the subgrade soil

The variables that serve as input to Eq. 4.7 are discussed in the following paragraphs. The graphical solution to Eq. 4.7 is shown in Fig. 4.8. The inputs to the nomograph solution (or Eq. 4.7) include:

Reliability.

Overall standard deviation.

18-kip equivalent axle loads.

Soil resilient modulus.

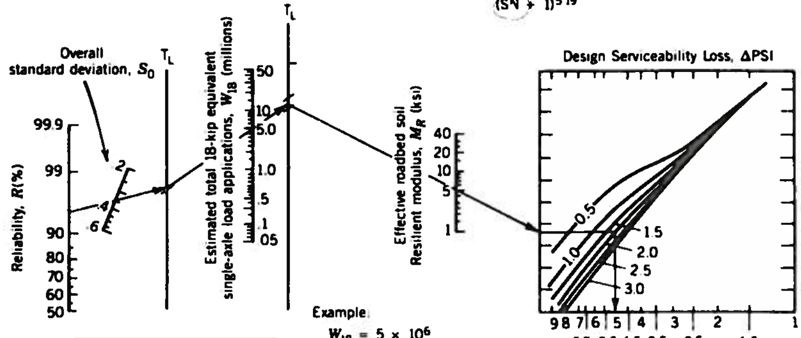
Serviceability loss.

Reliability is defined as "the probability that serviceability will be maintained at adequate levels from a user's point of view, throughout the design life of the facility." This factor insures that the pavement will perform at or above the TSI level during the design period. If the engineer would like to make sure that the pavement will not fail, a high reliability level is selected (90 percent, etc.).

The overall standard deviation factor takes into account the designers ability to estimate the variation in the ability to estimate future 18-kip equivalent axle loads. Typical values for the range of standard deviation for flexible pavement design are 0.4 to 0.5.

* Also, CERM 76-17

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$



Z_R's corresponding to R's

R	Z_R
99.5%	-2.576
99.0%	-2.326
97.5%	-1.960
95.0%	-1.645
90.0%	-1.282
80.0%	-0.842
70.0%	-0.524
60.0%	-0.253
50.0%	0.000

FIGURE 4.8
Design chart for flexible pavements based on using mean values for each input. Redrawn from "AASHTO Guide for Design of Pavement Structure," Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 1986. Used by permission.

There is a wide range of vehicle loadings on the highway system. Automobile and truck traffic provide a mixed spectrum of axle types and axle loads. To try and design for the mixed traffic loadings, this input variable would require a significant amount of data collection and design evaluation. Instead, the problem of handling mixed traffic loading was solved with the adoption of a standard 18-kip equivalent single-axle load, ESAL. With this method of traffic analysis, the various axle types and loadings can be related to one single-design load.

It was found at the AASHO Road Test that the 18-kip equivalent axle load was also a function of the Terminal Serviceability Index of the pavement structure. The axle load equivalency factors for flexible pavement design, with a TSI of 2.5, are presented in Tables 4.2 and 4.3.

The soil resilient modulus, M_R, is used to reflect the engineering properties of the subgrade. The resilient modulus can be determined by AASHTO Test Method T274. The M_R is important for the design, since it reflects the strength of the soil—which must ultimately support the load. The measurement of the resilient modulus is not performed by all transportation agencies, therefore, a relationship between M_R and the California Bearing Ratio, CBR, has been

TABLE 4.2
Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and TSI = 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	0.0004	0.0004	0.0003	0.0002	0.0002	0.0002
4	0.003	0.004	0.004	0.003	0.002	0.002
6	0.011	0.017	0.017	0.013	0.010	0.009
8	0.032	0.047	0.051	0.041	0.034	0.031
10	0.078	0.102	0.118	0.102	0.088	0.080
12	0.168	0.198	0.229	0.213	0.189	0.176
14	0.328	0.358	0.399	0.388	0.360	0.342
16	0.591	0.613	0.646	0.645	0.623	0.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

determined, since many agencies use the CBR test to determine the supporting characteristics of the subgrade. The relationship is

$$M_R = 1500 \times CBR \tag{4.8}$$

The amount of serviceability loss can be determined by the design engineer during the pavement selection process. The engineer must decide the final PSI level for the particular pavement. If the design is for a pavement with heavy traffic load, then the loss may only be 1.2 while a low volume road may have a total loss of 2.7.

TABLE 4.4
Structural Layer Coefficients

Pavement Component	Coefficient
Surface Course	
Hot mix asphalt concrete	0.44
Sand mix asphalt concrete	0.35
Base Course	
Crushed stone	0.14
Dense graded crushed stone	0.18
Soil cement	0.20
Emulsion/aggregate-bituminous	0.30
Portland cement/aggregate	0.40
Lime-pozzolan/aggregate	0.40
Hot mix asphaltic concrete	0.40
Subbase	
Crushed stone	0.11

Structural Number

After the input variables have been selected and applied to Fig. 4.8, a design structural number, SN, is selected. The SN represents the overall pavement system structural requirements needed to sustain the design traffic loadings for the design period. The structural number is similar to the Thickness Index as shown in Fig. 4.7. As stated earlier there is a number of pavement material combinations and thickness that will provide satisfactory service. The following equation can be used to relate individual material types and thickness to the structural number. Typical layer coefficients are shown in Table 4.4.

$$SN = a_1 D_1 + a_2 D_2 M_2 + a_3 D_3 M_3 \quad (4.9)$$

where a_1, a_2, a_3 = layer coefficient of the wearing, base and subbase layer, respectively

D_1, D_2, D_3 = thickness of wearing, base and subbase, respectively

M_2, M_3 = drainage coefficient for the base and subbase, respectively

$M_2, M_3 \approx 0.4$ to 1.4 ($M > 1.0$ good/excellent drainage)

A drainage coefficient, M_i, is used to modify the thickness of the lower pavement layers to take into account drainage characteristics. A value of 1.0 for M_i represents good drainage characteristics. A soil such as clay will not drain very well; consequently, it will have a lower coefficient. Since there are many combinations of layer coefficient and thickness that solve Eq. 4.9, there are some guidelines that can be used to narrow the number of solutions. Experience has

ATTACHMENT 4

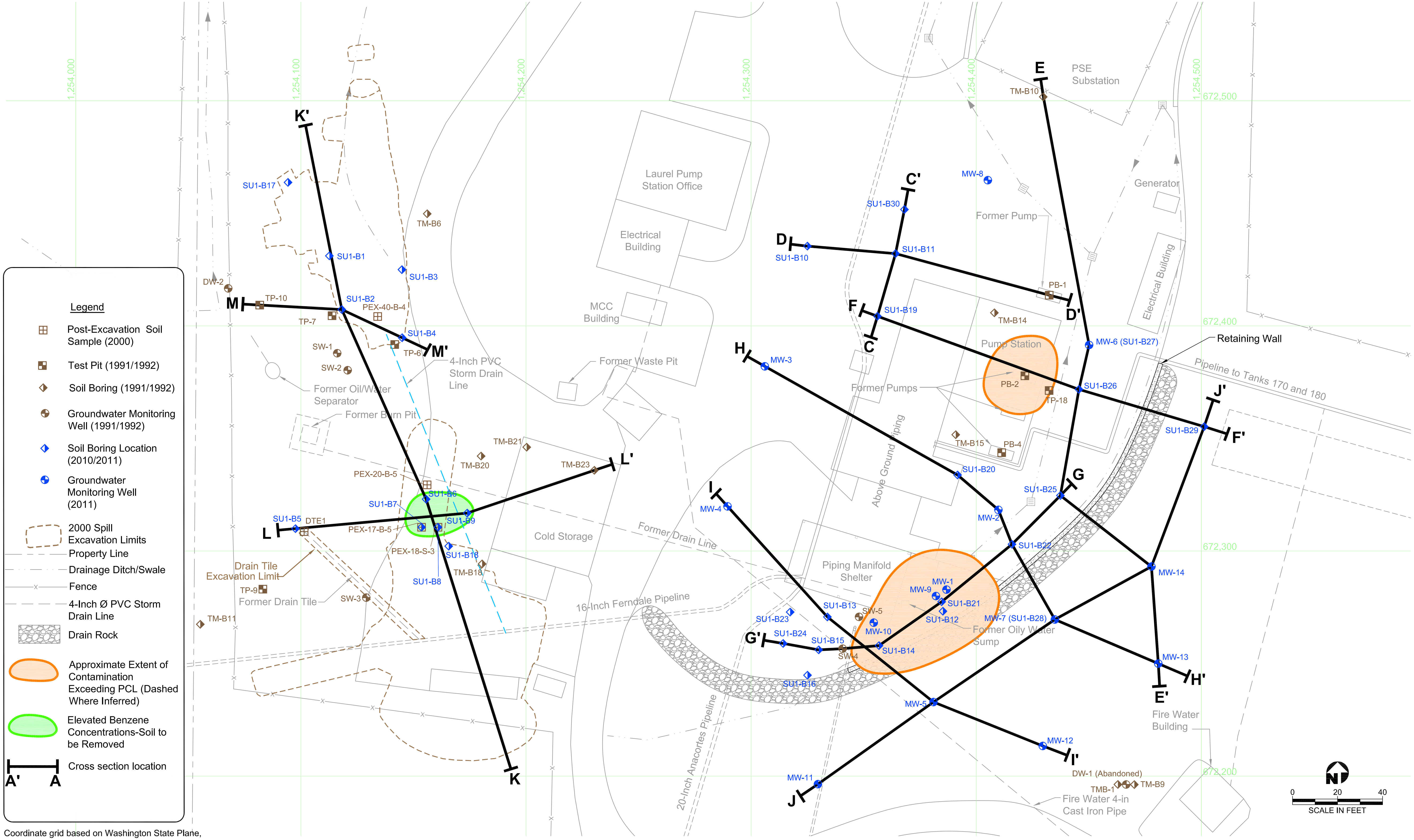
URS

DRAFT
REMEDIAL INVESTIGATION/
FEASIBILITY STUDY REPORT
Public Review Draft
LAUREL STATION
1009 EAST SMITH ROAD
BELLINGHAM, WASHINGTON

For

Trans Mountain Pipeline (Puget Sound) LLC
URS Job No.: 33764322

April 7, 2014



Coordinate grid based on Washington State Plane, North Zone, NAD83

J:\GIS\Projects\Kinder Morgan\Laurel Pump Station\SubTasks\RI-FS\Figure 9 (Unit 1 Samp Locs).dwg
Mod: 01/30/2014, 10:11 | Plotted: 02/10/2014, 09:03 | john_knobbs

Figure 9
Soil Boring/Monitoring Well Locations (Study Unit 1)

URS

Laurel Station
Bellingham, Washington

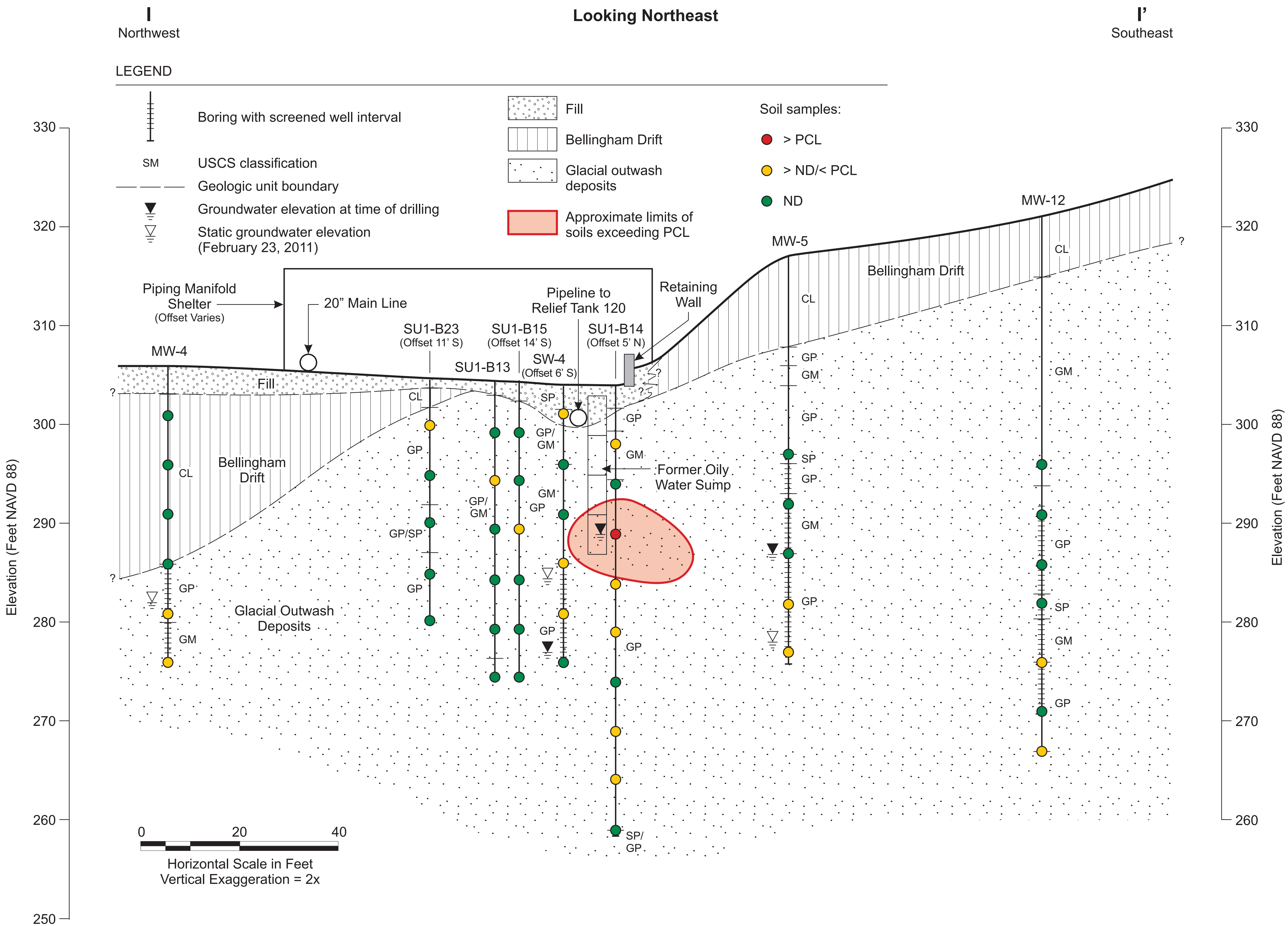


Figure 16
Geologic Cross Section I-I'

URS

Laurel Station
Bellingham, Washington

Project: Laurel Station Data Gap Investigation	# Log of Boring SU1-B14
Project Location: Bellingham, Washington	Sheet 1 of 2
Project Number: 33762344	

Date(s) Drilled	**6/8/10**	Logged By	**IPV**	Checked By	**DRR**
Drilling Method	**Hollow Stem Auger**	Drilling Contractor	**Cascade Drilling Inc.**	Total Depth of Borehole	**45.5 feet bgs**
Drill Rig Type	**Limited Access HSA**	Drill Bit Size/Type	**8.25" OD**	Ground Surface Elevation	**N/A**
Groundwater Level (feet bgs)	**15 and 30 ft**	Sampling Method	**SPT**	Hammer Data	**140#**
Borehole Backfill	**Bentonite Chips**	Location	**Study Unit #1**		

Elevation, feet	Downhole Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery (%)	OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0							GP	Gravel surface Cuttings are gravel	0800
				100/3	70	0.0		GM	Dark gray silty fine subrounded GRAVEL, fine to coarse sand (very dense) (moist) (no hydrocarbon odor)	
	5		SU1-B14-6	100/6		1.2			Grading (slight hydrocarbon odor)	
	10		SU1-B14-10	150/6	90	0.2		GP	Dark gray fine to medium subrounded GRAVEL with fine to coarse sand and silt (very dense) (moist to wet) (no hydrocarbon odor)	Sample moisture increasing
	15		SU1-B14-15	100/4	100	600			Grading dark gray fine to coarse subrounded GRAVEL with fine to coarse sand, trace silt (very dense) (wet) (slight hydrocarbon odor) 15 ft ▼	Soil-Dup-1
	20		SU1-B14-20	100/6	80	450			Grading (moist) (strong hydrocarbon odor, staining?)	
	25		SU1-B14-25	120/4	70	100			Grading (strong hydrocarbon odor)	
			SU1-B14-30	100/4	100	15				0946
	30									

Project: Laurel Station Data Gap Investigation	Log of Boring SU1-B14
Project Location: Bellingham, Washington	
Project Number: 33762344	Sheet 2 of 2

Elevation, feet	Downhole Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery (%)	OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	30								Grading (wet) (slight to moderate hydrocarbon odor)	Take double volume for MS/MSD - cannot get triple volume
	35		SU1-B14-35	100/6	~~100~~	12.5			Grading sandy GRAVEL with increasing sand (moist to wet) (slight hydrocarbon odor)	
	40		SU1-B14-40	100/5	~~90~~	2.5			Grading gray sandy fine to coarse GRAVEL with silt, fine to coarse sand (very dense) (no hydrocarbon odor)	
			SU1-B14-45	100/5	~~100~~	2.2				
	45							SP/GP	Gray sandy fine to medium subrounded GRAVEL to gravelly fine to coarse SAND (very dense) (moist) (no hydrocarbon odor)	1035
									Boring was completed to 45 ft bgs. Groundwater was encountered at 15 and 30-35 ft bgs. Boring was backfilled with bentonite chips.	
	50									
	55									
	60									
	65									

H.Y. Fang
Foundation Engng Handbook
1991

ATTACHMENT 5

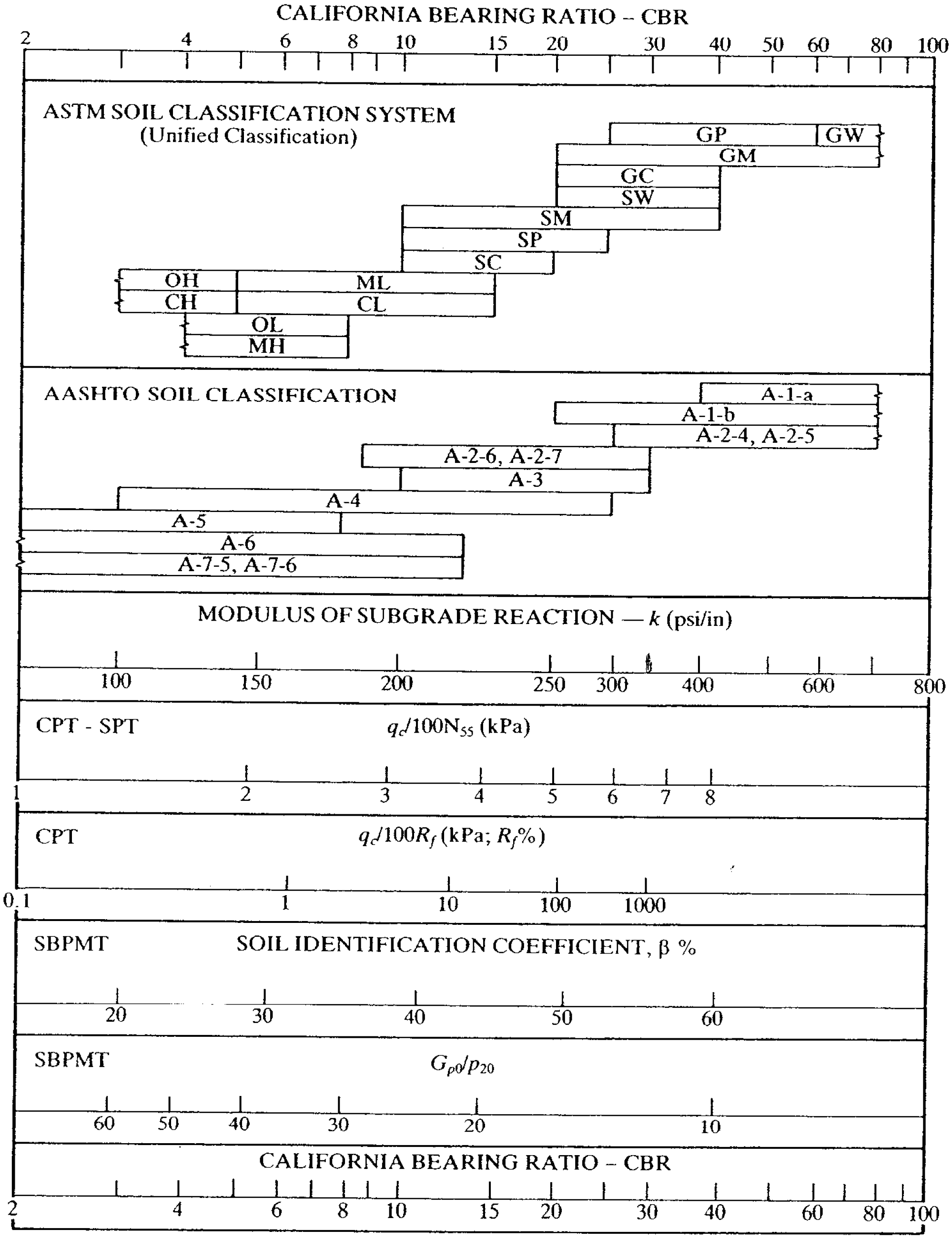


Fig. 3.37 Chart for approximate interrelationships between soil classification, bearing values, and some in-situ parameters: q_c, cone tip bearing; N_{55}, SPT blow count/ft; R_f, friction ratio (percent); G_{p0}, shear modulus at 0 percent strain; p_{20}, pressure at 20 percent strain; CBR, California Bearing Ratio. (*After Pamukcu and Fang, 1989.*)

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Piping Manifold Calculations

URS

Job Laurel station

Description

Project No.

Computed by KSL

Checked by

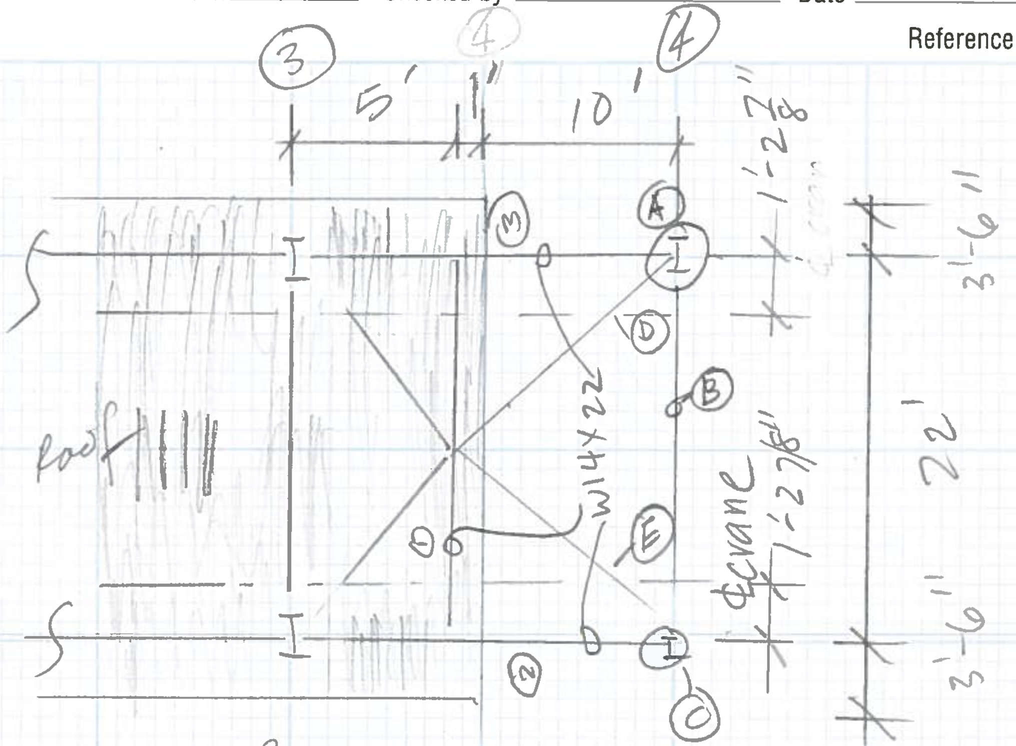
Page ___ of ___

Sheet 1 of ___

Date 6/5/14

Date

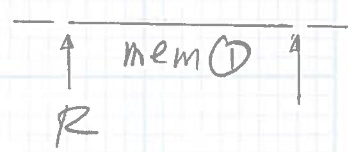
Reference



Estimated D.L. - Roof 15psf

① TRIBUTARY WIDTH $= \left(\frac{5}{2}+1\right) = 3.5'$

$W_{DL} = 15psf \times 3.5' = 52.5 plf$



$R_{D.L.} = 52.5^{plf} \times \left(\frac{22}{2}+3.5\right) = 762\#$

SAY 1000#

- Remove member Ⓐ Ⓑ Ⓒ Ⓓ & Ⓔ

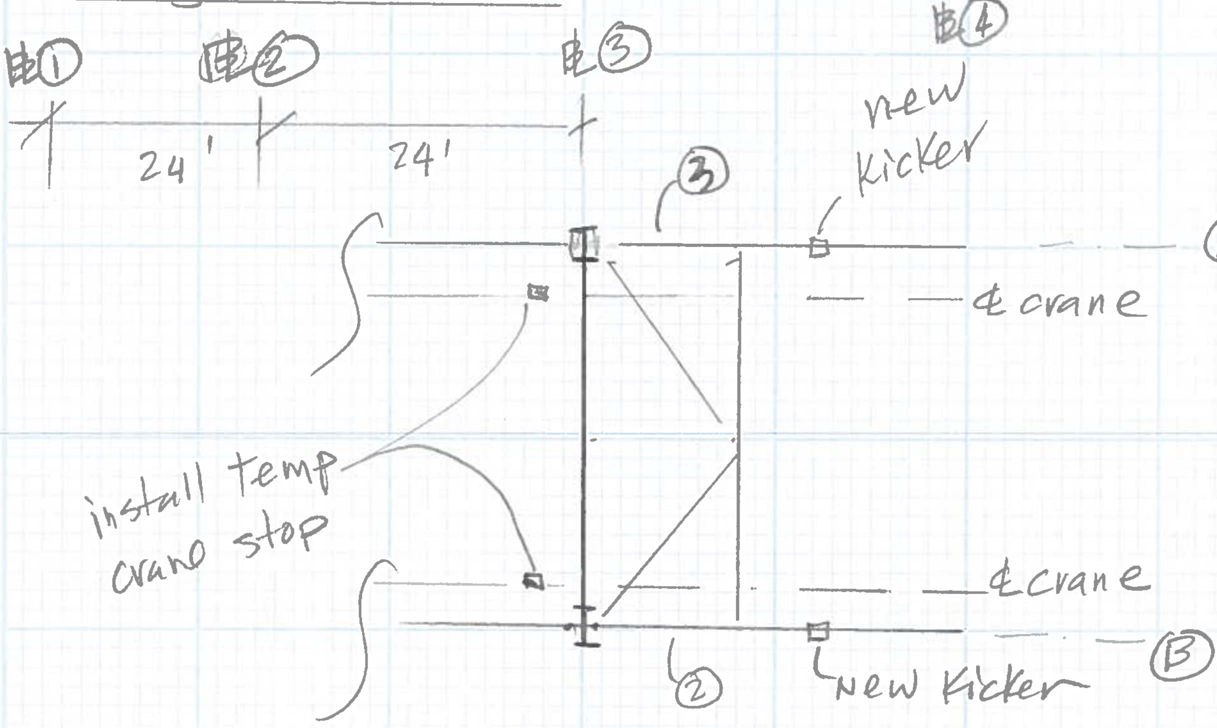
② ADD Kicker to member ② & ③

URS

Job: Laurel station | Project No. | Page ___ of ___
Description: | Computed by: KSL | Sheet 2 of ___
| Checked by: | Date: 6/5/14
| | Date:

Reference

During construction



Assumptions:

Roof D.L. = 15PSF

Crane: will be stationed between ℄ ① & ℄ ③

Roof snow = 0.0 (Summer construction)

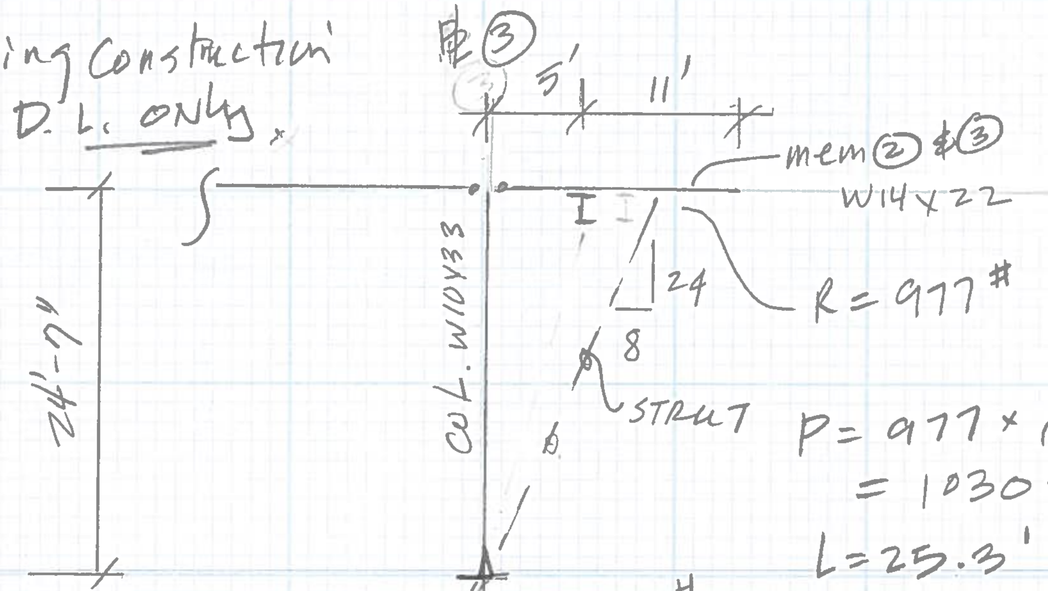
Roof Live load = 0.0 (Not allowed during construction)

URS

Job: Laurel station
Description:
Project No.:
Computed by: K&L
Checked by:
Page ___ of ___
Sheet 3 of ___
Date: 6/5/14
Date:

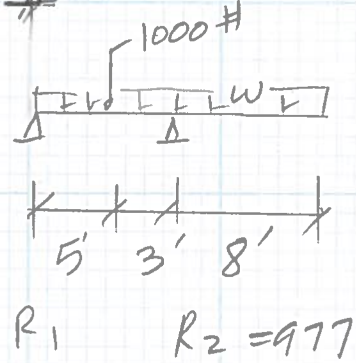
Reference

During construction
D.L. only



$P = 977 \times \sqrt{10}/3$
$= 1030\#$
$L = 25.3'$

mem ②



$R_2 = (1000^{\#} \times 5' + 22^{plf} \times 16' \times 8)/8$
$= 977^{\#}$ ✓

$R_1 = 1000 + 22 \times 16 - 977 = 375^{\#}$ ✓

$M_{support} = 22 \times 8 \times 4 = 704$

$M_{at\ cross\ Bm} = 374 \times 5 - 22 \times 5 \times 2.5 = 1221$ SAY 2000#'

W14x22 SAY unbrace length = 11'

$M_n/\Omega = 50KFT$, $F_y = 50ksi$
$M_n/\Omega = 36K'$, $F_y = 36ksi$
} by inspection, member OK

URS

Job Laurel station | Project No. | Page of
Sheet 4 of
Description | Computed by KBL | Date 6/5/14
Checked by | Date
Reference

Kicker design

P = 1030#

L = 25.3'

TRY L 6 x 6 x 1/2   L = 26'   Pn/Ω = 61^K

w = 39.3 #/FT

better choice

OR WT 6 x 22.5   L = 26'   Pn/Ω = 28.8^K

w = 26.5 #/FT

or 5"Ø x 0.125" HSS   w = 6.5#

Fy = 42 ksi   Pn/Ω = 8.2^K

or 5"Ø pipe standard $\frac{P_n}{\Omega}$ = 22^K

w = 14.6, Fy = 35 ksi

URS

Job Laurel station — Project No. ____ — Page ____ of ____

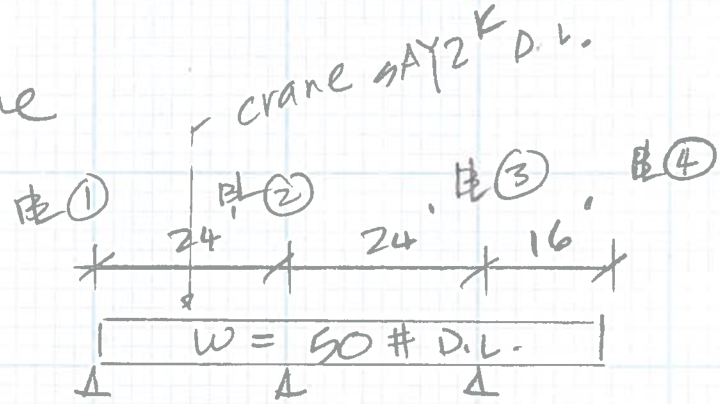
Description ____ — Computed by KSL — Sheet 5 of ____

Date 6/5/14

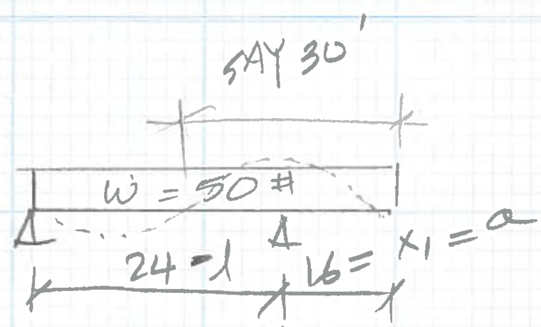
Checked by ____ — Date ____

Reference

Check Bridg crane



IGNORE crane D.L. @ ℄ ① TO ℄ ②



W12X50

$I_x = 391$

$M_2 = wa^2/2 = 50 \times 16^2/2 = 6400^{\#'}$

$$\Delta = \frac{wx_1}{24EI}(4a^2 l - l^3 + 6a^2 x_1 - 4a x_1^2 + x_1^3)$$

$$= \frac{50^{plf} \times 16}{24 \times 29 \times 10^6 \times 391}(4 \times 16^2 \times 24 - 24^3 + 6 \times 16^3 - 4 \times 16^3 + 16^3) \times 12^3$$

23040 ✓ ; 3×16^3

= 0.12"

SAY unbraced 30'

W12x50 $M_n/\Omega = 85^{k-1}$ OK w/o sharing

APPENDIX C

Field Forms

Sampling Record

Client: ______________________ Job Number: ______________
Location: ______________________ Sampled By: ______________
Site Name: ______________________
Date and Time: ______________________

Sample Classification

Soil: ☐ Water: ☐ Excavation: ☐
Boring: ☐ Surface Water: ☐ Pipe Outfall: ☐
Sediment: ☐ Groundwater Seep: ☐ Other: ______________

Sampling Method

Direct Fill Container: ☐ Peristaltic Pump: ☐ Hand Auger: ☐
Remote Fill: ☐ Bailer: ☐ Core Sampler: ☐
Dipper Jar Can: ☐ D M Sampler: ☐ Split Spoon: ☐
Positive Displacement Pump: ☐ Stainless Spoon Trowel: ☐ Other: ______________

Sample Type

Point: ☐ Grab: ☐ Composite: ☐

Sample Information

Sample ID: __________ Sample Depth: __________
Sample Treatment: ______________________
Sample Condition: ______________________

Field Tests (record units)

Temperature: __________ Dissolved Oxygen: __________
Conductivity: __________ Iron: __________
pH: __________ PID: __________
Other: ______________________

Laboratory Information

Laboratory Analyses: ______________________
Number of Containers and ID: ______________________
Field Blank ID: ______________________
Trip Blank ID: ______________________
Duplicate Sample ID: ______________________
Comments: ______________________

Project:	BORING NO. URS
Project Location:	
Project Number:	Sheet of

Location Sketch	Date(s) Drilled		Logged By	
	Drill Bit Size Type		Total Borehole Depth	
	Drilling Contractor		Drill Rig Type	
	Sampling Method(s)		Hammer Data	
	Level Date Measured		Surface Elevation	

Elevation (ft)	Depth (ft)	SAMPLES Type	ID	Blows ft	OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0								
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
	17								
	18								
	19								
	20								

Project:	BORING NO.
Project Location:	
Project Number:	Sheet of

Elevation (ft)	Depth (ft)	SAMPLES Type	ID	Blows ft	OVM (ppm)	Graphic Log	USCS	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS

URS

WELL DEVELOPMENT DATA SHEET

Project Information

Page _____ of _____

Project Name:		Location:	
Project/Task No.:		Weather:	
Date:		Samplers:	

Gauging and Purging Data

Well Number:				Screen Interval:			
Reference Point:		Elevation		Well Diameter:		Annulus Diameter:	
Depth to Water:		Elevation		Gallons per Casing Foot: (2" well: 0.16 gal/ft; 4" well: 0.65 gal/ft)			
Depth to Bottom:		Feet of Water:		Gallons per Annulus Foot: (8" annulus with 2" casing = 1.85 gal/ft; 6" annulus with 2" casing = 1.34 gal/ft)			
Purge Method:				One Purge Volume:			
Water Disposal/Qty:				Final Purge Volume:			

Meter Information

	Model	Calibration Date	Comments
pH:			
Eh:			
Conductivity:			
DO Meter:			
Turbidity:			
Temperature:			
Other:			

Field Parameters

Volume (gallons)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DO (mg/L)	Temperature (ºC)	ORP (mV)	Time (24 hr)
0							

Comments

WELL DEVELOPMENT DATA SHEET (continued)

Date: ________________ Well ID: ________________ Page ______ of _______

Volume (gallons)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DO (mg/L)	Temperature (ºC)	ORP (mV)	Time (24 hr)

Comments

GROUNDWATER SAMPLING DATA SHEET

Project Information

Page _____ of _____

Project Name:		Location:	
Project/Task No.:		Weather:	
Date:		Samplers:	

Gauging and Purging Data

Station Number:				Screen Interval:	
Station Type:				Well Diameter: ______ Annulus Dia.:	
Well Condition:				Gallons per Casing Foot: (2" well: 0.16 gal/ft; 4" well: 0.65 gal/ft)	
Reference Point:		Elevation:		Gallons per Annulus Foot: (8" annulus with 2" casing = 1.85 gal/ft; 6" annulus with 2" casing = 1.34 gal/ft)	
Depth to Water:		Elevation:		One Purge Volume:	
Depth to Bottom:		Feet of Water:		Final Purge Volume:	
Depth to LNAPL:		Thickness:		Purge Method:	
LNAPL Description:				Water Disposal/Qty:	

Containers

Analysis	Type	Primary Qty	MS/MSD Qty

Meter Information

Model & Calibration Date

pH:	
Eh:	
Conductivity:	
DO Meter:	
Turbidity:	
Temperature:	
Other:	

Sampling Data

Sample Name:	
Sample Method:	
Sampling Device:	
Tubing Depth:	
Pump Intake Depth:	

Field Test Kit Results:

PID:	
DO:	
Alkalinity:	
Ferrous Iron:	
Other:	

QA/QC Samples:

Duplicate:	
Replicate:	
MS/MSD:	
Blank:	
Other:	

Field Parameters

Volume (gallons)	pH (SU)	Conductivity (mS/cm)	Turbidity (NTU)	DO (mg/L)	Temperature (ºC)	ORP (mV)	Time (24 hr)	Water Level (Ft below TOC)	Flow Rate (L/min)
0									

Comments

URS

GROUNDWATER SAMPLING DATA SHEET (continued)

Date: ____________ Well ID: ______________________ Page ______ of _______

Volume (gallons)	pH (SU)	Conductivity (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temperature (ºC)	ORP (mV)	Time (24 hr)	Water Level (Ft bTOC)	Flow Rate (L/min)

Comments

PHOTOGRAPH LOG

Project Information

Project Name:		Location:	
Project/Task No.:		Weather:	
Date:		Personnel:	

Photograph Information

	File Name	Photograph Description (Subject, Direction of View, Etc)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
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23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		

Comments / Site Activities

URS

DAILY FIELD LOG

Project Information

Project Name:		Location:	
Project/Task No.:		Weather:	
Date:		Personnel:	

Observations

	Time	Observation Description
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
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29		
30		
31		
32		
33		

Comments / Site Activities / Personnel Tracking

APPENDIX D

Specifications List

Specifications to be Provided With Design Package

Section 01 00 00	Abbreviations and Acronyms
Section 01 11 00	Summary of Work
Section 01 33 00	Submittal Procedures
Section 01 50 00	Temporary Construction Facilities, Controls, and Construction Safety
Section 01 57 19	Temporary Environmental Controls
Section 02 61 13	Excavation and Handling of Contaminated Materials
Section 02 81 00	Transportation and Disposal of Waste Materials
Section 03 30 00	Cast-In-Place Concrete
Section 22 11 00	Piping and Equipment
Section 22 14 20	Storm Drainage Piping and Equipment
Section 26 05 19	Low-Voltage Electrical Power Conductors and Cables
Section 26 05 26	Grounding and Bonding for Electrical Systems
Section 26 05 33	Raceways and Boxes for Electrical System
Section 26 24 19	Motor Control Centers
Section 31 00 00	Earthwork
Section 31 00 10	Strategic Source Removal
Section 32 12 16	Hydraulic Asphalt Concrete
Section 32 32 23	Retaining Wall Removal and Reconstruction
Section 32 92 19	Site Restoration and Seeding
Section 33 23 13	Well Abandonment, Installation, and Protection
Section 44 20 00	Prefabricated Dual-Phase Extraction System
Section 44 30 00	DPE System O&M