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June 15, 2016

Jeffry Rodin, On-Scene Coordinator
United States Environmental Protection Agency, Region 10
1200 Sixth Avenue, ECL-133
Seattle, WA 98101

RE: 90% Work Plan and Conceptual Design
Bremerton Auto Wrecking Landfill Site, Port Orchard, Washington
Contract Number EP-S7-13-07, Technical Direction Document Number 16-04-0001

Dear Mr. Rodin:

Enclosed please find the 90% Work Plan and Conceptual Design for the Bremerton Auto Wrecking Landfill Site located in Port Orchard, Washington. If you have any questions regarding this report, please call me at (206) 624-9537.

Sincerely,

Steven G. Hall
START-IV Removal Team Leader

Enclosure

cc: Jake Moersen, Ecology and Environment, Inc.
Tom Campbell, P.E., Ecology and Environment, Inc.

90% WORK PLAN AND CONCEPTUAL DESIGN

Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

START IV
Region 10

June 2016

Prepared for:

U.S. Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900
Seattle, Washington 98101

Prepared by:

ECOLOGY AND ENVIRONMENT, INC.
720 Third Avenue, Suite 1700
Seattle, Washington 98104

PROFESSIONAL ENGINEER CERTIFICATION PAGE

WORK PLAN AND CONCEPTUAL DESIGN
Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

I hereby certify that this 90% Work Plan and Conceptual Design for the Bremerton Auto Wrecking Landfill Site in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE:

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 4/13/2016

THOMAS C. CAMPBELL
STATE OF WASHINGTON
51283
REGISTERED
PROFESSIONAL ENGINEER

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List of Abbreviations and Acronyms

BMP	Best Management Practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHSP	Contractor Health and Safety Plan
CQAP	Construction Quality Assurance Plan
DCD	Kitsap County Department of Community Development
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
E & E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ERRS	Emergency and Rapid Response Services
ESA	Endangered Species Act
HASP	site-specific health and safety plan
HPA	Hydraulics Project Approval
LWD	large woody debris
mg/kg	milligram per kilogram
MM&R	Monitoring, Maintenance and Repair
MTBE	methyl tert-butyl ether
MTCA	Washington Model Toxics Control Act
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PBoD	Preliminary Basis of Design
PCB	polychlorinated biphenyl
PM	project manager
PSCP	Permanent Stormwater Control Plan
RCW	Revised Code of Washington
RD	Removal Design
ROW	right-of-way
Site	Gorst Creek-Bremerton Auto Wrecking Landfill Site
SQuiRT	Screening Quick Reference Tables
SR	site representative
START	Superfund Technical Assessment and Response Team
SVOC	semivolatile organic compound
SWPPP	Stormwater Pollution Prevention Plan
TDD	Technical Direction Document
U.S.C.	United States Code
VOC	volatile organic compound

WM	Waste Management Corporation
WDFW	Washington Department of Fish and Wildlife
WSDOT	Washington State Department of Transportation

1 Introduction

Ecology and Environment, Inc. (E & E) has been tasked by the U.S. Environmental Protection Agency (EPA) under Superfund Technical Assessment and Response Team (START)-IV contract number EP-S7-13-07, Technical Direction Document (TDD) 16-04-0001, to provide support for a removal action at the Gorst Creek-Bremerton Auto Wrecking Landfill Site (Site).

EPA is performing a non-time-critical removal action in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. Funding for the removal action will be provided through an agreement pursuant to Section 122 of the CERCLA, 42 United States Code (U.S.C.) § 9622, between EPA, the ST Trust, and the U.S. Department of the Navy.

The removal design that is being developed is considered conceptual and identifies parameters to be used during construction; it will be considered final following construction under the direction of a Federal On-Scene Coordinator. An EPA Region 3 Emergency and Rapid Response Services (ERRS) contractor, Guardian Environmental Services, will contract construction-related subcontractors including a geotechnical engineering firm for assessing slope stability. General construction site guidelines will be implemented to protect the community and workers throughout the duration of the removal action activities. Best Management Practices (BMPs) will be implemented to control for potential short-term cleanup-related impacts to workers, the community, and the environment.

This 90% Work Plan and Conceptual Design Report is composed of four sections. Section 1 presents the introduction, states the purpose for developing the report, summarizes background information about the Site, and provides an overview of the existing site conditions. Section 2 presents preliminary surveys and investigations to assist in the planning of the removal action, and Section 3 discusses the proposed design and describes additional considerations for the removal action. Section 4 is a list of the references used in this report.

1.1 Site Description and Background

The Site is located at 4275 State Highway 3 SW, approximately 5 miles southwest of Port Orchard, 6 miles south-southwest of Bremerton, and 1.5 miles west of Gorst, Washington (see Figure 1-1, Site Location Map). The Site coordinates are latitude 47.509968° and longitude -122.740767° in the northwest quarter of the southwest quarter of Section 1, Township 23 North, Range 1 West. The Site is identified by the Kitsap County Tax Assessor as parcel 012301-4-022-1005. It is a triangular parcel centered over approximately 700 feet of the Gorst Creek Ravine (Figure 1-2, Site Conditions (2000)). Vehicle access to the site has historically been obtained from the northeast through the adjacent former auto wrecking yard (Airport Auto Wrecking). The Washington State Department of Transportation (WSDOT) owns the property directly north and west of the landfill. This property contains State Highway 3 SW and an easement corridor on either side of the highway. The property to the south-southwest is owned by Alpine Farms and was formerly operated as a tree farm. McCormick Land Company owns the property south-southeast of the site. A private landowner owns the parcel of land east-northeast of the landfill. Gorst Creek acts as the property boundary between McCormick Land Company and the private landowner.

The Site is a former landfill that operated from approximately 1968 to 1989. The Site is estimated to contain approximately 150,000 cubic yards of waste, including automotive wrecking debris, construction debris, industrial trash, medical wastes, and other wastes from public dumping. The sources of the waste disposed of at the Site include the adjacent automotive wrecking yard, the Puget Sound Naval Shipyard, construction and demolition companies, and residential dumping. Landfilling operations at the Site ceased in 1989, but the landfill was not closed pursuant to applicable landfill closure regulations.

The Site is located within Gorst Creek, a tributary of the Sinclair Inlet of the Puget Sound, approximately 2.5 miles upstream of Gorst Creek’s confluence with Puget Sound at Sinclair Inlet. The Suquamish tribe operates two Chinook rearing ponds and yearling fall Chinook raceways within the lower main stem of Gorst Creek. The program was established in 1981 as a cooperative effort with Washington Department of Fish and Wildlife (WDFW), the City of Bremerton, and the Poggie Club to provide salmon for both Tribal and sport harvest (Suquamish Tribe 2015).

In 1968, a 24-inch corrugated steel culvert was installed along the base of the Gorst Creek ravine so that the ravine could be filled with waste and Gorst Creek could flow through the culvert beneath the landfill (Figure 1-3, Site Plan (1968)). The ravine was 60 to 80 feet deep at this location before landfilling operations began in 1968. Gorst Creek currently flows northwest under the property through an approximate 880 foot-long 24-inch corrugated steel culvert (E & E 2004). Downstream of the landfill, Gorst Creek flows under State Highway 3 SW through a box culvert. Waste was placed on top of the culvert until the top of the waste became approximately even with the top of the ravine. In 1997 and 2002, after significant storm events, Gorst Creek backed up on the southeast side (upstream side) of the landfill and overtopped the surface of the landfill, causing a portion of the northwest slope of the landfill to fail and wash downstream into Gorst Creek. Review of a 2003 inspection video (Bravo Environmental 2003) revealed a collapse of the culvert approximately 460 feet upstream of the outflow, severely diminishing the maximum flow capacity of the culvert. A partial collapse was also noted approximately 20 feet downstream of the culvert inflow. Landfill debris was found approximately 0.5 miles downstream in Gorst Creek.

1.2 Previous Site Investigations and Cleanup Activities

Several investigations and cleanup activities have been performed to determine the potential risk of exposure for human health and the environment from Site sources. Site investigations and assessments have detected an array of hazardous substances in environmental media at and downstream of the landfill, including chlorinated pesticides, polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and metals. There is substantial information indicating that human health and environmental impacts are present at the Site. Substances found at the Site, including the substances identified above, constitute "hazardous substances" as defined by Section 101(14) of CERCLA, 42 U.S.C. § 9601(14).

EPA conducted a preliminary assessment at the Site in 2003 and an integrated assessment in 2003–2004. During the integrated assessment, subsurface samples were collected from six boreholes drilled directly into the landfill, and six surface soil samples were also collected at the same locations. Sediment samples were collected from Gorst Creek downstream of the landfill between the landfill and State Highway 3, downstream of State Highway 3, and just upstream of the landfill near the southeastern slope of the landfill. The results of the integrated assessment indicated that the Aroclor 1254, benzo(a)pyrene, benzo(a)anthracene, and lead in Site soil samples exceeded health-based screening levels. Dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), Aroclor 1254, and copper exceeded the National Oceanic and Atmospheric Administration Screening Quick Reference Tables (SQuiRT) screening levels in sediment samples located between the landfill and State Highway 3 and downstream of State Highway 3. In addition to these contaminants of concern, the integrated assessment noted that medical waste may also be present in the landfill; this seems to be confirmed by the presence of medical waste found in solid waste downstream of the landfill.

In an effort to collect additional information to prepare the Engineering Evaluation/Cost Analysis (EE/CA), EPA collected additional surface soil samples and sediment samples in July 2011. Surface soil samples were collected from seven locations in the landfill from the surface to 6 inches depth. Laboratory results indicated chromium at concentrations ranging from 19.6 milligram per kilogram (mg/kg) to 47.8 mg/kg, exceeding the EPA Regional Screening Level of 5.6 mg/kg for industrial soils, and the Washington Model Toxics Control Act (MTCA) Method A level of 19 mg/kg. Sediment samples from Gorst Creek were tested using 10-day midge (*Chironomus dilutus*) and 28-day amphipod (*Hyalella azteca*) sediment bioassays, as well as chemical analyses for VOCs, SVOCs, pesticides, PCBs, and metals. While no EPA or MTCA screening level exceedances of chemicals of potential concern were observed in the sediment samples, the sediment screening results suggest that growth of benthic organisms may be impaired in Gorst Creek, which may result in less prey for fish, amphibians, and other organisms that feed on benthic organisms. Consequently, sediment contamination may be having a negative impact.

EPA collected subsurface soil samples and a groundwater sample in August 2011 using an auger drilling rig. The chemicals of potential concern that exceeded the MTCA's cleanup levels and EPA's Regional Screening Levels for Chemical Contaminants at Superfund Sites included three metals (arsenic, chromium, and cobalt) and two VOCs (chloroform and methyl tert-butyl ether [MTBE]).

In addition to being a source of chemical contaminants to downstream receptors, the landfill has released solid waste into Gorst Creek as a result of high stream flows overtopping and scouring the landfill. On several occasions following significant storm events, Gorst Creek backed up on the southeast side (upstream side) of the landfill and overtopped the surface of the landfill, causing a portion of the northwest slope of the landfill to fail and wash waste downstream into Gorst Creek. A more thorough discussion of the Site investigations and data is presented in the EE/CA completed for the Site (E & E 2012).

1.3 Purpose of the Design Report

The purpose of this 90% Work Plan and Conceptual Design Report is to compile, for EPA Region 10 and stakeholder review, the functional and technical requirements and provisions applicable to the removal action, which include the following:

- Work plan assumptions and parameters, including technical and functional restrictions based on results of previous investigations;
- Stream restoration design calculations, including determination of hydrologic, hydraulic, and slope stability characteristics;
- Plans showing site and equipment layouts, process flows, and locations of construction activities;
- Requirements for equipment and identification of long-lead procurement items;
- Determination of governing disposal, emission, and discharge requirements;
- Identification of regulatory agency permits, coordination with outside agencies, site access agreements, and easements; and
- Final construction quality assurance objectives.

Comments from EPA, WDFW, and Suquamish Tribe Fisheries Department on the 30% and 60% Work Plan and Conceptual Design Report submittals have been incorporated into this 90% Work Plan and Conceptual Design Report package. Adjustments to the scope and direction of the project were discussed and agreed upon between ERRS, START and EPA Region 10 so that major revisions were incorporated prior to submission of the 90% Work Plan and Conceptual Design Report documents.

The removal work plan will be a comprehensive set of documents designed to meet the cleanup objectives established for the Site. EPA Region 10 will hold the contract with the selected removal action contractor. ERRS has prepared the construction schedule and Contractor Health and Safety Plan (CHSP). Additionally, START will draft the Monitoring, Maintenance and Repair (MM&R) Plan; however, following the EPA's comments upon completion of site construction activities, the MM&R Plan will require additional review and finalization.

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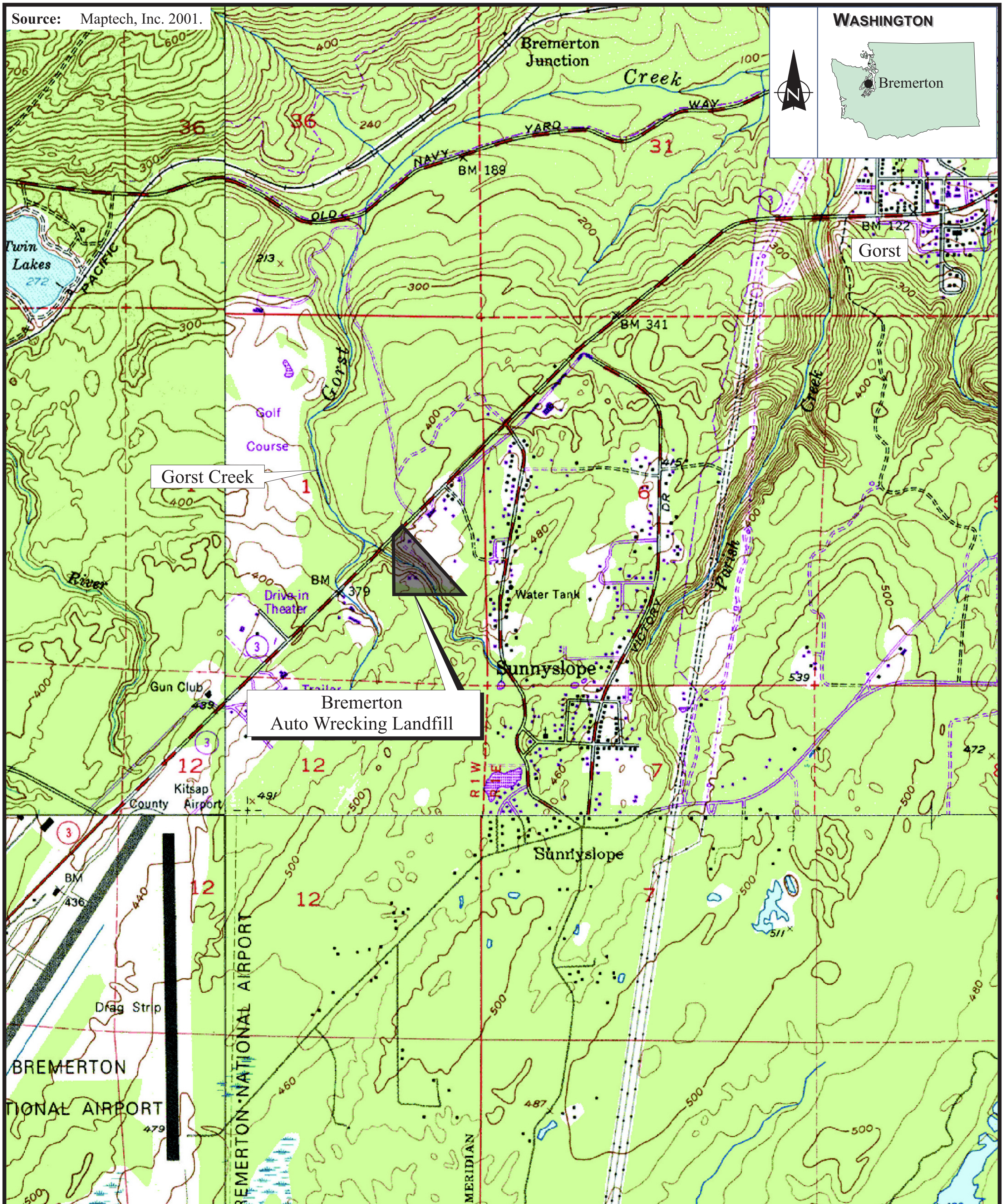
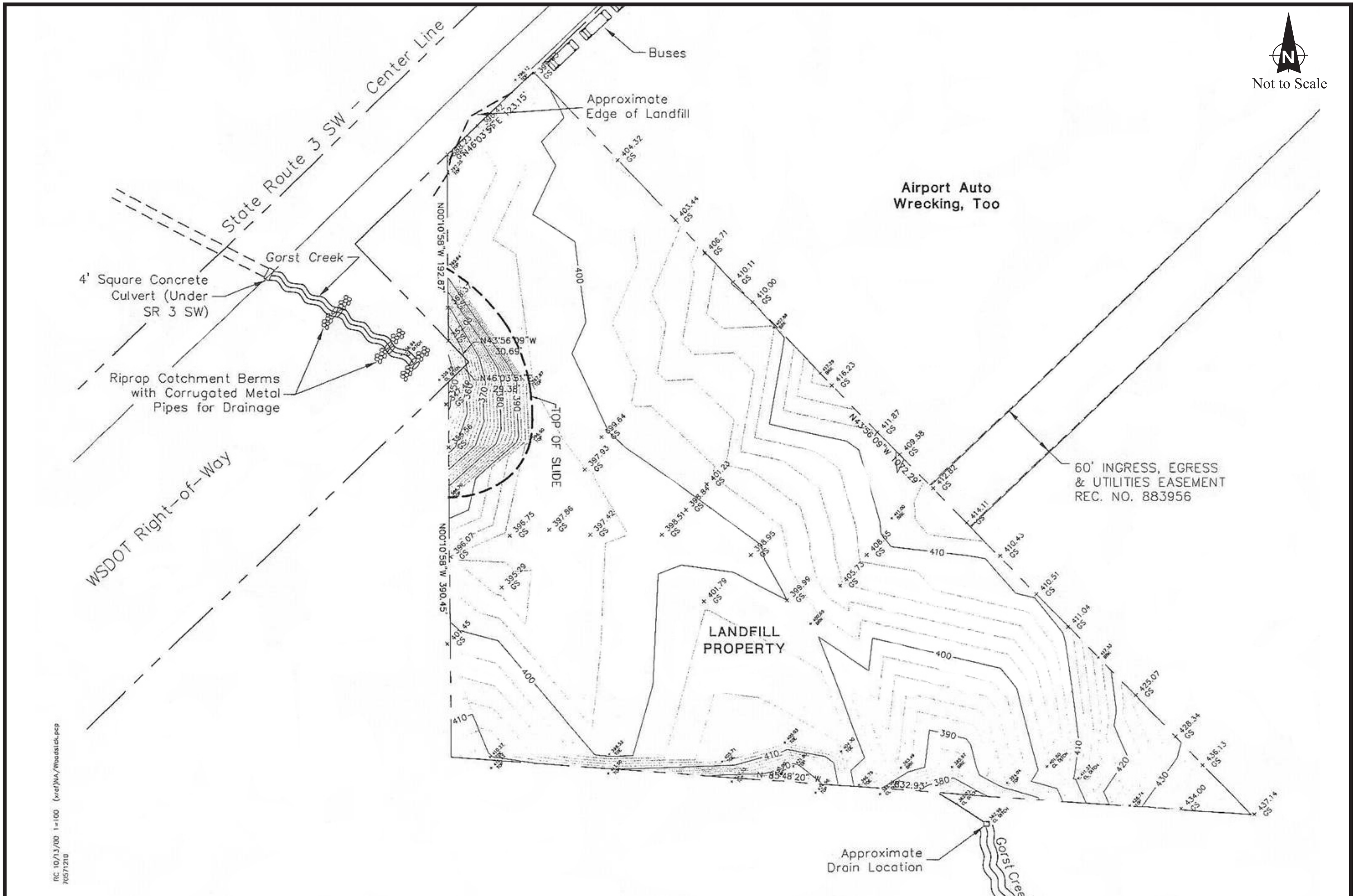


ecology and environment, inc. Global Environmental Specialists Seattle, Washington	GORST CREEK-BREMERTON AUTO WRECKING LANDFILL Port Orchard, Washington	Figure 1-1 SITE LOCATION MAP
	0 1000 2000 Approximate Scale in Feet	Date: 10-1-15 / Drawn by: AES / 10:START-IV\08090006\fig 1-1



ecology and environment, inc. Global Environmental Specialists Seattle, Washington	GORST CREEK-BREMERTON AUTO WRECKING LANDFILL Port Orchard, Washington	Figure 1-2 SITE CONDITIONS (2000)		
	Source: EPA, 2002.	Date: 10-1-15	Drawn by: AES	10:START-IV\08090006\fig 1-2

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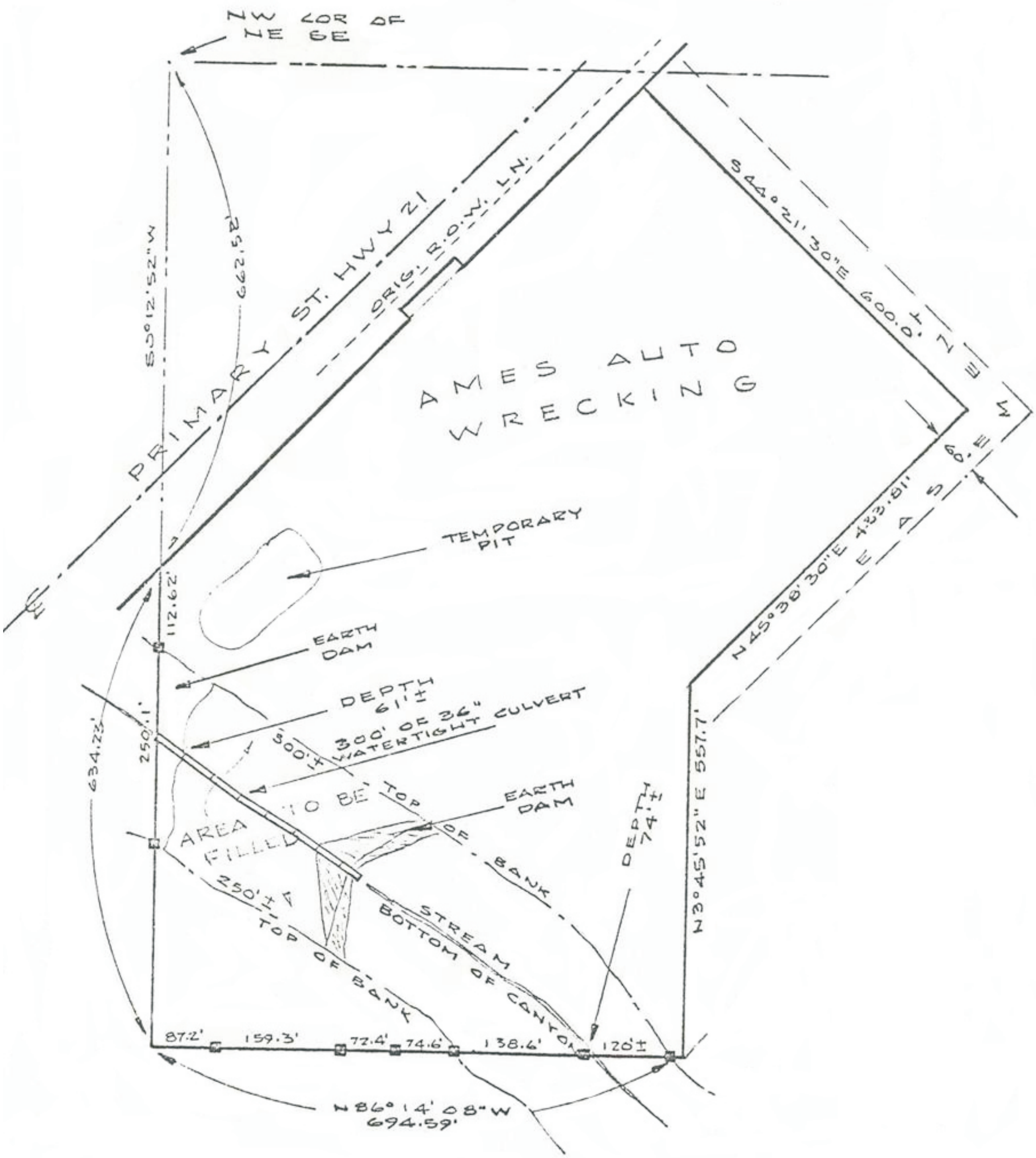

ecology and environment, inc.
Global Environmental Specialists
Seattle, Washington

GORST CREEK-BREMERTON
AUTO WRECKING LANDFILL
Port Orchard, Washington

Figure 1-3

SITE PLAN (1968)

Source: EPA, 2002.

Date:	Drawn by:	
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2 Preliminary Surveys and Data Collection

This section details Site surveys and investigations performed to assist in the planning of the removal action and provide compliance with certain applicable regulations.

2.1 Cultural Resources Survey

To comply with Section 106 of the National Historic Preservation Act of 1966, EPA has submitted the necessary forms for completion of a Site cultural review to the Washington State Department of Archaeology and Historic Preservation. The findings of this review are on file with EPA.

2.2 Endangered Species Act/Threatened & Endangered Species Survey

To comply with the Endangered Species Act (ESA), EPA coordinated with the United States Fish and Wildlife Service, WDFW, Washington State Department of Natural Resources, and National Marine Fisheries Service, a branch of National Oceanic and Atmospheric Administration regarding the presence of sensitive plant and animal species in the Site vicinity. START conducted a review of potential effects of the Gorst Creek removal action on any federal threatened or endangered species that could potentially occur near the site. The review was directed to federal agencies and thus only regards species that are listed, candidates for listing, or proposed for listing under the ESA that have been determined to possibly occur in the suggested action area. The suggested action area included the Site and downstream of the Site.

START prepared a memorandum detailing the findings from which EPA drafted a No Effect letter to the relevant federal agencies (USFWS and NOAA Fisheries). The EPA received a review and concurrence letter of the findings in March 2016, and the memorandum is on file with EPA.

2.3 Topographic Survey

A topographic survey of the Site in the summer and fall of 2011 used topographic elevations on a 50-foot grid to establish 1-foot contours. The topographic survey was used to establish cross-sections and profile of the upstream and downstream reaches of Gorst Creek adjacent to the culverted section beneath the landfill.

Following consultation with WSDOT, an additional survey was procured through the ERRS contractor in May 2016 to provide stream channel cross sections downstream of State Highway 3 SW. START used the additional survey to verify that the proposed channel configuration upstream of State Highway 3 SW would tie into the downstream channel. The 90% design incorporates these results. The results of the survey are shown on Figure C-2 in the conceptual design drawings included in Appendix A.

2.4 Geotechnical Sampling

Geotechnical borings were advanced by EPA in August 2011 on the north and south sides of Gorst Creek, with samples submitted for geotechnical analysis. The drilling was performed using a hollow stem auger with soil cuttings continuously logged by a geologist. The results were used to perform preliminary slope stability analysis calculations to evaluate the performance of the conceptual Gorst Creek restoration design. Results of the geotechnical analysis are included within the slope stability analysis technical memorandum; this is included along with other design memoranda in Appendix B. The ERRS contractor will retain a geotechnical engineering design form to perform slope stability analysis as the removal action progresses to ensure the safety of personnel working on or near the slopes created through landfill excavation.

2.5 Reference Reach Survey

An investigation of reference reach conditions was conducted by START from November 18 to 20, 2015. The investigation focused on the physical habitat and geomorphological conditions of the stream channel and floodplain. The survey design was influenced by the Stream Habitat Restoration Guidelines (Cramer 2012) and included the following observations and measurements:

1. Channel unit type identification, assessment of wetted channel dimensions, bank stability, and riparian vegetation composition according to the methods recommended in the Stream Inventory Handbook Level I & II (USFS 2012).
2. Large Woody Debris (LWD) assessment derived from guidance by USFS (2012) and Schuett-Hames et al. (1999).
3. Topographic survey according to Harrelson et al. (1994).
4. Pebble counts as guided by Kondolf (1997).

Assessment of wetted channel dimensions, bank stability, riparian vegetation, and LWD diameter and abundance was conducted within each identified channel unit type and throughout the entirety of the reference reaches. Topographic surveys and pebble counts were conducted in three separate channel units—one in the Gorst Creek reference reach and two in the Parish Creek reference reach. Topographic surveys were conducted within representative cross-sections and profiles; cross-section surveys extended to well above the bankfull elevation.

Pebble counts were conducted within the surveyed segments to determine channel substrate size distributions.

The survey included photographic documentation of channel units and their adjacent riparian areas. Appendix E in the 60% Design Report contained additional information, including findings, from the reference reach survey; the report has not been included here but findings from the survey have been incorporated into the design and are summarized in the WSDOT Preliminary Basis of Design (PBoD) report prepared for EPA and WSDOT by START and included as Appendix C.

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3 Preliminary Approach and Conceptual Design

Site controls and BMPs will be implemented during construction activities to protect workers, the community, and the environment from short-term construction impacts such as erosion, sedimentation, fugitive dust, and other similar potential impacts. Non-hazardous materials and wastes such as inert construction debris will be disposed of or recycled in accordance with appropriate solid waste disposal or recycling requirements.

The following subsections describe the preliminary approach and conceptual design for the proposed removal action. The removal action began in April 2016 and has been estimated to take up to 10 months to complete. The details presented below and in the accompanying appendices will be used as a basis for conducting the removal action. It is anticipated that Site conditions will vary as construction and excavation activities progress. This will result in field modifications to this preliminary approach and conceptual design.

3.1 Scope of Work

In general, the scope of work/conceptual design for the removal action includes:

- Preparation of support and laydown areas;
- Bypassing of Gorst Creek throughout the construction period;
- Removal of landfill waste with off-site transportation and disposal;
- Grading and stabilization of Gorst Creek ravine within the property boundaries upstream of State Highway 3 SW;
- Construction of Gorst Creek normal flow and overflow channel profiles utilizing fish passage criteria;
- Planting and stabilization of channel and ravine slopes; and
- Restoration of support and laydown areas.

3.2 Removal Assumptions

Based upon information available at the time of design, the proposed removal action will not impede future actions. The recommended response action may be the first and only action or one of a series of actions, depending on post-removal activities such as those necessary to maintain the protectiveness of the cleanup. If an impediment to future actions or maintenance activities is identified during design implementation, then attempts will be made to remedy it. The following removal assumptions have been made in developing this conceptual design.

3.2.1 Substantive Requirement Goals

The removal action is being performed under CERCLA and is therefore exempt from administrative permitting requirements for the actions performed. This does not preclude site work from meeting the substantive requirements of Federal, State, and local regulations. The following substantive requirements will be achieved throughout the removal action.

Under Chapter 77.55 Revised Code of Washington (RCW), the Hydraulics Act, the WDFW has the authority to require actions when stormwater discharges related to a project would change the natural flow or bed of state water. The implementing mechanism is the issuance of a Hydraulics Project Approval permit. In exercising this authority, the WDFW may require compliance with the Stormwater Management Manual for Western Washington or more stringent requirements determined necessary to meet statutory obligations to protect fish and wildlife. Additionally, for construction projects disturbing 7,000 square feet or more of land a National Pollutant Discharge Elimination System construction stormwater permit is required through the Washington State Department of Ecology (Ecology).

To address requirements of both the WDFW and Ecology, a Construction Stormwater Pollution Prevention Plan (SWPPP) has been prepared. The Construction SWPPP identifies how the project intends to control pollution generated during the construction phase only, mainly erosion and sedimentation. The reconstructed stream will mimic predevelopment conditions of the site; therefore, no permanent BMPs that require maintenance will be constructed. The SWPPP was included in the 60% Design. The SWPPP, SWPPP inspection forms, and monitoring data are located in the EPA Site Command Post during the removal action.

The Kitsap County Department of Community Development (DCD) Critical Areas Ordinance has setbacks for work conducted adjacent to streams and in geo-hazard areas. Gorst Creek is categorized as a Type F – fish bearing stream. Type F streams require setbacks of 150 feet where no clearing or grading may take place. Similarly, under the ordinance, this area of Gorst Creek is considered a high hazard area for geo-hazards. High hazard areas must maintain a native vegetation buffer from the toe of the slope to 25 feet beyond the top of the slope. Removal of trees requires approval and field marking. Under the ordinance, clearing, grading, and filling are permitted between April 1 and October 1 only. For this project, work will be performed within the required setback, including both clearing and grading, and in order to complete the project in one calendar year, work will occur outside the permitted calendar dates. To comply with the requirements of a Critical Area Buffer Reduction Request, the prepared SWPPP includes erosion and sediment controls for wet weather work.

Kitsap County DCD requires a Site Development Activity Permit when grading is greater than 150 cubic yards, the final constructed slope exceeds 5 feet in height, existing drainage courses are diverted, or land clearing occurs within the mandatory setback of a stream or on slopes greater than 30 percent. Consultation with Kitsap County DCD was initiated to meet the substantive requirements of this permitting process.

Work occurring within WSDOT right-of-way (ROW) requires an ROW work permit. It is anticipated that some clearing and channel work for this project will occur within the WSDOT ROW. EPA has consulted with WSDOT to meet the substantive requirements of this permitting process. Additionally, EPA and START met with WSDOT in March 2016 to address future plans for replacement of the State Highway 3 SW box culvert which acts as a barrier to fish passage. START performed calculations and prepared a PBoD report detailing the primary design objectives for a new crossing to be designed and constructed by WSDOT to provide fish passage and ecological connectivity of the upstream and downstream restoration sites. A copy of the memorandum is included in Appendix C.

3.2.2 Areas Targeted for Excavation

The details presented below and on Figure C-3 in Appendix A, which show the conceptual Site layout and excavation areas for the removal action, will be used as a basis for conducting the removal action. It is probable that upon implementation of excavation and other removal activities, actual Site conditions will result in field modifications to the presented approach.

As stated previously, the project will include removal of landfill waste. Landfill waste will be removed to the depth of the 24-inch corrugated metal pipe. This will result in what is anticipated to form the restored Gorst Creek ravine. Confirmation sampling will determine whether additional material beneath the pipe requires removal. START used known geologic characteristics from the 2011 sampling event to determine channel stability following landfill removal (although variations in geology may be present and will be assessed as the removal action progresses). Information on removal action operations is presented in Section 3.4.

3.2.3 Volume of Waste

The volume of landfill waste has been estimated at 150,000 cubic yards. This entire volume of material is anticipated to be excavated from the Site and segregated for transportation to recycling or disposal facilities. Removal extents will be determined based on field screening and visual observations. Field screening techniques are presented in Section 3.6.1. The effectiveness of the screening methods will be evaluated at the onset of the project and will undergo further evaluations throughout the removal process.

The EE/CA (E & E 2012) and subsequent cost memorandum (E & E 2015) presented removal volumes from estimates created by START. The total quantity of waste in the landfill has been estimated based on historical information and current site topography. Quantities of specific waste types within the landfill are unknown. For the purpose of planning, the following quantities have been assumed:

- 46,875 tons of municipal and general waste (nonhazardous);
- 7,500 tons of automobile waste (car bodies);
- 37,500 tons of waste soil (contaminated but non-hazardous);
- 100,000 tons of construction waste that includes asbestos-containing material;
- 100,000 tires; and
- 18,538 tons of soil contaminated with lead and other heavy metals.

3.3 Site Preparation

As part of Site preparation, access roads, equipment/material staging areas, and temporary facilities were constructed as required to conduct removal activities. Completed activities are detailed in this section.

3.3.1 Construction Site Layout

The locations of the temporary access roads, staging areas, temporary construction facilities (office trailer, temporary utilities, etc.), and vehicle loading zones were finalized in the field prior to commencement of the removal action; Figure C-3 in Appendix A shows the construction site layout zones that have been developed for the Site. Temporary staging and vehicle loading areas will not interfere with construction operations or necessary traffic flow. EPA and ERRS consulted with current landowners and tenants to determine impacts to their operation and to the scheduled removal operations based on daily and seasonal needs for access.

Support facilities are located south-southwest of the Site. ERRS established an area for staging and storage of clean construction materials and equipment (e.g., parking of personal vehicles, clean backfill/equipment, project trailer, etc.). Additionally, ERRS constructed a stockpile area consisting of eight lined containment cells for staging of waste materials prior to off-site transportation. Sorting and segregating of excavated landfill materials, as needed, will be performed within the containment cells constructed for that purpose.

Prior to construction of the containment cells, the support and staging areas were sampled to existing conditions prior to performing the removal action. Upon completion of the removal action, sampling of these areas will provide confirmation that activities have not adversely impacted these areas.

3.3.2 Site Control and Access

During implementation, temporary site controls will be utilized to provide means of added protection for public health, safety, welfare, and the environment and to maintain the effectiveness and integrity of the removal action. In general, these site controls will consist of fencing and other means to restrict public access to the Site that will be installed and maintained along the perimeter of the Site. Signage has been posted around the perimeter of the Site to prohibit unauthorized entry of persons to the work areas. Activities associated with the excavation and the placement of excavated material will be restricted to the designated working limits on Site. Staging and storage of construction materials or equipment will be maintained on site.

Site access utilizes State Highway 3 SW, Bree Drive, and temporary Site access roads. ERRS installed access roads by performing limited grading, then placing gravel on the graded surface. Access roads within and outside the working limits at the Site will be maintained to allow for uninterrupted equipment/personnel access. To provide equipment access to the excavation areas from the storage/staging and laydown zones, additional temporary access roads and gravel equipment pads were constructed for the staging of clean equipment and/or materials. Additional temporary access roads may be constructed as needed as the removal action progresses, and location selection will be based on equipment limitations and access requirements.

Off-hours security will be contracted by the ERRS contractor to secure equipment and materials. ERRS will maintain a locked gate located on the existing access road from Bree Lane to the McCormick Land Company throughout the removal. Upgrades to the access roads will allow for increased traffic load during the removal action.

3.3.3 Traffic Control

Publicly owned and operated vehicles (i.e., those not related to Site activities) will generally not be allowed on site. Traffic detours and disruption that may result from the removal action will be coordinated with local agencies and in accordance with a Traffic Control Plan. The movement of equipment and personnel during on-site operations (e.g., construction equipment staging, waste and fill hauling, and personnel access to the Site) will be controlled. Personnel vehicles will enter and exit the site through the existing Alpine Farms driveway. Supply and haul trucks will enter and exit the site by following an access road from Bree Drive. Trucks making left turns from Bree Drive onto State Highway 3 SW can utilize a center turn lane and have a greater line of sight than the Alpine Farms driveway.

3.3.4 Utility Locate and Services

Prior to initiating work at the Site, the ERRS contractor coordinated with local utility companies to obtain electric and phone service for the temporary on-site facilities that will be utilized during implementation of the removal action (i.e., temporary construction trailers, scale and scale house, etc.). ERRS also consulted the current landowners for information on the locations of utilities on their properties.

3.3.5 Safety and Contingency Planning

Each contractor and/or subcontractor working on site has prepared a site-specific health and safety plan (HASP) to govern their activities in relation to their scope of work and the specifications. The HASP is required in accordance with Occupational Safety and Health Administration (OSHA) Standards and Regulations contained in 29 Code of Federal Regulations (CFR) 1910 and 29 CFR 1926. Each plan specifically identifies the person with authority to stop work at the site. Safety of the ERRS' personnel and subcontractors will be the responsibility of the ERRS. The OSHA citations listed below are a few of the regulations that will be observed throughout the construction process and are not all encompassing. While START is not responsible for the safety of the ERRS' subcontractors, the regulations are listed here to serve as a reminder of the most cited OSHA violations and to keep employees focused on safety.

It is anticipated that at certain times construction activities may require entering a trench greater than 5 feet in depth. The safety of personnel in excavations is regulated by OSHA as specified in 29 CFR 1926.650–653. OSHA dictates standards for shoring, sloped sidewalls, hazardous atmosphere, access, and other aspects of excavation projects. The regulations state that personnel entering an excavation over 5 feet in depth work under an OSHA Safety Plan; that a minimum number of daily inspections of trenches and shoring are performed; and that an OSHA-defined Competent Person remain on site at all times when personnel are in trenches. OSHA regulations will be followed at all times throughout the construction process. The contractor will verify conformance with these regulations. The ERRS contractor will retain a geotechnical engineering design firm to perform slope stability analysis as the removal action progresses to ensure the safety of personnel working on or near the slopes created through landfill excavation.

Proper hoisting and lifting operations will be important to worker safety and are regulated under 29 CFR 1926.550–556. Hoisting and lifting operations are anticipated to take place on many occasions, including during loading and unloading of materials and equipment.

OSHA regulates the use of ladders in 29 CFR 1926.1050–1060 and the use of scaffolds under 29 CFR 1926.450–454. Fall protection standards are specified in 29 CFR 1926.500–503. Fall protection is required for anyone working at a level 6 feet or more above a lower level. For heights greater than 6 feet, employers have the choice of using either a guardrail system, safety net system, or personal fall arrest system to protect workers.

All site-specific HASPs are maintained in the site trailers during the removal action.

3.4 Removal Action Operations

3.4.1 Clearing and Grubbing

Throughout the removal action, activities will be restricted in an effort to preserve existing vegetation. This is especially true along the slopes that exist across the site. A limited amount of clearing and grubbing will be performed to remove trees and vegetation only in areas that are required for access during removal activities.

Clearing will consist of the felling, trimming, and cutting of trees into sections, and the reuse of the trees and other vegetation designated for removal, including downed timber, snags, and brush occurring within the support areas and excavation areas. Cleared trees and brush will be used as erosion control material and/or natural woody material for creek channel restoration to the extent practicable. Non-native species will not be preserved for re-use.

Pre-construction flagging will identify trees that have been selected for restoration of the stream channel, which will have alternative removal criteria (i.e., removing the root ball with a defined length of the trunk remaining intact). Whenever possible, whole trees not selected for channel restoration will also be pushed over intact and allowed to remain in the buffer (riparian or upland planting zones).

3.4.2 Temporary Creek Diversion

The creek will be diverted to temporarily route upper Gorst Creek flows around the work area during construction. Piping has been installed from the inlet of the 24-inch corrugated metal pipe inlet to the inlet of the box culvert beneath State Highway 3 SW. A hydrologic analysis for the Site determined the anticipated flow rates during peak storms that could potentially cause the overtopping of the landfill under existing conditions. These flows were used as the basis of design for the pumping capacity requirement. Two pumps have been installed in order to divert flow around the active construction area. The diversion can be maintained 24 hours per day during rain events. Under current conditions the damaged pipe is maintaining enough flow to prevent backup of water upstream of the site. The pump intake structure has a fish screen installed, which will be operated and maintained in accordance with RCW 77.57.010 and 77.57.070. The hydrologic analysis for the site is included within Appendix B.

3.4.3 Waste Excavation

The landfill material would be removed with excavators starting at the downstream end of the culvert and working upstream. Progressing in this manner will allow the upstream end of the landfill to act as a dam and maintain control of surface water flow through the work area. It has been estimated to take approximately eight months to remove the landfill material. This progression of work will also result in the upstream portion of the landfill being excavated near the beginning of the seasonal dry period, which occurs from July through September, which will further aid in controlling surface water flow through the downstream working areas. Laborers will be employed to visually segregate waste materials, spot off-road trucks, and inspect on-road trucks for overhanging material prior to shipment. Waste will be visually screened to remove, at a minimum, tires; construction waste; concrete; identifiable medical waste; municipal and general waste (non-hazardous); large metal objects including, automobile waste (car bodies); and waste soil (contaminated but non-hazardous). These materials will be loaded onto off-road trucks and dumped into stockpiles, where they will be further segregated and loaded to on-road trucks for disposal.

The initial limits and depths of the excavation areas will be determined in the field using visual recognition of waste. Field screening and sampling will be used following excavation to determine contaminant concentrations in the underlying soil. Additional excavation will occur as necessary following confirmation sampling performed by START (see Section 3.6 for sampling and testing procedures that will be utilized for the Site).

3.4.4 Off-Site Disposal

The total quantity of waste in the landfill has been estimated based on historical information and current site topography. Quantities of specific waste types within the landfill are unknown. Municipal and general waste, non-hazardous waste soil, and construction waste are being hauled by rail to Waste Management Corporation (WM) landfills. Soil contaminated with lead, chromium, and other heavy metals would be hauled by truck for stabilization and disposal at Chemical Waste Landfill of the Northwest, a Resource Conservation and Recovery Act Subtitle C landfill in Arlington, Oregon. Automobile wreckage without tires has a salvage/scrap value and are being sent off site for recycling. Salvageable scrap metal may offset a portion of the overall project cost. A vender was identified that will accept waste tires and automobile wheels for a flat per-tire fee that includes drop-box service.

3.4.5 Creek Channel Construction

Conceptual design plans, including a planting plan, have been developed for restoration of the creek channel. The design intends to make manifest the stream restoration objectives by establishing a stable and ecologically functional stream appropriately sized for its contributing basin. The channel dimension, pattern, and profile to be re-established will approximate pre-disturbance conditions and will be suited to providing salmonid habitat as well as minimizing degradation (down-cutting) or aggradation. Channel configuration and roughness elements (frictional forces created by bed and bank features) will emulate the reference reaches and thereby create a diversity of in-stream habitat and retain a mix of gravel and sand within the stream bed. Furthermore, native vegetation will be established in the reconstructed floodplain and the surrounding ravine slopes.

In-channel

The current design is based on current understanding of the Site's pre-disturbance conditions. The final design will benefit from the assessment described and from hydraulic analysis of the design configuration. Hydraulic analysis will predict water velocity and bed shear values, as well as inundation patterns. The design process will be iterative; results of hydraulic analyses will be compared with design objectives and subsequently revised until a best fit is formulated in accordance with anticipated constraints of cost and feasibility.

The restored reach will be set on a trajectory to become a forced alluvial step-pool channel within a moderately confining, forested ravine. A defined channel will be created with dimension, pattern, and profile similar to the reference reaches but appropriately sized for the anticipated flow volumes at its particular location and with adjustments to stabilize the channel and create quality habitat for native salmonids and other aquatic organisms.

Targeted sinuosity of the restoration reach will be 1.1 to 1.2. The floodplain will exhibit mild bends through the ravine, and the stream channel will exhibit mild bends within the flood-prone area. The course of the flood-prone area and the channel will be somewhat out of phase from each other (not parallel).

Moderately steep cut banks will be graded and stabilized at the outside of channel bends, and flat to gently sloping point bars will be established inside of channel bends. Overall, design of bankfull width will average 14 feet and aim for a range of 11 to 19 feet. Bankfull width to depth ratio will generally range from 8 to 10 but will be slightly lower in the pools than in the riffles.

The final constructed channel will focus on creating 60 to 70 percent of the channel length to support riffle channel units with the remainder mainly supporting pools. The target is for no more than 5 percent of the restored channel length to be classified as runs during base flows (0.25 to 8 cubic feet per second [cfs]). Thus, the proportion of pools will be much higher than what was observed in the reference reaches, but attainable with the given environmental and logistical constraints and highly beneficial to coho salmon spawning and rearing (Clark 2013).

Pools will be designed to sustain a maximum water depth of at least 1 foot and a pool depth to upstream drop height ratio of at least 1.25 to 1 when flow rates exceed 2 cfs. Pool lengths will target ranges from 15 to 30 feet.

The pools will be strategically positioned and enhanced with features designed to sustain their form. Most pools will be situated at the outside of bends (scour pools), and the remainder will be situated below moderately steep drops (plunge pools). Pools will be enhanced with features at their downstream ends that create a backwater effect under most flow conditions. The channel will be graded such that the longitudinal gradient of the thalweg to nearest upstream crest (downstream end of a pool) will be approximately two-thirds of the longitudinal gradient from the upstream crest to the nadir of the downstream pool.

Pool-to-pool distance will generally vary from 3.5 to 5 channel widths, depending partly on the local longitudinal gradient. These distances are in accordance with calculations using an empirically derived equation describing distances between crests for step-pool streams (Thomas et al. 2000). Prior to excavation of the landfill, exact channel width and gradient can only be assumed. An assumed pool-to-pool distance is 55 feet in the farthest upstream 200-foot length to 70 feet in the farthest downstream 200-foot length.

Channel substrate will primarily consist of locally sourced sediment ranging in size from silts and fine grained sands to boulders. Rounded fine and coarse gravel will be distributed throughout the reach and at greater concentrations within pools and runs. Boulders and large cobbles will be prevalent at the downstream ends of dam pools, at or near the upstream end of plunge pools, along the toes of steeply sloping banks, and at other locations where shear stress is anticipated to be high.

The channel will be stabilized and enhanced with boulders, cobble vanes, and a moderate abundance of LWD. These in-channel roughness elements will be established throughout the reach to dissipate energy and reduce the probability of down-cutting or lateral scour. The elements will be distributed individually and in clusters throughout the restored reach. They will serve a variety of purposes, including control of channel alignment, concentration of flow to retain gravel and fish refuge habitat, and allowance for fish passage across a wide range of flows.

LWD will consist of locally sourced logs from native trees. Most logs will have branches attached, and some will have root-wads. LWD will be at least 10 feet long and vary in diameter from 0.5 to 2.5 feet. Root-wad LWD will have root wad (root fans) at least 4 feet in diameter.

A large portion of the LWD will be partially buried into the bed and/or banks to serve as key pieces. These pieces will be at least 16 inches diameter (see ODFW 2010) and derived from coniferous tree species and will show little or no evidence of decomposition. Key piece LWD will consist of both root-wad LWD and standard LWD pieces. The pieces will be expected to substantially augment hydraulic complexity, establish and sustain channel form diversity, and capture and retain other woody debris.

Root-wad LWD to serve as key pieces will have their boles positioned at a downward slope of 2 to 8 degrees toward the bed and partially buried in the stream banks. Root-wads will face upstream at a 10- to 25-degree angle from the tangent line where the bole intercepts the stream bank. At least one two-man boulder, and possibly another in-channel LWD of similar or greater diameter to the root-wad LWD, will be placed immediately adjacent to the bole just below the root-wad.

Standard LWD pieces will be positioned at various angles from the tangent line where the bole intercepts the stream bank, and at various angles relative to the horizontal plane. These pieces will be partially buried either in the bank or in the bed.

Most LWD keyed into the bank will be placed adjacent to boulders and/or cobble vanes extending across at least one-half the channel. These LWD/rock clusters will mainly be positioned along and in close proximity to the graded crests to sustain and enhance pool habitat. A large portion of the key LWD pieces will have other in-channel LWD placed immediately upstream.

At least three timber step-downs (sometimes referred to as K-structures) will be established. These are comprised of a full-span LWD piece and two opposing LWD pieces extending from the banks at approximately 45-degree angles relative to the flow direction and terminating within a few feet of each other at the top of the full-span piece. The size and positioning of the full-span log will be sufficient to prevent undercutting. The step-downs will form moderately large pools immediately upstream that retain gravels and provide refuge for juvenile fish during high flows.

At least one off-channel backwater area will be established. This feature will consist of a 30 to 50-foot long alcove channel extending parallel to the main-stem channel and connecting to the main-stem channel at the alcove's downstream end. The backwater will provide a still-water refuge up to 3 feet deep that will be accessible to coho salmon and cutthroat trout at flow levels equal to and greater than the upper limit of baseflow (8 cfs).

Cut banks and other banks at a gradient greater than 65 percent and within 1.5 feet of the bankfull elevation will be stabilized with one to three stacked brush layers each consisting of an approximately 1.5-foot-thick layer of soil (gravelly sandy loam or gravelly silt loam) encased in biodegradable fabric and planted with native cuttings (mainly salmonberry and willows adapted to floodplain conditions) at 5 to 10 stems per square foot. Brush layers will be stacked at no more than a 100 percent (1:1) angle.

Riparian and Upland Ravine

The riparian zones will entail the areas extending upslope from the ordinary high water mark, which is just below top of bank, to the elevation contour reached at a flow stage that is twice the maximum bankfull depth (flood-prone area). The riparian zones on each side of the stream will generally range from 10 to 20 feet wide. The upland ravine zones will extend from the upper boundary of the riparian zone to the upper edge of the re-constructed slope. The width of the upland ravine zones will vary, but will be greater than 30 feet.

As with the channel, the riparian and upland ravine zones will be graded to simulate, but not replicate, the reference reaches. Side-slopes rising above bankfull elevations will generally be no steeper than 75 percent (1.33:1). Entrenchment ratio, the comparison between flood-prone width (numerator) and bankfull width (denominator), will range from 1.9 to 2.4.

Riparian zone substrate will consist of native soil with a large proportion of coarse substrate (mainly gravel). The proportion of coarse substrate to finer material will vary depending on elevation and position within the flood-prone area; low-elevation cut-banks will generally have the highest proportion of coarse substrate.

3.4.6 Creek Channel Vegetation

Following cleanup activities, disturbed areas will be restored, as closely as possible, to a natural state. Topsoil sources will be located prior to beginning work and will be sampled and analyzed to reduce the potential for additional contaminants to be brought on site, as discussed further in Section 3.6.2. At the conclusion of the removal action, areas disturbed during construction will be seeded and mulched in a manner appropriate for the area. The sequence of the work and phasing of excavations will be coordinated to move expeditiously, prevent excessive erosion from bare soil, and keep disruptions to the on-site businesses to a minimum.

Native vegetation adapted to the anticipated conditions will be planted in the riparian zone. Prior to planting, the soil surface in this planting zone will be stabilized with biodegradable coir fabric or equivalent. In addition, several LWD pieces will be placed at various angles, and many will be partially buried.

Ravine side-slopes above the active floodplain will be restored with slopes similar to the pre-development conditions. Native upland forest vegetation will be planted up to 30 feet above the riparian zone . The proportional length of unstable banks as determined by evidence of exposed soil, sloughing, and/or tension cracks within the riparian zone will remain below 5 percent.

Several LWD pieces will be placed at various densities in both the riparian and upland forest planting zones. LWD will be derived from local sources, be at least 5 feet in length, and vary in diameter from 0.5 to 2.5 feet. Some LWD pieces will be partially buried in the soil.

3.5 General Construction Site Guidelines

BMPs will be employed throughout construction for control of erosion, sediment, and fugitive dust and to avoid adverse impacts on wildlife and their habitats. The BMPs to be implemented during this removal action are based on the U.S. Army Corps of Engineers Nationwide Permit 38 and professional experience. The SWPPP has been implemented and is being maintained in the EPA Site Command Post during the removal action.

3.6 Site Monitoring and Inspections

3.6.1 Field Screening and Excavation Extent

The depth of excavation will be determined in the field based on a combination of field screening and visual evidence of waste materials. In general, excavation of waste materials is expected to continue to a depth of 60 to 80 feet below ground surface at certain areas of the Site. Additionally, field sampling will occur after excavation to determine if contaminant concentrations remain after excavation. Sampling is based on the sampling and testing program developed for the Site.

3.6.2 Sampling and Testing Program

Analytical testing during the removal action will include the following components:

- Dust and air monitoring during site excavation and waste material handling activities;
- Sampling of excavated waste materials for disposal profiling at the landfill;
- Sampling and analysis of borrow source materials for Site contaminants of concern; and
- Confirmation analyses of excavated areas.

Additional details can be found in the site-specific sampling plans for analytical testing during removal activities, which are maintained in the EPA Site Command Post during the removal action.

3.6.3 Air Monitoring

Air monitoring equipment will include a multi-gas monitor, particulate monitors, asbestos samplers, a weather station, and multi-gas monitors for personnel monitoring.

Perimeter air quality will be monitored regularly during construction activities to assess the impact of Site work on the community, workers, and the surrounding environment. DataRAM monitors will be utilized to measure particulate matter (particles less than 10 microns) in the air. The real-time monitors will be placed upwind (background) and downwind of Site activity to determine and record perimeter background and impacted conditions.

Additionally, ambient air quality at the perimeter of construction activities and inside work zones will be measured for organic vapor with a Multi-Rae multi-gas monitor. The results are communicated to on-site personnel in real-time via a video monitor located in the EPA Site Command Post.

Water quality will be monitored throughout the removal process to ensure that downstream receptors are not being impacted. Details of the air and water quality monitoring plans, including action levels to be utilized, are included in the site-specific sampling plans and HASPs which are maintained at the Command Post during the removal action.

3.6.4 Best Management Practice Monitoring and Inspections

Appropriate and practicable greener cleanup BMPs will be implemented during cleanup activities, including, but not limited to, minimizing: energy consumption, generation and transport of fugitive dust, waste generation through reuse and recycling, impacts to water resources, areas requiring activity or use limitation, unnecessary soil and habitat disturbance, and lighting and noise disturbance.

The objective of BMP monitoring and inspections is to protect the community, workers, and environment throughout the duration of the removal action. The Site will be inspected daily to assess proper mitigation efforts and whether BMPs are in place to achieve this objective. Erosion and sediment control BMPs will conform to the substantive requirements of Ecology.

3.6.5 Long-Term Monitoring, Maintenance and Repair

A long-term MM&R program will be prepared following the removal action with assistance and oversight provided by identified stakeholders. The purpose of the MM&R plan is to measure the on-going effectiveness of the removal action and to monitor Site conditions. EPA will prepare the MM&R plan in conjunction with stakeholders. Periodic inspections will include annual, semi-annual, and/or episodic inspections of the erosion and sediment control measures and establishment of vegetation. Depending on the results of periodic monitoring, the stakeholders may be required to perform needed maintenance and repairs. Engineering and institutional controls will regulate access to and use of certain areas such as hillsides until vegetation has been established.

The MM&R plan will expand on project objectives and performance standards. Project objectives are elements of a project goal that clearly define the project's intent and expectations. Performance standards are specific, measurable attributes used to gauge the project's success. Performance standards, also known as design criteria, are directly tied to project objectives and serve as the basis for post-project monitoring. Objectives and performance standards for this project are described below.

Objective A: Reconfigure an appropriate channel for reestablishing stable channel dynamics:

- <u>Performance Standard A-1:</u> Bankfull width-to-depth ratio will range from 8 to 10.
- <u>Performance Standard A-2:</u> At least 10 percent of the restored channel length will support pools that sustain a maximum water depth of at least 1 foot during flows that exceed 2 cfs.
- <u>Performance Standard A-3:</u> All keyed-in LWD will remain in place through all flows up to the 25-year discharge.
- <u>Performance Standard A-4:</u> The proportional length of unstable banks as determined by evidence of exposed soil, sloughing, and/or tension cracks within the riparian zone will remain below 5 percent.
- <u>Performance Standard A-5:</u> Entrenchment ratio will range from 1.9 to 2.4.

Objective B: Reconfigure a channel capable of supporting salmonid passage and spawning:

- Performance Standard B-1: The reconstructed stream channel will allow native trout and coho salmon to pass through the Site during times of sufficient flow (>2 cfs).

Objective C: Re-establish native riparian and upland forest vegetation capable of suppressing erosion, shading the channel, providing habitat value, and contributing large woody debris:

- Performance Standard C-1: Absolute total cover of native plants will be attained in the riparian and upland forest zones at levels equal to or exceeding those shown in the Design Drawings. The cover standards change over time to reflect expected rates of plant growth. Cover values include both planted and volunteer species. Volunteer plants are plants that establish on their own during the monitoring period without direct planting or seeding.

  To ensure that acceptable plant cover extends across the Site, the standard deviation of the mean cover value for each criterion presented in the Design Drawings should be less than one-fourth of the mean cover value.

Objective D: Suppress cover by non-native invasive vegetation:

- Performance Standard D-1: Cover by non-native invasive vegetation will be at or below the quantitative thresholds outlined in the MM&R Plan.

  To ensure that acceptable plant cover extends across the Site, the standard deviation of the mean cover value for each criterion above should be less than one-fourth of the mean cover value. Since re-invasion by non-native, invasive plants is expected to continue to be a threat for a long time, the thresholds given in the MM&R Plan should remain at the same levels for the duration of the monitoring period.

A monitoring and assessment program will be essential to ensure the long-term success of the restoration efforts. An outline of a post-restoration monitoring program, including the recommended schedule and benchmark criteria, will be presented in the MM&R plan.

3.7 Project Schedule

Contractors mobilized to the Site in April 2016 to begin setup. During this setup time, BMPs were installed and the Site was prepared for work. Removal of landfill waste began May 23, 2016 and is estimated to finish by late fall 2016. The proposed schedule is as follows:

Contractors begin to mobilize and prepare the Site:	April 2016
Removal activities begin:	May 23, 2016
Removal of landfill waste completed:	Fall 2016
Stream restoration activities:	TBD
Contractors demobilize from Site:	TBD
Draft removal action report submitted to EPA:	August 2017
Final removal action report is submitted to EPA:	November 2017

The schedule will be considered fluid in nature since most site activities are subject to the quantity and types of waste, availability of subcontractor personnel, and landfill quantity restrictions. The actions of the adjacent site owners and tenants may also affect the schedule.

3.8 Roles and Responsibilities

The Site removal action will be performed by EPA and its contractors. Specific details about the groups who will perform the removal action and their responsibilities are provided below.

EPA: The removal action will be managed by the EPA On-Scene Coordinator.

ERRS: The ERRS contractor will be the cleanup contractor responsible for implementing the removal action. Their primary responsibilities will be to mobilize the personnel, equipment, and supplies.

START: E & E, under the EPA Region 10 START IV contract, will provide on-site technical assistance and support. START will be responsible for field-screening, collecting analytical samples, and documenting the removal action. For third-party contracts, E & E has no control over the contractor's means or methods and is not a party to the construction contract. E & E is on site to monitor activities as EPA's representative, and any direction regarding means or methods provided to the contractor would be unwarranted. The following subsection details some of the monitoring activities that will be performed to track construction progress, testing, sampling, and compliance with design drawings and specifications under this relationship.

Table 3-1 provides a list of specific duties for the removal action and identifies the group that will be responsible for those duties.

3.8.1 Construction Monitoring

A document filing system has been set up for E & E office personnel to view documents that are being generated in the field. This system relies on a functional Internet connection, which may mean that field personnel will at times experience delays in uploading documents; however, this is not anticipated to be a problem since most time-critical information may be received via hand-held devices if required. The project file system will contain information necessary to successfully track the project's progress and completion. This system is intended to simplify records management for the construction phase of the project and allow office personnel, the project manager (PM), and START site representative (SR) greater access to project paperwork.

To ensure consistency in reporting, several forms have been generated for recording project information. These forms, which are described in the following paragraphs, have been created so that data is entered but the layout of the form cannot be manipulated. This ensures that the form remains consistent throughout the project; however, if the need arises to reformat any form, it will be addressed by the PM and SR. If unanticipated information requires tracking over the course of the construction phase of the project, a form will be produced for such use; otherwise, unanticipated information will be tracked using Microsoft Excel or other means.

The START SR will maintain a logbook while on site. The logbook will be used to record construction progress and other information pertinent to the construction process. Photographs will also be used to document construction progress and record construction methods. Both logbook and photograph logging procedures are covered in the Construction Quality Assurance Plan (CQAP) which will be maintained on site.

In addition to daily interaction between the ERRS PM and the SR, progress meetings will occur regularly. The CQAP covers meeting scheduling and the format that will be followed, but ultimate responsibility for this will fall to EPA. The CQAP also covers anticipated construction activity procedures used during the various phases of construction.

3.8.2 Contractor Quality Assurance Monitoring

The SR will monitor testing that occurs throughout the construction process as part of the ERRS' QA program as required by the specifications. This will include geotechnical testing of unrepresentative soils and disposal sampling. Monitoring is described further in the CQAP.

Table 3-1 Summary of Roles and Responsibilities

Task	Group Responsible
Overall management of the removal action	EPA
Implement removal action	ERRS
Improve and maintain access roads during the removal action	ERRS
Implement BMPs	ERRS
Monitor BMPs	EPA, ERRS, and START
Health and Safety	Each group is responsible for its own employees
Air monitoring	START
Analytical sampling (excavation or characterization)	START
Field-screening	START
Ship samples to an off-Site laboratory	START
Document Site conditions and methods and results of removal action	EPA, START

Key:
BMP = Best Management Practice
EPA = U.S. Environmental Protection Agency Federal On-Scene Coordinator
ERRS = Emergency and Rapid Response Services
START = Superfund Technical Assessment and Response Team

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A Design Drawings

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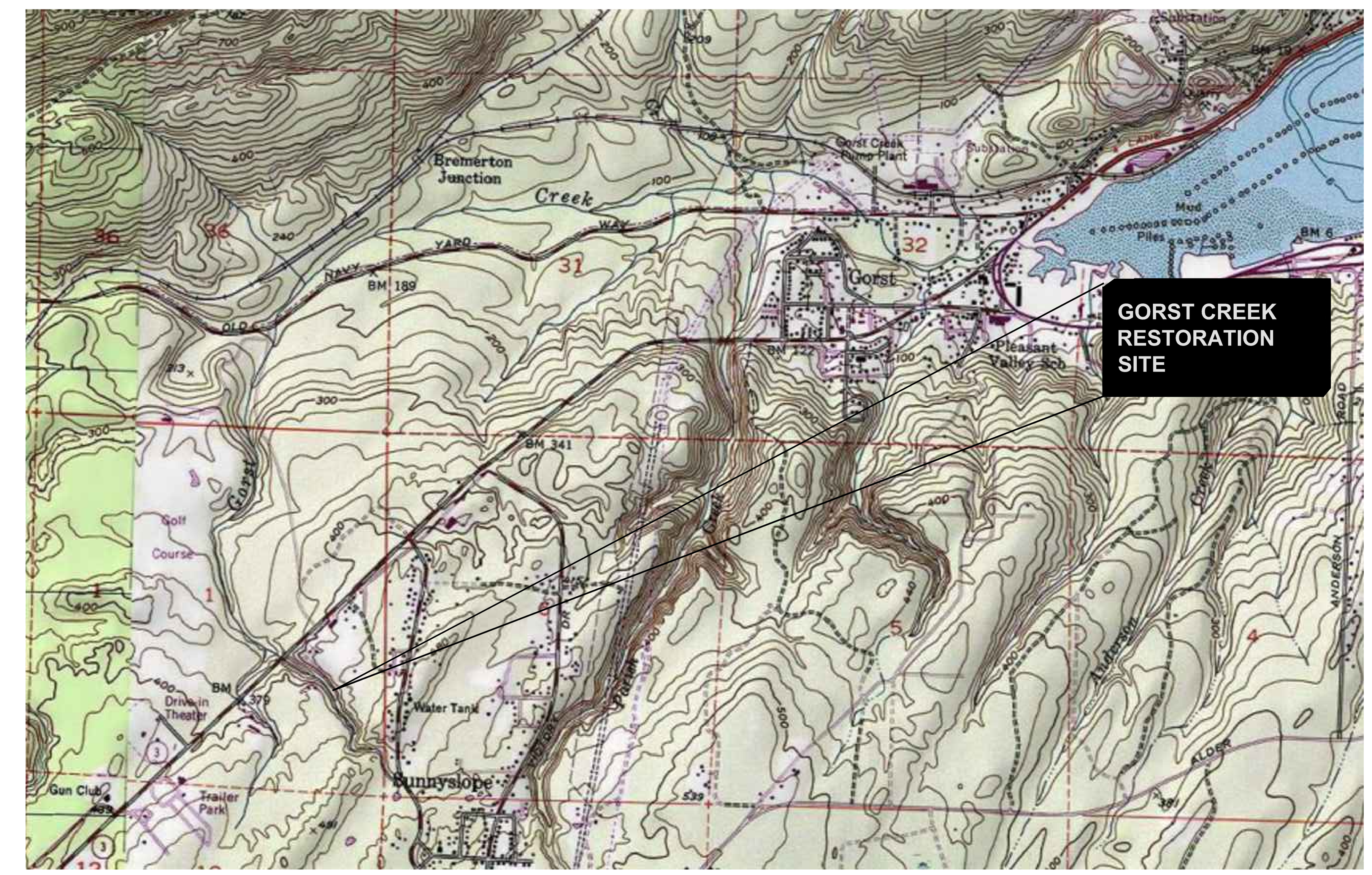
GORST CREEK RESTORATION - 90% DESIGN

BREMERTON AUTO WRECKING LANDFILL SITE
PORT ORCHARD, KITSAP COUNTY, WASHINGTON
TDD NO.: 15-08-0002
PAN NO.: 004530.0019.001.02

SOURCE: SEPTEMBER 2015 – APRIL 2015 GOOGLE INC.

VICINITY MAP
NTS



SOURCE: ERSI INC. 2015

SITE LOCATION
1" = 2,000'

LEGEND

- SITE BENCHMARK
- SIGN
- POWER POLE
- GUY ANCHOR
- STORM DRAIN CATCH BASIN
- TELEPHONE PEDESTAL
- EVERGREEN TREE
- DECIDUOUS TREE
- STORM LINE (SD)
- OVERHEAD POWER (OE)
- GUARD RAIL
- FENCE LINE, AS NOTED
- EDGE OF PAVEMENT
- CL DITCH/CREEK AS NOTED

LIST OF ABBREVIATIONS

APPROX	APPROXIMATE	MH	MANHOLE
℄	CENTER LINE	N	NORTH
CFS	CUBIC FOOT PER SECOND	NO., #	NUMBER
CY	CUBIC YARD	NTS	NOT TO SCALE
D, DIA, Ø	DIAMETER	NAD83	NORTH AMERICAN DATUM, 1983
EL	ELEVATION	NAVD88	NORTH AMERICAN VERTICAL DATUM, 1988
FT, '	FEET, FOOT	OC	ON CENTER
GW	GROUNDWATER	OD	OUTSIDE DIAMETER
H, HORIZ	HORIZONTAL	OZ/SQ YD	OUNCE PER SQUARE YARD
HR	HOUR	PVC	POLYVINYL CHLORIDE
I.E.	INVERT ELEVATION	RCP	REINFORCED CONCRETE PIPE
IN, "	INCH	TYP	TYPICAL
MAX	MAXIMUM	V	VERTICAL
MIN	MINIMUM		

SHEET INDEX

SHEET NO.	DESCRIPTION OF DRAWINGS
C-1	VICINITY MAP, SITE LOCATION AND SHEET INDEX
C-2	SITE SURVEY OCTOBER 25, 2011 AND MAY 11, 2016
C-3	SITE REMOVAL AND RESTORATION WORK PLAN
C-4	CONCEPTUAL SITE RESTORATION PLAN VIEW AND NOTES
C-5	CONCEPTUAL SITE RESTORATION PROFILE
C-6	SITE RESTORATION CROSS-SECTIONS
C-7	SITE RESTORATION PLAN VIEW-A
C-8	SITE RESTORATION PLAN VIEW-B
C-9	SITE RESTORATION PLAN VIEW-C
C-10	RESTORATION PLANTING PLAN
C-11	RESTORATION DETAILS
C-12	RESTORATION DETAILS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
C	90% DESIGN REVIEW	06-13-16	TDC
B	60% REVIEW – NOT FOR CONSTRUCTION	01-11-16	TDC
A	30% REVIEW – NOT FOR CONSTRUCTION	10-09-15	TDC

SIZE D
IF SHEET IS LESS THAN 22"X34" IT IS REDUCED PRINT– SCALE REDUCED ACCORDINGLY
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Designed by: T. CHATRIAND | Date: 6/13/2016
Drawn by: TJC | Spec No.: | TDD No.: 15-08-0002
Reviewed by: T. CAMPBELL | PAN No.: 004530.0019.001.02
Approved by: T. CAMPBELL P.E. | File name: | Plot date: | Dwg scale: AS SHOWN

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Seattle, Washington 98104
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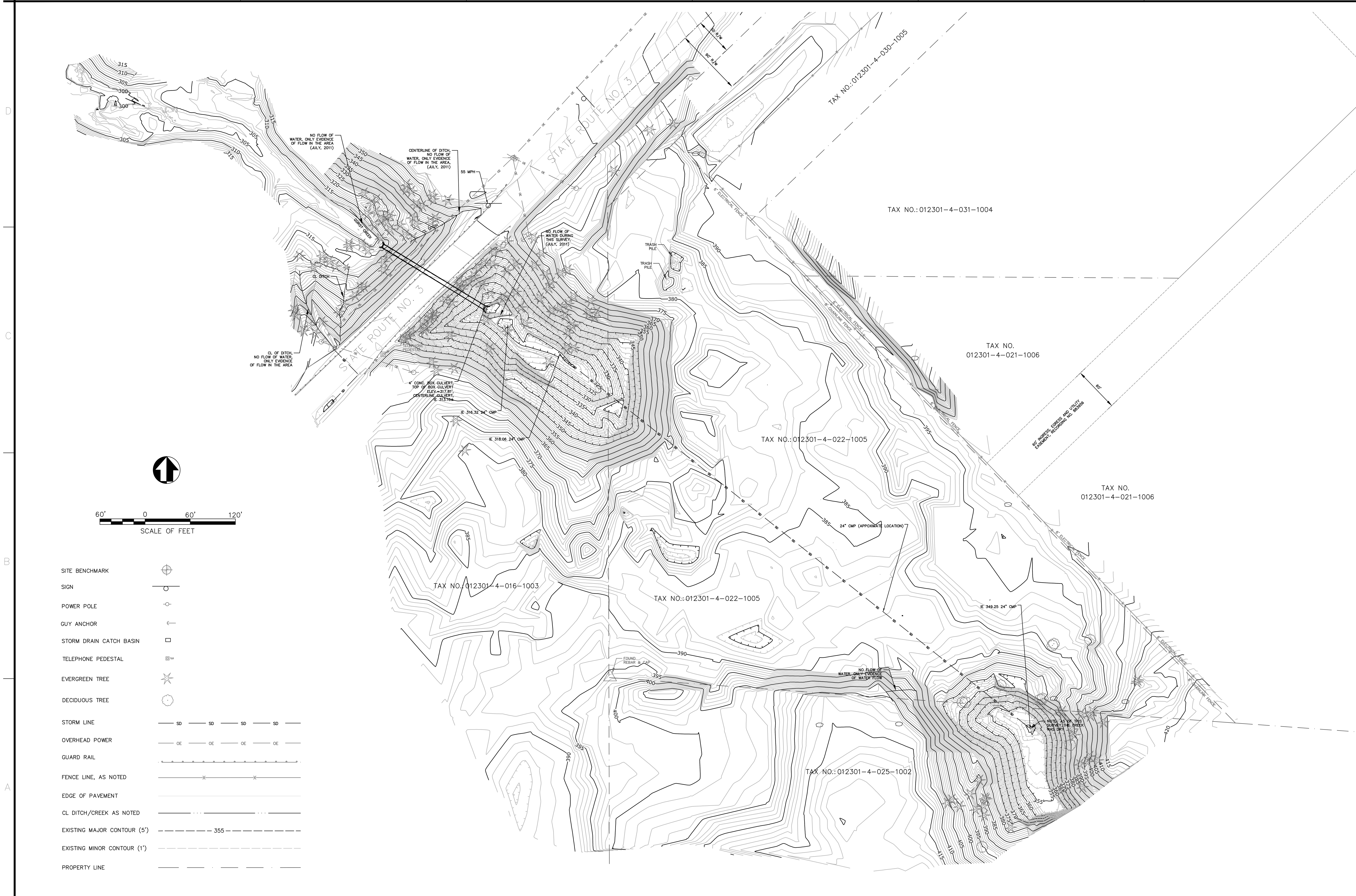
KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

VICINITY MAP, SITE LOCATION, AND SHEET INDEX

Sheet reference number: **C-1**
SHEET 1 OF 12



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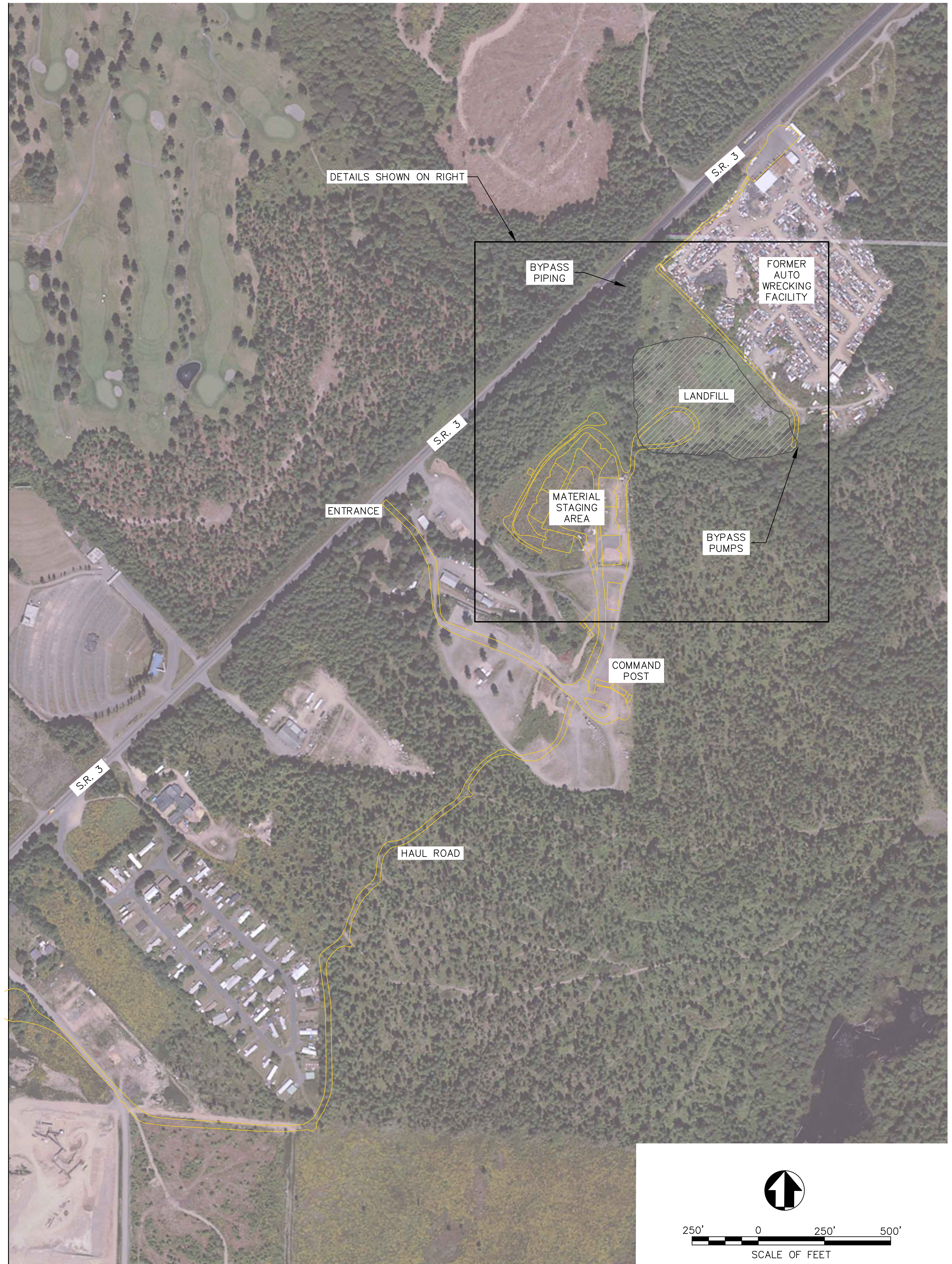
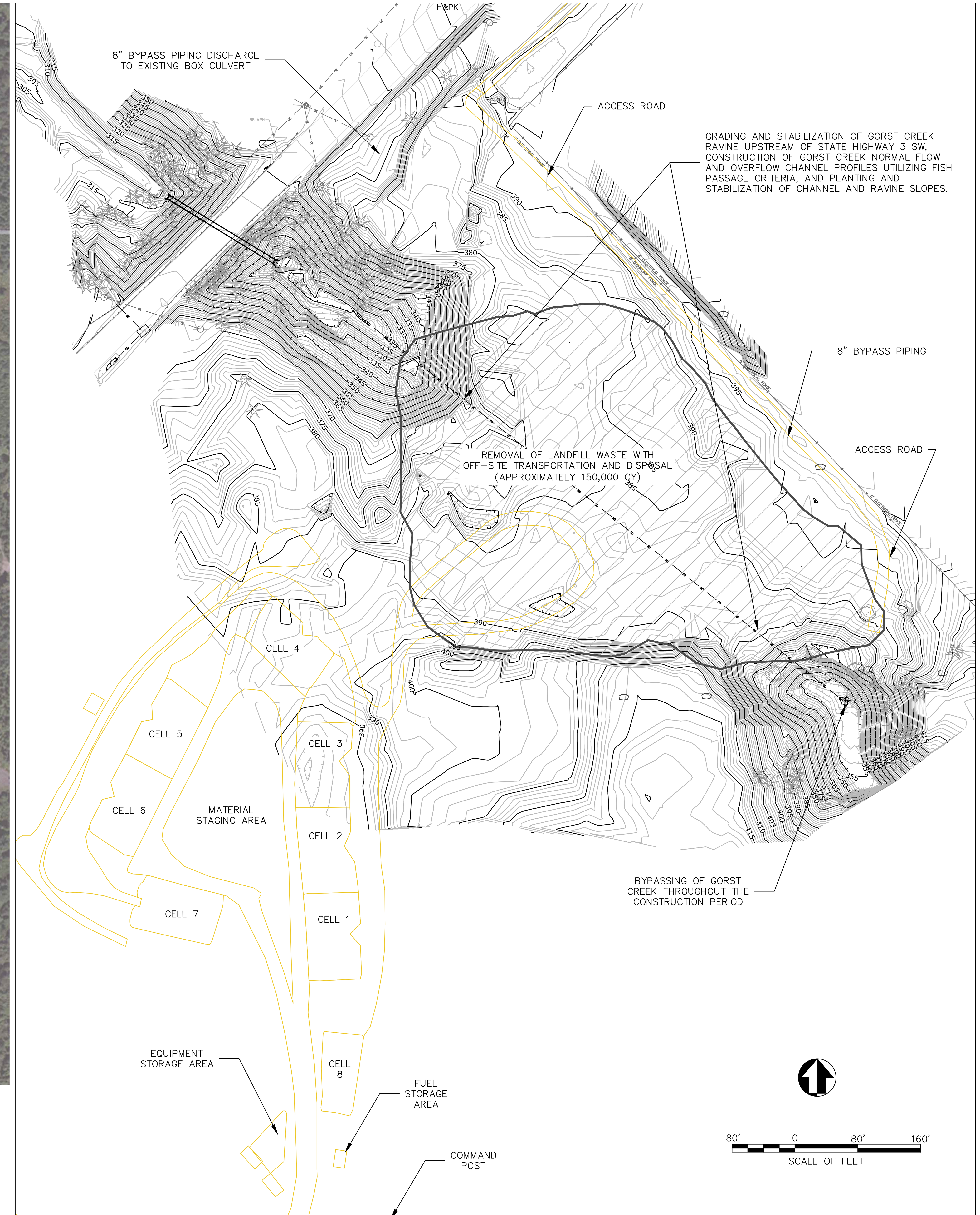
SITE SURVEY
OCTOBER 25, 2011 AND MAY 11, 2016

Sheet reference number:
C-2





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KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
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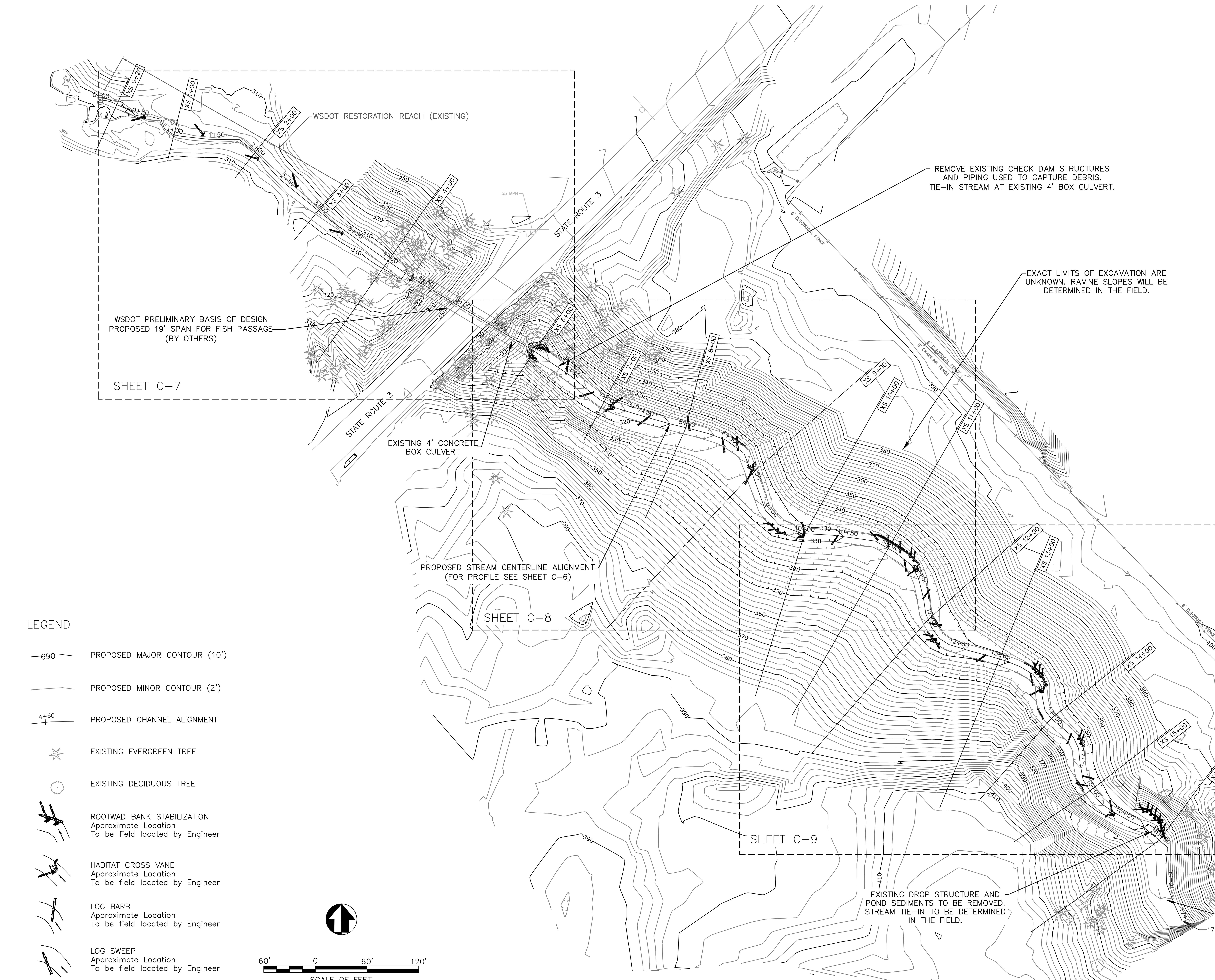
SITE REMOVAL AND RESTORATION WORK PLAN

Sheet reference number: C-3



GENERAL CONSTRUCTION NOTES

1. THESE DESIGNS AND DRAWINGS HAVE BEEN PREPARED FOR THE EXCLUSIVE USE OF THE ENVIRONMENTAL PROTECTION AGENCY (THE "OWNER"), AND THEIR AUTHORIZED AGENTS. THE DRAWINGS CONTAINED WITHIN SHOULD NOT BE APPLIED FOR ANY PURPOSE OR PROJECT EXCEPT THE ONE SPECIFIED.
2. SITE TOPOGRAPHY WAS COMPILED FROM GROUND SURVEYS BY WHITE SHIELD, INC. LIDAR DATA AVAILABLE FROM THE PUGET SOUND LIDAR CONSORTIUM AND AERIAL PHOTOGRAPHY WAS USED TO DEVELOP HYDRAULIC MODELS OUTSIDE THE GROUND SURVEY BOUNDARY TO ASSIST IN DESIGN. THE VERTICAL DATUM OF THE GROUND SURVEY AND LIDAR DATA IS NAVD 88 (US FOOT). THE HORIZONTAL DATUM IS NAD83 STATE PLANE WASHINGTON NORTH ZONE (US FOOT).
3. DETAILS ARE INTENDED TO SHOW THE CONCEPTUAL FINAL RESULT OF THE DESIGN. FINAL CONTOURS AND STREAM ALIGNMENT MAY VARY DEPENDING ON FINAL GRADE CONDITIONS UPON COMPLETION OF THE LANDFILL REMOVAL. MINOR MODIFICATIONS MAY BE REQUIRED TO SUIT JOB SITE DIMENSIONS OR CONDITIONS. SUCH MODIFICATIONS SHALL BE INCLUDED AS PART OF THE WORK.
4. THE EXISTING UTILITIES, STRUCTURES AND OTHER FEATURES SHOWN ARE APPROXIMATE; ACCURACY IN LOCATION, ELEVATION, DIMENSION AND COMPLETENESS IS NOT GUARANTEED. THE UTILITIES ARE SHOWN ACCORDING TO INFORMATION AVAILABLE AT THE PREPARATION OF THESE DOCUMENTS.
5. ANY AND ALL AREAS NOT SPECIFIED FOR CONSTRUCTION WHICH ARE DISTURBED AND OR DAMAGED BY THE CONTRACTOR SHALL BE RESTORED TO THE SATISFACTION OF THE OWNER.
6. IN GENERAL, THE IN-STREAM AND BANK STABILIZATION STRUCTURES ARE INTENDED TO PROVIDE STABLE STREAMBEDS, BANKS, AND FLOOD PLAINS. HOWEVER, LOCAL CHANNEL EROSION, CHANNEL MIGRATION AND/OR AVULSIONS CAN BE EXPECTED TO OCCUR TO SOME DEGREE OVER TIME. THESE CHANNEL PROCESSES ARE NATURAL AND APPROPRIATE FOR STREAM SYSTEMS.
7. THE CONTRACTOR SHALL PROVIDE BYPASS PUMPING OF NORMAL FLOWS IN GORST CREEK TO ISOLATE WORK AREAS FROM FLOWING WATER. THE CONTRACTOR SHALL ALSO STABILIZE THE SITE AT THE END OF EACH WORK DAY, SO ALL WORK AREAS WILL BE STABLE IN THE EVENT OF A 10-YEAR STORM. THE 10-YEAR, 24-HR STORM EVENT IS ESTIMATED TO PRODUCE APPROXIMATELY 20 MILLION GALLONS OF STORMWATER WITH A PEAK FLOW RATE IN GORST CREEK OF 52.4 CFS.
8. TO THE EXTENT PRACTICABLE, STREAMBED MATERIAL REMOVED FROM GORST CREEK BENEATH THE LANDFILL SHALL BE SEPARATED FROM LANDFILL MATERIAL AND STOCKPILED ON SITE. THE STOCKPILED MATERIAL SHALL BE EVALUATED BY THE OWNER FOR OFF-SITE DISPOSAL OR RE-USE IN THE RESTORATION CHANNEL. RE-USED MATERIAL MAY REQUIRE CLEANING, WHICH SHALL CONSIST OF POWER WASHING IN A CONTAINED AREA. WASH WATER SHALL BE COLLECTED FOR DISPOSAL OR TREATED PRIOR TO DISCHARGE TO GORST CREEK.
9. EXISTING STONE AND LARGE WOODY DEBRIS SHALL BE SALVAGED, WHEN POSSIBLE, FOR USE AS IN-STREAM AND BANK STRUCTURES. NEW STREAMBED AGGREGATES SHALL BE CLEAN, NATURALLY OCCURRING, WATER-ROUNDED GRAVEL MATERIAL. AGGREGATES FROM QUARRIES, LEDGE ROCK, AND TALUS SLOPES ARE NOT ACCEPTABLE. STREAMBED AGGREGATES AND RIPRAP ARE SPECIFIED IN THE RESTORATION DETAILS SHEET C-11 AND SHALL MEET THE FOLLOWING TESTS FOR QUALITY:

AGGREGATE PROPERTY	TEST METHOD	REQUIREMENT
Degradation Factor	WSDOT T 113	15 min.
Los Angeles Wear, 500 Rev.	AASHTO T 96	50% max.
Bulk Specific Gravity	AASHTO T85	2.55 min.

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Drawn by: TJC
Spec No.:
Reviewed by: T. CAMPBELL
Approved by: T. CAMPBELL, P.E.
WASHINGTON_PE_REGISTRATION
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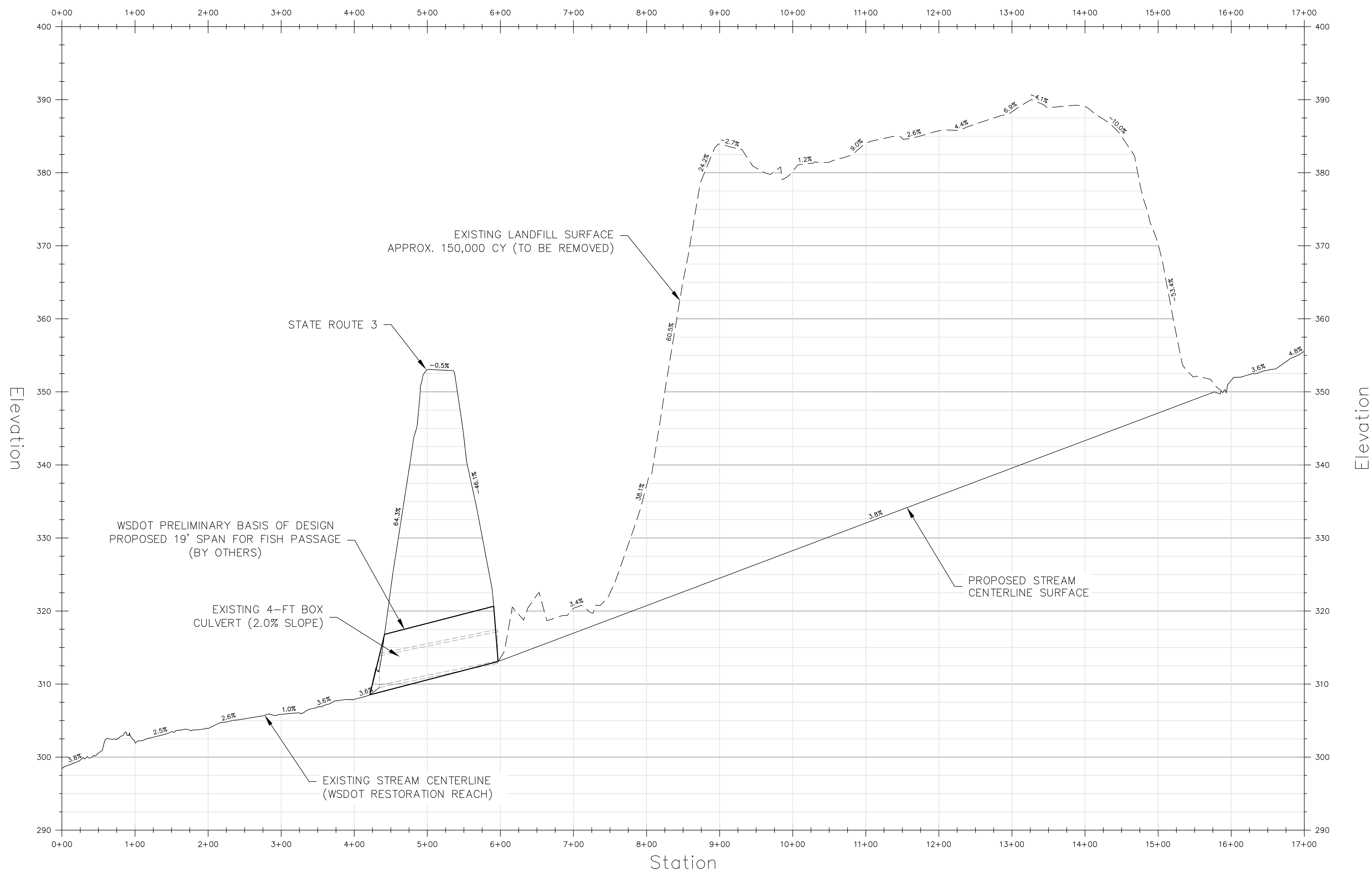
KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

CONCEPTUAL SITE RESTORATION PLAN VIEW AND NOTES

Sheet reference number: **C-4**

PROPOSED STREAM CENTERLINE PROFILE



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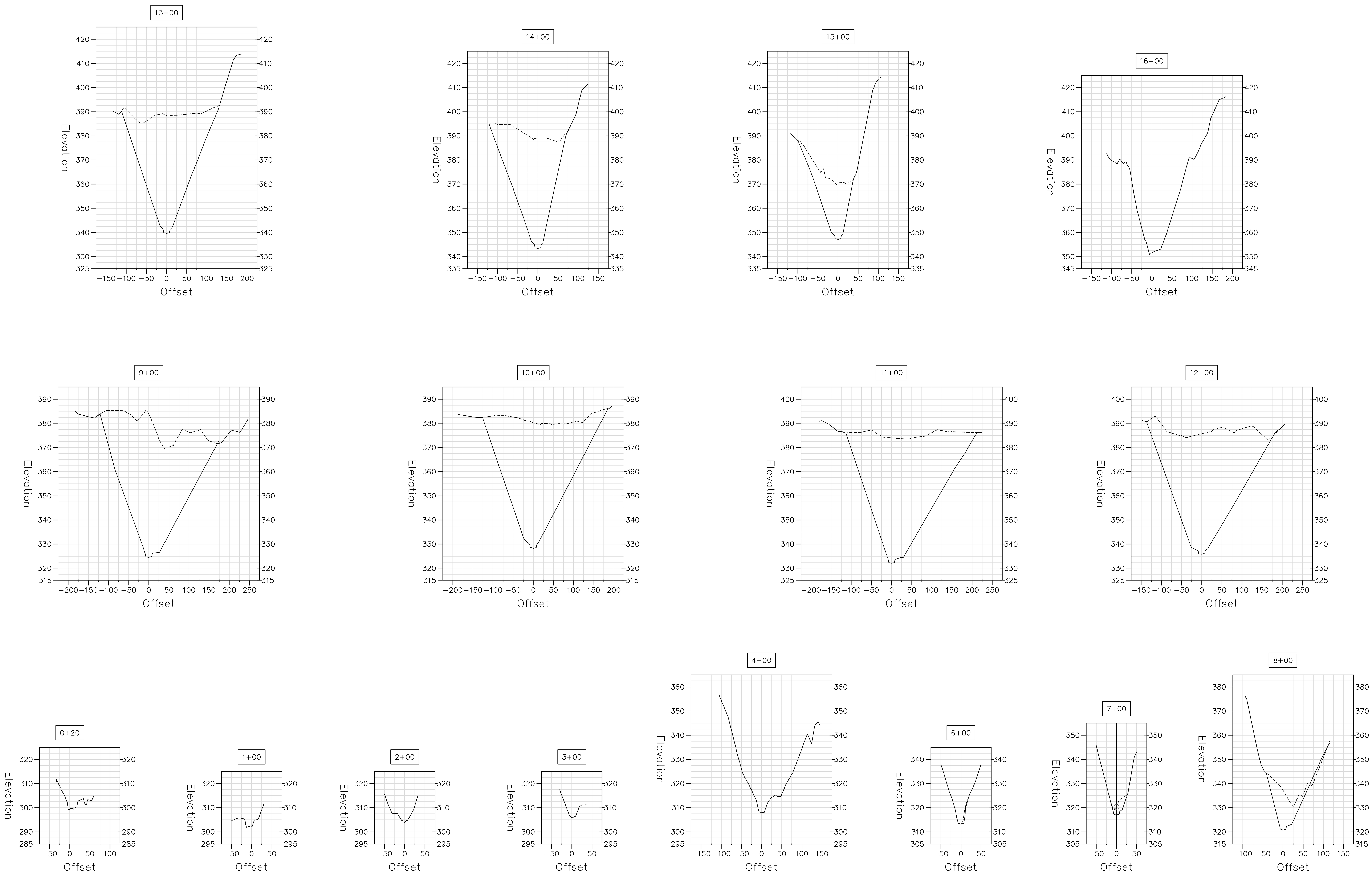
CONCEPTUAL
SITE RESTORATION PROFILE

Sheet reference number:
C-5
SHEET 5 OF 12



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
A	ADDED CROSS SECTION EVERY 100'	06-13-16	TDC

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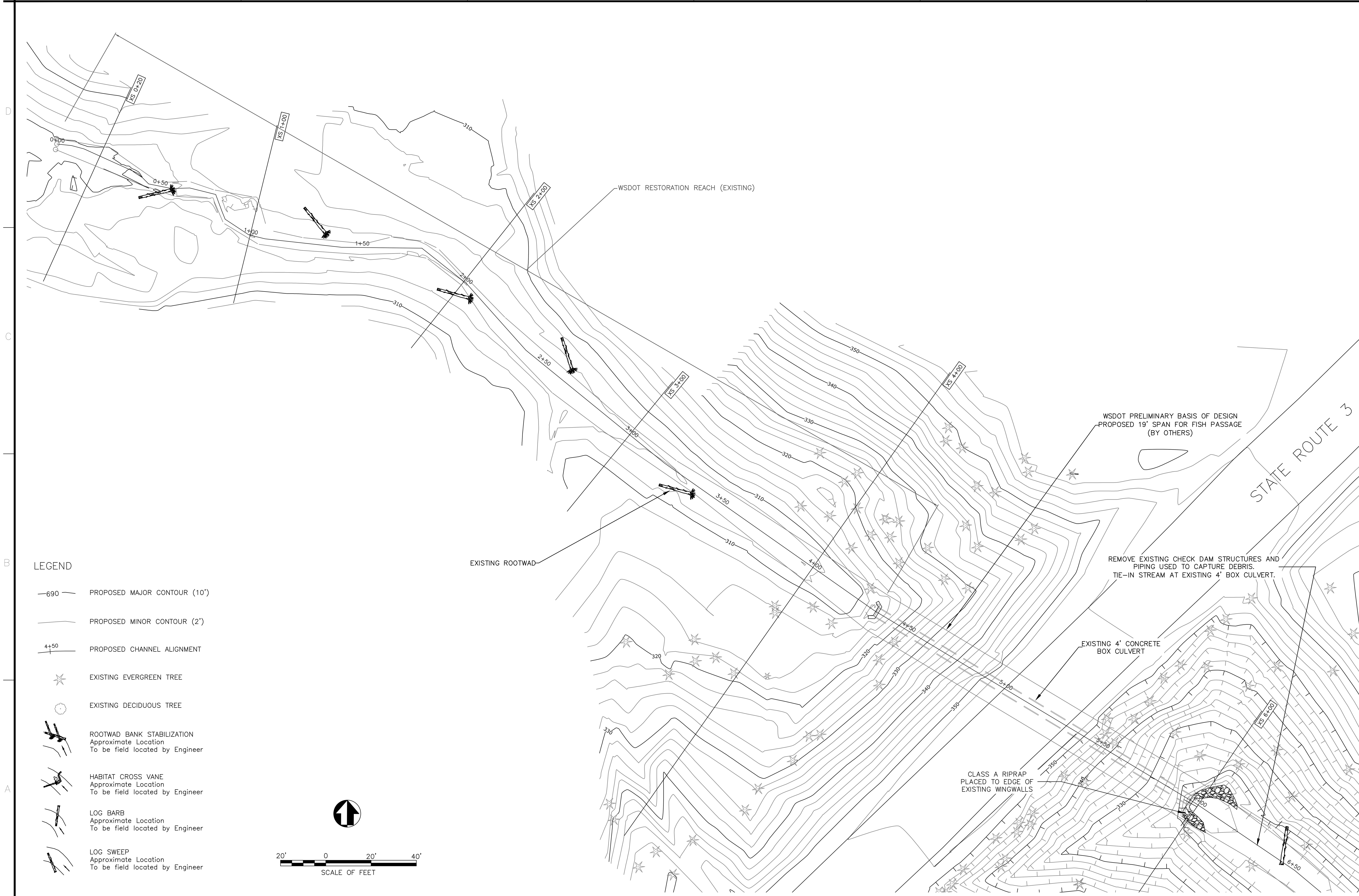
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

SITE RESTORATION CROSS SECTIONS

Sheet reference number:
C-6
SHEET 6 OF 12



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
A	90% DESIGN REVIEW, ADDED SHEET C-7	06-13-16	TCC

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Approved by: T. CAMPBELL, P.E. WASHINGTON_PE_REGISTRATION		File name: Plot date: Dwg scale: AS SHOWN

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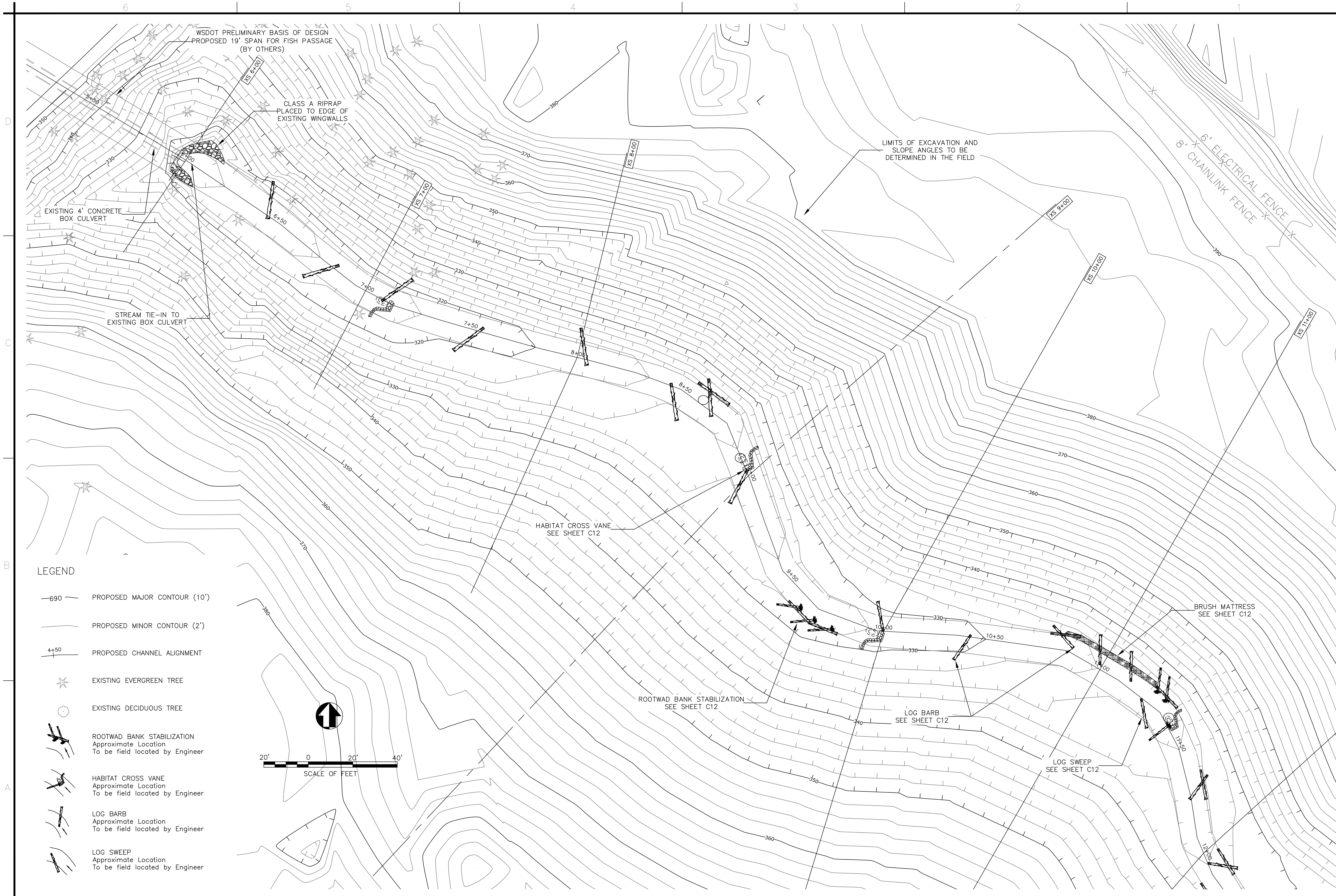
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

SITE RESTORATION
PLAN VIEW – A

Sheet reference number:
C-7



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
A	90% DESIGN REVIEW, ADDED SHEET C-8	06-13-16	TCC

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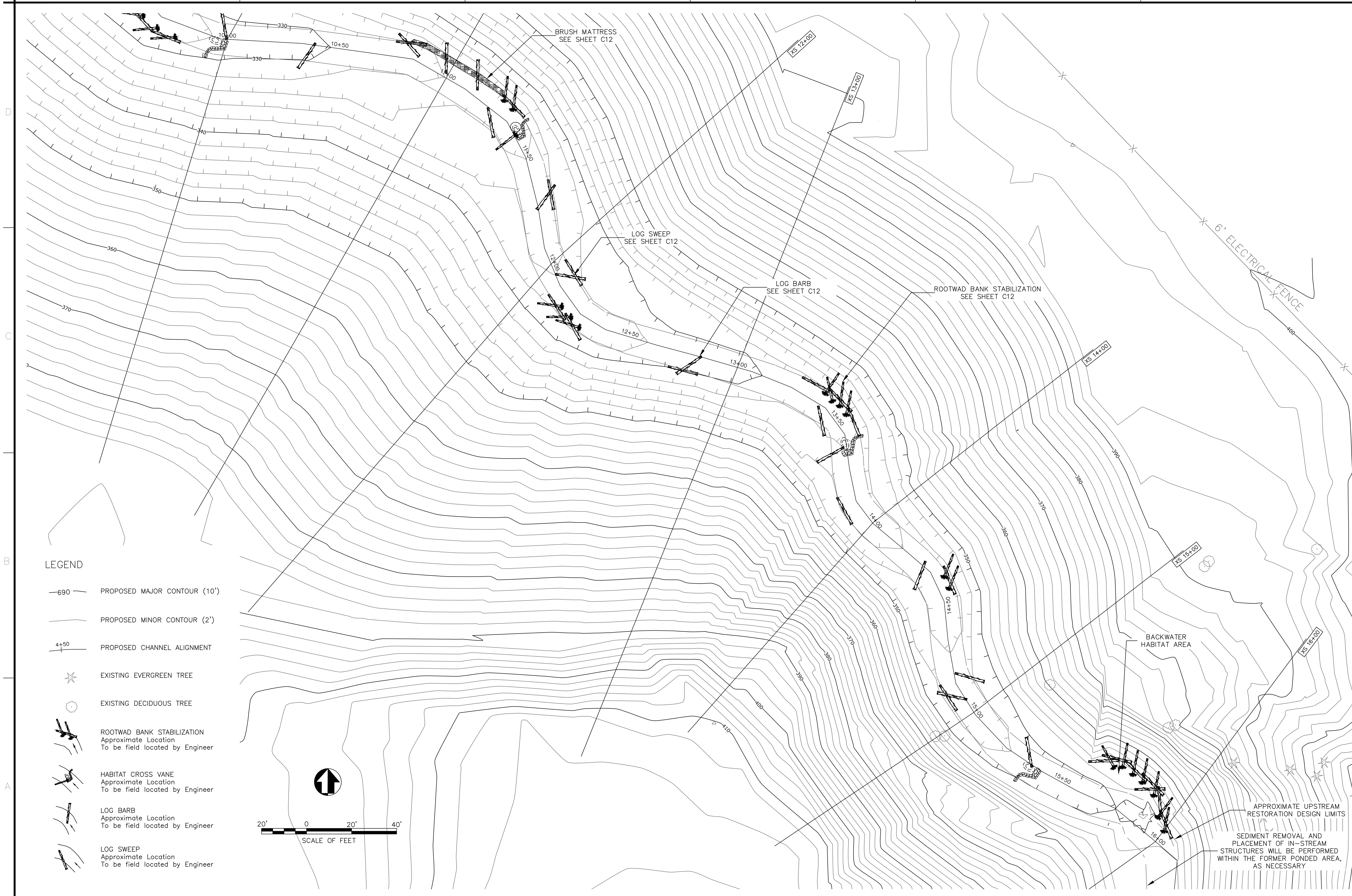
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

SITE RESTORATION
PLAN VIEW – B

Sheet reference number:
C-8
SHEET 8 OF 12



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
A	90% DESIGN REVIEW; ADDED SHEET C-10	06-13-16	TCC

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KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
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SITE RESTORATION PLAN VIEW – C

Sheet reference number:
C-9

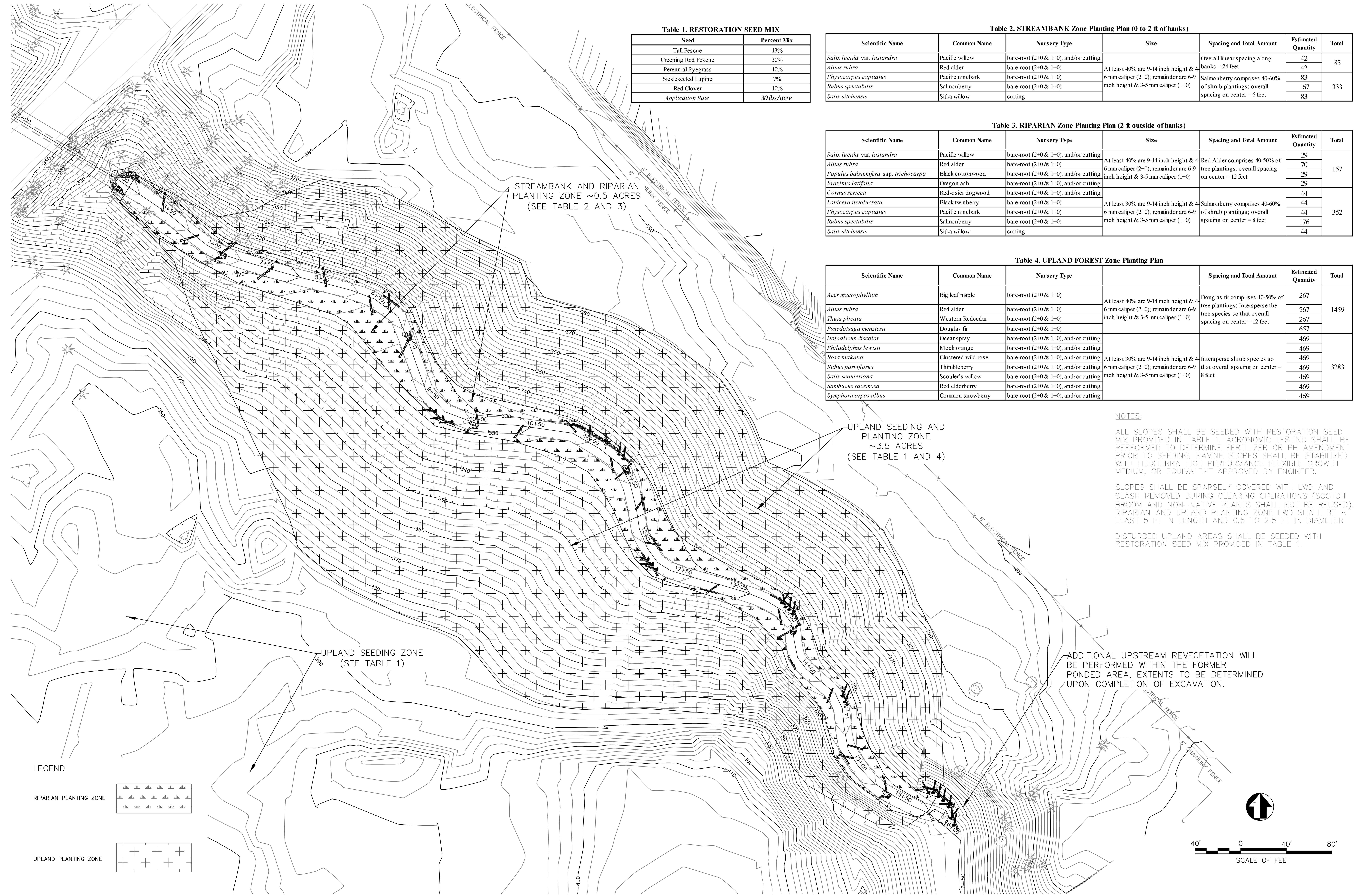

Table 1. RESTORATION SEED MIX

Seed	Percent Mix
Tall Fescue	13%
Creeping Red Fescue	30%
Perennial Ryegrass	40%
Sicklekeeled Lupine	7%
Red Clover	10%
Application Rate	*30 lbs/acre*

Table 2. STREAMBANK Zone Planting Plan (0 to 2 ft of banks)

Scientific Name	Common Name	Nursery Type	Size	Spacing and Total Amount	Estimated Quantity	Total
Salix lucida var. *lasiandra*	Pacific willow	bare-root (2+0 & 1+0), and/or cutting	At least 40% are 9-14 inch height & 4-6 mm caliper (2+0); remainder are 6-9 inch height & 3-5 mm caliper (1+0)	Overall linear spacing along banks = 24 feet	42	83
Alnus rubra	Red alder	bare-root (2+0 & 1+0)			42	
Physocarpus capitatus	Pacific ninebark	bare-root (2+0 & 1+0)		Salmonberry comprises 40-60% of shrub plantings; overall spacing on center = 6 feet	83	333
Rubus spectabilis	Salmonberry	bare-root (2+0 & 1+0)			167	
Salix sitchensis	Sitka willow	cutting			83	

Table 3. RIPARIAN Zone Planting Plan (2 ft outside of banks)

Scientific Name	Common Name	Nursery Type	Size	Spacing and Total Amount	Estimated Quantity	Total
Salix lucida var. *lasiandra*	Pacific willow	bare-root (2+0 & 1+0), and/or cutting	At least 40% are 9-14 inch height & 4-6 mm caliper (2+0); remainder are 6-9 inch height & 3-5 mm caliper (1+0)	Red Alder comprises 40-50% of tree plantings, overall spacing on center = 12 feet	29	157
Alnus rubra	Red alder	bare-root (2+0 & 1+0)			70	
Populus balsamifera ssp. *trichocarpa*	Black cottonwood	bare-root (2+0 & 1+0), and/or cutting			29	
Fraxinus latifolia	Oregon ash	bare-root (2+0 & 1+0), and/or cutting			29	
Cornus sericea	Red-osier dogwood	bare-root (2+0 & 1+0), and/or cutting	At least 30% are 9-14 inch height & 4-6 mm caliper (2+0); remainder are 6-9 inch height & 3-5 mm caliper (1+0)	Salmonberry comprises 40-60% of shrub plantings; overall spacing on center = 8 feet	44	352
Lonicera involucrata	Black twinberry	bare-root (2+0 & 1+0)			44	
Physocarpus capitatus	Pacific ninebark	bare-root (2+0 & 1+0)			44	
Rubus spectabilis	Salmonberry	bare-root (2+0 & 1+0)			176	
Salix sitchensis	Sitka willow	cutting			44	

Table 4. UPLAND FOREST Zone Planting Plan

Scientific Name	Common Name	Nursery Type		Spacing and Total Amount	Estimated Quantity	Total
Acer macrophyllum	Big leaf maple	bare-root (2+0 & 1+0)	At least 40% are 9-14 inch height & 4-6 mm caliper (2+0); remainder are 6-9 inch height & 3-5 mm caliper (1+0)	Douglas fir comprises 40-50% of tree plantings; Intersperse the tree species so that overall spacing on center = 12 feet	267	1459
Alnus rubra	Red alder	bare-root (2+0 & 1+0)			267	
Thuja plicata	Western Redcedar	bare-root (2+0 & 1+0)			267	
Psuedotsuga menziesii	Douglas fir	bare-root (2+0 & 1+0)			657	
Holodiscus discolor	Oceanspray	bare-root (2+0 & 1+0), and/or cutting	At least 30% are 9-14 inch height & 4-6 mm caliper (2+0); remainder are 6-9 inch height & 3-5 mm caliper (1+0)	Intersperse shrub species so that overall spacing on center = 8 feet	469	3283
Philadelphus lewisii	Mock orange	bare-root (2+0 & 1+0), and/or cutting			469	
Rosa nutkana	Clustered wild rose	bare-root (2+0 & 1+0), and/or cutting			469	
Rubus parviflorus	Thimbleberry	bare-root (2+0 & 1+0), and/or cutting			469	
Salix scouleriana	Scouler's willow	bare-root (2+0 & 1+0), and/or cutting			469	
Sambucus racemosa	Red elderberry	bare-root (2+0 & 1+0), and/or cutting			469	
Symphoricarpos albus	Common snowberry	bare-root (2+0 & 1+0), and/or cutting			469	

NOTES:

ALL SLOPES SHALL BE SEEDED WITH RESTORATION SEED MIX PROVIDED IN TABLE 1. AGRONOMIC TESTING SHALL BE PERFORMED TO DETERMINE FERTILIZER OR PH AMENDMENT PRIOR TO SEEDING. RAVINE SLOPES SHALL BE STABILIZED WITH FLEXTERRA HIGH PERFORMANCE FLEXIBLE GROWTH MEDIUM, OR EQUIVALENT APPROVED BY ENGINEER.

SLOPES SHALL BE SPARSELY COVERED WITH LWD AND SLASH REMOVED DURING CLEARING OPERATIONS (SCOTCH BROOM AND NON-NATIVE PLANTS SHALL NOT BE REUSED). RIPARIAN AND UPLAND PLANTING ZONE LWD SHALL BE AT LEAST 5 FT IN LENGTH AND 0.5 TO 2.5 FT IN DIAMETER

DISTURBED UPLAND AREAS SHALL BE SEEDED WITH RESTORATION SEED MIX PROVIDED IN TABLE 1.

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KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
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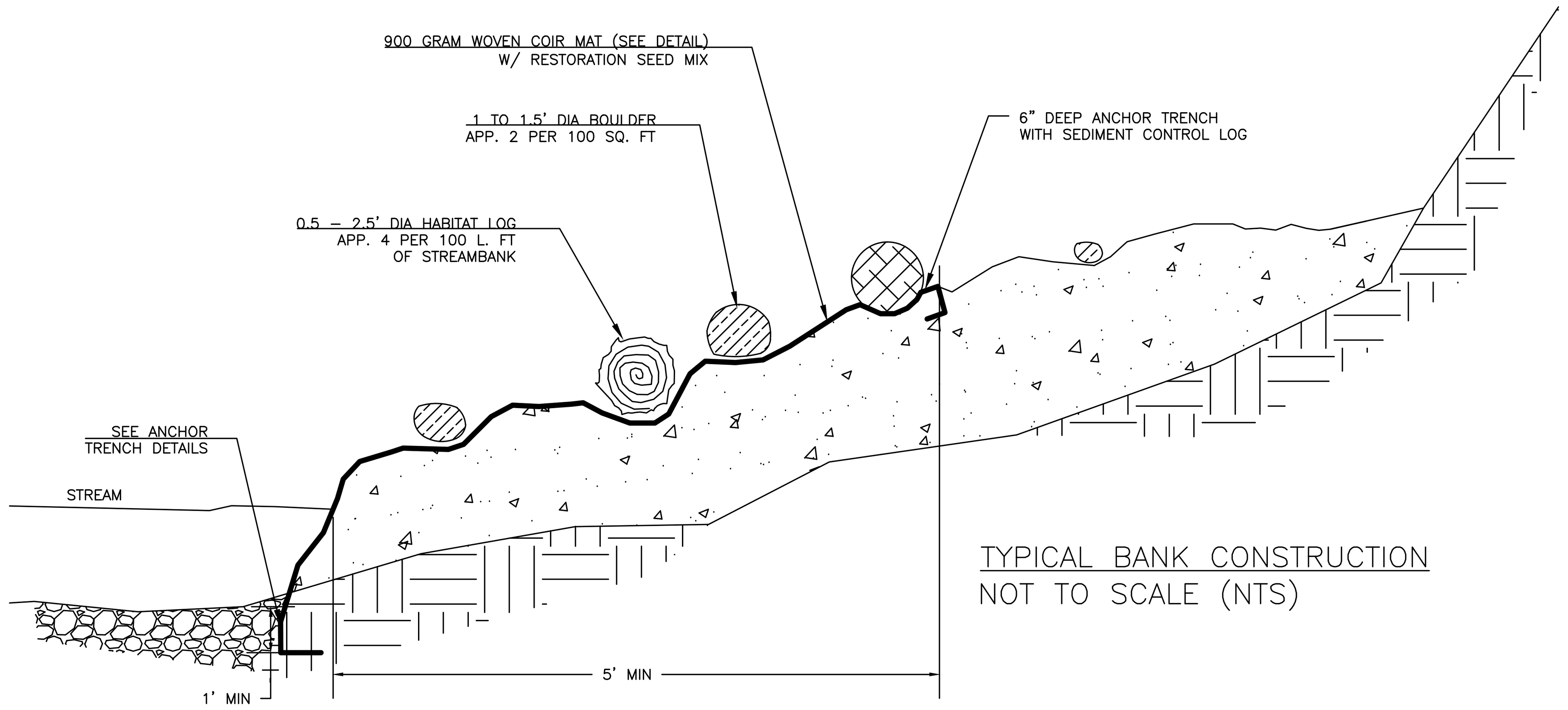
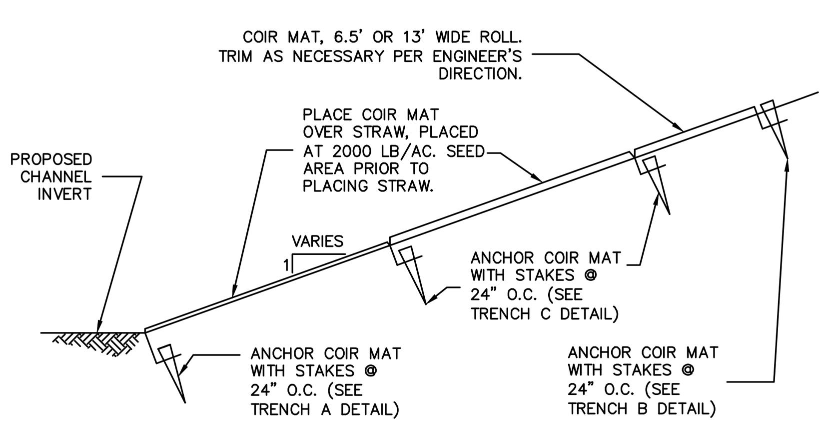
RESTORATION PLANTING PLAN

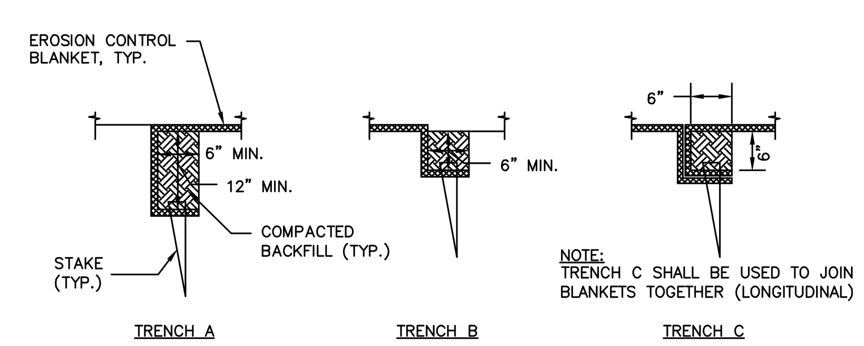
Sheet reference number:
C-10



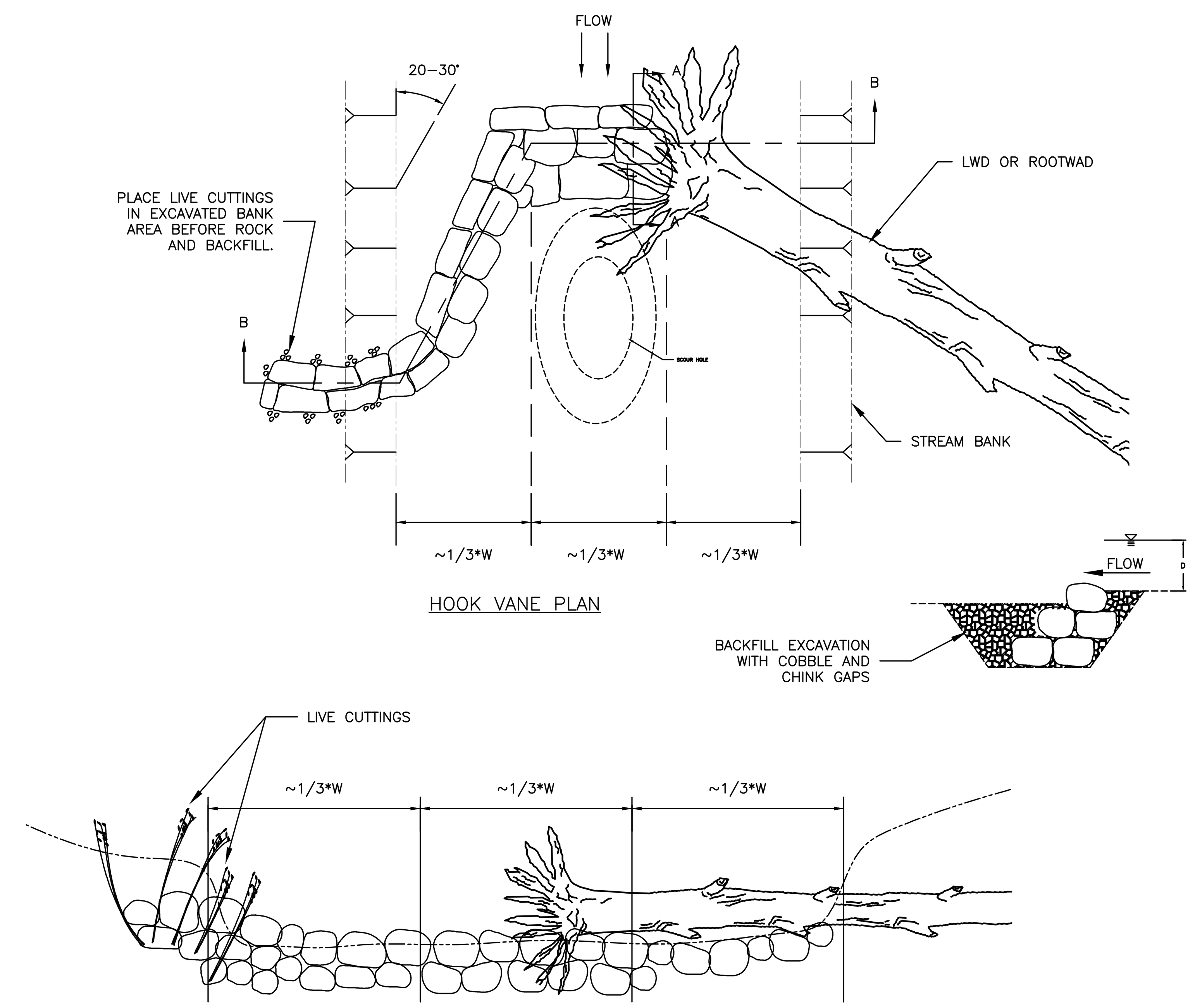
TYPICAL BANK CONSTRUCTION
NOT TO SCALE (NTS)



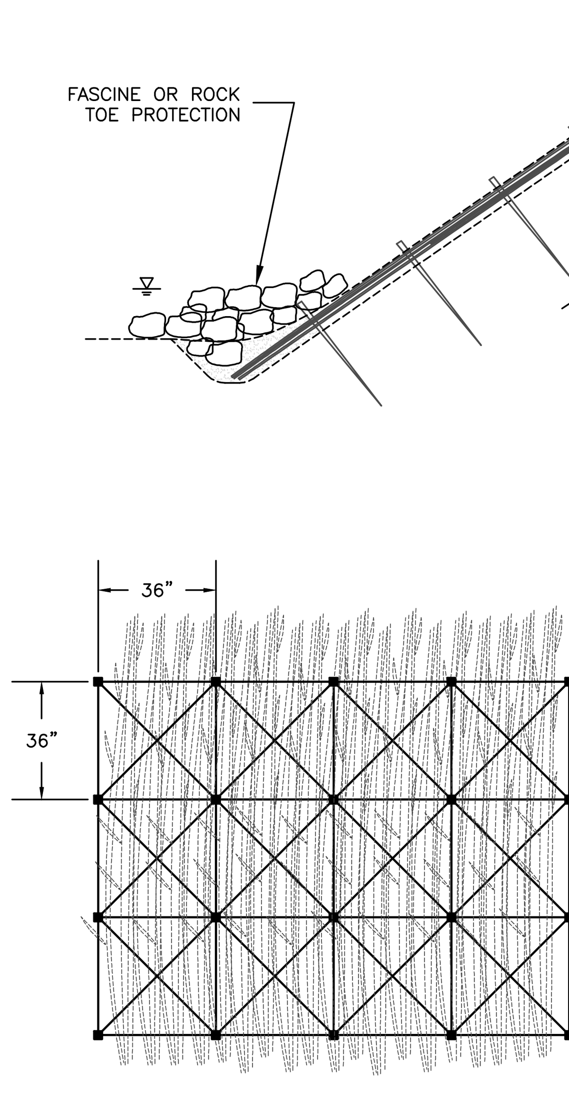
COIR MAT PLACEMENT DETAIL



ANCHOR TRENCH DETAILS FOR EROSION CONTROL BLANKETS



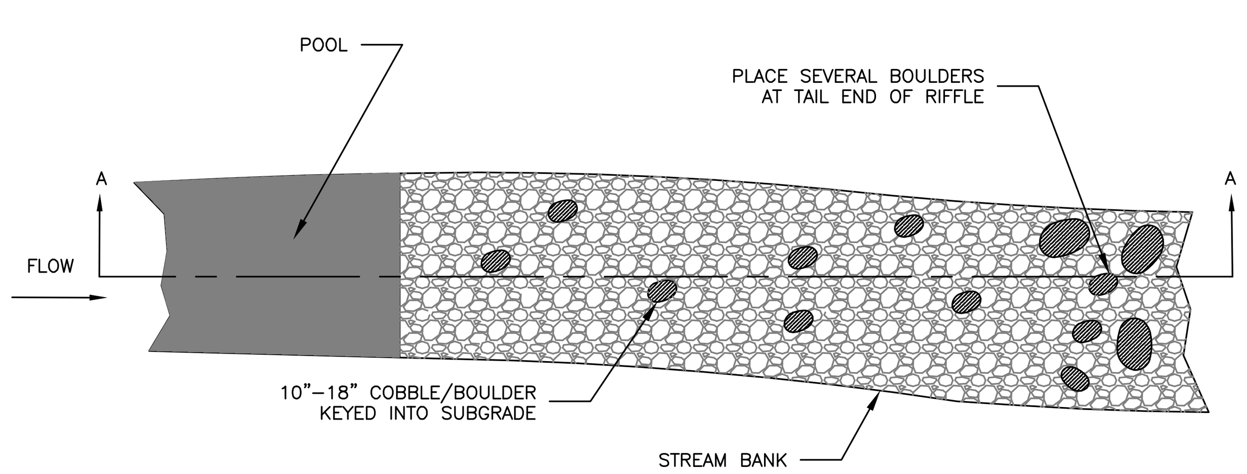
HABITAT CROSS VANE
NTS



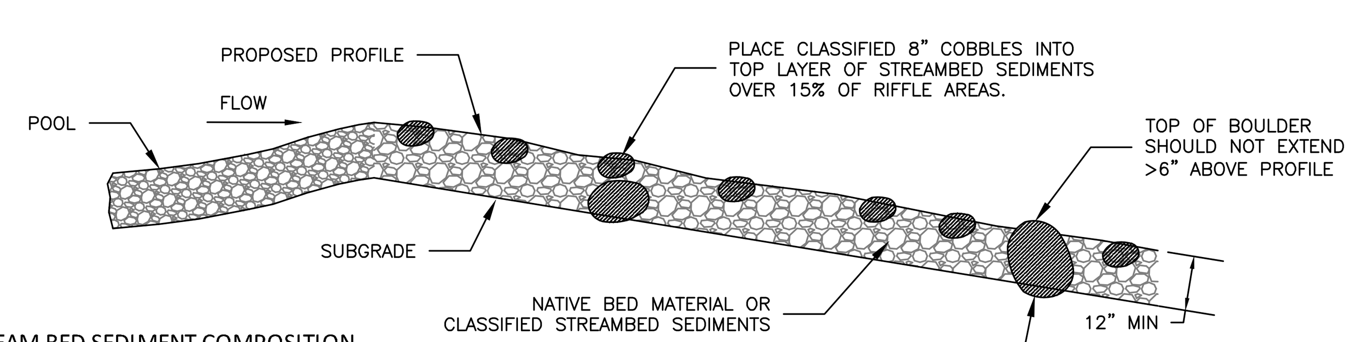
BRUSH MATTRESS
NTS

NOTES:

- EXCAVATE A TRENCH AT TOE OF SLOPE.
- DRIVE WOOD STAKES INTO SLOPE ON A 3'X3' GRID, LEAVING 12" EXPOSED ABOVE SURFACE.
- PLACE WILLOW OR WILLOW TYPE ROOTABLE STOCK 1/2 TO 1 INCH DIAMETER ON SLOPE (12 TO 24 BRANCHES PER FOOT), WITH THE CUT END DOWN IN THE TRENCH AND TERMINAL BUD EXTENDING ABOVE TOP OF SLOPE.
- UP TO 50% DEAD MATERIAL IS ACCEPTABLE.
- TIE CUTTINGS WITH SHORT LENGTHS OF STRING IN A DIAGONAL PATTERN.
- HAMMER STAKES TO FIRMLY PULL CUTTINGS AGAINST SOIL.
- WASH LOOS SOIL INTO CUTTINGS, APPROXIMATELY HALF OF THE DEPTH OF THE MATTRESS SHOULD BE COVERED.
- BACKFILL TRENCH AND APPLY SUITABLE TOE PROTECTION (ROCK,FASCINE, REVETMENT, ETC.)
- TRIM TERMINAL BUD.



PLAN VIEW



SECTION A

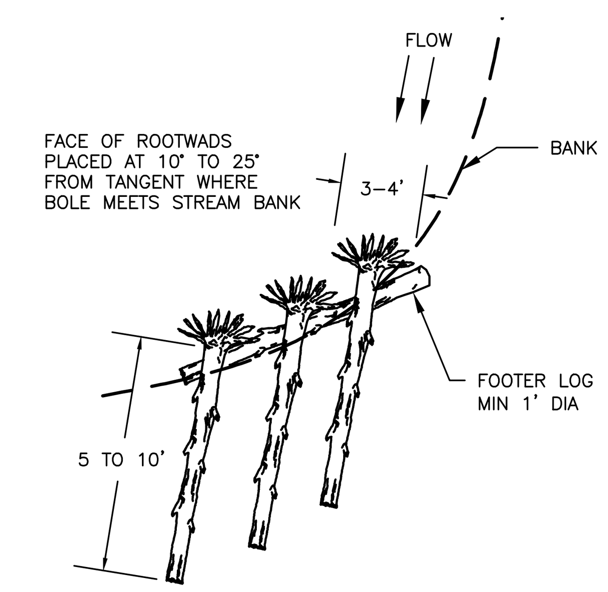
STREAM BED SEDIMENT COMPOSITION

SIEVE SIZE	PERCENT PASSING
2-1/2"	99-100%
2"	65-95%
1"	65-95%
NO. 4	26-44%
NO. 40	16%
NO. 400	5-9%

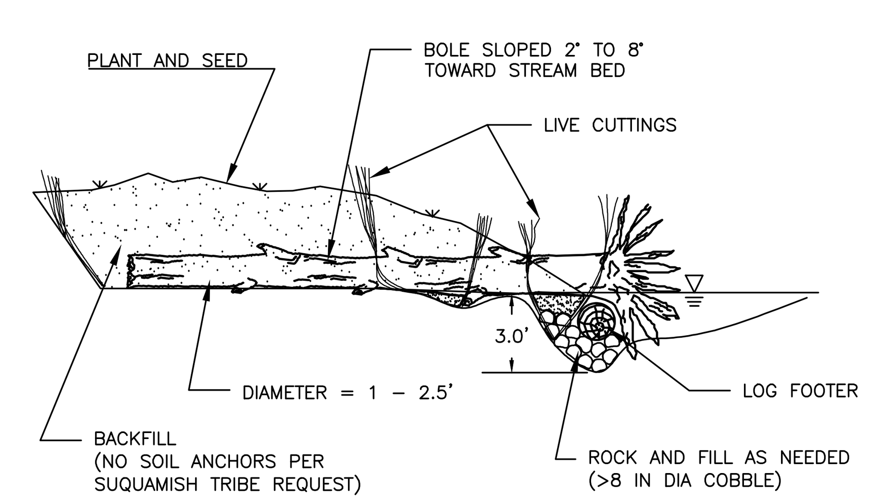
8" COBBLES

APP. SIZE	PERCENT PASSING
8"	99-100%
6"	70-90%
3"	30-60%
3/4"	10%

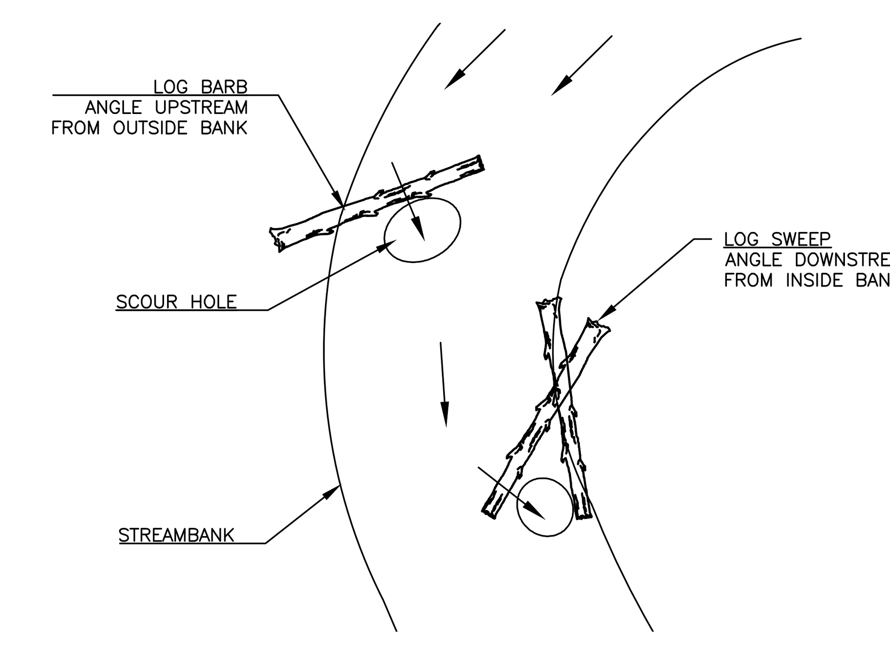
CONSTRUCTED RIFFLE
NTS

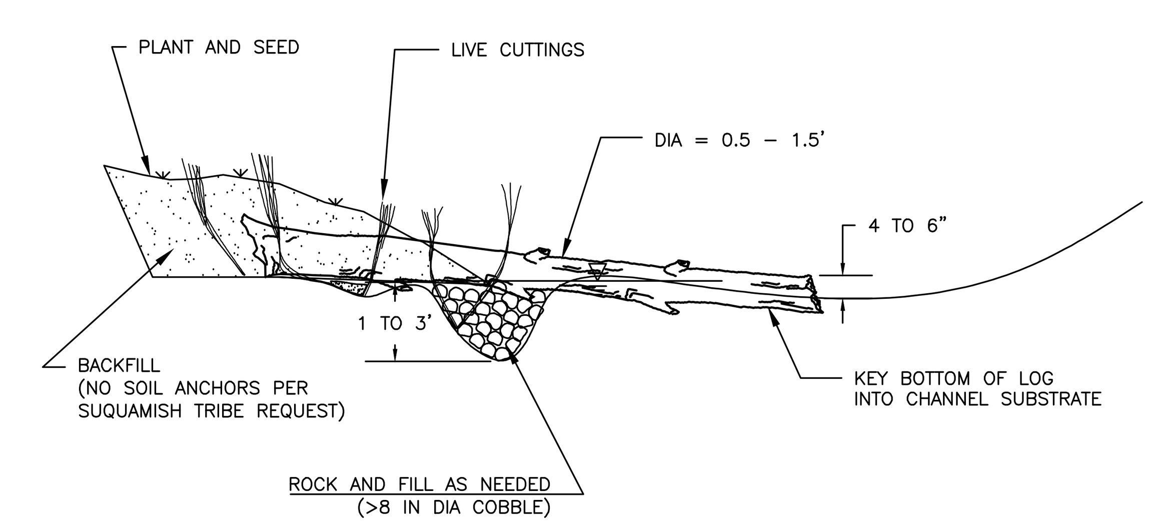


ROOTWAD PLAN



ROOTWAD BANK STABILIZATION
NTS





PROFILE

LOG BARB AND LOG SWEEP
NTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Symbol	Description	Date	Approved
C	90% DESIGN REVIEW	06-13-16	TCC
B	60% REVIEW – NOT FOR CONSTRUCTION	01-13-16	TCC
A	30% REVIEW – NOT FOR CONSTRUCTION	10-09-15	TCC

SIZE D
IF SHEET IS LESS THAN 22"X34" IT IS REDUCED PRINT– SCALE REDUCED ACCORDINGLY
ONE INCH

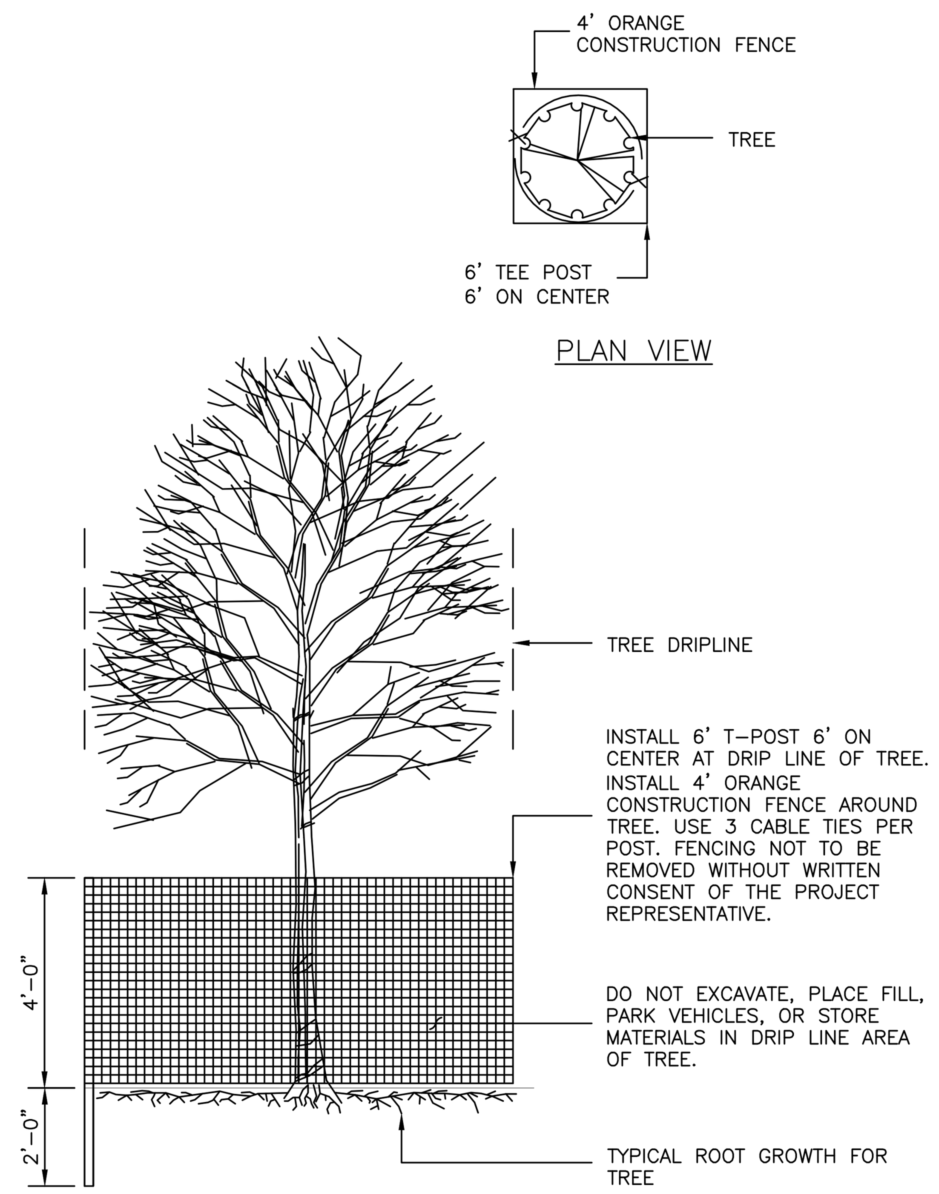
Designed by: T. CHATRIAND
Drawn by: TJC
Spec No.:
Reviewed by: T. CAMPBELL
Approved by: T. CAMPBELL, P.E.
WASHINGTON_PE_REGISTRATION
Date: 6/13/16
TDD No. 15-08-0002
PAN No. 1004530.0019.001.02
File name:
Plot date:
Dwg scale: AS SHOWN

ecology and environment, inc.
Global Environmental Specialists
720 Third Avenue, Suite 1700
Seattle, Washington 98104
(206) 624-9537

KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

RESTORATION DETAILS

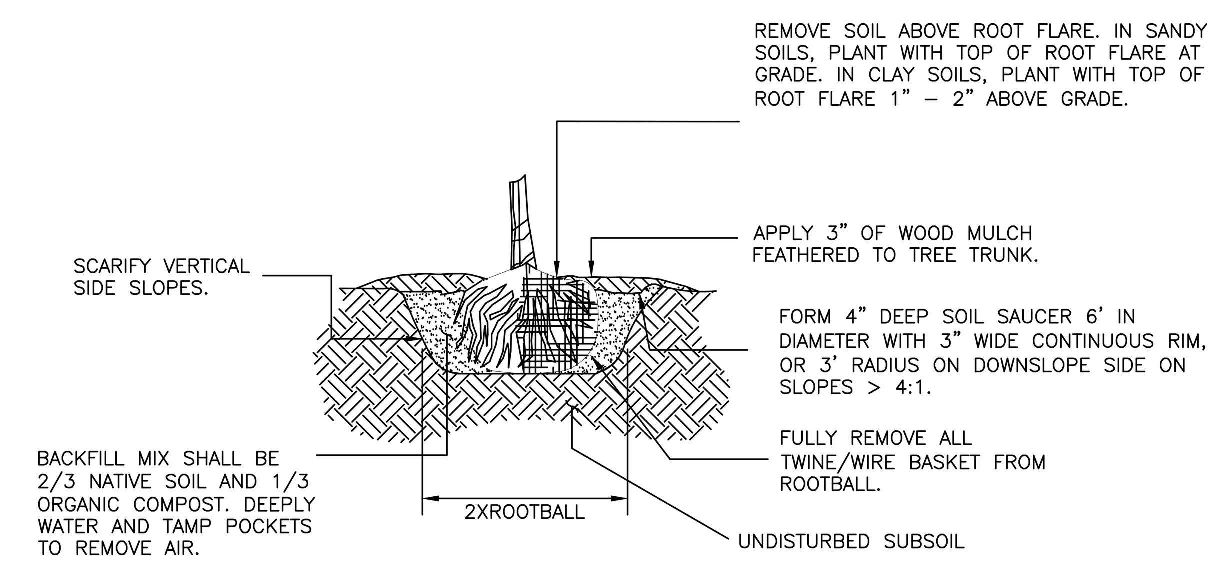
Sheet reference number:
C-11
SHEET 11 OF 12



TREE PROTECTION

(FOR EXISTING TREES TO BE PROTECTED)

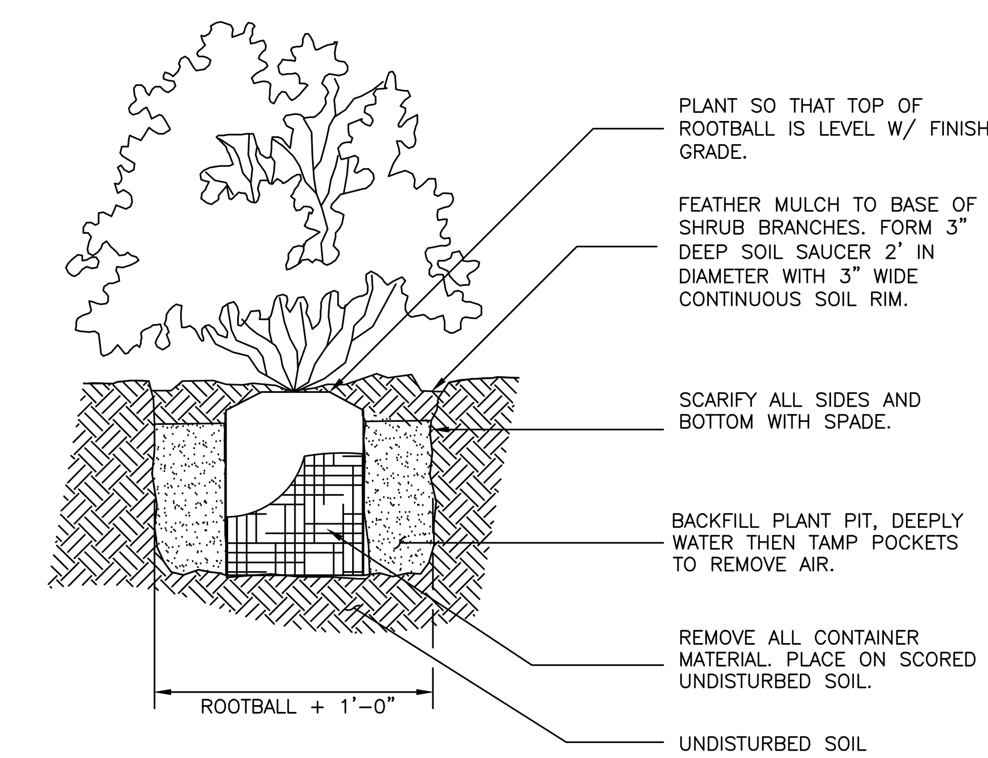
NOTES:
1. CHECK NATIVE SPECIES FOR ACCURACY PRIOR TO PLANTING.
2. KEEP PLANT MOIST AND SHADED IN MULCHED BEDS ON SITE UNTIL TIME OF PLANTING.
3. DO NOT DAMAGE OR CUT LEADER.
4. PRUNE ALL DAMAGED OR DEAD WOOD AFTER PLANTING, AND MULCHING.
5. KEEP CROWN SHAPE TYPICAL OF SPECIES. REMOVE ALL PLANTING TAGS, TAPE AND LABELS AFTER FINAL ACCEPTANCE BY ECOLOGIST.
6. CUT AND REMOVE ALL WIRE/TWINE WRAPPING AND BURLAP.



TREE PLANTING DETAIL

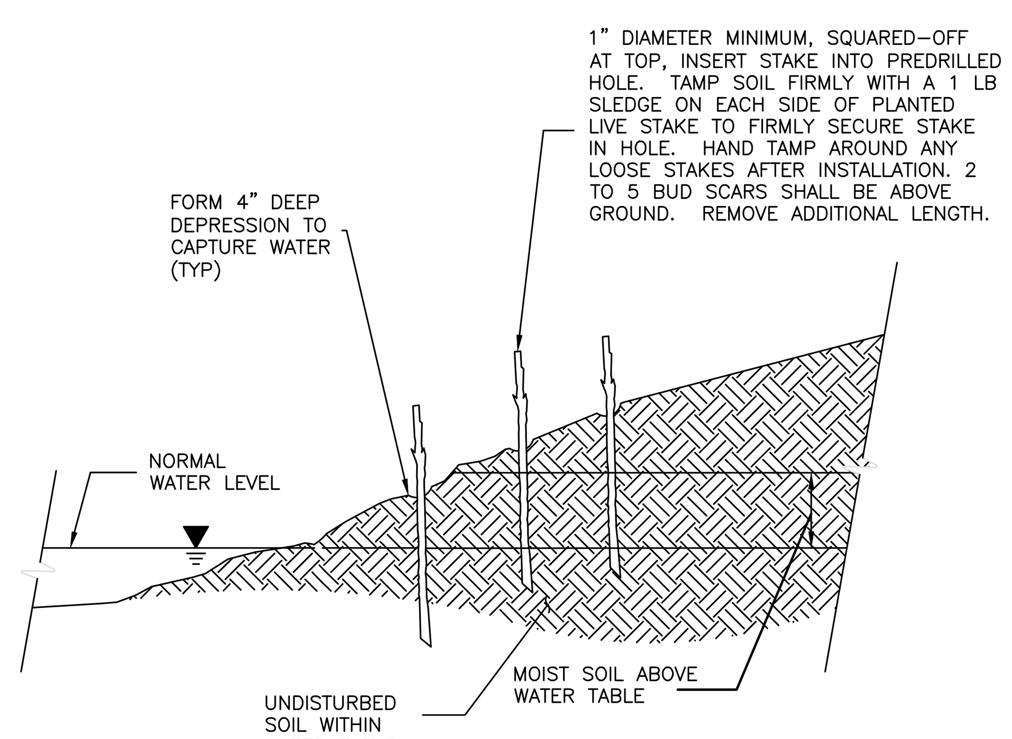
BARE ROOT, BALLED AND BURLAPPED, POTTED, OR CONTAINER GROWN

NOTES
1. KEEP PLANT MOIST AND SHADED IN MULCH BEDS ON SITE UNTIL TIME OF PLANTING.
2. FOR ROOT BOUND CONTAINER PLANTS, MAKE 4–5" DEEP VERTICAL CUTS INTO ROOT BALL EDGE AND PLANT IMMEDIATELY.
3. DO NOT CUT LEADER, PRUNE ALL DAMAGED OR DEAD WOOD AFTER PLANTING, STAKING AND MULCHING, KEEP CROWN SHAPE TYPICAL OF SPECIES, REMOVE ALL PLANTING TAGS, TAPE AND LABELS AFTER FINAL ACCEPTANCE BY ECOLOGIST.



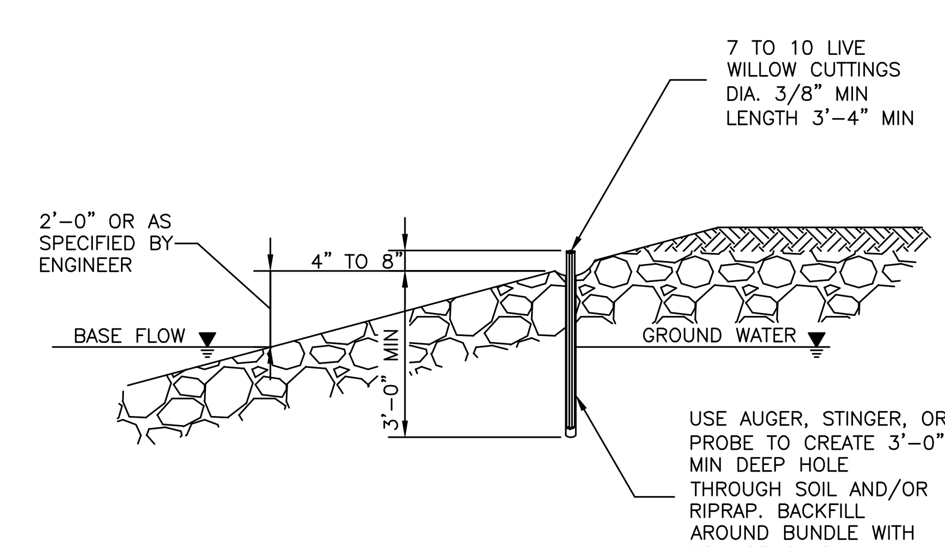
SHRUB PLANTING DETAIL

BARE ROOT OR CONTAINER



NOTES
1. HARVEST AND PLANT WILLOW LIVE STAKES DURING DORMANT SEASON
2. WILLOW STAKE SHALL HAVE CUT END ON AN ANGLE TO SIGNIFY PLANTING END.
3. USE HEALTHY, STRAIGHT, AND LIVE WOOD AT 2 TO 3 YEARS OLD (½"–1" DIA.).
4. MAKE CLEAN CUTS AND DO NOT DAMAGE STAKES OR SPLIT ENDS.
5. PLACE CUTTINGS IN 5 GALLON PAILS OR TRASHCANS WITH WATER IMMEDIATELY AFTER HARVESTING.
6. SOAK CUTTINGS FOR 24 HOURS (MIN.) PRIOR TO INSTALLATION.
7. STORE CUT WILLOWS WITH LOWER ENDS IN WATER FOR NO LONGER THAN 7 DAYS BEFORE PLANTING. DO NOT STORE WILLOW BUNDLES HORIZONTALLY AS SOME WILLOWS WILL DROWN AND OTHERS WILL DRY OUT
8. LENGTH OF STAKES SHALL BE 2' (MIN.). PRE-DRILL HOLES WITH STEEL REBAR.
9. PLANT AT LEAST 3/4 LENGTH OF STAKE INTO MOIST SOIL.

WILLOW LIVE STAKES (WLS)



WILLOW BUNDLING

Symbol	Description	Date	Approved
C	90% DESIGN REVIEW	06-13-16	TCC
B	60% REVIEW – NOT FOR CONSTRUCTION	01-13-16	TCC
A	30% REVIEW – NOT FOR CONSTRUCTION	10-09-15	TCC

SIZE D
IF SHEET IS LESS THAN 22"X34" IT IS REDUCED PRINT– SCALE REDUCED ACCORDINGLY
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Designed by: T. CHATRIAND | Date: 6/13/16
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KITSAP COUNTY WASHINGTON
BREMERTON AUTO WRECKING LANDFILL
PORT ORCHARD, KITSAP COUNTY, WASHINGTON

RESTORATION DETAILS

Sheet reference number:
C-12
SHEET 12 OF 12

B Design Memoranda

Appendix B-1	Slope Stability Analysis
Appendix B-2	Hydrologic Analysis
Appendix B-3	Hydraulic Design Methodology and Analysis
Appendix B-4	Scour Analysis

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ecology and environment, inc.

Design Memorandum

Date:	6/13/2016
To:	Design File
From:	Tom Campbell, P.E.
Reviewer:	Jen Jenkins
Subject:	**Bremerton Auto Wrecking Landfill Conceptual Slope Stability Analysis**

PROFESSIONAL ENGINEER CERTIFICATION

Gorst Creek/ Bremerton Auto Wrecking Landfill Conceptual Slope Stability Analysis
Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

I hereby certify that this Conceptual Slope Stability Analysis for the Bremerton Auto Wrecking Landfill Site in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE: Thos C Campbell

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 6/13/2016

THOMAS C. CAMPBELL
STATE OF WASHINGTON
51283
REGISTERED
PROFESSIONAL ENGINEER

OBJECTIVE

This memorandum describes the slope stability analysis that was conducted to evaluate the performance of the conceptual design for the restoration of Gorst Creek at the Bremerton Auto Wrecking Landfill Site. The calculations herein are intended to inform designers of potential slope issues but are not intended as guidance for constructability or construction. A registered professional geotechnical engineer must be consulted prior to and during construction.

CRITERIA

Slope stability analyses are routinely performed to assess the safety and functional design of excavated, natural, or graded slopes (Abramson et al. 2002). A Factor of Safety (FOS) was used as the criterion to evaluate the adequate performance of the conceptual slopes. Technically, the FOS represents the relationship between the average shear strength of the soil (T_f) and the average shear stress developed along potential failure surfaces (T_d) (Das 2010):

$$FOS = \frac{\mathrm{Tf}}{\mathrm{Td}}$$

When the FOS is equal to 1 or less, the slope is in a state of impending failure. The *Slope Stability Engineer Manual* recommends using a minimum FOS of 1.5 for normal long-term loading conditions for embankments (USACE 2003).

METHOD OF ANALYSIS

An initial evaluation of site conditions determined that the critical mode of failure for the site is a surface slide that could occur along the slope (translational failure) with small depth to length ratio. This is typical in low cohesion to cohesionless (granular) soils (NAVFAC 1982; Abramson 2002). XSTABL© Version 5.2 by Interactive Software Designs, Inc. was used to develop the slope geometry and perform the slope analysis. This program allows for a search of the most critical surface and returns a corresponding FOS using two-dimensional limit equilibrium analysis by the simplified Bishop and Janbu methods.

ASSUMPTIONS

As stated in the Gorst Creek – Bremerton Auto Wrecking Landfill Engineering Evaluation/Cost Analysis (E & E 2012):

> Kitsap County lies entirely within the Puget Trough. The Puget Trough is a large structural basin in consolidated rocks of Tertiary and earlier age that extends south from Canada to the central part of western Oregon (Raisz 1965), running along a north/south-trending lowland located between the Cascade Mountains to the east and the Olympic and Coast Range Mountains to the west. The trough has been partly filled by unconsolidated deposits of clay, silt, sand, gravel, and glacial till. These unconsolidated sedimentary materials were deposited by water and ice during the Pleistocene glacial epoch (Ice Age), but recent alluvial deposits underlie the surface in some low-lying areas. The upper materials of this fill, except the recent deposits, were deposited by ice and glacial melt water streams during the latest glaciation of the area (Vashon glaciation). During that glaciation, a large tongue of ice moved southward from British Columbia and Vancouver Island and partly filled the Puget Sound basin (Bretz 1913). The northern portion of the Gorst Creek watershed contains a large deposit of recessional outwash that consists of fine-grained sand (Sceva 1957).

The Gorst area basin is underlain by three geologic units: Vashon till, Vashon recessional outwash, and Tertiary bedrock (EPA 2003). Geotechnical borings advanced by the United States Environmental Protection Agency (EPA) in August 2011 on the north and south sides of Gorst Creek revealed sand and gravel deposits to depths up to 90 feet below grade, characteristic of the Vashon recessional outwash. During drilling of boring SB04, located within the ravine near the creek channel, groundwater was encountered at a depth of 5 feet below ground surface. This was the only boring that encountered groundwater.

The following design criteria and assumptions were used in this assessment:

[1] Maximum effective side slopes will be determined by analysis. Pre-disturbance (pre-landfilling) slopes are estimated at 1.5:1 to 2:1. This is the anticipated slope that will remain following site restoration. Conceptual slope analysis has been run in XSTABL© using both 1.5:1 and 2:1 slopes.

[2] Maximum height of finished slope is estimated at 50 feet above ground surface near the upstream end of the landfill and 55 feet above ground surface near the downstream end of the landfill. Slope heights of 55 feet have been used in the conceptual analysis.

[3] Groundwater was located at depths of 5 feet below the existing stream elevation northwest of Highway 3 SW. Drilling southeast of Highway 3 SW did not encounter groundwater above 90 feet below ground surface (bgs) from the top of bank; drilling did not extend deeper than 90 feet bgs (E & E 2012). It is assumed that no seepage is present in the estimated potential failure zone. No water surfaces were used in the analysis.

[4] Native soils include sands and gravels with silt and clay. Drilling logs recorded silty sand within 20 feet of the ground surface underlain by fine to coarse grained sand, fine to coarse grained gravel, and gravelly sand (E & E 2011). Drilling logs are included in Attachment C. Attachment B shows the locations of the borings.

[5] Depth to bedrock was estimated at approximately 243 feet above sea level in elevation based on United States Geological Survey (USGS) Publications Warehouse Field Studies Map 2265 (Buchanan-Banks 1994). This is approximately 70 feet below the upgradient end of the concrete box culvert beneath Highway 3 SW which is at an elevation of approximately 313 feet above sea level.

[6] Particle size analysis (ASTM D422-63) was performed on representative material samples collected during drilling (E & E 2011). Gravel content ranged from 1.2 percent to 46.1 percent, sand content ranged from 48.4 percent to 87.3 percent, and silt and clay content ranged from 4.2 percent to 11.5 percent. Complete Unified Soil Classification System soil descriptions could not be determined since the material below the #4 standard sieve size was not tested; however, partial classification reveals that soils from 0 to 25 feet are poorly graded sands, and poorly graded gravels with small portions of fines and soils 55 feet below ground surface to drilling termination are well graded sands with small portions of fines. This slope stability analysis uses soil parameters for poorly graded sand from 0 to 35 feet and well graded sand from 35 feet to bedrock depth (drilling was completed at 90 feet below ground surface or approximately 300 feet above sea level in elevation). Results of the analysis are included in Attachment A, and the geotechnical laboratory report in Attachment C.

[7] Direct shear testing (ASTM D3080-04) was performed on representative material samples collected during drilling (E & E 2011). Only one point was tested for each sample, so friction angles could not be calculated. To determine friction angles for the conceptual analysis, the shallow poorly graded soil testing results were plotted together, and the deeper well graded soil testing results were plotted together. This slope stability analysis uses a friction angle of 33 degrees for poorly graded sand and 52 degrees for well graded sand. Results of the analysis are

shown in Attachment B and the geotechnical laboratory report in Attachment C. Peak shear stress plots used to determine friction angles are included in Attachment C.

CONCLUSIONS

The soil geophysical properties used for the calculations are summarized in Attachment A. The results of the slope stability analysis are presented in Attachment D and indicate that the conceptual design has an FOS of less than 1.0 when excavated to a slope of 1.5:1. Based on the calculated FOS, a 1.5:1 slope is likely to fail under static load conditions. The FOS indicates that slope instability is likely to occur during construction. When excavated to a slope of 2:1, the FOS is 1.3. This slope does not meet the recommended criterion of a 1.5 FOS. A registered professional geotechnical engineer must be consulted to assess potential slope constructability issues.

It is recommended that geotechnical testing be performed on the embankment soils to determine the site-specific angle of internal friction, dry and saturated density, cohesion, hydraulic conductivity, and gradation to verify that the assumed soil properties are conservative and to evaluate methods by which the FOS could be increased to meet design criteria during construction.

REFERENCES

Abramson, L.W., Lee T.S., Sharma S. and Boyce G.M., 2002, *Slope Stability and Stabilization Methods*, John Wiley & Sons, Inc. (Pub.), 712 pages, ISBN 0-471-38493-3.

Bretz, J.H. 1913. Glaciation of the Puget Sound Region. In Washington Geological Survey Bulletin.

Buchanan-Banks, Jane M. and Donley S. Collins, 1994, Miscellaneous Field Studies Map 2265 showing depth to bedrock of the Tacoma and part of the Centralia 30' x 60' quadrangles, Washington, USGS Publications Warehouse - http://pubs.er.usgs.gov/publication/mf2265, accessed December 30, 2015.

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NAVFAC (Naval Facilities Engineering Command). 1982. Soil Mechanics Design Manual 7.1. NAVFAC DM-7.1, May 1982.

Raisz, Erwin. 1965. Landforms of the Northwest States. 3rd revised ed. Harvard University.

Sceva, Jack E. 1957. Geology and Ground-Water Resources in Kitsap County, Washington. U.S. Geological Survey, Water-Supply Paper 1413.)

USACE (United States Army Corps of Engineers). 2003. *Slope Stability Engineer Manual* No. 1110-2-1902; October 2003.

Attachment A: Table

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Table A-1. Grain Size (ASTM D 422), Direct Sheer (ASTM D 3080), and Other Parameters Summary

Boring ID	Depth, ft	Grain Size			Direct Shear		Other Parameters		
		Gravel, %	Sand, %	Fines, %	Normal Stress, psf	Maximum Shear Stress, psf	Bulk Density, pcf	Assumed Friction Angle, %	Assumed Cohesion, psf
SB-01	20.5	---	---	---	2400	2044	120	40.4	0
SB-01	25	38.3	53.4	8.3	---	---	---	---	---
SB-01	50-52	34.9	56.3	8.8	---	---	---	---	---
SB-02	22	2.0	87.3	10.7	---	---	---	---	---
SB-02	30.5	---	---	---	3600	3755	133	46.2	0
SB-02	50.5	---	---	---	6000	7794	137	52.4	0
SB-02	55	46.1	48.4	5.5	---	---	---	---	---
SB-03	20.5	---	---	---	2401	2522	122	46.4	0
SB-03	21	---	---	---	2400	2210	124	42.6	0
SB-03	25	36.5	53.1	10.4	---	---	---	---	---
SB-03	50	37.4	52.7	9.9	---	---	---	---	---
SB-03	57.5	---	---	---	6800	8687	142	51.9	0
SB-04	10	12.4	83.4	4.2	---	---	---	---	---
SB-04	10.5	---	---	---	1201	1452	136	50.4	0
SB-04	11	---	---	---	1300	1756	132	53.5	0
SB-05	20	45.8	45.4	8.8	---	---	---	---	---
SB-05	25.5	---	---	---	3000	2833	127	43.4	0
SB-05	55	1.2	87.3	11.5	---	---	---	---	---

Boring ID	Percent Finer than Designated Sieve Size, %												
	2.0-inch Sieve	1.5-inch Sieve	1-inch Sieve	3/4-inch Sieve	1/2-inch Sieve	3/8-inch Sieve	No. 4 Sieve	No. 10 Sieve	No. 20 Sieve	No. 40 Sieve	No. 60 Sieve	No. 100 Sieve	No. 200 Sieve
SB-01	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-01	100	94	89	83	76	71	62	50	37	23	15	11	8
SB-01	---	---	100	90	84	79	65	48	33	23	16	11	9
SB-02	---	---	---	---	100	99	98	96	92	74	34	16	11
SB-02	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-02	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-02	---	100	89	86	76	68	54	38	22	15	11	7	6
SB-03	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-03	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-03	---	100	86	80	780	67	64	59	52	34	18	12	10
SB-03	---	100	85	85	81	77	63	47	34	24	17	13	10
SB-03	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-04	---	---	100	96	95	91	88	77	59	34	14	6	4
SB-04	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-04	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-05	---	100	94	87	71	63	54	41	32	25	16	11	9
SB-05	---	---	---	---	---	---	---	---	---	---	---	---	---
SB-05	---	---	---	---	---	100	99	97	93	74	36	16	11

Attachment B: Figures

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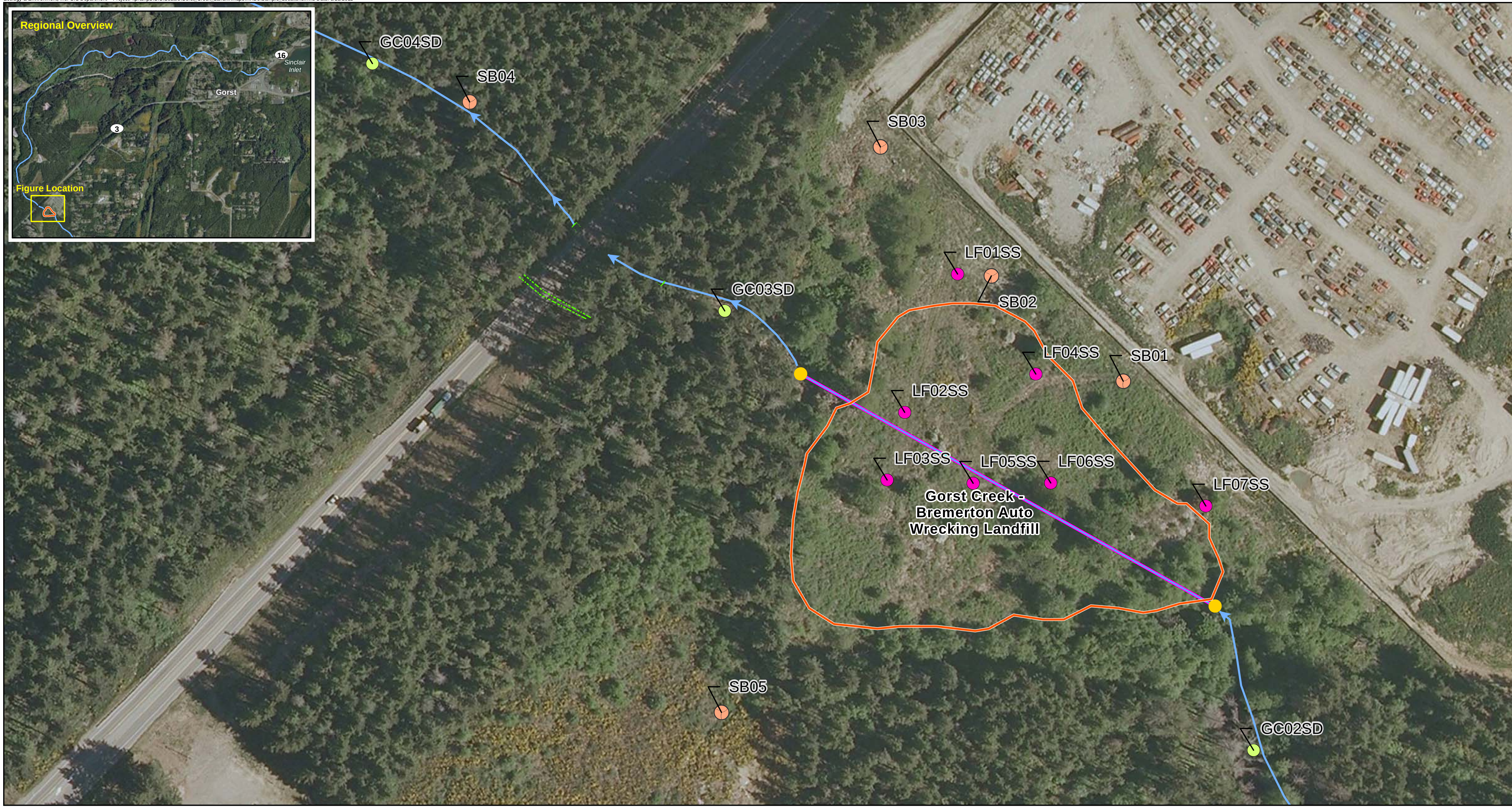
Ecology & Environment, Inc. GIS Department Project: \\prtbhp1\GIS\Seattle\Gorst_Creek_Landfill\Maps\MXDs\Sample_Locaitons.mxd Date: 8/25/2011



Soil Boring Locaitons
G Series Samples
L Series Samples
Existing well
Outfall location
24-inch corrugated metal pipe under the landfill
Gorst Creek - Bremerton Auto Wrecking landfill boundary

Gorst Creek Landfill

Port Orchard, Washington

N W E S

Map Projection: NAD 1983 UTM Zone 10N Meter
Map Scale: 1: 1,394
0 25 50 100 150 200 250
Feet
1 in = 116 ft

Figure
Sample Location

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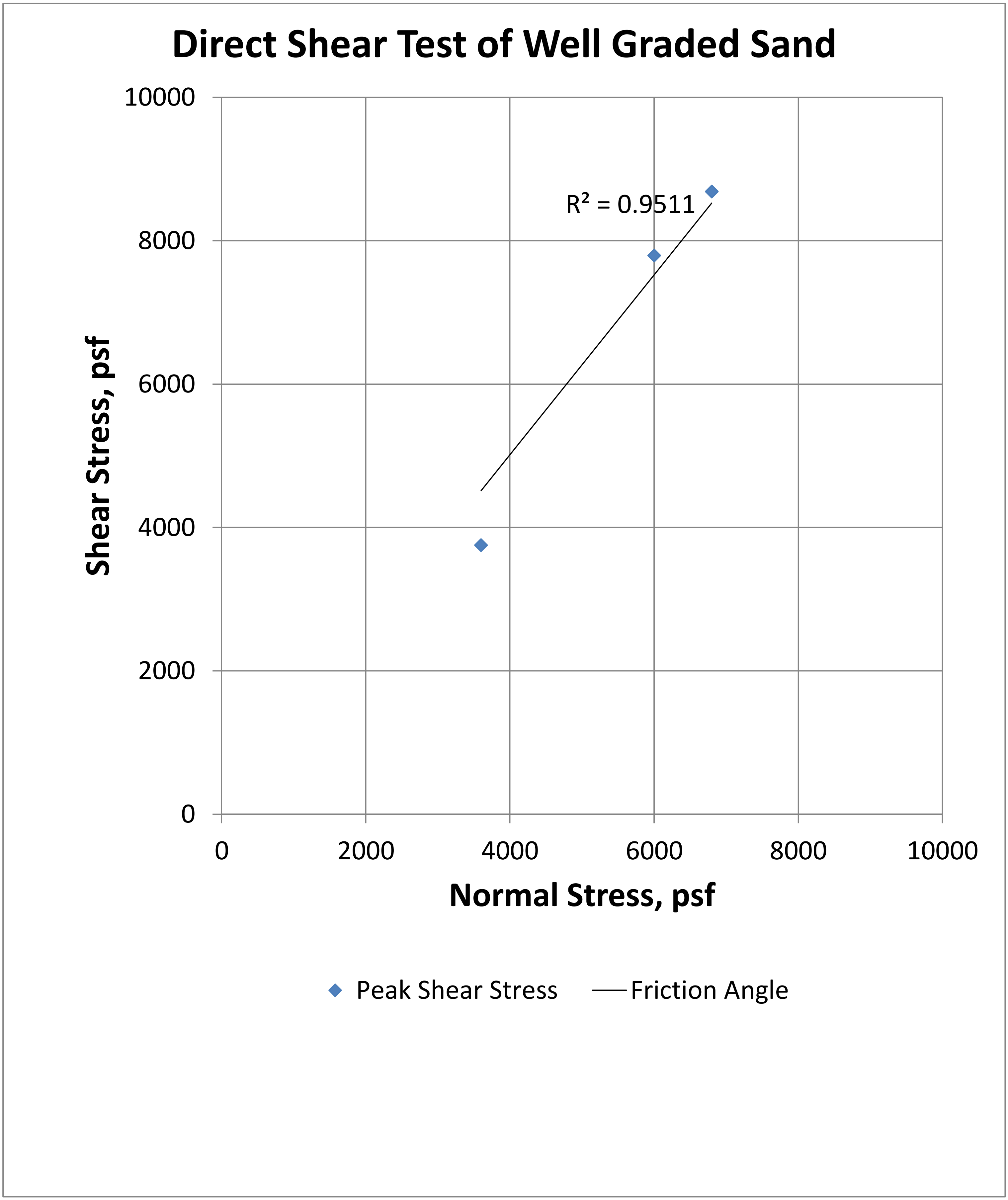
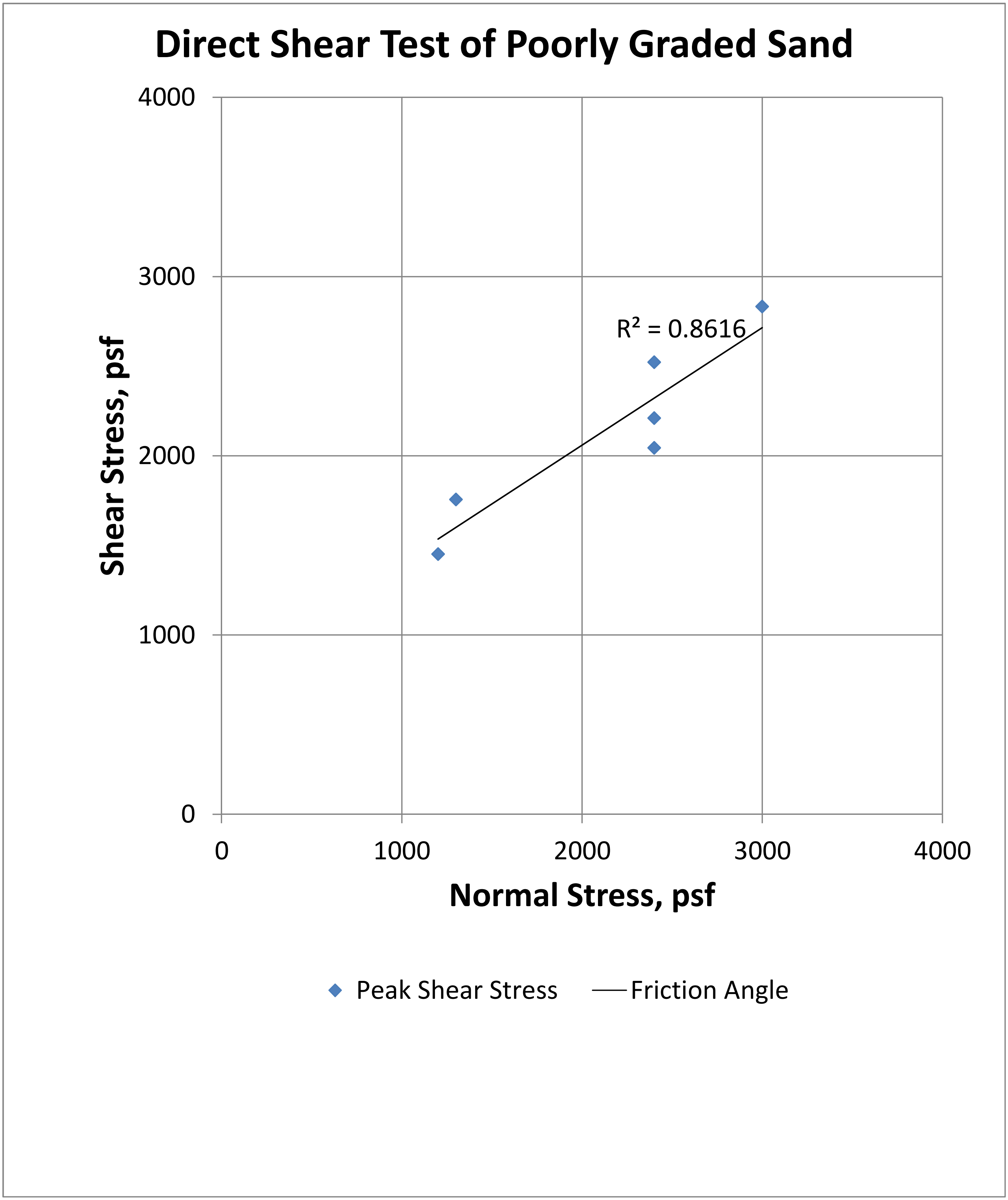

Direct Shear Test of Well Graded Sand
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000
R^2 = 0.9511
Shear Stress, psf
Normal Stress, psf
Peak Shear Stress
Friction Angle



Direct Shear Test of Poorly Graded Sand
4000
3000
2000
1000
0
0
1000
2000
3000
4000
Shear Stress, psf
Normal Stress, psf
R² = 0.8616
Peak Shear Stress
Friction Angle

Attachment C: Geotechnical Data

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DRILLING LOG OF BORING NO. SB01

DATE DRILLED: 8/17/2011
LOGGED BY: Tim Adair
CHECKED BY: Tim Adair
DRILLING CONTRACTOR: Cascade Drilling
DRILLING METHOD: Hollow Stem Auger
COORDINATE REFERENCE SYSTEM: NAD 83

PROJECT NAME: Gorst Creek
PROJECT LOCATION: Kitsap County, Washington

EPA TASK MONITOR: Jeff Rodin
PROJECT #: 002233.0599
PROJ MGR: Jim Peterson

ELEVATION	DEPTH (feet)	USCS	GRAPHIC LOG	CONTACT DEPTH (feet)	SOIL DESCRIPTION	PHOTO IONIZATION DETECTOR READINGS (PPM)	FLAME IONIZATION DETECTOR READINGS (PPM)	COMMENTS
					Top of Ground Surface (GS) Elevation			This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.
	5	SM		5	Silty Sand, fine to coarse sand with silt, trace fine to coarse gravel, trace cobbles, some metal, garbage fragments, plastic, etc., slightly moist			Using SPT and 140 lb slide auto-hammer for blow counts
	10			10				
	15			15				20/33/40 at 15'
	20	SP		20	Silty Sand, fine to coarse sand, with fine to coarse, gravel, moist	40	25	Debris to ~18' BGS
	25	SP-SM		25	Sand, fine to coarse sand, some silt, moist			
	30			30				19/36/54 at 30'
	35			35		5	6	
	40			40	Sand, fine to coarse sand, trace silt, moist more coarse sand, increasing coarse sand and gravel	4	5	
	45			45				27/37/41 at 45'
	50			50		5	4	
	60			60				50 for 6" at 60'
	90	GP		90	Gravelly Sand, fine to coarse sand and fine to coarse gravel			Total Depth = 90', Boring backfilled with bentonite chips, hydrated and cement from 5' - 0' bgs.

ENE SOIL BORING GORST_CREEK_BORINGLOGS.GPJ E&E PORTLAND.GDT 1/18/12

ecology and environment, inc.
333 SW Fifth Avenue
Suite 608
Portland, OR 97204
Phone: 503-248-5600 Fax: 503-248-5577

DRILLING LOG OF BORING NO. SB02

DATE DRILLED:	8/17/2011	PROJECT NAME:	Gorst Creek
LOGGED BY:	Tim Adair	PROJECT LOCATION:	Kitsap County, Washington
CHECKED BY:	Tim Adair	EPA TASK MONITOR:	Jeff Rodin
DRILLING CONTRACTOR:	Cascade Drilling	PROJECT #:	002233.0599
DRILLING METHOD:	Hollow Stem Auger	PROJ MGR:	Jim Peterson
COORDINATE REFERENCE SYSTEM:	NAD 83		

ELEVATION	DEPTH (feet)	USCS	GRAPHIC LOG	CONTACT DEPTH (feet)	SOIL DESCRIPTION	PHOTO IONIZATION DETECTOR READINGS (PPM)	FLAME IONIZATION DETECTOR READINGS (PPM)	COMMENTS
					Top of Ground Surface (GS) Elevation			This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.
	5	SM			Landfill debris plus Silty Sand, fine to medium sand and fine to coarse gravel, moist, black 10YR2/1	3	2	Using SPT and 140 lb slide auto-hammer for low counts
	10					3	2	
	15	SP			Silty Sand, fine to coarse sand and fine to coarse gravel, some silt, moist, olive brown, 2.5Y4/4	1	1	20/37/46 at 15'
	20	SP-SM			Sand, fine to coarse coarse, moist, olive brown, 2.5Y4/3			
	25				Sand, fine to coarse coarse, moist, increasing coarseness, olive brown, 2.5Y4/3			
	30							50/50 for 6" at 30'
	35	GP			Sand, fine to coarse coarse, moist, olive brown, 2.5Y4/3, coarse gravel cobble in shoe			
	40				Gravelly Sand, fine to coarse sand and fine to coarse gravel			
	45				Gravelly Sand, fine to coarse sand and fine to coarse gravel, trace silt, moist, olive brown, 2.5Y4/4			50 for 5.5" at 45'
	50							
	55							
	60							Total Depth = 60', Boring backfilled with bentonite chips hydrated, and wet cement from 5' - 0' bgs.
	65							
	70							
	75							
	80							
	85							
	90							
	95							
	100							

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Suite 608
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Phone: 503-248-5600 Fax: 503-248-5577

DRILLING LOG OF BORING NO. SB03

DATE DRILLED: 8/18/2011
LOGGED BY: Tim Adair
CHECKED BY: Tim Adair
DRILLING CONTRACTOR: Cascade Drilling
DRILLING METHOD: Hollow Stem Auger
COORDINATE REFERENCE SYSTEM: NAD 83

PROJECT NAME: Gorst Creek
PROJECT LOCATION: Kitsap County, Washington

EPA TASK MONITOR: Jeff Rodin
PROJECT #: 002233.0599
PROJ MGR: Jim Peterson

ELEVATION	DEPTH (feet)	USCS	GRAPHIC LOG	CONTACT DEPTH (feet)	SOIL DESCRIPTION	PHOTO IONIZATION DETECTOR READINGS (PPM)	FLAME IONIZATION DETECTOR READINGS (PPM)	COMMENTS
					Top of Ground Surface (GS) Elevation			This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.
	5	SM			Silty Sand, fine to coarse sand, trace fine to coarse gravel, debris, wood and landfill waste, moist, olive brown, 2.5Y4/4			Using SPT and 140 lb slide auto-hammer for blow counts, overburden contains landfill waste
	10					37	29	Still in waste black material (stained soil)
	15				Silty Sand, fine to coarse sand, trace fine to coarse gravel, debris, wood and landfill waste, moist, black, 10YR2/1	27	12	Waste to approximately 18' based on drilling conditions
	20	SP						
	25				Silty Sand, fine to coarse sand, moist, trace fine to coarse gravel	12	2	
	30	GP			Sand, fine to coarse sand, trace silt, moist, gray 2.5Y5/1, trace fine to coarse gravel, color change to dark yellowish brown 10YR4/6 at 22.5 ft			3/50 for 5" at 30'
	35							
	40							
	45				Sand, fine to coarse sand, trace silt, moist			50 for 4" at 45'
	50				Gravelly Sand, fine to coarse sand with fine to coarse gravel, trace silty, moist, dark yellowish brown 10YR3/6			
	55							50 for 3" at 55'
	60							
	65							
	70							
	75							
	80				Gravelly Sand, fine to coarse sand with fine to coarse gravel, trace silty, moist, dark yellowish brown 10YR3/6			Total Depth = 80', Boring backfilled with bentonite chips, hydrated, wet cement from 5' - 0' bgs.
	85							
	90							
	95							
	100							

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Phone: 503-248-5600 Fax: 503-248-5577

DRILLING LOG OF BORING NO. SB04

DATE DRILLED:	8/18/2011	PROJECT NAME:	Gorst Creek
LOGGED BY:	Tim Adair	PROJECT LOCATION:	Kitsap County, Washington
CHECKED BY:	Tim Adair	EPA TASK MONITOR:	Jeff Rodin
DRILLING CONTRACTOR:	Cascade Drilling	PROJECT #:	002233.0599
DRILLING METHOD:	Hollow Stem Auger	PROJ MGR:	Jim Peterson
COORDINATE REFERENCE SYSTEM:	NAD 83		

ELEVATION	DEPTH (feet)	USCS	GRAPHIC LOG	CONTACT DEPTH (feet)	SOIL DESCRIPTION	PHOTO IONIZATION DETECTOR READINGS (PPM)	FLAME IONIZATION DETECTOR READINGS (PPM)	COMMENTS
					Top of Ground Surface (GS) Elevation			This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.
	5	SP			Sand, fine to coarse grained some fine to coarse gravel, trace silt, wet, groundwater at 5'	0	0	Depth to water 5' 25/33/41 at 5' 18/30/39 at 10' Total Depth = 13', Boring backfilled with bentonite chips, hydrated, wet cement from 5' - 0' bgs.
	10							
	15							
	20							
	25							
	30							
	35							
	40							
	45							
	50							
	55							
	60							
	65							
	70							
	75							
	80							
	85							
	90							
	95							
	100							

ENE SOIL BORING GORST_CREEK_BORINGLOGS.GPJ E&E PORTLAND.GDT 1/18/12

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333 SW Fifth Avenue
Suite 608
Portland, OR 97204
Phone: 503-248-5600 Fax: 503-248-5577

DRILLING LOG OF BORING NO. SB05

DATE DRILLED:	8/18/2011
LOGGED BY:	Tim Adair
CHECKED BY:	Tim Adair
DRILLING CONTRACTOR:	Cascade Drilling
DRILLING METHOD:	Hollow Stem Auger
COORDINATE REFERENCE SYSTEM:	NAD 83
PROJECT NAME:	Gorst Creek
PROJECT LOCATION:	Kitsap County, Washington
EPA TASK MONITOR:	Jeff Rodin
PROJECT #:	002233.0599
PROJ MGR:	Jim Peterson

ELEVATION	DEPTH (feet)	USCS	GRAPHIC LOG	CONTACT DEPTH (feet)	SOIL DESCRIPTION	PHOTO IONIZATION DETECTOR READINGS (PPM)	FLAME IONIZATION DETECTOR READINGS (PPM)	COMMENTS
					Top of Ground Surface (GS) Elevation			This log is part of the report prepared for the named project and should be read together with that report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplification of actual conditions encountered.
	5	SM			Silty Sand, fine to coarse sand, some fine to coarse gravel some silt, cobbles, slightly moist, light yellowish brown, 10YR4/6			Using SPT and 140 lb slide auto-hammer for blow counts
	10	SP						Rounded gravel to 5' then more course sand
	15	SP-SM			Sand, fine to coarse trace silt, some fine to coarse gravel, slightly moist			26/26/50 for 6" at 15'
	20							
	25							40/50 for 6" at 25'
	30	GP			Gravelly Sand, fine to coarse trace silt, and fine to coarse gravel, slightly moist			
	35							31/50 for 6" at 35'
	40	SP			Gravelly Sand, fine to coarse sand and fine to coarse gravel, moist, light yellowish brown, 10YR4/6			40/5 for 6" at 40'
	45				Sand, fine to coarse, trace fine to coarse gravel, moist			50/50 for 2" at 45'
	50	SP-SM			Silty Sand, fine to coarse, trace fine to coarse gravel, moist			100 for 6" at 50'
	55							
	60							Total Depth = 61.5', Boring backfilled with bentonite chips, hydrated, wet cement from 5' - 0' bgs.
	65							
	70							
	75							
	80							
	85							
	90							
	95							
	100							

ecology and environment, inc.
333 SW Fifth Avenue
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Phone: 503-248-5600 Fax: 503-248-5577

GeoTesting
EXPRESS

125 Nagog Park
Acton, MA 01720
978 635 0424 Tel
978 635 0266 Fax

Transmittal

TO:
Tim Adair
Ecology & Environment, Inc.
720 Third Avenue, Suite 1700
Seattle, WA 98104

DATE: 9/21/2011	GTX NO: 11124
RE: 10-08-0011	

COPIES	DATE	DESCRIPTION
	9/21/2011	**September 2011 Laboratory Test Report**

REMARKS:

SIGNED: [signature]
Joe Tomei, Laboratory Manager

CC:

APPROVED BY: [signature]
Nancy Hubbard, Project Manager

GeoTesting
EXPRESS

Boston
Atlanta
New York

www.geotesting.com

September 21, 2011

Tim Adair
Ecology & Environment, Inc.
720 Third Avenue, Suite 1700
Seattle, WA 98104

RE: 10-08-0011, (GTX-11124)

Dear Tim:

Enclosed are the test results you requested for the above referenced project. GeoTesting Express, Inc. (GTX) received 18 samples from you between 9/2/2011 and 9/6/2011. These samples were labeled as follows:

Boring Number	Depth
SB-01	20.5
SB-01	25
SB-01	50-52
SB-02	22
SB-02	30.5
SB-02	50.5
SB-02	55
SB-03	20.5
SB-03	21
SB-03	25
SB-03	50
SB-03	57.5
SB-04	10
SB-04	10.5
SB-04	11
SB-05	20
SB-05	25.5
SB-05	55

GTX performed the following tests on these samples:
- 9 ASTM D 422 - Grain Size Analyses (sieve only)
- 9 ASTM D 3080 - Direct Shear Test Points

A copy of your test request is attached.

The results presented in this report apply only to the items tested. This report shall not be reproduced except in full, without written approval from GeoTesting Express. The remainder of these samples will be retained for a period of sixty (60) days and will then be discarded unless otherwise notified by you. Please call me if you have any questions or require additional information. Thank you for allowing GeoTesting Express the opportunity of providing you with testing services. We look forward to working with you again in the future.

Respectfully yours,

Joe Tomei
Laboratory Manager

GeoTesting
EXPRESS

125 Nagog Park
Acton, MA 01720
978 635 0424 Tel
978 635 0266 Fax

Geotechnical Test Report

9/21/2011

GTX-11124
10-08-0011

Client Project No.: TDD No. 10-08-0011

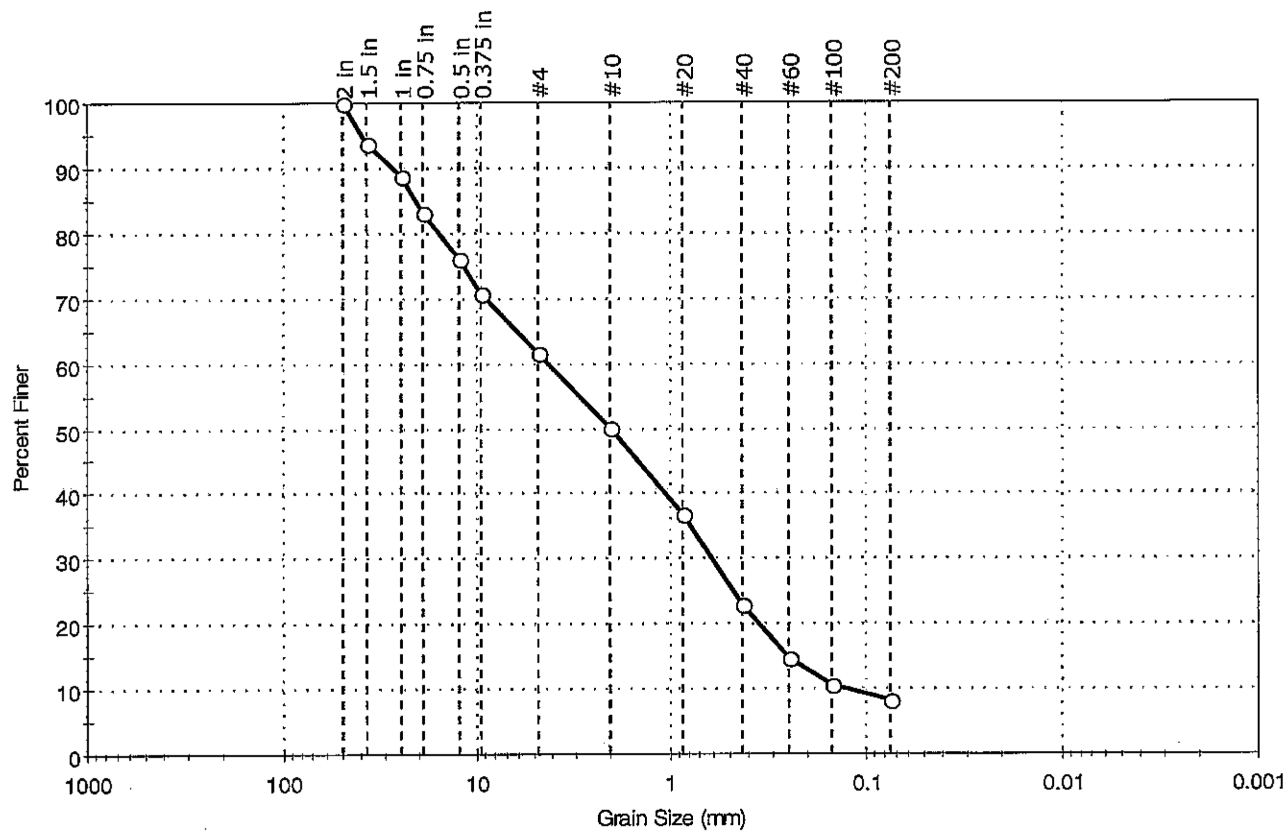
Prepared for:

Ecology & Environment, Inc.

GeoTesting EXPRESS

Client: Ecology & Environment, Inc.			
Project: 10-08-0011			
Location: ---		Project No:	GTX-11124
Boring ID: SB-01	Sample Type: bag	Tested By:	jbr
Sample ID:---	Test Date: 09/12/11	Checked By:	jdt
Depth : 25	Test Id: 217167		
Test Comment: ---			
Sample Description: Moist, brown sand with silt and gravel			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	38.3	53.4	8.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
2 in	50.00	100		
1.5 in	37.50	94		
1 in	25.00	89		
0.75 in	19.00	83		
0.5 in	12.50	76		
0.375 in	9.50	71		
#4	4.75	62		
#10	2.00	50		
#20	0.85	37		
#40	0.42	23		
#60	0.25	15		
#100	0.15	11		
#200	0.075	8		

Coefficients

D_{85} =20.7886 mm D_{30} =0.6037 mm

D_{60} =4.1858 mm D_{15} =0.2554 mm

D_{50} =1.9716 mm D_{10} =0.1224 mm

C_u =34.198 C_c =0.711

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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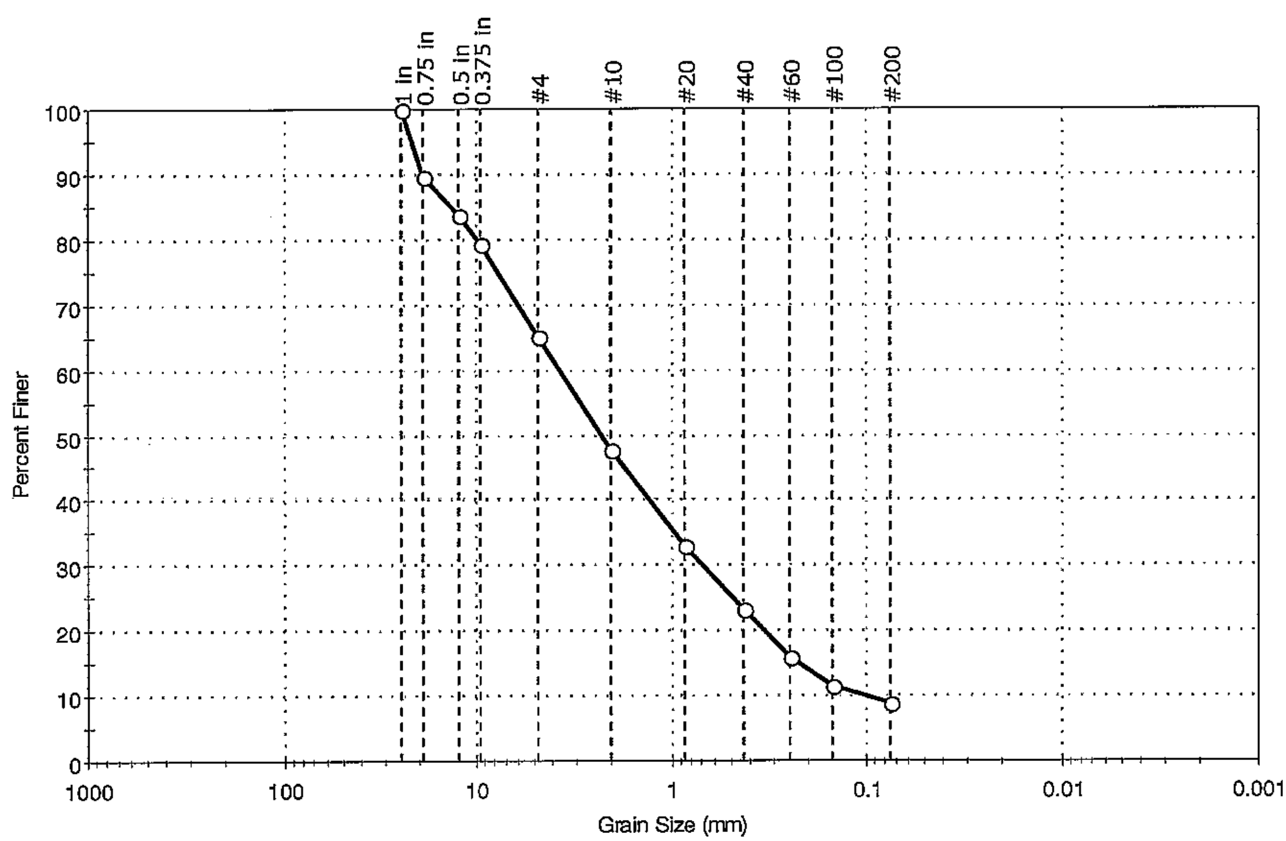
GeoTesting EXPRESS

Client: Ecology & Environment, Inc.	
Project: 10-08-0011	
Location: ---	Project No: GTX-11124
Boring ID: SB-01	Sample Type: bag	Tested By: jbr
Sample ID:---	Test Date: 09/14/11	Checked By: jdt
Depth : 50-52	Test Id: 217168	
Test Comment: ---		
Sample Description: Moist, brown sand with silt and gravel		
Sample Comment: ---		

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	34.9	56.3	8.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	90		
0.5 in	12.50	84		
0.375 in	9.50	79		
#4	4.75	65		
#10	2.00	48		
#20	0.85	33		
#40	0.42	23		
#60	0.25	16		
#100	0.15	11		
#200	0.075	9		

Coefficients

D_{85} = 13.6407 mm D_{30} = 0.6882 mm

D_{60} = 3.6895 mm D_{15} = 0.2238 mm

D_{50} = 2.2436 mm D_{10} = 0.1031 mm

C_u = 35.786 C_c = 1.245

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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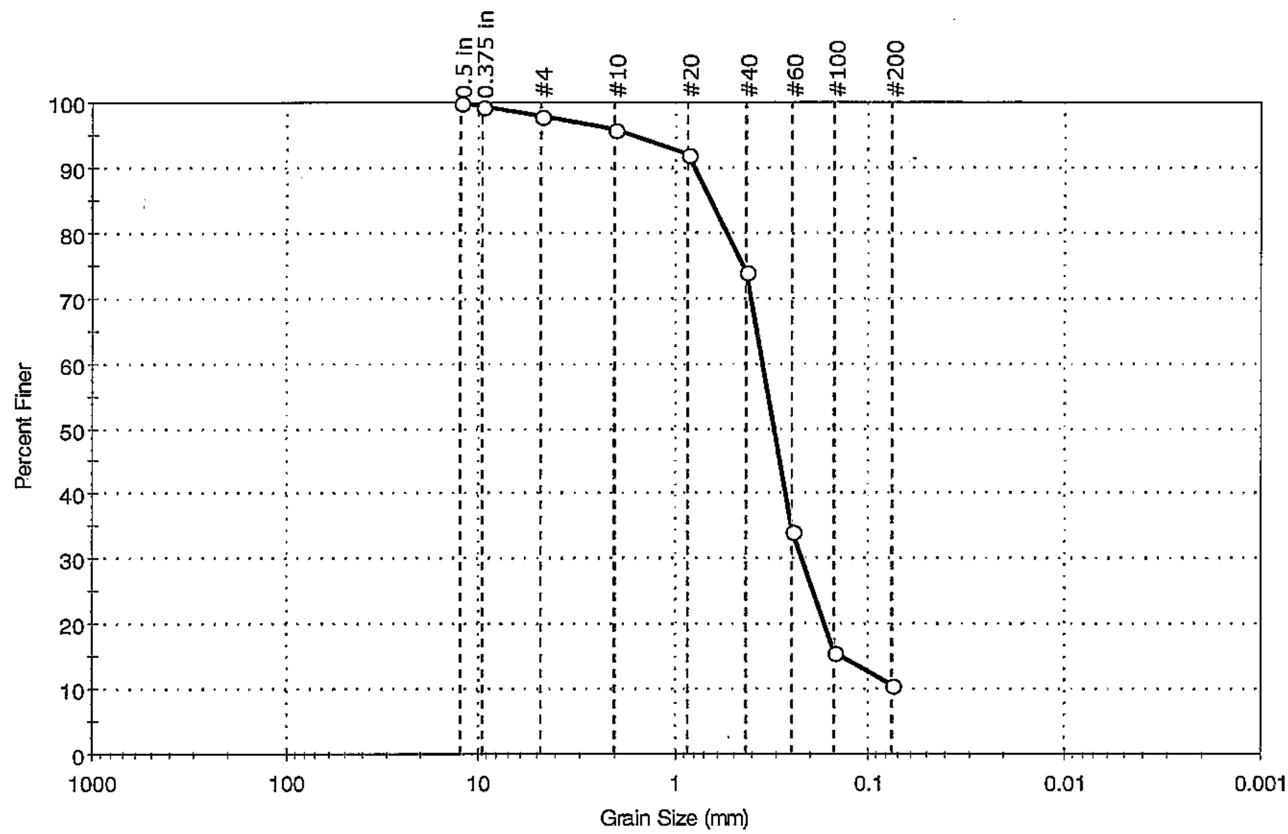
GeoTesting EXPRESS

Client: Ecology & Environment, Inc.			
Project: 10-08-0011			
Location: ---		Project No:	GTX-11124
Boring ID: SB-02	Sample Type: bag	Tested By:	jbr
Sample ID:---	Test Date: 09/13/11	Checked By:	jdt
Depth : 22	Test Id: 217169		
Test Comment: ---			
Sample Description: Moist, brown sand with silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	2.0	87.3	10.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	99		
#4	4.75	98		
#10	2.00	96		
#20	0.85	92		
#40	0.42	74		
#60	0.25	34		
#100	0.15	16		
#200	0.075	11		

Coefficients

D_{85} =0.6476 mm D_{30} =0.2234 mm

D_{60} =0.3528 mm D_{15} =0.1387 mm

D_{50} =0.3089 mm D_{10} =0.0680 mm

C_u =5.188 C_c =2.080

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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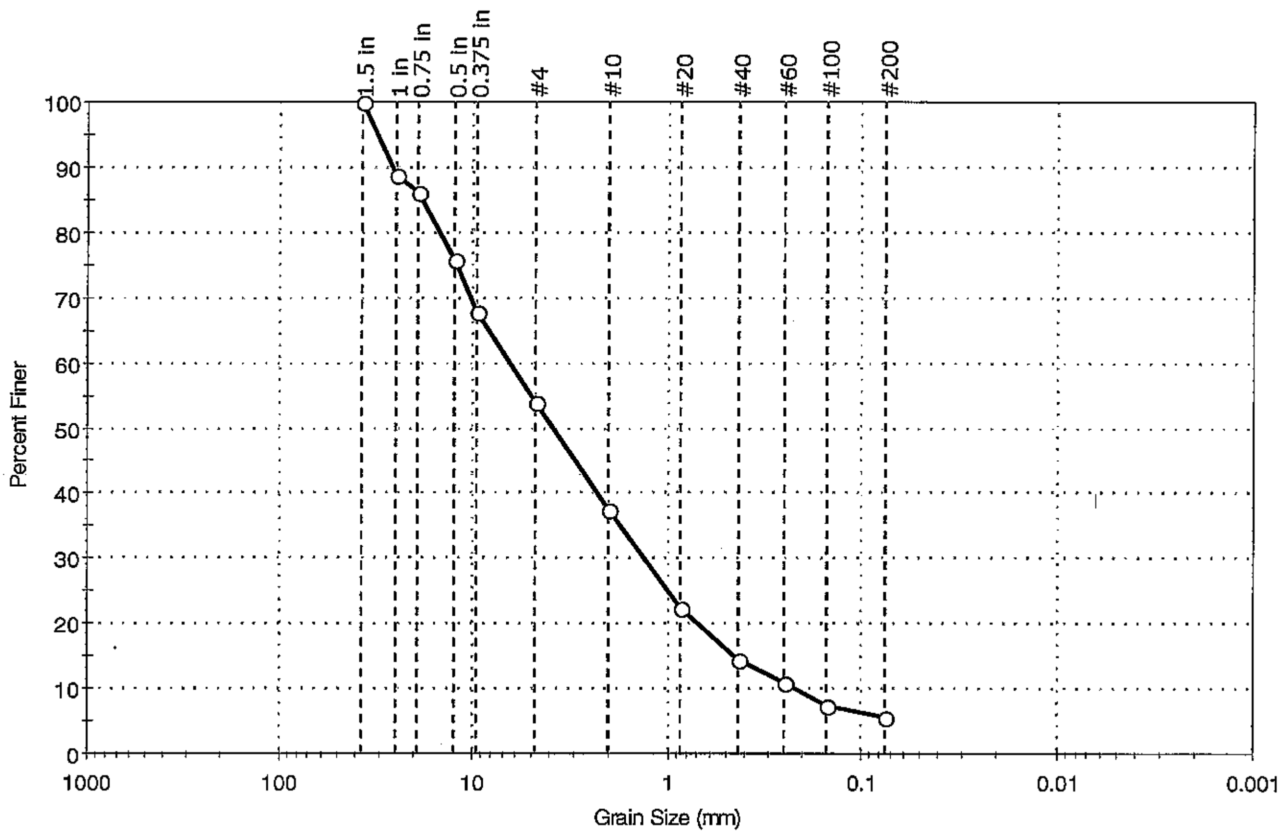
GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.				
Project:	10-08-0011				
Location:	---			Project No:	GTX-11124
Boring ID: SB-02		Sample Type:	bag	Tested By:	jbr
Sample ID:---		Test Date:	09/13/11	Checked By:	jdt
Depth : 55		Test Id:	217170		

Test Comment: ---
Sample Description: Moist, brown sand with silt and gravel
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	46.1	48.4	5.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	89		
0.75 in	19.00	86		
0.5 in	12.50	76		
0.375 in	9.50	68		
#4	4.75	54		
#10	2.00	38		
#20	0.85	22		
#40	0.42	15		
#60	0.25	11		
#100	0.15	7		
#200	0.075	6		

Coefficients

D_{85} =18.1146 mm D_{30} =1.3047 mm
D_{60} =6.4238 mm D_{15} =0.4417 mm
D_{50} =3.8666 mm D_{10} =0.2203 mm
C_u =29.159 C_c =1.203

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description

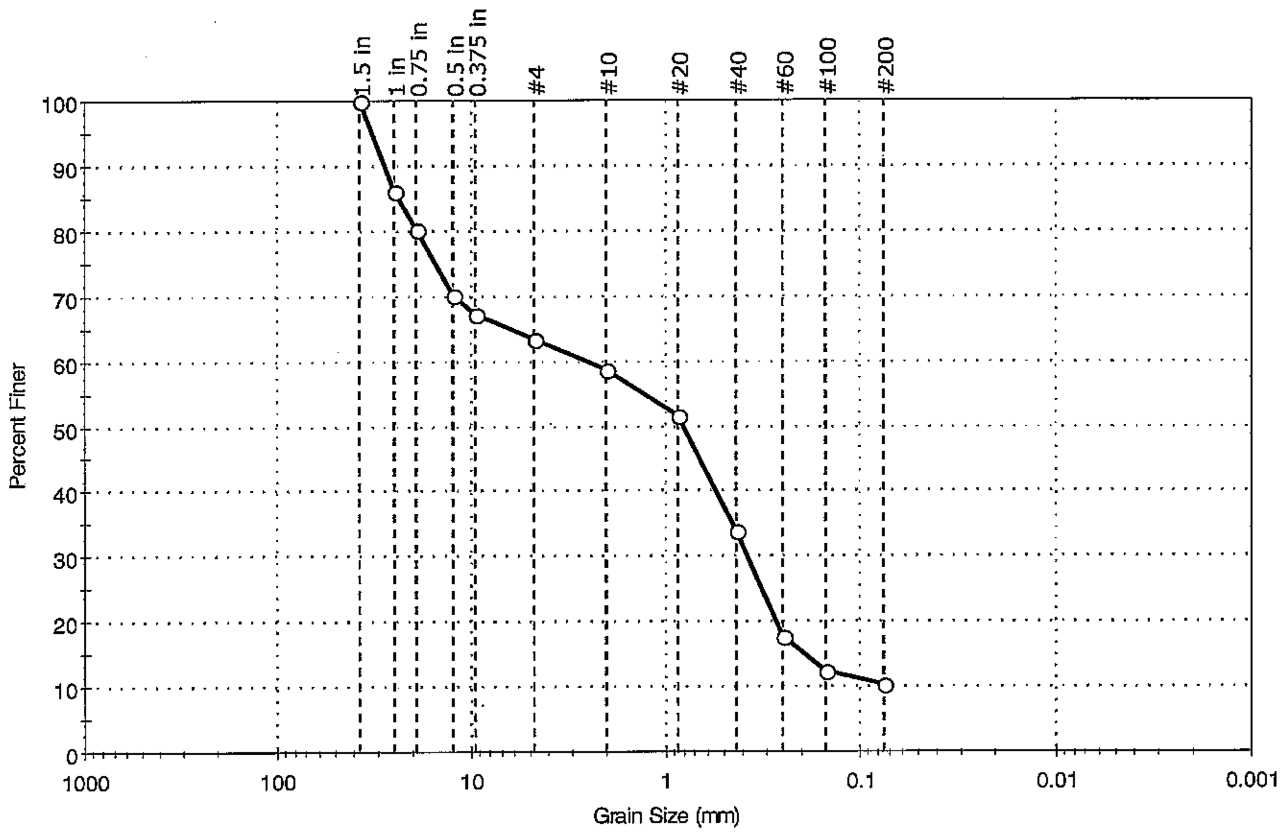
Sand/Gravel Particle Shape : ROUNDED
Sand/Gravel Hardness : HARD

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.				
Project:	10-08-0011				
Location:	---			Project No:	GTX-11124
Boring ID: SB-03		Sample Type:	bag	Tested By:	jbr
Sample ID:---		Test Date:	09/14/11	Checked By:	jdt
Depth : 25		Test Id:	217171		

Test Comment: ---
Sample Description: Moist, yellowish brown sand with silt and gravel
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	36.5	53.1	10.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	86		
0.75 in	19.00	80		
0.5 in	12.50	70		
0.375 in	9.50	67		
#4	4.75	64		
#10	2.00	59		
#20	0.85	52		
#40	0.42	34		
#60	0.25	18		
#100	0.15	12		
#200	0.075	10		

Coefficients

D_{85} =23.7701 mm	D_{30} =0.3742 mm
D_{60} =2.5118 mm	D_{15} =0.1928 mm
D_{50} =0.7955 mm	D_{10} =0.0660 mm
C_u =38.058	C_c =0.845

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

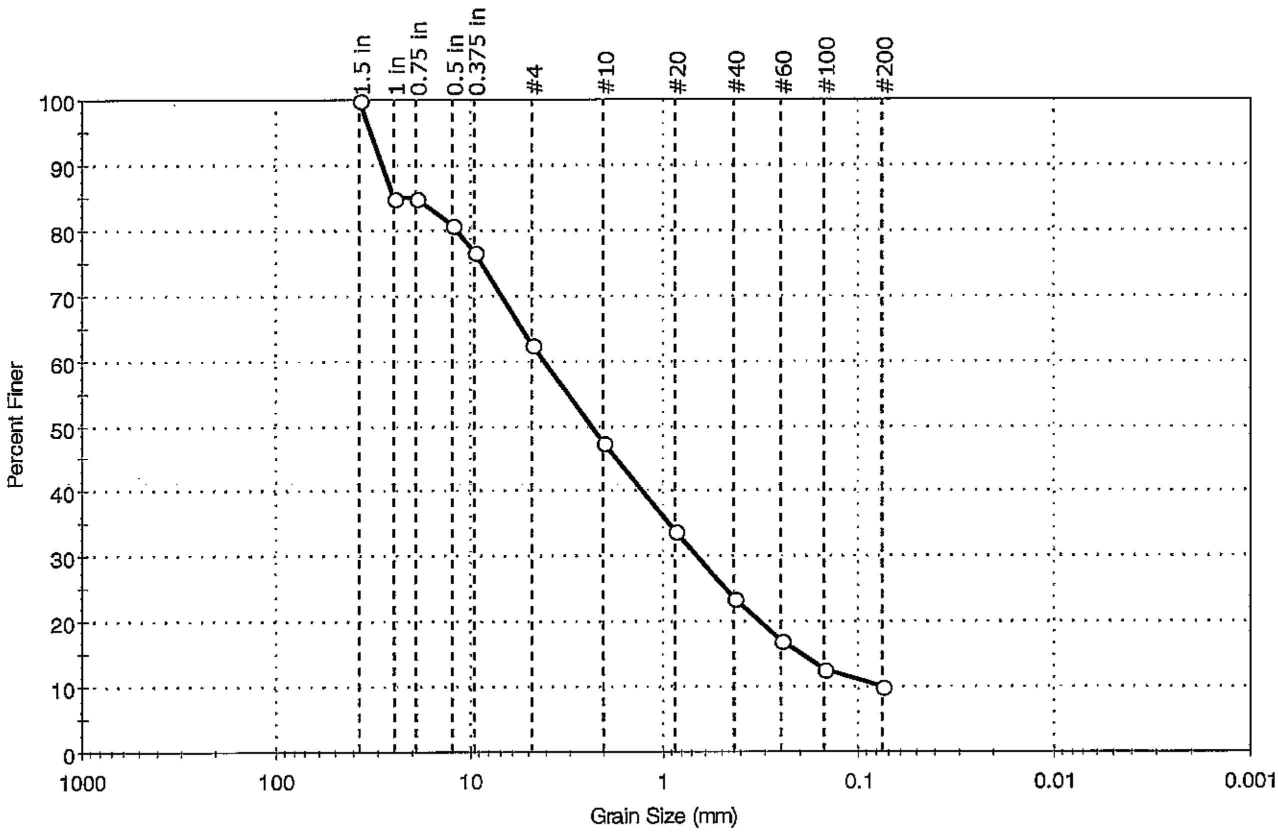
Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.				
Project:	10-08-0011				
Location:	---			Project No:	GTX-11124
Boring ID: SB-03		Sample Type:	bag	Tested By:	jbr
Sample ID:---		Test Date:	09/14/11	Checked By:	jdt
Depth :	50	Test Id:	217172		
Test Comment:	---				
Sample Description:	Moist, brown sand with silt and gravel				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	37.4	52.7	9.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	85		
0.75 in	19.00	85		
0.5 in	12.50	81		
0.375 in	9.50	77		
#4	4.75	63		
#10	2.00	47		
#20	0.85	34		
#40	0.42	24		
#60	0.25	17		
#100	0.15	13		
#200	0.075	10		

Coefficients

D_{85} =25.0761 mm D_{30} =0.6515 mm

D_{60} =4.0841 mm D_{15} =0.1970 mm

D_{50} =2.3175 mm D_{10} =0.0764 mm

C_u =53.457 C_c =1.360

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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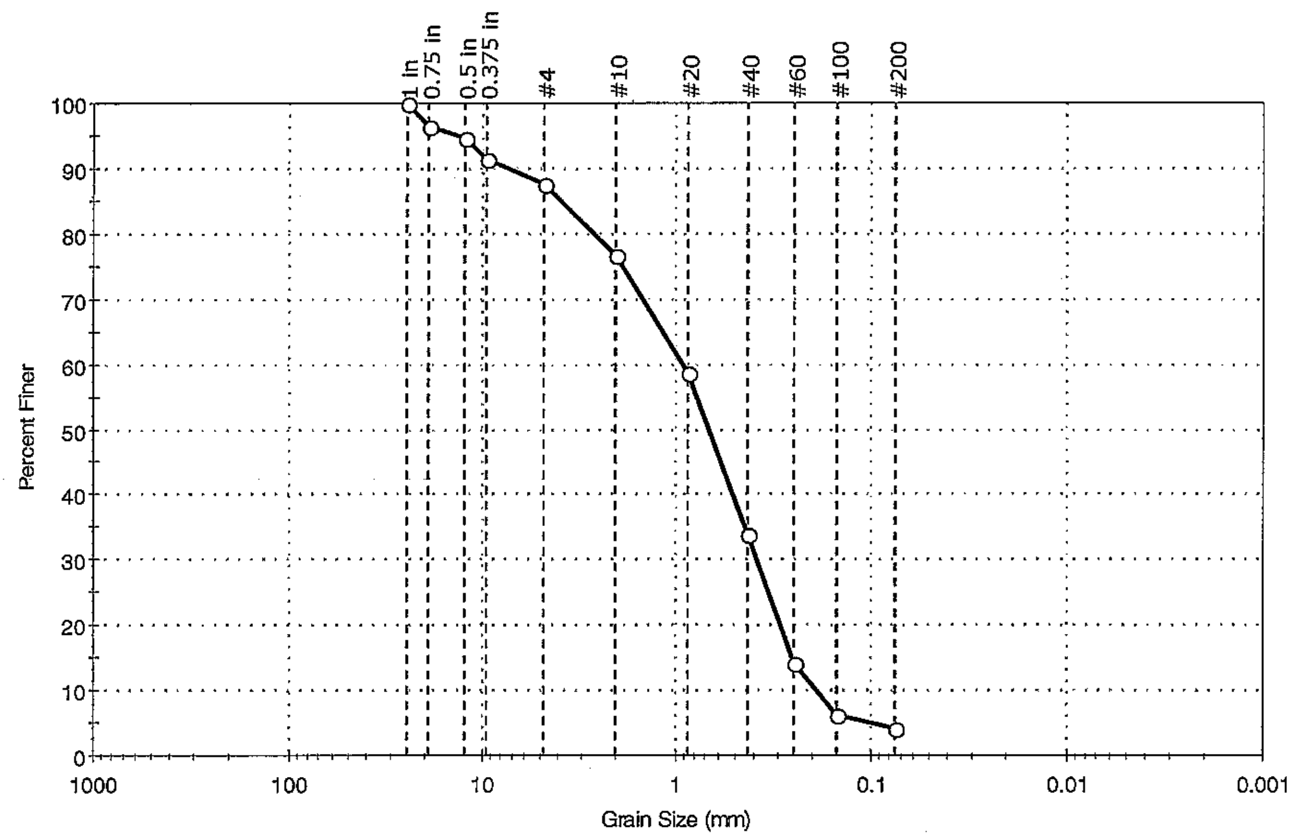
GeoTesting EXPRESS

Client: Ecology & Environment, Inc.			
Project: 10-08-0011			
Location: ---		Project No:	GTX-11124
Boring ID: SB-04	Sample Type: bag	Tested By:	jbr
Sample ID:---	Test Date: 09/14/11	Checked By:	jdt
Depth : 10	Test Id: 217173		
Test Comment: ---			
Sample Description: Moist, brownish yellow sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	12.4	83.4	4.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	96		
0.5 in	12.50	95		
0.375 in	9.50	91		
#4	4.75	88		
#10	2.00	77		
#20	0.85	59		
#40	0.42	34		
#60	0.25	14		
#100	0.15	6		
#200	0.075	4		

Coefficients

D_{85} =3.8405 mm D_{30} =0.3814 mm

D_{60} =0.8979 mm D_{15} =0.2548 mm

D_{50} =0.6639 mm D_{10} =0.1909 mm

C_u =4.704 C_c =0.849

Classification

ASTM Poorly graded sand (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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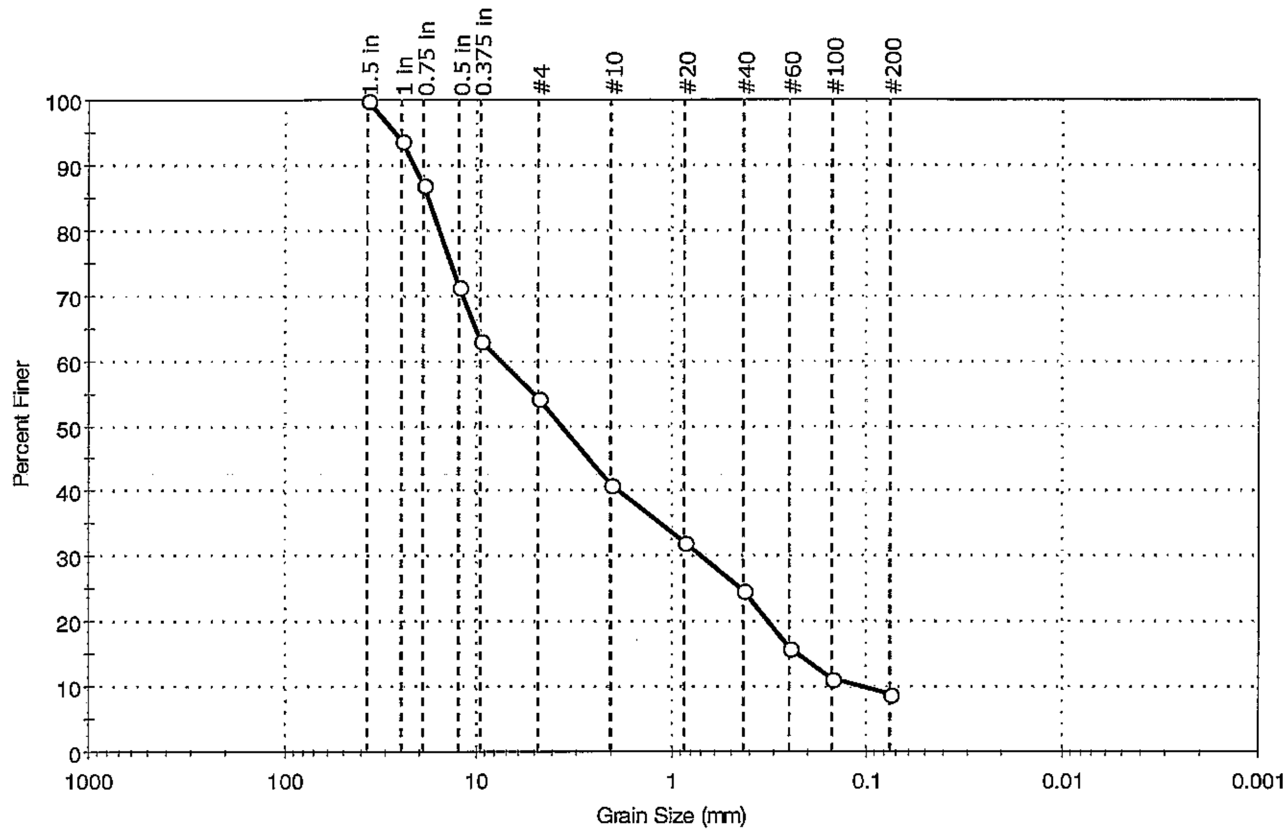
GeoTesting EXPRESS

Client: Ecology & Environment, Inc.			
Project: 10-08-0011			
Location: ---		Project No:	GTX-11124
Boring ID: SB-05	Sample Type: bag	Tested By:	jbr
Sample ID:---	Test Date: 09/12/11	Checked By:	jdt
Depth : 20	Test Id: 217174		
Test Comment: ---			
Sample Description: Moist, brown gravel with silt and sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	45.8	45.4	8.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	94		
0.75 in	19.00	87		
0.5 in	12.50	71		
0.375 in	9.50	63		
#4	4.75	54		
#10	2.00	41		
#20	0.85	32		
#40	0.42	25		
#60	0.25	16		
#100	0.15	11		
#200	0.075	9		

Coefficients

D_{85} =17.9761 mm D_{30} =0.7003 mm

D_{60} =7.4095 mm D_{15} =0.2279 mm

D_{50} =3.5984 mm D_{10} =0.1081 mm

C_u =68.543 C_c =0.612

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description

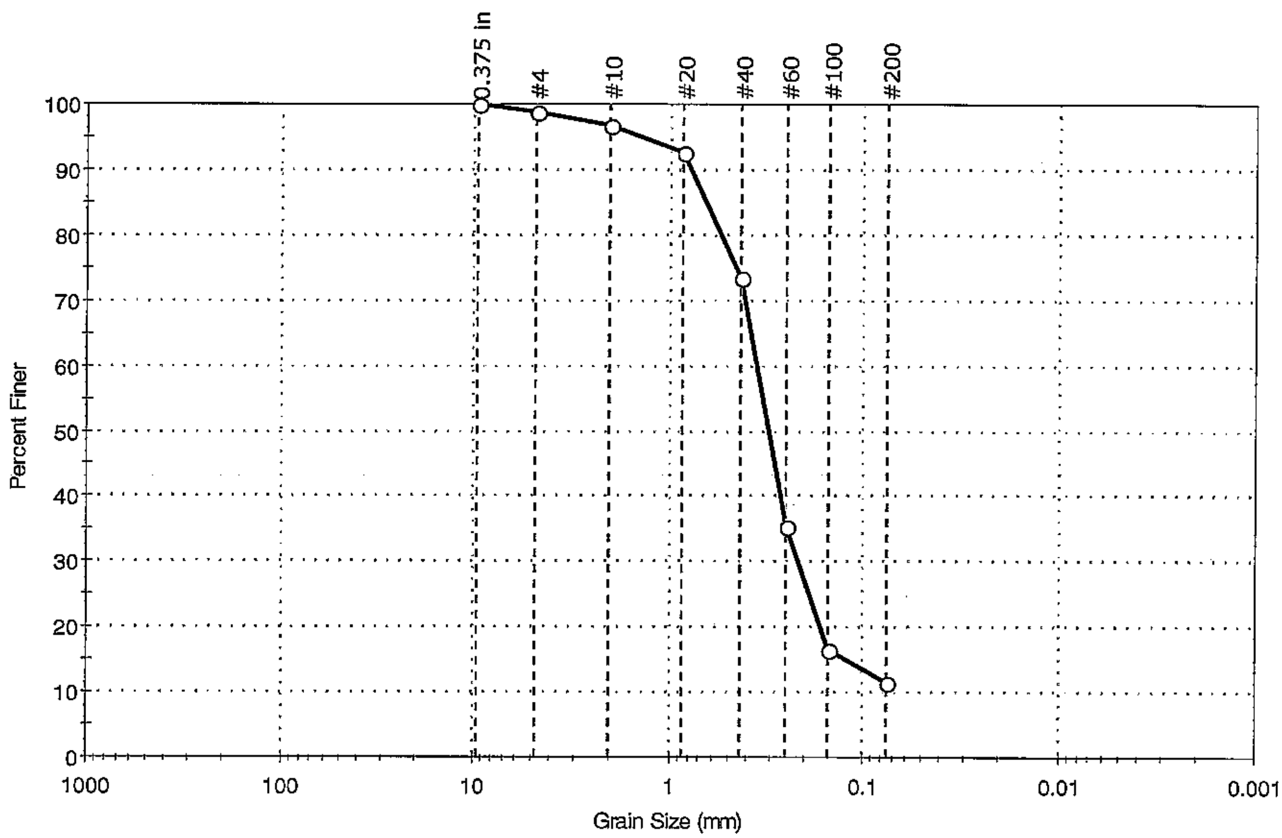
Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

GeoTesting EXPRESS

Client: Ecology & Environment, Inc.			
Project: 10-08-0011			
Location: ---		Project No:	GTX-11124
Boring ID: SB-05	Sample Type: bag	Tested By:	jbr
Sample ID:---	Test Date: 09/14/11	Checked By:	jdt
Depth : 55	Test Id: 217175		
Test Comment: ---			
Sample Description: Moist, brown sand with silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.2	87.3	11.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	97		
#20	0.85	93		
#40	0.42	74		
#60	0.25	36		
#100	0.15	16		
#200	0.075	11		

Coefficients

D_{85} =0.6429 mm	D_{30} =0.2156 mm
D_{60} =0.3519 mm	D_{15} =0.1230 mm
D_{50} =0.3060 mm	D_{10} =0.0610 mm
C_u =5.769	C_c =2.165

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

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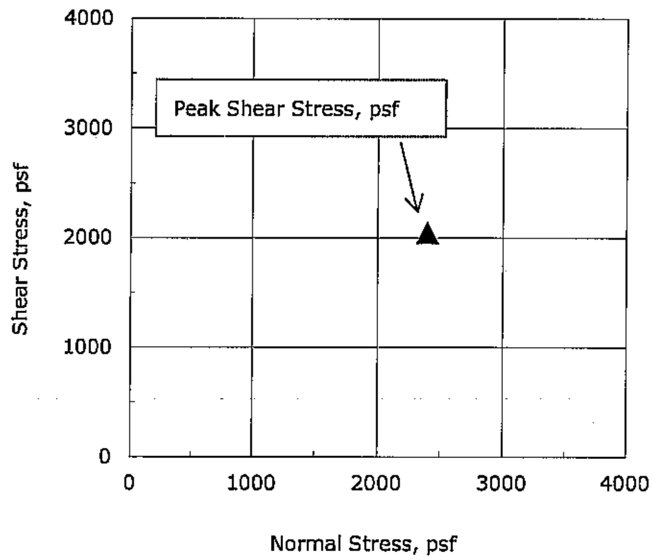
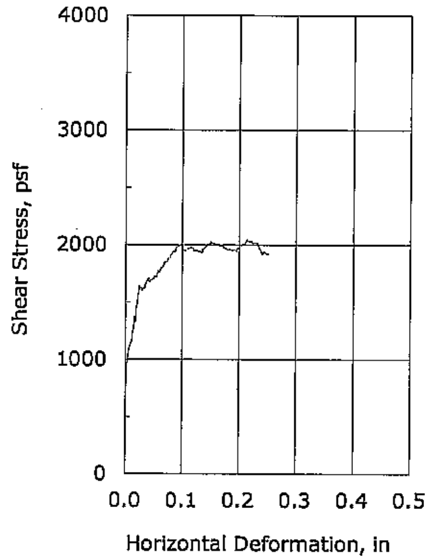
GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/12/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-01
Sample ID:	---
Depth, ft:	20.5
Visual Description:	Dry, brown sand

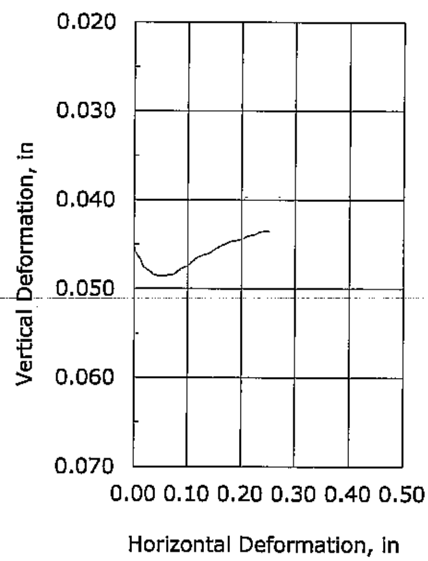
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-4		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	80.0		
Initial Dry Density, pcf	90.8		
Initial Moisture Content, %	6.7		
Initial Bulk Density, pcf	97		
Initial Degree of Saturation	21.7		
Initial Void Ratio	0.82		
Final Dry Density, pcf	95.0		
Final Moisture Content, %	26.3		
Final Bulk Density, pcf	120		
Normal Stress, psf	2400		
Maximum Shear Stress, psf	2044		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

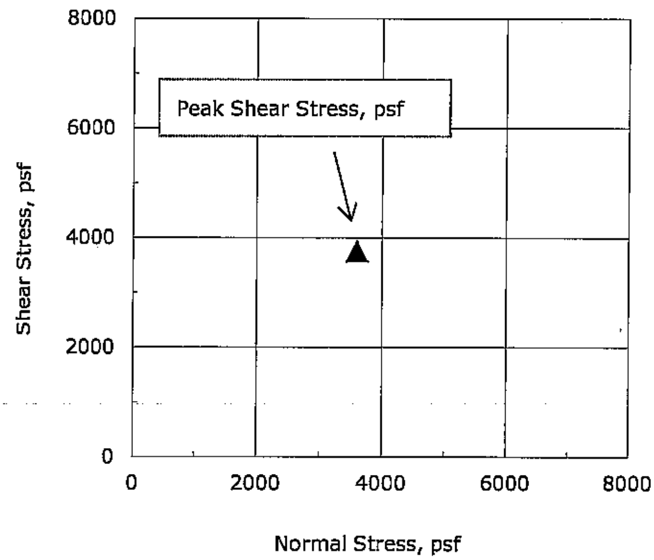
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 40.4°.

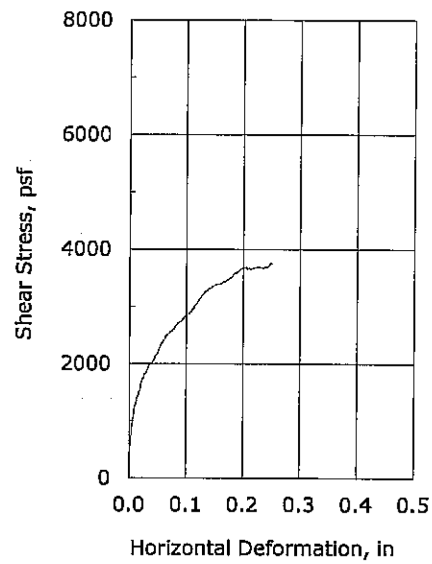
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/12/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-02
Sample ID:	---
Depth, ft:	30.5
Visual Description:	Dry, brown sand

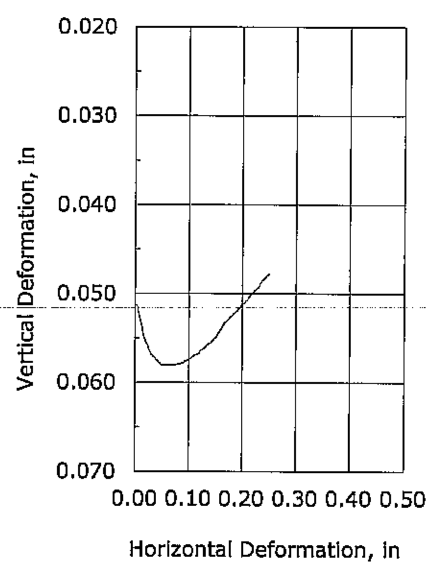
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-5		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	93.5		
Initial Dry Density, pcf	107.4		
Initial Moisture Content, %	5.5		
Initial Bulk Density, pcf	113		
Initial Degree of Saturation	27.1		
Initial Void Ratio	0.54		
Final Dry Density, pcf	113		
Final Moisture Content, %	18.0		
Final Bulk Density, pcf	133		
Normal Stress, psf	3600		
Maximum Shear Stress, psf	3755		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



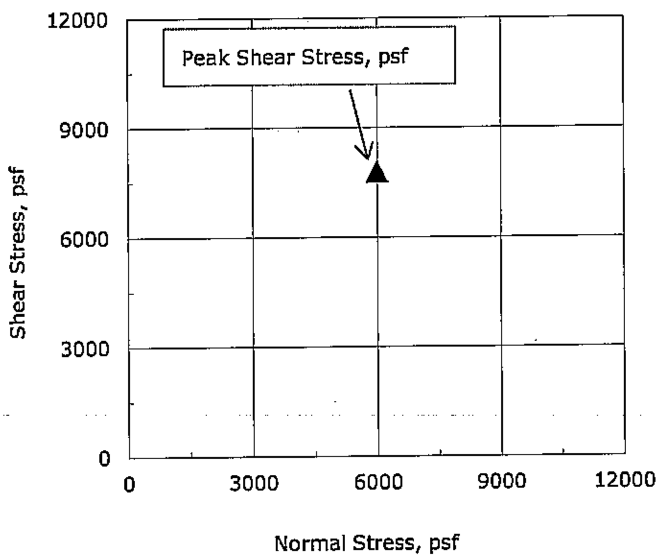
Notes: Moisture content obtained before shear from sample trimmings
Moisture Content determined by ASTM D 2216
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 46.2°.

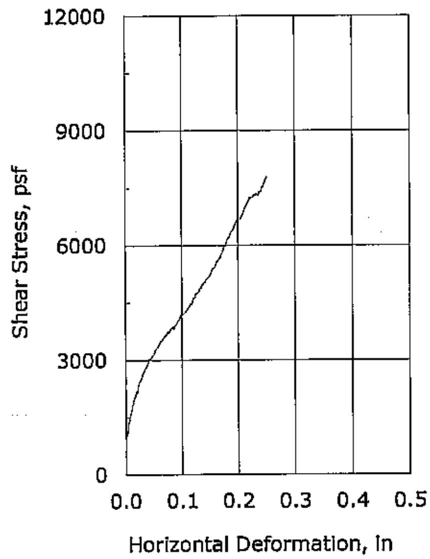
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/13/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-02
Sample ID:	---
Depth, ft:	50.5
Visual Description:	Dry, brown sand with gravel

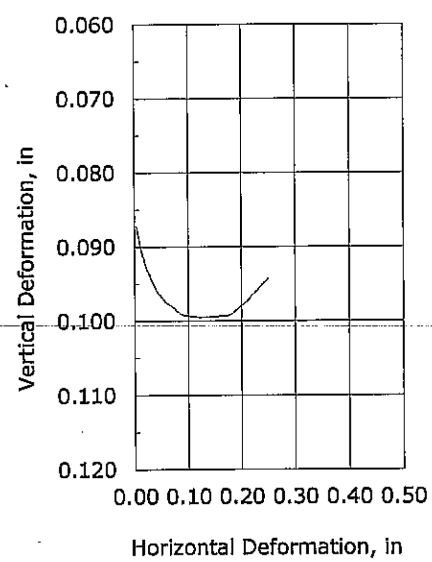
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-6		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	96.0		
Initial Dry Density, pcf	110		
Initial Moisture Content, %	6.0		
Initial Bulk Density, pcf	116		
Initial Degree of Saturation	31.4		
Initial Void Ratio	0.51		
Final Dry Density, pcf	121		
Final Moisture Content, %	13.3		
Final Bulk Density, pcf	137		
Normal Stress, psf	6000		
Maximum Shear Stress, psf	7794		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

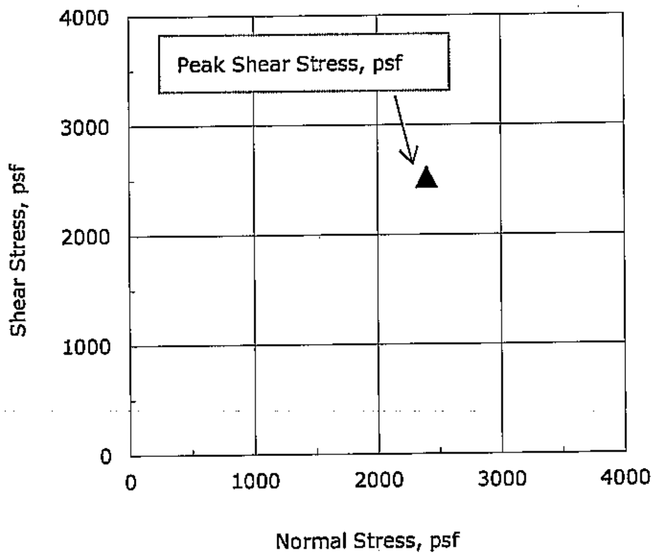
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 52.4°.

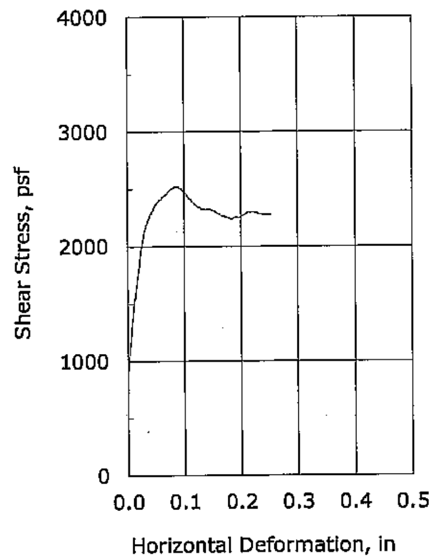
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/9/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-03
Sample ID:	---
Depth, ft:	20.5
Visual Description:	Moist, brown sand

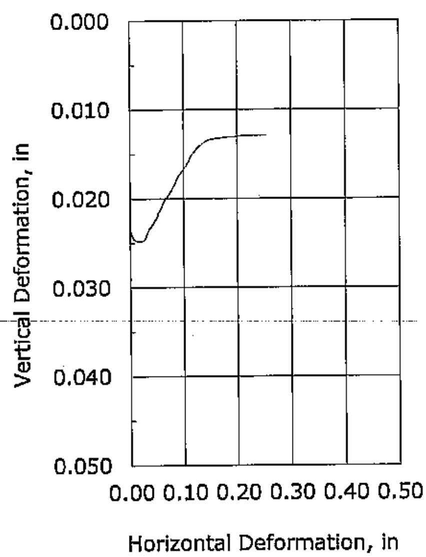
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-3		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	91.2		
Initial Dry Density, pcf	98.1		
Initial Moisture Content, %	12.8		
Initial Bulk Density, pcf	111		
Initial Degree of Saturation	49.4		
Initial Void Ratio	0.69		
Final Dry Density, pcf	99.4		
Final Moisture Content, %	22.9		
Final Bulk Density, pcf	122		
Normal Stress, psf	2401		
Maximum Shear Stress, psf	2522		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

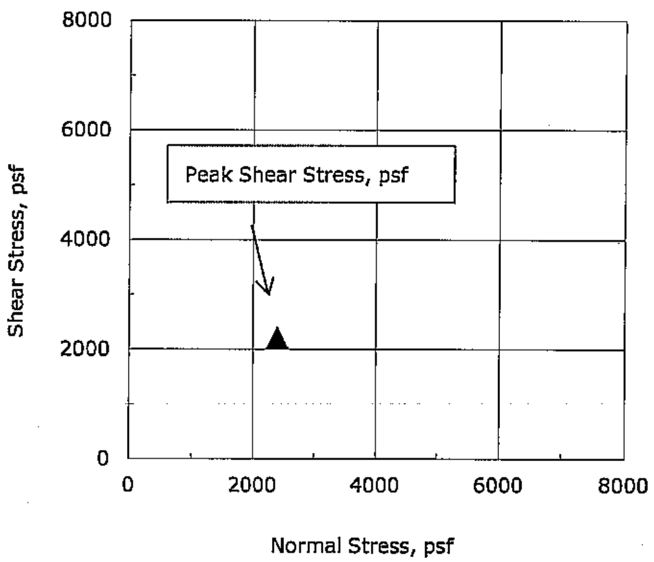
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 46.4°.

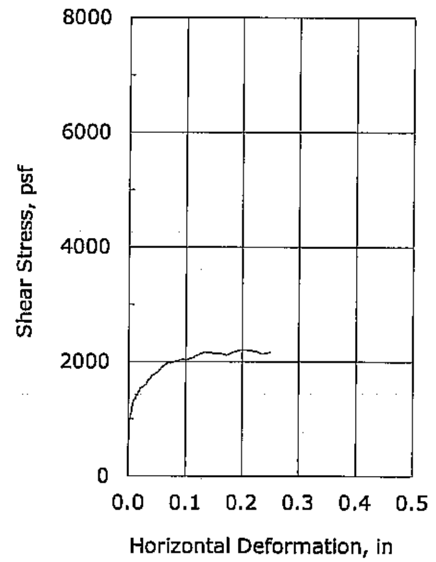
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/14/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-03
Sample ID:	---
Depth, ft:	21
Visual Description:	Moist, brown sand

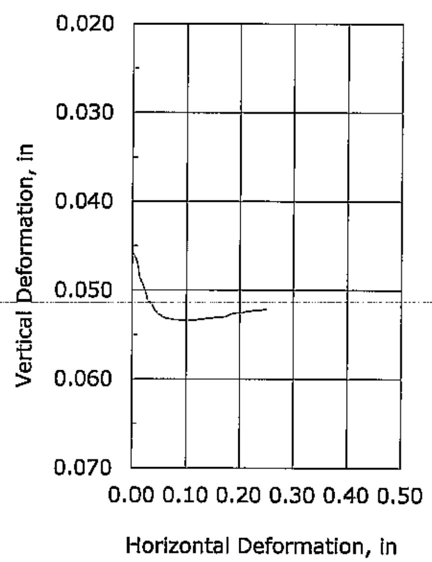
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-7		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	90.4		
Initial Dry Density, pcf	98.8		
Initial Moisture Content, %	10.9		
Initial Bulk Density, pcf	110		
Initial Degree of Saturation	42.8		
Initial Void Ratio	0.67		
Final Dry Density, pcf	104		
Final Moisture Content, %	19.4		
Final Bulk Density, pcf	124		
Normal Stress, psf	2400		
Maximum Shear Stress, psf	2210		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

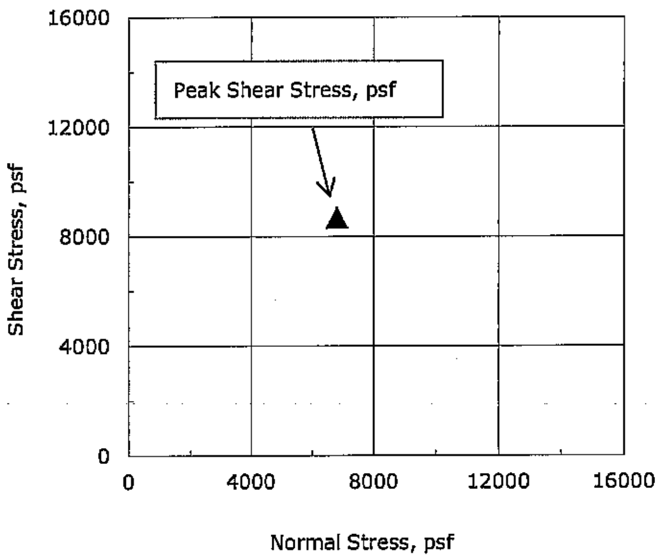
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 42.6°.

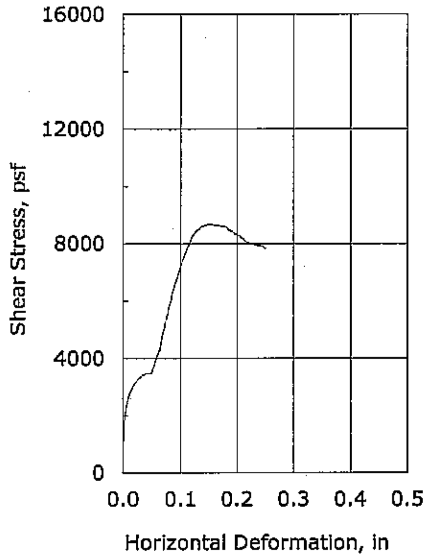
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/8/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-03
Sample ID:	---
Depth, ft:	57.5
Visual Description:	Moist, dark gray sand with gravel

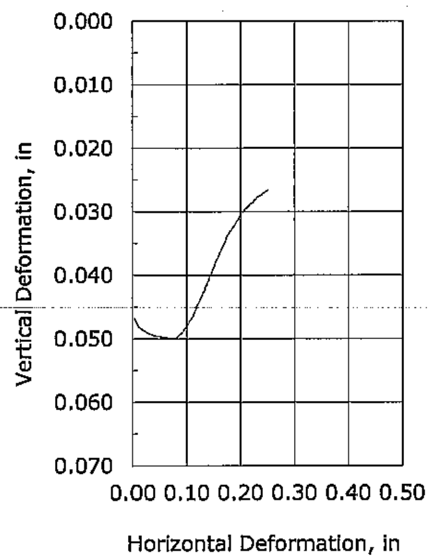
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-1		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	107		
Initial Dry Density, pcf	118		
Initial Moisture Content, %	10.2		
Initial Bulk Density, pcf	130		
Initial Degree of Saturation	67.3		
Initial Void Ratio	0.40		
Final Dry Density, pcf	121		
Final Moisture Content, %	17.4		
Final Bulk Density, pcf	142		
Normal Stress, psf	6800		
Maximum Shear Stress, psf	8687		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.70
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

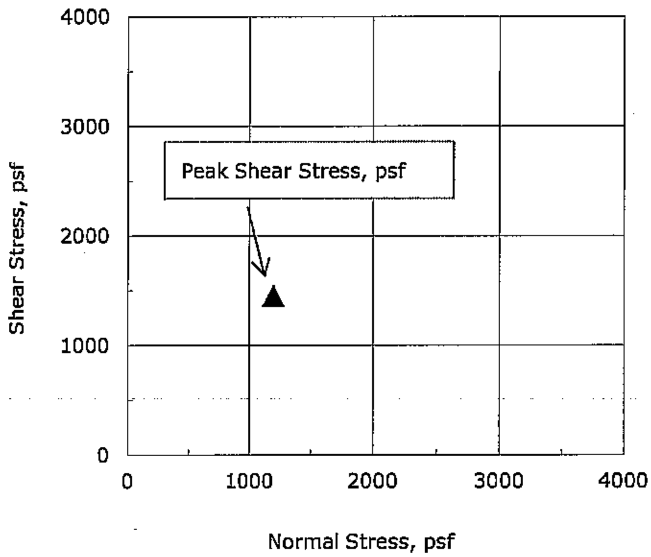
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 51.9°.

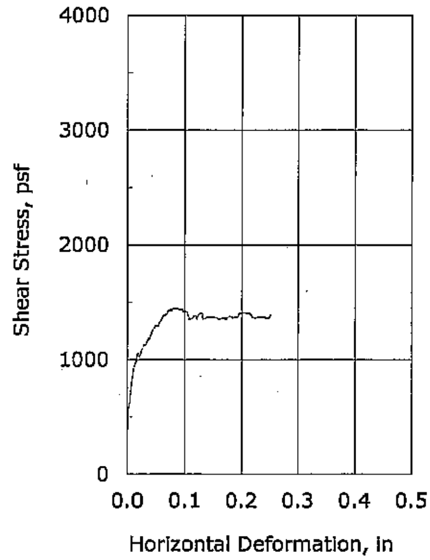
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/16/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-04
Sample ID:	---
Depth, ft:	10.5
Visual Description:	Moist, brown coarse sand and gravel

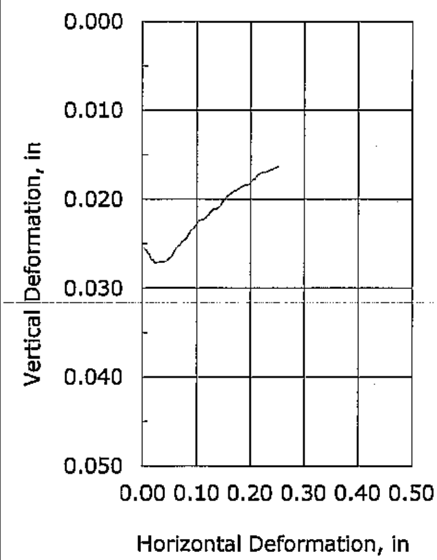
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-9		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	106.2		
Initial Dry Density, pcf	115		
Initial Moisture Content, %	12.3		
Initial Bulk Density, pcf	129		
Initial Degree of Saturation	73.8		
Initial Void Ratio	0.44		
Final Dry Density, pcf	117		
Final Moisture Content, %	16.3		
Final Bulk Density, pcf	136		
Normal Stress, psf	1201		
Maximum Shear Stress, psf	1452		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

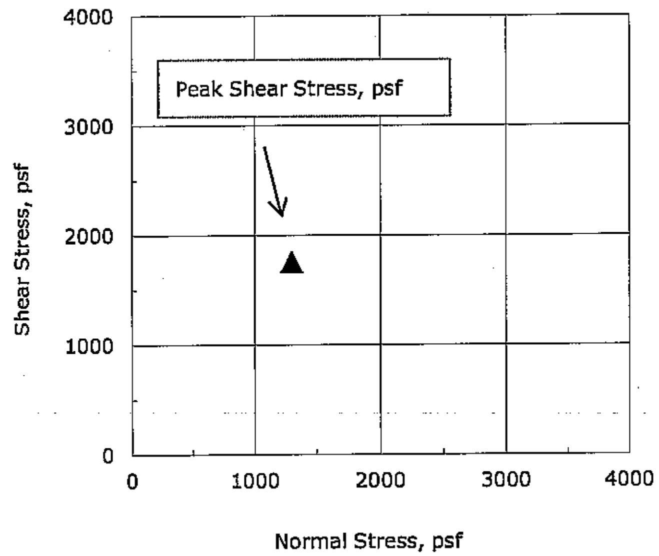
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 50.4°.

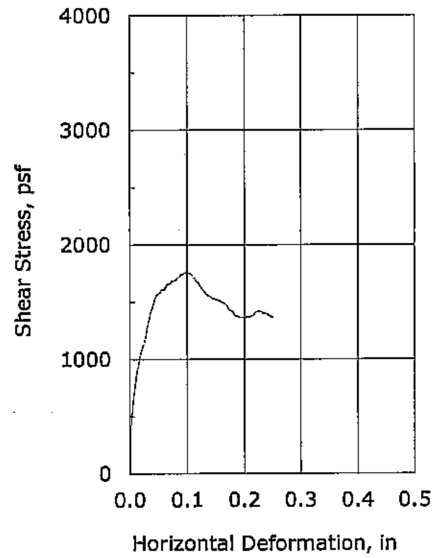
"---" indicates testing required to determine these values was not requested.

GeoTesting
EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/9/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-04
Sample ID:	---
Depth, ft:	11
Visual Description:	Moist, brown sand with clay

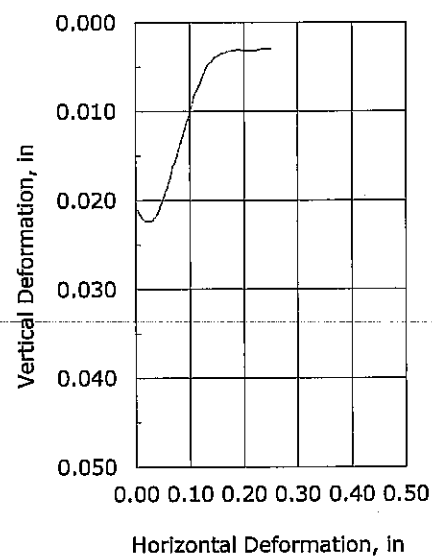
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-2		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	104		
Initial Dry Density, pcf	105		
Initial Moisture Content, %	20.3		
Initial Bulk Density, pcf	126		
Initial Degree of Saturation	90.0		
Initial Void Ratio	0.61		
Final Dry Density, pcf	105		
Final Moisture Content, %	26.0		
Final Bulk Density, pcf	132		
Normal Stress, psf	1300		
Maximum Shear Stress, psf	1756		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.70
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

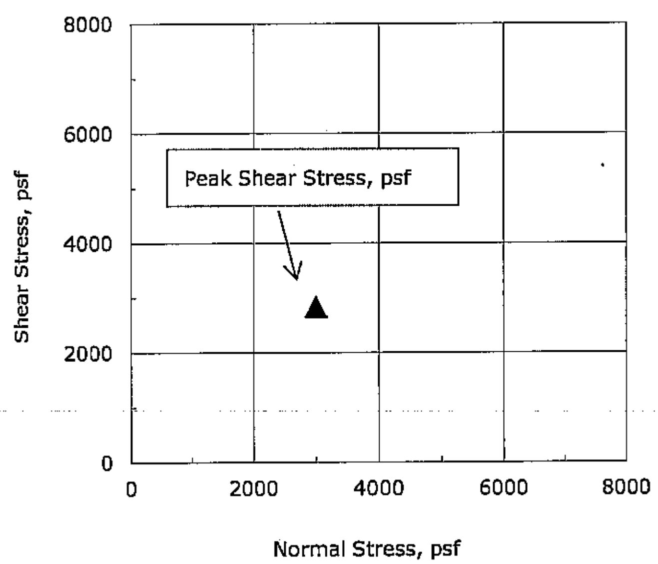
Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 53.5°.

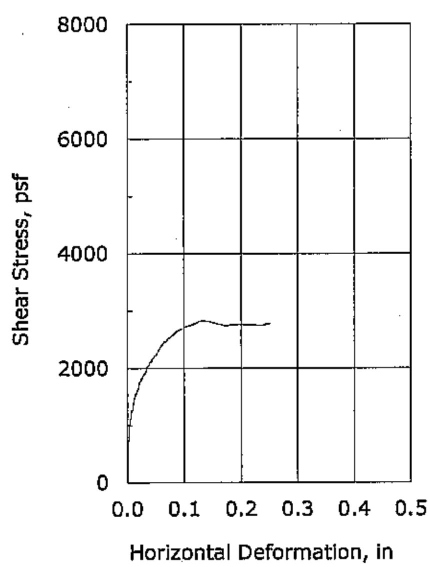
"---" indicates testing required to determine these values was not requested.

GeoTesting EXPRESS

Client:	Ecology & Environment, Inc.
Project Name:	10-08-0011
Project Location:	---
GTX #:	11124
Test Date:	9/14/2011
Tested By:	md
Checked By:	jdt
Boring ID:	SB-05
Sample ID:	---
Depth, ft:	25.5
Visual Description:	Moist, brown sand with gravel

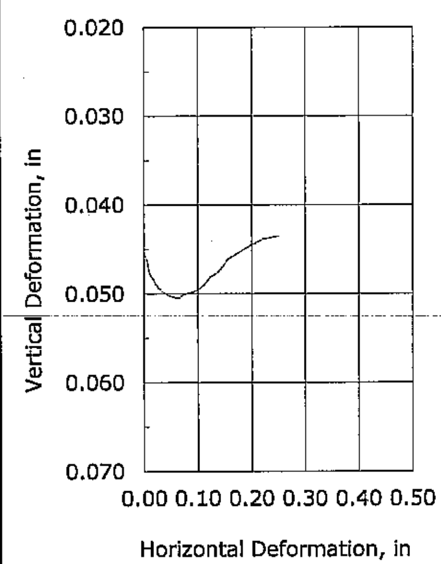
Direct Shear Test of Soils Under Consolidated Drained Conditions by ASTM D 3080-04





Test No.:	DS-8		
Initial Diameter, in	2.00		
Initial Height, in	1.00		
Initial Mass, grams	89.9		
Initial Dry Density, pcf	98.9		
Initial Moisture Content, %	10.2		
Initial Bulk Density, pcf	109		
Initial Degree of Saturation	40.2		
Initial Void Ratio	0.67		
Final Dry Density, pcf	103		
Final Moisture Content, %	22.6		
Final Bulk Density, pcf	127		
Normal Stress, psf	3000		
Maximum Shear Stress, psf	2833		
Shear Rate, in/min	0.004		

Sample Type:	tube
Estimated Specific Gravity:	2.65
Liquid Limit:	---
Plastic Limit:	---
Plasticity Index:	---
% Passing #200 sieve:	---
Soil Classification:	---
Group Symbol:	---



Notes: Moisture content obtained before shear from sample trimmings

Moisture Content determined by ASTM D 2216

Values for cohesion and friction angle not presented because only one test point was requested. If zero cohesion is assumed, the approximate friction angle would be 43.4°.

"---" indicates testing required to determine these values was not requested.

USEPA
DateShipped:
CarrierName:
AirbillNo:

CHAIN OF CUSTODY RECORD
Site #: 10GL
Contact Name: Tim Adair
Contact Phone: 503-248-5600

No: 10-081611-135111-0003
Cooler #:
Lab: GeoTesting Express
Lab Phone: 978-635-0424

Lab #	Sample #	Location	Analyses	Matrix	Collected	Numb Cont	Container	Preservative	MS/MSD
✓	SB01-20.5	SB01	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB01-25	SB01	Grain Size	Soil	8/18/2011	1	bag		
✓	SB01-50 - 52	SB01	Grain Size	Soil	8/18/2011	1	bag		
✓	SB02-22	SB02	Grain Size	Soil	8/18/2011	1	bag		
✓	SB02-30.5	SB02	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB02-55	SB02	Grain Size	Soil	8/18/2011	1	bag		
✓	SB03-20.5	SB03	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB03-21	SB03	Direct Shear	Soil	8/18/201	1	sleeve		
✓	SB03-25	SB03	Grain Size	Soil	8/18/2011	1	bag		
✓	SB03-50	SB03	Grain Size	Soil	8/18/2011	1	bag		
✓	SB03-57.5	SB03	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB04-10	SB04	Grain Size	Soil	8/18/2011	1	bag		
✓	SB04-10.5	SB04	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB04-11	SB04	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB05-20	SB05	Grain Size	Soil	8/18/2011	1	bag		
✓	SB05-25.5	SB05	Direct Shear	Soil	8/18/2011	1	sleeve		
✓	SB05-55	SB05	Grain Size	Soil	8/18/2011	1	bag		
✓	SB02-50.5	SB02	Direct Shear	Soil	8/18/2011	1	sleeve		

Special Instructions:

SAMPLES TRANSFERRED FROM
CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time

GeoTesting
EXPRESS

WARRANTY and LIABILITY

GeoTesting Express (GTX) warrants that all tests it performs are run in general accordance with the specified test procedures and accepted industry practice. GTX will correct or repeat any test that does not comply with this warranty. GTX has no specific knowledge as to conditioning, origin, sampling procedure or intended use of the material.

GTX may report engineering parameters that require us to interpret the test data. Such parameters are determined using accepted engineering procedures. However, GTX does not warrant that these parameters accurately reflect the true engineering properties of the *in situ* material. Responsibility for interpretation and use of the test data and these parameters for engineering and/or construction purposes rests solely with the user and not with GTX or any of its employees.

GTX's liability will be limited to correcting or repeating a test which fails our warranty. GTX's liability for damages to the Purchaser of testing services for any cause whatsoever shall be limited to the amount GTX received for the testing services. GTX will not be liable for any damages, or for any lost benefits or other consequential damages resulting from the use of these test results, even if GTX has been advised of the possibility of such damages. GTX will not be responsible for any liability of the Purchaser to any third party.

Commonly Used Symbols

A	pore pressure parameter for $\Delta\sigma_1 - \Delta\sigma_3$
B	pore pressure parameter for $\Delta\sigma_3$
CIU	isotropically consolidated undrained triaxial shear test
CR	compression ratio for one dimensional consolidation
C_c	coefficient of curvature, $(D_{30})^2 / (D_{10} \times D_{60})$
C_u	coefficient of uniformity, D_{60}/D_{10}
C_c	compression index for one dimensional consolidation
C_α	coefficient of secondary compression
c_v	coefficient of consolidation
c	cohesion intercept for total stresses
c'	cohesion intercept for effective stresses
D	diameter of specimen
D_{10}	diameter at which 10% of soil is finer
D_{15}	diameter at which 15% of soil is finer
D_{30}	diameter at which 30% of soil is finer
D_{50}	diameter at which 50% of soil is finer
D_{60}	diameter at which 60% of soil is finer
D_{85}	diameter at which 85% of soil is finer
d_{50}	displacement for 50% consolidation
d_{90}	displacement for 90% consolidation
d_{100}	displacement for 100% consolidation
E	Young's modulus
e	void ratio
e_c	void ratio after consolidation
e_o	initial void ratio
G	shear modulus
G_s	specific gravity of soil particles
H	height of specimen
PI	plasticity index
i	gradient
K_o	lateral stress ratio for one dimensional strain
k	permeability
LI	Liquidity Index
m_v	coefficient of volume change
n	porosity
PI	plasticity index
P_c	preconsolidation pressure
p	$(\sigma_1 + \sigma_3) / 2$, $(\sigma_v + \sigma_h) / 2$
p'	$(\sigma'_1 + \sigma'_3) / 2$, $(\sigma'_v + \sigma'_h) / 2$
p'_c	p' at consolidation
Q	quantity of flow
q	$(\sigma_1 - \sigma_3) / 2$
q_f	q at failure
q_o, q_i	initial q
q_c	q at consolidation
S	degree of saturation
SL	shrinkage limit
s_u	undrained shear strength
T	time factor for consolidation
T	temperature
t	time
U, UC	unconfined compression test
UU, Q	unconsolidated undrained triaxial test
u_a	pore gas pressure
u_e	excess pore water pressure
u, u_w	pore water pressure
V	total volume
V_g	volume of gas
V_s	volume of solids
V_v	volume of voids
V_w	volume of water
V_o	initial volume
v	velocity
W	total weight
W_s	weight of solids
W_w	weight of water
w	water content
w_c	water content at consolidation
w_f	final water content
w_l	liquid limit
w_n	natural water content
w_p	plastic limit
w_s	shrinkage limit
w_o, w_i	initial water content
α	slope of q_f versus p_f
α'	slope of q_f versus p_f'
γ_t	total unit weight
γ_d	dry unit weight
γ_s	unit weight of solids
γ_w	unit weight of water
ε	strain
ε_{vol}	volume strain
ε_h, ε_v	horizontal strain, vertical strain
μ	Poisson's ratio, also viscosity
σ	normal stress
σ'	effective normal stress
σ_c, σ'_c	consolidation stress in isotropic stress system
σ_h, σ'_h	horizontal normal stress
σ_v, σ'_v	vertical normal stress
σ_1	major principal stress
σ_2	intermediate principal stress
σ_3	minor principal stress
τ	shear stress
φ	friction angle based on total stresses
φ'	friction angle based on effective stresses
φ'_r	residual friction angle
φ_{ult}	φ for ultimate strength

Attachment D: Static Slope Stability XSTABL© Run Output

XSTABL File: GC15JMS   12-31-15   17:37

```
******************************************
*              X S T A B L               *
*                                        *
*        Slope Stability Analysis        *
*               using the                *
*            Method of Slices            *
*                                        *
*        Copyright (C) 1992 - 2015       *
*   Interactive Software Designs, Inc.   *
*        Moscow, ID 83843, U.S.A.        *
*                                        *
*          All Rights Reserved           *
*                                        *
*  Ver. 5.209                96 - 2099   *
******************************************
```

Problem Description: Bremerton Auto Wrecking LF 1.5:1

SEGMENT BOUNDARY COORDINATES

4 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	340.0	30.0	340.0	1
2	30.0	340.0	56.3	357.5	1
3	56.3	357.5	108.8	392.5	2
4	108.8	392.5	150.0	392.5	2

1 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	56.3	357.5	150.0	357.5	1

ISOTROPIC Soil Parameters

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	121.0	142.0	.0	52.00	.000	.0	0
2	113.0	133.0	.0	33.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

2500 trial surfaces will be generated and analyzed.

50 Surfaces initiate from each of 50 points equally spaced along the ground surface between x = .0 ft
and x = 100.0 ft

Each surface terminates between x = 50.0 ft
and x = 150.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 243.0 feet

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

6.0 foot line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit = -45.0 degrees
Upper angular limit = (slope angle - 5.0) degrees

Factors of safety have been calculated by the:

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	63.27	362.14
2	68.55	364.98
3	73.68	368.09
4	78.65	371.46

5	83.44	375.08
6	86.39	377.56

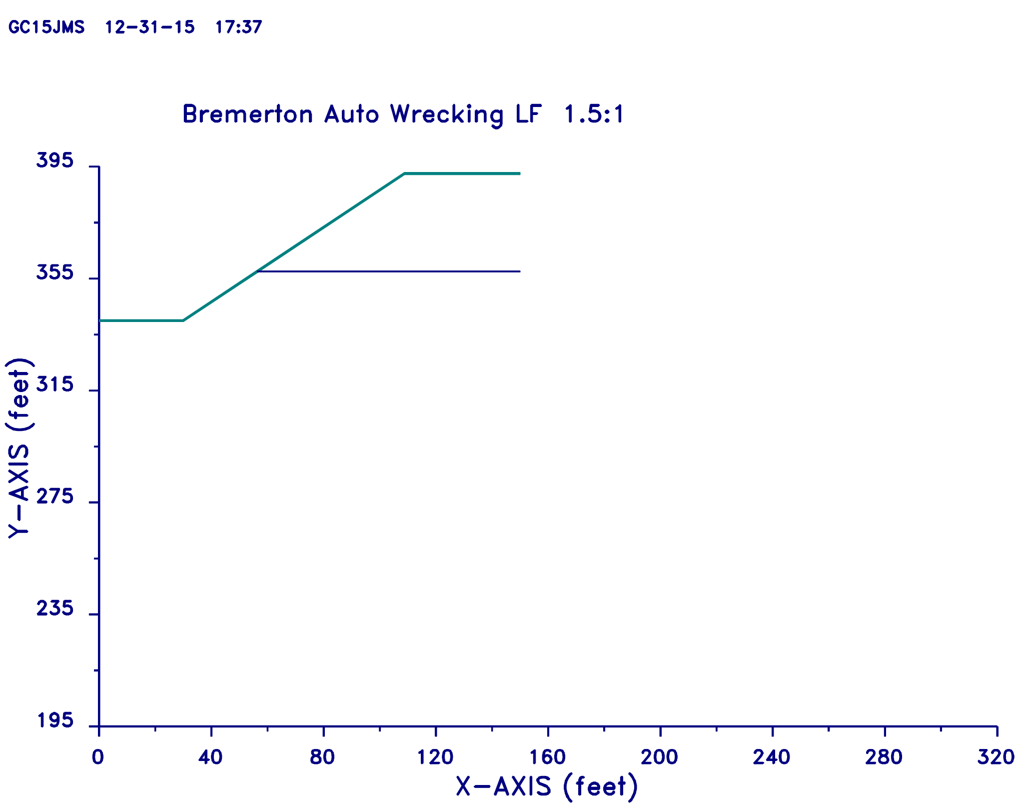
**** Simplified BISHOP FOS = .982 ****

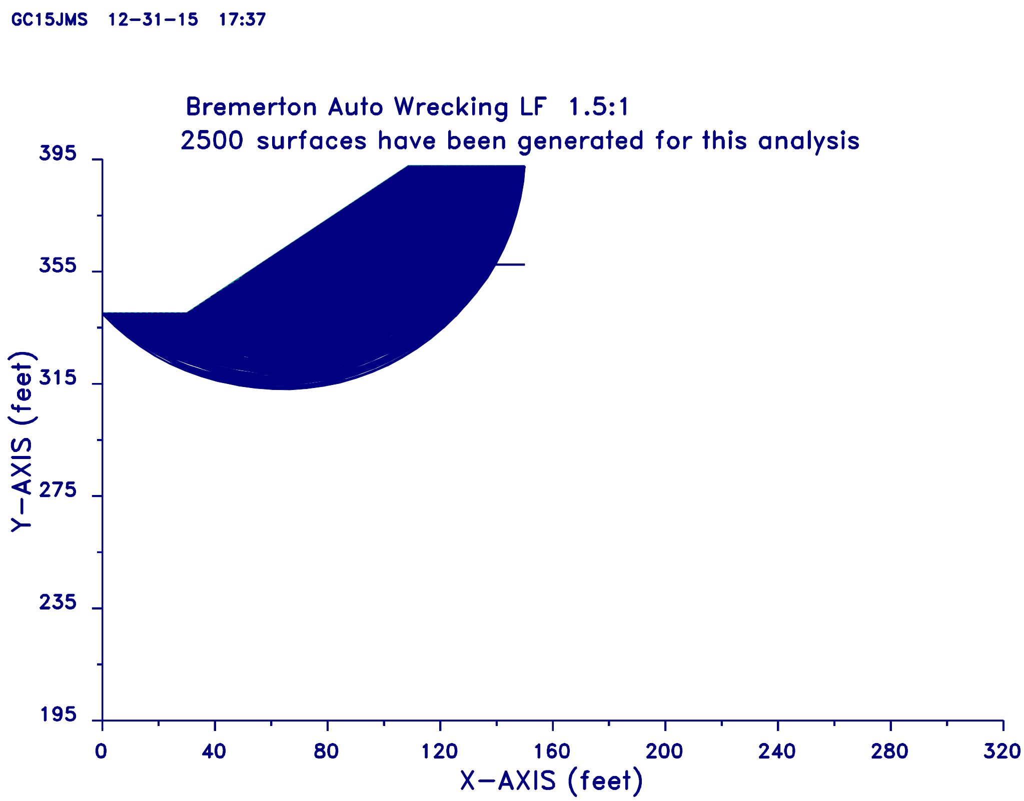
The following is a summary of the TEN most critical surfaces

Problem Description: Bremerton Auto Wrecking LF 1.5:1

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	.982	10.84	466.10	116.42	63.27	86.39	1.085E+05
2.	.985	37.42	454.51	92.06	77.55	98.29	7.702E+04
3.	.987	39.07	441.78	80.55	73.47	92.97	6.290E+04
4.	.987	28.35	424.89	72.36	59.18	76.56	4.599E+04
5.	.987	25.92	465.28	107.78	71.43	98.37	1.735E+05
6.	.988	8.82	462.86	115.40	57.14	86.96	2.309E+05
7.	.988	57.60	437.67	66.77	85.71	102.35	4.009E+04
8.	.989	37.88	459.22	96.13	77.55	103.30	1.499E+05
9.	.993	41.15	399.91	44.32	59.18	71.08	1.444E+04
10.	.994	43.46	426.68	65.78	69.39	89.28	6.650E+04

* * * END OF FILE * * *

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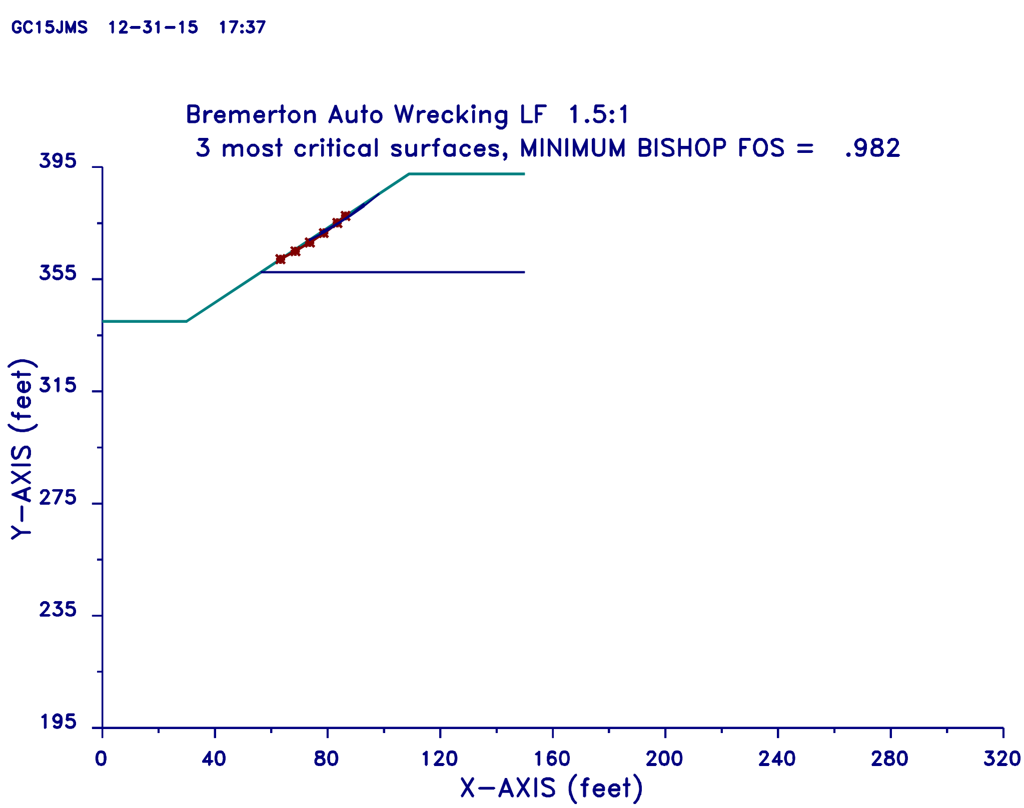
Bremerton Auto Wrecking LF 1.5:1
2500 surfaces have been generated for this analysis
395
355
315
275
235
195
Y-AXIS (feet)
0
40
80
120
160
200
240
280
320
X-AXIS (feet)


GC15JMS 12-31-15 17:37
Bremerton Auto Wrecking LF 1.5:1
3 most critical surfaces, MINIMUM BISHOP FOS = .982
395
355
315
275
235
195
Y-AXIS (feet)
0
40
80
120
160
200
240
280
320
X-AXIS (feet)

XSTABL File: GC15JJB   12-31-15   17:34

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*        Copyright (C) 1992 - 2015      *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.209                96 - 2099  *
*****************************************
```

Problem Description: Bremerton Auto Wrecking LF 1.5:1

SEGMENT BOUNDARY COORDINATES

4 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	340.0	30.0	340.0	1
2	30.0	340.0	56.3	357.5	1
3	56.3	357.5	108.8	392.5	2
4	108.8	392.5	150.0	392.5	2

1 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	56.3	357.5	150.0	357.5	1

ISOTROPIC Soil Parameters
----

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	121.0	142.0	.0	52.00	.000	.0	0
2	113.0	133.0	.0	33.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

2500 trial surfaces will be generated and analyzed.

50 Surfaces initiate from each of 50 points equally spaced along the ground surface between x = .0 ft
and x = 100.0 ft

Each surface terminates between x = 50.0 ft
and x = 150.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 243.0 feet

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

6.0 foot line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit = -45.0 degrees
Upper angular limit = (slope angle - 5.0) degrees

Factors of safety have been calculated by the:

* * * * *   SIMPLIFIED JANBU METHOD   * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	63.27	362.14
2	68.55	364.98
3	73.68	368.09
4	78.65	371.46
5	83.44	375.08
6	86.39	377.56

** Corrected JANBU FOS = .987 ** (Fo factor = 1.009)

Failure surface No. 2 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	77.55	371.67
2	82.86	374.46
3	87.98	377.59
4	92.89	381.05
5	97.55	384.82
6	98.29	385.49

** Corrected JANBU FOS = .990 ** (Fo factor = 1.010)

Failure surface No. 3 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	73.47	368.95
2	78.80	371.71
3	83.90	374.86
4	88.76	378.38
5	92.97	381.95

** Corrected JANBU FOS = .991 ** (Fo factor = 1.011)

Failure surface No. 4 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	59.18	359.42
2	64.50	362.20
3	69.57	365.41
4	74.36	369.03
5	76.56	371.01

** Corrected JANBU FOS = .992 ** (Fo factor = 1.011)

Failure surface No. 5 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	71.43	367.59
2	76.79	370.27
3	82.00	373.25
4	87.04	376.51
5	91.88	380.05
6	96.52	383.85
7	98.37	385.55

** Corrected JANBU FOS = .992 ** (Fo factor = 1.011)

Failure surface No. 6 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	85.71	377.11
2	91.04	379.88
3	96.09	383.11
4	100.83	386.79
5	102.35	388.20

** Corrected JANBU FOS = .992 ** (Fo factor = 1.011)

Failure surface No. 7 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	57.14	358.06
2	62.52	360.72
3	67.76	363.64
4	72.84	366.84

5	77.74	370.30
6	82.46	374.01
7	86.96	377.94

** Corrected JANBU FOS = .992 ** (Fo factor = 1.011)

Failure surface No. 8 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	77.55	371.67
2	82.94	374.31
3	88.15	377.29
4	93.16	380.59
5	97.96	384.19
6	102.52	388.08
7	103.30	388.83

** Corrected JANBU FOS = .993 ** (Fo factor = 1.012)

Failure surface No. 9 specified by 4 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	59.18	359.42
2	64.49	362.23
3	69.36	365.73
4	71.08	367.35

** Corrected JANBU FOS = .996 ** (Fo factor = 1.012)

Failure surface No.10 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	69.39	366.23
2	74.79	368.84
3	79.93	371.94
4	84.76	375.49
5	89.26	379.46
6	89.28	379.49

** Corrected JANBU FOS = .997 ** (Fo factor = 1.013)

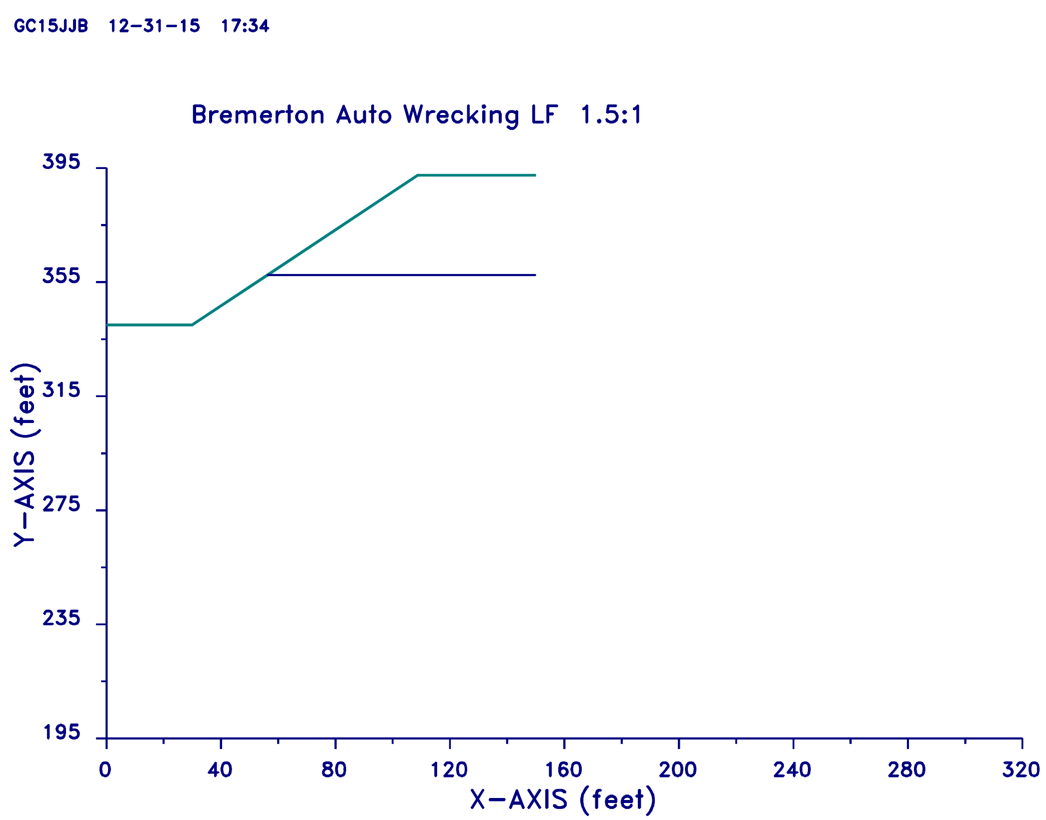
```
************************************************************************
**                                                                    **
**   Out of the 2500 surfaces generated and analyzed by XSTABL,       **
**        1 surface was found to have MISLEADING FOS values.          **
**   The information related to the 1 surface was not retained.       **
**                                                                    **
************************************************************************
```

The following is a summary of the TEN most critical surfaces

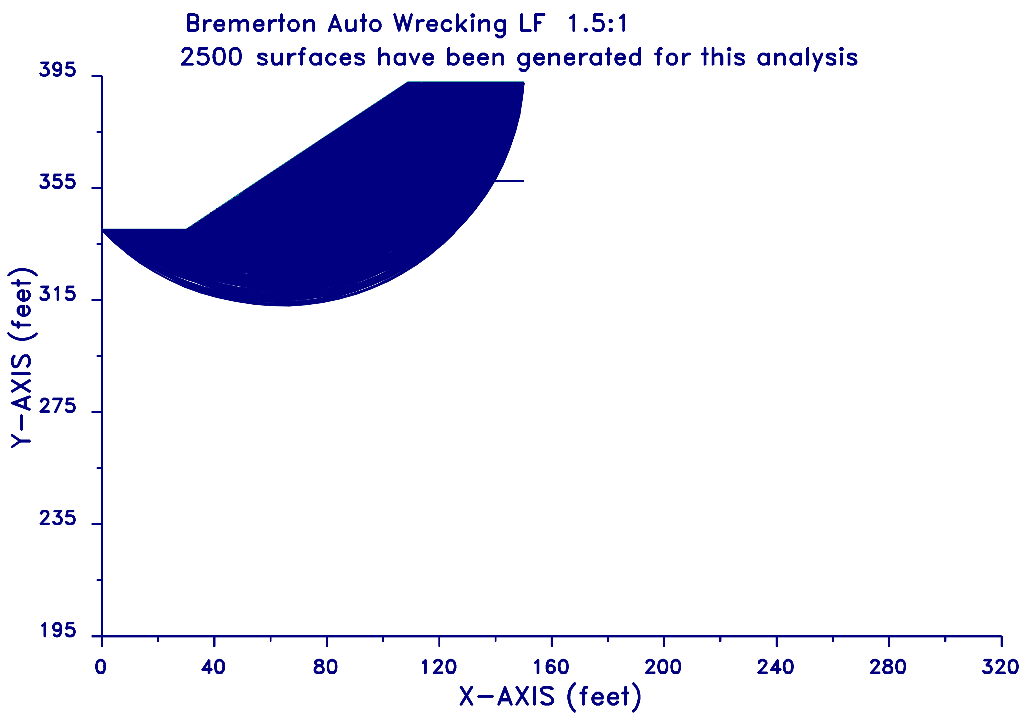
Problem Description: Bremerton Auto Wrecking LF 1.5:1

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	.987	1.009	63.27	86.39	9.309E+02
2.	.990	1.010	77.55	98.29	8.356E+02
3.	.991	1.011	73.47	92.97	7.796E+02
4.	.992	1.011	59.18	76.56	6.345E+02
5.	.992	1.011	71.43	98.37	1.607E+03
6.	.992	1.011	85.71	102.35	5.993E+02
7.	.992	1.011	57.14	86.96	1.997E+03
8.	.993	1.012	77.55	103.30	1.557E+03
9.	.996	1.012	59.18	71.08	3.250E+02
10.	.997	1.013	69.39	89.28	1.008E+03

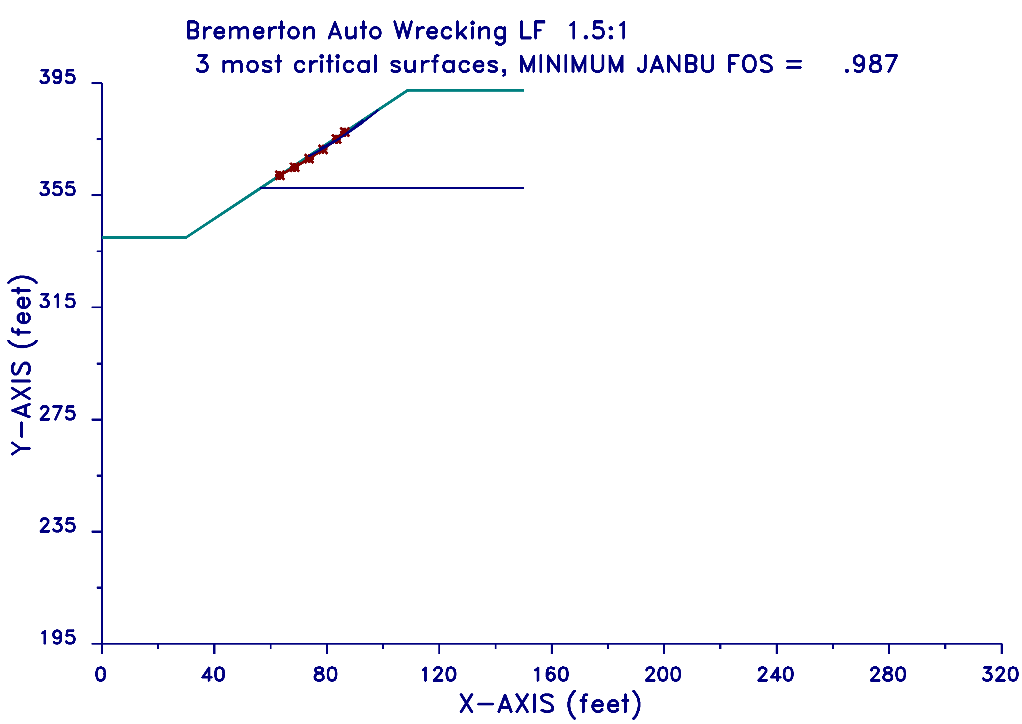
* * * END OF FILE * * *



GC15JJB 12-31-15 17:34



GC15JJB 12-31-15 17:34



XSTABL File: GC21AMS   1-04-16   17:45

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******************************************
*               X S T A B L              *
*                                        *
*        Slope Stability Analysis        *
*               using the                *
*            Method of Slices            *
*                                        *
*        Copyright (C) 1992 - 2015       *
*   Interactive Software Designs, Inc.   *
*        Moscow, ID 83843, U.S.A.        *
*                                        *
*          All Rights Reserved           *
*                                        *
*  Ver. 5.209                96 - 2099   *
******************************************
```

Problem Description: Bremerton Auto Wrecking LF 2:1

SEGMENT BOUNDARY COORDINATES

4 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	340.0	30.0	340.0	1
2	30.0	340.0	65.0	357.5	1
3	65.0	357.5	135.0	392.5	2
4	135.0	392.5	175.0	392.5	2

1 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	65.0	357.5	175.0	357.5	1

ISOTROPIC Soil Parameters

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	121.0	142.0	.0	52.00	.000	.0	0
2	113.0	133.0	.0	33.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

2500 trial surfaces will be generated and analyzed.

50 Surfaces initiate from each of 50 points equally spaced along the ground surface between x = .0 ft
and x = 100.0 ft

Each surface terminates between x = 50.0 ft
and x = 175.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 243.0 feet

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

6.0 foot line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit = -45.0 degrees
Upper angular limit = (slope angle - 5.0) degrees

Factors of safety have been calculated by the:

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	93.88	371.94
2	99.46	374.14
3	104.99	376.48

4	110.45	378.95
5	115.86	381.55
6	121.20	384.29
7	126.47	387.15
8	131.67	390.14
9	135.55	392.50

**** Simplified BISHOP FOS = 1.308 ****

The following is a summary of the TEN most critical surfaces

Problem Description : Bremerton Auto Wrecking LF 2:1

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	1.308	6.33	602.07	246.22	93.88	135.55	6.395E+05
2.	1.309	30.95	468.12	115.04	69.39	94.37	1.181E+05
3.	1.311	38.22	485.63	127.72	79.59	109.84	2.112E+05
4.	1.313	48.76	487.18	124.57	87.76	119.99	2.521E+05
5.	1.313	42.54	433.71	79.03	67.35	87.41	6.035E+04
6.	1.314	46.80	428.44	72.36	69.39	87.86	4.769E+04
7.	1.315	46.42	415.98	61.31	65.31	81.65	3.077E+04
8.	1.317	55.19	419.95	61.02	73.47	90.53	3.655E+04
9.	1.320	21.30	516.59	164.49	67.35	119.94	1.123E+06
10.	1.321	71.73	423.19	56.63	87.76	105.23	4.002E+04

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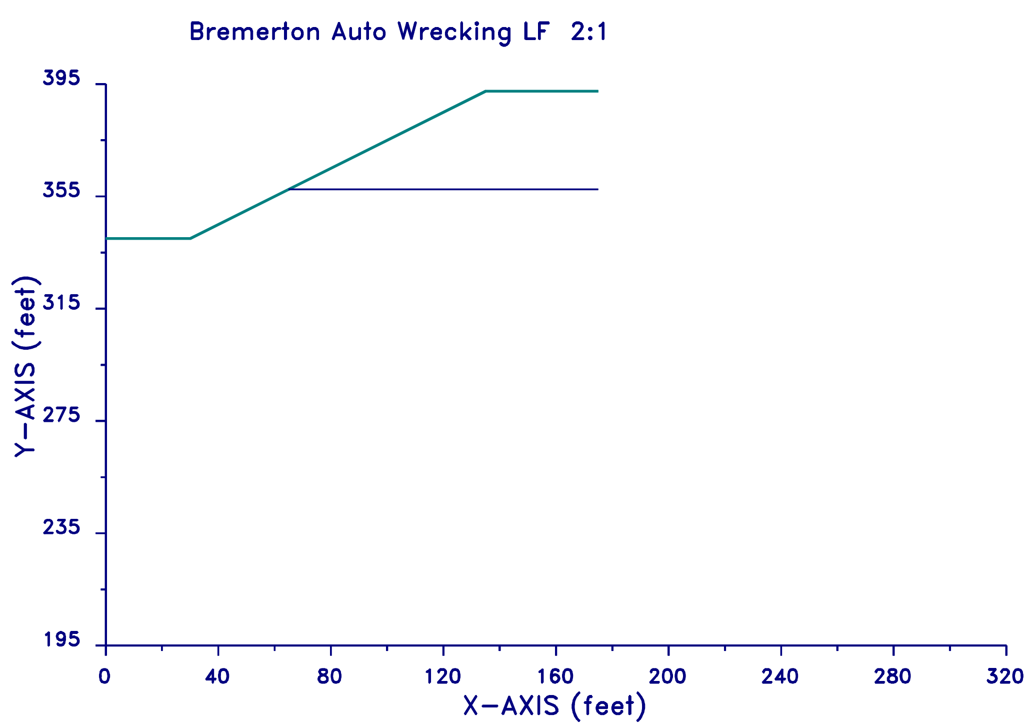
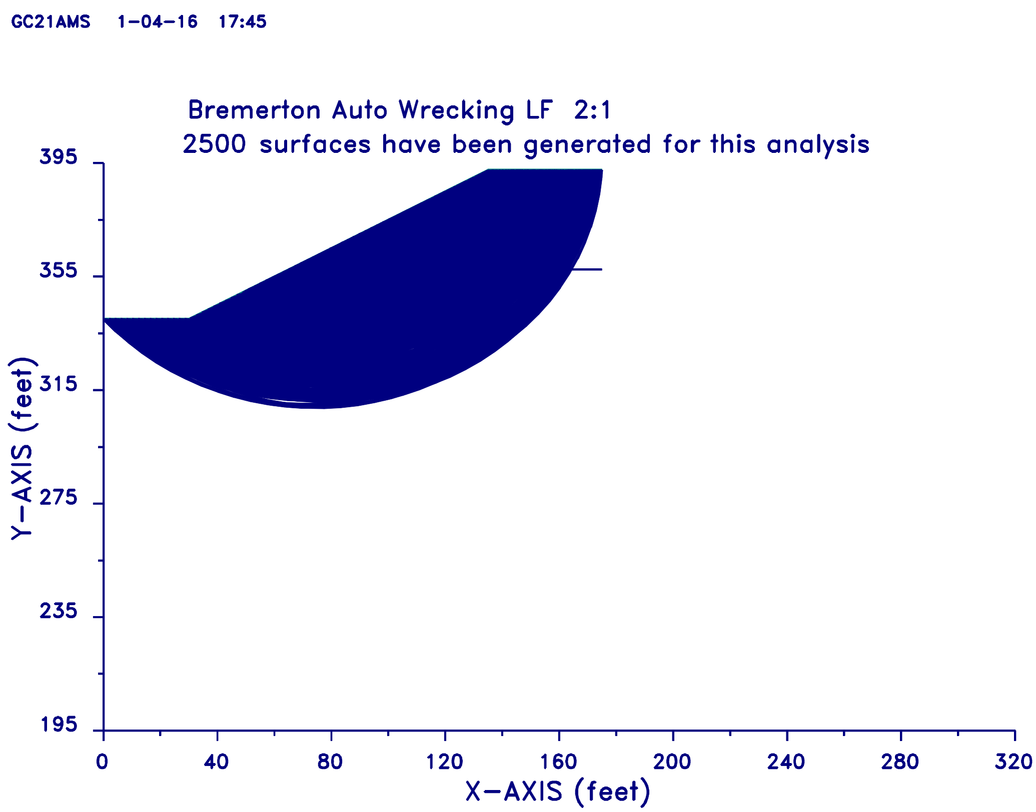
GC21AMS 1-04-16 17:45

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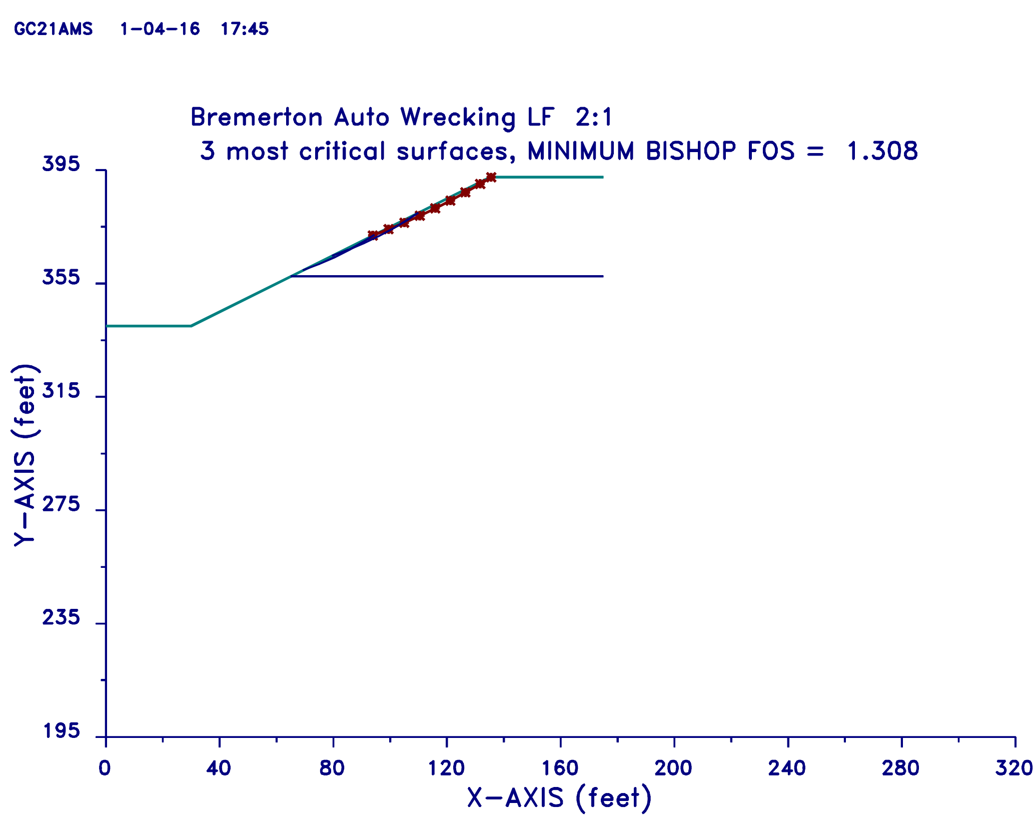
Bremerton Auto Wrecking LF 2:1
2500 surfaces have been generated for this analysis
395
355
315
275
235
195
Y-AXIS (feet)
0
40
80
120
160
200
240
280
320
X-AXIS (feet)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Bremerton Auto Wrecking LF 2:1
3 most critical surfaces, MINIMUM BISHOP FOS = 1.308
395
355
315
275
235
195
Y-AXIS (feet)
0
40
80
120
160
200
240
280
320
X-AXIS (feet)

XSTABL File: GC21AJB   12-31-15   17:50

```
*******************************************
*               X S T A B L               *
*                                         *
*        Slope Stability Analysis         *
*                using the                *
*             Method of Slices            *
*                                         *
*        Copyright (C) 1992 - 2015        *
*   Interactive Software Designs, Inc.    *
*        Moscow, ID 83843, U.S.A.         *
*                                         *
*          All Rights Reserved            *
*                                         *
*  Ver. 5.209                96 - 2099    *
*******************************************
```

Problem Description: Bremerton Auto Wrecking LF 2:1

SEGMENT BOUNDARY COORDINATES
----

4 SURFACE boundary segments

	Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below
Segment	1	.0	340.0	30.0	340.0	1
	2	30.0	340.0	65.0	357.5	1
	3	65.0	357.5	135.0	392.5	2
	4	135.0	392.5	175.0	392.5	2

1 SUBSURFACE boundary segments

	Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below
Segment	1	65.0	357.5	175.0	357.5	1

ISOTROPIC Soil Parameters
----

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	121.0	142.0	.0	52.00	.000	.0	0
2	113.0	133.0	.0	33.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

2500 trial surfaces will be generated and analyzed.

50 Surfaces initiate from each of 50 points equally spaced along the ground surface between x = .0 ft
and x = 100.0 ft

Each surface terminates between x = 50.0 ft
and x = 175.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = 243.0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

6.0 foot line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit:= -45.0 degrees
Upper angular limit:= (slope angle - 5.0) degrees

Factors of safety have been calculated by the:

* * * * *   SIMPLIFIED JANBU METHOD   * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	93.88	371.94
2	99.46	374.14
3	104.99	376.48
4	110.45	378.95
5	115.86	381.55
6	121.20	384.29
7	126.47	387.15
8	131.67	390.14
9	135.55	392.50

** Corrected JANBU FOS = 1.314 **   (Fo factor = 1.007)

Failure surface No. 2 specified by 6 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	69.39	359.69
2	74.99	361.85
3	80.47	364.29
4	85.82	367.01
5	91.01	370.01
6	94.37	372.18

** Corrected JANBU FOS = 1.316 **   (Fo factor = 1.009)

Failure surface No. 3 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	79.59	364.80
2	85.22	366.87
3	90.75	369.21
4	96.16	371.81
5	101.44	374.65

6	106.58	377.75
7	109.84	379.92

** Corrected JANBU FOS = 1.318 ** (Fo factor = 1.010)

Failure surface No. 4 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	87.76	368.88
2	93.41	370.89
3	98.95	373.18
4	104.39	375.73
5	109.69	378.53
6	114.85	381.59
7	119.86	384.90
8	119.99	384.99

** Corrected JANBU FOS = 1.320 ** (Fo factor = 1.011)

Failure surface No. 5 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	65.31	357.65
2	70.92	359.78
3	76.29	362.44
4	81.38	365.62
5	81.65	365.83

** Corrected JANBU FOS = 1.320 ** (Fo factor = 1.010)

Failure surface No. 6 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	67.35	358.67
2	72.97	360.77
3	78.41	363.29
4	83.65	366.22
5	87.41	368.71

** Corrected JANBU FOS = 1.320 ** (Fo factor = 1.011)

Failure surface No. 7 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	69.39	359.69
2	75.01	361.80
3	80.43	364.37
4	85.62	367.37
5	87.86	368.93

** Corrected JANBU FOS = 1.320 ** (Fo factor = 1.011)

Failure surface No. 8 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	73.47	361.73
2	79.10	363.81
3	84.50	366.43
4	89.61	369.57
5	90.53	370.26

** Corrected JANBU FOS = 1.322 ** (Fo factor = 1.011)

Failure surface No. 9 specified by 5 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	87.76	368.88
2	93.41	370.88
3	98.82	373.47
4	103.93	376.61
5	105.23	377.62

** Corrected JANBU FOS = 1.326 ** (Fo factor = 1.013)

Failure surface No.10 specified by 11 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	67.35	358.67
2	73.08	360.46
3	78.74	362.45
4	84.32	364.65
5	89.82	367.05
6	95.23	369.64

7	100.54	372.44
8	105.74	375.42
9	110.83	378.60
10	115.81	381.95
11	119.94	384.97

** Corrected JANBU FOS = 1.327 ** (Fo factor = 1.013)

The following is a summary of the TEN most critical surfaces

Problem Description: Bremerton Auto Wrecking LF 2:1

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.314	1.007	93.88	135.55	2.596E+03
2.	1.316	1.009	69.39	94.37	1.026E+03
3.	1.318	1.010	79.59	109.84	1.653E+03
4.	1.320	1.011	87.76	119.99	2.022E+03
5.	1.320	1.010	65.31	81.65	5.013E+02
6.	1.320	1.011	67.35	87.41	7.628E+02
7.	1.320	1.011	69.39	87.86	6.583E+02
8.	1.322	1.011	73.47	90.53	5.981E+02
9.	1.326	1.013	87.76	105.23	7.056E+02
10.	1.327	1.013	67.35	119.94	6.814E+03

* * * END OF FILE * * *

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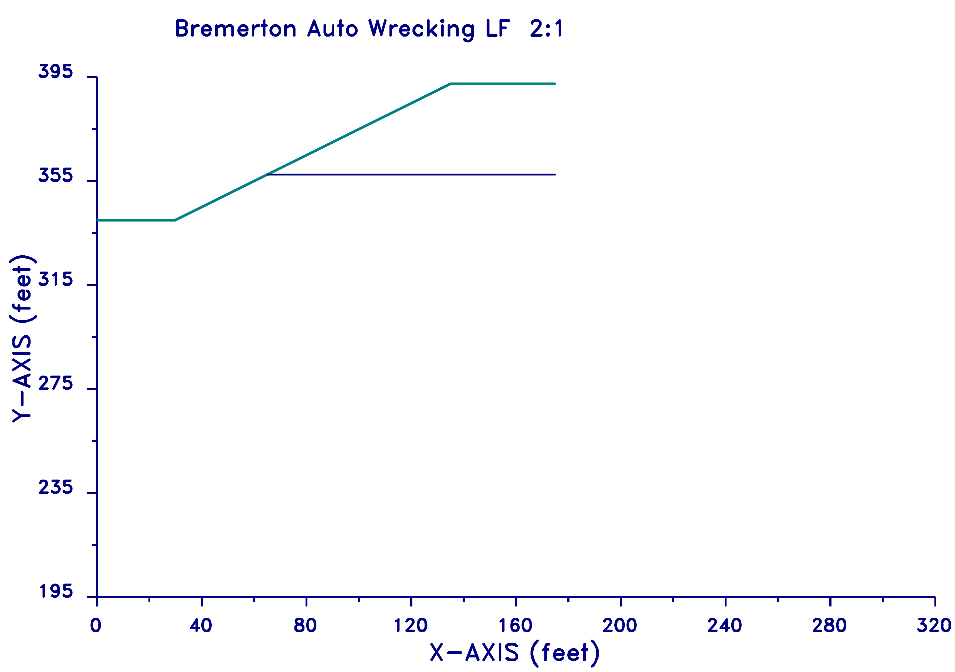

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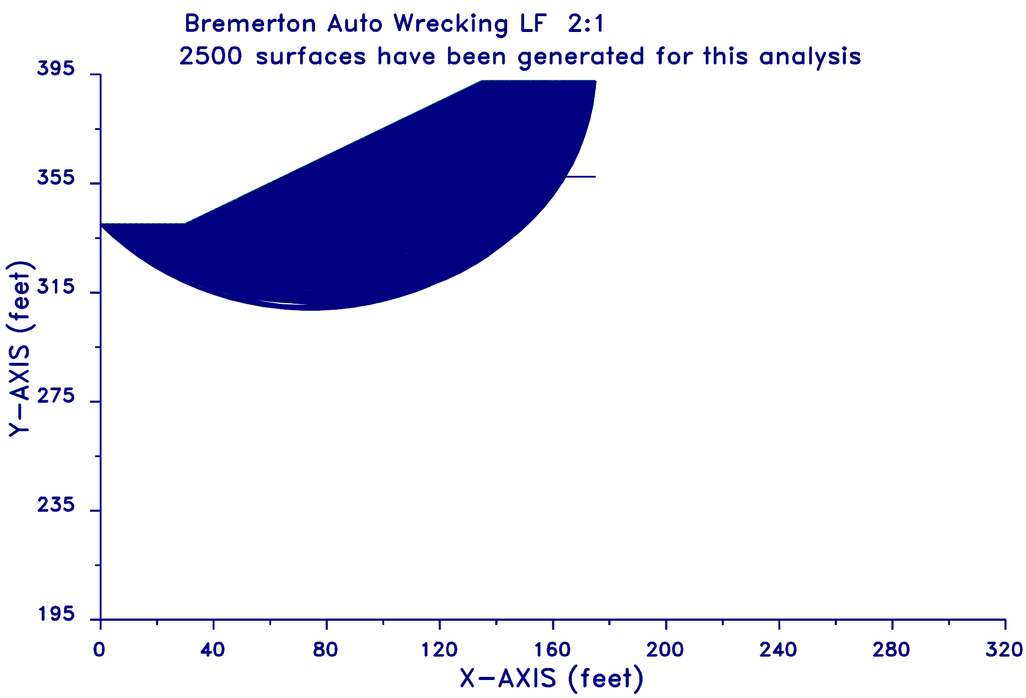

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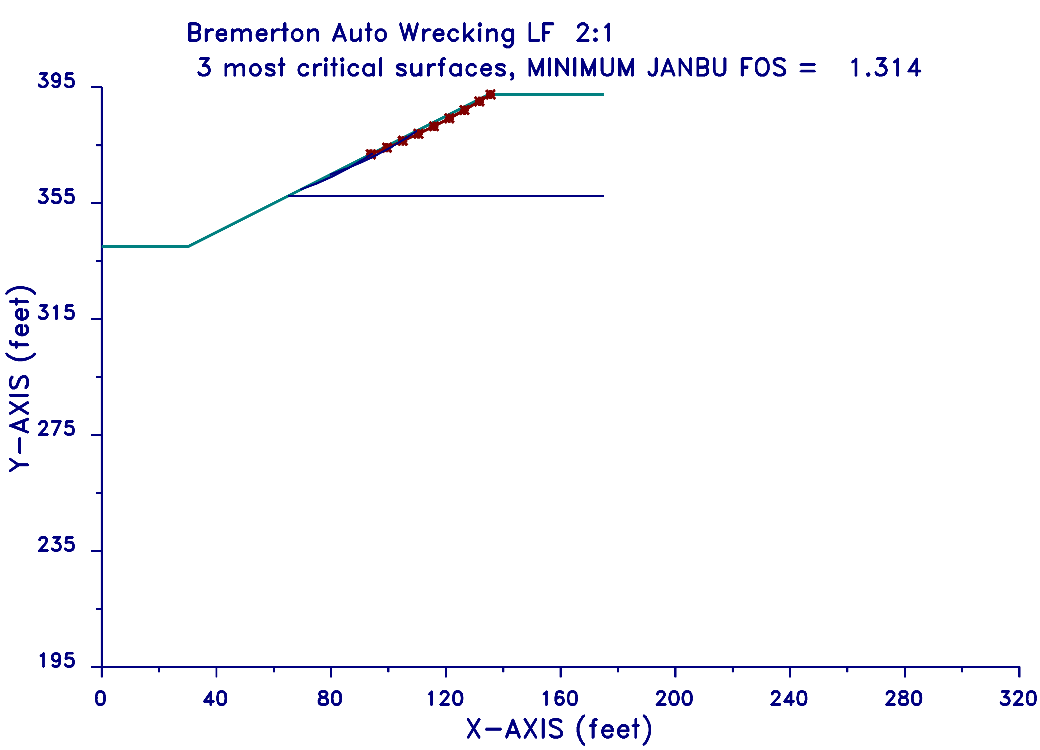

ecology and environment, inc.

Design Memorandum

Date:	6/13/2016
To:	Design File
From:	Tyler Chatriand, P.E.
Reviewer:	Tom Campbell, P.E.
Subject:	**Bremerton Auto Wrecking Landfill Conceptual Stormwater Runoff and Hydrology Analysis**

PROFESSIONAL ENGINEER CERTIFICATION

Conceptual Stormwater Runoff and Hydrology Analysis
Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

I hereby certify that this Conceptual Stormwater Runoff and Hydrology Analysis for the Bremerton Auto Wrecking Landfill Site in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE: Thomas Campbell

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 6/13/2016

THOMAS C. CAMPBELL
STATE OF WASHINGTON
51283
REGISTERED
PROFESSIONAL ENGINEER

Objective

This memorandum describes the hydrologic analysis that was performed to predict stormwater runoff from the contributing watersheds to Gorst Creek at the Gorst Creek - Bremerton Auto Wrecking Landfill site (Site). The estimated flow rates will be used in the design of the stream channel restoration. The stream restoration will be conducted to establish a stable and ecologically functional stream appropriately sized for its contributing basin.

Criteria

Kitsap County Code Title 12.20.090 for stormwater conveyance facilities requires proposed developments to provide on-site stormwater conveyance facilities with sufficient capacity to convey, without flooding or otherwise damaging existing or proposed structures, the post-development peak stormwater runoff rate resulting from a 100-year storm event, plus any existing upstream runoff that will be conveyed through the development site (Kitsap County 2015). The estimation of peak stormwater runoff rates used in the design of water conveyance facilities will use the rational method as shown in the Kitsap County Stormwater Design Manual (Kitsap County 2010), the Santa Barbara urban hydrology event model method as defined in the Stormwater Management Manual for Western Washington (2005), or the latest version of the Western Washington hydrology model (WSDOE 2014).

Method of Analysis

The drainage basin was delineated using topographic contours and the National Hydrography Dataset Hydrologic Unit Code 12 watershed boundaries as a guide. The drainage basin area was estimated based on this delineation. Figure A-1 shows the delineated drainage basin and the drainage path through the watershed (Attachment A).

Calculations for time of concentration (Tc) are based on Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55). TR-55 is a simplified method for estimating runoff and peak discharges in smaller and less complex watersheds where the runoff is predominantly unconfined flow over land or in drainage channels (NRCS 1999). The time of concentration estimated for each drainage basin significantly influences the shape and peak of the hydrograph and is very sensitive to slopes, type of flow conveyance, and land cover. The slopes of the contributing drainage basins are steep, reducing the potential for infiltration, evaporation, and vegetation interference. The majority of runoff is likely concentrated as channelized flow in distinct drainage paths within the basin prior to discharging to the Site. The drainage path presented on Figure A-1 was used to develop Tc calculations. The slope along the drainage path was estimated based on the topographic contours in this figure. Attachment B contains the Tc calculation.

The runoff curve number (CN) within the basin was based on assumed watershed characteristics of the basin (soil type, land cover, watershed slope, etc.)(Parametrix 2012, WSDOE 2015). The CN is determined by the hydrologic soil group, land cover type, treatment, and hydrologic condition (amount of vegetation cover and imperviousness). The amount of land cover type, watershed slope, and pervious versus impervious land area was estimated based on analysis of available data and mapping information (via geographic information system [GIS]). Figure B-1 in Attachment B shows land cover type. The predominant hydrologic soil groups for each of stormwater drainage areas were obtained from the NRCS soil survey (see Attachment C)(NRCS 2015), and the land cover and hydrologic conditions were evaluated based on current aerials for each of the drainage basins. Soil type, hydrologic condition, and estimated CN assumptions are presented in Attachment C.

The watershed runoff (rates and volumes) was determined using the Santa Barbara Urban Hydrograph Method as required by local and state guidelines for stormwater conveyance systems (WSDOE 2014). Precipitation depths used to predict peak flows were estimated using 6-hour and 24-hour isopluvial maps (NOAA 2015). Isopluvial maps are included in Attachment D.

Assumptions

Assumptions were made based on engineering judgement using information and observations collected from ArcGIS aerials and measurements as well as downloaded NRCS soil data. Estimates of the drainage basin channel geometry are included in Attachment A, Tc assumptions in Attachment B, and CN assumptions in Attachment C.

Conclusions

The assumptions were used as inputs into spreadsheets utilizing the Santa Barbara Hydrograph Method. The peak flow rates obtained will be used for design of the reconstructed creek channel. Table 1 summarizes the calculation output. Peak discharge calculations are included in Attachment D.

Table 1. Peak Discharge Rates at the Gorst Creek - Bremerton Auto Wrecking Landfill Site

Storm Event	Estimated Peak Flow (cubic feet per second)
2-year / 6-hour	4.3
2-year / 24-hour	26.4
5-year / 24-hour	40.0
10-year / 24-hour	52.4
25-year / 24-hour	72.2
50-year / 24-hour	90.2
100-year / 24-hour	110.8

References

Parametrix. 2012. City of Bremerton; Gorst Creek Watershed Characterization Report; Washington State Department of Ecology and Washington Department of Fish and Wildlife in collaboration with Parametrix, Bellevue, Washington; May 2012.

Kitsap County. 2010. Kitsap County, Washington; Stormwater Design Manual; February 16, 2010.

Kitsap County. 2015. Kitsap County Code. Accessed in October 2015 at http://www.codepublishing.com/WA/KitsapCounty/html/Kitsap12/Kitsap1220.html

NOAA (National Oceanic and Atmospheric Administration /National Weather Service). 2015. Hydrometeorological Design Studies Center, Washington Precipitation Frequency Data, accessed at http://hdsc.nws.noaa.gov/cgi-bin/hdsc/na3.perl?qlat=47.509842&qlon=-122.740394&submit=Submit on October 16, 2015.

NRCS (Natural Resources Conservation Service). 1999. United States Department of Agriculture, Natural Resources Conservation Service; Urban Hydrology for Small Watersheds TR-55; January 1999 (originally developed by the Soil Conservation Service).

NRCS. 2015. United States Department of Agriculture, Natural Resources Conservation Service; Web Soil Survey, accessed at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm on October 9, 2015.

WSDOE (Washington State Department of Ecology). 2015. Puget Sound Watershed Characterization Project (Beta version); 2013; https://fortress.wa.gov/ecy/coastalatlas/wc/landingpage.html, referenced September 18, 2015.

WSDOE. 2014. 2012 Stormwater Management Manual for Western Washington, as Amended in December 2014, http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

Attachment A: Drainage Basin Channel Geometry Calculations

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Watershed Characteristics: Upper Gorst Creek Drainage Basin

Gorst Creek Basin	
Acreage	388.14
Basin length (ft)	7,641.52
Length of drainage to the start of Gorst Creek (ft)	4,038.84
Length of drainage along Gorst Creek to the outlet (ft)	3,602.68
Min elevation (ft)	345
Max elevation (ft)	525
Ave slope	2.36%
upper basin slope	0.92%
lower basin slope	3.80%

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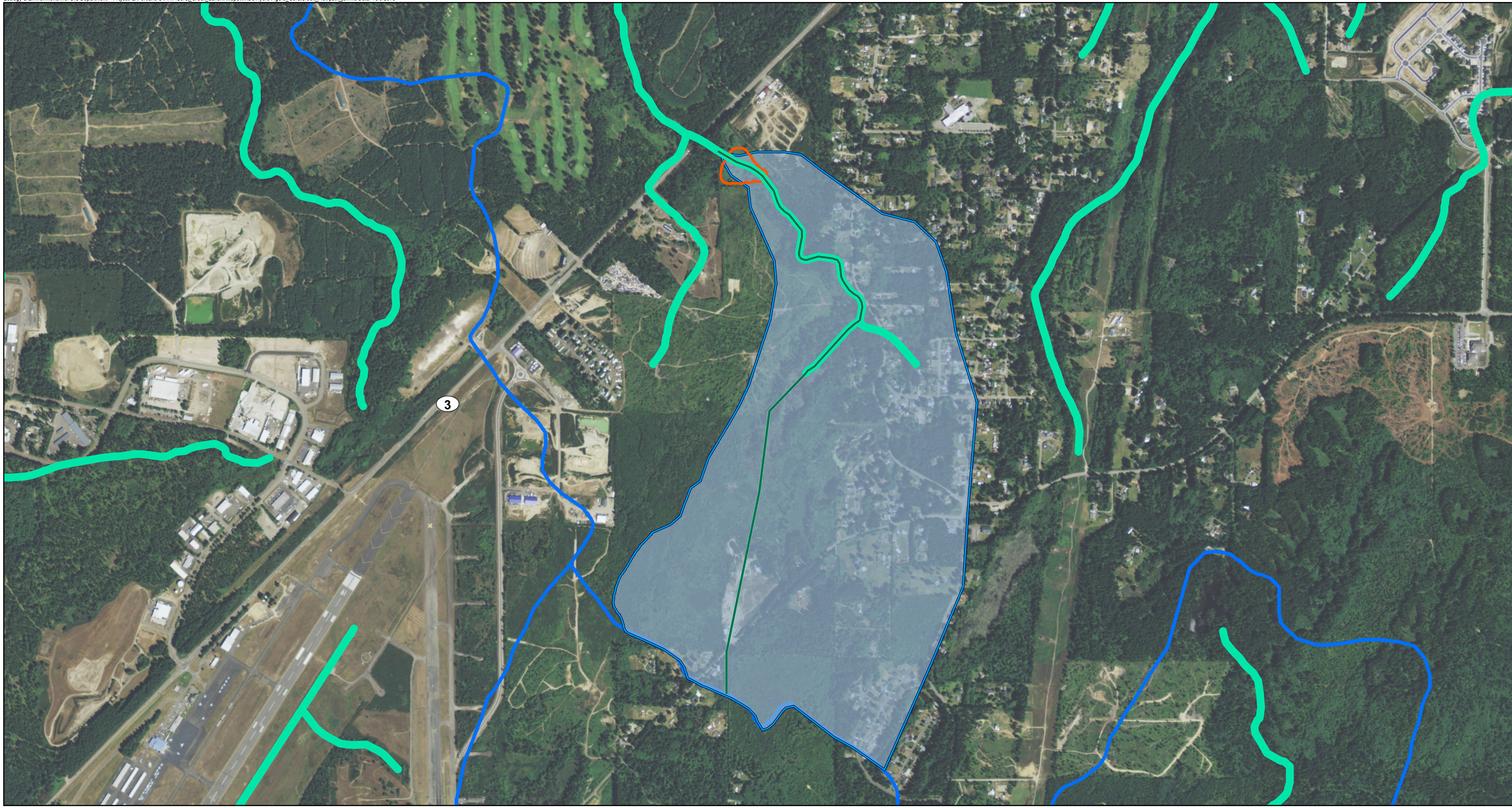

Gorst Creek - Bremerton Auto Wrecking landfill boundary
Flowpath
Watershed
NHD HUC12 Watershed Boundary
NHD Streams

Gorst Creek Landfill

Port Orchard, Washington

N
W E
S

Map Projection: NAD 1983 UTM Zone 10N Meter
Map Scale: 1: 12,772

0 250 500 1,000 1,500 2,000 2,500
Feet
1 in = 1,064 ft

Figure 1
Gorst Creek
Upper Watershed Boundary

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Attachment B: Time of Concentration Calculations

Time of Concentration: Upper Gorst Creek Drainage Basin

Equations:

Overland Flow
Tc = (0.007*(nL)^0.8)/((P24^0.5)*(S^0.4))
max L= 300 based on NRCS TR-55 definitions

Sheet Flow
Tc=L/(3600*K*S^0.5)
where K = 16.13 for unpaved and 20.32 for paved

Waterway Flow
Tc = L/(V*3600)

Overland Flow

		Variables	Value	Unit	Description
Tc1=	**1.29 hour**	n	0.8		Woods - Dense Under brush
		L	300	feet	Topographic map
		P24	3.23	inches	2 year, 24 hour Figure 25 NOAA Atlas 2
		S	0.02886	ft/ft	20 feet/693 feet

Sheet Flow

		Variables	Value	Unit	Description
Tc2=	**0.46 hour**	n	0.8		Woods - Dense Under brush
		L	3739	feet	Topographic map
		P24	3.23	inches	2 year, 24 hour Figure 25 NOAA Atlas 2
		S	0.02	ft/ft	20 feet/ 1000 feet

Waterway Flow

Tc3= 0.39 hours total

Section	Elevation	Length	Area	Slope	Velocity	Time Sec	Time Min
A	460	1371.00	Ill defined stream	0.015	1.95	703	12
B	440	612.00	Ill defined stream	0.033	2.85	215	4
C	420	500.00	stream	0.040	3.2	156	3
D	400	570.00	stream	0.035	2.95	193	3
E	380	465.00	stream	0.043	3.3	141	2
F	360	85.00	stream	0.176	6.8	13	0
	345		Outlet				24 minutes total

Velocities taken from TR-55 Figure 3-1 (June 1986 Version)
Elevations and slope determined from GIS database

Tctotal = 2.14 hour
128 minutes

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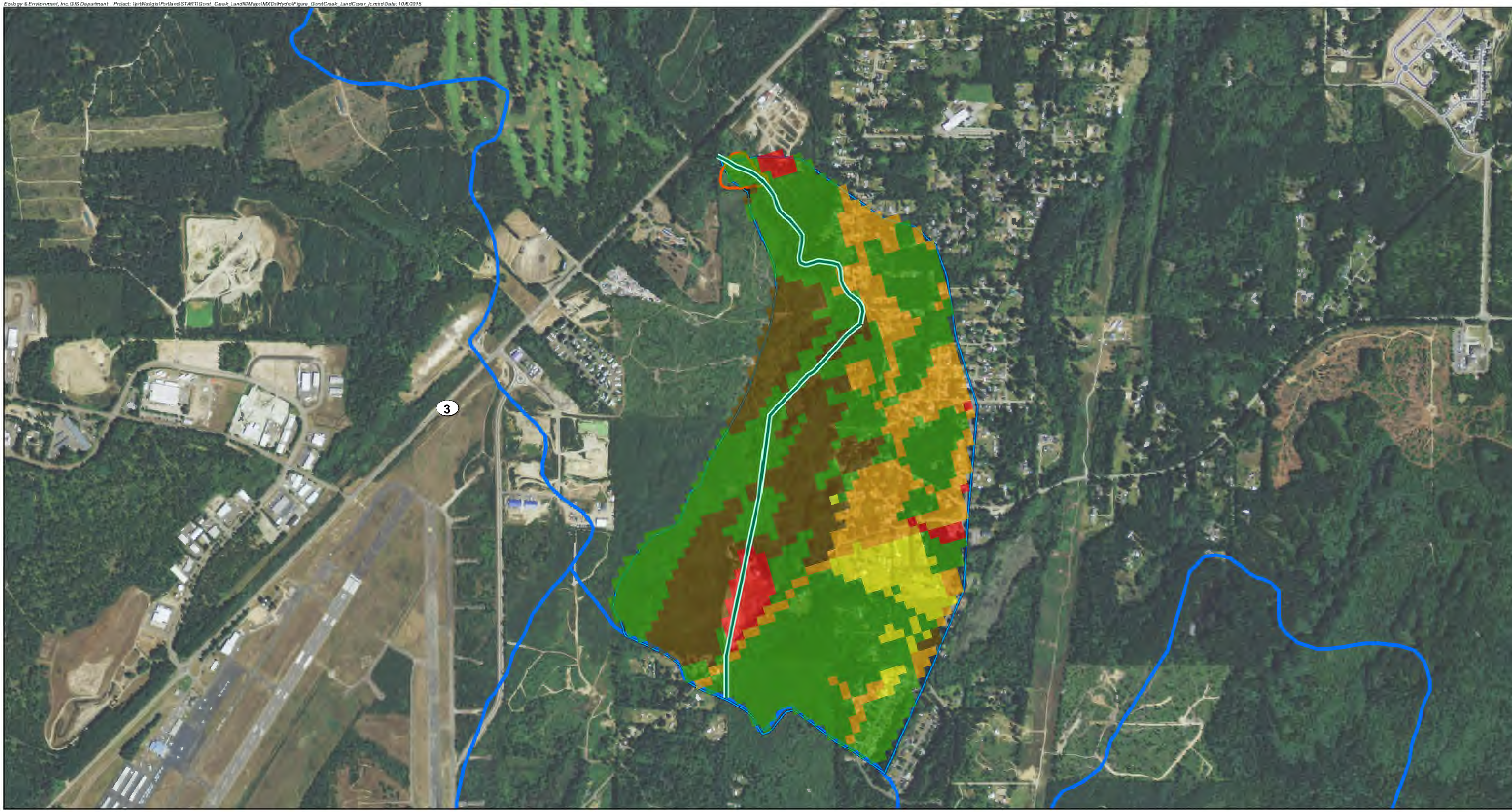
Ecology & Environment, Inc. GIS Department



- Gorst Creek - Bremerton Auto Wrecking landfill boundary
- Flowpath
- Watershed
- NHD HUC12 Watershed Boundary

Land Cover Class

- Industrial Areas, Light
- Light Residential
- Meadow/Pasture Land
- Unimproved Areas
- Woodland/Forests

Gorst Creek Landfill

Port Orchard, Washington

N
W E
S

Map Projection: NAD 1983 UTM Zone 10N Meter
Map Scale: 1: 12,772

0 250 500 1,000 1,500 2,000 2,500
Feet
1 in = 1,064 ft

Figure
Time of Concentration

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Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation.

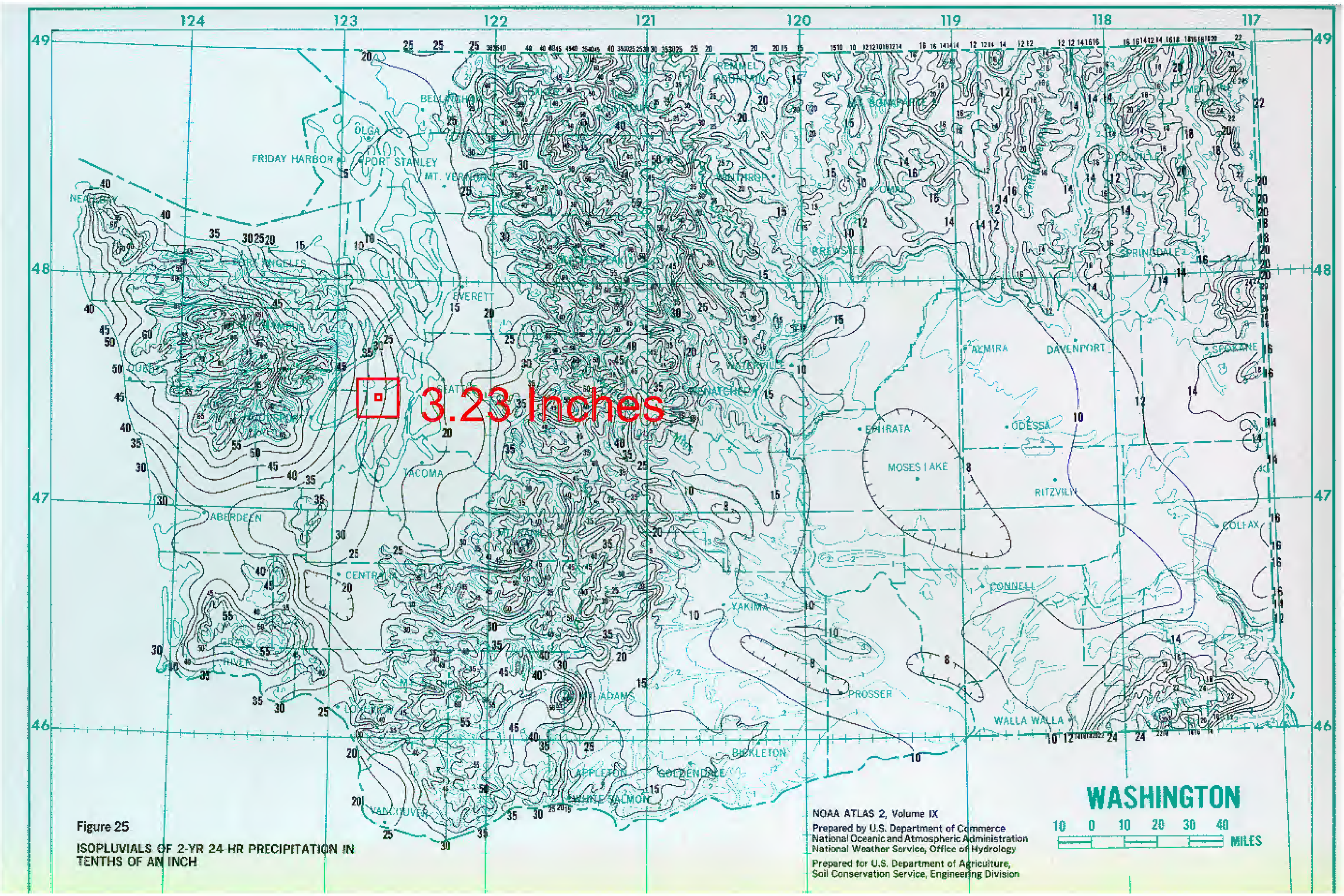


Figure 25
ISOPLUVIALS OF 2-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

Precipitation Frequency Data Output

NOAA Atlas 2

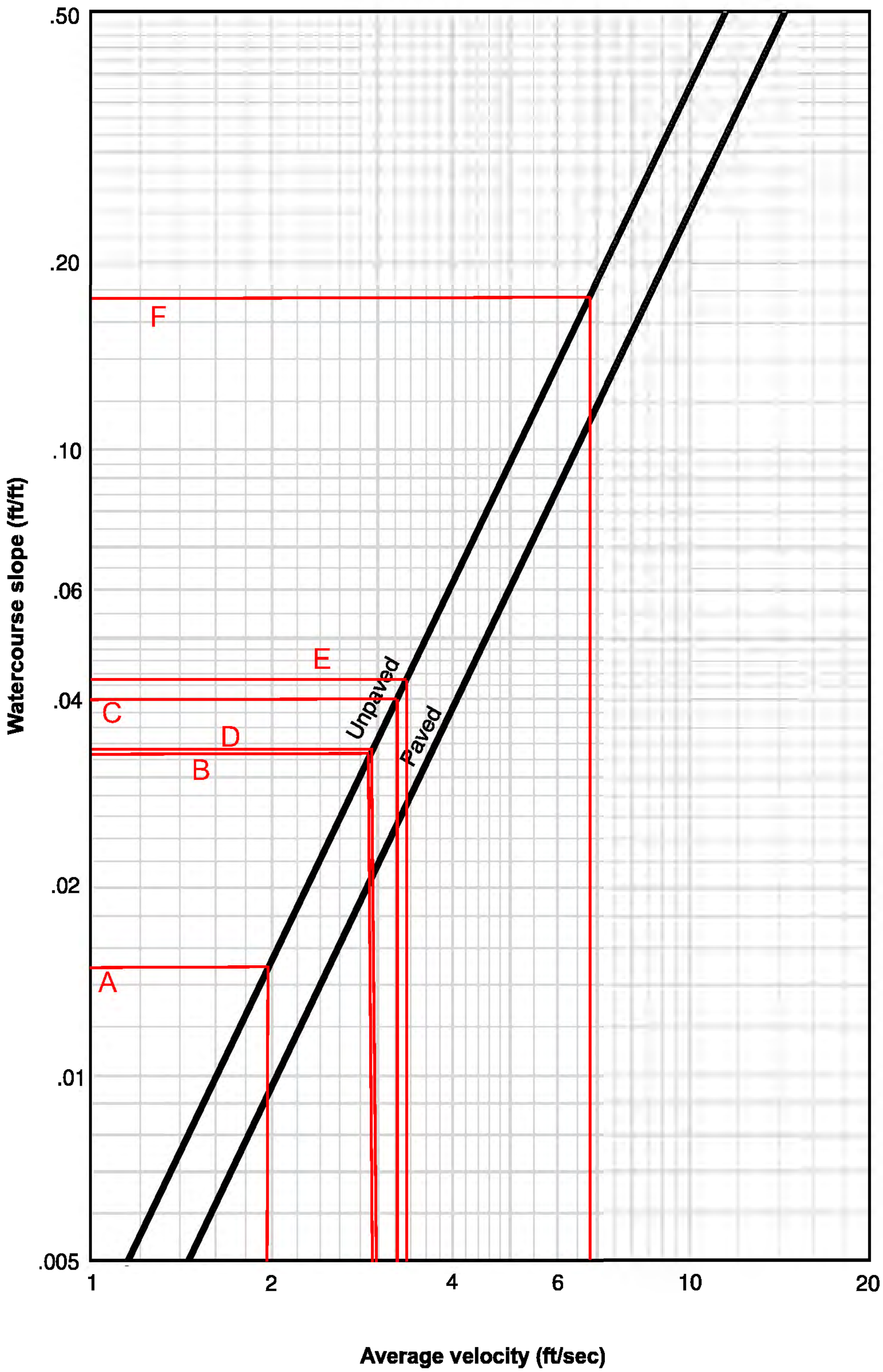
Washington 47.509842°N 122.740394°W
Site-specific Estimates

Map	Precipitation (inches)	Precipitation Intensity (in/hr)
2-year 6-hour	1.51	0.25
2-year 24-hour	3.23	0.13
100-year 6-hour	2.93	0.49
100-year 24-hour	6.35	0.26

Go to PFDS
Go to NA2

Hydrometeorological Design Studies Center - NOAA/National Weather Service
1325 East-West Highway - Silver Spring, MD 20910 - (301) 713-1669
Tue Oct 6 16:46:14 2015

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Attachment C: Curve Number Calculations

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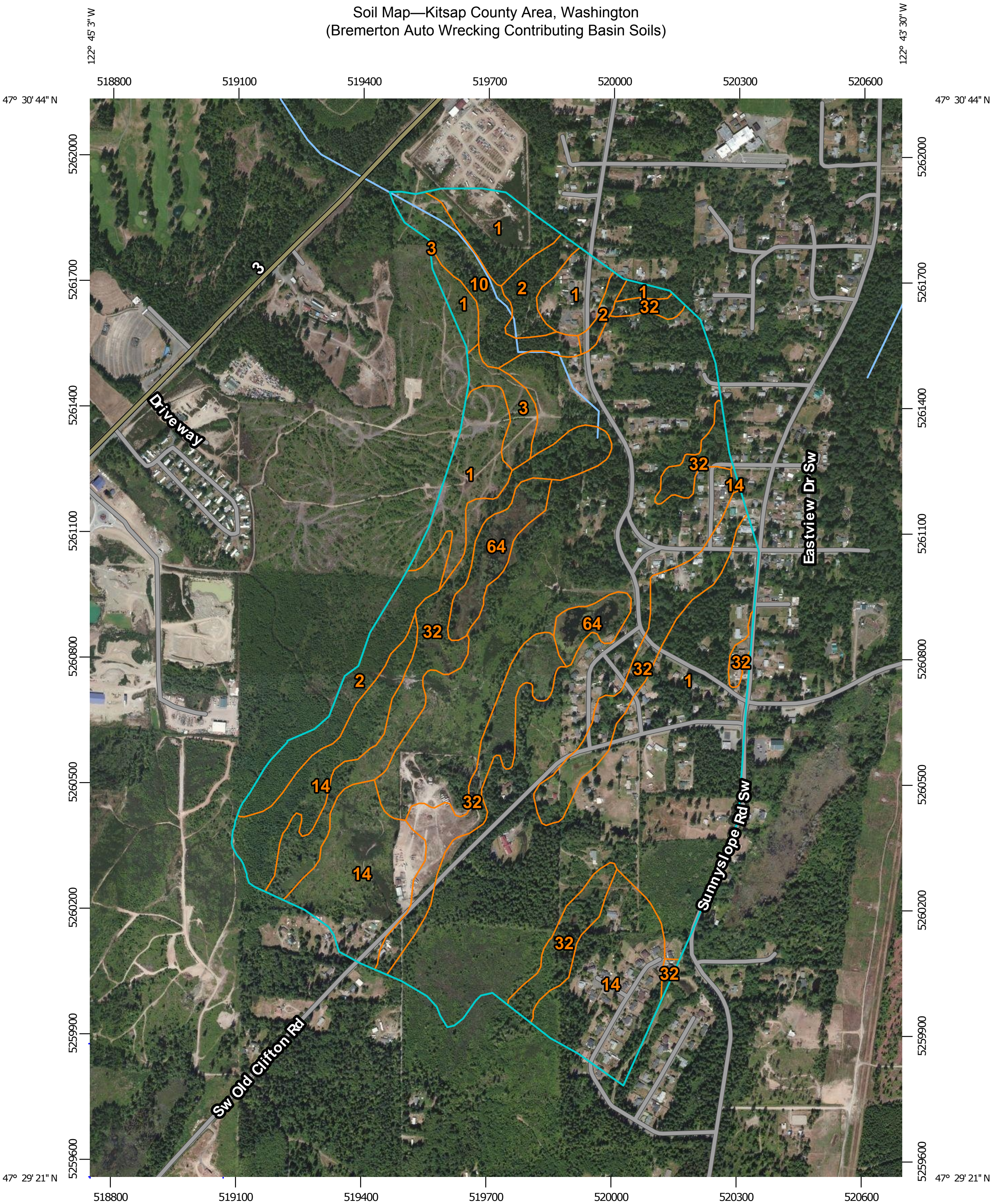
Runoff Curve Number: Upper Gorst Creek Drainage Basin

Aggregated Gorst Creek Basin Land Cover							
Land Cover Class	**Total Acreage**	**Relative %**	**CN**	**Assumption**	**Slope <2%**	**Slope 2-10%**	**Slope >10%**
Industrial Areas, Light	13.78	3.55%	91	Industrial, group C	9.60	3.45	0.73
Light Residential	66.02	17.01%	81	Residential, 1/3 ac lots, Group C	31.51	32.09	2.42
Meadow/Pasture Land	20.20	5.20%	79	Pasture, fair condition, Group C	1.62	18.58	0.00
Unimproved Areas	83.40	21.49%	73	Woods, fair condition, group C	39.97	35.72	7.70
Woodland/Forests	204.74	52.75%	70	Woods, good condition, group C	66.56	113.12	25.07
Grand Total	**388.14**	**100.00%**			**149.26**	**202.96**	**35.92**

Weighted CN	**73.7**

Soil Map—Kitsap County Area, Washington
(Bremerton Auto Wrecking Contributing Basin Soils)



Map Scale: 1:12,500 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0, 150, 300, 600, 900

Feet: 0, 500, 1000, 2000, 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kitsap County Area, Washington
Survey Area Data: Version 10, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 9, 2010—Aug 20, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Kitsap County Area, Washington (WA635)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
1	Alderwood gravelly sandy loam, 0 to 8 percent slopes	226.7	57.6%
2	Alderwood gravelly sandy loam, 8 to 15 percent slopes	18.9	4.8%
3	Alderwood gravelly sandy loam, 15 to 30 percent slopes	4.7	1.2%
10	Dystric Xerorthents, 45 to 70 percent slopes	11.0	2.8%
14	Harstine gravelly ashy sandy loam, 0 to 6 percent slopes	56.7	14.4%
32	McKenna gravelly loam	63.6	16.2%
64	Water	11.8	3.0%
Totals for Area of Interest		**393.5**	**100.0%**

4,000 soil types into these four soil groups. Table 2.3.1 shows the hydrologic soil group of most soils in the state of Washington and provides a brief description of the four groups. For details on other soil types refer to the NRCS publication mentioned above (TR-55, 1986).

Table 2.3.1
Hydrologic Soil Series for Selected Soils in Washington State

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Agnew	C	Hoko	C
Ahl	B	Hoodsport	C
Aits	C	Hoogdal	C
Alderwood	C	Hoypus	A
Arents, Alderwood	B	Huel	A
Arents, Everett	B	Indianola	A
Ashoe	B	Jonas	B
Baldhill	B	Jumpe	B
Barneston	C	Kalaloch	C
Baumgard	B	Kapowsin	C/D
Beausite	B	Katula	C
Belfast	C	Kilchis	C
Bellingham	D	Kitsap	C
Bellingham variant	C	Klaus	C
Boistfort	B	Klone	B
Bow	D	Lates	C
Briscot	D	Lebam	B
Buckley	C	Lummi	D
Bunker	B	Lynnwood	A
Cagey	C	Lystair	B
Carlsborg	A	Mal	C
Casey	D	Manley	B
Cassolary	C	Mashel	B
Cathcart	B	Maytown	C
Centralia	B	McKenna	D
Chehalis	B	McMurray	D
Chesaw	A	Melbourne	B
Cinebar	B	Menzel	B
Clallam	C	Mixed Alluvial	variable
Clayton	B	Molson	B
Coastal beaches	variable	Mukilteo	C/D
Colter	C	Naff	B
Custer	D	Nargar	A
Custer, Drained	C	National	B
Dabob	C	Neilton	A
Delphi	D	Newberg	B
Dick	A	Nisqually	B
Dimal	D	Nooksack	C
Dupont	D	Norma	C/D
Earlmont	C	Ogarty	C
Edgewick	C	Olete	C
Eld	B	Olomount	C
Elwell	B	Olympic	B
Esquatzel	B	Orcas	D
Everett	A	Oridia	D
Everson	D	Orting	D
Galvin	D	Oso	C
Getchell	A	Ovall	C
Giles	B	Pastik	C
Godfrey	D	Pheeney	C
Greenwater	A	Phelan	D

Table 2.3.1
Hydrologic Soil Series for Selected Soils in Washington State

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Grove	C	Pilchuck	C
Harstine	C	Potchub	C
Hartnit	C	Poulsbo	C
Hoh	B	Prather	C
Puget	D	Solleks	C
Puyallup	B	Spana	D
Queets	B	Spanaway	A/B
Quilcene	C	Springdale	B
Ragnar	B	Sulsavar	B
Rainier	C	Sultan	C
Raught	B	Sultan variant	B
Reed	D	Sumas	C
Reed, Drained or Protected	C	Swantown	D
Renton	D	Tacoma	D
Republic	B	Tanwax	D
Riverwash	variable	Tanwax, Drained	C
Rober	C	Tealwhit	D
Salal	C	Tenino	C
Salkum	B	Tisch	D
Sammamish	D	Tokul	C
San Juan	A	Townsend	C
Scamman	D	Triton	D
Schneider	B	Tukwila	D
Seattle	D	Tukey	C
Sekiu	D	Urbana	C
Semiahmoo	D	Vailton	B
Shalcar	D	Verlot	C
Shano	B	Wapato	D
Shelton	C	Warden	B
Si	C	Whidbey	C
Sinclair	C	Wilkeson	B
Skipopa	D	Winston	A
Skykomish	B	Woodinville	B
Snahopish	B	Yelm	C
Snohomish	D	Zynbar	B
Solduc	B		

Notes:

Hydrologic Soil Group Classifications, as Defined by the Soil Conservation Service:

A = *(Low runoff potential) Soils having low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr.).*

B = *(Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.3 in/hr.).*

C = *(Moderately high runoff potential). Soils having low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05-0.15 in/hr.).*

D = *(High runoff potential). Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr.).*

** = From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.*

Additional Note: Where field infiltration tests indicate a measured (initial) infiltration rate less than 0.30 in/hr, the WWHM user may model the site as a C soil. .

Table 2.3.2
Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992. See Section 2.1.1 for explanation)				
	CNs for hydrologic soil group			
Cover type and hydrologic condition.	A	B	C	D
Curve Numbers for Pre-Development Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Post-Development Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable Pavement (See Appendix C to decide which condition below to use)				
Landscaped area	77	85	90	92
50% landscaped area/50% impervious	87	91	94	96
100% impervious area	98	98	98	98
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number shall be selected for pervious & impervious portions of the site or basin
1.5 DU/GA		20	
2.0 DU/GA		25	
2.5 DU/GA		30	
3.0 DU/GA		34	
3.5 DU/GA		38	
4.0 DU/GA		42	
4.5 DU/GA		46	
5.0 DU/GA		48	
5.5 DU/GA		50	
6.0 DU/GA		52	
6.5 DU/GA		54	
7.0 DU/GA		56	
7.5 DU/GA		58	
PUD's, condos, apartments, commercial businesses, industrial areas & & subdivisions < 50 acres	%impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site	
For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).			

[1] Composite CN's may be computed for other combinations of open space cover type.

[2] Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Chapter 3, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" (Section 3.1.1), and "Flow Credit for Roof Downspout Dispersion" (Section 3.1.2).

[3] Assumes roof and driveway runoff is directed into street/storm system.

[4] All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

Attachment D: Peak Discharge Calculations

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		Return Period	Duration
Site: Gorst Creek		year	hour
	Rainfall: 1.50 in.	2	6

Time Increment: 10 minutes   w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area		CN	S	0.2 S
Pervious Area:	388.14	acres	74	3.56	0.71
Impervious Area:	0.00	acres	89	1.24	0.25
Total Area:	388.14	acres			

Time of Concentration: 128 minutes   **Qmax=** **4.3** cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.006	0.006	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.006	0.012	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.006	0.018	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.006	0.024	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.006	0.030	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.006	0.036	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.006	0.042	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.006	0.048	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.006	0.054	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.006	0.060	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.008	0.068	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
13	120	0.0050	0.008	0.075	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
14	130	0.0050	0.008	0.083	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
15	140	0.0050	0.008	0.090	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
16	150	0.0050	0.008	0.098	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
17	160	0.0050	0.008	0.105	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
18	170	0.0060	0.009	0.114	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
19	180	0.0060	0.009	0.123	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
20	190	0.0060	0.009	0.132	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
21	200	0.0060	0.009	0.141	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
22	210	0.0060	0.009	0.150	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
23	220	0.0060	0.009	0.159	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
24	230	0.0070	0.011	0.170	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
25	240	0.0070	0.011	0.180	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
26	250	0.0070	0.011	0.191	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
27	260	0.0070	0.011	0.201	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
28	270	0.0070	0.011	0.212	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
29	280	0.0070	0.011	0.222	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
30	290	0.0082	0.012	0.234	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
31	300	0.0082	0.012	0.247	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
32	310	0.0082	0.012	0.259	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
33	320	0.0082	0.012	0.271	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
34	330	0.0082	0.012	0.284	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0
35	340	0.0082	0.012	0.296	0.000	0.000	0.002	0.001	0.000	0.0	0.0	0.0
36	350	0.0095	0.014	0.310	0.000	0.000	0.003	0.001	0.000	0.0	0.0	0.0
37	360	0.0095	0.014	0.324	0.000	0.000	0.005	0.001	0.000	0.0	0.0	0.0
38	370	0.0095	0.014	0.339	0.000	0.000	0.006	0.002	0.000	0.0	0.0	0.0
39	380	0.0095	0.014	0.353	0.000	0.000	0.008	0.002	0.000	0.0	0.0	0.0
40	390	0.0095	0.014	0.367	0.000	0.000	0.011	0.002	0.000	0.0	0.0	0.0
41	400	0.0095	0.014	0.381	0.000	0.000	0.013	0.003	0.000	0.0	0.0	0.0
42	410	0.0134	0.020	0.401	0.000	0.000	0.017	0.004	0.000	0.0	0.0	0.0
43	420	0.0134	0.020	0.422	0.000	0.000	0.022	0.004	0.000	0.0	0.0	0.0
44	430	0.0134	0.020	0.442	0.000	0.000	0.026	0.005	0.000	0.0	0.0	0.0
45	440	0.0180	0.027	0.469	0.000	0.000	0.034	0.007	0.000	0.0	0.0	0.0
46	450	0.0180	0.027	0.496	0.000	0.000	0.042	0.008	0.000	0.0	0.0	0.0
47	460	0.0340	0.051	0.547	0.000	0.000	0.058	0.017	0.000	0.0	0.0	0.0
48	470	0.0540	0.081	0.628	0.000	0.000	0.090	0.031	0.000	0.0	0.0	0.0
49	480	0.0270	0.041	0.668	0.000	0.000	0.107	0.017	0.000	0.0	0.0	0.0
50	490	0.0180	0.027	0.695	0.000	0.000	0.119	0.012	0.000	0.0	0.0	0.0
51	500	0.0134	0.020	0.715	0.000	0.000	0.129	0.009	0.000	0.0	0.0	0.0
52	510	0.0134	0.020	0.735	0.000	0.000	0.138	0.010	0.000	0.3	0.0	0.0
53	520	0.0134	0.020	0.755	0.001	0.000	0.148	0.010	0.000	0.9	0.1	0.1
54	530	0.0088	0.013	0.769	0.001	0.000	0.155	0.007	0.000	0.8	0.1	0.1
55	540	0.0088	0.013	0.782	0.001	0.000	0.161	0.007	0.000	1.1	0.2	0.2
56	550	0.0088	0.013	0.795	0.002	0.001	0.168	0.007	0.001	1.3	0.3	0.3
57	560	0.0088	0.013	0.808	0.002	0.001	0.175	0.007	0.001	1.5	0.3	0.3
58	570	0.0088	0.013	0.821	0.003	0.001	0.182	0.007	0.001	1.7	0.4	0.4
59	580	0.0088	0.013	0.835	0.004	0.001	0.189	0.007	0.001	1.9	0.5	0.5
60	590	0.0088	0.013	0.848	0.005	0.001	0.196	0.007	0.001	2.1	0.6	0.6
61	600	0.0088	0.013	0.861	0.006	0.001	0.204	0.007	0.001	2.3	0.8	0.8
62	610	0.0088	0.013	0.874	0.007	0.001	0.211	0.007	0.001	2.5	0.9	0.9
63	620	0.0088	0.013	0.887	0.008	0.001	0.218	0.007	0.001	2.7	1.0	1.0
64	630	0.0088	0.013	0.901	0.009	0.001	0.226	0.008	0.001	2.9	1.2	1.2
65	640	0.0088	0.013	0.914	0.011	0.001	0.234	0.008	0.001	3.1	1.3	1.3
66	650	0.0072	0.011	0.925	0.012	0.001	0.240	0.006	0.001	2.7	1.4	1.4
67	660	0.0072	0.011	0.935	0.013	0.001	0.246	0.006	0.001	2.8	1.5	1.5
68	670	0.0072	0.011	0.946	0.014	0.001	0.253	0.006	0.001	3.0	1.6	1.6
69	680	0.0072	0.011	0.957	0.016	0.001	0.259	0.006	0.001	3.1	1.7	1.7
70	690	0.0072	0.011	0.968	0.017	0.001	0.265	0.006	0.001	3.2	1.8	1.8
71	700	0.0072	0.011	0.979	0.018	0.001	0.272	0.007	0.001	3.3	1.9	1.9
72	710	0.0072	0.011	0.989	0.020	0.001	0.278	0.007	0.001	3.5	2.1	2.1
73	720	0.0072	0.011	1.000	0.021	0.002	0.285	0.007	0.002	3.6	2.2	2.2

74	730	0.0072	0.011	1.011	0.023	0.002	0.292	0.007	0.002	3.7	2.3	2.3
75	740	0.0072	0.011	1.022	0.025	0.002	0.298	0.007	0.002	3.8	2.4	2.4
76	750	0.0072	0.011	1.033	0.026	0.002	0.305	0.007	0.002	3.9	2.5	2.5
77	760	0.0072	0.011	1.043	0.028	0.002	0.312	0.007	0.002	4.1	2.6	2.6
78	770	0.0057	0.009	1.052	0.030	0.001	0.317	0.005	0.001	3.3	2.7	2.7
79	780	0.0057	0.009	1.061	0.031	0.001	0.323	0.005	0.001	3.4	2.7	2.7
80	790	0.0057	0.009	1.069	0.032	0.001	0.328	0.005	0.001	3.4	2.8	2.8
81	800	0.0057	0.009	1.078	0.034	0.001	0.334	0.005	0.001	3.5	2.8	2.8
82	810	0.0057	0.009	1.086	0.035	0.002	0.339	0.006	0.002	3.6	2.9	2.9
83	820	0.0057	0.009	1.095	0.037	0.002	0.345	0.006	0.002	3.7	3.0	3.0
84	830	0.0057	0.009	1.103	0.039	0.002	0.350	0.006	0.002	3.7	3.0	3.0
85	840	0.0057	0.009	1.112	0.040	0.002	0.356	0.006	0.002	3.8	3.1	3.1
86	850	0.0057	0.009	1.120	0.042	0.002	0.361	0.006	0.002	3.9	3.1	3.1
87	860	0.0057	0.009	1.129	0.044	0.002	0.367	0.006	0.002	3.9	3.2	3.2
88	870	0.0057	0.009	1.137	0.045	0.002	0.373	0.006	0.002	4.0	3.2	3.2
89	880	0.0057	0.009	1.146	0.047	0.002	0.378	0.006	0.002	4.1	3.3	3.3
90	890	0.0050	0.008	1.154	0.049	0.002	0.383	0.005	0.002	3.6	3.3	3.3
91	900	0.0050	0.008	1.161	0.050	0.002	0.388	0.005	0.002	3.7	3.4	3.4
92	910	0.0050	0.008	1.169	0.052	0.002	0.393	0.005	0.002	3.7	3.4	3.4
93	920	0.0050	0.008	1.176	0.053	0.002	0.399	0.005	0.002	3.8	3.4	3.4
94	930	0.0050	0.008	1.184	0.055	0.002	0.404	0.005	0.002	3.8	3.5	3.5
95	940	0.0050	0.008	1.191	0.057	0.002	0.409	0.005	0.002	3.9	3.5	3.5
96	950	0.0050	0.008	1.199	0.058	0.002	0.414	0.005	0.002	3.9	3.5	3.5
97	960	0.0050	0.008	1.206	0.060	0.002	0.419	0.005	0.002	4.0	3.6	3.6
98	970	0.0050	0.008	1.214	0.062	0.002	0.424	0.005	0.002	4.0	3.6	3.6
99	980	0.0050	0.008	1.221	0.063	0.002	0.429	0.005	0.002	4.1	3.6	3.6
100	990	0.0050	0.008	1.229	0.065	0.002	0.434	0.005	0.002	4.1	3.7	3.7
101	1,000	0.0050	0.008	1.236	0.067	0.002	0.439	0.005	0.002	4.2	3.7	3.7
102	1,010	0.0040	0.006	1.242	0.068	0.001	0.444	0.004	0.001	3.4	3.7	3.7
103	1,020	0.0040	0.006	1.248	0.070	0.001	0.448	0.004	0.001	3.4	3.7	3.7
104	1,030	0.0040	0.006	1.254	0.071	0.001	0.452	0.004	0.001	3.5	3.7	3.7
105	1,040	0.0040	0.006	1.260	0.073	0.001	0.456	0.004	0.001	3.5	3.7	3.7
106	1,050	0.0040	0.006	1.266	0.074	0.001	0.460	0.004	0.001	3.5	3.6	3.6
107	1,060	0.0040	0.006	1.272	0.076	0.002	0.465	0.004	0.002	3.5	3.6	3.6
108	1,070	0.0040	0.006	1.278	0.077	0.002	0.469	0.004	0.002	3.6	3.6	3.6
109	1,080	0.0040	0.006	1.284	0.079	0.002	0.473	0.004	0.002	3.6	3.6	3.6
110	1,090	0.0040	0.006	1.290	0.081	0.002	0.477	0.004	0.002	3.6	3.6	3.6
111	1,100	0.0040	0.006	1.296	0.082	0.002	0.481	0.004	0.002	3.7	3.6	3.6
112	1,110	0.0040	0.006	1.302	0.084	0.002	0.486	0.004	0.002	3.7	3.6	3.6
113	1,120	0.0040	0.006	1.308	0.085	0.002	0.490	0.004	0.002	3.7	3.6	3.6
114	1,130	0.0040	0.006	1.314	0.087	0.002	0.494	0.004	0.002	3.8	3.6	3.6
115	1,140	0.0040	0.006	1.320	0.088	0.002	0.499	0.004	0.002	3.8	3.7	3.7
116	1,150	0.0040	0.006	1.326	0.090	0.002	0.503	0.004	0.002	3.8	3.7	3.7
117	1,160	0.0040	0.006	1.332	0.092	0.002	0.507	0.004	0.002	3.8	3.7	3.7
118	1,170	0.0040	0.006	1.338	0.093	0.002	0.511	0.004	0.002	3.9	3.7	3.7
119	1,180	0.0040	0.006	1.344	0.095	0.002	0.516	0.004	0.002	3.9	3.7	3.7
120	1,190	0.0040	0.006	1.350	0.097	0.002	0.520	0.004	0.002	3.9	3.7	3.7
121	1,200	0.0040	0.006	1.356	0.098	0.002	0.524	0.004	0.002	4.0	3.7	3.7
122	1,210	0.0040	0.006	1.362	0.100	0.002	0.529	0.004	0.002	4.0	3.8	3.8
123	1,220	0.0040	0.006	1.368	0.102	0.002	0.533	0.004	0.002	4.0	3.8	3.8
124	1,230	0.0040	0.006	1.374	0.104	0.002	0.537	0.004	0.002	4.1	3.8	3.8
125	1,240	0.0040	0.006	1.380	0.105	0.002	0.542	0.004	0.002	4.1	3.8	3.8
126	1,250	0.0040	0.006	1.386	0.107	0.002	0.546	0.004	0.002	4.1	3.8	3.8
127	1,260	0.0040	0.006	1.392	0.109	0.002	0.550	0.004	0.002	4.1	3.9	3.9
128	1,270	0.0040	0.006	1.398	0.111	0.002	0.555	0.004	0.002	4.2	3.9	3.9
129	1,280	0.0040	0.006	1.404	0.112	0.002	0.559	0.004	0.002	4.2	3.9	3.9
130	1,290	0.0040	0.006	1.410	0.114	0.002	0.564	0.004	0.002	4.2	3.9	3.9
131	1,300	0.0040	0.006	1.416	0.116	0.002	0.568	0.004	0.002	4.2	3.9	3.9
132	1,310	0.0040	0.006	1.422	0.118	0.002	0.573	0.004	0.002	4.3	4.0	4.0
133	1,320	0.0040	0.006	1.428	0.120	0.002	0.577	0.004	0.002	4.3	4.0	4.0
134	1,330	0.0040	0.006	1.434	0.121	0.002	0.581	0.004	0.002	4.3	4.0	4.0
135	1,340	0.0040	0.006	1.440	0.123	0.002	0.586	0.004	0.002	4.4	4.0	4.0
136	1,350	0.0040	0.006	1.446	0.125	0.002	0.590	0.004	0.002	4.4	4.1	4.1
137	1,360	0.0040	0.006	1.452	0.127	0.002	0.595	0.004	0.002	4.4	4.1	4.1
138	1,370	0.0040	0.006	1.458	0.129	0.002	0.599	0.004	0.002	4.4	4.1	4.1
139	1,380	0.0040	0.006	1.464	0.131	0.002	0.604	0.004	0.002	4.5	4.1	4.1
140	1,390	0.0040	0.006	1.470	0.133	0.002	0.608	0.004	0.002	4.5	4.2	4.2
141	1,400	0.0040	0.006	1.476	0.135	0.002	0.613	0.004	0.002	4.5	4.2	4.2
142	1,410	0.0040	0.006	1.482	0.137	0.002	0.617	0.004	0.002	4.5	4.2	4.2
143	1,420	0.0040	0.006	1.488	0.139	0.002	0.622	0.005	0.002	4.6	4.2	4.2
144	1,430	0.0040	0.006	1.494	0.141	0.002	0.626	0.005	0.002	4.6	4.3	4.3
145	1,440	0.0040	0.0060	1.500	0.143	0.002	0.631	0.005	0.002	4.6	4.3	4.3
146	Total:	1.0000	1.5000			0.1425		0.6306	0.1425			4.1
147							Max:	**4.3**				4.0
148							Cumulative Runoff at Period 145	0.12 inches	Start Flow		4.3	3.8
149							Unaccounted Runoff	0.02 inches	End Flow		0.0	3.7
150								16,052.57 sec	Flow Dec./per		0.2	3.5
151		Column	Description					267.54 min				3.3
152		1	Time Increment					26.75 periods				3.2
153		2	Time (min)					27 periods				3.0
154		3	Type IA Storm Distibution					0.1412 Total Runoff				2.9
155		4	Column 3 * Precipitation									2.7
156		5	Accumulated Sum of Column 4									2.5
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									2.4
158		7	Column 6 of the present step - Column 6 of the previous step									2.2
159		8	Same as Column 6, except Impervious Area Calculations									2.0
160		9	Column 8 of the present step - Column 8 of the previous step									1.9
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									1.7
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									1.6
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									1.4
164			(2 * Column 12 of previous step))									1.2
165												1.1

	Return Period	Duration
Site: Gorst Creek Upper Watershed	year	hour
Rainfall: 3.23 in.	2	24

Time Increment: 10 minutes w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area		CN	S	0.2 S
Pervious Area:	388	acres	74	3.56	0.71
Impervious Area:	0.00	acres	89	1.24	0.25
Total Area:	388.14	acres			

Time of Concentration: 128 minutes, 2.14 hours

Qmax= **26.4** cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.013	0.013	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.013	0.026	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.013	0.039	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.013	0.052	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.013	0.065	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.013	0.078	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.013	0.090	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.013	0.103	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.013	0.116	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.013	0.129	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.016	0.145	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
13	120	0.0050	0.016	0.162	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
14	130	0.0050	0.016	0.178	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
15	140	0.0050	0.016	0.194	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
16	150	0.0050	0.016	0.210	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
17	160	0.0050	0.016	0.226	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
18	170	0.0060	0.019	0.245	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
19	180	0.0060	0.019	0.265	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
20	190	0.0060	0.019	0.284	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0
21	200	0.0060	0.019	0.304	0.000	0.000	0.002	0.001	0.000	0.0	0.0	0.0
22	210	0.0060	0.019	0.323	0.000	0.000	0.004	0.002	0.000	0.0	0.0	0.0
23	220	0.0060	0.019	0.342	0.000	0.000	0.007	0.002	0.000	0.0	0.0	0.0
24	230	0.0070	0.023	0.365	0.000	0.000	0.010	0.003	0.000	0.0	0.0	0.0
25	240	0.0070	0.023	0.388	0.000	0.000	0.014	0.004	0.000	0.0	0.0	0.0
26	250	0.0070	0.023	0.410	0.000	0.000	0.019	0.005	0.000	0.0	0.0	0.0
27	260	0.0070	0.023	0.433	0.000	0.000	0.024	0.005	0.000	0.0	0.0	0.0
28	270	0.0070	0.023	0.455	0.000	0.000	0.030	0.006	0.000	0.0	0.0	0.0
29	280	0.0070	0.023	0.478	0.000	0.000	0.036	0.006	0.000	0.0	0.0	0.0
30	290	0.0082	0.026	0.505	0.000	0.000	0.044	0.008	0.000	0.0	0.0	0.0
31	300	0.0082	0.026	0.531	0.000	0.000	0.053	0.009	0.000	0.0	0.0	0.0
32	310	0.0082	0.026	0.557	0.000	0.000	0.062	0.009	0.000	0.0	0.0	0.0
33	320	0.0082	0.026	0.584	0.000	0.000	0.072	0.010	0.000	0.0	0.0	0.0
34	330	0.0082	0.026	0.610	0.000	0.000	0.083	0.010	0.000	0.0	0.0	0.0
35	340	0.0082	0.026	0.637	0.000	0.000	0.093	0.011	0.000	0.0	0.0	0.0
36	350	0.0095	0.031	0.668	0.000	0.000	0.107	0.013	0.000	0.0	0.0	0.0
37	360	0.0095	0.031	0.698	0.000	0.000	0.121	0.014	0.000	0.0	0.0	0.0
38	370	0.0095	0.031	0.729	0.000	0.000	0.135	0.015	0.000	0.2	0.0	0.0
39	380	0.0095	0.031	0.760	0.001	0.001	0.150	0.015	0.001	1.3	0.1	0.1
40	390	0.0095	0.031	0.790	0.002	0.001	0.166	0.016	0.001	2.5	0.2	0.2
41	400	0.0095	0.031	0.821	0.003	0.002	0.182	0.016	0.002	3.6	0.4	0.4
42	410	0.0134	0.043	0.864	0.006	0.003	0.206	0.024	0.003	7.0	0.8	0.8
43	420	0.0134	0.043	0.908	0.010	0.004	0.230	0.024	0.004	9.2	1.3	1.3
44	430	0.0134	0.043	0.951	0.015	0.005	0.255	0.025	0.005	11.3	2.0	2.0
45	440	0.0180	0.058	1.009	0.023	0.008	0.291	0.035	0.008	18.4	3.0	3.0
46	450	0.0180	0.058	1.067	0.032	0.009	0.327	0.037	0.009	21.9	4.2	4.2
47	460	0.0340	0.110	1.177	0.054	0.021	0.399	0.072	0.021	50.4	6.6	6.6
48	470	0.0540	0.174	1.351	0.097	0.044	0.521	0.122	0.044	102.3	11.9	11.9
49	480	0.0270	0.087	1.439	0.123	0.026	0.585	0.064	0.026	60.5	17.1	17.1
50	490	0.0180	0.058	1.497	0.141	0.019	0.628	0.043	0.019	43.6	19.7	19.7
51	500	0.0134	0.043	1.540	0.156	0.014	0.661	0.033	0.014	34.0	21.1	21.1
52	510	0.0134	0.043	1.583	0.171	0.015	0.694	0.033	0.015	35.4	22.2	22.2
53	520	0.0134	0.043	1.627	0.187	0.016	0.728	0.033	0.016	36.6	23.2	23.2
54	530	0.0088	0.028	1.655	0.197	0.011	0.750	0.022	0.011	24.7	23.8	23.8
55	540	0.0088	0.028	1.683	0.208	0.011	0.772	0.022	0.011	25.3	23.8	23.8
56	550	0.0088	0.028	1.712	0.219	0.011	0.794	0.022	0.011	25.8	24.0	24.0
57	560	0.0088	0.028	1.740	0.230	0.011	0.817	0.023	0.011	26.3	24.1	24.1
58	570	0.0088	0.028	1.769	0.241	0.011	0.840	0.023	0.011	26.8	24.3	24.3
59	580	0.0088	0.028	1.797	0.253	0.012	0.862	0.023	0.012	27.3	24.5	24.5
60	590	0.0088	0.028	1.826	0.265	0.012	0.885	0.023	0.012	27.8	24.7	24.7
61	600	0.0088	0.028	1.854	0.277	0.012	0.908	0.023	0.012	28.2	25.0	25.0
62	610	0.0088	0.028	1.882	0.289	0.012	0.931	0.023	0.012	28.7	25.2	25.2
63	620	0.0088	0.028	1.911	0.302	0.012	0.955	0.023	0.012	29.1	25.5	25.5
64	630	0.0088	0.028	1.939	0.314	0.013	0.978	0.023	0.013	29.6	25.8	25.8
65	640	0.0088	0.028	1.968	0.327	0.013	1.001	0.023	0.013	30.0	26.1	26.1
66	650	0.0072	0.023	1.991	0.338	0.011	1.020	0.019	0.011	24.9	26.2	26.2
67	660	0.0072	0.023	2.014	0.348	0.011	1.040	0.019	0.011	25.2	26.1	26.1
68	670	0.0072	0.023	2.037	0.359	0.011	1.059	0.019	0.011	25.5	26.1	26.1
69	680	0.0072	0.023	2.061	0.370	0.011	1.079	0.019	0.011	25.7	26.0	26.0
70	690	0.0072	0.023	2.084	0.381	0.011	1.098	0.019	0.011	26.0	26.0	26.0
71	700	0.0072	0.023	2.107	0.392	0.011	1.118	0.020	0.011	26.3	26.0	26.0
72	710	0.0072	0.023	2.131	0.404	0.011	1.137	0.020	0.011	26.5	26.0	26.0
73	720	0.0072	0.023	2.154	0.415	0.011	1.157	0.020	0.011	26.8	26.1	26.1

74	730	0.0072	0.023	2.177	0.427	0.012	1.176	0.020	0.012	27.1	26.2	26.2
75	740	0.0072	0.023	2.200	0.438	0.012	1.196	0.020	0.012	27.3	26.2	26.2
76	750	0.0072	0.023	2.224	0.450	0.012	1.216	0.020	0.012	27.6	26.3	26.3
77	760	0.0072	0.023	2.247	0.462	0.012	1.236	0.020	0.012	27.8	26.4	26.4
78	770	0.0057	0.018	2.265	0.471	0.009	1.252	0.016	0.009	22.2	26.3	26.3
79	780	0.0057	0.018	2.284	0.481	0.010	1.267	0.016	0.010	22.3	26.0	26.0
80	790	0.0057	0.018	2.302	0.490	0.010	1.283	0.016	0.010	22.5	25.7	25.7
81	800	0.0057	0.018	2.320	0.500	0.010	1.299	0.016	0.010	22.6	25.5	25.5
82	810	0.0057	0.018	2.339	0.510	0.010	1.315	0.016	0.010	22.8	25.3	25.3
83	820	0.0057	0.018	2.357	0.519	0.010	1.331	0.016	0.010	22.9	25.1	25.1
84	830	0.0057	0.018	2.376	0.529	0.010	1.347	0.016	0.010	23.1	25.0	25.0
85	840	0.0057	0.018	2.394	0.539	0.010	1.362	0.016	0.010	23.2	24.8	24.8
86	850	0.0057	0.018	2.412	0.549	0.010	1.378	0.016	0.010	23.3	24.7	24.7
87	860	0.0057	0.018	2.431	0.559	0.010	1.394	0.016	0.010	23.5	24.6	24.6
88	870	0.0057	0.018	2.449	0.569	0.010	1.410	0.016	0.010	23.6	24.5	24.5
89	880	0.0057	0.018	2.468	0.579	0.010	1.427	0.016	0.010	23.8	24.5	24.5
90	890	0.0050	0.016	2.484	0.588	0.009	1.441	0.014	0.009	21.0	24.3	24.3
91	900	0.0050	0.016	2.500	0.597	0.009	1.455	0.014	0.009	21.1	24.1	24.1
92	910	0.0050	0.016	2.516	0.606	0.009	1.469	0.014	0.009	21.2	23.8	23.8
93	920	0.0050	0.016	2.532	0.615	0.009	1.483	0.014	0.009	21.3	23.6	23.6
94	930	0.0050	0.016	2.548	0.624	0.009	1.497	0.014	0.009	21.4	23.5	23.5
95	940	0.0050	0.016	2.565	0.633	0.009	1.511	0.014	0.009	21.5	23.3	23.3
96	950	0.0050	0.016	2.581	0.643	0.009	1.526	0.014	0.009	21.6	23.2	23.2
97	960	0.0050	0.016	2.597	0.652	0.009	1.540	0.014	0.009	21.7	23.1	23.1
98	970	0.0050	0.016	2.613	0.661	0.009	1.554	0.014	0.009	21.7	23.0	23.0
99	980	0.0050	0.016	2.629	0.670	0.009	1.568	0.014	0.009	21.8	22.9	22.9
100	990	0.0050	0.016	2.645	0.680	0.009	1.583	0.014	0.009	21.9	22.8	22.8
101	1,000	0.0050	0.016	2.662	0.689	0.009	1.597	0.014	0.009	22.0	22.7	22.7
102	1,010	0.0040	0.013	2.674	0.697	0.008	1.608	0.011	0.008	17.7	22.5	22.5
103	1,020	0.0040	0.013	2.687	0.704	0.008	1.620	0.011	0.008	17.8	22.2	22.2
104	1,030	0.0040	0.013	2.700	0.712	0.008	1.631	0.011	0.008	17.8	21.8	21.8
105	1,040	0.0040	0.013	2.713	0.719	0.008	1.643	0.011	0.008	17.9	21.5	21.5
106	1,050	0.0040	0.013	2.726	0.727	0.008	1.654	0.011	0.008	17.9	21.3	21.3
107	1,060	0.0040	0.013	2.739	0.735	0.008	1.666	0.011	0.008	18.0	21.0	21.0
108	1,070	0.0040	0.013	2.752	0.742	0.008	1.677	0.012	0.008	18.0	20.8	20.8
109	1,080	0.0040	0.013	2.765	0.750	0.008	1.689	0.012	0.008	18.1	20.6	20.6
110	1,090	0.0040	0.013	2.778	0.758	0.008	1.700	0.012	0.008	18.2	20.4	20.4
111	1,100	0.0040	0.013	2.791	0.766	0.008	1.712	0.012	0.008	18.2	20.2	20.2
112	1,110	0.0040	0.013	2.804	0.773	0.008	1.723	0.012	0.008	18.3	20.1	20.1
113	1,120	0.0040	0.013	2.817	0.781	0.008	1.735	0.012	0.008	18.3	19.9	19.9
114	1,130	0.0040	0.013	2.829	0.789	0.008	1.746	0.012	0.008	18.4	19.8	19.8
115	1,140	0.0040	0.013	2.842	0.797	0.008	1.758	0.012	0.008	18.4	19.7	19.7
116	1,150	0.0040	0.013	2.855	0.805	0.008	1.770	0.012	0.008	18.5	19.6	19.6
117	1,160	0.0040	0.013	2.868	0.813	0.008	1.781	0.012	0.008	18.5	19.5	19.5
118	1,170	0.0040	0.013	2.881	0.820	0.008	1.793	0.012	0.008	18.6	19.5	19.5
119	1,180	0.0040	0.013	2.894	0.828	0.008	1.804	0.012	0.008	18.6	19.4	19.4
120	1,190	0.0040	0.013	2.907	0.836	0.008	1.816	0.012	0.008	18.7	19.3	19.3
121	1,200	0.0040	0.013	2.920	0.844	0.008	1.828	0.012	0.008	18.7	19.3	19.3
122	1,210	0.0040	0.013	2.933	0.852	0.008	1.839	0.012	0.008	18.8	19.3	19.3
123	1,220	0.0040	0.013	2.946	0.860	0.008	1.851	0.012	0.008	18.8	19.2	19.2
124	1,230	0.0040	0.013	2.959	0.868	0.008	1.863	0.012	0.008	18.9	19.2	19.2
125	1,240	0.0040	0.013	2.972	0.876	0.008	1.874	0.012	0.008	19.0	19.2	19.2
126	1,250	0.0040	0.013	2.985	0.885	0.008	1.886	0.012	0.008	19.0	19.2	19.2
127	1,260	0.0040	0.013	2.997	0.893	0.008	1.898	0.012	0.008	19.1	19.2	19.2
128	1,270	0.0040	0.013	3.010	0.901	0.008	1.909	0.012	0.008	19.1	19.2	19.2
129	1,280	0.0040	0.013	3.023	0.909	0.008	1.921	0.012	0.008	19.2	19.1	19.1
130	1,290	0.0040	0.013	3.036	0.917	0.008	1.933	0.012	0.008	19.2	19.2	19.2
131	1,300	0.0040	0.013	3.049	0.925	0.008	1.944	0.012	0.008	19.2	19.2	19.2
132	1,310	0.0040	0.013	3.062	0.934	0.008	1.956	0.012	0.008	19.3	19.2	19.2
133	1,320	0.0040	0.013	3.075	0.942	0.008	1.968	0.012	0.008	19.3	19.2	19.2
134	1,330	0.0040	0.013	3.088	0.950	0.008	1.979	0.012	0.008	19.4	19.2	19.2
135	1,340	0.0040	0.013	3.101	0.958	0.008	1.991	0.012	0.008	19.4	19.2	19.2
136	1,350	0.0040	0.013	3.114	0.967	0.008	2.003	0.012	0.008	19.5	19.2	19.2
137	1,360	0.0040	0.013	3.127	0.975	0.008	2.015	0.012	0.008	19.5	19.2	19.2
138	1,370	0.0040	0.013	3.140	0.983	0.008	2.026	0.012	0.008	19.6	19.3	19.3
139	1,380	0.0040	0.013	3.152	0.992	0.008	2.038	0.012	0.008	19.6	19.3	19.3
140	1,390	0.0040	0.013	3.165	1.000	0.008	2.050	0.012	0.008	19.7	19.3	19.3
141	1,400	0.0040	0.013	3.178	1.008	0.008	2.062	0.012	0.008	19.7	19.4	19.4
142	1,410	0.0040	0.013	3.191	1.017	0.008	2.074	0.012	0.008	19.8	19.4	19.4
143	1,420	0.0040	0.013	3.204	1.025	0.008	2.085	0.012	0.008	19.8	19.4	19.4
144	1,430	0.0040	0.013	3.217	1.034	0.008	2.097	0.012	0.008	19.9	19.4	19.4
145	1,440	0.0040	0.0129	3.230	1.042	0.008	2.109	0.012	0.008	19.9	19.5	19.5
146	Total:	1.0000	3.2300			1.0422		2.1089	1.0422			18.7
147							Max:	**26.4**				18.0
148							Cumulative Runoff at Period 145	0.93	inches	Start Flow	19.5	17.3
149							Unaccounted Runoff	0.11	inches	End Flow	-0.2	16.6
150								16,019.75	sec	Flow Dec./per	0.7	15.8
151		Column	Description					267.00	min			15.1
152		1	Time Increment					26.70	periods			14.4
153		2	Time (min)					27	periods			13.6
154		3	Type IA Storm Distibution					1.0363	Total Runoff			12.9
155		4	Column 3 * Precipitation									12.2
156		5	Accumulated Sum of Column 4									11.5
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									10.7
158		7	Column 6 of the present step - Column 6 of the previous step									10.0
159		8	Same as Column 6, except Impervious Area Calculations									9.3
160		9	Column 8 of the present step - Column 8 of the previous step									8.5
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									7.8
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									7.1
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									6.3
164			(2 * Column 12 of previous step))									5.6
165												4.9

		Return Period	Duration
Site:	Gorst Creek Upper Watershed	year	hour
Rainfall:	3.90 in.	5	24

Time Increment: 10 minutes

w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area	CN	S	0.2 S
Pervious Area:	388 acres	74	3.56	0.71
Impervious Area:	0.00 acres	89	1.24	0.25
Total Area:	388.14 acres			

Time of Concentration: 128 minutes, 2.14 hours

Qmax= 40.0 cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.016	0.016	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.016	0.031	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.016	0.047	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.016	0.062	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.016	0.078	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.016	0.094	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.016	0.109	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.016	0.125	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.016	0.140	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.016	0.156	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.020	0.176	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
13	120	0.0050	0.020	0.195	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
14	130	0.0050	0.020	0.215	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
15	140	0.0050	0.020	0.234	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
16	150	0.0050	0.020	0.254	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
17	160	0.0050	0.020	0.273	0.000	0.000	0.001	0.000	0.000	0.0	0.0	0.0
18	170	0.0060	0.023	0.296	0.000	0.000	0.002	0.001	0.000	0.0	0.0	0.0
19	180	0.0060	0.023	0.320	0.000	0.000	0.004	0.002	0.000	0.0	0.0	0.0
20	190	0.0060	0.023	0.343	0.000	0.000	0.007	0.003	0.000	0.0	0.0	0.0
21	200	0.0060	0.023	0.367	0.000	0.000	0.011	0.004	0.000	0.0	0.0	0.0
22	210	0.0060	0.023	0.390	0.000	0.000	0.015	0.004	0.000	0.0	0.0	0.0
23	220	0.0060	0.023	0.413	0.000	0.000	0.020	0.005	0.000	0.0	0.0	0.0
24	230	0.0070	0.027	0.441	0.000	0.000	0.026	0.006	0.000	0.0	0.0	0.0
25	240	0.0070	0.027	0.468	0.000	0.000	0.033	0.007	0.000	0.0	0.0	0.0
26	250	0.0070	0.027	0.495	0.000	0.000	0.041	0.008	0.000	0.0	0.0	0.0
27	260	0.0070	0.027	0.523	0.000	0.000	0.050	0.009	0.000	0.0	0.0	0.0
28	270	0.0070	0.027	0.550	0.000	0.000	0.060	0.009	0.000	0.0	0.0	0.0
29	280	0.0070	0.027	0.577	0.000	0.000	0.070	0.010	0.000	0.0	0.0	0.0
30	290	0.0082	0.032	0.609	0.000	0.000	0.082	0.012	0.000	0.0	0.0	0.0
31	300	0.0082	0.032	0.641	0.000	0.000	0.095	0.013	0.000	0.0	0.0	0.0
32	310	0.0082	0.032	0.673	0.000	0.000	0.109	0.014	0.000	0.0	0.0	0.0
33	320	0.0082	0.032	0.705	0.000	0.000	0.124	0.015	0.000	0.0	0.0	0.0
34	330	0.0082	0.032	0.737	0.000	0.000	0.139	0.015	0.000	0.4	0.0	0.0
35	340	0.0082	0.032	0.769	0.001	0.001	0.155	0.016	0.001	1.7	0.1	0.1
36	350	0.0095	0.037	0.806	0.002	0.002	0.174	0.019	0.002	3.5	0.3	0.3
37	360	0.0095	0.037	0.843	0.005	0.002	0.194	0.020	0.002	5.2	0.6	0.6
38	370	0.0095	0.037	0.880	0.008	0.003	0.214	0.021	0.003	6.8	1.0	1.0
39	380	0.0095	0.037	0.917	0.011	0.004	0.236	0.021	0.004	8.4	1.5	1.5
40	390	0.0095	0.037	0.954	0.015	0.004	0.257	0.022	0.004	10.0	2.1	2.1
41	400	0.0095	0.037	0.991	0.020	0.005	0.280	0.022	0.005	11.4	2.7	2.7
42	410	0.0134	0.052	1.044	0.028	0.008	0.312	0.032	0.008	18.6	3.6	3.6
43	420	0.0134	0.052	1.096	0.037	0.009	0.346	0.033	0.009	21.3	4.9	4.9
44	430	0.0134	0.052	1.148	0.047	0.010	0.380	0.034	0.010	24.0	6.2	6.2
45	440	0.0180	0.070	1.218	0.063	0.015	0.427	0.047	0.015	36.2	8.0	8.0
46	450	0.0180	0.070	1.289	0.080	0.017	0.476	0.049	0.017	40.6	10.3	10.3
47	460	0.0340	0.133	1.421	0.118	0.037	0.572	0.096	0.037	87.8	14.3	14.3
48	470	0.0540	0.211	1.632	0.188	0.071	0.732	0.160	0.071	166.6	22.8	22.8
49	480	0.0270	0.105	1.737	0.229	0.040	0.814	0.083	0.040	94.6	30.9	30.9
50	490	0.0180	0.070	1.807	0.257	0.028	0.870	0.056	0.028	66.9	34.6	34.6
51	500	0.0134	0.052	1.860	0.279	0.022	0.913	0.042	0.022	51.7	36.5	36.5
52	510	0.0134	0.052	1.912	0.302	0.023	0.955	0.043	0.023	53.3	37.7	37.7
53	520	0.0134	0.052	1.964	0.325	0.023	0.998	0.043	0.023	54.8	38.9	38.9
54	530	0.0088	0.034	1.998	0.341	0.016	1.027	0.028	0.016	36.8	39.4	39.4
55	540	0.0088	0.034	2.033	0.357	0.016	1.055	0.029	0.016	37.4	39.2	39.2
56	550	0.0088	0.034	2.067	0.373	0.016	1.084	0.029	0.016	38.0	39.1	39.1
57	560	0.0088	0.034	2.101	0.389	0.016	1.113	0.029	0.016	38.6	39.0	39.0
58	570	0.0088	0.034	2.136	0.406	0.017	1.141	0.029	0.017	39.2	39.0	39.0
59	580	0.0088	0.034	2.170	0.423	0.017	1.170	0.029	0.017	39.7	39.1	39.1
60	590	0.0088	0.034	2.204	0.440	0.017	1.200	0.029	0.017	40.3	39.1	39.1
61	600	0.0088	0.034	2.239	0.458	0.017	1.229	0.029	0.017	40.8	39.2	39.2
62	610	0.0088	0.034	2.273	0.475	0.018	1.258	0.029	0.018	41.4	39.4	39.4
63	620	0.0088	0.034	2.307	0.493	0.018	1.288	0.029	0.018	41.9	39.5	39.5
64	630	0.0088	0.034	2.342	0.511	0.018	1.317	0.030	0.018	42.4	39.7	39.7
65	640	0.0088	0.034	2.376	0.529	0.018	1.347	0.030	0.018	42.9	40.0	40.0
66	650	0.0072	0.028	2.404	0.544	0.015	1.371	0.024	0.015	35.5	39.9	39.9
67	660	0.0072	0.028	2.432	0.560	0.015	1.395	0.024	0.015	35.8	39.6	39.6
68	670	0.0072	0.028	2.460	0.575	0.015	1.420	0.024	0.015	36.1	39.3	39.3
69	680	0.0072	0.028	2.488	0.591	0.016	1.444	0.025	0.016	36.4	39.1	39.1
70	690	0.0072	0.028	2.516	0.606	0.016	1.469	0.025	0.016	36.7	38.9	38.9
71	700	0.0072	0.028	2.544	0.622	0.016	1.494	0.025	0.016	37.0	38.7	38.7
72	710	0.0072	0.028	2.572	0.638	0.016	1.518	0.025	0.016	37.3	38.6	38.6
73	720	0.0072	0.028	2.601	0.654	0.016	1.543	0.025	0.016	37.6	38.5	38.5

74	730	0.0072	0.028	2.629	0.670	0.016	1.568	0.025	0.016	37.9	38.5	38.5
75	740	0.0072	0.028	2.657	0.686	0.016	1.593	0.025	0.016	38.2	38.4	38.4
76	750	0.0072	0.028	2.685	0.703	0.016	1.617	0.025	0.016	38.5	38.4	38.4
77	760	0.0072	0.028	2.713	0.719	0.017	1.642	0.025	0.017	38.8	38.4	38.4
78	770	0.0057	0.022	2.735	0.732	0.013	1.662	0.020	0.013	30.9	38.2	38.2
79	780	0.0057	0.022	2.757	0.746	0.013	1.682	0.020	0.013	31.0	37.6	37.6
80	790	0.0057	0.022	2.780	0.759	0.013	1.702	0.020	0.013	31.2	37.1	37.1
81	800	0.0057	0.022	2.802	0.772	0.013	1.722	0.020	0.013	31.4	36.7	36.7
82	810	0.0057	0.022	2.824	0.786	0.013	1.741	0.020	0.013	31.5	36.3	36.3
83	820	0.0057	0.022	2.846	0.799	0.013	1.761	0.020	0.013	31.7	36.0	36.0
84	830	0.0057	0.022	2.868	0.813	0.014	1.781	0.020	0.014	31.9	35.6	35.6
85	840	0.0057	0.022	2.891	0.826	0.014	1.801	0.020	0.014	32.0	35.4	35.4
86	850	0.0057	0.022	2.913	0.840	0.014	1.821	0.020	0.014	32.2	35.1	35.1
87	860	0.0057	0.022	2.935	0.854	0.014	1.841	0.020	0.014	32.3	34.9	34.9
88	870	0.0057	0.022	2.957	0.868	0.014	1.861	0.020	0.014	32.5	34.7	34.7
89	880	0.0057	0.022	2.980	0.882	0.014	1.881	0.020	0.014	32.6	34.6	34.6
90	890	0.0050	0.020	2.999	0.894	0.012	1.899	0.018	0.012	28.7	34.3	34.3
91	900	0.0050	0.020	3.019	0.906	0.012	1.917	0.018	0.012	28.9	33.9	33.9
92	910	0.0050	0.020	3.038	0.918	0.012	1.934	0.018	0.012	29.0	33.5	33.5
93	920	0.0050	0.020	3.058	0.931	0.012	1.952	0.018	0.012	29.1	33.2	33.2
94	930	0.0050	0.020	3.077	0.943	0.012	1.970	0.018	0.012	29.2	32.9	32.9
95	940	0.0050	0.020	3.097	0.956	0.012	1.987	0.018	0.012	29.3	32.6	32.6
96	950	0.0050	0.020	3.116	0.968	0.013	2.005	0.018	0.013	29.4	32.3	32.3
97	960	0.0050	0.020	3.136	0.981	0.013	2.023	0.018	0.013	29.5	32.1	32.1
98	970	0.0050	0.020	3.155	0.993	0.013	2.041	0.018	0.013	29.6	31.9	31.9
99	980	0.0050	0.020	3.175	1.006	0.013	2.058	0.018	0.013	29.7	31.8	31.8
100	990	0.0050	0.020	3.194	1.019	0.013	2.076	0.018	0.013	29.8	31.6	31.6
101	1,000	0.0050	0.020	3.214	1.031	0.013	2.094	0.018	0.013	29.9	31.5	31.5
102	1,010	0.0040	0.016	3.229	1.042	0.010	2.108	0.014	0.010	24.0	31.1	31.1
103	1,020	0.0040	0.016	3.245	1.052	0.010	2.122	0.014	0.010	24.1	30.6	30.6
104	1,030	0.0040	0.016	3.260	1.062	0.010	2.137	0.014	0.010	24.1	30.1	30.1
105	1,040	0.0040	0.016	3.276	1.073	0.010	2.151	0.014	0.010	24.2	29.7	29.7
106	1,050	0.0040	0.016	3.292	1.083	0.010	2.165	0.014	0.010	24.3	29.3	29.3
107	1,060	0.0040	0.016	3.307	1.093	0.010	2.180	0.014	0.010	24.3	28.9	28.9
108	1,070	0.0040	0.016	3.323	1.104	0.010	2.194	0.014	0.010	24.4	28.6	28.6
109	1,080	0.0040	0.016	3.338	1.114	0.010	2.208	0.014	0.010	24.5	28.3	28.3
110	1,090	0.0040	0.016	3.354	1.125	0.010	2.223	0.014	0.010	24.5	28.0	28.0
111	1,100	0.0040	0.016	3.370	1.135	0.010	2.237	0.014	0.010	24.6	27.7	27.7
112	1,110	0.0040	0.016	3.385	1.145	0.010	2.251	0.014	0.010	24.6	27.5	27.5
113	1,120	0.0040	0.016	3.401	1.156	0.011	2.266	0.014	0.011	24.7	27.3	27.3
114	1,130	0.0040	0.016	3.416	1.167	0.011	2.280	0.014	0.011	24.8	27.1	27.1
115	1,140	0.0040	0.016	3.432	1.177	0.011	2.294	0.014	0.011	24.8	26.9	26.9
116	1,150	0.0040	0.016	3.448	1.188	0.011	2.309	0.014	0.011	24.9	26.8	26.8
117	1,160	0.0040	0.016	3.463	1.198	0.011	2.323	0.014	0.011	24.9	26.6	26.6
118	1,170	0.0040	0.016	3.479	1.209	0.011	2.338	0.014	0.011	25.0	26.5	26.5
119	1,180	0.0040	0.016	3.494	1.220	0.011	2.352	0.014	0.011	25.1	26.4	26.4
120	1,190	0.0040	0.016	3.510	1.230	0.011	2.366	0.014	0.011	25.1	26.3	26.3
121	1,200	0.0040	0.016	3.526	1.241	0.011	2.381	0.014	0.011	25.2	26.2	26.2
122	1,210	0.0040	0.016	3.541	1.252	0.011	2.395	0.014	0.011	25.2	26.1	26.1
123	1,220	0.0040	0.016	3.557	1.263	0.011	2.410	0.014	0.011	25.3	26.1	26.1
124	1,230	0.0040	0.016	3.572	1.273	0.011	2.424	0.014	0.011	25.3	26.0	26.0
125	1,240	0.0040	0.016	3.588	1.284	0.011	2.439	0.014	0.011	25.4	26.0	26.0
126	1,250	0.0040	0.016	3.604	1.295	0.011	2.453	0.014	0.011	25.4	25.9	25.9
127	1,260	0.0040	0.016	3.619	1.306	0.011	2.468	0.014	0.011	25.5	25.9	25.9
128	1,270	0.0040	0.016	3.635	1.317	0.011	2.482	0.014	0.011	25.5	25.9	25.9
129	1,280	0.0040	0.016	3.650	1.328	0.011	2.497	0.014	0.011	25.6	25.8	25.8
130	1,290	0.0040	0.016	3.666	1.339	0.011	2.511	0.014	0.011	25.7	25.8	25.8
131	1,300	0.0040	0.016	3.682	1.349	0.011	2.526	0.015	0.011	25.7	25.8	25.8
132	1,310	0.0040	0.016	3.697	1.360	0.011	2.540	0.015	0.011	25.8	25.8	25.8
133	1,320	0.0040	0.016	3.713	1.371	0.011	2.555	0.015	0.011	25.8	25.8	25.8
134	1,330	0.0040	0.016	3.728	1.382	0.011	2.569	0.015	0.011	25.9	25.8	25.8
135	1,340	0.0040	0.016	3.744	1.393	0.011	2.584	0.015	0.011	25.9	25.8	25.8
136	1,350	0.0040	0.016	3.760	1.405	0.011	2.598	0.015	0.011	26.0	25.8	25.8
137	1,360	0.0040	0.016	3.775	1.416	0.011	2.613	0.015	0.011	26.0	25.8	25.8
138	1,370	0.0040	0.016	3.791	1.427	0.011	2.627	0.015	0.011	26.1	25.8	25.8
139	1,380	0.0040	0.016	3.806	1.438	0.011	2.642	0.015	0.011	26.1	25.9	25.9
140	1,390	0.0040	0.016	3.822	1.449	0.011	2.656	0.015	0.011	26.2	25.9	25.9
141	1,400	0.0040	0.016	3.838	1.460	0.011	2.671	0.015	0.011	26.2	25.9	25.9
142	1,410	0.0040	0.016	3.853	1.471	0.011	2.686	0.015	0.011	26.3	25.9	25.9
143	1,420	0.0040	0.016	3.869	1.483	0.011	2.700	0.015	0.011	26.3	26.0	26.0
144	1,430	0.0040	0.016	3.884	1.494	0.011	2.715	0.015	0.011	26.4	26.0	26.0
145	1,440	0.0040	0.0156	3.900	1.505	0.011	2.729	0.015	0.011	26.4	26.0	26.0
146	Total:	1.0000	3.9000			1.5050		2.7293	1.5050			25.0
147							Max:	**40.0**				24.1
148							Cumulative Runoff at Period 145	1.36	inches	Start Flow	26.0	23.1
149							Unaccounted Runoff	0.15	inches	End Flow	-0.3	22.1
150								16,015.61	sec	Flow Dec./per	1.0	21.1
151		Column	Description					266.93	min			20.2
152		1	Time Increment					26.69	periods			19.2
153		2	Time (min)					27	periods			18.2
154		3	Type IA Storm Distibution					1.4971	Total Runoff			17.2
155		4	Column 3 * Precipitation									16.3
156		5	Accumulated Sum of Column 4									15.3
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									14.3
158		7	Column 6 of the present step - Column 6 of the previous step									13.3
159		8	Same as Column 6, except Impervious Area Calculations									12.4
160		9	Column 8 of the present step - Column 8 of the previous step									11.4
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									10.4
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									9.4
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									8.5
164			(2 * Column 12 of previous step))									7.5
165												6.5

Site:	Gorst Creek Upper Watershed		Return Period year	Duration hour
	Rainfall:	4.40 in.	10	24

Time Increment: 10 minutes   w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area	CN	S	0.2 S
Pervious Area:	388 acres	74	3.56	0.71
Impervious Area:	0.00 acres	89	1.24	0.25
Total Area:	388.14 acres			

Time of Concentration: 128 minutes   **Qmax= 52.4 cfs**

2.14 hours

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.018	0.018	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.018	0.035	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.018	0.053	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.018	0.070	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.018	0.088	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.018	0.106	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.018	0.123	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.018	0.141	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.018	0.158	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.018	0.176	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.022	0.198	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
13	120	0.0050	0.022	0.220	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
14	130	0.0050	0.022	0.242	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
15	140	0.0050	0.022	0.264	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
16	150	0.0050	0.022	0.286	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0
17	160	0.0050	0.022	0.308	0.000	0.000	0.003	0.002	0.000	0.0	0.0	0.0
18	170	0.0060	0.026	0.334	0.000	0.000	0.006	0.003	0.000	0.0	0.0	0.0
19	180	0.0060	0.026	0.361	0.000	0.000	0.010	0.004	0.000	0.0	0.0	0.0
20	190	0.0060	0.026	0.387	0.000	0.000	0.014	0.005	0.000	0.0	0.0	0.0
21	200	0.0060	0.026	0.414	0.000	0.000	0.020	0.006	0.000	0.0	0.0	0.0
22	210	0.0060	0.026	0.440	0.000	0.000	0.026	0.006	0.000	0.0	0.0	0.0
23	220	0.0060	0.026	0.466	0.000	0.000	0.033	0.007	0.000	0.0	0.0	0.0
24	230	0.0070	0.031	0.497	0.000	0.000	0.042	0.009	0.000	0.0	0.0	0.0
25	240	0.0070	0.031	0.528	0.000	0.000	0.052	0.010	0.000	0.0	0.0	0.0
26	250	0.0070	0.031	0.559	0.000	0.000	0.063	0.011	0.000	0.0	0.0	0.0
27	260	0.0070	0.031	0.590	0.000	0.000	0.074	0.012	0.000	0.0	0.0	0.0
28	270	0.0070	0.031	0.620	0.000	0.000	0.087	0.012	0.000	0.0	0.0	0.0
29	280	0.0070	0.031	0.651	0.000	0.000	0.100	0.013	0.000	0.0	0.0	0.0
30	290	0.0082	0.036	0.687	0.000	0.000	0.116	0.016	0.000	0.0	0.0	0.0
31	300	0.0082	0.036	0.723	0.000	0.000	0.132	0.017	0.000	0.1	0.0	0.0
32	310	0.0082	0.036	0.759	0.001	0.001	0.150	0.018	0.001	1.4	0.1	0.1
33	320	0.0082	0.036	0.796	0.002	0.001	0.169	0.018	0.001	3.0	0.2	0.2
34	330	0.0082	0.036	0.832	0.004	0.002	0.188	0.019	0.002	4.6	0.5	0.5
35	340	0.0082	0.036	0.868	0.006	0.003	0.207	0.020	0.003	6.2	0.9	0.9
36	350	0.0095	0.042	0.909	0.010	0.004	0.231	0.024	0.004	9.0	1.4	1.4
37	360	0.0095	0.042	0.951	0.015	0.005	0.256	0.024	0.005	11.0	2.0	2.0
38	370	0.0095	0.042	0.993	0.020	0.005	0.281	0.025	0.005	12.9	2.7	2.7
39	380	0.0095	0.042	1.035	0.027	0.006	0.307	0.026	0.006	14.7	3.6	3.6
40	390	0.0095	0.042	1.077	0.034	0.007	0.333	0.027	0.007	16.5	4.5	4.5
41	400	0.0095	0.042	1.118	0.042	0.008	0.360	0.027	0.008	18.2	5.4	5.4
42	410	0.0134	0.059	1.177	0.054	0.012	0.399	0.039	0.012	28.5	6.8	6.8
43	420	0.0134	0.059	1.236	0.067	0.013	0.440	0.040	0.013	31.7	8.5	8.5
44	430	0.0134	0.059	1.295	0.082	0.015	0.481	0.041	0.015	34.7	10.4	10.4
45	440	0.0180	0.079	1.375	0.104	0.022	0.538	0.057	0.022	51.2	12.8	12.8
46	450	0.0180	0.079	1.454	0.128	0.024	0.596	0.058	0.024	56.1	15.9	15.9
47	460	0.0340	0.150	1.603	0.178	0.051	0.710	0.114	0.051	118.7	21.2	21.2
48	470	0.0540	0.238	1.841	0.271	0.093	0.898	0.188	0.093	218.9	32.3	32.3
49	480	0.0270	0.119	1.960	0.323	0.052	0.995	0.097	0.052	122.0	42.7	42.7
50	490	0.0180	0.079	2.039	0.360	0.036	1.060	0.066	0.036	85.6	47.3	47.3
51	500	0.0134	0.059	2.098	0.388	0.028	1.110	0.049	0.028	65.8	49.4	49.4
52	510	0.0134	0.059	2.157	0.417	0.029	1.159	0.050	0.029	67.5	50.7	50.7
53	520	0.0134	0.059	2.216	0.446	0.029	1.209	0.050	0.029	69.2	52.0	52.0
54	530	0.0088	0.039	2.255	0.466	0.020	1.242	0.033	0.020	46.3	52.4	52.4
55	540	0.0088	0.039	2.293	0.486	0.020	1.276	0.033	0.020	47.0	52.0	52.0
56	550	0.0088	0.039	2.332	0.506	0.020	1.309	0.033	0.020	47.6	51.6	51.6
57	560	0.0088	0.039	2.371	0.527	0.021	1.342	0.033	0.021	48.3	51.4	51.4
58	570	0.0088	0.039	2.409	0.547	0.021	1.376	0.034	0.021	48.9	51.2	51.2
59	580	0.0088	0.039	2.448	0.568	0.021	1.409	0.034	0.021	49.5	51.0	51.0
60	590	0.0088	0.039	2.487	0.590	0.021	1.443	0.034	0.021	50.1	50.9	50.9
61	600	0.0088	0.039	2.526	0.611	0.022	1.477	0.034	0.022	50.7	50.9	50.9
62	610	0.0088	0.039	2.564	0.633	0.022	1.511	0.034	0.022	51.3	50.9	50.9
63	620	0.0088	0.039	2.603	0.655	0.022	1.545	0.034	0.022	51.8	50.9	50.9
64	630	0.0088	0.039	2.642	0.678	0.022	1.579	0.034	0.022	52.4	51.0	51.0
65	640	0.0088	0.039	2.680	0.700	0.023	1.614	0.034	0.023	52.9	51.1	51.1
66	650	0.0072	0.032	2.712	0.719	0.019	1.642	0.028	0.019	43.7	50.9	50.9
67	660	0.0072	0.032	2.744	0.738	0.019	1.670	0.028	0.019	44.0	50.4	50.4
68	670	0.0072	0.032	2.776	0.756	0.019	1.698	0.028	0.019	44.4	49.9	49.9
69	680	0.0072	0.032	2.807	0.775	0.019	1.726	0.028	0.019	44.7	49.5	49.5
70	690	0.0072	0.032	2.839	0.795	0.019	1.755	0.028	0.019	45.1	49.2	49.2
71	700	0.0072	0.032	2.871	0.814	0.019	1.783	0.028	0.019	45.4	48.9	48.9
72	710	0.0072	0.032	2.902	0.833	0.019	1.812	0.028	0.019	45.7	48.6	48.6
73	720	0.0072	0.032	2.934	0.853	0.020	1.840	0.029	0.020	46.0	48.4	48.4

74	730	0.0072	0.032	2.966	0.873	0.020	1.869	0.029	0.020	46.3	48.3	48.3
75	740	0.0072	0.032	2.997	0.893	0.020	1.897	0.029	0.020	46.6	48.1	48.1
76	750	0.0072	0.032	3.029	0.913	0.020	1.926	0.029	0.020	46.9	48.0	48.0
77	760	0.0072	0.032	3.061	0.933	0.020	1.955	0.029	0.020	47.2	48.0	48.0
78	770	0.0057	0.025	3.086	0.949	0.016	1.977	0.023	0.016	37.6	47.5	47.5
79	780	0.0057	0.025	3.111	0.965	0.016	2.000	0.023	0.016	37.8	46.8	46.8
80	790	0.0057	0.025	3.136	0.981	0.016	2.023	0.023	0.016	37.9	46.1	46.1
81	800	0.0057	0.025	3.161	0.997	0.016	2.046	0.023	0.016	38.1	45.5	45.5
82	810	0.0057	0.025	3.186	1.013	0.016	2.069	0.023	0.016	38.3	45.0	45.0
83	820	0.0057	0.025	3.211	1.030	0.016	2.092	0.023	0.016	38.5	44.5	44.5
84	830	0.0057	0.025	3.236	1.046	0.016	2.115	0.023	0.016	38.6	44.0	44.0
85	840	0.0057	0.025	3.261	1.063	0.017	2.138	0.023	0.017	38.8	43.6	43.6
86	850	0.0057	0.025	3.286	1.079	0.017	2.161	0.023	0.017	39.0	43.3	43.3
87	860	0.0057	0.025	3.311	1.096	0.017	2.184	0.023	0.017	39.1	43.0	43.0
88	870	0.0057	0.025	3.337	1.113	0.017	2.207	0.023	0.017	39.3	42.7	42.7
89	880	0.0057	0.025	3.362	1.130	0.017	2.230	0.023	0.017	39.4	42.4	42.4
90	890	0.0050	0.022	3.384	1.144	0.015	2.250	0.020	0.015	34.7	42.0	42.0
91	900	0.0050	0.022	3.406	1.159	0.015	2.270	0.020	0.015	34.8	41.5	41.5
92	910	0.0050	0.022	3.428	1.174	0.015	2.290	0.020	0.015	35.0	41.0	41.0
93	920	0.0050	0.022	3.450	1.189	0.015	2.311	0.020	0.015	35.1	40.5	40.5
94	930	0.0050	0.022	3.472	1.204	0.015	2.331	0.020	0.015	35.2	40.1	40.1
95	940	0.0050	0.022	3.494	1.219	0.015	2.351	0.020	0.015	35.3	39.8	39.8
96	950	0.0050	0.022	3.516	1.234	0.015	2.372	0.020	0.015	35.4	39.4	39.4
97	960	0.0050	0.022	3.538	1.249	0.015	2.392	0.020	0.015	35.5	39.1	39.1
98	970	0.0050	0.022	3.560	1.264	0.015	2.412	0.020	0.015	35.6	38.9	38.9
99	980	0.0050	0.022	3.582	1.280	0.015	2.433	0.020	0.015	35.8	38.6	38.6
100	990	0.0050	0.022	3.604	1.295	0.015	2.453	0.020	0.015	35.9	38.4	38.4
101	1,000	0.0050	0.022	3.626	1.310	0.015	2.474	0.020	0.015	36.0	38.2	38.2
102	1,010	0.0040	0.018	3.643	1.323	0.012	2.490	0.016	0.012	28.9	37.8	37.8
103	1,020	0.0040	0.018	3.661	1.335	0.012	2.506	0.016	0.012	28.9	37.1	37.1
104	1,030	0.0040	0.018	3.678	1.347	0.012	2.523	0.016	0.012	29.0	36.5	36.5
105	1,040	0.0040	0.018	3.696	1.360	0.012	2.539	0.016	0.012	29.1	36.0	36.0
106	1,050	0.0040	0.018	3.714	1.372	0.012	2.555	0.016	0.012	29.1	35.4	35.4
107	1,060	0.0040	0.018	3.731	1.384	0.012	2.572	0.016	0.012	29.2	35.0	35.0
108	1,070	0.0040	0.018	3.749	1.397	0.012	2.588	0.016	0.012	29.2	34.5	34.5
109	1,080	0.0040	0.018	3.766	1.409	0.012	2.605	0.016	0.012	29.3	34.1	34.1
110	1,090	0.0040	0.018	3.784	1.422	0.013	2.621	0.016	0.013	29.4	33.8	33.8
111	1,100	0.0040	0.018	3.802	1.434	0.013	2.637	0.016	0.013	29.4	33.5	33.5
112	1,110	0.0040	0.018	3.819	1.447	0.013	2.654	0.016	0.013	29.5	33.2	33.2
113	1,120	0.0040	0.018	3.837	1.460	0.013	2.670	0.016	0.013	29.6	32.9	32.9
114	1,130	0.0040	0.018	3.854	1.472	0.013	2.687	0.016	0.013	29.6	32.6	32.6
115	1,140	0.0040	0.018	3.872	1.485	0.013	2.703	0.016	0.013	29.7	32.4	32.4
116	1,150	0.0040	0.018	3.890	1.498	0.013	2.720	0.016	0.013	29.7	32.2	32.2
117	1,160	0.0040	0.018	3.907	1.510	0.013	2.736	0.016	0.013	29.8	32.0	32.0
118	1,170	0.0040	0.018	3.925	1.523	0.013	2.753	0.016	0.013	29.9	31.9	31.9
119	1,180	0.0040	0.018	3.942	1.536	0.013	2.769	0.016	0.013	29.9	31.7	31.7
120	1,190	0.0040	0.018	3.960	1.548	0.013	2.786	0.016	0.013	30.0	31.6	31.6
121	1,200	0.0040	0.018	3.978	1.561	0.013	2.802	0.017	0.013	30.0	31.5	31.5
122	1,210	0.0040	0.018	3.995	1.574	0.013	2.819	0.017	0.013	30.1	31.4	31.4
123	1,220	0.0040	0.018	4.013	1.587	0.013	2.835	0.017	0.013	30.2	31.3	31.3
124	1,230	0.0040	0.018	4.030	1.600	0.013	2.852	0.017	0.013	30.2	31.2	31.2
125	1,240	0.0040	0.018	4.048	1.613	0.013	2.868	0.017	0.013	30.3	31.1	31.1
126	1,250	0.0040	0.018	4.066	1.626	0.013	2.885	0.017	0.013	30.3	31.1	31.1
127	1,260	0.0040	0.018	4.083	1.639	0.013	2.901	0.017	0.013	30.4	31.0	31.0
128	1,270	0.0040	0.018	4.101	1.651	0.013	2.918	0.017	0.013	30.4	31.0	31.0
129	1,280	0.0040	0.018	4.118	1.664	0.013	2.934	0.017	0.013	30.5	30.9	30.9
130	1,290	0.0040	0.018	4.136	1.677	0.013	2.951	0.017	0.013	30.6	30.9	30.9
131	1,300	0.0040	0.018	4.154	1.691	0.013	2.968	0.017	0.013	30.6	30.9	30.9
132	1,310	0.0040	0.018	4.171	1.704	0.013	2.984	0.017	0.013	30.7	30.9	30.9
133	1,320	0.0040	0.018	4.189	1.717	0.013	3.001	0.017	0.013	30.7	30.8	30.8
134	1,330	0.0040	0.018	4.206	1.730	0.013	3.017	0.017	0.013	30.8	30.8	30.8
135	1,340	0.0040	0.018	4.224	1.743	0.013	3.034	0.017	0.013	30.8	30.8	30.8
136	1,350	0.0040	0.018	4.242	1.756	0.013	3.051	0.017	0.013	30.9	30.8	30.8
137	1,360	0.0040	0.018	4.259	1.769	0.013	3.067	0.017	0.013	30.9	30.8	30.8
138	1,370	0.0040	0.018	4.277	1.782	0.013	3.084	0.017	0.013	31.0	30.8	30.8
139	1,380	0.0040	0.018	4.294	1.796	0.013	3.100	0.017	0.013	31.0	30.9	30.9
140	1,390	0.0040	0.018	4.312	1.809	0.013	3.117	0.017	0.013	31.1	30.9	30.9
141	1,400	0.0040	0.018	4.330	1.822	0.013	3.134	0.017	0.013	31.1	30.9	30.9
142	1,410	0.0040	0.018	4.347	1.835	0.013	3.150	0.017	0.013	31.2	30.9	30.9
143	1,420	0.0040	0.018	4.365	1.849	0.013	3.167	0.017	0.013	31.2	30.9	30.9
144	1,430	0.0040	0.018	4.382	1.862	0.013	3.184	0.017	0.013	31.3	31.0	31.0
145	1,440	0.0040	0.0176	4.400	1.875	0.013	3.200	0.017	0.013	31.3	31.0	31.0
146	Total:	1.0000	4.4000			1.8753		3.2003	1.8753			29.8
147							Max:	**52.4**				28.7
148							Cumulative Runoff at Period 145	1.70	inches	Start Flow	31.0	27.5
149							Unaccounted Runoff	0.18	inches	End Flow	-0.4	26.3
150								16,013.33	sec	Flow Dec./per	1.2	25.2
151		Column	Description					266.89	min			24.0
152		1	Time Increment					26.69	periods			22.9
153		2	Time (min)					27	periods			21.7
154		3	Type IA Storm Distibution					1.8659	Total Runoff			20.5
155		4	Column 3 * Precipitation									19.4
156		5	Accumulated Sum of Column 4									18.2
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									17.1
158		7	Column 6 of the present step - Column 6 of the previous step									15.9
159		8	Same as Column 6, except Impervious Area Calculations									14.7
160		9	Column 8 of the present step - Column 8 of the previous step									13.6
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									12.4
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									11.2
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									10.1
164			(2 * Column 12 of previous step))									8.9
165												7.8

				Return Period	Duration
Site:	Gorst Creek Upper Watershed			year	hour
		Rainfall:	5.10 in.	25	24

Time Increment: 10 minutes   w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area		CN	S	0.2 S
Pervious Area:	388	acres	74	3.56	0.71
Impervious Area:	0.00	acres	89	1.24	0.25
Total Area:	388.14	acres			

Time of Concentration: 128 minutes
2.14 hours

Qmax= 72.2 cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13	
					PERVIOUS		IMPERVIOUS						
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)	
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	
2	10	0.0040	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
3	20	0.0040	0.020	0.041	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
4	30	0.0040	0.020	0.061	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
5	40	0.0040	0.020	0.082	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
6	50	0.0040	0.020	0.102	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
7	60	0.0040	0.020	0.122	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
8	70	0.0040	0.020	0.143	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
9	80	0.0040	0.020	0.163	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
10	90	0.0040	0.020	0.184	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
11	100	0.0040	0.020	0.204	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
12	110	0.0050	0.026	0.230	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
13	120	0.0050	0.026	0.255	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.166667
14	130	0.0050	0.026	0.281	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0	0.166667
15	140	0.0050	0.026	0.306	0.000	0.000	0.003	0.002	0.000	0.0	0.0	0.0	0.166667
16	150	0.0050	0.026	0.332	0.000	0.000	0.005	0.003	0.000	0.0	0.0	0.0	0.166667
17	160	0.0050	0.026	0.357	0.000	0.000	0.009	0.004	0.000	0.0	0.0	0.0	0.166667
18	170	0.0060	0.031	0.388	0.000	0.000	0.014	0.005	0.000	0.0	0.0	0.0	0.166667
19	180	0.0060	0.031	0.418	0.000	0.000	0.021	0.006	0.000	0.0	0.0	0.0	0.166667
20	190	0.0060	0.031	0.449	0.000	0.000	0.028	0.007	0.000	0.0	0.0	0.0	0.166667
21	200	0.0060	0.031	0.479	0.000	0.000	0.037	0.008	0.000	0.0	0.0	0.0	0.166667
22	210	0.0060	0.031	0.510	0.000	0.000	0.046	0.009	0.000	0.0	0.0	0.0	0.166667
23	220	0.0060	0.031	0.541	0.000	0.000	0.056	0.010	0.000	0.0	0.0	0.0	0.166667
24	230	0.0070	0.036	0.576	0.000	0.000	0.069	0.013	0.000	0.0	0.0	0.0	0.166667
25	240	0.0070	0.036	0.612	0.000	0.000	0.083	0.014	0.000	0.0	0.0	0.0	0.166667
26	250	0.0070	0.036	0.648	0.000	0.000	0.098	0.015	0.000	0.0	0.0	0.0	0.166667
27	260	0.0070	0.036	0.683	0.000	0.000	0.114	0.016	0.000	0.0	0.0	0.0	0.166667
28	270	0.0070	0.036	0.719	0.000	0.000	0.130	0.017	0.000	0.0	0.0	0.0	0.166667
29	280	0.0070	0.036	0.755	0.000	0.000	0.148	0.017	0.000	1.1	0.0	0.0	0.166667
30	290	0.0082	0.042	0.797	0.002	0.001	0.169	0.021	0.001	3.4	0.2	0.2	0.166667
31	300	0.0082	0.042	0.838	0.004	0.002	0.191	0.022	0.002	5.5	0.5	0.5	0.166667
32	310	0.0082	0.042	0.880	0.008	0.003	0.214	0.023	0.003	7.6	1.0	1.0	0.166667
33	320	0.0082	0.042	0.922	0.012	0.004	0.238	0.024	0.004	9.6	1.6	1.6	0.166667
34	330	0.0082	0.042	0.964	0.017	0.005	0.263	0.025	0.005	11.6	2.2	2.2	0.166667
35	340	0.0082	0.042	1.006	0.022	0.006	0.288	0.025	0.006	13.4	3.0	3.0	0.166667
36	350	0.0095	0.048	1.054	0.030	0.008	0.319	0.030	0.008	17.8	3.9	3.9	0.166667
37	360	0.0095	0.048	1.103	0.038	0.009	0.350	0.031	0.009	20.2	5.1	5.1	0.166667
38	370	0.0095	0.048	1.151	0.048	0.010	0.382	0.032	0.010	22.5	6.3	6.3	0.166667
39	380	0.0095	0.048	1.200	0.059	0.010	0.414	0.033	0.010	24.6	7.6	7.6	0.166667
40	390	0.0095	0.048	1.248	0.070	0.011	0.448	0.033	0.011	26.8	8.9	8.9	0.166667
41	400	0.0095	0.048	1.296	0.082	0.012	0.482	0.034	0.012	28.8	10.4	10.4	0.166667
42	410	0.0134	0.068	1.365	0.101	0.019	0.531	0.049	0.019	43.9	12.3	12.3	0.166667
43	420	0.0134	0.068	1.433	0.121	0.020	0.581	0.050	0.020	47.6	14.8	14.8	0.166667
44	430	0.0134	0.068	1.501	0.143	0.022	0.632	0.051	0.022	51.2	17.4	17.4	0.166667
45	440	0.0180	0.092	1.593	0.175	0.032	0.702	0.070	0.032	74.1	20.8	20.8	0.166667
46	450	0.0180	0.092	1.685	0.208	0.034	0.773	0.071	0.034	79.8	25.0	25.0	0.166667
47	460	0.0340	0.173	1.858	0.279	0.070	0.912	0.139	0.070	165.1	32.3	32.3	0.166667
48	470	0.0540	0.275	2.134	0.405	0.126	1.140	0.228	0.126	296.9	47.2	47.2	0.166667
49	480	0.0270	0.138	2.272	0.474	0.069	1.257	0.117	0.069	162.6	60.9	60.9	0.166667
50	490	0.0180	0.092	2.363	0.523	0.048	1.336	0.079	0.048	113.1	66.7	66.7	0.166667
51	500	0.0134	0.068	2.432	0.559	0.037	1.395	0.059	0.037	86.5	69.1	69.1	0.166667
52	510	0.0134	0.068	2.500	0.597	0.038	1.455	0.060	0.038	88.4	70.5	70.5	0.166667
53	520	0.0134	0.068	2.568	0.636	0.038	1.515	0.060	0.038	90.2	71.9	71.9	0.166667
54	530	0.0088	0.045	2.613	0.661	0.026	1.554	0.040	0.026	60.2	72.2	72.2	0.166667
55	540	0.0088	0.045	2.658	0.687	0.026	1.594	0.040	0.026	60.9	71.3	71.3	0.166667
56	550	0.0088	0.045	2.703	0.713	0.026	1.634	0.040	0.026	61.7	70.6	70.6	0.166667
57	560	0.0088	0.045	2.748	0.740	0.027	1.674	0.040	0.027	62.4	69.9	69.9	0.166667
58	570	0.0088	0.045	2.793	0.767	0.027	1.714	0.040	0.027	63.0	69.4	69.4	0.166667
59	580	0.0088	0.045	2.838	0.794	0.027	1.754	0.040	0.027	63.7	68.9	68.9	0.166667
60	590	0.0088	0.045	2.883	0.821	0.027	1.794	0.040	0.027	64.4	68.6	68.6	0.166667
61	600	0.0088	0.045	2.927	0.849	0.028	1.834	0.040	0.028	65.0	68.3	68.3	0.166667
62	610	0.0088	0.045	2.972	0.877	0.028	1.875	0.040	0.028	65.6	68.0	68.0	0.166667
63	620	0.0088	0.045	3.017	0.905	0.028	1.915	0.041	0.028	66.2	67.9	67.9	0.166667
64	630	0.0088	0.045	3.062	0.934	0.028	1.956	0.041	0.028	66.8	67.8	67.8	0.166667
65	640	0.0088	0.045	3.107	0.962	0.029	1.997	0.041	0.029	67.4	67.7	67.7	0.166667
66	650	0.0072	0.037	3.144	0.986	0.024	2.030	0.033	0.024	55.6	67.3	67.3	0.166667
67	660	0.0072	0.037	3.180	1.010	0.024	2.064	0.033	0.024	55.9	66.4	66.4	0.166667
68	670	0.0072	0.037	3.217	1.034	0.024	2.097	0.034	0.024	56.3	65.6	65.6	0.166667
69	680	0.0072	0.037	3.254	1.058	0.024	2.131	0.034	0.024	56.7	64.9	64.9	0.166667
70	690	0.0072	0.037	3.291	1.082	0.024	2.164	0.034	0.024	57.0	64.3	64.3	0.166667
71	700	0.0072	0.037	3.327	1.107	0.024	2.198	0.034	0.024	57.4	63.8	63.8	0.166667
72	710	0.0072	0.037	3.364	1.131	0.025	2.232	0.034	0.025	57.7	63.3	63.3	0.166667
73	720	0.0072	0.037	3.401	1.156	0.025	2.266	0.034	0.025	58.0	62.9	62.9	0.166667
74	730	0.0072	0.037	3.437	1.181	0.025	2.299	0.034	0.025	58.4	62.6	62.6	0.166667
75	740	0.0072	0.037	3.474	1.206	0.025	2.333	0.034	0.025	58.7	62.3	62.3	0.166667
76	750	0.0072	0.037	3.511	1.231	0.025	2.367	0.034	0.025	59.0	62.0	62.0	0.166667
77	760	0.0072	0.037	3.548	1.256	0.025	2.401	0.034	0.025	59.3	61.8	61.8	0.166667

78	770	0.0057	0.029	3.577	1.276	0.020	2.428	0.027	0.020	47.2	61.2	61.2	0.166667
79	780	0.0057	0.029	3.606	1.296	0.020	2.455	0.027	0.020	47.4	60.1	60.1	0.166667
80	790	0.0057	0.029	3.635	1.317	0.020	2.482	0.027	0.020	47.6	59.2	59.2	0.166667
81	800	0.0057	0.029	3.664	1.337	0.020	2.509	0.027	0.020	47.8	58.3	58.3	0.166667
82	810	0.0057	0.029	3.693	1.357	0.020	2.536	0.027	0.020	47.9	57.5	57.5	0.166667
83	820	0.0057	0.029	3.722	1.378	0.020	2.563	0.027	0.020	48.1	56.8	56.8	0.166667
84	830	0.0057	0.029	3.751	1.398	0.021	2.590	0.027	0.021	48.3	56.2	56.2	0.166667
85	840	0.0057	0.029	3.780	1.419	0.021	2.617	0.027	0.021	48.5	55.6	55.6	0.166667
86	850	0.0057	0.029	3.809	1.440	0.021	2.644	0.027	0.021	48.6	55.1	55.1	0.166667
87	860	0.0057	0.029	3.838	1.461	0.021	2.672	0.027	0.021	48.8	54.6	54.6	0.166667
88	870	0.0057	0.029	3.867	1.481	0.021	2.699	0.027	0.021	49.0	54.2	54.2	0.166667
89	880	0.0057	0.029	3.896	1.502	0.021	2.726	0.027	0.021	49.1	53.8	53.8	0.166667
90	890	0.0050	0.026	3.922	1.521	0.018	2.750	0.024	0.018	43.2	53.2	53.2	0.166667
91	900	0.0050	0.026	3.947	1.539	0.018	2.774	0.024	0.018	43.4	52.5	52.5	0.166667
92	910	0.0050	0.026	3.973	1.558	0.019	2.798	0.024	0.019	43.5	51.8	51.8	0.166667
93	920	0.0050	0.026	3.998	1.576	0.019	2.822	0.024	0.019	43.6	51.2	51.2	0.166667
94	930	0.0050	0.026	4.024	1.595	0.019	2.845	0.024	0.019	43.7	50.6	50.6	0.166667
95	940	0.0050	0.026	4.049	1.614	0.019	2.869	0.024	0.019	43.9	50.1	50.1	0.166667
96	950	0.0050	0.026	4.075	1.632	0.019	2.893	0.024	0.019	44.0	49.6	49.6	0.166667
97	960	0.0050	0.026	4.100	1.651	0.019	2.917	0.024	0.019	44.1	49.2	49.2	0.166667
98	970	0.0050	0.026	4.126	1.670	0.019	2.941	0.024	0.019	44.2	48.8	48.8	0.166667
99	980	0.0050	0.026	4.151	1.689	0.019	2.965	0.024	0.019	44.3	48.5	48.5	0.166667
100	990	0.0050	0.026	4.177	1.708	0.019	2.989	0.024	0.019	44.4	48.2	48.2	0.166667
101	1,000	0.0050	0.026	4.202	1.727	0.019	3.014	0.024	0.019	44.5	47.9	47.9	0.166667
102	1,010	0.0040	0.020	4.223	1.742	0.015	3.033	0.019	0.015	35.7	47.3	47.3	0.166667
103	1,020	0.0040	0.020	4.243	1.757	0.015	3.052	0.019	0.015	35.8	46.5	46.5	0.166667
104	1,030	0.0040	0.020	4.264	1.772	0.015	3.071	0.019	0.015	35.9	45.7	45.7	0.166667
105	1,040	0.0040	0.020	4.284	1.788	0.015	3.091	0.019	0.015	35.9	44.9	44.9	0.166667
106	1,050	0.0040	0.020	4.304	1.803	0.015	3.110	0.019	0.015	36.0	44.3	44.3	0.166667
107	1,060	0.0040	0.020	4.325	1.818	0.015	3.129	0.019	0.015	36.1	43.6	43.6	0.166667
108	1,070	0.0040	0.020	4.345	1.834	0.015	3.148	0.019	0.015	36.1	43.1	43.1	0.166667
109	1,080	0.0040	0.020	4.366	1.849	0.015	3.168	0.019	0.015	36.2	42.6	42.6	0.166667
110	1,090	0.0040	0.020	4.386	1.865	0.015	3.187	0.019	0.015	36.3	42.1	42.1	0.166667
111	1,100	0.0040	0.020	4.406	1.880	0.015	3.206	0.019	0.015	36.3	41.6	41.6	0.166667
112	1,110	0.0040	0.020	4.427	1.896	0.015	3.226	0.019	0.015	36.4	41.2	41.2	0.166667
113	1,120	0.0040	0.020	4.447	1.911	0.016	3.245	0.019	0.016	36.5	40.9	40.9	0.166667
114	1,130	0.0040	0.020	4.468	1.927	0.016	3.264	0.019	0.016	36.5	40.6	40.6	0.166667
115	1,140	0.0040	0.020	4.488	1.942	0.016	3.284	0.019	0.016	36.6	40.3	40.3	0.166667
116	1,150	0.0040	0.020	4.508	1.958	0.016	3.303	0.019	0.016	36.6	40.0	40.0	0.166667
117	1,160	0.0040	0.020	4.529	1.974	0.016	3.323	0.019	0.016	36.7	39.7	39.7	0.166667
118	1,170	0.0040	0.020	4.549	1.989	0.016	3.342	0.019	0.016	36.8	39.5	39.5	0.166667
119	1,180	0.0040	0.020	4.570	2.005	0.016	3.361	0.019	0.016	36.8	39.3	39.3	0.166667
120	1,190	0.0040	0.020	4.590	2.021	0.016	3.381	0.019	0.016	36.9	39.1	39.1	0.166667
121	1,200	0.0040	0.020	4.610	2.036	0.016	3.400	0.019	0.016	36.9	39.0	39.0	0.166667
122	1,210	0.0040	0.020	4.631	2.052	0.016	3.419	0.019	0.016	37.0	38.8	38.8	0.166667
123	1,220	0.0040	0.020	4.651	2.068	0.016	3.439	0.019	0.016	37.1	38.7	38.7	0.166667
124	1,230	0.0040	0.020	4.672	2.084	0.016	3.458	0.019	0.016	37.1	38.6	38.6	0.166667
125	1,240	0.0040	0.020	4.692	2.100	0.016	3.478	0.019	0.016	37.2	38.5	38.5	0.166667
126	1,250	0.0040	0.020	4.712	2.115	0.016	3.497	0.019	0.016	37.2	38.4	38.4	0.166667
127	1,260	0.0040	0.020	4.733	2.131	0.016	3.517	0.019	0.016	37.3	38.3	38.3	0.166667
128	1,270	0.0040	0.020	4.753	2.147	0.016	3.536	0.019	0.016	37.4	38.2	38.2	0.166667
129	1,280	0.0040	0.020	4.774	2.163	0.016	3.556	0.019	0.016	37.4	38.1	38.1	0.166667
130	1,290	0.0040	0.020	4.794	2.179	0.016	3.575	0.019	0.016	37.5	38.1	38.1	0.166667
131	1,300	0.0040	0.020	4.814	2.195	0.016	3.594	0.019	0.016	37.5	38.0	38.0	0.166667
132	1,310	0.0040	0.020	4.835	2.211	0.016	3.614	0.019	0.016	37.6	38.0	38.0	0.166667
133	1,320	0.0040	0.020	4.855	2.227	0.016	3.633	0.019	0.016	37.6	38.0	38.0	0.166667
134	1,330	0.0040	0.020	4.876	2.243	0.016	3.653	0.019	0.016	37.7	38.0	38.0	0.166667
135	1,340	0.0040	0.020	4.896	2.259	0.016	3.672	0.019	0.016	37.7	37.9	37.9	0.166667
136	1,350	0.0040	0.020	4.916	2.275	0.016	3.692	0.020	0.016	37.8	37.9	37.9	0.166667
137	1,360	0.0040	0.020	4.937	2.291	0.016	3.711	0.020	0.016	37.8	37.9	37.9	0.166667
138	1,370	0.0040	0.020	4.957	2.308	0.016	3.731	0.020	0.016	37.9	37.9	37.9	0.166667
139	1,380	0.0040	0.020	4.978	2.324	0.016	3.750	0.020	0.016	38.0	37.9	37.9	0.166667
140	1,390	0.0040	0.020	4.998	2.340	0.016	3.770	0.020	0.016	38.0	37.9	37.9	0.166667
141	1,400	0.0040	0.020	5.018	2.356	0.016	3.790	0.020	0.016	38.1	37.9	37.9	0.166667
142	1,410	0.0040	0.020	5.039	2.372	0.016	3.809	0.020	0.016	38.1	37.9	37.9	0.166667
143	1,420	0.0040	0.020	5.059	2.389	0.016	3.829	0.020	0.016	38.2	38.0	38.0	0.166667
144	1,430	0.0040	0.020	5.080	2.405	0.016	3.848	0.020	0.016	38.2	38.0	38.0	0.166667
145	1,440	0.0040	0.0204	5.100	2.421	0.016	3.868	0.020	0.016	38.3	38.0	38.0	0.166667
146	Total:	1.0000	5.1000			2.4211		3.8677	2.4211			36.6	0.166667
147							Max:	**72.2**				35.1	0.166667
148							Cumulative Runoff at Period 145	2.21 inches		Start Flow	38.0	33.7	0.166667
149							Unaccounted Runoff	0.22 inches		End Flow	-0.4	32.3	0.166667
150								16,010.89 sec		Flow Dec./per	1.4	30.9	0.166667
151		Column	Description					266.85 min				29.5	0.166667
152		1	Time Increment					26.68 periods				28.0	0.166667
153		2	Time (min)					27 periods				26.6	0.166667
154		3	Type IA Storm Distibution					2.4096 Total Runoff				25.2	0.166667
155		4	Column 3 * Precipitation									23.8	0.166667
156		5	Accumulated Sum of Column 4									22.3	0.166667
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									20.9	0.166667
158		7	Column 6 of the present step - Column 6 of the previous step									19.5	0.166667
159		8	Same as Column 6, except Impervious Area Calculations									18.1	0.166667
160		9	Column 8 of the present step - Column 8 of the previous step									16.6	0.166667
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									15.2	0.166667
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									13.8	0.166667
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									12.4	0.166667
164			(2 * Column 12 of previous step))									10.9	0.166667
165												9.5	0.166667

		Return Period	Duration	
Site: Gorst Creek Upper Watershed		year	hour	
Rainfall:	5.70 in.	50	24	

Time Increment: 10 minutes w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area		CN	S	0.2 S
Pervious Area:	388	acres	74	3.56	0.71
Impervious Area:	0.00	acres	89	1.24	0.25
Total Area:	388.14	acres			

Time of Concentration: 128 minutes, 2.14 hours

Qmax= 90.2 cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.023	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.023	0.068	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.023	0.091	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.023	0.114	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.023	0.137	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.023	0.160	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.023	0.182	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.023	0.205	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.023	0.228	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.029	0.257	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
13	120	0.0050	0.029	0.285	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0
14	130	0.0050	0.029	0.314	0.000	0.000	0.003	0.002	0.000	0.0	0.0	0.0
15	140	0.0050	0.029	0.342	0.000	0.000	0.007	0.003	0.000	0.0	0.0	0.0
16	150	0.0050	0.029	0.371	0.000	0.000	0.011	0.004	0.000	0.0	0.0	0.0
17	160	0.0050	0.029	0.399	0.000	0.000	0.017	0.005	0.000	0.0	0.0	0.0
18	170	0.0060	0.034	0.433	0.000	0.000	0.024	0.008	0.000	0.0	0.0	0.0
19	180	0.0060	0.034	0.467	0.000	0.000	0.033	0.009	0.000	0.0	0.0	0.0
20	190	0.0060	0.034	0.502	0.000	0.000	0.043	0.010	0.000	0.0	0.0	0.0
21	200	0.0060	0.034	0.536	0.000	0.000	0.055	0.011	0.000	0.0	0.0	0.0
22	210	0.0060	0.034	0.570	0.000	0.000	0.067	0.012	0.000	0.0	0.0	0.0
23	220	0.0060	0.034	0.604	0.000	0.000	0.080	0.013	0.000	0.0	0.0	0.0
24	230	0.0070	0.040	0.644	0.000	0.000	0.096	0.016	0.000	0.0	0.0	0.0
25	240	0.0070	0.040	0.684	0.000	0.000	0.114	0.018	0.000	0.0	0.0	0.0
26	250	0.0070	0.040	0.724	0.000	0.000	0.133	0.019	0.000	0.1	0.0	0.0
27	260	0.0070	0.040	0.764	0.001	0.001	0.152	0.020	0.001	1.6	0.1	0.1
28	270	0.0070	0.040	0.804	0.002	0.002	0.173	0.020	0.002	3.6	0.3	0.3
29	280	0.0070	0.040	0.844	0.005	0.002	0.194	0.021	0.002	5.6	0.6	0.6
30	290	0.0082	0.047	0.890	0.008	0.004	0.220	0.026	0.004	8.9	1.1	1.1
31	300	0.0082	0.047	0.937	0.013	0.005	0.247	0.027	0.005	11.4	1.8	1.8
32	310	0.0082	0.047	0.984	0.019	0.006	0.275	0.028	0.006	13.8	2.6	2.6
33	320	0.0082	0.047	1.031	0.026	0.007	0.304	0.029	0.007	16.1	3.5	3.5
34	330	0.0082	0.047	1.077	0.034	0.008	0.334	0.030	0.008	18.3	4.5	4.5
35	340	0.0082	0.047	1.124	0.043	0.009	0.364	0.030	0.009	20.5	5.7	5.7
36	350	0.0095	0.054	1.178	0.054	0.011	0.400	0.036	0.011	26.3	7.0	7.0
37	360	0.0095	0.054	1.232	0.066	0.012	0.437	0.037	0.012	29.0	8.5	8.5
38	370	0.0095	0.054	1.286	0.080	0.013	0.475	0.038	0.013	31.6	10.2	10.2
39	380	0.0095	0.054	1.341	0.094	0.015	0.513	0.039	0.015	34.1	11.9	11.9
40	390	0.0095	0.054	1.395	0.110	0.016	0.553	0.039	0.016	36.4	13.6	13.6
41	400	0.0095	0.054	1.449	0.126	0.016	0.592	0.040	0.016	38.7	15.4	15.4
42	410	0.0134	0.076	1.525	0.151	0.025	0.650	0.057	0.025	58.3	17.9	17.9
43	420	0.0134	0.076	1.602	0.178	0.027	0.708	0.058	0.027	62.5	21.1	21.1
44	430	0.0134	0.076	1.678	0.206	0.028	0.768	0.059	0.028	66.4	24.3	24.3
45	440	0.0180	0.103	1.781	0.246	0.040	0.849	0.081	0.040	95.1	28.6	28.6
46	450	0.0180	0.103	1.883	0.290	0.043	0.932	0.083	0.043	101.4	33.8	33.8
47	460	0.0340	0.194	2.077	0.378	0.088	1.092	0.160	0.088	207.4	42.8	42.8
48	470	0.0540	0.308	2.385	0.534	0.156	1.355	0.262	0.156	367.1	61.2	61.2
49	480	0.0270	0.154	2.539	0.619	0.085	1.489	0.134	0.085	198.8	77.8	77.8
50	490	0.0180	0.103	2.641	0.677	0.059	1.579	0.090	0.059	137.6	84.6	84.6
51	500	0.0134	0.076	2.718	0.722	0.045	1.647	0.068	0.045	104.9	87.3	87.3
52	510	0.0134	0.076	2.794	0.768	0.046	1.715	0.068	0.046	106.9	88.7	88.7
53	520	0.0134	0.076	2.871	0.814	0.046	1.783	0.068	0.046	108.8	90.1	90.1
54	530	0.0088	0.050	2.921	0.845	0.031	1.828	0.045	0.031	72.5	90.2	90.2
55	540	0.0088	0.050	2.971	0.876	0.031	1.873	0.045	0.031	73.3	88.9	88.9
56	550	0.0088	0.050	3.021	0.908	0.032	1.919	0.045	0.032	74.0	87.7	87.7
57	560	0.0088	0.050	3.071	0.939	0.032	1.964	0.045	0.032	74.8	86.7	86.7
58	570	0.0088	0.050	3.121	0.972	0.032	2.010	0.046	0.032	75.5	85.9	85.9
59	580	0.0088	0.050	3.171	1.004	0.032	2.056	0.046	0.032	76.2	85.1	85.1
60	590	0.0088	0.050	3.222	1.037	0.033	2.101	0.046	0.033	76.9	84.5	84.5
61	600	0.0088	0.050	3.272	1.070	0.033	2.147	0.046	0.033	77.6	83.9	83.9
62	610	0.0088	0.050	3.322	1.103	0.033	2.193	0.046	0.033	78.2	83.5	83.5
63	620	0.0088	0.050	3.372	1.137	0.034	2.239	0.046	0.034	78.9	83.1	83.1
64	630	0.0088	0.050	3.422	1.171	0.034	2.285	0.046	0.034	79.5	82.8	82.8
65	640	0.0088	0.050	3.472	1.205	0.034	2.332	0.046	0.034	80.1	82.6	82.6
66	650	0.0072	0.041	3.513	1.233	0.028	2.370	0.038	0.028	66.0	81.9	81.9
67	660	0.0072	0.041	3.555	1.261	0.028	2.408	0.038	0.028	66.4	80.7	80.7
68	670	0.0072	0.041	3.596	1.289	0.028	2.446	0.038	0.028	66.7	79.6	79.6
69	680	0.0072	0.041	3.637	1.318	0.029	2.484	0.038	0.029	67.1	78.7	78.7
70	690	0.0072	0.041	3.678	1.347	0.029	2.522	0.038	0.029	67.5	77.8	77.8
71	700	0.0072	0.041	3.719	1.376	0.029	2.560	0.038	0.029	67.8	77.1	77.1
72	710	0.0072	0.041	3.760	1.405	0.029	2.598	0.038	0.029	68.2	76.4	76.4
73	720	0.0072	0.041	3.801	1.434	0.029	2.637	0.038	0.029	68.5	75.8	75.8

74	730	0.0072	0.041	3.842	1.463	0.029	2.675	0.038	0.029	68.9	75.3	75.3
75	740	0.0072	0.041	3.883	1.493	0.029	2.713	0.038	0.029	69.2	74.8	74.8
76	750	0.0072	0.041	3.924	1.522	0.030	2.752	0.038	0.030	69.5	74.4	74.4
77	760	0.0072	0.041	3.965	1.552	0.030	2.790	0.038	0.030	69.9	74.0	74.0
78	770	0.0057	0.032	3.997	1.576	0.024	2.821	0.030	0.024	55.5	73.2	73.2
79	780	0.0057	0.032	4.030	1.599	0.024	2.851	0.031	0.024	55.7	71.9	71.9
80	790	0.0057	0.032	4.062	1.623	0.024	2.882	0.031	0.024	55.9	70.7	70.7
81	800	0.0057	0.032	4.095	1.647	0.024	2.912	0.031	0.024	56.1	69.6	69.6
82	810	0.0057	0.032	4.127	1.671	0.024	2.943	0.031	0.024	56.3	68.6	68.6
83	820	0.0057	0.032	4.160	1.695	0.024	2.973	0.031	0.024	56.5	67.7	67.7
84	830	0.0057	0.032	4.192	1.719	0.024	3.004	0.031	0.024	56.7	66.8	66.8
85	840	0.0057	0.032	4.225	1.743	0.024	3.035	0.031	0.024	56.9	66.1	66.1
86	850	0.0057	0.032	4.257	1.768	0.024	3.065	0.031	0.024	57.0	65.4	65.4
87	860	0.0057	0.032	4.290	1.792	0.024	3.096	0.031	0.024	57.2	64.8	64.8
88	870	0.0057	0.032	4.322	1.817	0.024	3.127	0.031	0.024	57.4	64.2	64.2
89	880	0.0057	0.032	4.355	1.841	0.025	3.158	0.031	0.025	57.6	63.7	63.7
90	890	0.0050	0.029	4.383	1.863	0.022	3.185	0.027	0.022	50.6	63.0	63.0
91	900	0.0050	0.029	4.412	1.884	0.022	3.212	0.027	0.022	50.8	62.1	62.1
92	910	0.0050	0.029	4.440	1.906	0.022	3.239	0.027	0.022	50.9	61.2	61.2
93	920	0.0050	0.029	4.469	1.928	0.022	3.266	0.027	0.022	51.0	60.4	60.4
94	930	0.0050	0.029	4.497	1.949	0.022	3.293	0.027	0.022	51.1	59.7	59.7
95	940	0.0050	0.029	4.526	1.971	0.022	3.320	0.027	0.022	51.2	59.1	59.1
96	950	0.0050	0.029	4.554	1.993	0.022	3.347	0.027	0.022	51.4	58.5	58.5
97	960	0.0050	0.029	4.583	2.015	0.022	3.374	0.027	0.022	51.5	58.0	58.0
98	970	0.0050	0.029	4.611	2.037	0.022	3.401	0.027	0.022	51.6	57.5	57.5
99	980	0.0050	0.029	4.640	2.059	0.022	3.428	0.027	0.022	51.7	57.1	57.1
100	990	0.0050	0.029	4.668	2.081	0.022	3.455	0.027	0.022	51.8	56.7	56.7
101	1,000	0.0050	0.029	4.697	2.103	0.022	3.482	0.027	0.022	52.0	56.3	56.3
102	1,010	0.0040	0.023	4.720	2.121	0.018	3.504	0.022	0.018	41.6	55.6	55.6
103	1,020	0.0040	0.023	4.742	2.139	0.018	3.526	0.022	0.018	41.7	54.6	54.6
104	1,030	0.0040	0.023	4.765	2.157	0.018	3.548	0.022	0.018	41.8	53.6	53.6
105	1,040	0.0040	0.023	4.788	2.174	0.018	3.569	0.022	0.018	41.9	52.7	52.7
106	1,050	0.0040	0.023	4.811	2.192	0.018	3.591	0.022	0.018	41.9	51.9	51.9
107	1,060	0.0040	0.023	4.834	2.210	0.018	3.613	0.022	0.018	42.0	51.2	51.2
108	1,070	0.0040	0.023	4.856	2.228	0.018	3.635	0.022	0.018	42.1	50.5	50.5
109	1,080	0.0040	0.023	4.879	2.246	0.018	3.656	0.022	0.018	42.1	49.8	49.8
110	1,090	0.0040	0.023	4.902	2.264	0.018	3.678	0.022	0.018	42.2	49.3	49.3
111	1,100	0.0040	0.023	4.925	2.282	0.018	3.700	0.022	0.018	42.3	48.7	48.7
112	1,110	0.0040	0.023	4.948	2.300	0.018	3.722	0.022	0.018	42.3	48.3	48.3
113	1,120	0.0040	0.023	4.970	2.318	0.018	3.744	0.022	0.018	42.4	47.8	47.8
114	1,130	0.0040	0.023	4.993	2.336	0.018	3.765	0.022	0.018	42.5	47.4	47.4
115	1,140	0.0040	0.023	5.016	2.354	0.018	3.787	0.022	0.018	42.5	47.0	47.0
116	1,150	0.0040	0.023	5.039	2.372	0.018	3.809	0.022	0.018	42.6	46.7	46.7
117	1,160	0.0040	0.023	5.062	2.390	0.018	3.831	0.022	0.018	42.7	46.4	46.4
118	1,170	0.0040	0.023	5.084	2.409	0.018	3.853	0.022	0.018	42.7	46.1	46.1
119	1,180	0.0040	0.023	5.107	2.427	0.018	3.875	0.022	0.018	42.8	45.9	45.9
120	1,190	0.0040	0.023	5.130	2.445	0.018	3.897	0.022	0.018	42.8	45.6	45.6
121	1,200	0.0040	0.023	5.153	2.463	0.018	3.918	0.022	0.018	42.9	45.4	45.4
122	1,210	0.0040	0.023	5.176	2.482	0.018	3.940	0.022	0.018	43.0	45.2	45.2
123	1,220	0.0040	0.023	5.198	2.500	0.018	3.962	0.022	0.018	43.0	45.1	45.1
124	1,230	0.0040	0.023	5.221	2.518	0.018	3.984	0.022	0.018	43.1	44.9	44.9
125	1,240	0.0040	0.023	5.244	2.537	0.018	4.006	0.022	0.018	43.1	44.8	44.8
126	1,250	0.0040	0.023	5.267	2.555	0.018	4.028	0.022	0.018	43.2	44.7	44.7
127	1,260	0.0040	0.023	5.290	2.574	0.018	4.050	0.022	0.018	43.3	44.6	44.6
128	1,270	0.0040	0.023	5.312	2.592	0.018	4.072	0.022	0.018	43.3	44.5	44.5
129	1,280	0.0040	0.023	5.335	2.610	0.018	4.094	0.022	0.018	43.4	44.4	44.4
130	1,290	0.0040	0.023	5.358	2.629	0.018	4.116	0.022	0.018	43.4	44.3	44.3
131	1,300	0.0040	0.023	5.381	2.647	0.019	4.137	0.022	0.019	43.5	44.2	44.2
132	1,310	0.0040	0.023	5.404	2.666	0.019	4.159	0.022	0.019	43.5	44.2	44.2
133	1,320	0.0040	0.023	5.426	2.685	0.019	4.181	0.022	0.019	43.6	44.1	44.1
134	1,330	0.0040	0.023	5.449	2.703	0.019	4.203	0.022	0.019	43.6	44.1	44.1
135	1,340	0.0040	0.023	5.472	2.722	0.019	4.225	0.022	0.019	43.7	44.1	44.1
136	1,350	0.0040	0.023	5.495	2.740	0.019	4.247	0.022	0.019	43.8	44.0	44.0
137	1,360	0.0040	0.023	5.518	2.759	0.019	4.269	0.022	0.019	43.8	44.0	44.0
138	1,370	0.0040	0.023	5.540	2.778	0.019	4.291	0.022	0.019	43.9	44.0	44.0
139	1,380	0.0040	0.023	5.563	2.796	0.019	4.313	0.022	0.019	43.9	44.0	44.0
140	1,390	0.0040	0.023	5.586	2.815	0.019	4.335	0.022	0.019	44.0	44.0	44.0
141	1,400	0.0040	0.023	5.609	2.834	0.019	4.357	0.022	0.019	44.0	44.0	44.0
142	1,410	0.0040	0.023	5.632	2.853	0.019	4.379	0.022	0.019	44.1	44.0	44.0
143	1,420	0.0040	0.023	5.654	2.871	0.019	4.401	0.022	0.019	44.1	44.0	44.0
144	1,430	0.0040	0.023	5.677	2.890	0.019	4.423	0.022	0.019	44.2	44.0	44.0
145	1,440	0.0040	0.0228	5.700	2.909	0.019	4.445	0.022	0.019	44.2	44.0	44.0
146	Total:	1.0000	5.7000			2.9091		4.4452	2.9091			42.4
147							Max:	**90.2**				40.7
148							Cumulative Runoff at Period 145	2.66	inches	Start Flow	44.0	39.1
149							Unaccounted Runoff	0.25	inches	End Flow	-0.5	37.4
150								16,009.27	sec	Flow Dec./per	1.6	35.8
151		Column	Description					266.82	min			34.1
152		1	Time Increment					26.68	periods			32.5
153		2	Time (min)					27	periods			30.8
154		3	Type IA Storm Distibution					2.8958	Total Runoff			29.2
155		4	Column 3 * Precipitation									27.5
156		5	Accumulated Sum of Column 4									25.9
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									24.2
158		7	Column 6 of the present step - Column 6 of the previous step									22.6
159		8	Same as Column 6, except Impervious Area Calculations									20.9
160		9	Column 8 of the present step - Column 8 of the previous step									19.3
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									17.6
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									16.0
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									14.3
164			(2 * Column 12 of previous step))									12.7
165												11.0

Site:	Gorst Creek Upper Watershed		Return Period year	Duration hour
	Rainfall:	6.35 in.	100	24

Time Increment: 10 minutes   w: 0.037484

w = Time increment / (2 * Time of Concentration + Time Increment)

	Area	CN	S	0.2 S
Pervious Area:	388 acres	74	3.56	0.71
Impervious Area:	0.00 acres	89	1.24	0.25
Total Area:	388.14 acres			

Time of Concentration: 128 minutes, 2.14 hours

Qmax= 110.8 cfs

Column

1	2	3	4	5	6	7	8	9	10	11	12	13
					PERVIOUS		IMPERVIOUS					
Time Increment	Time (minutes)	Rainfall Distribu-tion (fraction)	Incre-mental Rainfall (inches)	Accum. Rainfall (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Accum. Rainfall (inches)	Increm. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)	Design Flowrate with Tail (cfs)
1	0	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
2	10	0.0040	0.025	0.025	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
3	20	0.0040	0.025	0.051	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
4	30	0.0040	0.025	0.076	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
5	40	0.0040	0.025	0.102	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
6	50	0.0040	0.025	0.127	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
7	60	0.0040	0.025	0.152	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
8	70	0.0040	0.025	0.178	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
9	80	0.0040	0.025	0.203	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
10	90	0.0040	0.025	0.229	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
11	100	0.0040	0.025	0.254	0.000	0.000	0.000	0.000	0.000	0.0	0.0	0.0
12	110	0.0050	0.032	0.286	0.000	0.000	0.001	0.001	0.000	0.0	0.0	0.0
13	120	0.0050	0.032	0.318	0.000	0.000	0.004	0.003	0.000	0.0	0.0	0.0
14	130	0.0050	0.032	0.349	0.000	0.000	0.008	0.004	0.000	0.0	0.0	0.0
15	140	0.0050	0.032	0.381	0.000	0.000	0.013	0.005	0.000	0.0	0.0	0.0
16	150	0.0050	0.032	0.413	0.000	0.000	0.020	0.006	0.000	0.0	0.0	0.0
17	160	0.0050	0.032	0.445	0.000	0.000	0.027	0.008	0.000	0.0	0.0	0.0
18	170	0.0060	0.038	0.483	0.000	0.000	0.038	0.011	0.000	0.0	0.0	0.0
19	180	0.0060	0.038	0.521	0.000	0.000	0.050	0.012	0.000	0.0	0.0	0.0
20	190	0.0060	0.038	0.559	0.000	0.000	0.063	0.013	0.000	0.0	0.0	0.0
21	200	0.0060	0.038	0.597	0.000	0.000	0.077	0.014	0.000	0.0	0.0	0.0
22	210	0.0060	0.038	0.635	0.000	0.000	0.093	0.015	0.000	0.0	0.0	0.0
23	220	0.0060	0.038	0.673	0.000	0.000	0.109	0.017	0.000	0.0	0.0	0.0
24	230	0.0070	0.044	0.718	0.000	0.000	0.130	0.021	0.000	0.0	0.0	0.0
25	240	0.0070	0.044	0.762	0.001	0.001	0.151	0.022	0.001	1.6	0.1	0.1
26	250	0.0070	0.044	0.806	0.002	0.002	0.174	0.023	0.002	4.1	0.3	0.3
27	260	0.0070	0.044	0.851	0.005	0.003	0.198	0.024	0.003	6.5	0.6	0.6
28	270	0.0070	0.044	0.895	0.009	0.004	0.223	0.025	0.004	8.8	1.2	1.2
29	280	0.0070	0.044	0.940	0.014	0.005	0.249	0.026	0.005	11.0	1.8	1.8
30	290	0.0082	0.052	0.992	0.020	0.007	0.280	0.031	0.007	15.7	2.7	2.7
31	300	0.0082	0.052	1.044	0.028	0.008	0.312	0.032	0.008	18.5	3.8	3.8
32	310	0.0082	0.052	1.096	0.037	0.009	0.346	0.033	0.009	21.3	5.0	5.0
33	320	0.0082	0.052	1.148	0.047	0.010	0.380	0.034	0.010	23.9	6.3	6.3
34	330	0.0082	0.052	1.200	0.059	0.011	0.415	0.035	0.011	26.4	7.7	7.7
35	340	0.0082	0.052	1.252	0.071	0.012	0.451	0.036	0.012	28.9	9.2	9.2
36	350	0.0095	0.060	1.313	0.086	0.015	0.493	0.042	0.015	36.4	11.0	11.0
37	360	0.0095	0.060	1.373	0.103	0.017	0.537	0.043	0.017	39.4	13.0	13.0
38	370	0.0095	0.060	1.433	0.121	0.018	0.581	0.044	0.018	42.3	15.1	15.1
39	380	0.0095	0.060	1.494	0.140	0.019	0.626	0.045	0.019	45.0	17.2	17.2
40	390	0.0095	0.060	1.554	0.161	0.020	0.671	0.046	0.020	47.7	19.4	19.4
41	400	0.0095	0.060	1.614	0.182	0.021	0.718	0.046	0.021	50.2	21.6	21.6
42	410	0.0134	0.085	1.699	0.214	0.032	0.784	0.067	0.032	74.9	24.7	24.7
43	420	0.0134	0.085	1.784	0.248	0.034	0.852	0.068	0.034	79.5	28.6	28.6
44	430	0.0134	0.085	1.869	0.284	0.036	0.921	0.069	0.036	83.9	32.6	32.6
45	440	0.0180	0.114	1.984	0.334	0.051	1.014	0.094	0.051	119.1	37.8	37.8
46	450	0.0180	0.114	2.098	0.388	0.054	1.110	0.095	0.054	126.0	44.1	44.1
47	460	0.0340	0.216	2.314	0.497	0.109	1.293	0.184	0.109	255.1	55.1	55.1
48	470	0.0540	0.343	2.657	0.686	0.190	1.593	0.299	0.190	445.8	77.2	77.2
49	480	0.0270	0.171	2.828	0.788	0.102	1.745	0.153	0.102	239.2	97.1	97.1
50	490	0.0180	0.114	2.943	0.858	0.070	1.848	0.103	0.070	164.8	105.0	105.0
51	500	0.0134	0.085	3.028	0.912	0.053	1.925	0.077	0.053	125.3	108.0	108.0
52	510	0.0134	0.085	3.113	0.966	0.054	2.002	0.077	0.054	127.4	109.4	109.4
53	520	0.0134	0.085	3.198	1.021	0.055	2.080	0.078	0.055	129.5	110.8	110.8
54	530	0.0088	0.056	3.254	1.058	0.037	2.131	0.051	0.037	86.1	110.6	110.6
55	540	0.0088	0.056	3.310	1.095	0.037	2.182	0.051	0.037	86.9	108.8	108.8
56	550	0.0088	0.056	3.366	1.132	0.037	2.233	0.051	0.037	87.7	107.2	107.2
57	560	0.0088	0.056	3.421	1.170	0.038	2.285	0.051	0.038	88.5	105.7	105.7
58	570	0.0088	0.056	3.477	1.208	0.038	2.336	0.052	0.038	89.2	104.5	104.5
59	580	0.0088	0.056	3.533	1.246	0.038	2.388	0.052	0.038	90.0	103.4	103.4
60	590	0.0088	0.056	3.589	1.285	0.039	2.440	0.052	0.039	90.7	102.4	102.4
61	600	0.0088	0.056	3.645	1.324	0.039	2.491	0.052	0.039	91.4	101.5	101.5
62	610	0.0088	0.056	3.701	1.363	0.039	2.543	0.052	0.039	92.1	100.8	100.8
63	620	0.0088	0.056	3.757	1.402	0.039	2.595	0.052	0.039	92.7	100.2	100.2
64	630	0.0088	0.056	3.813	1.442	0.040	2.648	0.052	0.040	93.4	99.6	99.6
65	640	0.0088	0.056	3.868	1.482	0.040	2.700	0.052	0.040	94.0	99.2	99.2
66	650	0.0072	0.046	3.914	1.515	0.033	2.743	0.043	0.033	77.4	98.2	98.2
67	660	0.0072	0.046	3.960	1.548	0.033	2.785	0.043	0.033	77.8	96.6	96.6
68	670	0.0072	0.046	4.006	1.582	0.033	2.828	0.043	0.033	78.2	95.2	95.2
69	680	0.0072	0.046	4.051	1.615	0.033	2.871	0.043	0.033	78.6	94.0	94.0
70	690	0.0072	0.046	4.097	1.649	0.034	2.914	0.043	0.034	78.9	92.8	92.8
71	700	0.0072	0.046	4.143	1.682	0.034	2.957	0.043	0.034	79.3	91.8	91.8
72	710	0.0072	0.046	4.188	1.716	0.034	3.000	0.043	0.034	79.7	90.9	90.9
73	720	0.0072	0.046	4.234	1.750	0.034	3.044	0.043	0.034	80.0	90.0	90.0

74	730	0.0072	0.046	4.280	1.785	0.034	3.087	0.043	0.034	80.4	89.3	89.3
75	740	0.0072	0.046	4.326	1.819	0.034	3.130	0.043	0.034	80.7	88.7	88.7
76	750	0.0072	0.046	4.371	1.854	0.035	3.173	0.043	0.035	81.1	88.1	88.1
77	760	0.0072	0.046	4.417	1.888	0.035	3.216	0.043	0.035	81.4	87.6	87.6
78	770	0.0057	0.036	4.453	1.916	0.028	3.251	0.034	0.028	64.7	86.5	86.5
79	780	0.0057	0.036	4.489	1.943	0.028	3.285	0.034	0.028	64.9	84.8	84.8
80	790	0.0057	0.036	4.526	1.971	0.028	3.320	0.034	0.028	65.1	83.4	83.4
81	800	0.0057	0.036	4.562	1.999	0.028	3.354	0.034	0.028	65.3	82.0	82.0
82	810	0.0057	0.036	4.598	2.027	0.028	3.388	0.034	0.028	65.5	80.7	80.7
83	820	0.0057	0.036	4.634	2.055	0.028	3.423	0.034	0.028	65.6	79.6	79.6
84	830	0.0057	0.036	4.670	2.083	0.028	3.457	0.034	0.028	65.8	78.6	78.6
85	840	0.0057	0.036	4.707	2.111	0.028	3.492	0.034	0.028	66.0	77.6	77.6
86	850	0.0057	0.036	4.743	2.139	0.028	3.526	0.035	0.028	66.2	76.8	76.8
87	860	0.0057	0.036	4.779	2.167	0.028	3.561	0.035	0.028	66.4	76.0	76.0
88	870	0.0057	0.036	4.815	2.196	0.028	3.595	0.035	0.028	66.5	75.3	75.3
89	880	0.0057	0.036	4.851	2.224	0.028	3.630	0.035	0.028	66.7	74.6	74.6
90	890	0.0050	0.032	4.883	2.249	0.025	3.660	0.030	0.025	58.7	73.7	73.7
91	900	0.0050	0.032	4.915	2.274	0.025	3.691	0.030	0.025	58.8	72.6	72.6
92	910	0.0050	0.032	4.947	2.299	0.025	3.721	0.030	0.025	58.9	71.6	71.6
93	920	0.0050	0.032	4.978	2.324	0.025	3.751	0.030	0.025	59.1	70.6	70.6
94	930	0.0050	0.032	5.010	2.350	0.025	3.782	0.030	0.025	59.2	69.8	69.8
95	940	0.0050	0.032	5.042	2.375	0.025	3.812	0.030	0.025	59.3	69.0	69.0
96	950	0.0050	0.032	5.074	2.400	0.025	3.842	0.030	0.025	59.4	68.2	68.2
97	960	0.0050	0.032	5.105	2.425	0.025	3.873	0.030	0.025	59.5	67.6	67.6
98	970	0.0050	0.032	5.137	2.451	0.025	3.903	0.030	0.025	59.7	67.0	67.0
99	980	0.0050	0.032	5.169	2.476	0.025	3.934	0.030	0.025	59.8	66.4	66.4
100	990	0.0050	0.032	5.201	2.502	0.026	3.964	0.030	0.026	59.9	66.0	66.0
101	1,000	0.0050	0.032	5.232	2.527	0.026	3.995	0.030	0.026	60.0	65.5	65.5
102	1,010	0.0040	0.025	5.258	2.548	0.020	4.019	0.024	0.020	48.1	64.6	64.6
103	1,020	0.0040	0.025	5.283	2.568	0.021	4.044	0.024	0.021	48.2	63.4	63.4
104	1,030	0.0040	0.025	5.309	2.589	0.021	4.068	0.024	0.021	48.2	62.3	62.3
105	1,040	0.0040	0.025	5.334	2.609	0.021	4.092	0.024	0.021	48.3	61.2	61.2
106	1,050	0.0040	0.025	5.359	2.630	0.021	4.117	0.024	0.021	48.4	60.3	60.3
107	1,060	0.0040	0.025	5.385	2.651	0.021	4.141	0.024	0.021	48.4	59.4	59.4
108	1,070	0.0040	0.025	5.410	2.671	0.021	4.166	0.024	0.021	48.5	58.5	58.5
109	1,080	0.0040	0.025	5.436	2.692	0.021	4.190	0.024	0.021	48.6	57.8	57.8
110	1,090	0.0040	0.025	5.461	2.713	0.021	4.215	0.024	0.021	48.7	57.1	57.1
111	1,100	0.0040	0.025	5.486	2.734	0.021	4.239	0.024	0.021	48.7	56.5	56.5
112	1,110	0.0040	0.025	5.512	2.754	0.021	4.264	0.024	0.021	48.8	55.9	55.9
113	1,120	0.0040	0.025	5.537	2.775	0.021	4.288	0.024	0.021	48.9	55.4	55.4
114	1,130	0.0040	0.025	5.563	2.796	0.021	4.313	0.024	0.021	48.9	54.9	54.9
115	1,140	0.0040	0.025	5.588	2.817	0.021	4.337	0.024	0.021	49.0	54.4	54.4
116	1,150	0.0040	0.025	5.613	2.838	0.021	4.362	0.025	0.021	49.0	54.0	54.0
117	1,160	0.0040	0.025	5.639	2.859	0.021	4.386	0.025	0.021	49.1	53.7	53.7
118	1,170	0.0040	0.025	5.664	2.880	0.021	4.411	0.025	0.021	49.2	53.3	53.3
119	1,180	0.0040	0.025	5.690	2.900	0.021	4.435	0.025	0.021	49.2	53.0	53.0
120	1,190	0.0040	0.025	5.715	2.921	0.021	4.460	0.025	0.021	49.3	52.7	52.7
121	1,200	0.0040	0.025	5.740	2.943	0.021	4.484	0.025	0.021	49.4	52.5	52.5
122	1,210	0.0040	0.025	5.766	2.964	0.021	4.509	0.025	0.021	49.4	52.2	52.2
123	1,220	0.0040	0.025	5.791	2.985	0.021	4.533	0.025	0.021	49.5	52.0	52.0
124	1,230	0.0040	0.025	5.817	3.006	0.021	4.558	0.025	0.021	49.5	51.8	51.8
125	1,240	0.0040	0.025	5.842	3.027	0.021	4.582	0.025	0.021	49.6	51.7	51.7
126	1,250	0.0040	0.025	5.867	3.048	0.021	4.607	0.025	0.021	49.7	51.5	51.5
127	1,260	0.0040	0.025	5.893	3.069	0.021	4.632	0.025	0.021	49.7	51.4	51.4
128	1,270	0.0040	0.025	5.918	3.090	0.021	4.656	0.025	0.021	49.8	51.3	51.3
129	1,280	0.0040	0.025	5.944	3.112	0.021	4.681	0.025	0.021	49.8	51.1	51.1
130	1,290	0.0040	0.025	5.969	3.133	0.021	4.705	0.025	0.021	49.9	51.1	51.1
131	1,300	0.0040	0.025	5.994	3.154	0.021	4.730	0.025	0.021	49.9	51.0	51.0
132	1,310	0.0040	0.025	6.020	3.175	0.021	4.755	0.025	0.021	50.0	50.9	50.9
133	1,320	0.0040	0.025	6.045	3.197	0.021	4.779	0.025	0.021	50.0	50.8	50.8
134	1,330	0.0040	0.025	6.071	3.218	0.021	4.804	0.025	0.021	50.1	50.8	50.8
135	1,340	0.0040	0.025	6.096	3.239	0.021	4.828	0.025	0.021	50.2	50.7	50.7
136	1,350	0.0040	0.025	6.121	3.261	0.021	4.853	0.025	0.021	50.2	50.7	50.7
137	1,360	0.0040	0.025	6.147	3.282	0.021	4.878	0.025	0.021	50.3	50.6	50.6
138	1,370	0.0040	0.025	6.172	3.304	0.021	4.902	0.025	0.021	50.3	50.6	50.6
139	1,380	0.0040	0.025	6.198	3.325	0.021	4.927	0.025	0.021	50.4	50.6	50.6
140	1,390	0.0040	0.025	6.223	3.347	0.021	4.952	0.025	0.021	50.4	50.6	50.6
141	1,400	0.0040	0.025	6.248	3.368	0.021	4.976	0.025	0.021	50.5	50.6	50.6
142	1,410	0.0040	0.025	6.274	3.390	0.022	5.001	0.025	0.022	50.5	50.6	50.6
143	1,420	0.0040	0.025	6.299	3.411	0.022	5.026	0.025	0.022	50.6	50.6	50.6
144	1,430	0.0040	0.025	6.325	3.433	0.022	5.050	0.025	0.022	50.6	50.6	50.6
145	1,440	0.0040	0.0254	6.350	3.454	0.022	5.075	0.025	0.022	50.7	50.6	50.6
146	Total:	1.0000	6.3500			3.4542		5.0750	3.4542			48.7
147							Max:	**110.8**				46.8
148							Cumulative Runoff at Period 145	3.17	inches	Start Flow	50.6	44.9
149							Unaccounted Runoff	0.29	inches	End Flow	-0.6	43.0
150								16,007.85	sec	Flow Dec./per	1.9	41.1
151		Column	Description					266.80	min			39.2
152		1	Time Increment					26.68	periods			37.3
153		2	Time (min)					27	periods			35.4
154		3	Type IA Storm Distibution					3.4389	Total Runoff			33.5
155		4	Column 3 * Precipitation									31.6
156		5	Accumulated Sum of Column 4									29.7
157		6	If P<0.2S then 0, else (Column 5 - 0.2 * S)/(Column 5 +0.8 * S)									27.8
158		7	Column 6 of the present step - Column 6 of the previous step									25.9
159		8	Same as Column 6, except Impervious Area Calculations									24.0
160		9	Column 8 of the present step - Column 8 of the previous step									22.1
161		10	PerviousArea/TotalArea*Column 7 + ImperviousArea/TotalArea*Column 9									20.2
162		11	(60.5 * Column 10 * TotalArea)/Time Increment									18.4
163		12	Column 12 of previous step + w * ((Column 11 of previous step + column 11 of present step) -									16.5
164			(2 * Column 12 of previous step))									14.6
165												12.7

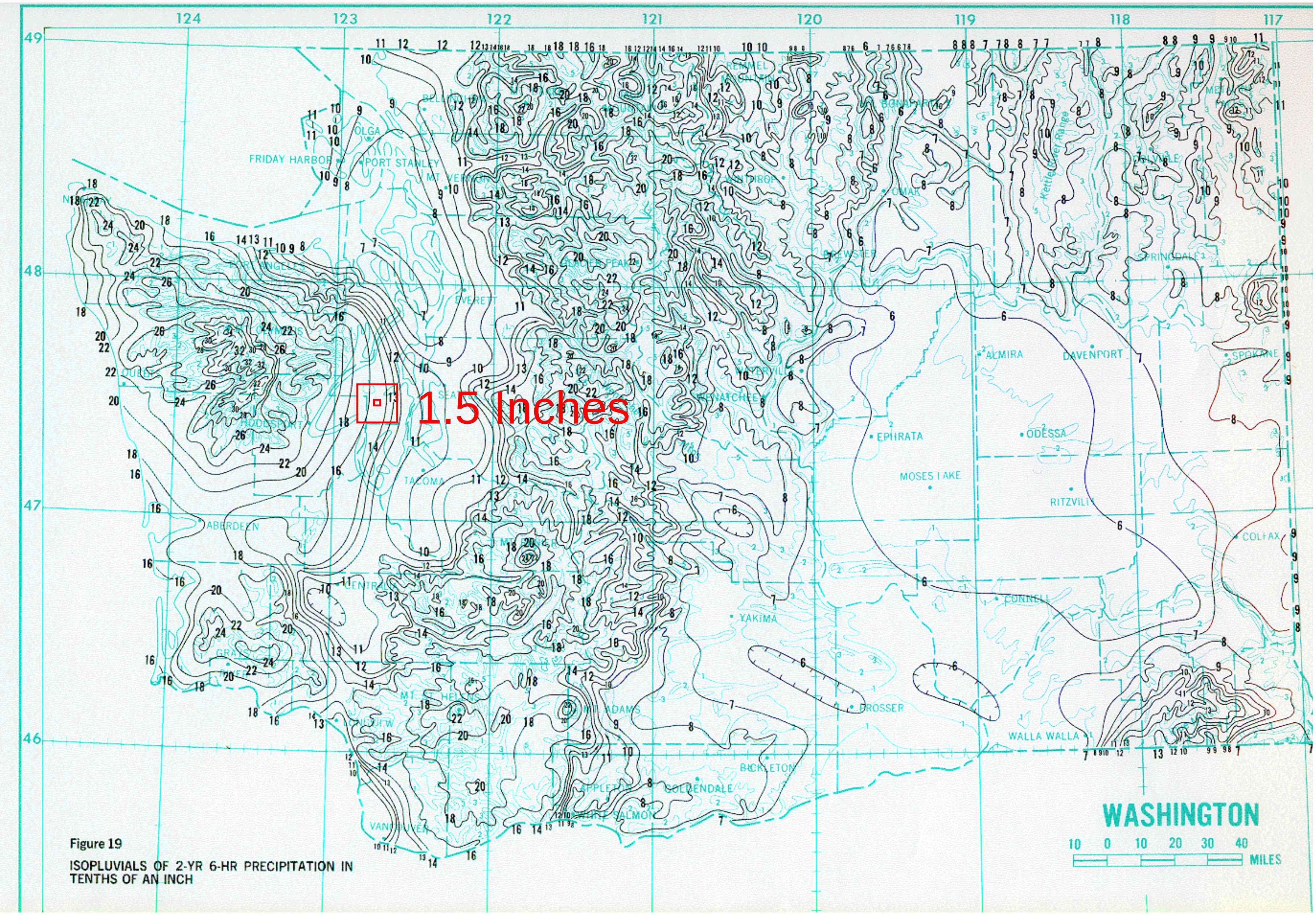

Figure 19

ISOPLUVIALS OF 2-YR 6-HR PRECIPITATION IN TENTHS OF AN INCH

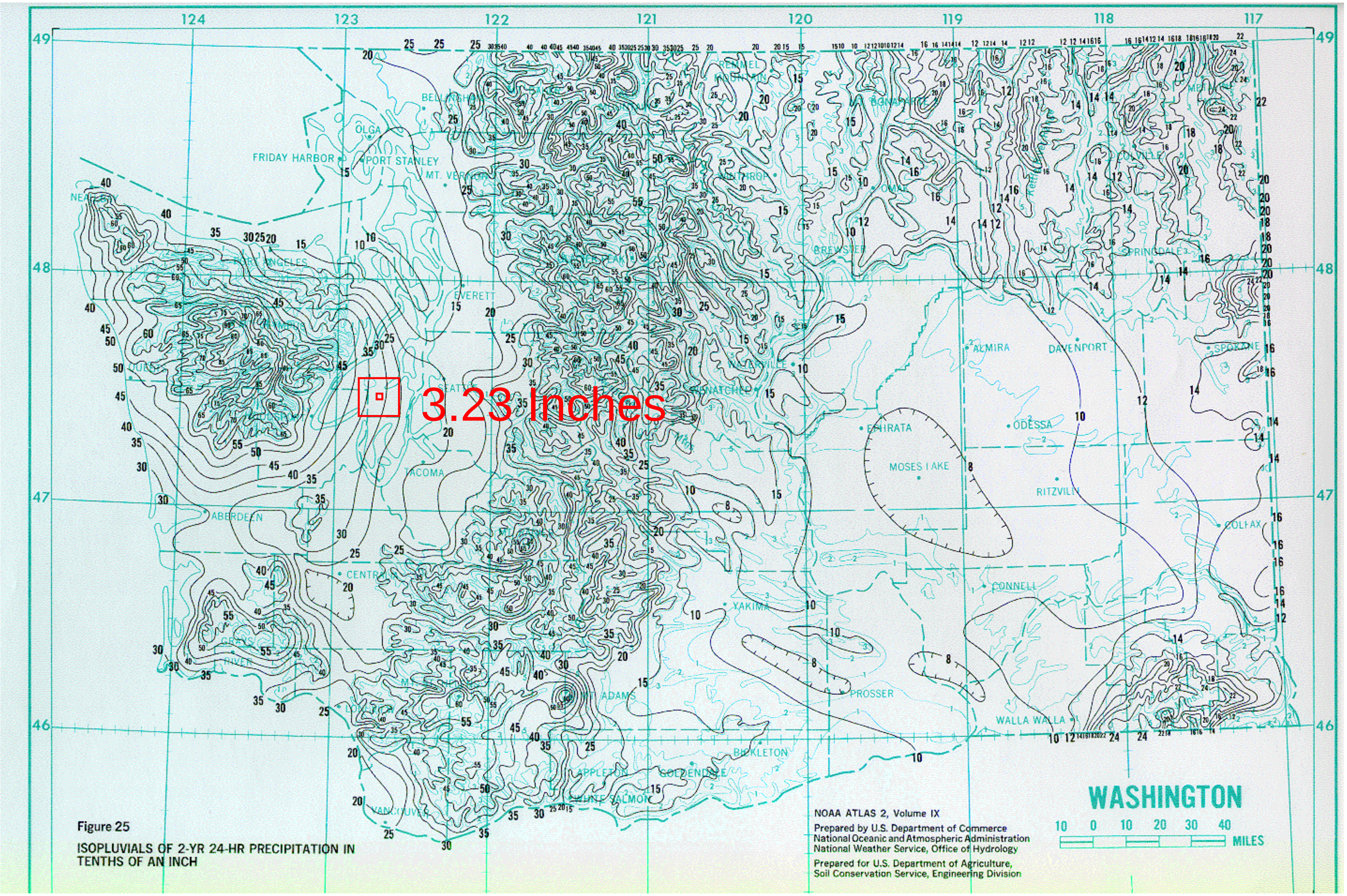

Figure 25

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

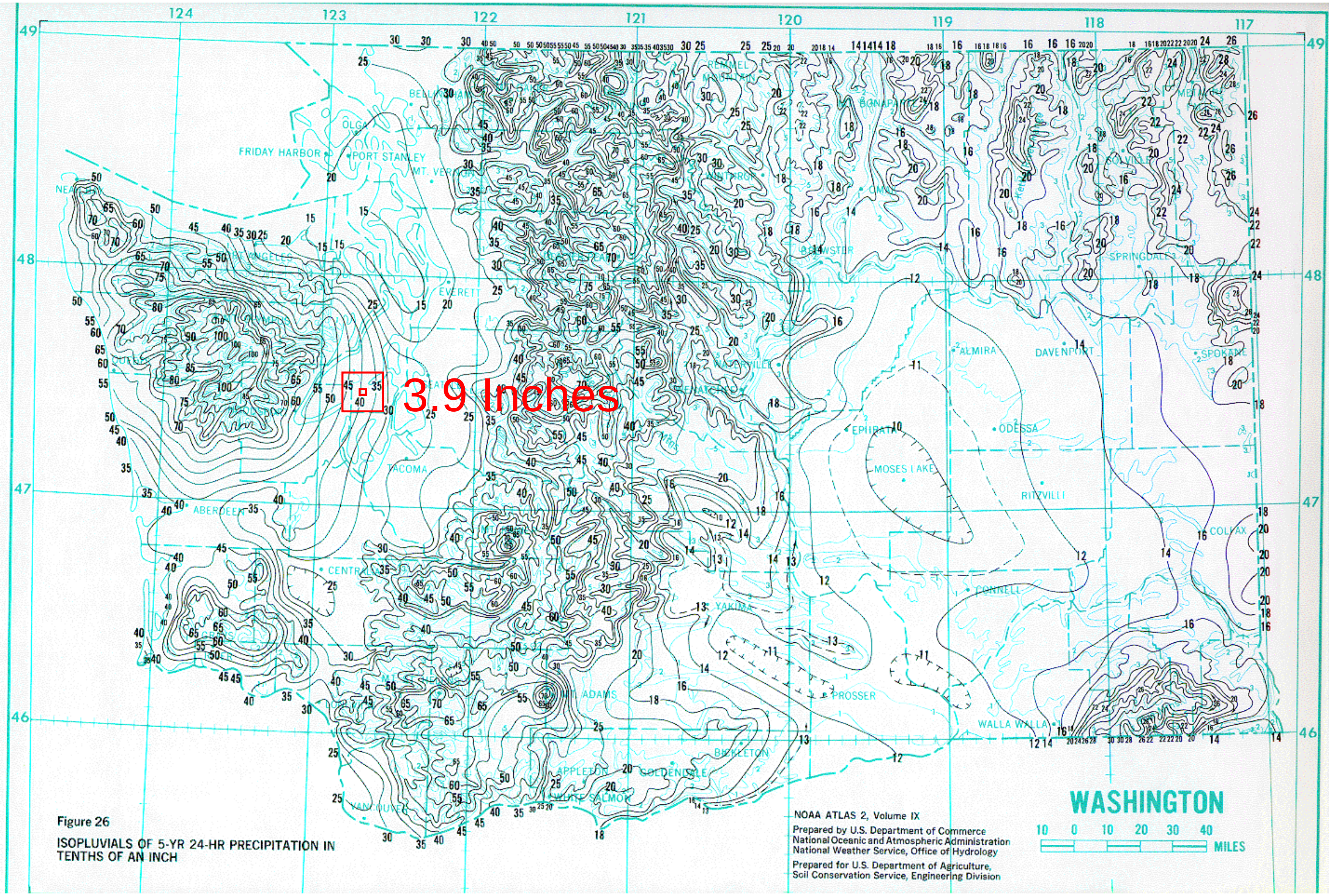

Figure 26

ISOPLUVIALS OF 5-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

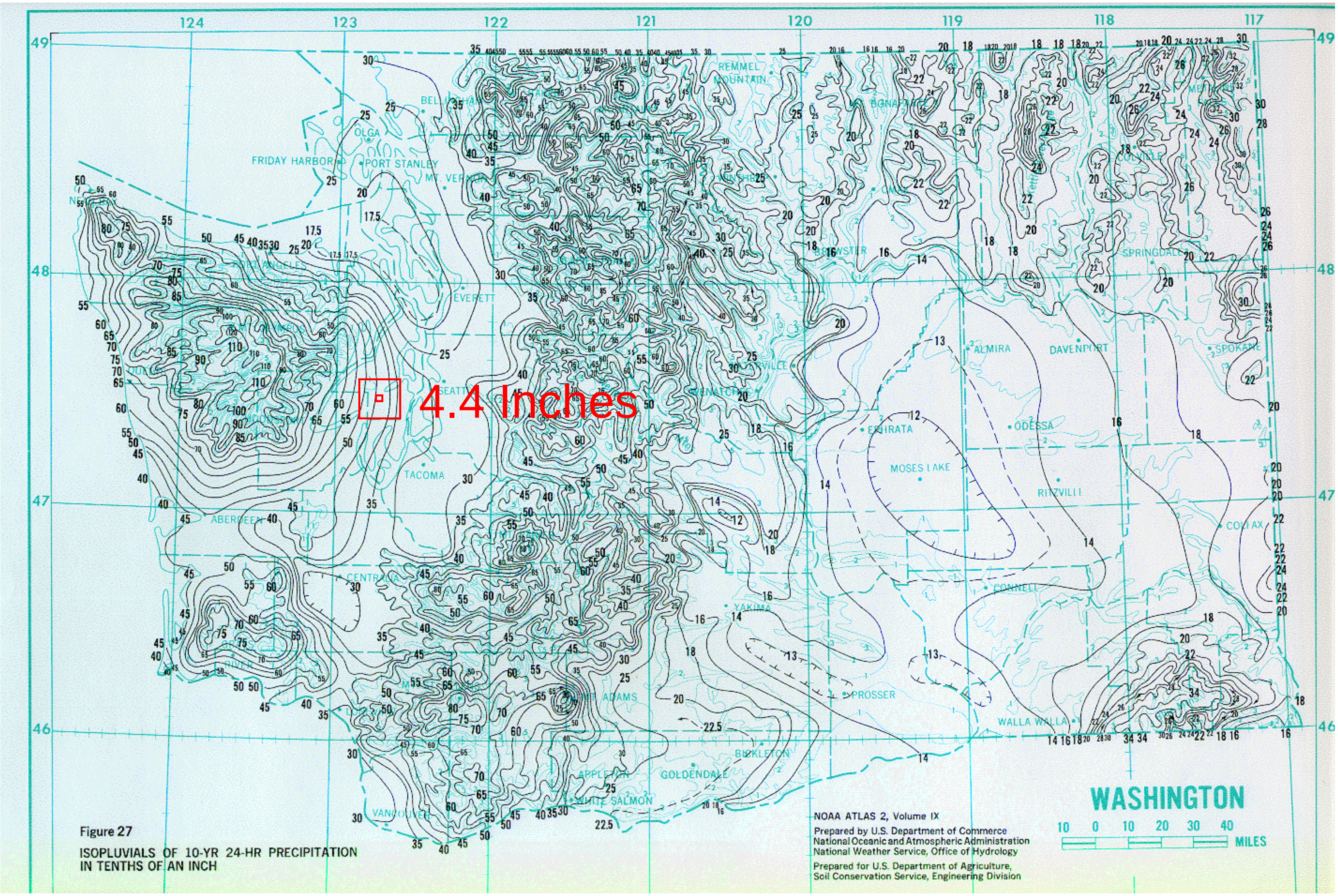

Figure 27
ISOPLUVIALS OF 10-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

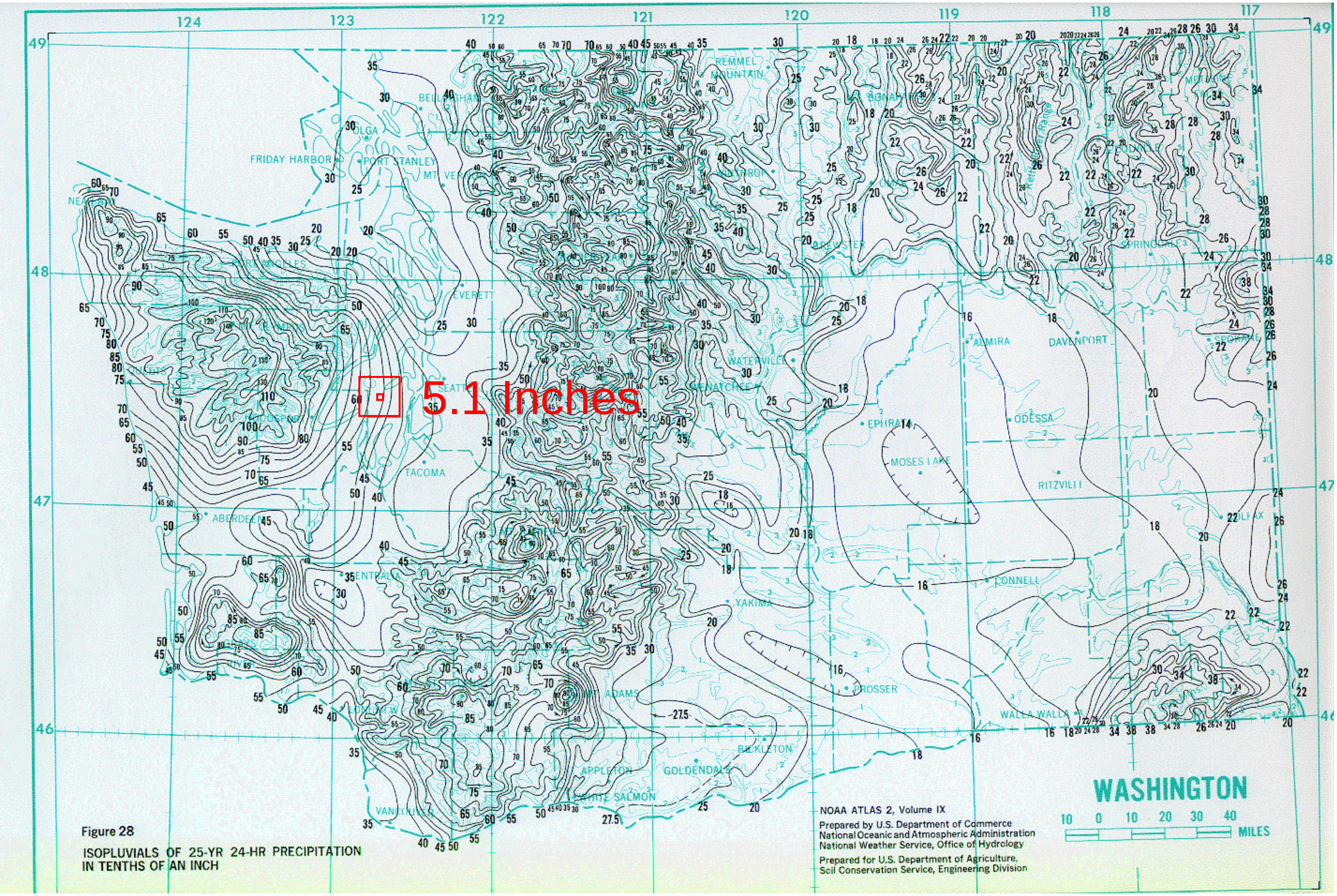

Figure 28

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

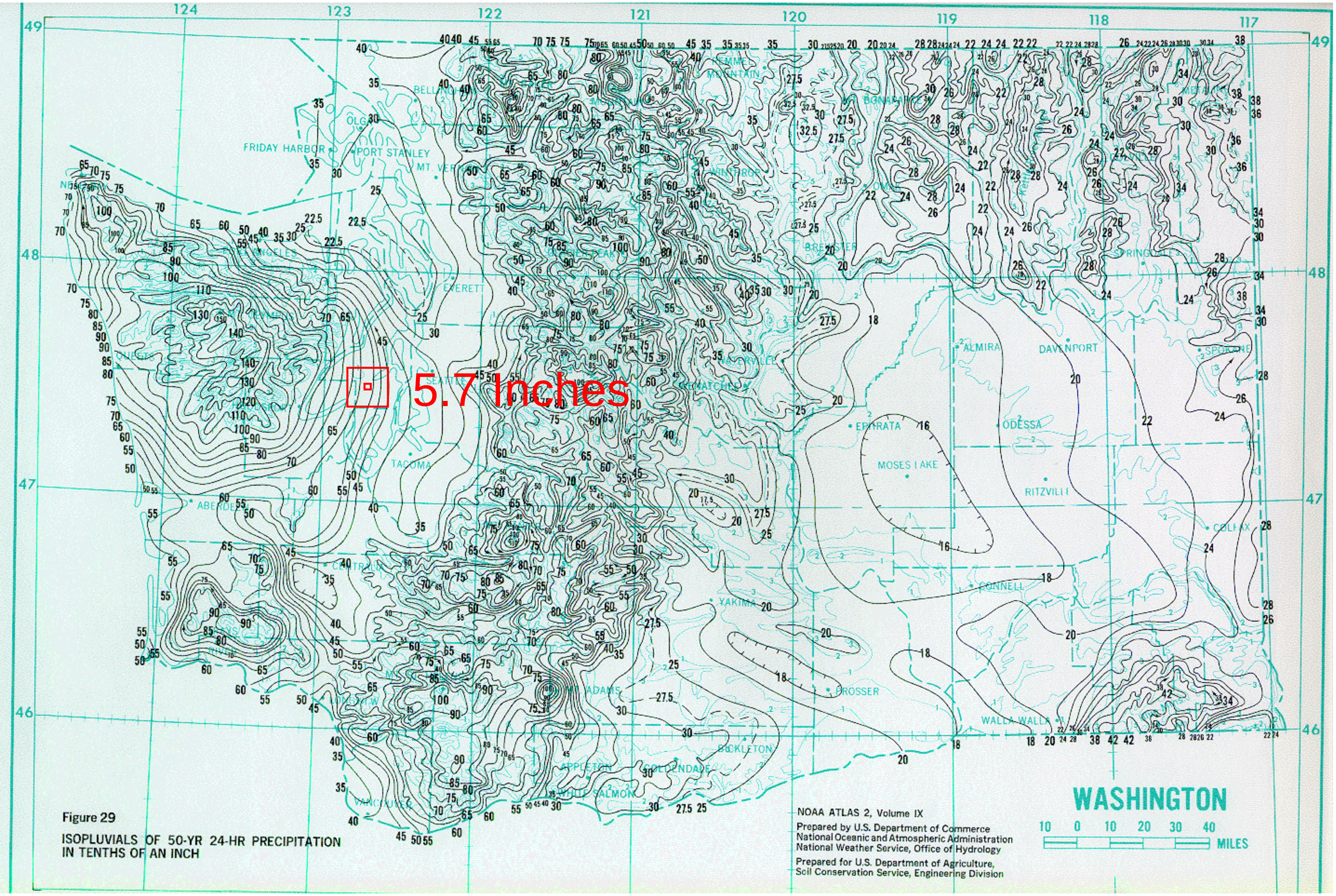

Figure 29

ISOPLUVIALS OF 50-YR 24-HR PRECIPITATION IN TENTHS OF AN INCH

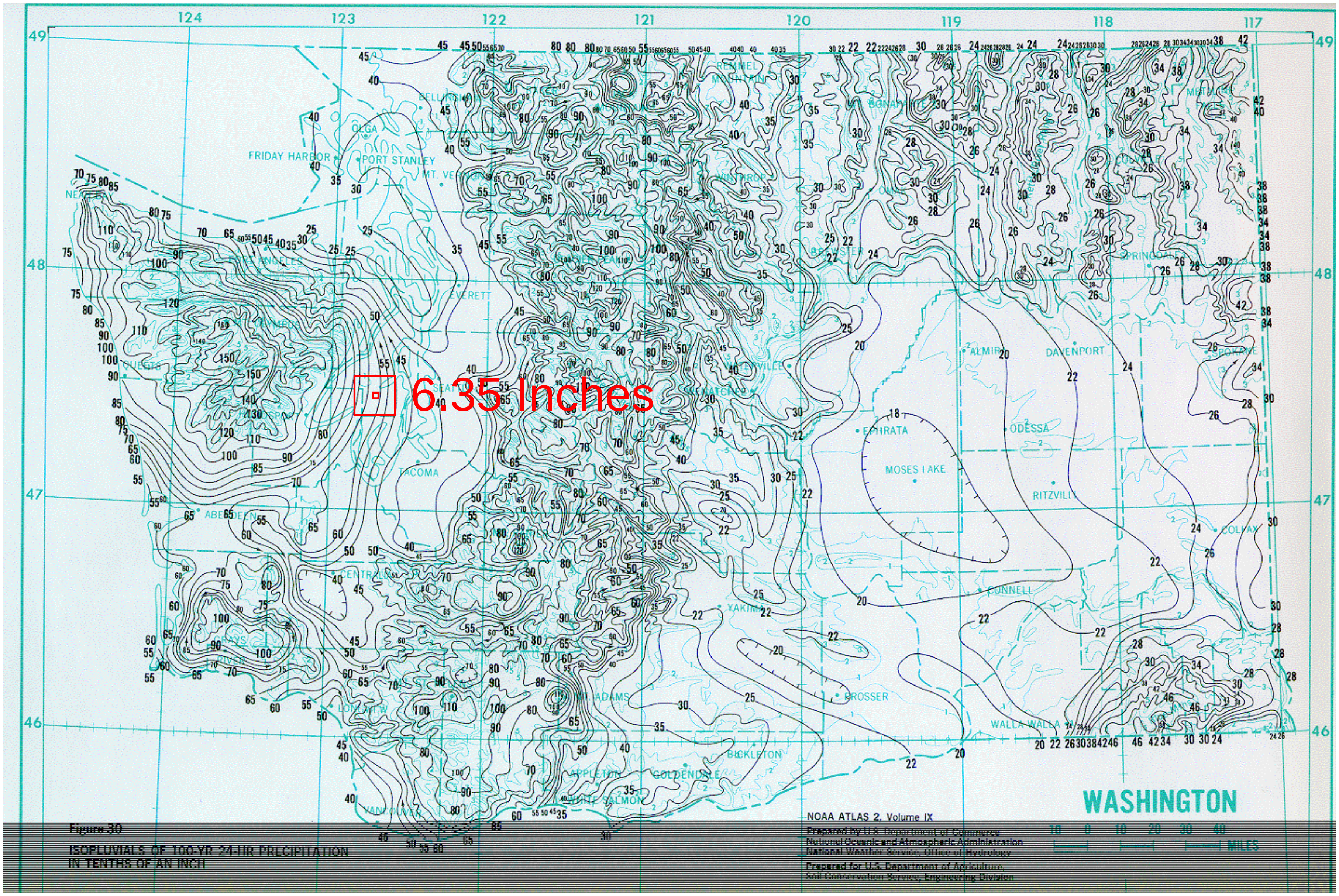

Figure 30

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

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ecology and environment, inc.

Design Memorandum

Date:	6/13/2016
To:	Design File
From:	Tyler Chatriand, P.E.
Reviewer:	Tom Campbell, P.E.
Subject:	**Bremerton Auto Wrecking Landfill Conceptual Stream Hydraulic Analysis and Sediment Transport Analysis**

PROFESSIONAL ENGINEER CERTIFICATION

Gorst Creek/ Bremerton Auto Wrecking Landfill Conceptual Stream Hydraulic Analysis and Sediment Transport Analysis
Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

I hereby certify that this Habitat Restoration Plan for the Bremerton Auto Wrecking Landfill Site in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE:

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 6/13/2016

THOMAS C. CAMPBELL
STATE OF WASHINGTON
51283
REGISTERED
PROFESSIONAL ENGINEER

Objective

This memorandum summarizes the hydraulic analysis that was performed to simulate flow mechanics of the conceptual stream design through the Bremerton Auto Wrecking Landfill site (the site). A one-dimensional integrated hydraulic and sediment transport model was developed for the existing and proposed stream channel and floodplain using the U.S. Army Corps of Engineers' River Analysis System (HEC-RAS 5.0). The model encompasses approximately 1,600 feet of Gorst Creek extending south (upstream) from a location north of State Route (S.R.) 3 through the existing stream channel located southeast of the landfill.

Steady State Model

A steady state hydraulic analysis was conducted to provide estimates for water surface elevations and stream hydraulic parameters under various flow conditions. The following sections provide a discussion on the various model inputs and assumptions used to execute the hydraulic model.

Hydrology

Hydrologic inputs were obtained from the 90% Conceptual Design submittal (see Appendix D of the 90% Work Plan and Conceptual Design); those hydrology values are presented below in Table 1. In addition to the peak design flow rates, base flow was modeled at both a low and high flow range of 2 cubic feet per second (cfs) and 8 cfs, respectively.

Table 1. Predicted peak flow rates for the Gorst Creek Restoration Reach

Storm Event	Predicted Peak Flow (cfs)
2-year / 6 hour	4.3
2-year / 24 hour	26.4
5-year / 24 hour	40.0
10-year / 24 hour	52.4
25-year / 24 hour	72.2
50-year / 24 hour	90.2
100-year / 24 hour	110.8

Channel Alignment and Geometry

Basic geometry data such as cross-sections, bank stations, stream lengths, and floodplain flow lengths were extracted from a triangular irregular network (TIN) that was developed using topographic survey data collected in October 2011 and May 2016. The geometry information was prepared using a AutoCAD Civil 3D 2014, which is able to export the information into HEC-RAS. This base information was supplemented with field surveys of cross sections, structure elevations and dimensions, and topographic survey data to provide additional detailed ground elevation information. A reference reach field survey was conducted by Ecology & Environment in November 2015 to assess representative stream conditions from reference reaches in the vicinity of the project site, including upper Gorst Creek above the landfill site and two locations on Parish Creek (see Appendix E of the 60% Work Plan and Conceptual Design).

The conceptual channel alignment through the landfill site was designed to mimic the stream characteristics observed during the field survey and generally follows the estimated culvert path under the landfill, which is assumed to parallel the original stream channel. The conceptual profile provides an average sinuosity of 1.1 and an average channel slope of 3.8%. Cross sectional geometry was modeled to simulate the parameters developed during the reference reach survey, which includes a trapezoidal channel with an average top width of 14 feet, average bank height of 1.6 feet, and 1:1 side slopes. The conceptual channel alignment, profile, and cross-sections are shown on Sheets C-4, C-5, and C-6 of the design drawings, respectively.

Manning Roughness

Manning's *n* values for the model were determined by field reconnaissance and engineering judgment. A roughness value of 0.16 is used for the existing overbank areas upstream of the restoration reach, which contain dense brush, trees, and deadfall. The overbanks in the restoration reach are modeled with a lower roughness value of 0.1 because it is assumed that vegetation may not be well established during the first few years following construction. A roughness value of 0.07 is used for the channel along the reach. The channel is mostly composed of course gravel and cobbles indicative of a lower roughness value of approximately 0.05; however, the channel is littered with large woody debris (LWD) and brush that form natural weirs and log drops that drastically increase the roughness, which is typical of steep mountain streams. The restoration design calls for the placement of LWD and hook vanes to maintain increased roughness in the channel.

Hydraulic Structures

One hydraulic structure is included in the study reach at the downstream end of the landfill. The structure is a 160-ft long 4-ft concrete box culvert that conveys stream flows underneath S.R. 3. The inlet and outlet of the culvert are equipped with 30 degree flared wingwalls. Entrance and exit loss coefficients are assumed to be 0.3 and 0.1, respectively, and manning's n for top and bottom is 0.011. Upstream and downstream road embankments were measured at 1.3:1 and 1.75:1 using topographic survey data.

Boundary Conditions

The HEC-RAS steady state model was executed under the assumption of subcritical flow. Normal depth was used as the boundary condition and the channel slope of the downstream reach was determined from topographic data (0.025 feet/foot).

Ineffective Flow Areas

Ineffective flow areas were added to the model cross sections in low lying areas or depressions outside the main channel where velocities are negligible. This prevents the model from allowing water to flow through these areas until the water surface overtops the barrier.

Steady State Model Results

In summary, the main channel is expected to convey the estimated low and high base flows without overtopping the banks, while maintaining an average water surface depth of 0.42 feet during the high base flow. Peak flows as a result of 24-hour design storm events are expected to reach bankfull width and slightly overtop banks at varying capacities throughout the reach, although water surface depths are not predicted to exceed 1.8 feet. The water surface elevations of the low and high base flows and peak flows for the 2-year, 10-year, 25-year, and 100-year flood events are plotted across each cross section in Attachment A. Detailed model output tables are included in Attachment B.

Sediment Transport Model

A sediment transport model was developed for the project reach during the 60% design submittal and remains unchanged for the 90% submittal since the overall geometry and design has not undergone significant change. The results of the sediment transport model are discussed in this section. Additionally, scour calculations for long-term degradation, general scour, and bend scour were evaluated at a central location (cross section 11+00) in the restoration reach. The scour analysis is discussed in Appendix B of the 90% submittal.

The sediment transport model was developed for the project reach from the upper limits of the steady state model to the downstream end of the landfill (S.R. 3 and the box culvert were excluded). HEC-RAS was utilized to model the sediment transport capacity of the conceptual stream to help predict potential physical changes in the stream bed and to aid in stable channel design. The model solves the sediment continuity equation for each cross section in the study reach, which assumes that the change of sediment load in a control volume is equal to the difference between the inflowing and outflowing loads. Bed sediments from upper Gorst Creek were characterized during the November 2015 reference reach survey.

Dozens of transport functions have been developed to predict sediment transport potential. The Meyer-Peter Muller equation was used in this exercise as the transport function due to its widespread use and success in applications with sediments in the gravel range. Sorting and armoring of the stream bed was characterized in the model using the default Exner 5 algorithm, while sediment fall velocity was computed using the Ruby method. Abbreviated discussion on the various transport function principles can be found in Chapter 13 of the *HEC RAS 4.1 Reference Manual.*

In order to execute the sediment computations, river hydraulics must first be determined using quasi-unsteady flow assumptions, which allows the program to approximate a continuous hydrograph with a series of discrete steady flow profiles that are subdivided into shorter time increments. This model simulates two flow conditions: the high base flow of 8 cfs and the 2-year design flow rate of 26.4 cfs, both over a 24-hour duration with 1 hour time increments for sediment transport computations. Final deposition and erosion masses are computed for each control volume, which is then added or subtracted by changing the cross section station and elevation points. The result is a prediction in bed changes throughout the study reach.

Sediment Transport Model Results

High Base Flow Condition

The sediment transport model indicates that the stream bed is stable during the high base flow condition, resulting in only minor changes in channel invert elevations that are typically less than 0.1 feet throughout the restoration reach. Channel velocities range from 3.25 feet per second (fps) in the upper portion of the site to 2.3 fps in the lower reach. Bed shear stress values range from 0.6 to 1.1 pounds per square foot (lb/sq. ft), with an average stress value of 0.8 lb/sq. ft within the landfill reach. The results of the model indicate that the stream bed is likely to experience negligible bed changes during the high base flow condition.

High Frequency High Flow Condition

The model also suggests that relatively minimal bed changes are predicted during an extended high frequency (2-year), high flow event. During this event, channel velocities in the reach above the landfill range from 4.5 to 4.9 fps and gradually decrease with channel slope in the restored portion through the landfill, resulting in velocities ranging from 3.6 to 4.1 fps. Bed shear stress values range from 1.1 to 2.9 lb/sq. ft, with an average shear stress of 1.5 through the landfill reach. The results of the model indicate that the stream bed is likely to experience minor aggradation and deposition throughout the reach during an extended high flow event and is representative of a dynamic steep mountain stream.

Conclusions

A one-dimensional integrated hydraulic and sediment transport model was developed to compute hydraulic parameters for the stream restoration design of Gorst Creek through the Bremerton Auto Wrecking Landfill. Proposed channel dimensions were designed from a reference reach survey and were used in conjunction with topographic survey data to establish the overall geometric configuration of the model. A steady state hydraulic model was performed to determine hydraulic parameters such as water surface elevations and flow velocities under various flow conditions for the design. A sediment transport model was completed in order to check the design for stability under high base flow and high frequency, high duration flow events.

In summary, the main channel is expected to convey the estimated low and high base flows without overtopping the banks, while maintaining an average water surface depth of 0.42 feet during the high base flow of 8 cfs. Peak flows as a result of 24-hour design storm events are expected to reach the overbanks at varying capacities, although water surface depths are not predicted to exceed 1.8 feet.

The sediment analysis indicates that the stream bed is not likely to experience significant changes under the high base flow condition or during the 2-year peak flow rate over a duration of 24 hours. Bed changes are nearly negligible under base flow conditions while minor aggradation and deposition is likely to occur throughout the reach during an extended high flow event. These changes are representative of a dynamic, steep mountain stream and are components of a healthy stream corridor developing changing patterns of pools and riffles.

References

[1] Ecology and Environment, Inc. (E & E), Bremerton Auto Wrecking Landfill 60% Hydrologic Analysis, January 2015

[2] E & E, 60% Restoration Design, January 2015

[3] United States Army Corps of Engineers (USACE), HEC-GeoRAS, Version 4.2.92, 2008

[4] USACE, *HEC-RAS*, Version 4.1.0, March, 2008

[5] USACE, *HEC-RAS User's Manual*, Version 4.1.0, March, 2008

[6] USACE, *HEC-RAS Reference Manual*, Version 4.1.0, March, 2008

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Attachment A

HEC RAS CROSS SECTIONS

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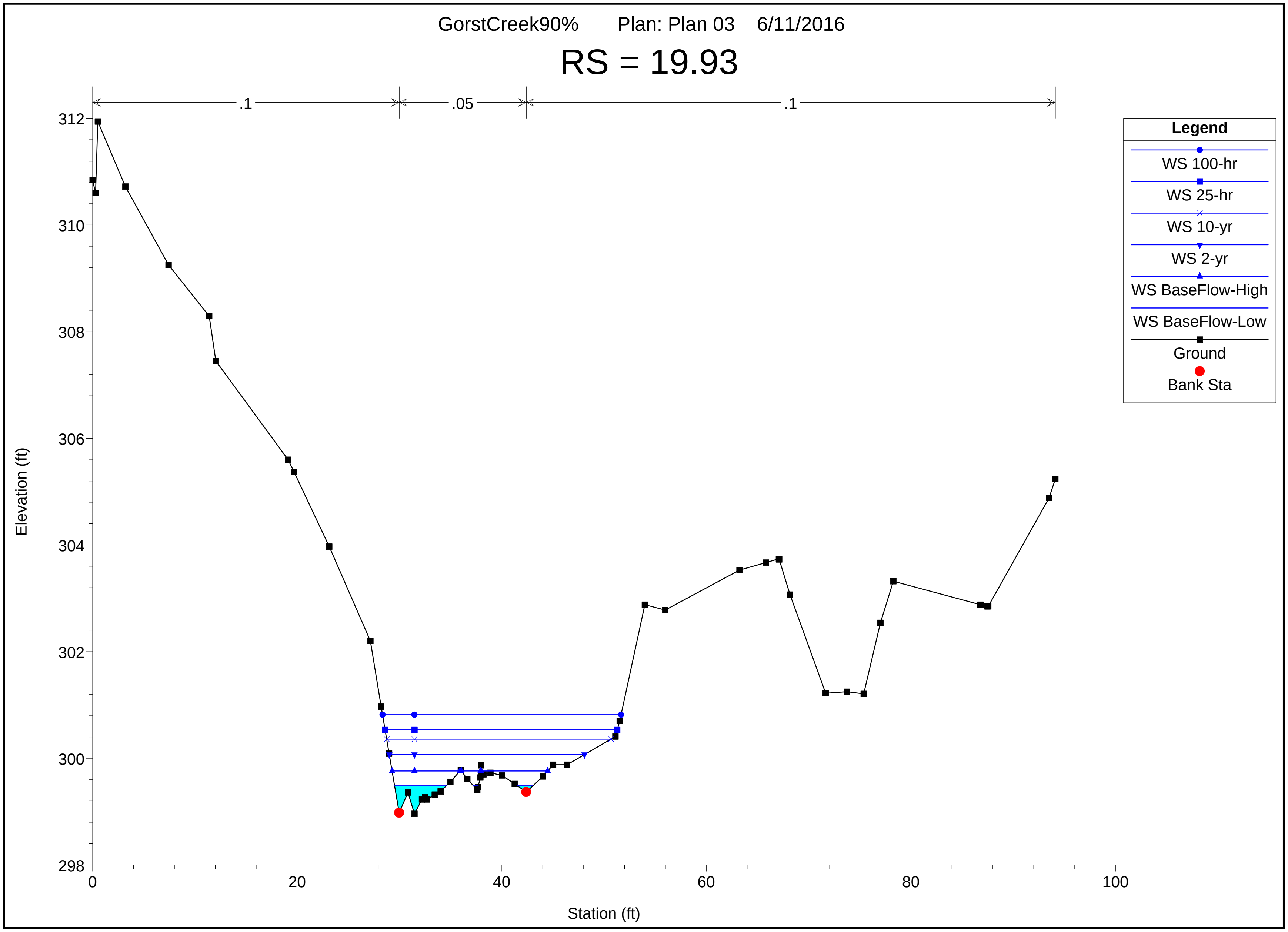

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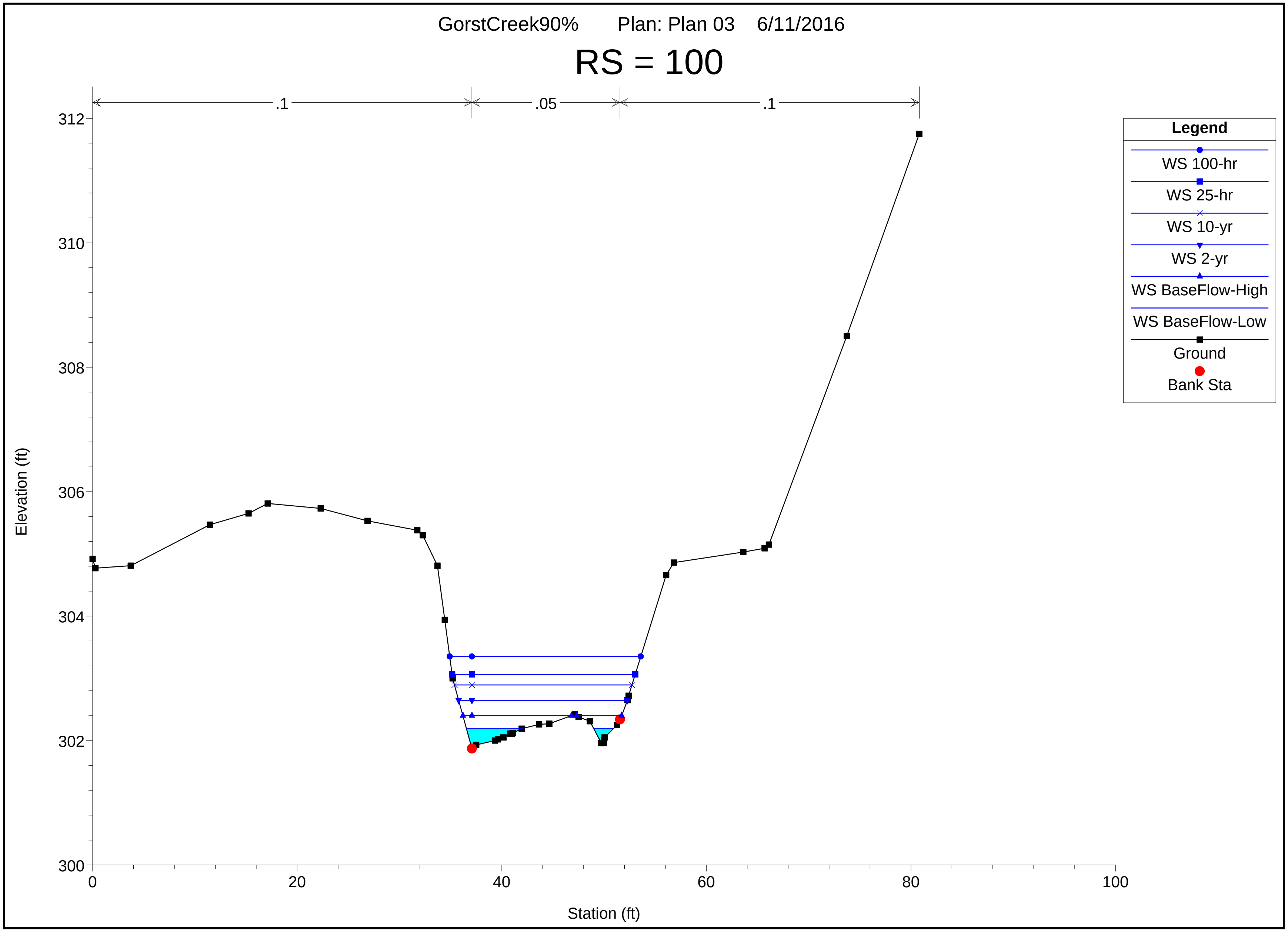
RS = 19.93
.1
.05
.1
312
310
308
306
304
302
300
298
Elevation (ft)
0
20
40
60
80
100
Station (ft)
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta



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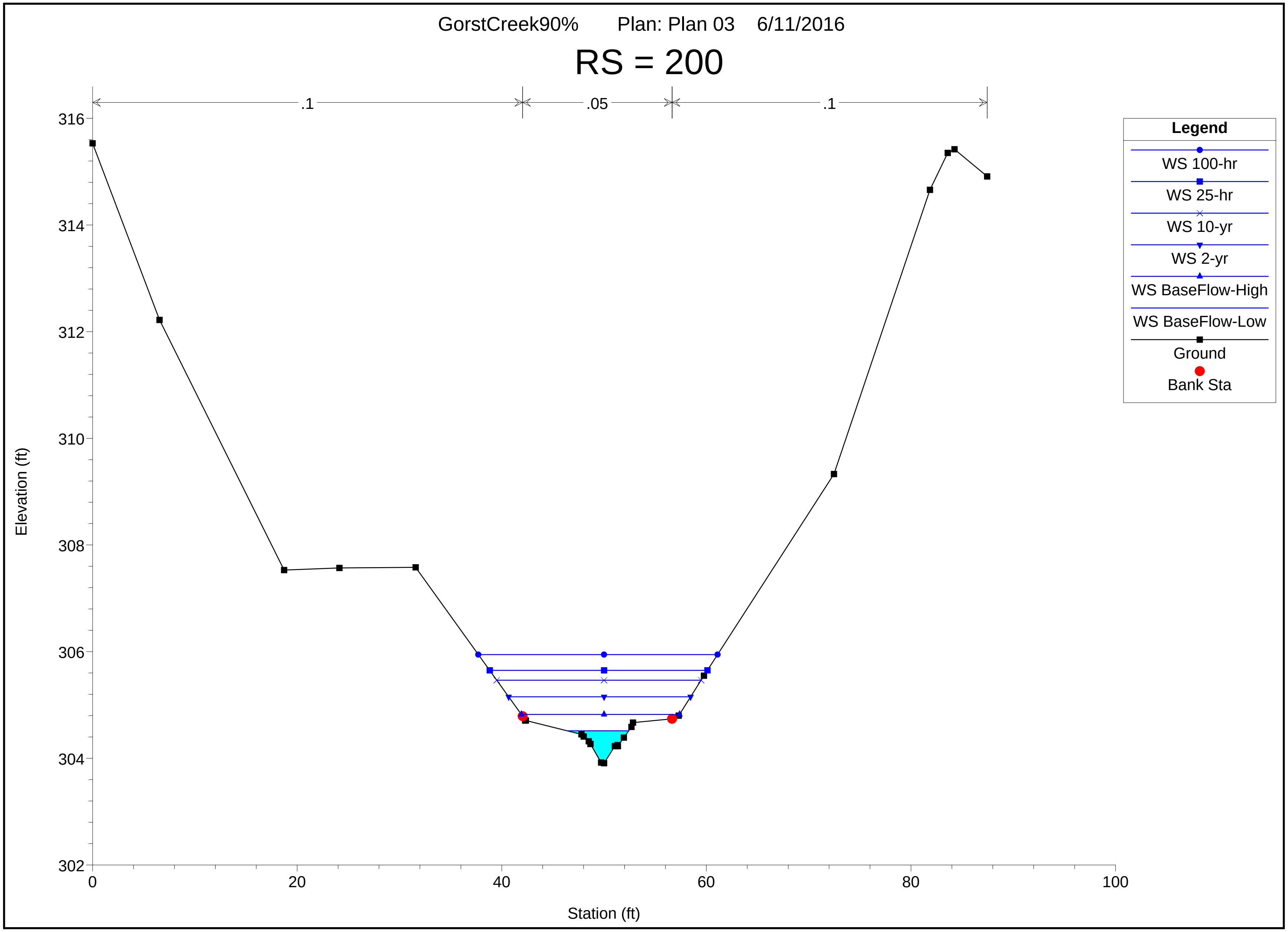
.1
.05
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
312
310
308
306
304
302
300
0
20
40
60
80
100
Station (ft)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.05
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Legend
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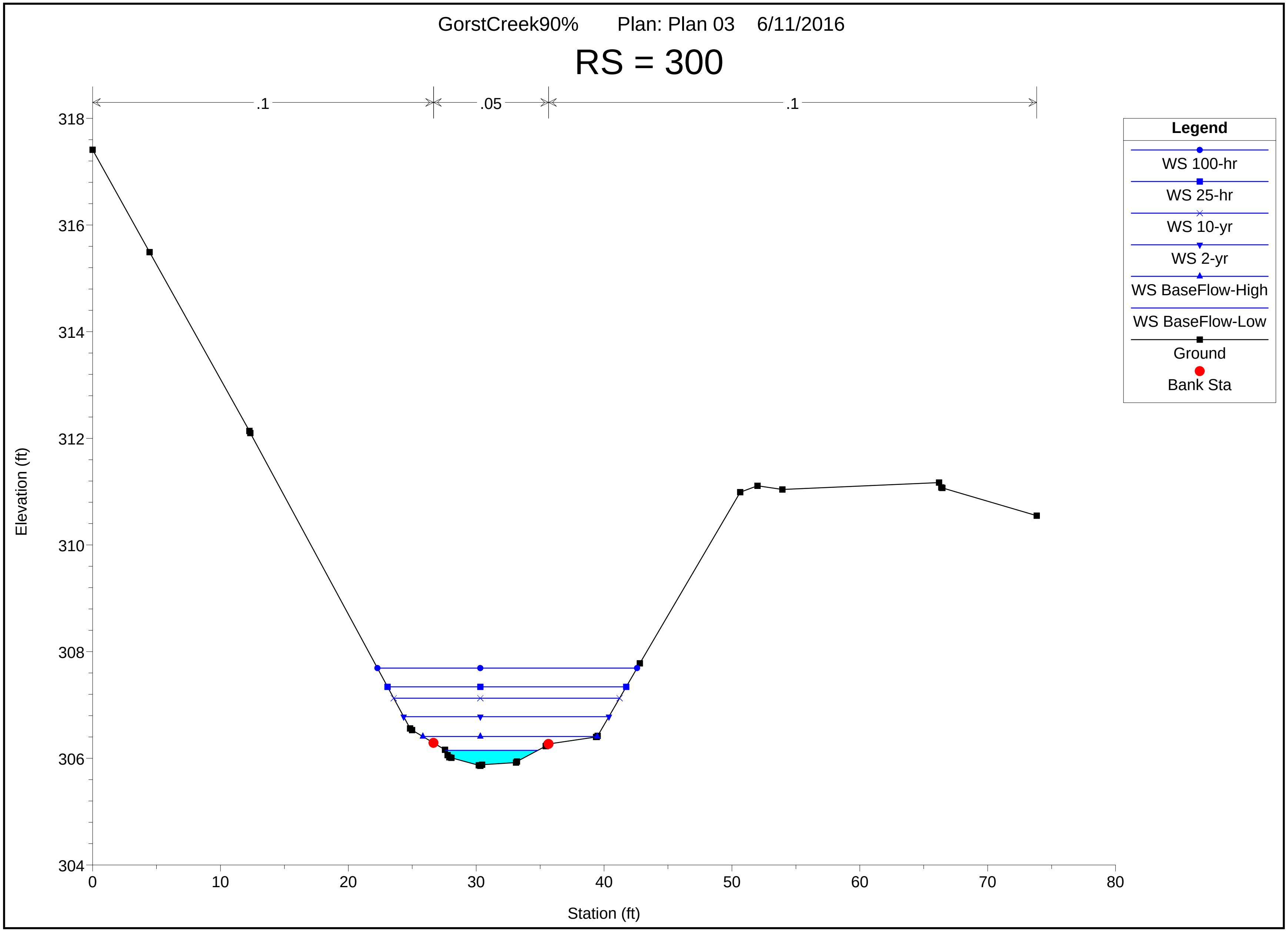
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
316
314
312
310
308
306
304
302
Station (ft)
0
20
40
60
80
100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.05
.1
Legend
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WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
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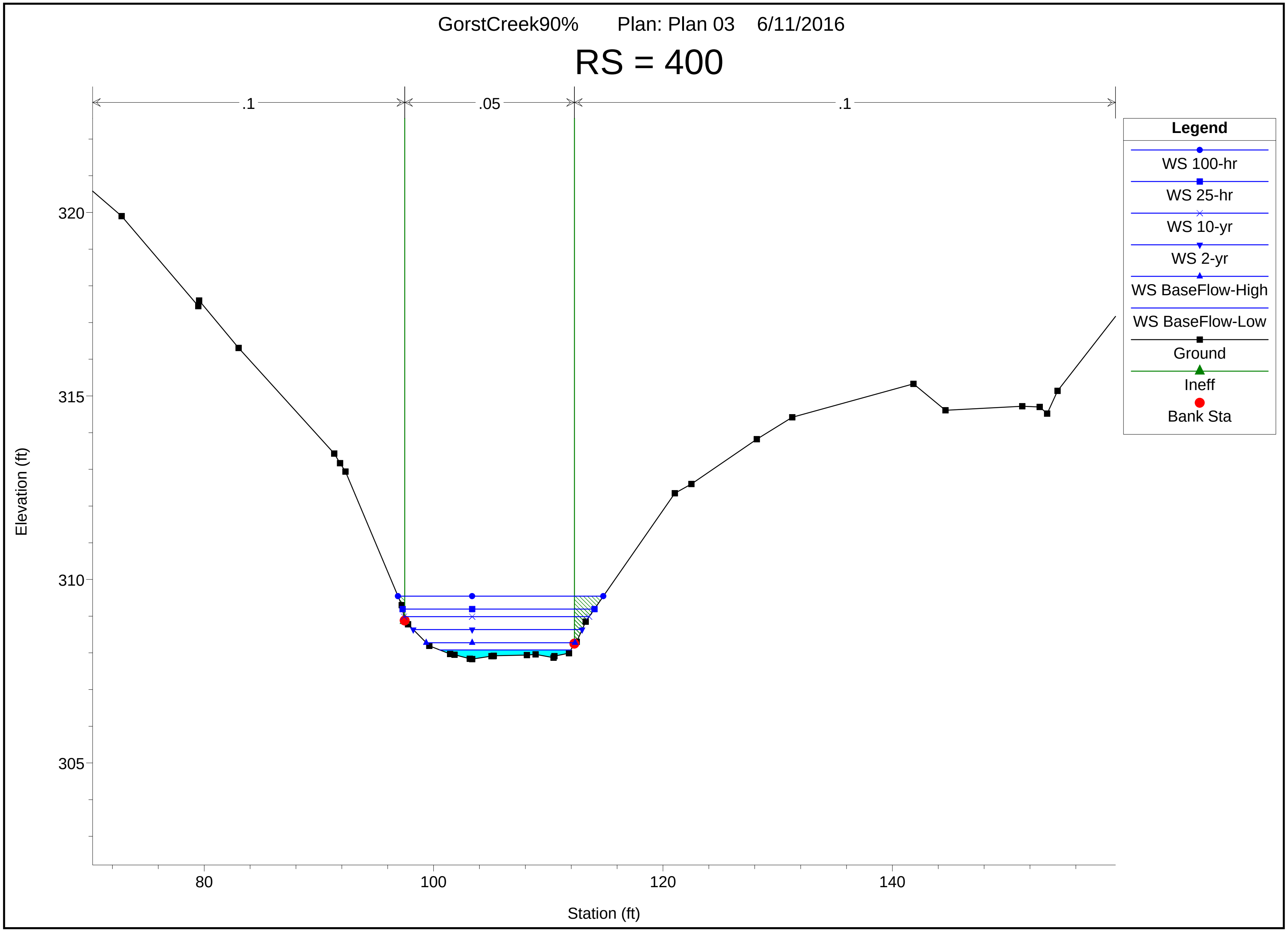
316
314
312
310
308
306
304
0
10
20
30
40
50
60
70
80
Station (ft)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.05
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Legend
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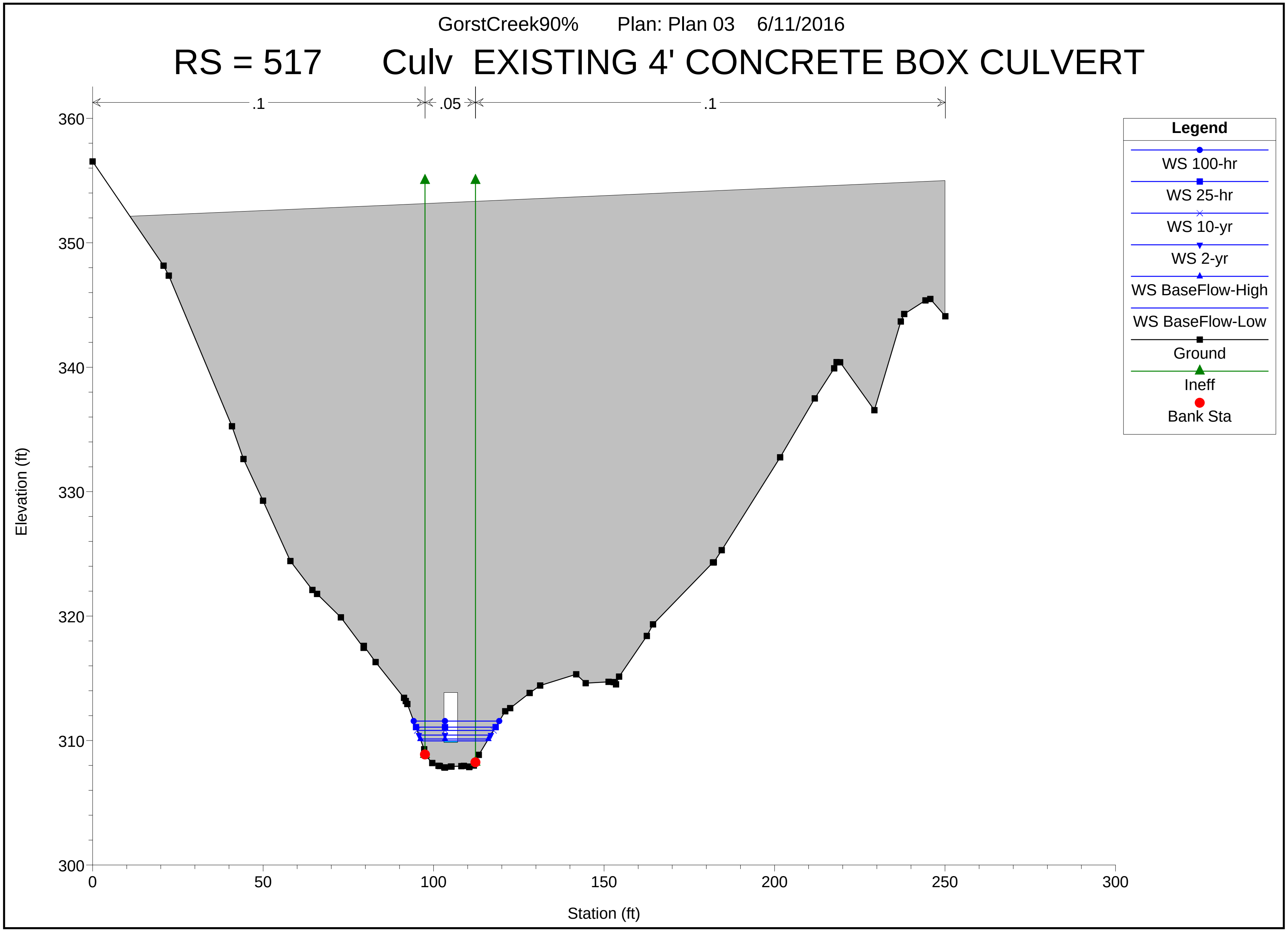
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Ineff
Bank Sta
Elevation (ft)
320
315
310
305
80
100
120
140
Station (ft)


GorstCreek90%   Plan: Plan 03   6/11/2016
RS = 517   Culv EXISTING 4' CONCRETE BOX CULVERT
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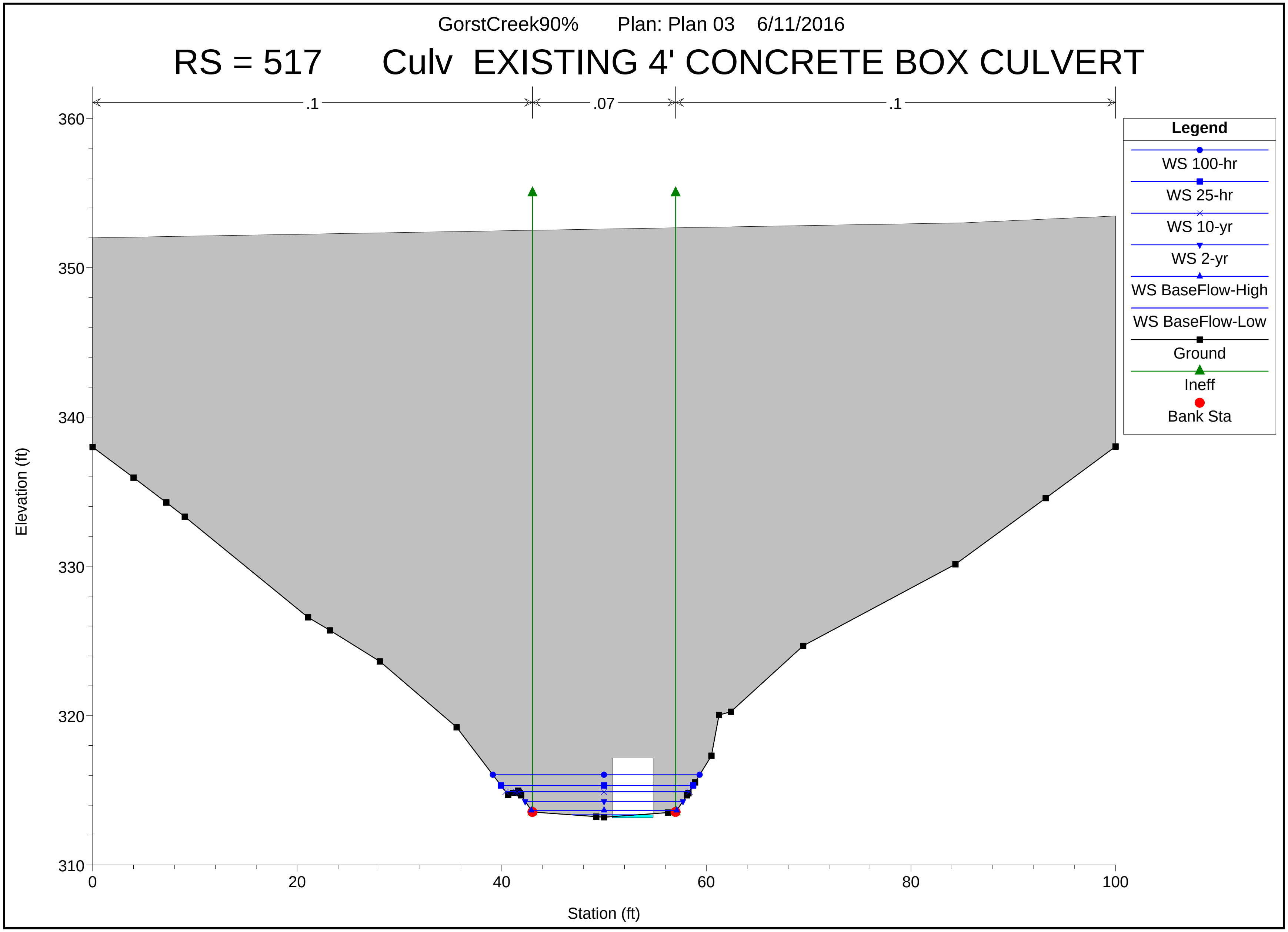
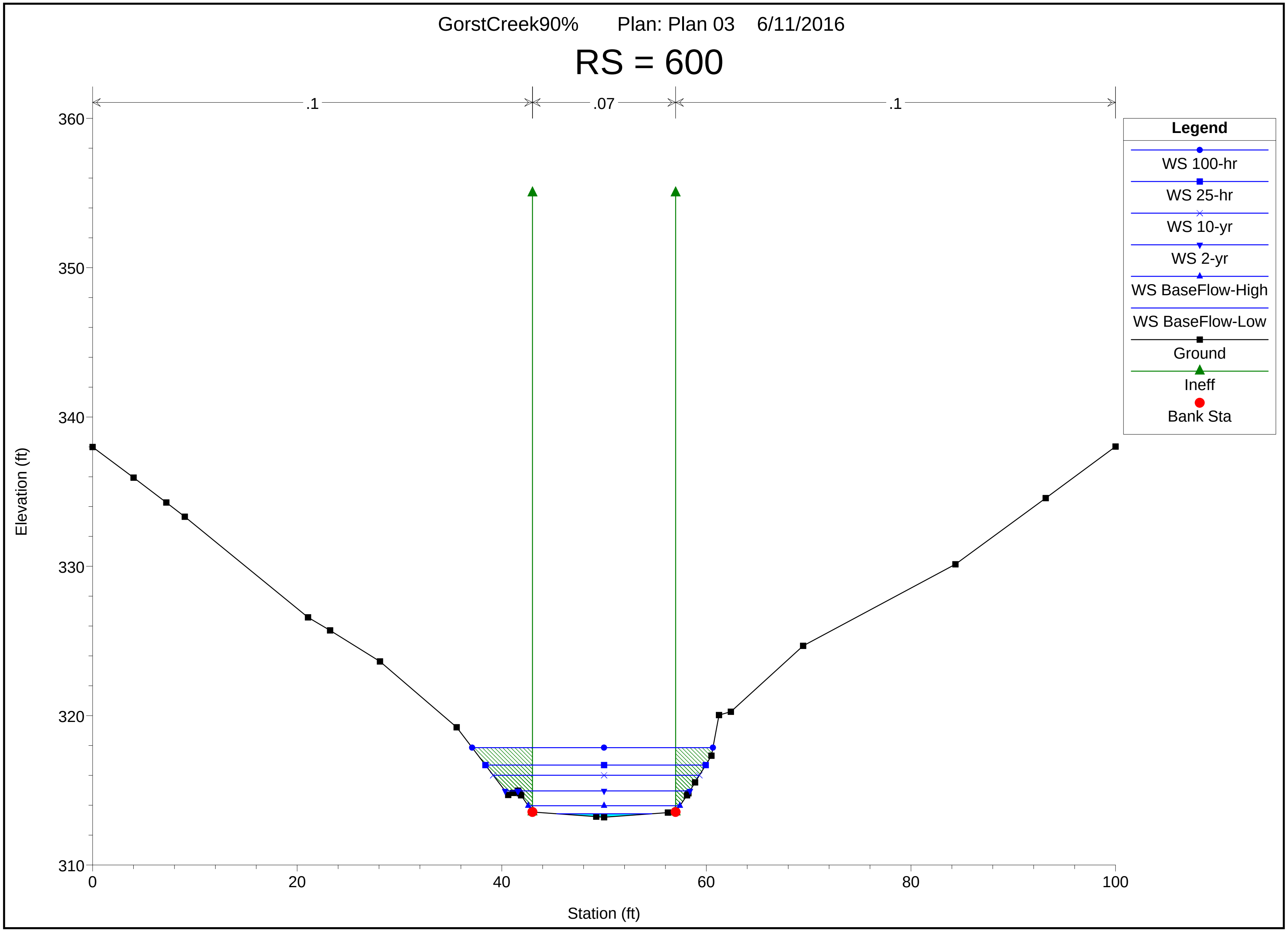
.05
.1
Elevation (ft)
Station (ft)
360
350
340
330
320
310
300
0
50
100
150
200
250
300
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Ineff
Bank Sta


GorstCreek90% Plan: Plan 03 6/11/2016
RS = 517 Culv EXISTING 4' CONCRETE BOX CULVERT
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Ineff
Bank Sta
Elevation (ft)
360
350
340
330
320
310
0
20
40
60
80
100
Station (ft)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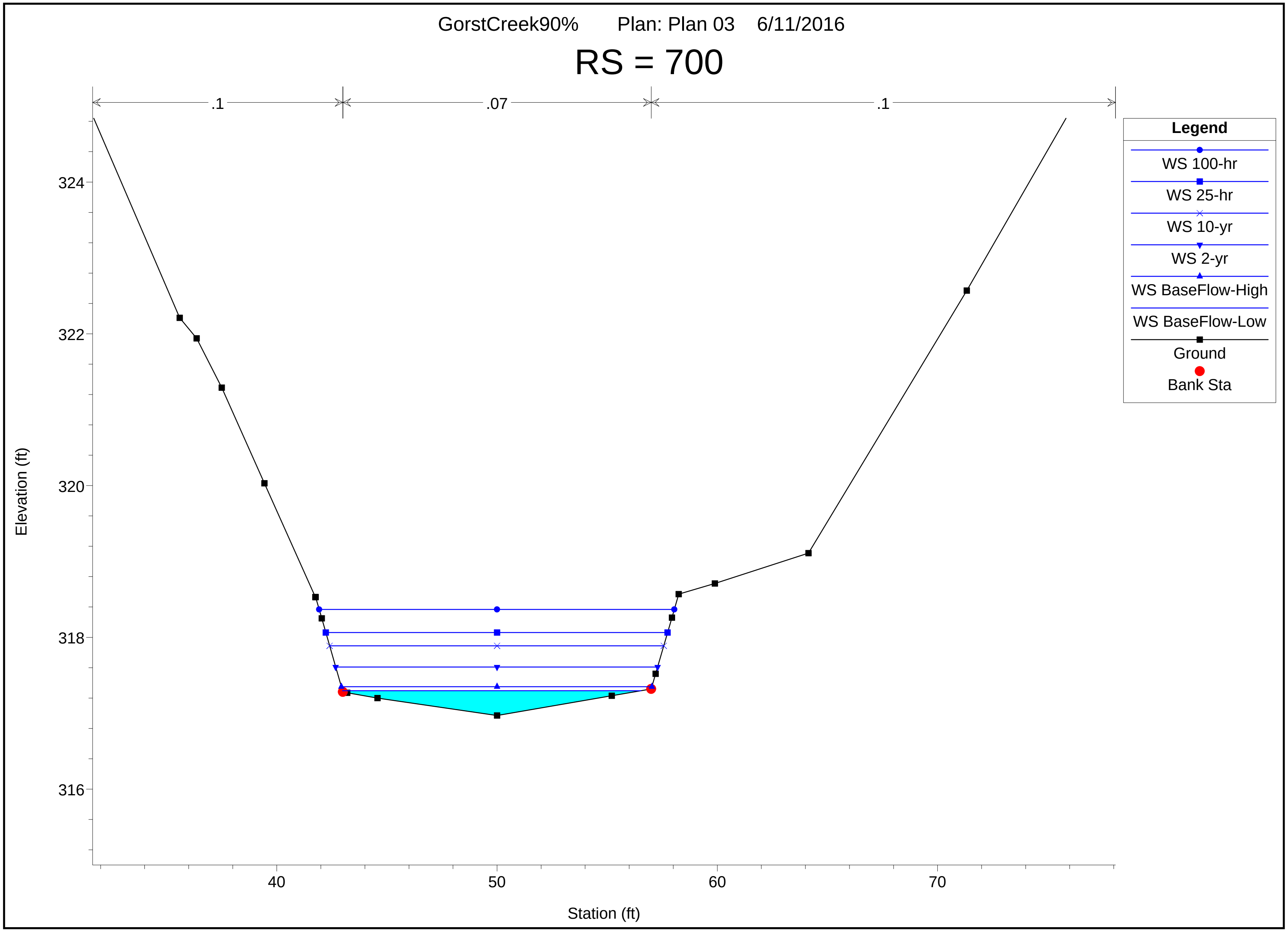
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Ineff
Bank Sta
Elevation (ft)
360
350
340
330
320
310
0
20
40
60
80
100
Station (ft)



GorstCreek90% Plan: Plan 03 6/11/2016
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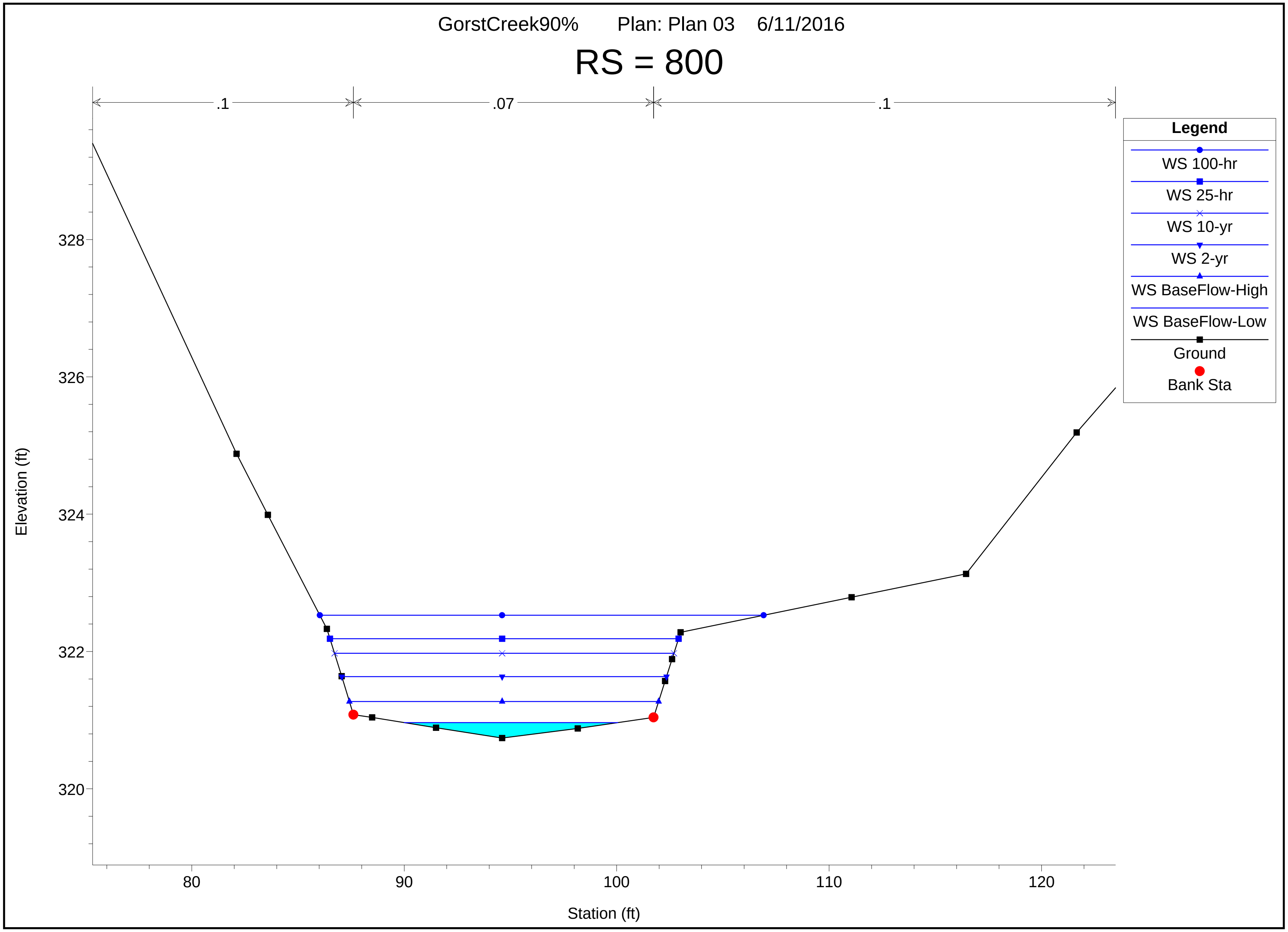
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
324
322
320
318
316
40
50
60
70
Station (ft)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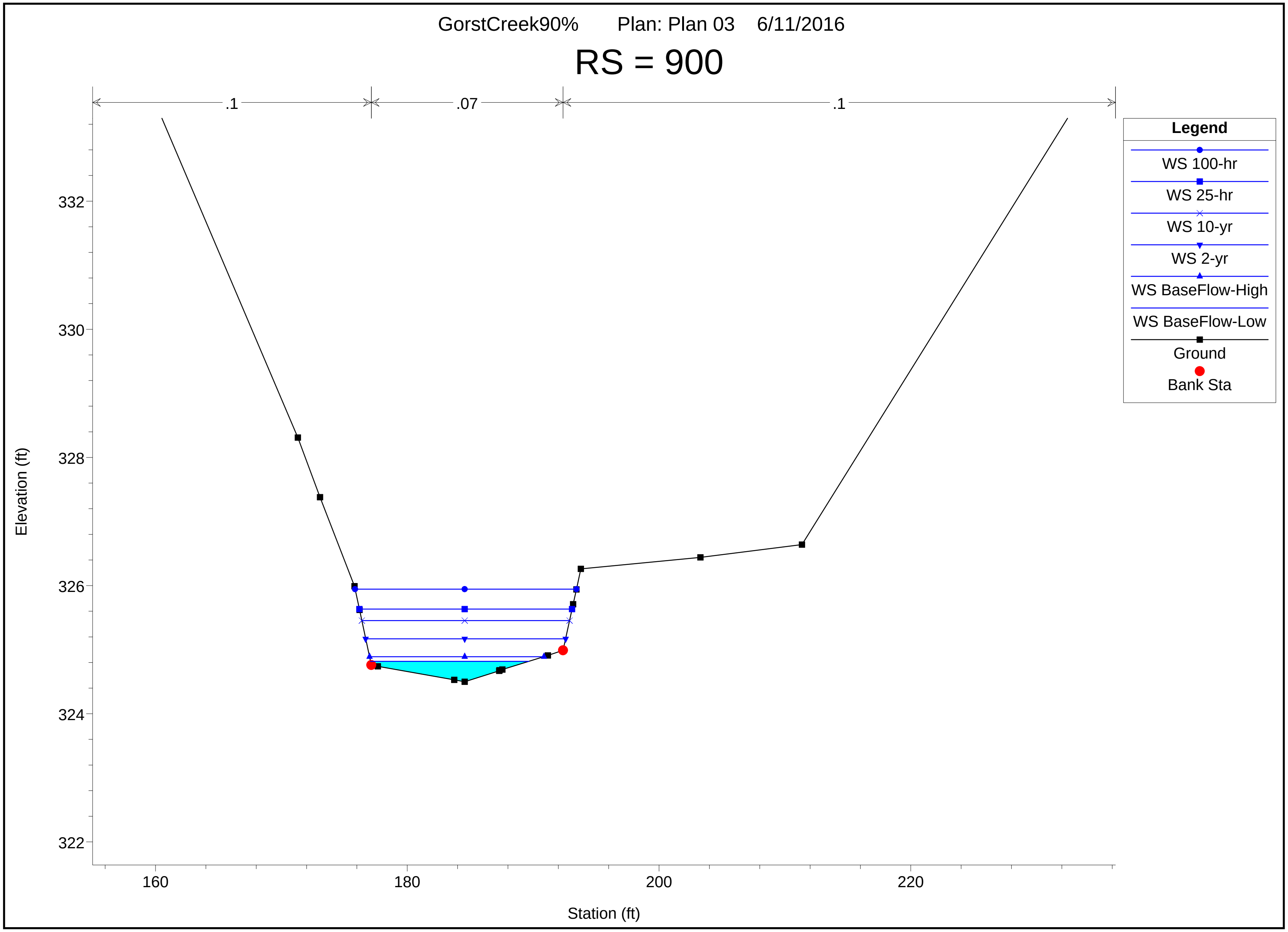
RS = 800
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
328
326
324
322
320
80
90
100
110
120
Station (ft)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RS = 900
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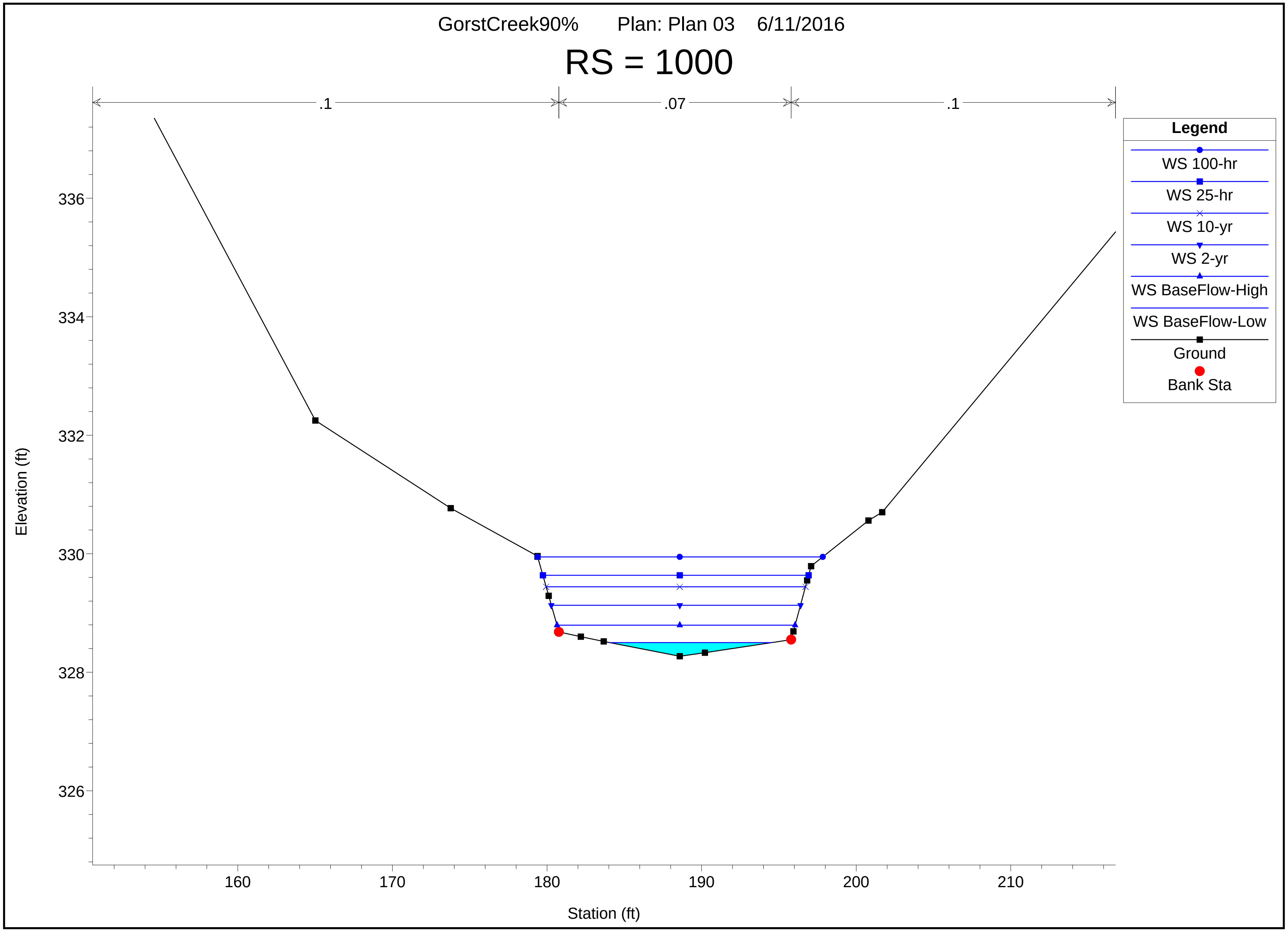
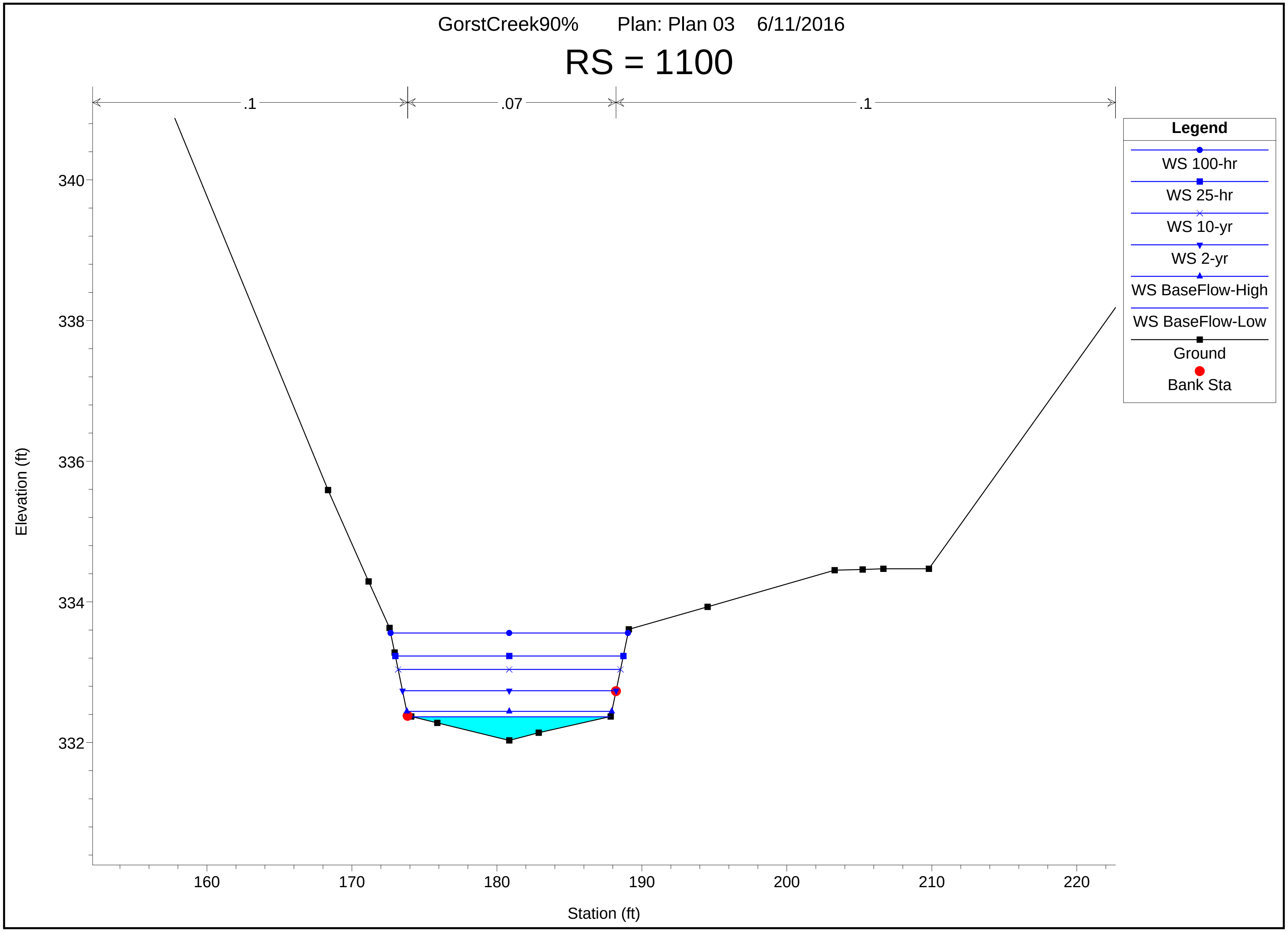
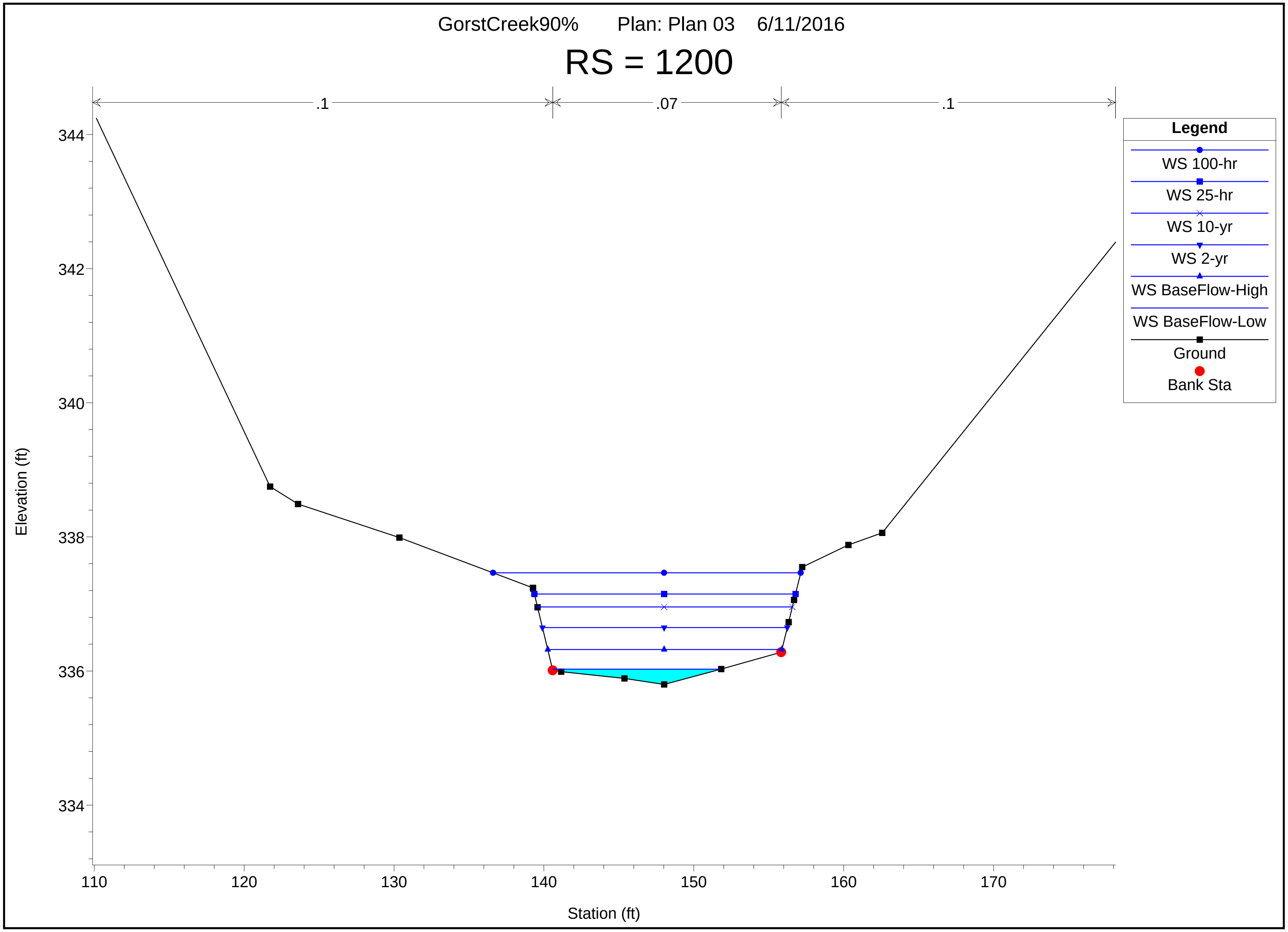
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
332
330
328
326
324
322
160
180
200
220
Station (ft)



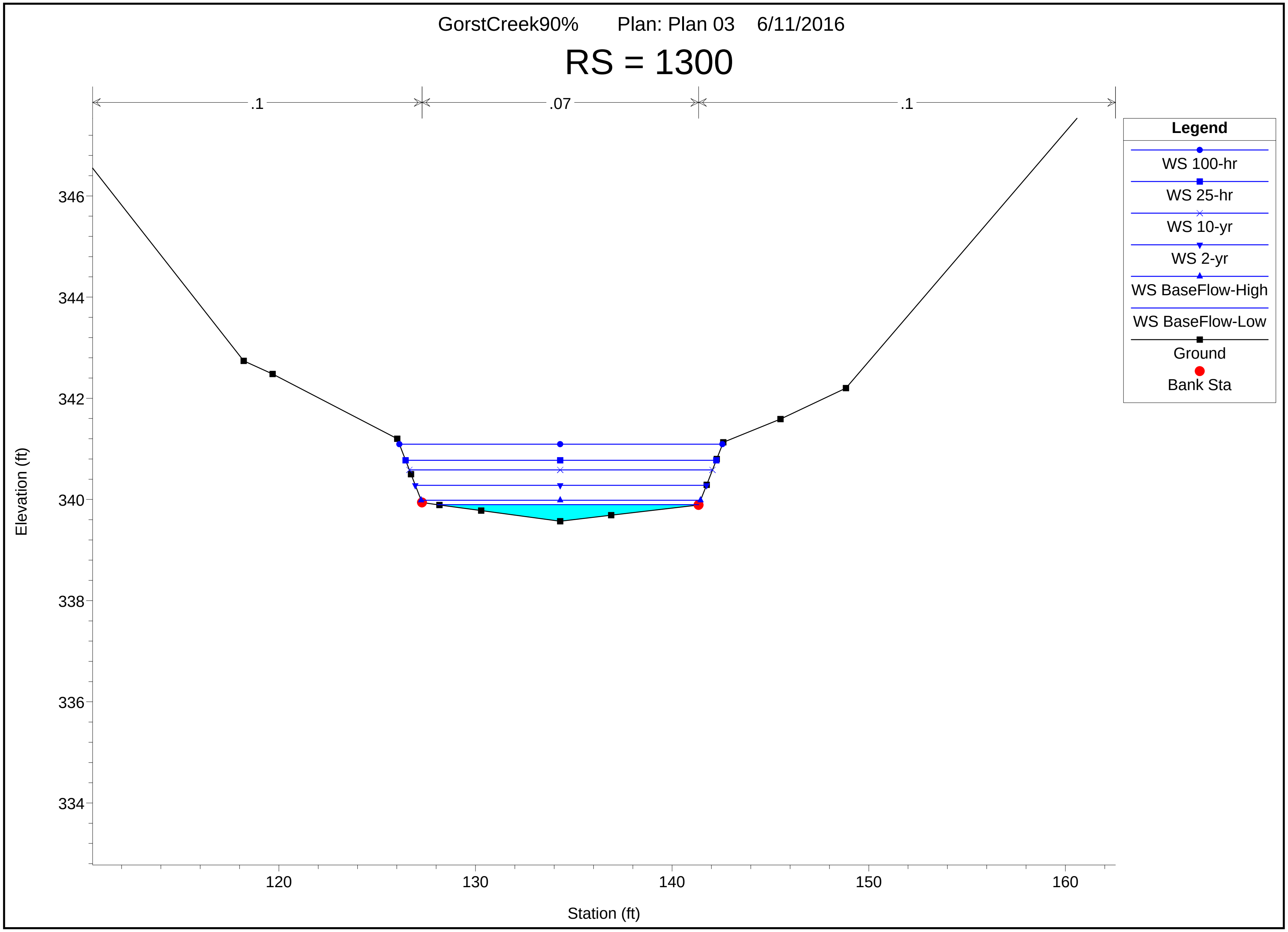
GorstCreek90%
Plan: Plan 03
6/11/2016
RS = 1000
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
336
334
332
330
328
326
160
170
180
190
200
210
Station (ft)



GorstCreek90% Plan: Plan 03 6/11/2016
RS = 1100
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
340
338
336
334
332
160
170
180
190
200
210
220
Station (ft)



GorstCreek90% Plan: Plan 03 6/11/2016
RS = 1200
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
344
342
340
338
336
334
Station (ft)
110
120
130
140
150
160
170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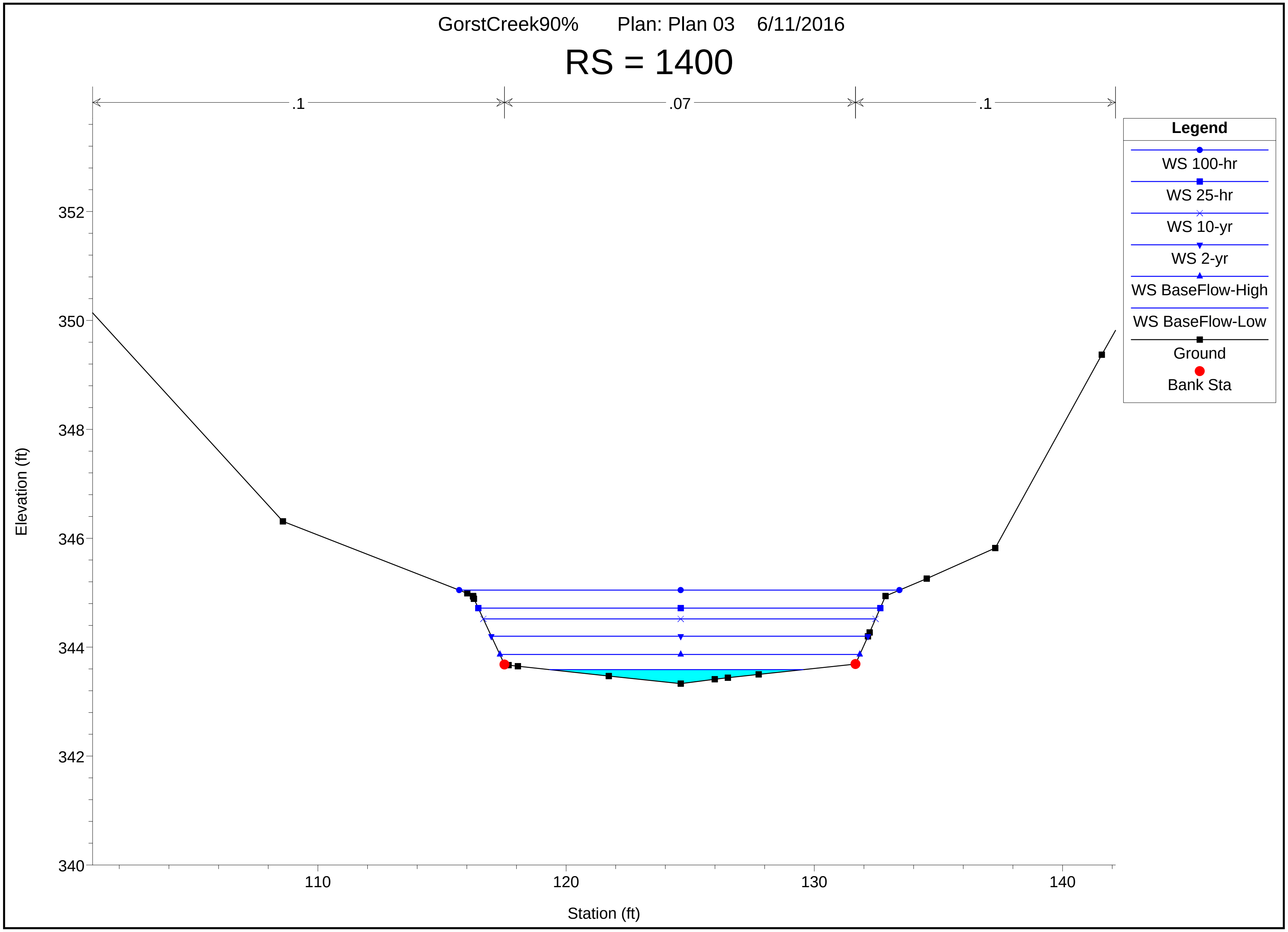
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
346
344
342
340
338
336
334
120
130
140
150
160
Station (ft)



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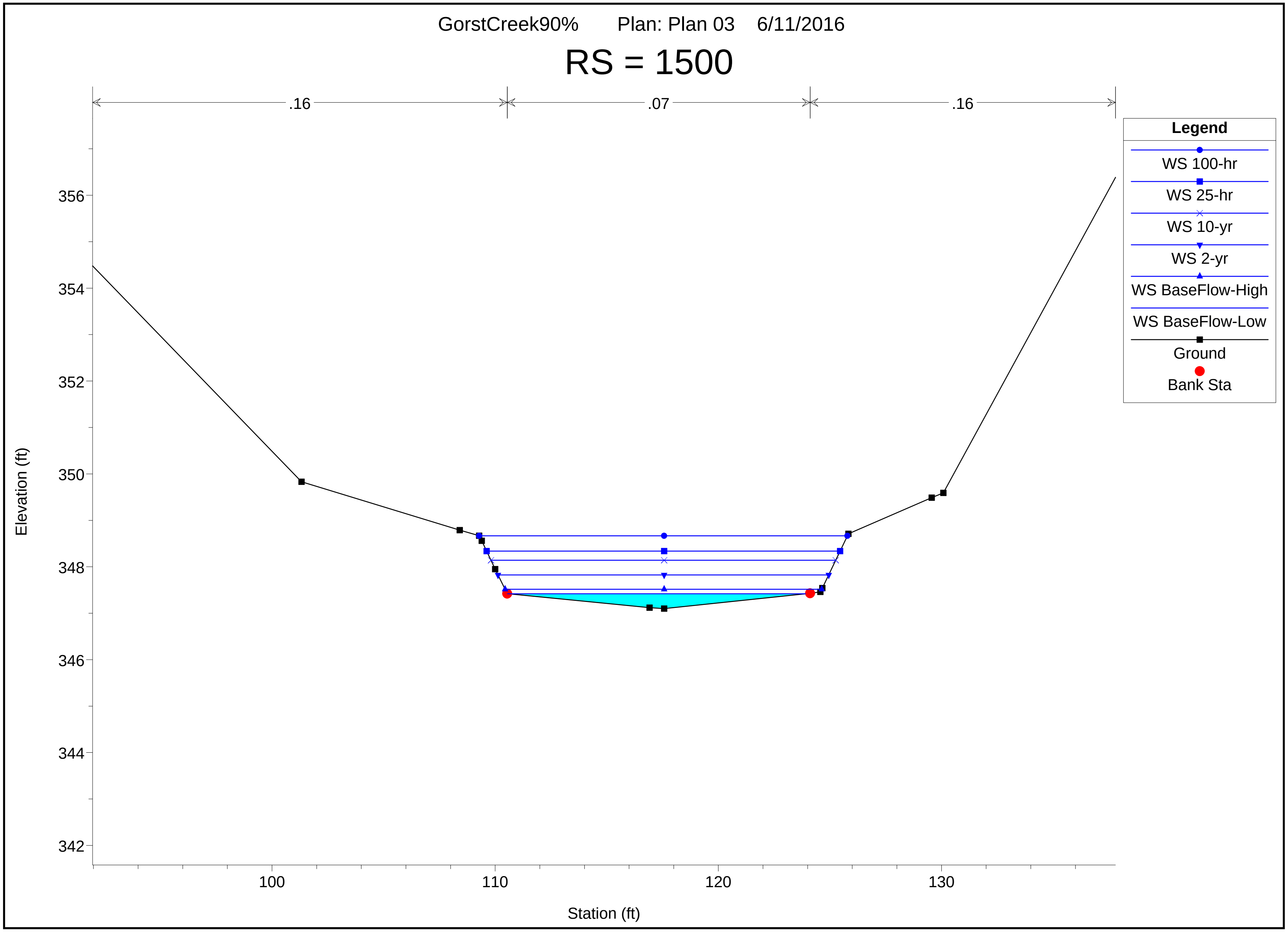
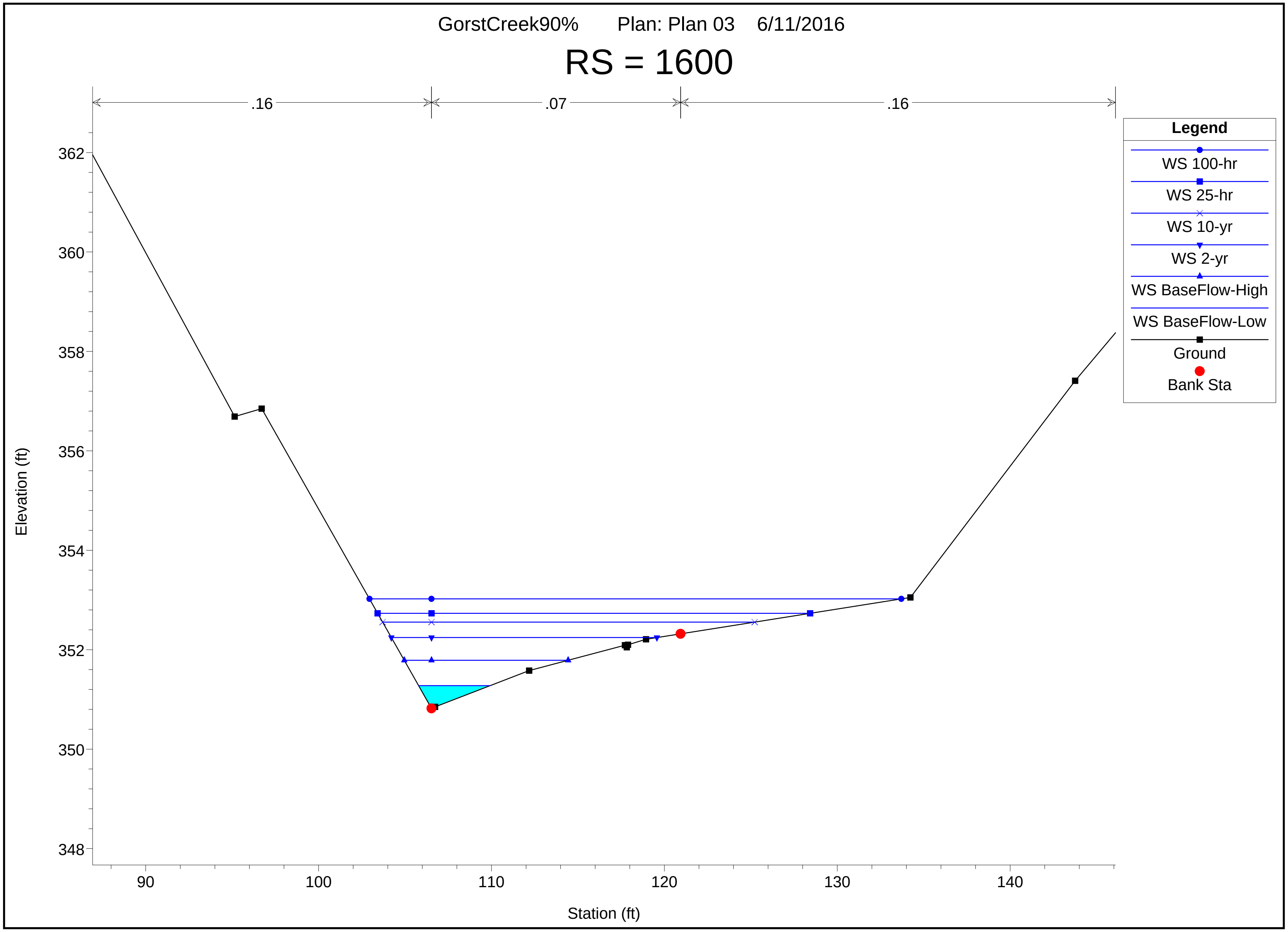
RS = 1400
.1
.07
.1
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
352
350
348
346
344
342
340
Elevation (ft)
110
120
130
140
Station (ft)



GorstCreek90% Plan: Plan 03 6/11/2016
RS = 1500
.16
.07
.16
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
356
354
352
350
348
346
344
342
100
110
120
130
Station (ft)


GorstCreek90% Plan: Plan 03 6/11/2016
RS = 1600
.16
.07
.16
Legend
WS 100-hr
WS 25-hr
WS 10-yr
WS 2-yr
WS BaseFlow-High
WS BaseFlow-Low
Ground
Bank Sta
Elevation (ft)
362
360
358
356
354
352
350
348
90
100
110
120
130
140
Station (ft)

Attachment B

HEC RAS MODEL OUTPUT TABLES

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HEC-RAS Plan: 90%_1   River: GORST CREEK   Reach: Site 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Site 1	1600	BaseFlow-Low	2.00	350.82	351.28	351.25	351.36	0.091775	2.38	0.94	4.14	0.88
Site 1	1600	BaseFlow-High	8.00	350.82	351.79	351.56	351.85	0.027971	2.07	4.31	9.48	0.54
Site 1	1600	2-yr	26.40	350.82	352.24	352.01	352.37	0.035190	2.93	9.95	15.36	0.65
Site 1	1600	5-yr	40.00	350.82	352.43	352.22	352.60	0.037529	3.40	13.11	19.00	0.69
Site 1	1600	10-yr	52.40	350.82	352.56	352.36	352.77	0.038422	3.81	15.69	21.52	0.72
Site 1	1600	25-hr	72.20	350.82	352.73	352.52	353.01	0.039287	4.35	19.78	25.02	0.75
Site 1	1600	50-yr	90.20	350.82	352.87	352.67	353.20	0.039694	4.75	23.50	27.81	0.76
Site 1	1600	100-hr	110.80	350.82	353.02	352.83	353.39	0.039507	5.13	27.87	30.77	0.78
Site 1	1500	BaseFlow-Low	2.00	347.10	347.42		347.43	0.021468	0.92	2.16	13.34	0.40
Site 1	1500	BaseFlow-High	8.00	347.10	347.52	347.48	347.60	0.072100	2.30	3.52	14.19	0.80
Site 1	1500	2-yr	26.40	347.10	347.83		348.00	0.055290	3.41	8.00	14.82	0.80
Site 1	1500	5-yr	40.00	347.10	348.00		348.24	0.050979	3.92	10.64	15.17	0.80
Site 1	1500	10-yr	52.40	347.10	348.14		348.43	0.049038	4.32	12.77	15.45	0.81
Site 1	1500	25-hr	72.20	347.10	348.34		348.70	0.047032	4.84	15.87	15.84	0.82
Site 1	1500	50-yr	90.20	347.10	348.50	348.35	348.92	0.045825	5.24	18.46	16.16	0.83
Site 1	1500	100-hr	110.80	347.10	348.67	348.51	349.15	0.045068	5.66	21.19	16.51	0.84
Site 1	1400	BaseFlow-Low	2.00	343.33	343.59	343.56	343.62	0.084947	1.55	1.29	10.20	0.77
Site 1	1400	BaseFlow-High	8.00	343.33	343.87		343.90	0.022186	1.59	5.07	14.50	0.47
Site 1	1400	2-yr	26.40	343.33	344.20		344.31	0.026197	2.68	10.03	15.17	0.57
Site 1	1400	5-yr	40.00	343.33	344.38		344.54	0.027781	3.22	12.76	15.52	0.61
Site 1	1400	10-yr	52.40	343.33	344.52		344.72	0.028720	3.62	14.97	15.80	0.63
Site 1	1400	25-hr	72.20	343.33	344.72		344.98	0.029696	4.15	18.14	16.19	0.66
Site 1	1400	50-yr	90.20	343.33	344.88		345.19	0.030503	4.56	20.74	16.50	0.69
Site 1	1400	100-hr	110.80	343.33	345.05		345.42	0.030912	4.97	23.65	17.73	0.71
Site 1	1300	BaseFlow-Low	2.00	339.57	339.90	339.81	339.91	0.020592	0.91	2.19	13.31	0.40
Site 1	1300	BaseFlow-High	8.00	339.57	339.98	339.96	340.07	0.081124	2.35	3.41	14.21	0.84
Site 1	1300	2-yr	26.40	339.57	340.28	340.22	340.47	0.061427	3.47	7.70	14.81	0.84
Site 1	1300	5-yr	40.00	339.57	340.45	340.37	340.69	0.056245	3.99	10.23	15.15	0.84
Site 1	1300	10-yr	52.40	339.57	340.58	340.49	340.88	0.053377	4.37	12.31	15.42	0.84
Site 1	1300	25-hr	72.20	339.57	340.77	340.67	341.14	0.051172	4.90	15.25	15.80	0.85
Site 1	1300	50-yr	90.20	339.57	340.93	340.82	341.36	0.049551	5.29	17.75	16.11	0.86
Site 1	1300	100-hr	110.80	339.57	341.09	340.97	341.59	0.048494	5.70	20.38	16.43	0.87
Site 1	1200	BaseFlow-Low	2.00	335.80	336.03	336.01	336.06	0.095617	1.55	1.29	11.20	0.81
Site 1	1200	BaseFlow-High	8.00	335.80	336.32		336.36	0.021058	1.52	5.32	15.62	0.45
Site 1	1200	2-yr	26.40	335.80	336.65		336.75	0.024633	2.55	10.54	16.33	0.55
Site 1	1200	5-yr	40.00	335.80	336.82		336.97	0.026184	3.07	13.39	16.71	0.59
Site 1	1200	10-yr	52.40	335.80	336.96		337.14	0.027311	3.46	15.65	17.00	0.62
Site 1	1200	25-hr	72.20	335.80	337.15		337.39	0.028218	3.96	18.97	17.42	0.64
Site 1	1200	50-yr	90.20	335.80	337.30		337.59	0.029044	4.36	21.72	18.43	0.67
Site 1	1200	100-hr	110.80	335.80	337.46		337.81	0.029672	4.76	24.86	20.52	0.69
Site 1	1100	BaseFlow-Low	2.00	332.03	332.37	332.25	332.38	0.019334	0.89	2.25	13.61	0.39
Site 1	1100	BaseFlow-High	8.00	332.03	332.44	332.42	332.53	0.088785	2.41	3.32	14.14	0.87
Site 1	1100	2-yr	26.40	332.03	332.74	332.68	332.93	0.066476	3.52	7.55	14.73	0.86
Site 1	1100	5-yr	40.00	332.03	332.90	332.83	333.15	0.059753	4.02	10.06	15.07	0.85
Site 1	1100	10-yr	52.40	332.03	333.04	332.95	333.34	0.056029	4.39	12.13	15.34	0.85
Site 1	1100	25-hr	72.20	332.03	333.23	333.13	333.60	0.053008	4.90	15.08	15.72	0.86
Site 1	1100	50-yr	90.20	332.03	333.39	333.28	333.82	0.050518	5.27	17.62	16.04	0.86
Site 1	1100	100-hr	110.80	332.03	333.56	333.43	334.05	0.048648	5.65	20.32	16.37	0.86
Site 1	1000	BaseFlow-Low	2.00	328.27	328.50	328.50	328.54	0.108947	1.66	1.20	10.43	0.86
Site 1	1000	BaseFlow-High	8.00	328.27	328.80		328.83	0.019989	1.50	5.36	15.40	0.44
Site 1	1000	2-yr	26.40	328.27	329.13		329.23	0.023305	2.53	10.65	16.11	0.54
Site 1	1000	5-yr	40.00	328.27	329.31		329.45	0.024858	3.04	13.52	16.49	0.58
Site 1	1000	10-yr	52.40	328.27	329.44		329.62	0.026070	3.43	15.78	16.78	0.60
Site 1	1000	25-hr	72.20	328.27	329.64		329.87	0.027191	3.94	19.07	17.19	0.64
Site 1	1000	50-yr	90.20	328.27	329.79		330.08	0.028257	4.35	21.72	17.51	0.66
Site 1	1000	100-hr	110.80	328.27	329.95		330.29	0.029296	4.77	24.56	18.45	0.69
Site 1	900	BaseFlow-Low	2.00	324.50	324.82	324.73	324.83	0.018463	0.91	2.21	12.59	0.38
Site 1	900	BaseFlow-High	8.00	324.50	324.89	324.88	324.99	0.100599	2.53	3.17	13.86	0.93
Site 1	900	2-yr	26.40	324.50	325.17	325.14	325.37	0.075383	3.58	7.45	15.88	0.91
Site 1	900	5-yr	40.00	324.50	325.33	325.28	325.58	0.067317	4.08	9.97	16.23	0.90
Site 1	900	10-yr	52.40	324.50	325.45	325.40	325.76	0.062528	4.44	12.06	16.51	0.89
Site 1	900	25-hr	72.20	324.50	325.63	325.57	326.01	0.058404	4.94	15.06	16.90	0.90
Site 1	900	50-yr	90.20	324.50	325.79	325.71	326.22	0.055133	5.30	17.65	17.24	0.89
Site 1	900	100-hr	110.80	324.50	325.94	325.86	326.43	0.052596	5.66	20.42	17.59	0.89
Site 1	800	BaseFlow-Low	2.00	320.74	320.96	320.95	321.01	0.120867	1.74	1.15	10.05	0.91
Site 1	800	BaseFlow-High	8.00	320.74	321.27	321.11	321.31	0.018793	1.51	5.33	14.55	0.44
Site 1	800	2-yr	26.40	320.74	321.63	321.37	321.73	0.021057	2.51	10.74	15.28	0.52
Site 1	800	5-yr	40.00	320.74	321.82	321.52	321.96	0.022311	3.01	13.68	15.67	0.55
Site 1	800	10-yr	52.40	320.74	321.97	321.65	322.15	0.023113	3.39	16.05	15.97	0.58

HEC-RAS Plan: 90%_1 River: GORST CREEK Reach: Site 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Site 1	800	25-hr	72.20	320.74	322.19	321.82	322.41	0.023876	3.88	19.47	16.41	0.60
Site 1	800	50-yr	90.20	320.74	322.36	321.97	322.63	0.024610	4.28	22.33	17.88	0.62
Site 1	800	100-hr	110.80	320.74	322.53	322.13	322.86	0.025298	4.67	25.68	20.89	0.65
Site 1	700	BaseFlow-Low	2.00	316.97	317.30		317.31	0.017633	0.87	2.31	13.56	0.37
Site 1	700	BaseFlow-High	8.00	316.97	317.35	317.35	317.46	0.117439	2.63	3.05	14.10	0.99
Site 1	700	2-yr	26.40	316.97	317.61	317.61	317.85	0.092495	3.94	6.77	14.62	1.01
Site 1	700	5-yr	40.00	316.97	317.76	317.76	318.08	0.082828	4.49	9.06	14.92	1.00
Site 1	700	10-yr	52.40	316.97	317.89	317.89	318.26	0.077725	4.91	10.92	15.17	0.99
Site 1	700	25-hr	72.20	316.97	318.06	318.06	318.52	0.073058	5.47	13.61	15.52	1.00
Site 1	700	50-yr	90.20	316.97	318.21	318.21	318.74	0.069277	5.87	15.93	15.81	1.00
Site 1	700	100-hr	110.80	316.97	318.37	318.37	318.97	0.066071	6.28	18.43	16.12	1.00
Site 1	600	BaseFlow-Low	2.00	313.20	313.43	313.43	313.49	0.136920	1.86	1.07	9.30	0.97
Site 1	600	BaseFlow-High	8.00	313.20	313.97	313.59	313.98	0.004122	0.96	8.32	14.83	0.22
Site 1	600	2-yr	26.40	313.20	314.96	313.86	314.99	0.001691	1.19	22.24	18.01	0.17
Site 1	600	5-yr	40.00	313.20	315.54	314.01	315.57	0.001381	1.32	30.32	19.23	0.16
Site 1	600	10-yr	52.40	313.20	316.01	314.14	316.04	0.001230	1.42	36.91	20.17	0.15
Site 1	600	25-hr	72.20	313.20	316.69	314.32	316.73	0.001086	1.55	46.44	21.54	0.15
Site 1	600	50-yr	90.20	313.20	317.26	314.46	317.30	0.001003	1.66	54.36	22.67	0.15
Site 1	600	100-hr	110.80	313.20	317.86	314.62	317.91	0.000935	1.76	62.80	23.54	0.15
Site 1	517		Culvert									
Site 1	400	BaseFlow-Low	2.00	307.83	308.08		308.10	0.017927	1.14	1.76	11.44	0.51
Site 1	400	BaseFlow-High	8.00	307.83	308.28		308.33	0.018991	1.92	4.18	12.98	0.59
Site 1	400	2-yr	26.40	307.83	308.63		308.77	0.017846	2.93	9.01	14.72	0.64
Site 1	400	5-yr	40.00	307.83	308.84		309.01	0.017231	3.36	11.90	15.62	0.66
Site 1	400	10-yr	52.40	307.83	308.99		309.20	0.016969	3.72	14.10	16.13	0.67
Site 1	400	25-hr	72.20	307.83	309.19		309.47	0.016622	4.20	17.20	16.73	0.69
Site 1	400	50-yr	90.20	307.83	309.36		309.69	0.016476	4.58	19.71	17.26	0.70
Site 1	400	100-hr	110.80	307.83	309.55		309.93	0.016257	4.95	22.39	17.90	0.71
Site 1	300	BaseFlow-Low	2.00	305.86	306.15		306.18	0.020431	1.42	1.41	7.22	0.57
Site 1	300	BaseFlow-High	8.00	305.86	306.41		306.48	0.018000	2.17	3.97	13.63	0.60
Site 1	300	2-yr	26.40	305.86	306.78	306.64	306.94	0.018579	3.40	9.56	16.04	0.68
Site 1	300	5-yr	40.00	305.86	306.97	306.81	307.19	0.019154	4.00	12.71	16.94	0.72
Site 1	300	10-yr	52.40	305.86	307.13	306.95	307.39	0.019250	4.43	15.38	17.66	0.74
Site 1	300	25-hr	72.20	305.86	307.34	307.15	307.67	0.019409	4.99	19.27	18.66	0.76
Site 1	300	50-yr	90.20	305.86	307.52		307.90	0.019437	5.42	22.59	19.48	0.78
Site 1	300	100-hr	110.80	305.86	307.69		308.13	0.019634	5.87	26.11	20.31	0.80
Site 1	200	BaseFlow-Low	2.00	303.91	304.52		304.54	0.013388	1.34	1.50	6.02	0.47
Site 1	200	BaseFlow-High	8.00	303.91	304.82		304.87	0.014456	1.68	4.80	15.46	0.52
Site 1	200	2-yr	26.40	303.91	305.15	304.97	305.26	0.014845	2.71	10.28	17.78	0.59
Site 1	200	5-yr	40.00	303.91	305.33	305.11	305.48	0.014953	3.19	13.57	19.04	0.62
Site 1	200	10-yr	52.40	303.91	305.47	305.22	305.66	0.015322	3.57	16.19	19.98	0.64
Site 1	200	25-hr	72.20	303.91	305.65		305.90	0.015930	4.08	19.97	21.28	0.67
Site 1	200	50-yr	90.20	303.91	305.79		306.09	0.016416	4.49	23.14	22.31	0.69
Site 1	200	100-hr	110.80	303.91	305.95		306.29	0.016781	4.88	26.61	23.39	0.71
Site 1	100	BaseFlow-Low	2.00	301.87	302.20	302.17	302.25	0.048689	1.84	1.14	7.51	0.84
Site 1	100	BaseFlow-High	8.00	301.87	302.40	302.37	302.49	0.046111	2.39	3.47	15.03	0.88
Site 1	100	2-yr	26.40	301.87	302.65	302.63	302.86	0.044655	3.76	7.40	16.49	0.97
Site 1	100	5-yr	40.00	301.87	302.78	302.78	303.08	0.044522	4.44	9.61	16.94	1.01
Site 1	100	10-yr	52.40	301.87	302.89	302.89	303.25	0.042550	4.87	11.57	17.35	1.02
Site 1	100	25-hr	72.20	301.87	303.06	303.06	303.50	0.039097	5.39	14.59	17.90	1.01
Site 1	100	50-yr	90.20	301.87	303.20	303.20	303.70	0.037218	5.79	17.11	18.28	1.01
Site 1	100	100-hr	110.80	301.87	303.35	303.35	303.92	0.035480	6.19	19.85	18.68	1.01
Site 1	19.93	BaseFlow-Low	2.00	298.96	299.49	299.40	299.52	0.025030	1.58	1.36	7.03	0.61
Site 1	19.93	BaseFlow-High	8.00	298.96	299.76	299.65	299.82	0.025014	2.03	4.34	15.02	0.66
Site 1	19.93	2-yr	26.40	298.96	300.07	299.96	300.22	0.025038	3.22	9.65	19.09	0.73
Site 1	19.93	5-yr	40.00	298.96	300.23	300.12	300.43	0.025018	3.77	12.87	20.68	0.76
Site 1	19.93	10-yr	52.40	298.96	300.36	300.23	300.60	0.025007	4.18	15.57	21.92	0.78
Site 1	19.93	25-hr	72.20	298.96	300.53	300.42	300.84	0.025005	4.71	19.45	22.69	0.80
Site 1	19.93	50-yr	90.20	298.96	300.67	300.55	301.02	0.025045	5.11	22.62	23.02	0.82
Site 1	19.93	100-hr	110.80	298.96	300.82	300.68	301.22	0.025029	5.51	26.00	23.32	0.84

ecology and environment, inc.

Design Memorandum

Date: 6/13/2016

To: Design File

From: Tyler Chatriand, P.E.

Reviewer: Tom Campbell, P.E.

Subject: **Bremerton Auto Wrecking Landfill Conceptual Restoration Design Scour Analysis**

PROFESSIONAL ENGINEER CERTIFICATION

Gorst Creek/ Bremerton Auto Wrecking Landfill Conceptual Restoration Design Scour Analysis
Bremerton Auto Wrecking Landfill Site
Port Orchard, Washington
TDD: 16-04-0001

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

I hereby certify that this Conceptual Restoration Design Scour Analysis for the Bremerton Auto Wrecking Landfill Site in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE:

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 6/13/2016

THOMAS C. CAMPBELL
STATE OF WASHINGTON
51283
REGISTERED
PROFESSIONAL ENGINEER

Introduction

This memorandum summarizes the methods and results of a scour analysis that E & E performed to support the stream restoration design of Gorst Creek through the Bremerton Auto Wrecking Landfill site. The scour analysis provides estimates of scour depth to be considered in designing and constructing the new channel and banks. Due to the conceptual nature of the proposed channel alignment, E & E evaluated scour at one location where hydraulic modeling indicates the highest velocities and shear stresses in order to provide a conservative range of scour depths. As such, potential scour should be re-examined if the final alignment varies considerably from the proposed alignment in terms of channel slope, sinuosity, and/or bend radius of curvatures. In summary, this scour analysis indicates that the 100-year design flood event may produce scour depths ranging from 1.82 feet to 4.21 feet.

Methods

The scour analysis includes an evaluation of three main types of scour that are applicable to this restoration reach, which extends through the existing landfill delineation. This includes long-term scour due to degradation of the channel bed over time, general scour caused by contraction or constriction of flow, and bend scour caused by transverse currents that occur at stream meanders. Local scour, bed-form scour, and low-flow incisement are not applicable to this restoration reach and therefore were not included in this analysis; however, local scour should be evaluated for the new culvert design at State Route 3 located downstream of the restoration site.

The scour analysis performed for this project is based on several empirical equations developed primarily for streambank stabilization and natural channel design. The equations require data inputs related to the hydraulic properties of the location of interest, which E & E obtained from the hydraulic analysis that was completed for the restoration design (Hydraulic Analysis Technical Memorandum). A detailed description of all equations used for this analysis is provided in Attachment A, and references are cited at the end of the memo.

Hydraulic Analysis

E & E performed a hydraulic analysis for the proposed channel alignment to estimate hydraulic parameters such as water surface elevations, stream velocities, and tractive shear stress (Hydraulic Analysis Technical Memorandum), which are used as inputs to determine scour estimates. E & E evaluated scour at cross-section 11+00 as shown in the HEC-RAS geometry as well as the design drawings. The resulting hydraulic output data from the model are displayed in Table 1 below. The table includes the relevant data for channel forming discharge (10-year flow), the design event (100-year flow), and the approach channel that is defined from the HEC-RAS cross section 12+00. Detailed hydraulic model output is provided in Appendix B of the 90% design submittal.

TABLE 1. HYDRAULIC PARAMETERS FOR SCOUR ANALYSIS AT HEC RAS CROSS SECTION 11+00

Channel Forming Discharge		
10-Year design flow rate	52.4	cfs
Mean Hydraulic Depth	0.85	ft
Velocity of Flow	4.24	ft/sec
Channel Top Width	14.37	ft
Design Event		
100-year design flow rate	110.8	cfs
Minimum Channel Elevation	332.03	ft (msl)
Manning's n (main channel)	0.075	
Water Surface Elevation	333.6	ft
Max Flow Depth	1.8	ft
Mean (hydraulic) Depth in Channel	1.57	ft
Channel Slope	0.038	ft/ft
Channel Froude Number	0.82	
Energy Grade Slope	0.04957	ft/ft
Average Channel Velocity	5.45	ft/sec
Channel Centerline Radius of Curvature	72	ft
Channel Top Width	14.37	ft
Channel Substrate D50	23.88	mm
Channel Substrate D90	83	mm
Approach Channel (XS 12+00)		
Max Flow Depth	1.73	ft
Mean (hydraulic) Depth (A/T)	1.55	ft
Energy Slope	0.0295	ft/ft
Average Channel Velocity	4.55	ft/sec
Channel Top Width	15.24	ft
cfs = cubic feet per second	mm = millimeter	
ft = feet	msl = mean sea level	
sec = second		

Scour Analysis

The total maximum scour depth is equal to the sum of the individual scour components (long-term scour + general scour + bend scour). Evaluation of long-term degradation considered armoring calculations and an equilibrium slope analysis. Armoring was not considered because 90% of the channel substrate (D90) is smaller than the estimated particle size for incipient motion. E & E calculated equilibrium slope using four different methods: the Schoklitsch method, the Meyer-Peter Muller method, the Lane's tractive force method, and the Shield's diagram. It should be noted that the Meyer-Peter Muller method results in a much steeper stable slope than the other three methods; however, the values were included in the scour calculation due to the success of this method being applied in gravel bed streams (HEC-RAS Reference Manual). The average of the four values (0.0143 ft/ft) was used to calculate a long-term degradation of 1.66 ft.

General scour evaluates lowering of the streambed across the channel over relatively short time periods (i.e., a single flood event). Standard practice is to compute general scour by several methods and use engineering judgment to select an appropriate method or average some or all of the results. This analysis used three Regime equations known as Neill's, Blench, and Lacey equations, as well as the mean velocity method. It is important to note that these methods all factor in general scour, bend scour, and thalweg formation (low-flow incisement). The scour values for Neill's, Blench, Lacey and mean velocity methods are 1.78 ft, 1.48 ft, 0.55 ft, and 0.79 ft, respectively.

Bend scour is associated with meandering channels that can induce transverse or "secondary" currents that scour sediment from the outside of a bend and deposit it along the inside of the next bend. It should be noted that while several theoretical relationships have been developed to predict scour through a river bend, there are no known procedures that consistently yield accurate predictions of bend scour. This analysis utilized equations from Maynord, Thorne, and the US Army Corps of Engineers, which provide respective scour values of 1.34 ft, 1.53 ft, and 2.17 ft.

A summary of the scour calculations is presented in Table 2, which includes the total scour computation for each method considered. The total scour calculations include a safety factor of 1.1 to ensure conservative estimates. In summary, the total scour depth ranges from 1.82 ft to 4.21 ft, resulting in an average total scour of 3.02 ft.

TABLE 2. Total Scour Calculations Summary

Scour Component	Method	Zeller	Neill	Blench	Lacey	Mean Velocity	Competent Velocity	Maynord	Thorne	USACE
Long Term	Equilibrium slope	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
General	Zeller	N/A								
General	Competent Velocity						0.1			
General, Bend, Thalweg	Niel		1.78							
General, Bend, Thalweg	Blench			1.48						
General, Bend, Thalweg	Lacey				0.55					
General, Bend, Thalweg	Mean Velocity					0.785				
Local - pier	N/A									
Local - abutment	N/A									
Bend	Zeller	N/A								
Bend, General, Thalweg	Maynord							1.34		
Bend, General, Thalweg	Thorne								1.53	
Bend, General, Thalweg	USACE									2.17
Bedforms	N/A									
Thalweg (low flow)	N/A			incl.	incl.	incl.	incl.	incl.	incl.	incl.
subtotal		1.66	3.44	3.13	2.21	2.44	1.80	3.00	3.19	3.83
Safety Factor	1.1									
Total Scour (feet below stream bed)		**1.82**	**3.78**	**3.45**	**2.43**	**2.69**	**1.98**	**3.30**	**3.51**	**4.21**

Conclusions and Recommendations

This scour analysis provides estimates of scour depth to be considered in designing and constructing the new channel and banks for the restoration of Gorst Creek through the Bremerton Auto Wrecking Landfill site. Scour was evaluated at one location in the proposed channel where hydraulic modeling indicates the highest velocities and shear stresses in order to provide a conservative range of scour depths. In summary, this scour analysis indicates that the 100-year design flood event may produce scour depths ranging from 1.82 feet to 4.21 feet, with an average total scour of 3.02 feet.

The scour depth should be considered in areas where channel migration may present a risk to adjacent land owners or infrastructure. In the restoration reach through the landfill site, this includes areas where the stream may cut into the steep ravine slopes and jeopardize the stability of the slopes. These areas are likely to correspond with bends in the stream that carry higher velocities. Therefore, it is recommended that bends near the toe of the ravine be constructed with bank stabilization measures to prevent undercutting of the ravine slopes. The toes of streambanks on the outside of bends should be armored with large cobbles (>10 inches) and boulders to a minimum depth of 3 feet below the design channel surface, and rootwads and log barbs should be keyed into the armoring. Streambanks that do not present high risk during a potential failure should be allowed to scour and migrate as would be expected of a natural channel.

References

[1] Ecology and Environment, Inc. (E & E), Bremerton Auto Wrecking Landfill 60% Hydraulic and Sediment Transport Analysis, January 2016

[2] E & E, 60% Restoration Design, January 2016

[3] USACE, *HEC-RAS*, Version 5.0.0, March, 2016

[4] USACE, *HEC-RAS User's Manual*, Version 5.0.0, March, 2016

[5] USACE, *HEC-RAS Reference Manual*, Version 5.0.0, March, 2016

[6] Washington Department of Fish and Wildlife (WDFW), "Design of Road Culverts for Fish Passage". 2003

Attachment A: Scour Calculations

Long-Term Bed Elevation Change

- may be a response to an imbalance of stream flow, sediment discharge, sediment size, and channel slope
- Should consider both a.) an equilibrium slope analysis and b.) armoring calculations

a.) Check if Vertical Stability is Influenced by Armoring

a.1 Estimate Particle Size for Incipient Motion

$Dc = \tau_o / (K_s (\Upsilon_s - \Upsilon))$

where:

Dc ~ critical particle diameter for incipient motion

τ_o ~ tractive shear stress, see calculation below

Ks ~	0.047	constant
Υ_s ~	165	specific weight of substrate, lbs/ft^3
Υ ~	62.4	specific weight of water, lbs/ft^3

Based on Manning's Equation for Slope

$S = (Vn)^2/K_u^2 R^{4/3}$

$\tau_o = \Upsilon RS$

$\tau_o = (\Upsilon n^2 V^2) / (K_u^2 * R^{1/3})$

width/depth 7.98 width to depth > 10, therefore, R ~ y

τ_o	4.06	lbs/ft^2	
Dc	0.84	ft	
	10.11	in	
	257	mm	
D90	83	mm	**Dc > D90, armoring not a consideration**

b.) Equilibrium (Stable) Slope

b.1 Schoklitsch Method used for sand beds and low sediment loads, assumes zero bed load transport

$S_L = K_S (D50\ W_{bf} / Q)^{3/4}$

where:

S_L ~ Equilibrium (stable) slope

K_s ~	0.00174	constant
W_{bf} ~	14.37	channel width, bank full (ft)
D50 ~	23.88	median bed sediment diameter (mm)
Q ~	52.4	dominant discharge (cfs)

S_L	0.007123	ft/ft

b.2 Meyer-Peter, Muller Method

$S_L = K_{mpm} (Q / Q_{bf}) (n_s / D90^{1/6})^{3/2} D50 / d$

where:

K_{mpm} ~	0.19	constant
Q / Q_b ~	1	ratio of total flow to flow over the channel
n_s ~	0.075	Manning's for stream bed
D90 ~	83	bed sediment diameter for 90% finer (mm)
D50 ~	23.88	median bed sediment diameter (mm)
d ~	0.85	mean depth (ft)

S_L	0.036324	ft/ft

b.3 Lane's Tractive Force Method

$S_L = \tau_c / (\Upsilon_w * d)$

where:

τ_c ~	0.35	critical shear stress (lb/ft^2), Fig. VI-3
d ~	0.85	mean flow depth (ft)
Υ_w ~	62.4	specific weight of water (lb/ft^3)

S_L	0.006599	ft/ft

b.4 *Shield's Diagram*

$R_* = U_* * D50 / \upsilon$

where:

$U_* = (S*R*g)^{1/2}$ = shear velocity (ft/s)

where:

S ~	0.04957	energy slope (ft/ft)
R ~	0.85	hydraulic radius (ft)
g ~	32.2	acceleration of gravity (ft/s/s)
U* ~	1.1648	ft/s
D50 ~	0.078346	ft
υ ~	0.000014	kinematic viscosity of water (ft^2/s)

R_*	6,518	ft
τ*	0.048	Shields diagram

$\tau^* = \tau c / ((\Upsilon s - \Upsilon w) D50)$

τc	0.39	lb/ft^2

$S_L = \tau_c / (\Upsilon_{w*} d)$

S_L	0.007274522	ft/ft

Recompute

R*	2,497	ft
τ*	0.048	
τc	0.39	lb/ft^2

S_L	0.007275	ft/ft

c.) **Long-Term Degradation**

$y_{lt} = (S_0 - S_L)*L$

where:

S_0 ~	0.038	channel bed slope (ft/ft)
S_L ~	0.014330056	Equilibrium (stable) slope, average of methods in Section b
L ~	70	distance between downstream control point and point of interest (ft)

y_{lt}	**1.66**	**ft**

General Scour

Lowering of the stream bed across the channel or stream over relatively short time periods (i.e., single flood event). USBR practice is to compute scour by several methods, use judgment averaging results or selecting appropriate method.

Utilize four methods for estimating general scour

1. Field measurements of scour
2. Regime equations
3. Mean velocity from field measurements
4. Competent or limiting velocity

a.) *Zeller's Equation* *applicable to sand bed streams - not applicable for Gorst Creek.*

$ygs = ymax\ [(0.0685\ Vm^{0.8}) / (yh^{0.4}\ Se^{0.3}) - 1]$

where

ymax	1.8	maximum flow depth, ft
Vm	5.45	average velocity of flow, ft/s
yh	1.57	hydraulic depth of flow, ft
Se	0.04957	energy slope, ft/ft

ygs	-0.81564	ft

b.1) *Regime Equations - Neill's Approach*

$y_f = y_i\ (q_f / q_i)^m$

where:

y_i ~	1.57	average depth at bankfull discharge in incised reach, ft
q_f ~	7.71	design flood channel discharge per unit width, cfs/ft
q_i ~	3.65	bankfull discharge in incised reach per unit width, cfs/ft
m ~	0.85	exponent varying from 0.67 for sand to 0.85 for coarse gravel

y_f 2.97 ft

ys = Z * yf

where

Z ~ 0.6 multiplying factor from Table VII-1 (Pemberton and Lara, 1984)

Table VII-I	Value of Z		
Condition	*Neill*	*Lacey*	*Blench*
Straight reach	0.5	0.25	0.6
Moderate Bend	0.6	0.5	0.6
Severe Bend	0.7	0.75	0.6
Right angle bends		1	1.25
Vertical rock bank or wall		1.25	

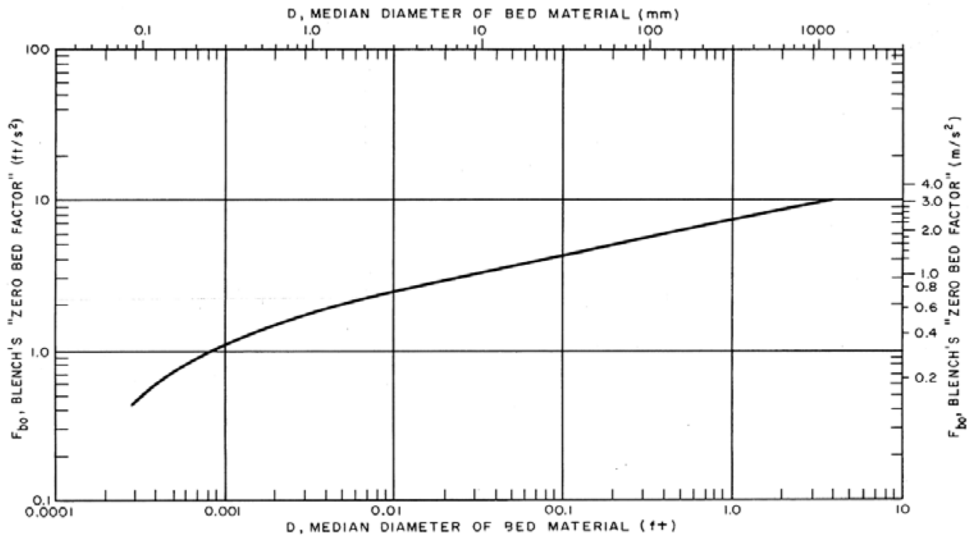
ys	1.78	ft	includes general scour, bend scour, and thalweg formation.

b.2) *Regime Equations - Blench Equation*

$y_{f0} = q_f^{2/3} / F_{b0}^{1/3}$

where

q_f ~	7.71	design discharge per unit width, cfs/ft
F_{bo} ~	4	Blench's "zero bed factor", ft/s^2, from Figure below



y_{f0}	2.46	ft	water depth for zero bed sediment transport, ft

$ys = Z * y_{f0}$

where:

Z ~	0.6	multiplying factor from Table VII-1 (Pemberton and Lara, 1984)

ys	1.48	ft	includes general scour, bend scour, and thalweg formation.

b.3) *Regime Equations - Lacey Equation*

$y_m = 0.47 (Q / f)^{1/3}$

where:

Q ~	110.8	design discharge, cfs
f ~	8.60	Lacey's silt factor = 1.76 * D50$^{1/2}$

y_m	1.1018	ft	mean water depth

$ys = Z * y_m$

where:

Z ~	0.5	multiplying factor from Table VII-1 (Pemberton and Lara, 1984)

ys	0.55	ft	includes general scour, bend scour, and thalweg formation.

c.) *Mean Velocity Method*

$y_s = Z * y_m$

where:

Z ~	0.5	Lacey Z value from Table VII-1
y_m ~	1.57	mean water depth, ft (from model output)

ys	0.785	ft

includes general scour, bend scour, and thalweg formation.

Bend Scour

Bends associated with meandering channels can induce transverse or "secondary" currents, which scour sediment from the outside of a bend and deposit it along the inside of the next bend. Theoretical relationships developed to predict scour through a river bend, but no known procedure consistently yields an accurate prediction of bend scour.

a.) *Zeller Equation* — *use for sand bed streams - not applicable to Gorst Creek*

$y_{bs} = 0.0685\, y_{max}\, V^{0.8} / (y_h^{0.4}\, S_e^{0.3})]\, [2.1(\mathrm{Sin}^2(\alpha/2) / \mathrm{Cos}\,\alpha)^{0.2} - 1]$

where:

y_{max} ~	1.73	maximum depth of upstream flow, ft
y_h ~	1.55	hydraulic depth of upstream flow, ft
V ~	4.55	mean velocity of upstream flow, ft/s
S_e ~	0.0295	upstream energy slope, ft/ft
α ~	23.9	angle formed by projection of channel centerline from point of curvature to a point which meets a line tangent to the outer bank of channel, degrees

$r_c / W_u = (\mathrm{Cos}\,\alpha) / (4*(\mathrm{Sin}^2 (\alpha/2))$

y_{bs}	0.13	ft	Not applicable for Gorst Creek

b.) *Maynord Equation*

$y_{mxb} / y_u = 1.8 – 0.051 (r_c / W_u) + 0.0084 (W_u / y_u)$

where:

y_u ~	1.55	average water depth in crossing upstream of bend, ft
r_c ~	72	centerline radius of bend, ft
W_u ~	15.24	water surface width at upstream end of bend, ft
r_c/W_u ~	4.72	if $r_c/W_u < 1.5$, then use 1.5. should be between 1.5 and 10.
W_u/y_u ~	20.00	if $W_u/y_u<20$, then use 20. should be between 20 and 125.

y_{mxb}	2.68	maximum water depth in the bend, ft
S.F.	1.08	safety factor
y_{mxb}	2.89	ft

$y_{bs} = y_{mxb} - y_u$

y_{bs}	1.34	ft	scour depth below stream bed, includes general scour, bend scour, and thalweg formation

c.) *Thorne Bend Scour Equation*

$y_{max} / y_u = 2.07 – 0.19 \log (r_c / W_u – 2)$

where:

y_u ~	1.55	average water depth in crossing upstream of bend, ft
r_c ~	72	centerline radius of bend, ft
W_u ~	15.24	water surface width at upstream end of bend, ft

r_c/W_u ~ 4.72 must be >2

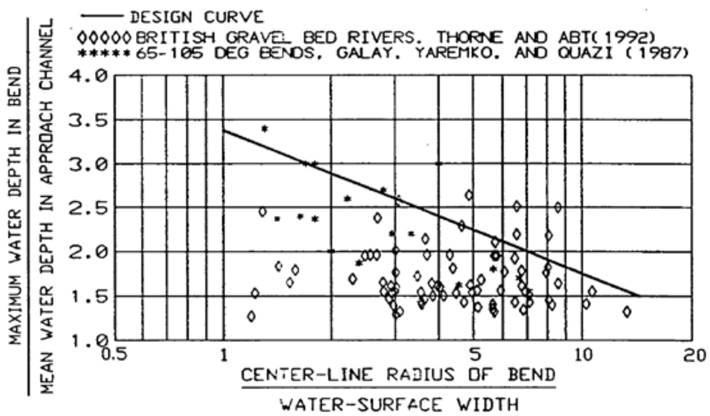
y_{mxb} 3.08 maximum water depth in the bend, ft

$y_{bs} = y_{mxb} - y_u$

y_{bs}	1.53	ft

scour depth below stream bed, includes general scour, bend scour, and thalweg formation

d.) *US Army Corps of Engineers Method*



GRAVEL BED CHANNELS

y_u ~ 1.55 average water depth in crossing upstream of bend, ft

r_c ~ 72 centerline radius of bend, ft

W_u ~ 15.24 water surface width at upstream end of bend, ft

r_c/W_u ~ 4.72

y_{max}/y_u 2.4 From Figure, use r_c/W_u to line

y_{max} 3.72 ft max water depth in the bend

$y_{bs} = y_{max} - y_u$

y_{bs}	2.17	ft

scour depth below stream bed, includes general scour, bend scour, and thalweg formation

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Washington State Department of Transportation Preliminary Basis of Design

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State Route 3 MP 32.1 Gorst Creek

Preliminary Basis of Design Report

Prepared for:
Julie Heilman PE, State Hydraulic Engineer
WSDOT Headquarters Hydraulics Office

Prepared by:
Ecology & Environment, Inc.
720 3rd Ave, Suite 1700
Seattle, WA 98104

S.R. 3 Gorst Creek – Fish Barrier Removal Project
MP 32.1 Gorst Creek
Preliminary Basis of Design Report
June 2016

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Materials can be made available in an alternative format by emailing the WSDOT Diversity/ADA Affairs Team at wsdotada@wsdot.wa.gov or by calling toll free: 855-362-4ADA (4232). Persons who are deaf or hard of hearing may contact that number via the Washington Relay Service at 7-1-1.

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It is Washington State Department of Transportation (WSDOT) policy to ensure no person shall, on the grounds of race, color, national origin, or sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For Title VI complaint forms and advice, please contact OEO's Title VI Coordinator at 360-705-7082 or 509-324-6018.

Professional Engineer Certification

State Route 3 MP 32.1 Gorst Creek Preliminary Basis of Design Report

Pursuant to Washington Administrative Code (WAC) 196-23, this document is required to be submitted under the seal of a State of Washington-licensed professional engineer. This page provides the signature and seal to comply with the regulation.

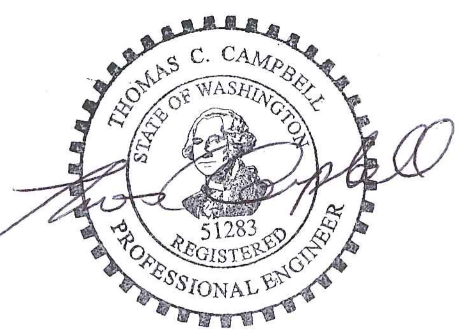
I hereby certify that this Preliminary Basis of Design Report for State Route 3 MP 32.1 Gorst Creek in Port Orchard, Kitsap County, Washington, was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Washington. All engineering calculations and recommendations included therein are in accordance with standard and appropriate engineering practices.

REGISTERED PROFESSIONAL
ENGINEER: Thomas C. Campbell

SIGNATURE: Thos C Campbell

REGISTRATION NUMBER: 51283
STATE: Washington

DATE: 6/13/2016



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1.0 Introduction and Purpose

To comply with federal permanent injunction No. C70-9213 dated March 29, 2013, the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at Mile Post (MP) 32.1 of the State Route 3 (S.R. 3) crossing of Gorst Creek. The Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) have identified the existing structure on S.R. 3 as a fish barrier (Site ID 990168). The fish barrier identification is the result of a calculated flow velocity through the culvert that exceeds high velocity passage criteria and flow depth in the culvert during low flow conditions that are less than minimum depth passage criteria. Per the injunction, and in order of preference, fish passage should be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, or (c) use of the stream simulation methodology. Ecology and Environment, Inc. (E & E), under contract to U.S. Environmental Protection Agency (EPA) Region 10, evaluated design options on behalf of WSDOT as defined in the injunction. Avoidance of the stream crossing is not viable given the location of the highway and the need to maintain this critical north-south transportation corridor. The next option, designing the structure using the bridge design methodology, was determined plausible; however, due to the relatively small size of this stream, the use of stream simulation methodology was determined to be the most practical option. Use of stream simulation methodology, intended for smaller streams, provides similar fish passage benefits as using bridge design methodology.

The structure at MP 32.1 is located in Kitsap County approximately 2 miles south of Gorst, WA (refer to Figure 1 for the vicinity map). The highway runs northeast-southwest at this location and is about 3.5 miles from where this tributary joins the Sinclair Inlet of Puget Sound. Gorst Creek flows southeast to northwest at the S.R. 3 crossing. The Bremerton Auto Wrecking Landfill currently lies in the stream ravine immediately upstream of the crossing, which acts as an additional fish barrier. The EPA is performing a non-time-critical removal action of the landfill in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. The removal action includes complete restoration of the Gorst Creek channel, riparian, and upland ravine through the landfill reach, which is approximately 1,000 feet (ft.) long. The EPA is performing a non-time-critical removal action of the landfill, which includes complete restoration of the Gorst Creek channel, riparian, and upland ravine through the landfill reach. As part of the restoration design, EPA and WSDOT are coordinating restoration efforts to make the upper reaches of Gorst Creek habitable for fish and other native flora and fauna.

The proposed project will replace the existing 4 ft. wide by 4 ft. tall, 160-foot long concrete box culvert with a 19-foot span culvert to improve fish passage while providing a safe roadway for the traveling public. Design of this proposed structure will meet the requirements of the federal injunction utilizing stream simulation design methodology outlined in the 2013 WDFW Water Crossing Design Guidelines (WCDG). The EPA has agreed to fund this Preliminary Basis of Design Report as part of the Bremerton Auto Wrecking Landfill - Gorst Creek Restoration Design to ensure that current restoration efforts do not negatively influence future design efforts for fish passage at S.R. 3.

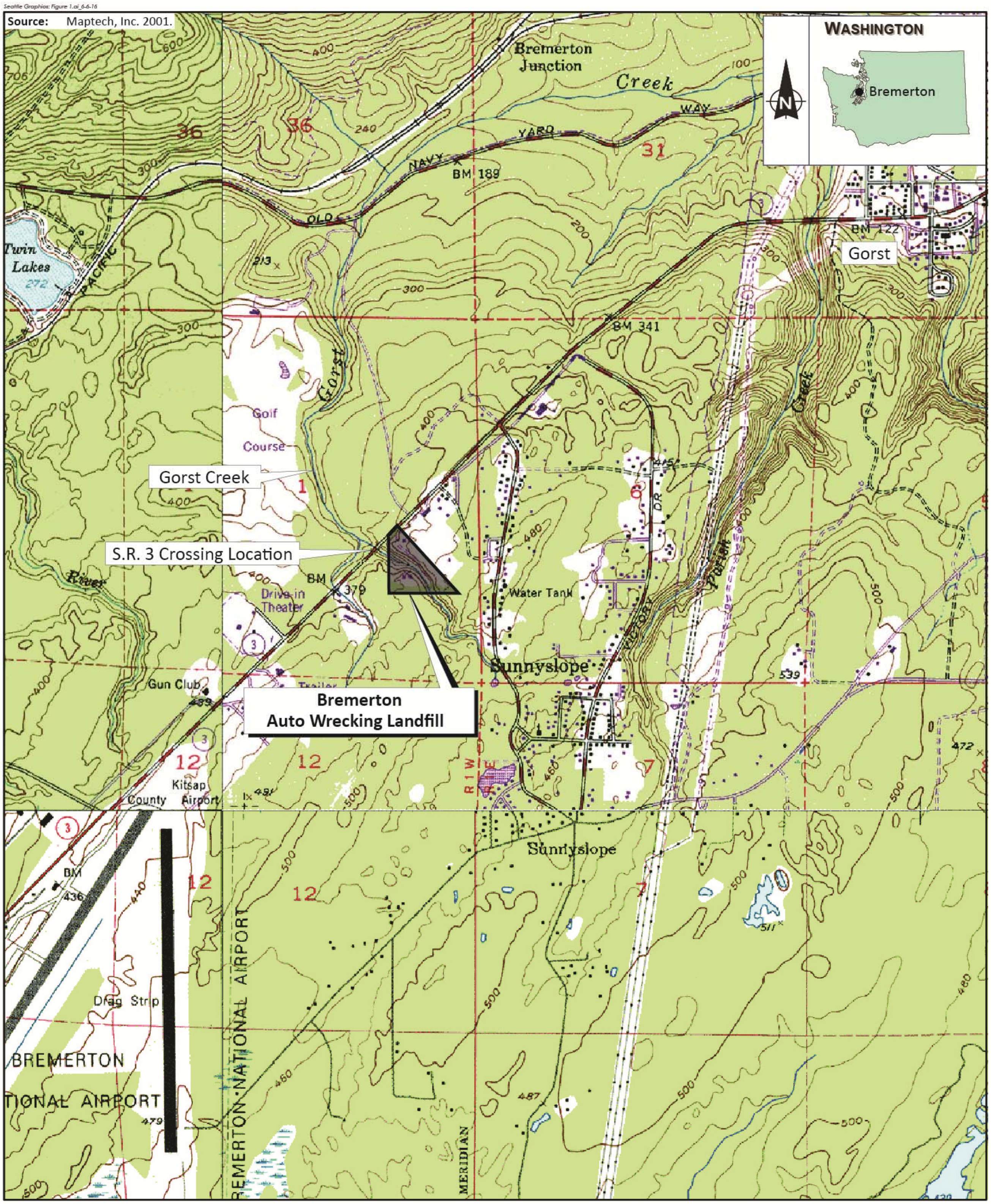

Figure 1. Vicinity Map

Site Reconnaissance

Gorst Creek contains significant natural resources and supports runs of Chinook, coho, chum, steelhead, and sea-run cutthroat trout. However, the upper reach of Gorst Creek has been impacted by an inadequate conveyance crossing at S.R. 3 and industrial development, namely the Bremerton Auto Wrecking Landfill. In 1968, property owners installed a 24-inch corrugated steel culvert along the base of the Gorst Creek ravine just upstream of S.R. 3 for placement of waste within the ravine leaving Gorst Creek to flow through the culvert beneath the landfill. Waste was placed on top of the culvert until the top of the waste became approximately even with the top of the ravine. In 1997 and 2002, after significant storm events, Gorst Creek backed up on the southeast side (upstream end) of the landfill and overtopped the surface causing a portion of the northwest slope of the landfill to fail and wash downstream into Gorst Creek. EPA performed video inspection of the pipe in 2003. Inspection video revealed a collapse of the culvert approximately 460 feet upstream of the outflow, severely diminishing the maximum flow capacity of the culvert. EPA also noted a partial collapse approximately 20 feet downstream of the culvert inflow. The EPA is performing a non-time-critical removal action of the landfill, which includes complete restoration of the Gorst Creek channel, riparian, and upland ravine. Figure 2 includes a photo of the reach upstream of S.R. 3 looking toward the landfill.

In 2012, WSDOT performed stream restoration efforts in Gorst Creek immediately downstream of S.R. 3 for approximately 500 linear feet of channel. The restoration work included repair of the stream channel with bankfull width ranging from 6 to 19 feet, construction of a low-flow channel, installation of habitat root wads adjacent to the stream, and planting native plants for riparian and channel bank areas. Figure 2 shows the restored reach, taken from S.R. 3 looking downstream. Figure 3 displays photos of the inlet and outlet of the box culvert.

Figure 2. Gorst Creek Upstream (Left) and Downstream (Right) of S.R. 3

Figure 3. Existing Box Culvert Inlet (Left) and Outlet (Right)

As shown in Figure 3, the streambed at the outlet of the box culvert is scoured approximately 8 inches deep. A topographic survey performed by EPA contractors in 2011 noted significant sediment depth at the outlet of the box culvert. The sediment was causing partial blockage of the culvert but WSDOT apparently removed the sediment during their restoration effort. Figure 4 displays the restored streambed immediately below the box culvert outlet.

Figure 4. Restored Streambed Below S.R. 3 (looking downstream)

As part of the restoration design for the landfill removal, E & E conducted a reference reach survey in November 2015 in order to obtain design parameters. A reference reach is a stream section that exhibits structure and function that may be ultimately achieved at a restoration reach. The reference reaches included a 665-foot length of Gorst Creek situated less than ¼ mile upstream of the site, and a 1,125-foot length of Parish Creek, located approximately ¾ of a mile east of the site (Figure 5). The investigation focused on the physical habitat and geomorphological conditions of the stream channel and floodplain. The survey design was influenced by the Stream Habitat Restoration Guidelines (Cramer 2012) and included the following observations and measurements:

1. Channel unit type identification, assessment of wetted channel dimensions, bank stability and riparian vegetation composition according to the methods recommended in the Stream Inventory Handbook Level I & II (USFS 2012).
2. Large Woody Debris (LWD) assessment derived from guidance by USFS (2012) and Schuett-Hames et al. (1999).
3. Topographic survey according to Harrelson et al. (1994).
4. Pebble counts as guided by Kondolf (1997).

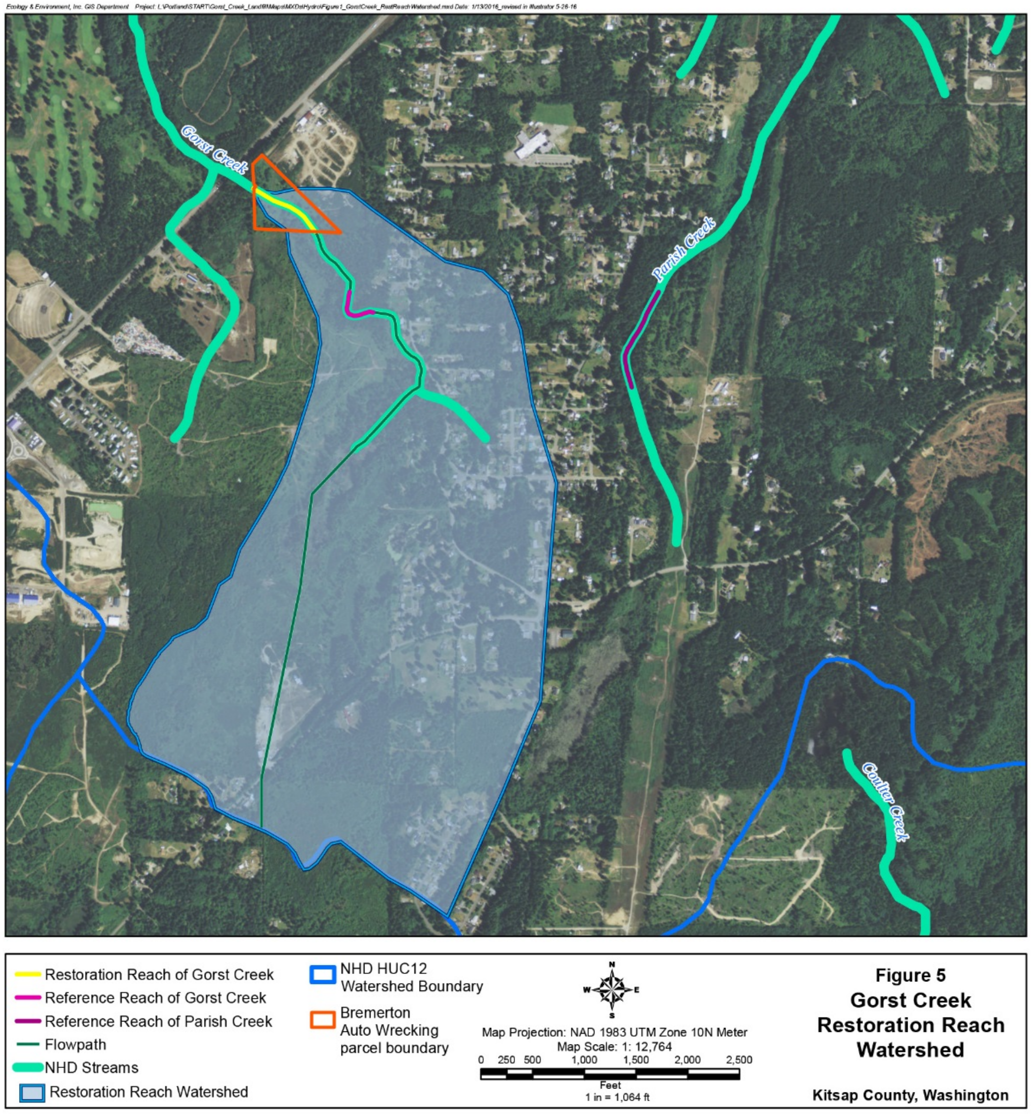

Figure 5. Reference Reach Location Map

Reach Classification and Sinuosity

The reference reaches are alluvial streams that exhibit characteristics of both free-form plane-bed channels and forced pool-riffle channels according to the Montgomery-Buffington Classification (Montgomery and Buffington 1997). Characteristic of plane-bed streams, grains and banks are the dominant roughness elements, which serve to create form friction, deflect and converge flow, and impound sediment. As a result, there are long riffle segments with low to moderate hydraulic and channel form heterogeneity, and the frequency and magnitude of pools are limited. However, in a few short segments, there are sufficient roughness elements, primarily consisting of LWD, boulders, and cobble vanes, to form plunge pools, scour pools, runs, and gravel bars. Furthermore, there is some oscillating cross-channel flow causing convergence and scour on alternating banks, a hallmark of pool-riffle channels.

Channel sinuosity, the ratio of stream channel length to valley floor length (USFS 2012), is fairly limited in these reaches due to their confinement within relatively steep-sided ravines. Using GPS marks and review of aerial photos and digital elevation models, it was estimated that the Gorst Creek reference reach sinuosity is 1.11, whereas the Parish Creek reference reach sinuosity is 1.05.

Channel Units

Three channel unit types (riffles, runs and pools) were present in each reference reach. Riffles dominate the reaches, making up 93.5 percent of the total length of the Gorst Creek reference reach and 92.6 percent of the total length of the Parish Creek reference reach. All riffles appear to contain short stretches of non-turbulent fast water that may or may not be caused by readily identifiable roughness elements. These "micro-runs" were not sufficiently sized to be distinguished as separate channel units.

The segments identified as runs are at least 10 feet long and generally contain roughness elements at their upstream or downstream edges. Runs make up 3.5 percent of the Gorst Creek reference reach and 4.4 percent of the Parish Creek reference reach. Pools are also at least 10 feet long and contain roughness elements but have no or very little hydraulic gradient and a greater abundance of fine substrate (e.g., sand and gravel). Pools make up 3 percent of the length of each reference reach.

Dimensions of the wetted channel within riffles and runs were not readily distinguishable from each other but were distinct from the wetted dimensions of pools. As expected, riffles and runs were typically narrower and almost uniformly shallower than pools within the surveyed reference reaches (refer to Table 1).

Table 1. Channel Unit Water Widths and Depths

Channel Unit	Mean Average water width (feet)	Mean Average water depth (feet)	Mean Maximum water depth (feet)
Riffle/Run	9.1	0.5	0.9
Pool	10.9	0.9	1.4

Large Woody Debris (LWD)

Most LWD pieces appear to consist of boles and branches that entered the creek as a result of tree fall and have not been transported very far, if at all, downstream. Within the riffle and run channel units, LWD extending into the channel and below bankfull elevation (in-channel LWD) is generally 0.5 to 2 feet in diameter. For the combined reference reaches in-channel LWD in riffles and runs average 5.4 pieces per 100 linear feet of channel. Generally, 20 to 30 percent of in-channel LWD within riffles and runs are considered key pieces, which are sufficiently large and embedded in the bed or bank to persist under most high flow events and substantially alter flow and channel form (USFS 2012).

As with riffles and runs, in-channel LWD in the pools is generally 0.5 to 2 feet in diameter. For the combined reference reaches, in-channel LWD in pools average 14.7 pieces per 100 linear feet of channel. Generally, 75 to 100 percent of in-channel LWD within pools are considered key pieces, which span a relatively large portion of the channel width and are thereby critical to pool formation.

LWD located outside the channel and/or above the bankfull elevation but within 10 feet of the channel was present at nearly four pieces per 100 linear feet. These pieces are considered to be a potential source of roughness during flood events and may eventually become in-channel LWD via fracturing from wood decay, bank erosion/channel migration, debris flows, etc.

Cross Sections and Profiles

Three sets of cross sections and profiles were surveyed in representative locations within the reference reaches in order to calculate channel geomorphology metrics, including channel gradient, hydraulic gradient, bankfull width to depth ratio, and entrenchment ratio. The number of in-channel LWD pieces per 100 linear feet of channel was also included in Table 2 to demonstrate the influence that in-channel LWD has upon channel dimensions. The bankfull width to depth ratios of the surveyed segments are well below 12, which is considered to be a threshold for discerning relatively steep headwater channels from lower gradient, higher order reaches, which generally have ratios higher than 12. The entrenchment ratios of the surveyed segments indicate a moderate degree of confinement, as expected for headwater streams within steep-sided ravines.

Table 2. Channel Dimensions of Surveyed Stream Segments

Metric	Gorst Creek	Parish Creek	
	Riffle 2	Riffle 5	Riffle 6
Channel gradient (%)	3.1	4.1	2.8
Hydraulic slope (%)	2.2	3.5	2.5
In-channel LWD per 100 linear feet	5.7	1.5	2.3
Bankfull width to depth ratio	8.09	8.35	9.48
Entrenchment ratio	1.91	1.61	1.73

In-channel Substrate

Most channel units within the reference reaches contain a diversity of channel substrate, ranging from silt to fine sand, less than 2 millimeters in diameter, to large boulders, generally 1,024 to 2,048 millimeters (40 to 80 inches) in diameter. Coarse gravel, generally 16 to 32 millimeters (5/8 to 1-1/4 inches) in diameter, and very coarse gravel, generally 32 to 64 millimeters (1-1/4 to 2-1/2 inches) in diameter, appeared to be most prevalent in riffles and runs. However, fine gravel, generally 4 to 8 millimeters (5/32 to 5/16 inches) in diameter, and cobbles, generally 64 to 256 millimeters (2-1/2 to 10 inches) in diameter, were also abundant in these channel units. In contrast, fine gravel appeared to dominate most of the pools, although other substrate classes, including large boulders, were also present.

Results of the pebble counts demonstrate that the surveyed segments each have a moderately even distribution of the following predominant substrate classes: coarse gravel, very coarse gravel, small cobbles, and large cobbles. Boulders were very uncommon in all segments and entirely lacking in Gorst Creek Riffle 2. Of the three surveyed segments, Gorst Creek Riffle 2 has the highest proportion of fine substrate, as indicated by the low median and 84th percentile substrate diameters (Table 3). However, the proportion of gravel substrate is similar between Gorst Creek Riffle 2 and Parish Creek Riffle 5.

Table 3. Channel Substrate Diameters of Reference Reaches

Metric	Gorst Creek	Parish Creek	
	Riffle 2	Riffle 5	Riffle 6
D50 (median), mm	23.9	31.2	41.2
D84 (84th percentile), mm	61.4	64.0	140.1

Upland Ravine and Riparian Areas

Ravine back-slopes appear to range in gradient from 60 to well over 100 percent. The toe-slopes are slightly less steep, generally ranging in gradient from 30 to 70 percent. Because the toe-slopes lead down to the reference reach channel banks throughout much of their length, a large portion of the flood-prone area (channel and surrounding riparian area) has moderate to steep slopes.

Both reference reaches are within mature second-growth forests dominated by Douglas fir (*Psuedotsuga menziesii*) in the overstory and sword fern (*Polystichum munitum*) in the understory. A few mature red alder (*Alnus rubra*) and a few semi-mature western red cedars (*Thuja plicata*) are also present. Other shrubs prevalent in the forest understory are tall Oregon grape (*Berberis aquifolium*), evergreen huckleberry (*Vaccinium ovatum*), and salal (*Gaultheria shallon*). This community extends across the ravine slopes, which are adjacent to the stream channel on the outside of a stream bend (e.g., cut bank) and adjacent to the relatively narrow floodplains on the inside of a stream bend (e.g., point bar).

A different plant community occupies the riparian area, which extends from slightly below the bankfull elevation to the upper edge of the flood-prone area. This community is typically dominated by salmonberry (*Rubus spectabilis*), but is often co-dominated by sword fern and red alder. Also present in lesser abundance and frequency are Oregon ash (*Fraxinus latifolia*) saplings, beaked hazelnut (*Corylus cornuta*), devil's club (*Oplopanax horridus*), youth-on-age (*Tolmiea menziesii*), fringecup (*Tellima grandiflora*), and lady fern (*Athyrium filix-femina*).

Two non-native invasive plant species were observed in the riparian community along the Gorst Creek channel downstream of the landfill and upstream of the State Route 3 crossing. These species are Japanese knotweed (*Polygonum cuspidatum*) and evergreen clematis (*Clematis vitalba*), which is also known as traveler's joy and old man's beard. Japanese knotweed is a Class B Noxious Weed in Washington and considered a priority species by the Washington Invasive Species Council.

2.0 Hydrology

This section summarizes the hydrologic analysis that was performed for the restoration design of Gorst Creek through the Bremerton Auto Wrecking Landfill. Kitsap County Code Title 12.20.090 for stormwater conveyance facilities requires proposed developments to provide on-site stormwater conveyance facilities with sufficient capacity to convey, without flooding or otherwise damaging existing or proposed structures, the post-development peak stormwater runoff rate resulting from a 100-year storm event, plus any existing upstream runoff that will be conveyed through the development site (Kitsap County 2015). The Santa Barbara Urban Hydrograph (SBUH) event model method as defined in the Stormwater Management Manual for Western Washington (2005) was utilized in this analysis and results were compared to hydrology published in the Flood Insurance Study for Kitsap County (No Name Creek #4, similar drainage area), as well as the USGS regional regression equations using the StreamStats program.

The drainage basin area is 388 acres and was delineated using topographic contours. Time of Concentration was calculated to be 128 minutes, which was based on Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) methodology. The runoff curve number (CN) is based on the hydrologic soil group, land cover type, treatment, and hydrologic condition (amount of vegetation cover and imperviousness) of the contributing drainage basin, which provides a weighted CN of 73.7. The amount of land cover type, watershed slope, and pervious versus impervious land area was estimated based on analysis of available data and mapping information (via geographic information system [GIS]). The predominant hydrologic soil groups for each of the stormwater drainage areas were obtained from the NRCS soil survey (NRCS 2015), and the land cover and hydrologic conditions were evaluated based on current aerials for each of the drainage basins.

Peak flow rates and volumes were determined using the Santa Barbara Urban Hydrograph Method as required by local and state guidelines for stormwater conveyance systems (WSDOE 2014). Precipitation depths used to predict peak flows were estimated using 6-hour and 24-hour isopluvial maps (NOAA 2015). The resulting peak flow rates are summarized in Table 4 and engineering calculations are provided in Appendix A.

Table 4. Peak Discharge Rates

Storm Event	Estimated Peak Flow (cubic feet per second)
2-year / 6-hour	4.3
2-year / 24-hour	26.4
5-year / 24-hour	40.0
10-year / 24-hour	52.4
25-year / 24-hour	72.2
50-year / 24-hour	90.2
100-year / 24-hour	110.8

3.0 Hydraulic Analysis

E & E performed the hydraulic analysis of the existing and proposed S.R. 3 Gorst Creek crossing using the U.S. Army Corps of Engineers' HEC-RAS computer program, a one-dimensional, gradually varied, steady flow numerical model. The channel geometry data in the model was obtained from the reference reach survey discussed in Section 2.0, as well as, topographic survey data collected during the landfill removal assessment in March 2013 and May 2016. The hydraulic model was run using a subcritical flow regime.

Hydraulic roughness values in the vicinity of the crossing were set based on comparison of site observations to standard text book and engineering manual recommendations for similar conditions. A roughness value of 0.16 was used for the overbank areas, which contain dense brush, trees, and deadfall. A roughness value of 0.07 was used for the channel along the reach. The channel is mostly composed of course gravel and cobbles indicative of a lower roughness value of approximately 0.05; however, the channel is littered with woody debris and thick brush that form natural weirs and log drops that drastically increase the roughness, which is typical of steep mountain streams. These same Manning's n values for the channel and overbank areas will be applicable to the proposed condition, the proposed condition assumes areas cleared for construction activities have grown back either naturally or from re-vegetation efforts. Expansion and contraction loss coefficients were set to standard values of 0.03 and 0.01 respectively. Figure 5 displays a photograph of the Gorst Creek channel and floodplain upstream of the landfill that demonstrates roughness elements within the channel.

Figure 6. Upper Gorst Creek Roughness Photo

Two scenarios were analyzed for determining flow characteristics for Gorst Creek with the HEC-RAS models: 1) existing conditions with the 4 foot concrete box culvert, and 2) future conditions with the proposed 19 foot span structure.

3.1 Existing Conditions – 4 Foot Concrete Box Culvert

The existing structure is a 160-foot-long 4-foot concrete box culvert that conveys stream flows underneath S.R. 3 at a design slope of 2.0%. The inlet and outlet of the culvert are equipped with 30 degree flared wingwalls. Entrance and exit loss coefficients are assumed to be 0.3 and 0.1, respectively, and Manning's n for top and bottom is 0.011. Upstream and downstream road embankments were measured at 1.5:1 using LiDAR data.

The HEC-RAS model indicates that flows inside the culvert contain high velocities and are entirely supercritical. Backwater begins to occur upstream of the culvert at the 2-year event and the inlet of the culvert becomes submerged at the 50-year peak flow event, although the roadway is not overtopped. Water surface elevations and velocities for the 2-, 25-, 50-, and 100-year events are presented in Table 5.

Table 5. Water Surface Elevations and Velocities for Existing Conditions

	2-Year Flow	25-Year Flow	50-Year Flow	100-Year Flow
WSE at the Existing Inlet (ft.)	314.27	315.32	315.67	316.04
Outlet Velocity (ft./s)	11.35	14.84	15.59	16.29
Upstream Channel Velocity (ft./s)	1.19	1.55	1.66	1.76
Downstream Channel Velocity (ft./s)	2.93	4.20	4.58	4.95

3.2 Future conditions – Proposed 19 Foot Span Structure

The reference reach survey estimates an average bankfull width of 14 feet to be used in the restoration reach design upstream of the culvert, which would result in a culvert span of 19 feet using the stream simulation method specified in the WCDG (see Section 5.0). This width is also consistent with the restored stream channel immediately downstream of the culvert, which ranges from 6 to 15 feet wide. The length to span ratio of this culvert is 8.4, which is less than the recommended maximum ratio of 10.

The future conditions scenario modeled in HEC-RAS simulated this proposed 19-foot wide structure with a 7-foot rise under S.R. 3. The channel through the replacement structure and through the project area being graded was set to the a slope of 3.2%.

Table 6. Water Surface Elevations and Velocities for Proposed Conditions

	2-Year Flow	100-Year Flow
Water Surface Elevation (ft.)	313.61	314.27
Outlet Velocity (ft./s)	3.55	5.11
Upstream Channel Velocity (ft./s)	3.94	6.28
Downstream Channel Velocity (ft./s)	2.92	4.87

The HEC-RAS model of future conditions indicates a flow velocity during the 100-year peak flow event of approximately 5.72 ft./s with a bed shear stress value of 1.51 pounds/square ft downstream of the culvert. During the 100-year peak flow, the model simulation shows 5.7 feet of freeboard between the water surface and the low chord of the proposed structure, which exceeds the recommended 3 feet in order to provide passage of large woody debris. The additional height of the culvert also serves as a wildlife crossing.

4.0 Fish Passage Design Selection Methods

4.1 Design Methodology Selection

The WCDG contain methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and bridge design method unless extraordinary circumstances exist on site. According to the WCDG, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bankfull width of greater than 15 feet, the channel is believed to be unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, or the culvert would be very long. Using these design criteria, stream simulation was deemed the most appropriate method for this crossing.

4.2 Stream Simulation Design Criteria

The WCDG methodology for designing a stream simulation culvert is defined by the Floodplain Utilization Ratio (FUR), bankfull width, channel gradient, channel shape, and substrate. The FUR is defined as the flood-prone width (FPW) divided by the bankfull width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood. Streams appropriate for stream simulation design will generally have a FUR of less than 3, with some exceptions for low gradient streams with limited potential for meander.

The average bankfull width of the stream near the crossing is approximately 14 feet. The average width of the 100-year floodplain is approximately 26 feet, resulting in a FUR of 1.9; therefore, the crossing meets this criteria for a stream simulation design.

4.2.1 Culvert Span and Length

The WCDG recommend sizing the span of the proposed structure based on the agreed upon bankfull width with the span being 1.2 x bankfull width + 2 feet (WCDG Equation 3.2). Using this equation, along with the modelled bankfull width of 14 feet discussed in Section 4.2, results in a structure span of 19 feet.

However, the WCDG also recommend that the length of a stream simulation culvert should be checked against its span. If the ratio of the culvert length to the culvert span is greater than 10 it is considered a long culvert and special design considerations are necessary. The length of the proposed structure is expected to roughly equal the existing structure of 160 feet, resulting in a ratio of 8.4. Therefore, special design considerations for long culverts are not necessary for this crossing.

4.2.2 Backwater and Freeboard

The WCDG recommend the prevention of excessive backwater rise during floods that might lead to coarsening of the stream substrate from scour of the streambed, not allow the free passage of woody debris expected to be encountered, and generally recommends a 3 foot minimum freeboard. Modeling shows that no backwater effect is expected during the 100-year peak flow at this crossing. As discussed in Section 4.2, the proposed culvert will provide 5.7 feet of freeboard at this crossing.

4.2.3 Channel Planform and Shape

The WCDG require that the channel planform and shape mimic conditions within a reference reach. Existing conditions were evaluated both upstream and downstream of the crossing. It was determined that matching the shape of the proposed restored channel upstream above the S.R. 3 crossing makes the most sense. This channel shape will extend through the structure as well as downstream through the section of stream previously restored by WSDOT.

4.2.4 Channel Gradient

The WCDG recommend that the proposed culvert bed gradient not be more than 25% different than the existing stream gradient upstream of the crossing (WCDG Equation 3.1). At this site, the upstream gradient is expected to be roughly 3.8% and the gradient proposed for the crossing structure is 3.2%, which falls within the 25% difference recommended by the WCDG.

Channel gradient also dictates whether additional stream stability measures need to be taken to ensure that the channel through the culvert keeps its shape. If the slope of the streambed through the culvert is less than 4% then coarse bands, placing larger material along the sides of the culvert, or similar channel shaping measures are recommended. Since the channel slope here is below 4%, coarse bands shall be installed inside the culvert to provide stability to the bed through the structure. The size of material and the number of coarse bands is further discussed in Section 6.3.

4.2.5 Substrate

The WCDG recommend using the same size of material that exists in a reference reach of the stream as a guide for what to place into the proposed structure and channel. Pebble counts were conducted during the reference reach assessments of upper Gorst Creek and Parish Creek. E & E designed bed material for the proposed channel using the Critical Unit Discharge Method as described in Section 6.3, which gave a gradation that very closely matched the bed material observed in the Parish Creek reference reach.

5.0 Streambed Design

5.1 Alignment

The proposed channel bed through the project area is designed to mimic a natural streambed with a slope of approximately 3.2%. The proposed horizontal alignment is unchanged from existing.

5.2 Proposed Section

The main channel cross sectional configuration proposed for inside the replacement structure will continue upstream and downstream through the project area where channel grading will occur. The proposed channel work will generally follow the existing creek alignment, which will create a diversity of flow characteristics and aquatic habitat through the constructed area. The proposed channel cross sections shown in the attached plan sheets (Appendix D – to be added later) are "neat line" drawings that do not accurately depict the complexity of the finished low flow channel bed. If constructed as proposed, the low flow channel will have portions of cobbles projecting up from the bed that will create flow diversity and improve fish passage for juvenile salmonids by creating a boundary layer of very low flow velocity along the bed. To provide habitat, the streambed material will include a significant amount of cobbles while also including gravels, sands, and a minor portion of fines to keep flow in the creek on the surface of the bed, especially during low flow conditions. The channel sections are shown on the plan sheets in Appendix D (to be added later).

5.3 Bed Material

For channels steeper than 1 percent (S = 0.01) where the flow depth is shallow with respect to the channel bed particle sizes (R/D50 < 10), water depth can be quite variable because large rocks or wood pieces on or near the surface influence depth (Bathurst 1987). For such channels, Bathurst et al. (1987) used flume data to construct an equation that predicts the critical unit discharge for entraining the D50 particle size in well-sorted sediments. The ratio of flow depth to D50 particle size in this case is roughly equal to 3.5 during the 2-year event; therefore, the critical unit discharge method was used to estimate entrainment. This method indicates that the streambed materials matching the Parish Creek reference reach substrate will be mostly stable at the 2-year peak flow but also allows for transport of the finer particles through the system during higher flows. The proposed streambed material will be constructed using materials as described in WSDOT Standard Specifications, specifically 9-03.11(1) streambed sediment and 9-03.11(2) 8" cobbles. This closely matches what was found on site during the reference reach survey of Parish Creek. The streambed material found in the upper Gorst Creek reference reach contains smaller gravels and cobbles that are likely to be entrained during the 2-year event if placed at the culvert location; therefore, it is recommended that streambed sediments simulate the Parish Creek riffle 6 substrate. The calculations and gradation charts from the reference reach survey are contained within Appendix B.

6.0 References

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7.0 Appendices

Appendix A – HEC-RAS Model Results

Appendix B – Streambed Material Sizing Calculations

Appendix D – Scour Calculations (to be added later)

Appendix E – Stream Plan Sheets, Profile, Details (to be added later)

HEC-RAS Plan: Plan 05 River: GORST CREEK Reach: Site 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Site 1	1600	2-yr	26.40	350.82	352.10	352.01	352.30	0.063710	3.69	7.92	13.48	0.86
Site 1	1600	100-hr	110.80	350.82	352.95	352.83	353.37	0.047481	5.43	25.84	29.43	0.85
Site 1	1500	2-yr	26.40	347.10	347.94		348.06	0.029941	2.83	9.69	15.05	0.61
Site 1	1500	100-hr	110.80	347.10	348.75		349.18	0.037139	5.34	22.62	17.35	0.77
Site 1	1400	2-yr	26.40	343.33	344.08		344.24	0.050142	3.26	8.20	14.93	0.76
Site 1	1400	100-hr	110.80	343.33	344.94		345.38	0.038996	5.33	21.87	16.66	0.78
Site 1	1300	2-yr	26.40	339.57	340.42		340.54	0.028385	2.75	9.77	15.09	0.59
Site 1	1300	100-hr	110.80	339.57	341.22		341.63	0.036065	5.22	22.45	17.20	0.76
Site 1	1200	2-yr	26.40	335.80	336.50	336.43	336.67	0.055414	3.26	8.20	16.02	0.79
Site 1	1200	100-hr	110.80	335.80	337.32		337.75	0.041760	5.28	22.07	18.68	0.80
Site 1	1100	2-yr	26.40	332.03	332.91	332.68	333.02	0.025642	2.64	10.11	15.07	0.56
Site 1	1100	100-hr	110.80	332.03	333.74	333.43	334.12	0.031739	4.97	23.46	18.92	0.71
Site 1	1000	2-yr	26.40	328.27	328.95	328.90	329.13	0.064965	3.44	7.76	15.73	0.85
Site 1	1000	100-hr	110.80	328.27	329.74	329.62	330.21	0.048954	5.57	20.78	17.40	0.86
Site 1	900	2-yr	26.40	324.50	325.37	325.14	325.47	0.023205	2.51	10.72	16.33	0.53
Site 1	900	100-hr	110.80	324.50	326.20		326.53	0.027883	4.67	25.05	18.34	0.67
Site 1	800	2-yr	26.40	320.74	321.40	321.37	321.61	0.075561	3.69	7.24	14.81	0.92
Site 1	800	100-hr	110.80	320.74	322.20	322.13	322.73	0.054241	5.89	19.70	16.43	0.91
Site 1	700	2-yr	26.40	316.97	317.87	317.61	317.97	0.021041	2.52	10.71	15.14	0.52
Site 1	700	100-hr	110.80	316.97	318.77	318.37	319.11	0.025305	4.69	25.35	19.17	0.65
Site 1	600	2-yr	26.40	313.20	313.85	313.85	314.09	0.092714	3.94	6.77	14.60	1.01
Site 1	600	100-hr	110.80	313.20	314.61	314.61	315.21	0.066144	6.28	18.41	16.10	1.00
Site 1	517		Culvert									
Site 1	400	2-yr	26.40	307.83	308.63		308.77	0.017762	2.92	9.15	14.72	0.64
Site 1	400	100-hr	110.80	307.83	309.54		309.90	0.015804	4.87	23.87	17.89	0.70
Site 1	300	2-yr	26.40	305.86	306.78	306.64	306.94	0.018629	3.40	9.55	16.04	0.68
Site 1	300	100-hr	110.80	305.86	307.69		308.13	0.019634	5.87	26.11	20.31	0.80
Site 1	200	2-yr	26.40	303.91	305.15	304.97	305.27	0.014805	2.70	10.29	17.79	0.59
Site 1	200	100-hr	110.80	303.91	305.95		306.29	0.016781	4.88	26.61	23.39	0.71
Site 1	100	2-yr	26.40	301.87	302.65	302.63	302.86	0.044869	3.77	7.39	16.49	0.97
Site 1	100	100-hr	110.80	301.87	303.35	303.35	303.92	0.035480	6.19	19.85	18.68	1.01
Site 1	19.93	2-yr	26.40	298.96	300.07	299.96	300.22	0.025038	3.22	9.65	19.09	0.73
Site 1	19.93	100-hr	110.80	298.96	300.82	300.68	301.22	0.025029	5.51	26.00	23.32	0.84

Plan: Plan 05 GORST CREEK Site 1 RS: 517 Culv Group: Culvert #1 Profile: 2-yr

Q Culv Group (cfs)	26.40	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	3.06
Q Barrel (cfs)	26.40	Culv Vel DS (ft/s)	3.55
E.G. US. (ft)	313.80	Culv Inv El Up (ft)	313.16
W.S. US. (ft)	313.85	Culv Inv El Dn (ft)	308.40
E.G. DS (ft)	308.77	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	308.63	Culv Exit Loss (ft)	0.22
Delta EG (ft)	5.04	Culv Entr Loss (ft)	0.04
Delta WS (ft)	5.22	Q Weir (cfs)	
E.G. IC (ft)	313.79	Weir Sta Lft (ft)	
E.G. OC (ft)	313.80	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	313.61	Weir Max Depth (ft)	
Culv WS Outlet (ft)	308.79	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	0.45	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	0.39	Min El Weir Flow (ft)	353.13

Plan: Plan 05 GORST CREEK Site 1 RS: 517 Culv Group: Culvert #1 Profile: 100-hr

Q Culv Group (cfs)	110.80	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	5.26
Q Barrel (cfs)	110.80	Culv Vel DS (ft/s)	5.11
E.G. US. (ft)	314.83	Culv Inv El Up (ft)	313.16
W.S. US. (ft)	314.61	Culv Inv El Dn (ft)	308.40
E.G. DS (ft)	309.90	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	309.54	Culv Exit Loss (ft)	0.04
Delta EG (ft)	4.93	Culv Entr Loss (ft)	0.13
Delta WS (ft)	5.07	Q Weir (cfs)	
E.G. IC (ft)	314.81	Weir Sta Lft (ft)	
E.G. OC (ft)	314.83	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	314.27	Weir Max Depth (ft)	
Culv WS Outlet (ft)	309.54	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	1.11	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	1.02	Min El Weir Flow (ft)	353.13

Critical Unit Discharge Method

For channels steeper than 1 percent (S = 0.01) where the flow depth is shallow with respect to the channel bed particle sizes (R/D50 < 10), water depth can be quite variable because large rocks or wood pieces on or near the surface influence depth (Bathurst 1987). For such channels, Bathurst et al. (1987) used flume data to construct the following equation, which predicts the critical unit discharge for entraining the D50 particle size in well-sorted sediments:

1) Calculate the critical unit discharge (qc-D50) needed to entrain the D50 particle size at any given cross section.

Bathurst Equation

$q_{c\text{-}D50} = 0.15 * g^{0.5} * D50^{1.5} / S^{1.12}$

where:

$q_{c\text{-}D50}$ ~	critical unit discharge (cfs/ft)	
g ~	32.2	gravity (ft/s/s)
D_{50} ~	0.134514	median particle size diameter (ft)
S ~	0.038	channel slope (ft/ft)

$q_{c\text{-}D50}$ 1.64 cfs/ft

2) Calculate the critical unit discharge (q_{ci}) needed to entrain the particle size of interest at any given cross section (e.g., D84 or D95).

$q_{ci} = q_{c\text{-}D50} (D_i / D_{50})^b$

where:

q_{ci} ~	critical unit discharge to entrain the particle size of interest (cfs/ft)	
$q_{c\text{-}D50}$ ~	1.64	critical unit discharge (cfs/ft)
D_i ~	0.459318	particle size of interest (D84, (ft))
D_{50} ~	0.134514	median particle size diameter (ft)
b ~	a measure of the range of particle sizes that make up the channel bed. It quantifies the effects on particle entrainment of smaller particles being hidden and of larger particles being exposed to flow. Calculate the exponent from: Equation E.9	

$b = 1.5(D_{84}/D_{16})^{-1}$

b = 0.080357

q_{ci} 1.81 cfs/ft

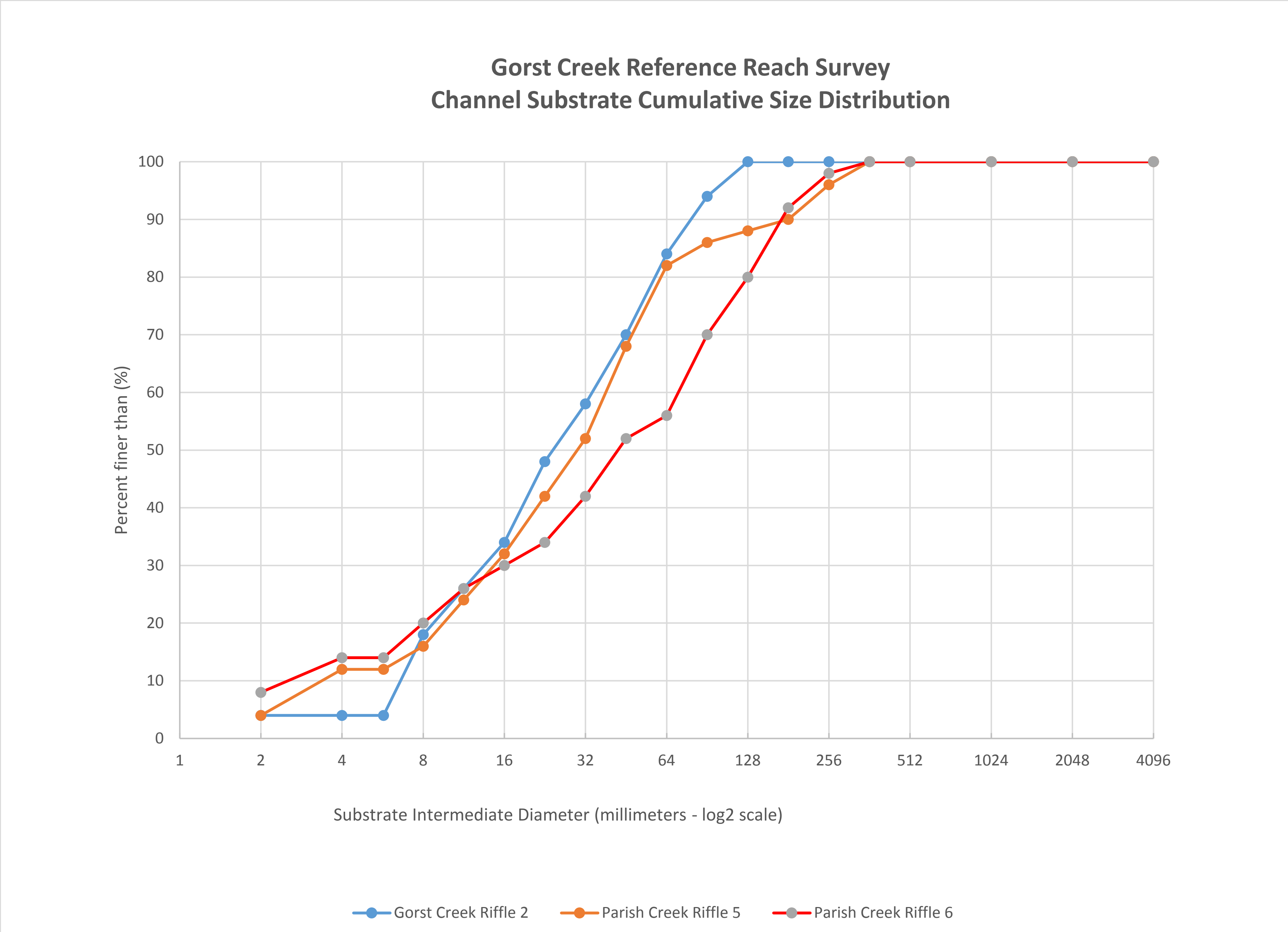
4) Calculate the unit discharge within the active channel for a range of discharges using a hydraulic model such as WinXSPRO or HEC-RAS.

q = Q/w

where:

q ~	unit discharge (cfs/ft)	
Q ~	26.40	discharge (cfs)
w ~	14	active channel width for bedload transport (ft)

$q_{c\text{-}D50}$ 1.89 cfs/ft


Gorst Creek Reference Reach Survey
Channel Substrate Cumulative Size Distribution
Percent finer than (%)
100
90
80
70
60
50
40
30
20
10
0
1
2
4
8
16
32
64
128
256
512
1024
2048
4096
Substrate Intermediate Diameter (millimeters - log2 scale)
Gorst Creek Riffle 2
Parish Creek Riffle 5
Parish Creek Riffle 6