FINAL REPORT

Perrinville Creek Stormwater Flow Reduction Retrofit Study

Grant Number G1400022

February 2015

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ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations are used in this report.

BMP	Best Management Practice
BR	Blue Ridge (wet pond)
CB	Catch basin
DEM	Digital Elevation Model
Ecology	Washington State Department of Ecology
GDB	Global Database (a GIS data file)
GIS	Geographic Information System
GPS	Global Positioning System
HSPF	Hydrologic Simulation Program - Fortran
LID	Low Impact Development
NRCS	Natural Resources Conservation Service
OVD	Olympic View Drive (infiltration and detention facility)
SSURGO	Soil Survey Geographic Database
USGS	U.S. Geological Survey
WWHM	Western Washington Hydrology Model

Units of Measurement

ac	acre(s)
cfs	cubic feet per second
ft	feet
yr	year

ACKNOWLEDGEMENT

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EXECUTIVE SUMMARY

The City of Edmonds ("City") desires to improve the water quality and aquatic habitat in Perrinville Creek. The 764-acre watershed, located both within the City of Edmonds and the City of Lynnwood, largely developed prior to modern stormwater quantity and quality controls. Perrinville Creek has the three conditions typical of Puget Sound coastal watersheds: a broad headwater plateau, urban land use, and runoff concentrated in storm drains. The creek drops about 260 feet in elevation over 1 mile, first passing through the heavily-wooded, undeveloped Southwest County Park, then through residential yards, under Talbot Road, and ultimately discharging into Browns Bay in Puget Sound adjacent to residential properties. Approximately 90 percent of the watershed is residential land use; the remaining 10 percent is commercial.

In the mid-1990s, the City installed a flow bypass structure in the lower reach of Perrinville Creek. The purpose the bypass was to protect homes downstream from flooding, capture sediment, and prevent washout of the culvert under the BNSF railroad tracks at the creek mouth. Due to its location and the characteristics of the creek, this bypass is subject to excessive sedimentation that requires frequent maintenance to preserve its function.

The 30-inch-diameter Perrinville Creek culvert under Talbot Road near Puget Sound is a fish barrier for anadromous fish (RW Beck 1991). The City has completed a preliminary design report for replacing the existing culvert with a larger fish-friendly box culvert to permit access to some upstream habitat located on private property (Herrera 2012). Replacing this culvert, however, also could broaden sedimentation deposition and flooding risk in the lower reaches of Perrinville Creek, since the existing culvert restricts some high creek flows. According to a fish presence and habitat survey done by Pentec Environmental (1998), replacing this culvert can result in fish access to approximately 600 feet of upstream habitat. Allowing fish access to this upstream habitat, however, would require substantial re-engineering of the existing stream channel on private property to remove fish passage barriers.

The City would initially like to improve aquatic habitat in the reach between Talbot Road and the creek mouth at Puget Sound prior to improvements upstream of Talbot Road. This first reach, approximately 500 feet long, will also require substantial improvements of the existing stream channel located on private property. The City also wants to reduce the level of maintenance required to keep the bypass structure functioning and, eventually, be able to safely remove the structure. Achieving all of these objectives necessitates flow reduction in Perrinville Creek.

The primary goal of this project is to reduce flows in Perrinville Creek that are causing erosion in the upper reaches and sedimentation and some flooding in the lower reaches. This goal will be accomplished by reducing the amount of stormwater runoff that flows directly into Perrinville Creek. The flow reduction will provide multiple hydrologic and biological benefits to both the creek and Browns Bay in Puget Sound, such as allowing for the replacement of an anadromous fish barrier culvert, reducing erosion and sedimentation that are impacting aquatic habitat and City infrastructure, and reducing the amount of pollutants in the aquatic environment. This study evaluates and recommends means to reduce the erosive degradation in Perrinville Creek and the consequent sediment deposition in the creek's lower reaches, as well as to mitigate the potential flood risk from replacing the Talbot Road culvert.

The study process for this project developed a hydrologic model of the watershed draining to Perrinville Creek and flow monitoring data collected over the 2013-2014 wet season was used to calibrate the model to assure it is representative of current flow regime experienced in the creek. Conditions in the creek were analyzed to assess instabilities in the stream channel and to estimate the flow thresholds at which significant erosion occurs. Geotechnical explorations and tests were performed across the watershed to characterize the surficial soils, the underlying geology, and the ability to infiltrate stormwater runoff in various locations.

The scope of this stormwater retrofit plan to reduce flows in Perrinville Creek focuses on capital improvements in public rights-of-way and on city-owned parcels. The identification of specific capital project opportunities emphasizes sites in the City of Edmonds; however, several projects were identified in Lynnwood, particularly cost effective structural retrofits to existing flow control facilities. This analysis identified 30 discrete flow reduction opportunities within public rights-of-way and on public properties (specifically park lands). Evaluating the 30 candidate opportunities, it recommended that 12 projects be advanced to design and implementation in the near term, listed in Table ES-1.

Table ES-1. Recommended Project Summary

ID	RETROFIT TYPE	NEW/ MODIFIED FACILITY	LOCATION	CITY	TOTAL TRIBUTARY AREA (AC)	2-YEAR PEAK FLOW REDUCTION (CFS)	COST ESTIMATE
10-1	Bio-retention	New	18027 73rd Ave W	Edmonds	1.9	0.18	$89,000
11-1	Bio-retention	New	17922 72nd Ave W	Edmonds	0.8	0.18	$37,000
13-1	Bio-retention	New	7418 Ridge Way	Edmonds	3.5	0.24	$77,000
16-1	Infiltration Facility	New	Seaview Park	Edmonds	52.8	3.50	$841,000
19-1	Vault	New	7300 196th St SW	Lynnwood	35.7	4.50	$1,123,000
20-1	Pond	Modify	Copper Ridge	Lynnwood	3.8	0.38	$22,000
22-1	Pond	Modify	Blue Ridge	Lynnwood	55.2	2.55	$22,000
25-1	Bio-retention	New	7226 182nd St SW	Edmonds	1.3	0.28	$96,000
26-1	Vault	New	7332 192nd Pl SW	Lynnwood	28.1	1.39	$286,000
27-1	Pond	Modify	Olympic View Crest	Edmonds	3.1	0.32	$74,000
28-1	Infiltration Facility	Modify	Lynndale Park	Lynnwood	82.1	0.20	$22,000
29-1	Infiltration Facility	New	Olympic View Dr/ 76th St SW	Edmonds	4.0	0.25	$233,000

Two of the recommended projects, No. 16-1 in Seaview Park and No. 26-1 at 74th Avenue W and 192nd Place SW, are in preliminary design as part of this project.

The hydraulic effects on the stream channel from implementing the recommended projects were evaluated using the calibrated hydrologic model developed for this study. Two retrofit scenarios were modeled as follows to better understand the corresponding effects. These scenarios are as follows:

- Recommended Projects - This scenario evaluates effects from constructing the 12 capital projects for near-term implementation (approximate cost $2.9M).
- Basin Wide LID retrofit – This scenario evaluates the effect of implementing LID retrofits more comprehensively within city rights-of-way throughout the watershed (approximate additional cost $2.8M).

Results from the modeled scenarios, summarized in Table ES-2, indicate an average 20% reduction in the **magnitude** of peak flood flows for 2-year through the 100-year return period for the 12 recommended projects. When a comparison is made between existing conditions and those following implementation of the 12 recommended projects, it is observed that the **frequency of flooding** at any given rate is reduced roughly by half; by example, the current 25-year flood flow of 99 cfs approximates the 50-year flood flow under the retrofitted condition. This represents a substantial reduction in flooding risk with the recommended projects implemented.

Table ES-2. Selected Peak Flood Flow Reduction at Talbot Road Crossing

RETURN PERIOD	EXISTING CONDITIONS (CFS)	RETROFIT WITH RECOMMENDED PROJECTS (CFS)	REDUCTION	BASIN-WIDE RIGHT-OF-WAY RETROFIT (CFS)	PRE-DEVELOPED FORESTED CONDITION (CFS)
2-Year	41	31	26%	28	6.9
10-Year	77	59	25%	56	13.5
25-Year	99	87	14%	80	16.0
50-Year	126	100	22%	99	17.4
100-Year	135	115	15%	105	18.6

Table ES-2 also indicates that implementing additional right-of-way BMPs basin-wide provides limited additional flood flow reduction beyond that of the recommended projects.

Implementing the recommended projects will reduce flood flows sufficiently to allow replacement of the fish barrier culvert without increasing flood risk to properties downstream of Talbot Road. Sufficient flood flow reduction will be achieved to mitigate removal of the existing culvert by construction of two of the most highly effective of the recommended projects: Project 16-1 (Seaview Park facility) and Project 22-1 (Blue Ridge Pond modifications).

Implementing the recommended near-term projects was also shown to reduce the amount of scour along the Perrinville Creek channel. The generation of new sediment material occurs when discharge in the stream channel exceeds the mobilization flow rate of approximately 7.2 cfs. Reducing the amount of time that flows exceed this erosive threshold represents reductions in the amounts of damage to the stream channel, new sediment generated in the stream, sediment deposited in the lower reaches, and sediment needing removal from the City’s sediment control facility. The recommended projects would reduce erosive flows by 18%.

Similarly, the threshold at which sediment existing in the creek channel is transported downstream is reduced from 22 percent to 18 percent of the 60-year period of record used in the model. This represents an 18% reduction in the duration of sediment transporting flows. The percent exceedances are summarized below in Table ES-3. Again, implementing right-of-way BMPs basin wide provides limited additional benefit.

Table ES-3. Erosive Flow Duration Reduction in Perrinville Creek

THRESHOLD FLOW (CFS)	PERCENT OF TIME THRESHOLD EXCEEDED UNDER EXISTING CONDITIONS	PERCENT OF TIME THRESHOLD EXCEEDED WITH RECOMMENDED PROJECTS	PERCENT REDUCTION IN DURATION OF FLOW EXCEEDING THRESHOLD	PERCENT OF TIME THRESHOLD EXCEEDED UNDER PRE-DEVELOPED FORESTED CONDITION
4.5 *transport*	22%	18%	21%	2.2%
7.2 *scour*	14%	11%	18%	0.6%

It should be noted that city-owned and controlled properties, consisting of road rights-of-way and parks, account for only approximately 13 percent of the Perrinville Creek watershed, with the balance owned by private businesses and individuals or other public entities (such as school districts, community college). Because most of the watershed were developed in the absence of stormwater flow control or water quality treatment standards, there is a large collective opportunity for flow reduction and water quality improvement in the basin as these properties redevelop under modern technical standards. Hence, it is recommended that a flow control standard be developed and placed into effect for the Perrinville Creek watershed to reduce the erosive flows.

The first step in developing a flow control standard would be to evaluate if the flow control standard in the Department of Ecology’s 2012 Stormwater Management Manual for Western Washington is adequate for this creek. If not, a stricter flow control standards should be developed and implemented throughout the Perrinville Creek watershed. In addition, flow control requirements should strongly promote infiltration of runoff, particularly in areas of the watershed where outwash soils can be accessed within 10 feet of the ground surface, as mapped in this study. This mimics the predevelopment condition by reducing the amount of surface runoff entering the creek.

In addition to occasions of redevelopment, private initiatives such as a rain garden program can improve flow control and water quality of runoff. Both redevelopment and private initiatives can improve conditions in Perrinville Creek, but as their timing and scope are indeterminate, their benefits to the creek are not modeled in this study.

This study has located those reaches of Perrinville Creek that are most prone to scour during erosive flows. These areas, however, are predominately located within a deep canyon in the undeveloped Snohomish County Park and immediately below the park. While it may be beneficial to stabilize these areas, thus potentially raising the threshold flow rates where scour and transport occur, the inaccessibility of these areas likely makes this work very costly. Further study of options for stabilizing these areas may be warranted.

Finally, with this study's understanding of the basin hydrology, the cities of Edmonds and Lynnwood can appropriately consider flow control enhancements as they make improvements to drainage systems over time. Examples of these types of interventions include:

- Oversizing storm drainage system replacements to incorporate storage and flow control of smaller events
- Incorporating bioretention or infiltration systems and pervious pavements, and/or reducing in impervious areas when reconstructing roadways
- Collaborating with redeveloping property owners to expand flow control capacity beyond that strictly required for their project.

The recommended improvements involve substantial investment to redress the hydrologic effects of historical urbanization in the watershed. The benefits to accrue to the community, however, are several:

- The sediment loading to the City's sediment trapping facility that protects the lower reaches of the stream will be reduced, and bring a corresponding reduction in maintenance costs for cleaning the facility
- The degradation of the stream channel and hillslope failures through public and private properties will be slowed, and stream reaches will become more stable
- The risk of blockage to the existing Talbot Road culvert will be reduced, and with it the risk of overtopping the roadway (and damaging city-owned water, sewer, and stormwater infrastructure).
- Flood flow magnitudes will be reduced, lowering risk of damage to Talbot Road and properties below and immediately above the road
- Flood frequencies will be reduced by one-half
- The rate of sediment deposited in the lower reaches of Perrinville Creek and at the shoreline of Browns Bay will be reduced, along with the associated damage to aquatic habitat
- The reduction in flood magnitudes will allow construction of the fish-friendly culvert proposed for Talbot Road without increasing flood risks.

These benefits align with regional, statewide and national objectives to protect and improve water quality and habitat function in coastal ecosystems. This alignment promotes the eligibility of the recommended projects for continued outside funding support.

INTRODUCTION

The City of Edmonds ("City") desires to improve the water quality and aquatic habitat in Perrinville Creek. The 764-acre watershed, located both within the City of Edmonds and the City of Lynnwood, largely developed prior to modern stormwater quantity and quality controls. Perrinville Creek has the three conditions typical of Puget Sound coastal watersheds: a broad headwater plateau, urban land use, and runoff concentrated in storm drains. The creek drops about 260 feet in elevation over 1 mile, first passing through the heavily-wooded, undeveloped Southwest County Park, then through residential yards, under Talbot Road, and ultimately discharging into Browns Bay in Puget Sound adjacent to residential properties. Approximately 90 percent of the watershed is residential land use; the remaining 10 percent is commercial.

In the mid-1990s, the City installed a flow bypass structure in the lower reach of Perrinville Creek. The purpose the bypass was to protect homes downstream from flooding, capture sediment, and prevent washout of the culvert under the BNSF railroad track at the creek mouth. Due its location and the characteristics of the creek, this bypass is subject to excessive sedimentation that requires frequent maintenance to preserve its function.

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PROJECT GOAL

The primary goal of this project is to reduce flows in Perrinville Creek by reducing stormwater runoff. The flow reduction will provide multiple hydrologic and biological benefits to both the creek and Browns Bay in Puget Sound, such as allowing for the replacement of an anadromous fish barrier culvert, reducing erosion and sedimentation that are impacting aquatic habitat and City infrastructure, and reducing the amount of pollutants in the aquatic environment.

This goal is achieved through hydrologic modeling, geomorphic and geologic characterization of the creek, developing target flow levels, and identifying locations and approaches for flow reduction methodologies.

WATERSHED CHARACTERISTICS

Draining approximately 800 acres in northern Edmonds and western Lynnwood, Perrinville Creek has the three conditions typical of Puget Sound coastal watersheds: a broad headwater plateau, urban land use, and runoff concentrated in storm drains. Below the confluence of four tributary drainages, the creek drops steeply through a ravine eroded into glacial and pre-glacial deposits. The creek emerges from the ravine and transitions to a lower-gradient channel, forming an alluvial fan. The creek drops 260 feet in elevation over about one mile before discharging to Browns Bay in Puget Sound. Approximately 90 percent of the watershed is residential land use; the remaining 10 percent is commercial.

Climate Data

Precipitation records were obtained from the Everett, WA precipitation gauge (COOP: 452675) at a 15-minute interval. Pan evaporation was adopted from the WSU Puyallup climate station. Regional scaling factors of 0.80 and 0.76 were applied to precipitation and evaporation datasets, respectively, by the 2012 Western Washington Hydrology Model (WWHM), which was used for the hydrologic modeling in this study. Average climate values from the model are shown in Figure 1. Everett precipitation data was evaluated against the King County Bruggers Bog gauge, located a few miles southeast of the Perrinville project area. Analysis shows that the gauges produce a difference in average annual rainfall of approximately 2 inches, with the Everett gauge having a higher average spring volume. The discrepancy in precipitation totals is considered to be acceptable for modeling and targeting objectives.

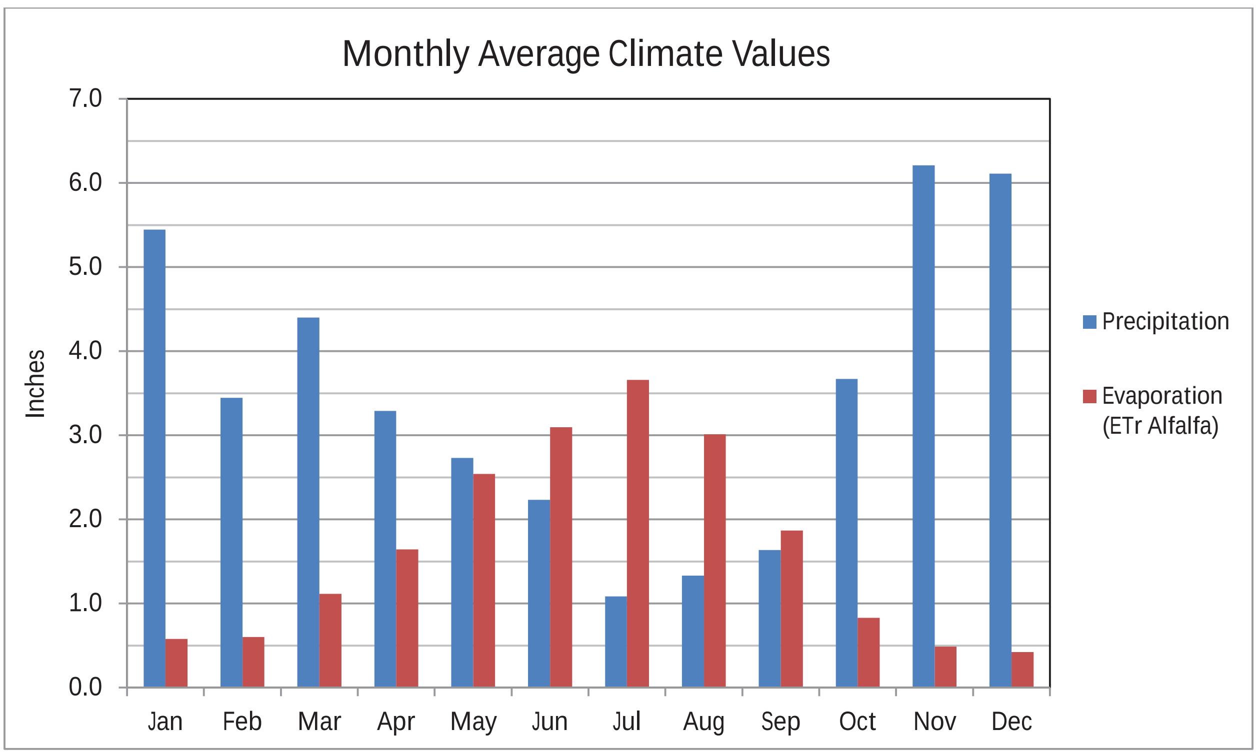

Figure 1. Monthly Average Climate Inputs for Perrinville Creek WWHM Model

Land Use

Project area land use is defined by allocations of impervious and pervious surfaces for each subbasin represented in the hydrologic model. Total impervious area is defined as the total land area that generates impervious surface runoff. This area may or may not hydraulically connect to downstream conveyance or infiltration. Effective impervious area represents the area of impervious coverage where there is no infiltration potential and runoff is directly connected to the stream or drainage system (ineffective impervious areas pond or infiltrate without connecting to the stormwater conveyance system). Effective impervious area coefficients were approximated based on analysis of aerial photography, site inspections, and previous experience in urban hydrologic model development.

Total impervious area was initially delineated using a combination of aerial photography and GIS coverages provided by the City of Edmonds and the City of Lynnwood. Roadway centerlines and building footprints were used to aid in the delineation of total impervious area for the Perrinville watershed. Centerlines are used to verify existing roadways alongside aerial photography to define the roadway extent, parking lots, and any other existing pavement located in the watershed. Building footprints were overlaid to complete the total impervious area delineation. Buildings were classified separately to distinguish between effective impervious area coefficients for roadways and rooftops.

Typical hydrologic models classify pervious area into three distinct categories: forest, lawn, and pasture. Forest was delineated manually utilizing city-furnished GIS aerial photography. The remaining area not classified as impervious surface or forest was designated lawn (there is no significant pasture are in the urbanized watershed). Table 1 and Figure 2 summarize and illustrate the resulting land use for the hydrologic modeling. Note that, although only 27% of the total watershed area is situated within the City of Edmonds, the Edmonds portion of the watershed contains 35% of the effective impervious area due to its higher density.

TABLE 1.
PERRINVILLE WATERSHED LAND USE CLASSIFICATION

	City of Edmonds	City of Lynnwood
Total Area (acres)	212	552
Effective Impervious Area Density	25%	17%
Pavement (acres)	37	70
Building (acres)	16	25
Pervious Area	75%	83%
Lawn (acres)	121	361
Forest (acres)	37	97

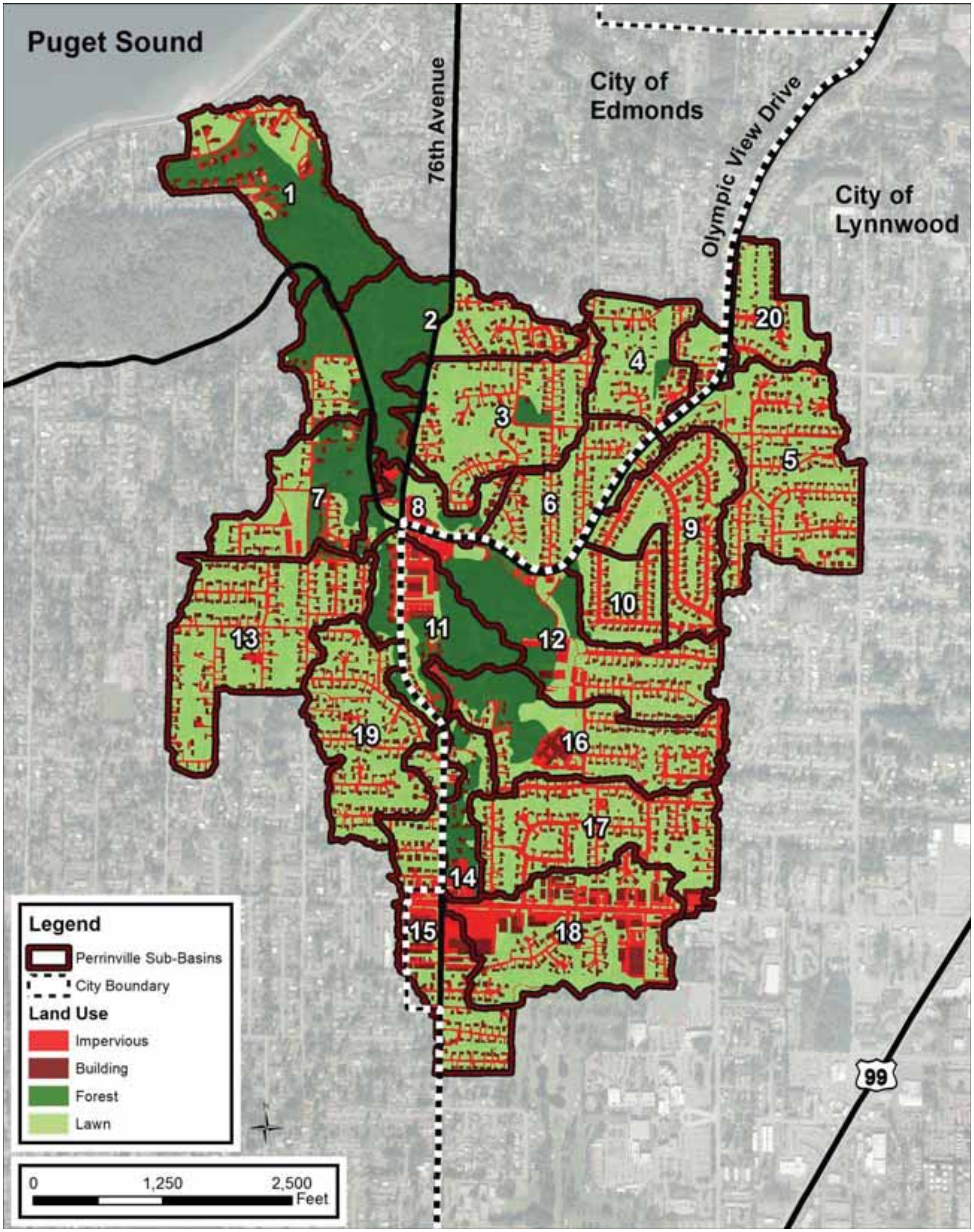

Figure 2. Perrinville Watershed Land Use Classification

Geology and Soil

Two GIS coverages were considered for incorporation into the Perrinville watershed hydrologic model to represent soil characteristics:

- The first is the spatial mapping of NRCS hydrologic soil groups that was downloaded from the NRCS SSURGO database and clipped to the project area. Hydrologic soil groups represent the potential for infiltration based on the surficial soil classification and range from Group A, which have low runoff potential and high infiltration rates, to Group D, which have high runoff potential with negligible infiltration rates.
- The second coverage is a subsurface geology layer provided by Associated Earth Sciences, Inc. created as a digitalization of USGS geologic map MF-1541 (Minard 1983).

The subsurface geology was chosen for incorporation into the model due to its higher resolution of infiltration potential for local soils at depths greater than 5 feet. Table 2 and Figure 3 present an area summary and visual representation of the subsurface geology present in the Perrinville Creek watershed. The NRCS surface soils are plotted for information in Appendix A.

TABLE 2.
WATERSHED GEOLOGY CLASSIFICATION

Geologic Soil Group	Area (Acres)
Glacial Outwash (A)	163
Transitional Bed (A)	1.62
Vashon Glacial Till (C)	599

Slope

Slope was generated for modeling input using a digital elevation model (DEM). The DEM was created using the 2-foot contour data provided by the City of Edmonds and the City of Lynnwood. Slope is calculated as percent rise between DEM cells and is designated into one of three categories for input into the hydrologic model. Table 3 and Figure 4 provide an area summary and visual representation of the slope variation present in the Perrinville Creek watershed.

TABLE 3.
WATERSHED SLOPE CLASSIFICATION

Slope Group	Area (Acres)
Low Slope (< 5%)	340
Moderate Slope (5% - 15%)	264
High Slope (> 15%)	160

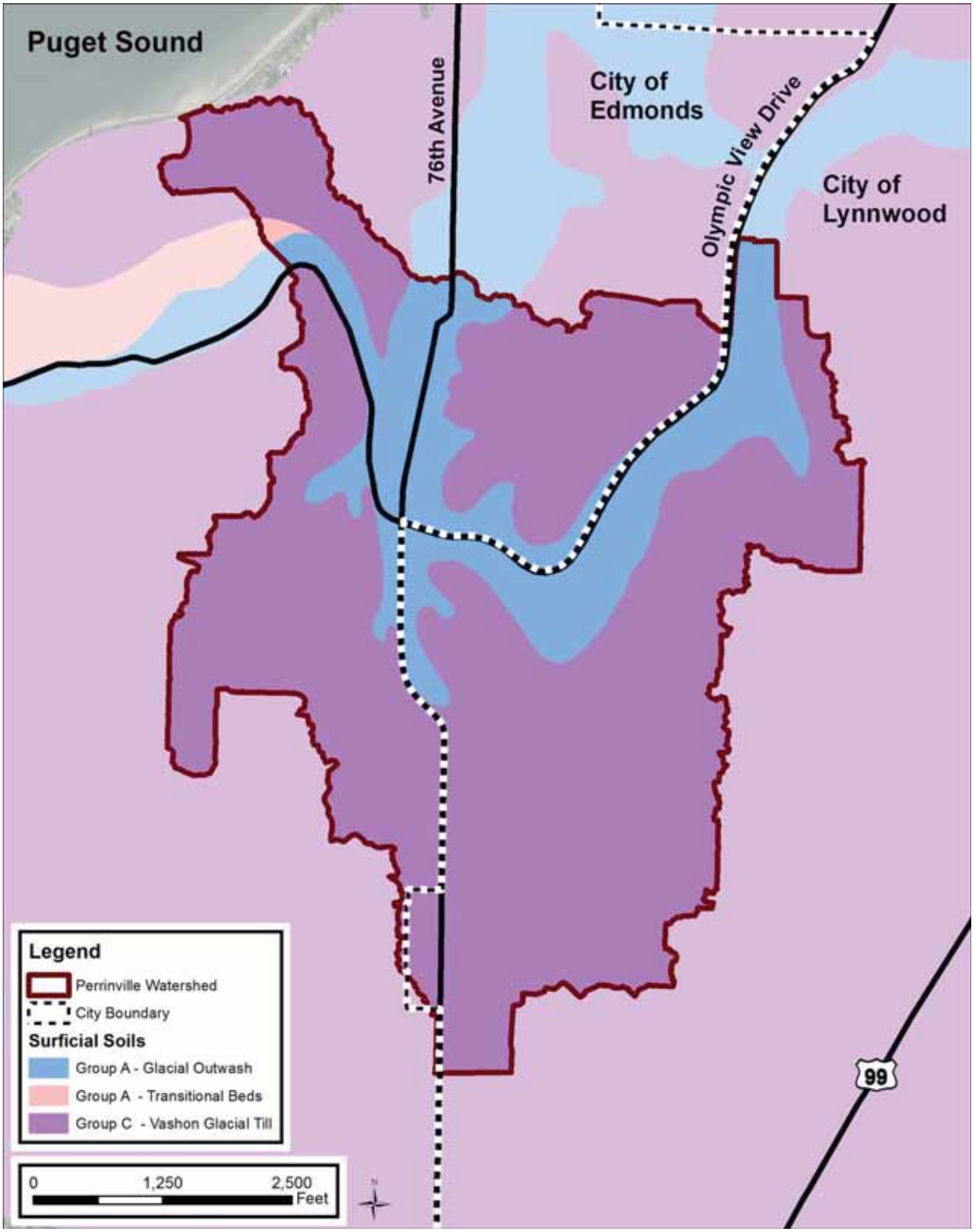

Figure 3. Perrinville Watershed Subsurface Geology

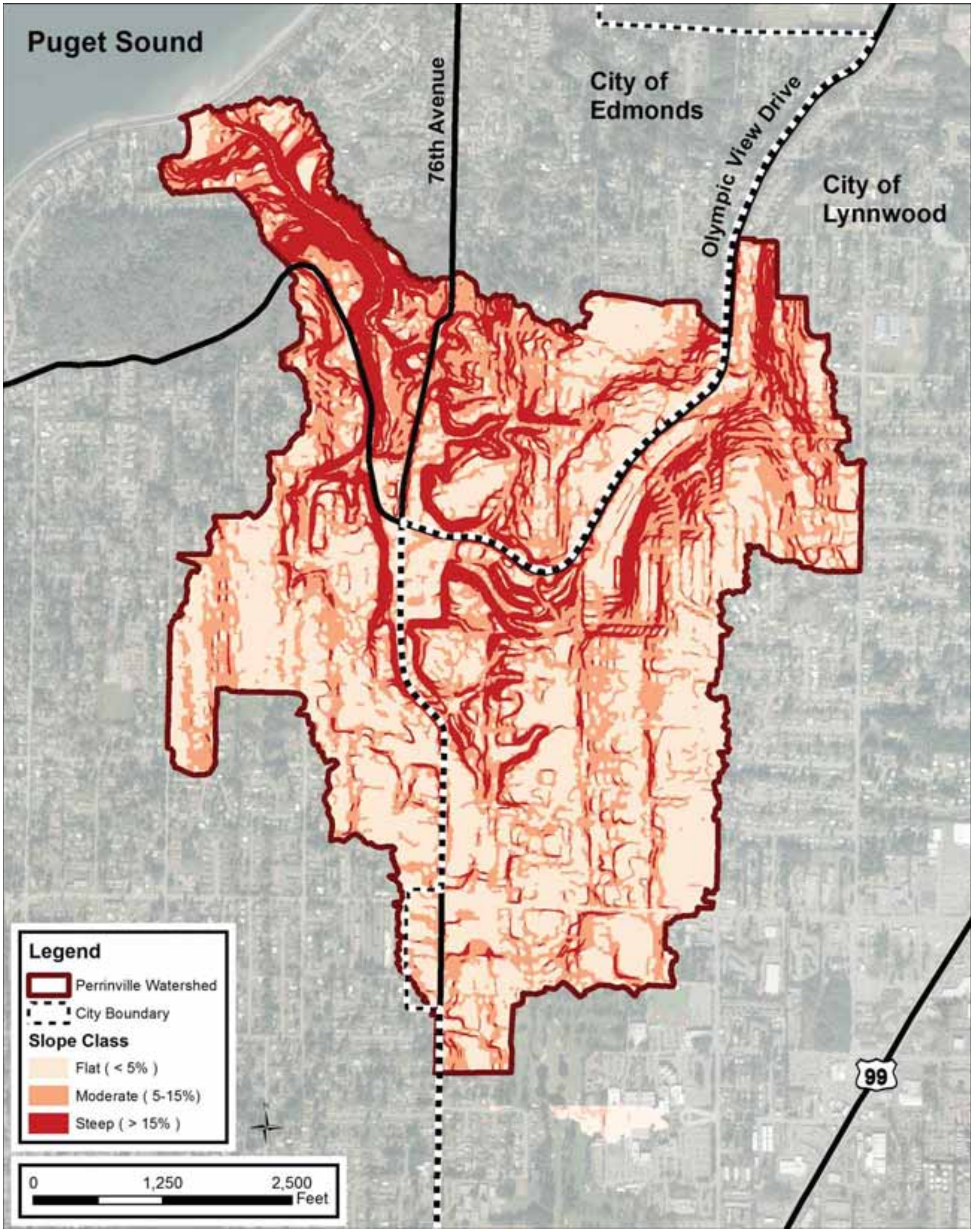

Figure 4. Perrinville Watershed Slope

HYDROLOGIC MODEL DEVELOPMENT

The Perrinville Creek hydrologic model is a planning-level model used to estimate seasonal base flow and peak flow in Perrinville Creek under existing conditions. Estimation of the magnitude and timing of peak flows is necessary to understand the baseline hydrologic condition so that effective flow-control measures can be developed. The model provides enough detail to allow for basin-wide evaluation of stormwater best management practices (BMPs) that currently provide significant flow control. This study is not focused on conveyance system capacity, and urban flooding is not an issue; therefore, storm drain modeling is limited to the minimum network necessary to attenuate and route runoff to downstream subbasins and watercourses.

Model Selection

Hydrologic models assess the physical characteristics of a basin and determine the amount of stormwater runoff that will be generated during a storm or series of storms. Typically, hydrologic models are event-based or continuous simulation:

- Event-based modeling provides a simple method for comparing runoff results under different land use conditions for statistically relevant design storms. Event-based modeling is commonly used for evaluating flood risk and peak flows in drainage systems.
- Continuous modeling accounts for soil moisture and infiltration and other losses over an extended period of time. Continuous simulation incorporates the full probability distribution of storms, including flood events, frequent erosive flows at levels less than the 2-year storm flow, drought and high rainfall periods, antecedent conditions and back-to-back storms. A continuous simulation model is particularly important in the Puget Sound region because high runoff is generally experienced after a series of back-to-back storms, rather than one isolated rainfall event.

The Western Washington Hydrologic Model used for this stormwater management study is a continuous-simulation model maintained by the Washington Department of Ecology. Stormwater runoff is simulated from pervious and impervious land surfaces, soil moisture dynamics, and hydrologic routing on a continuous basis. WWHM was selected for this project because it provides long-term rainfall records and pre-determined soil parameters for specific regions in Western Washington based on the provided land use characteristics. This makes it well-suited to assess the cumulative impact of development on stormwater runoff.

Prior to the selection of WWHM, several modeling programs were considered for the Perrinville Creek hydrologic model. Appendix A provides a brief description of advantages and disadvantages pertaining to this project for the hydrologic models considered.

Data Development

The Perrinville Creek hydrologic model was constructed with GIS coverages developed by the City of Edmonds, City of Lynnwood, and Tetra Tech. Data sources are detailed in Appendix A and input parameters for each subbasin are provided in Appendix B. Following initial sub-catchment creation for the model, sub-catchment delineations were adjusted to reflect the stormwater gravity mains and flow control facilities inventoried from the city-supplied datasets. Storm drain trunk lines larger than 18 inches in diameter were incorporated into the model, as well as significant flow control structures.

Subbasin Delineation

The initial Perrinville Creek basin boundary was provided by the City of Edmonds. The basin boundary was modified by Tetra Tech to eliminate areas that did not contribute runoff to Perrinville Creek. During the subbasin delineation, three areas that were included in the initial watershed boundary delineation were determined to contribute no flow into the Perrinville drainage: a 312-acre area in the City of Lynnwood, a 110-acre area in the City of Edmonds, and a portion of the Edmonds Community College campus (see Figure 5). The “East Infiltration Basin,” lying predominantly in the City of Lynnwood, was removed due to the recent installation of the Meadowdale Drive infiltration pond. The pond collects all tributary surface runoff for deep infiltration and effectively removes it from the basin. The “West Basin,” located in the City of Edmonds, was removed from the watershed delineation because it was determined to discharge to Puget Sound from Talbot Road through an outfall located to the west of Perrinville Creek. The golf course area at the community college was removed upon investigation of the campus’ internal drainage infrastructure.

The subbasin delineation utilized the ArcHydro tools extension for ArcMap 10. ArcHydro automatically delineates basins at a specified scale utilizing a digital elevation model generated from topographic contour data. Following the ArcHydro subbasin delineation, a visual review was performed against the elevation and storm drain network boundaries. Adjustments to the auto-delineation were made to achieve a desired spatial scale that maximizes subbasin simplicity and effectiveness for analysis of flow reduction opportunities. Figure 6 shows the final subbasin boundaries defined for the hydrologic modeling.

Stormwater Facilities

Stormwater facility as-built and design memos were provided by the City of Edmonds and City of Lynnwood. Three facilities included in the model provide significant flow attenuation and are located in the City of Lynnwood. The identified facilities provide flow attenuation to lateral drainage basins that feed into the Olympic View Drive trunk line:

- Olympic View Drive (OVD) infiltration and detention facility (CH2MHill 2005)—The Olympic View Drive facility captures runoff from Subbasins 4, 5 and 20 and has a maximum storage volume of 0.36 acre-feet at the riser head. It is designed with multiple flow splitters that allow a maximum flow rate of 0.16 cfs to be diverted for deep infiltration. Detention within the facility is controlled with three horizontal orifices and a weir overflow.
- Blue Ridge Pond (BRP)—The Blue Ridge Pond attenuates runoff from Subbasin 9 and 10 and has a maximum volume of 1.0 acre-foot at the riser. Detention within the pond is controlled by an 11.25-inch orifice within the riser structure.
- Olympic View Drive Wetland (OVDW)—The Olympic View Drive wetland captures flow from Subbasin 20 and has a maximum storage of 0.28 acre-feet. Detention within the wetland is controlled by a 24-inch pipe within the riser structure.

Figure 7 is a map of the regional facility locations and their contributing subbasins. Two additional facilities in Lynnwood provide flow attenuation from limited drainage areas. The Copper Ridge pond north of 196th Street SW controls releases from commercial and multifamily development in a portion of Subbasin 18, and the Olympic View Crest pond controls releases from residential properties in a portion of Subbasin 4.

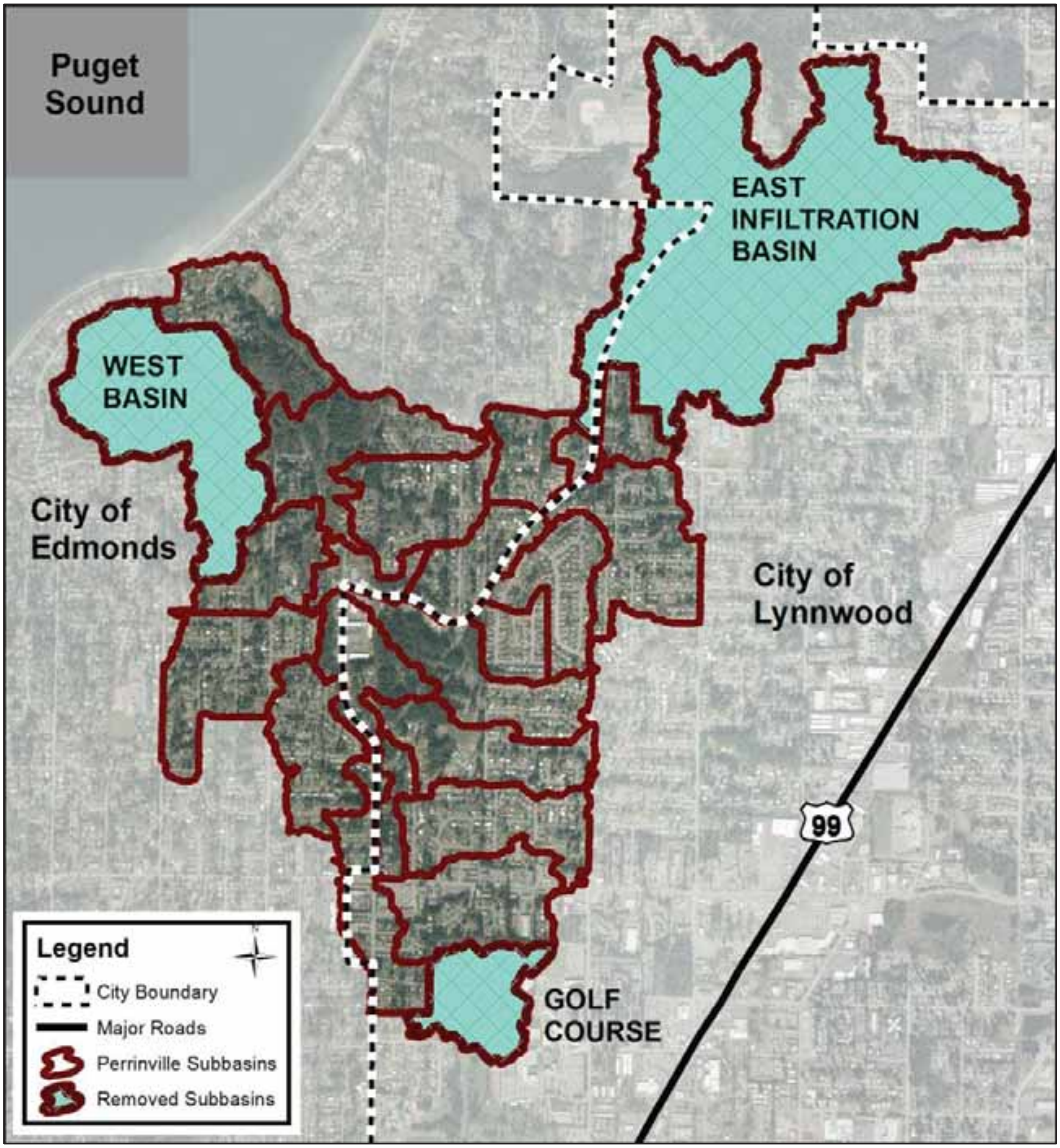

Figure 5. Subbasins Removed from Watershed Limits

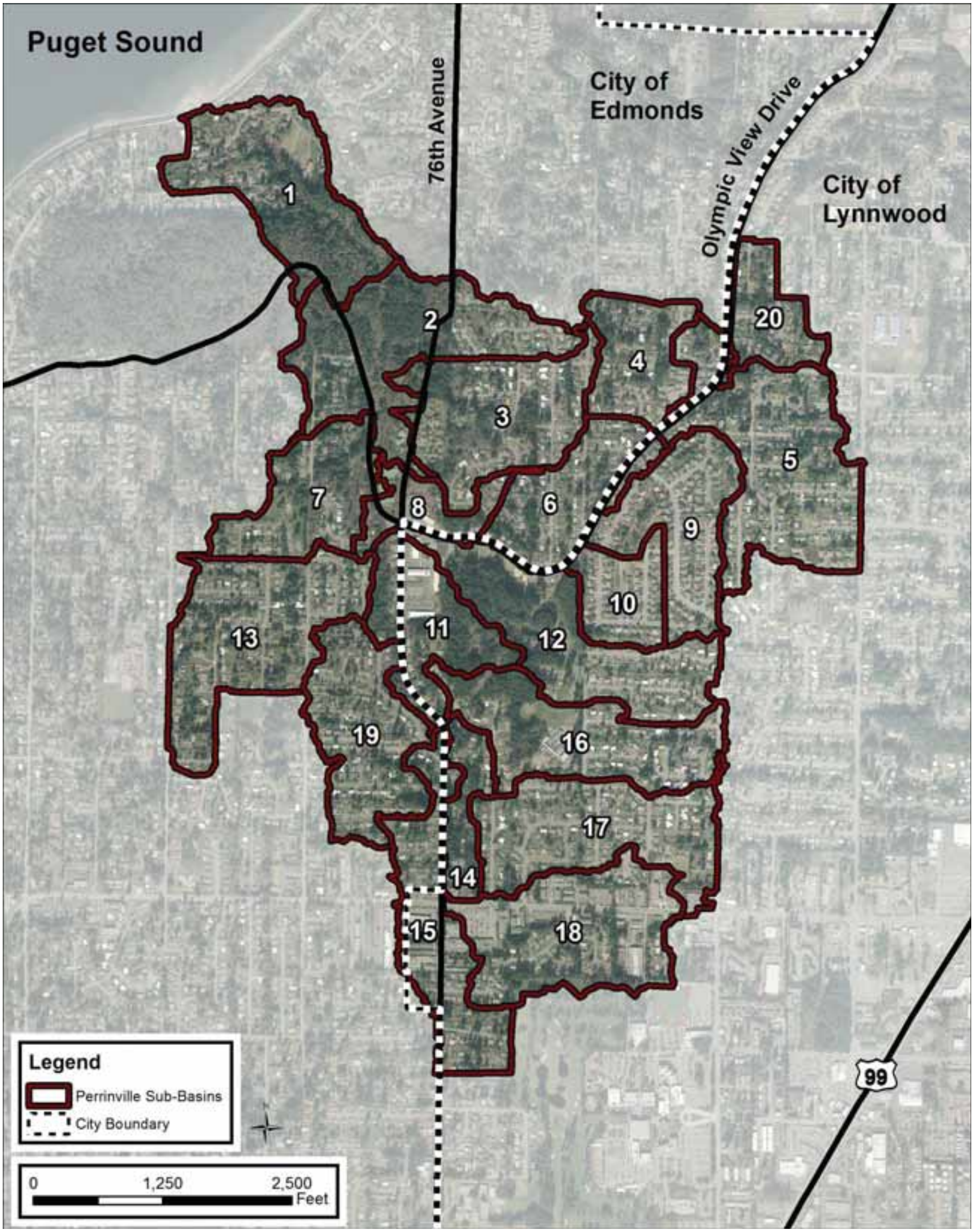

Figure 6. Perrinville Creek Subbasin Delineation

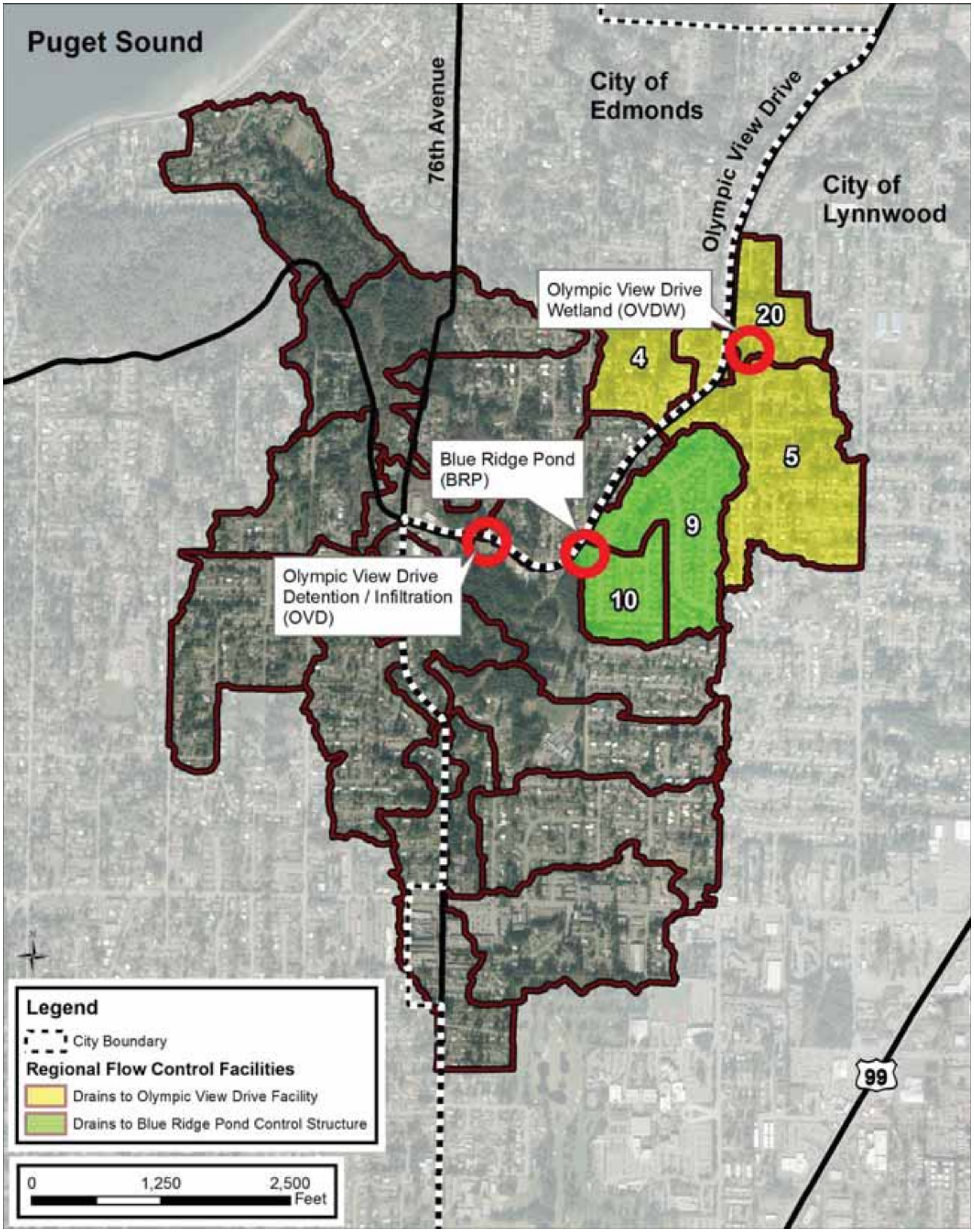

Figure 7. Perrinville Regional Detention Locations

Stormwater Conveyance

Stormwater infrastructure GIS coverage was provided by the City of Edmonds and the City of Lynnwood for incorporation into the hydrologic model to aid in the representation of conveyance timing. WWHM does not directly model stormwater conveyance systems; therefore, only arterial storm lines of 18 inches in diameter or larger were considered for model input.

WWHM uses input parameters to automatically create RCHRES function tables (ftable). RCHRES is the nomenclature for a routing object. A standard ftable creates a relationship between elevation head, storage volume, and discharge for routing runoff through a conduit or low-impact development (LID) facility. Pipe length, diameter, and material provided through the GIS coverages are used as ftable inputs. Pipe diameters were cross-checked with catch-basin layer attributes to identify any inconsistencies in the reporting of main transmission lines versus lateral lines. Pipe elevation and slopes were not provided in the GIS coverages. Due to the degree of error associated with using the DEM ground elevation for pipe slope, all pipes slopes were given a standard design slope of 0.02 feet/foot.

To characterize the conveyance of stormwater in Perrinville Creek open channels, the ArcMap 3D analyst tool was used to generate creek cross-sections from LiDAR-based topographic mapping. The natural channel object in WWHM was used to create the associated ftables for routing. Parameters such as channel bottom width, depth, length and slope were approximated from GIS sections. Manning’s roughness coefficient was chosen based on visual field inspection. Figure 8 is a schematic of the WWHM model for the basin showing the hydrologic routing. A representation of the model overlaid on the drainage basins is provided in Figure 9.

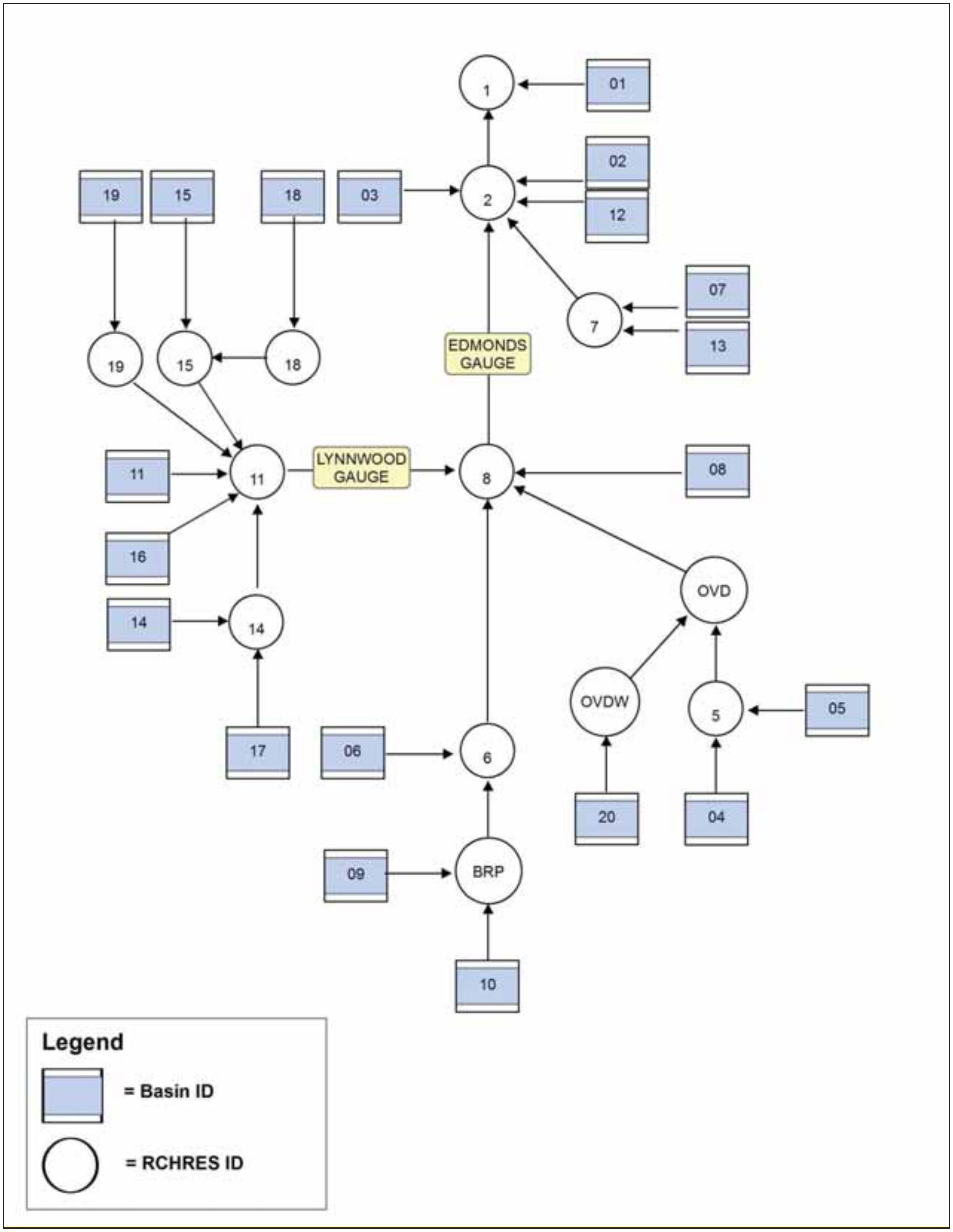

Figure 8. Perrinville WWHM Routing Schematic

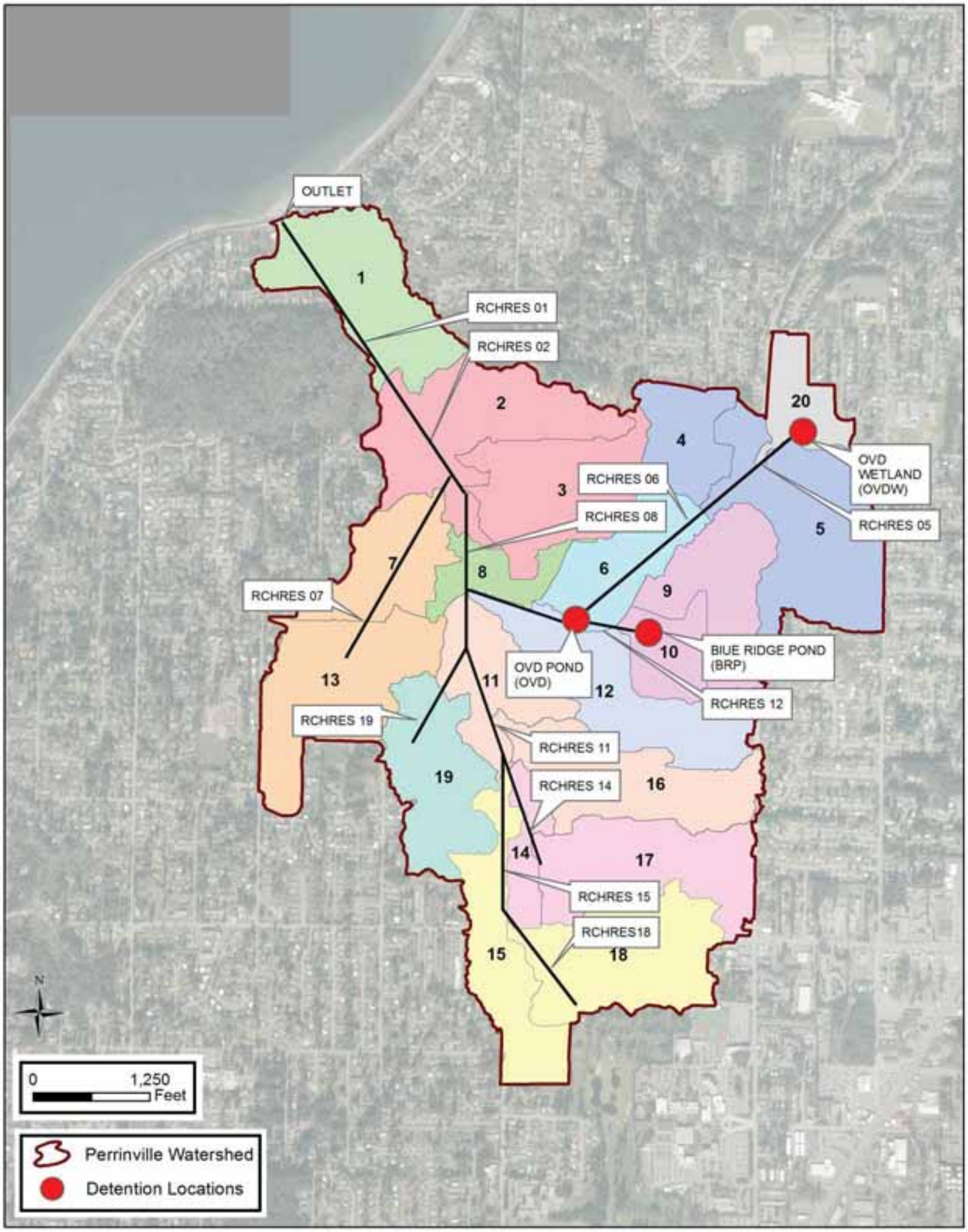

Figure 9. Perrinville Hydrologic Model Representation

HYDROLOGIC ANALYSIS

One model encompassing the 20 subbasins and major conveyance elements was created in order to determine creek flows at the Talbot Road crossing, identify where significant flows are being generated, and eventually evaluate the potential performance of recommended stormwater treatment facilities.

Previous Results

The most recent hydrologic study in the watershed was performed in 1991 by RW Beck (1991) using a Santa Barbara Urban Hydrograph (SBUH) 24-hour event model of the watershed. The watershed delineation for the 1991 study differs from the delineation used for this retrofit study. The original basin and subbasin delineations cannot be directly compared, but the 1991 report references a total drainage area of 921 acres, approximately 20 percent greater than the delineation used for the current modeling. Basin delineation most likely differs due to the accuracy of topographic information available at the time, and the inclusion of basin area between the Talbot Road crossing and the creek mouth on the sound. For comparison to the current modeling, results of the peak stream discharges reported in the 1991 study are listed in Table 4.

TABLE 4.
PEAK STORMWATER RUNOFF PREDICTIONS FROM 1991 STUDY

Return Period	Talbot Road Culvert Peak Discharge (cfs)		Perrinville Creek Mouth Peak Discharge (cfs)	
	Existing Land Use (1991)	Future Land Use	Existing Land Use (1991)	Future Land Use
2-year	49	63	54	68
5-year	75	92	83	100
10-year	95	112	105	122
100-year	203	225	228	251

Source: RW Beck 1991

Model Calibration

The WWHM model was calibrated at two locations following flow-monitoring by ADS Environmental Services. Two flow-monitoring gauges were installed in major trunk lines that represent a high percentage of impervious surface drainage in the watershed. Installed gauge locations are shown in Figure 8. The Lynnwood gauge measures a portion of the system that has no in-line flow control devices; the Edmonds gauge measures the portion of the system that contains the Blue Ridge detention pond, the Olympic View Drive regional flow control facility, and the Olympic View Drive wetland. Flow meters recorded depth and velocity data at a 15-minute time-step for their period of operation between 10/30/2013 and 03/31/2014. Hydrologic model calibration was performed utilizing Alderwood Water & Sewer District rain gauge data provided by Snohomish County. Rainfall data was processed to determine peak precipitation events that occurred during the period of flow-monitoring operation.

Event selection for calibration considered rainfall intensity and rainfall duration. Preference was given to events with short duration and high rainfall intensity. Subbasins contributing to each flow gauge were treated as a collective basin for calibration. Calibration of simulated flows focused on matching event peak flow. The effective impervious area (EIA) percentage was found to be the dominant variable for peak flow sensitivity. EIA percentages were iterated until the simulated events displayed a reasonably close fit to observed peak flow and volume, based on the engineer's best professional judgment. Table 5 shows the calibrated and uncalibrated EIA percentages for the contributing basins to each gauge.

TABLE 5.
WWHM BASIN EFFECTIVE IMPERVIOUS AREA FOR CALIBRATION

Model	Edmonds Gauge	Lynnwood Gauge
Uncalibrated	24%	28%
Calibrated	26%	15%

Modeling Results

WWHM calculates flow frequency statistics using multiple methods. For this study, a Gringorten flood frequency methodology was applied to the annual maximum discharge because it performs better than the commonly used Log Pearson method under the future conditions model scenario where stormwater flow reduction retrofits can reduce discharge from areas to zero. Return intervals and the associated peak discharge from the calibrated and uncalibrated model are listed in Table 6. These data were validated for planning purposes using the validation process described in Appendix C.

TABLE 6.
HYDROLOGIC MODEL RESULTS FOR EXISTING CONDITION AT TALBOT ROAD

Return Period (Years)	Peak Flow (CFS) Uncalibrated	Peak Flow (CFS) Calibrated
2	47	41
5	69	64
10	85	77
25	110	99
50	130	126
100	153	135

Comparison to Previous Modeling

Examining the peak flows in Table 4 and Table 6 shows that the current modeling produced flow rates lower than those calculated by the earlier modeling effort for the Talbot Road location. Differences can be attributed to the following:

- More detailed land use delineation and updated basin boundaries/areas
- The basin area delineated in the 1991 study was 17% greater than the current analysis demonstrates – this corresponds to the difference in peak discharges for the 2-, 5- and 10-year return periods
- Differences between results produced by continuous simulation models (WWHM) and single-event models (SBUH). Single-event models generally predict higher peak flows and lower storm volumes.

The consistent differences in discharge for return periods up to 10 years, and the correspondence to the differences in tributary basin area indicate that the subbasin-level details of the WWHM model can be used for evaluation of stormwater treatment practices that target smaller, more frequent storm events.

GEOMORPHIC CHARACTERISTICS

The geomorphic analysis provides a context to establish target flow criteria for reducing high sediment loads resulting from slope failures in Perrinville Creek. The volume of sediment creates an unstable environment in the creek. Cycles of channel incision are followed by slope failure, channel enlargement, and streambed aggradation. The sediment transport negatively affects aquatic habitat by scouring and burying spawning gravels, creating passage barriers, and reducing pool volume (Pentec 1998).

Review of Data from Prior Studies

Several geomorphology studies have been performed in the Perrinville basin over the last decade, including a streambank stabilization study (Pentec 1998). A recent preliminary design study for a fish passage culvert in the lower reach of the creek (Herrera 2012) included a geomorphic reconnaissance of Perrinville Creek.

Both studies detailed fluvial processes of channel incision and streambank toe erosion. Neither included a sediment budget, although they do discuss the sources of the large sediment supplies. Excerpts from the two previous studies are provided below to provide additional detail on the geomorphic processes responsible for the high sediment loads.

The Pentec (1998) report identified four mechanisms that contribute to the geomorphic instability within the study reach:

1. Channel enlargement in response to increased stormwater volume
2. Slope failures
3. Unstable large woody debris (LWD) blockages
4. Variable sediment transport through the channel

Of these processes, the initial driver is the channel enlargement that "occurs naturally when flooding occurs and increases the stress on the channel bed and banks beyond a threshold of movement or erosion." Secondary responses include the redirecting of the channel towards the opposite valley wall after a slope failure or rearrangement of channel LWD. Along with the secondary responses that impact lateral stability, several nickpoints have been identified that impact vertical stability. Over the next several decades, the nickpoints will continue to advance upstream and release additional sediment stored in the bed, cause incision, and lead to more hillslope failures. Increases in sediment supply to the lower reaches of Perrinville Creek are a function of channel incision and hillslope failures.

The Herrera (2012) report also describes the processes of channel incision and hillslope failures. Furthermore, the fine grain sediment contributed from the valley walls is documented as a contribution to the "large volume of sediment" provided to the lower reach of the creek near Talbot Road.

The two previous reports establish a baseline geomorphic assessment that the watershed has a "large" sediment supply and high flows from increases in storm water flow. They had different objectives for means of fixing the problems associated with the sedimentation issues near Talbot Road. The Pentec report was looking at addressing geomorphic channel stability, while the Herrera report evaluated culvert upgrades. The Herrera (2012) study included Wolman pebble counts (Wolman 1954) at three locations, as shown in Figure 10.

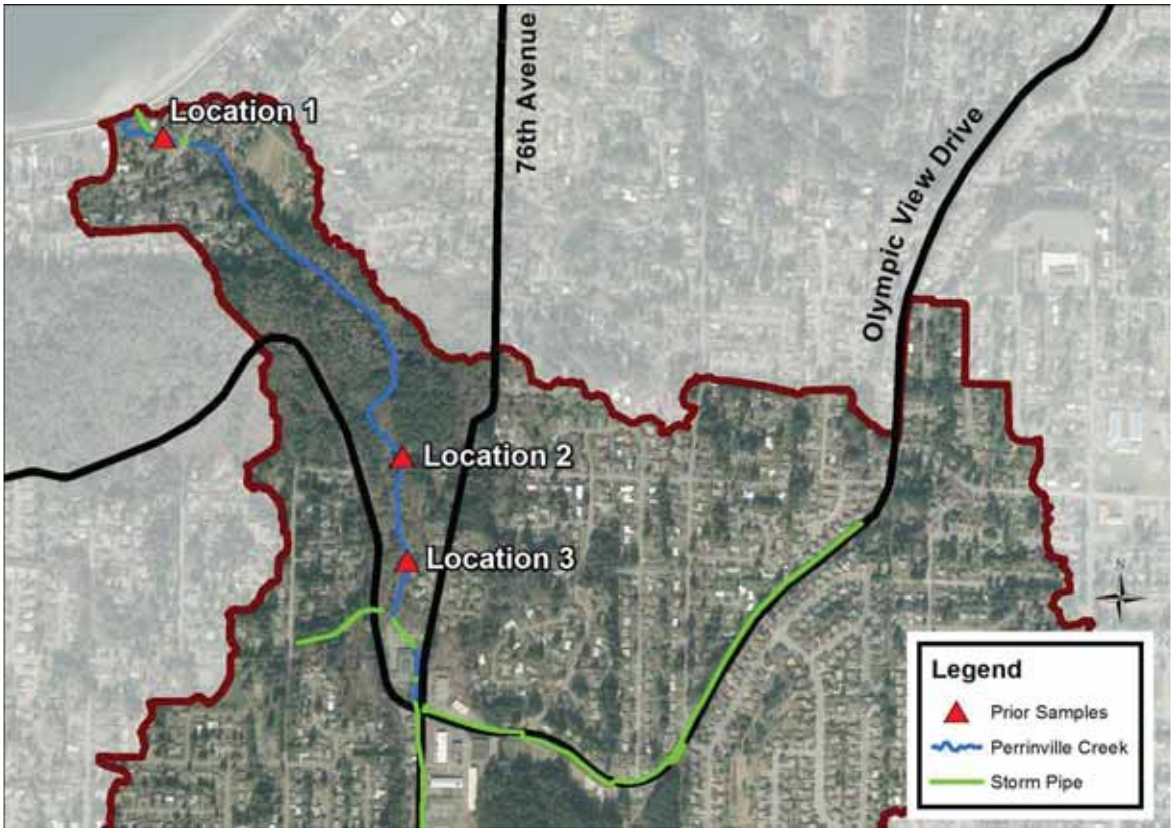

Figure 10. Herrera (2012) Wolman Pebble Count Sampling Locations.

Sediment sampling distribution results from the 2012 study are presented in Table 7. This information served a similar purpose to that collected for this study, and the new data was collected to specify sediment grain size and hydraulics between locations 1 and 2 in Figure 10.

TABLE 7.
WOLMAN PEBBLE COUNT RESULTS FROM HERRERA (2012)

	Surface (mm)					
Location	D16	D50	D84	D90	% Sand	Armor Ratio
1. High Flow Div.	17.8	38.1	61.0	70.5	5.6	2.6
2. Upstream of Talbot Rd.	9.1	19.5	52.4	61.8	14.2	1.3
3. Upper Watershed	12.9	25.5	42.8	49.4	4.8	1.6

Data Collection

Data was collected in late August of 2013 in support of an incipient-motion analysis. Four reaches of Perrinville Creek were selected for sampling between the Talbot Road culvert and the stream crossing of Olympic View Drive. Reaches were visually selected based on similar channel processes, vegetation, and form. A map of the selected sampling locations is provided in Figure 11. Data collection included a Wolman pebble count, cross-section survey, and longitudinal profile at each selected reach (see Appendix F for details). Pebble counts were performed in order to calculate the surface layer grain size distribution. The objective of the data sampling is to relate the modeled flow frequency at a particular cross section to the channel shear capable of significant channel degradation and sediment transport to downstream reaches. The channel degradation is the primary cause of the channel incision that leads to toe erosion and subsequent hillslope failures. Net channel degradation has been documented in the Pentec (1998) and Herrera (2012) studies.

Sediment sampling results are summarized in Table 8 and include the sediment distribution sampled and reach slope measured. Sand values were not recorded because the distribution served to approximate the armor layer, not the bedload. Values presented in this section serve as the starting point for the geomorphic analysis. Sampling locations and methods differed from those used in the Herrera 2012 study. Results cannot be compared between the two studies due to the inability to reoccupy cross sections established in the previous study.

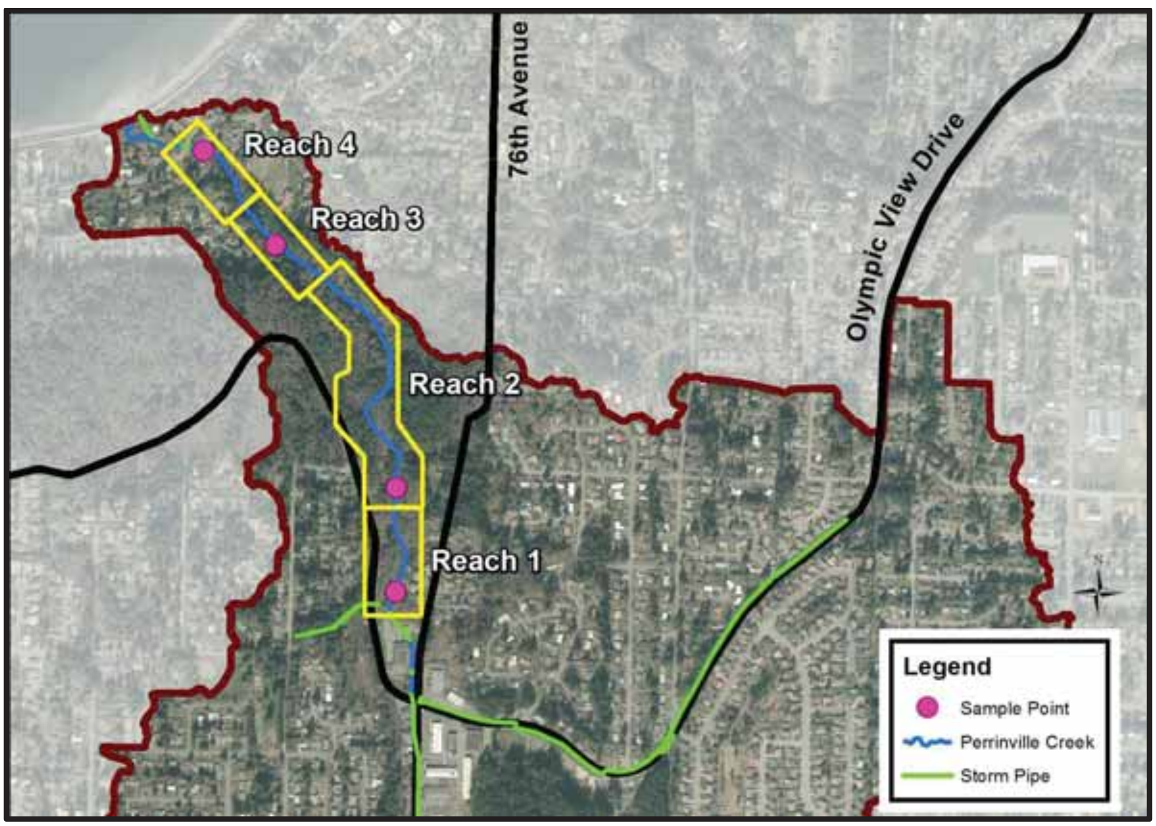

Figure 11. Geomorphic Data Sampling Reach Locations.

TABLE 8.
SEDIMENT SAMPLING DISTRIBUTION SUMMARY

Reach ID	Surface (mm) D16	D50	D84	D90	Reach Slope (feet/foot)	Schumm Channel Evolutionary Stage (see Figure 12)
1	13	32	58	64	0.012	I
2	24	66	190	290	0.032	III
3	28	58	130	150	0.033	IV
HERR4	14	46	100	140	0.034	V

Geomorphic Analysis

Field observations and previous studies suggest that the channel is not incised in the area of the Southwest County Park (Reach 1). Incision on the order of a foot or two was estimated to have occurred in Reach 2 based on the elevation of historical tree stumps relative to the channel. Reach 3 has experienced significant channel degradation, channel widening, and toe erosion of the terrace (valley) walls. Reach 4 primarily serves to route the excess sediment from Reach 3 to the channel downstream of Talbot Road.

Figure 12 shows the evolution of a typical incising creek (Schumm et al. 1984) using a location-for-time substitution (ASCE, 2008). The stream evolutionary model helps explain processes (degradation, aggradation, widening) and response (valley wall failure) in stream reaches. Schumm's channel evolutionary stages for the studied reaches are listed in Table 8. Reach 1 is relatively stable and remains in the premodified stage. Some minor channel degradation has occurred in Reach 2, on the order of a foot or two, but the streambanks are still relatively stable.

In Reach 3, the channel is in Stage IV and exhibits channel degradation and increased bank heights as compared to Reach 1. Hillslope (or confining valley) wall failures occur when the channel degrades and the bank heights exceed the critical bank heights. Sediment supplied from hillslope failures within Reach 3 and bedload from Reach 2 are the dominant sources of sediment to Reach 4. Reach 4, from about the gauge location to the sediment trap at Talbot Road, is in Stage V, slightly aggradational with semi-stable banks and hydraulically controlled by the Talbot Road culvert. Several knickpoints on the order of 3 to 6 feet high are present in Reaches 3 and 4. Several clay lenses in the channel are temporarily holding grade, as well as boulder drops that may be rearranged during high flows. Downstream of Talbot Road, the reach containing the sediment trap is also aggradational and in Stage V.

To validate the field observations and sediment routing assumptions, an incipient motion analysis was conducted for Reach 3 and 4. Reach 3 was selected because it serves to increase the sediment load over the supply from the upstream reach. Reach 4 was selected because it represents the conditions that are responsible for routing the sediment load to the Talbot Road culvert and the downstream sediment trap. Shear stress (τ) parameters were used to relate the hydrology to the median grain size (D_{50}) of the bed sediment and from that, determine the velocity or flow rate associated with bed movement. When the critical shear stress for the median particle size is exceeded, the bed is mobilized and all sizes of sediment up to about five times the median size are capable of being transported by the flow (Parker et al. 1982, Andrews 1984). Example calculations from the incipient motion analysis are presented in Appendix G.

With the results of this analysis, an assessment can be made of the rate of flow in the stream channel at which the creek channel is scoured to introduce new sediment material into the stream.

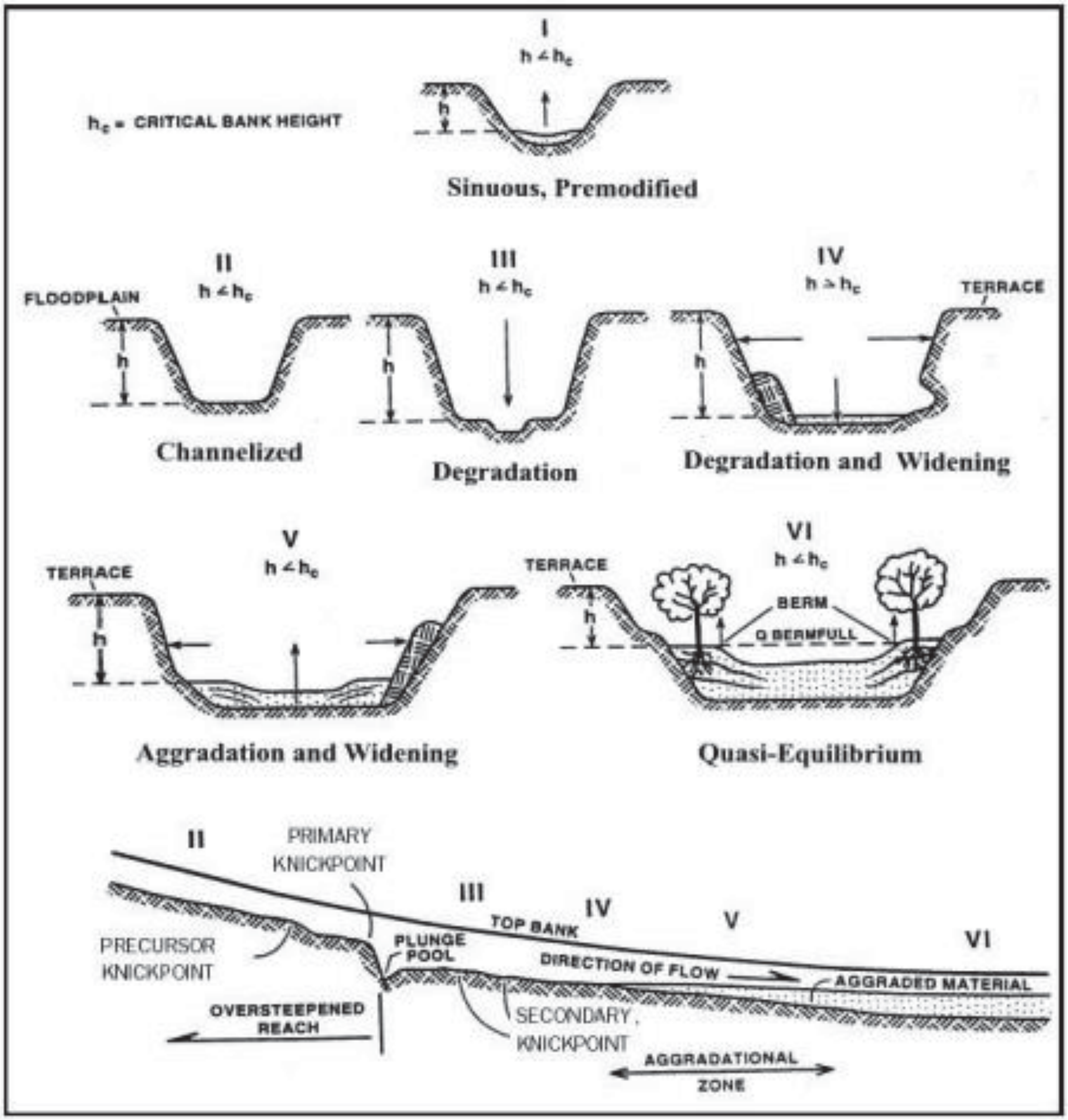

Figure 12. Channel Evolution Model (Schumm et al. 1984)

Flow Targets

Flow targets were considered at two locations. One is the approximate location of the Perrinville stream gauge, about 150 feet upstream of Talbot Road. This is the location of Cross Section 4 (Reach 4). The second flow target location is at Cross Section 3 (Reach 3), representing the portion of the creek producing significant sediment load.

Using the shear stress approach described above, the flow at which sediment transport of the subsurface layer and potential channel degradation is expected to occur was calculated for Reaches 3 and 4. Sediment transport of the subsurface layer will occur at Cross Section 4 at a flow of 4.5 cfs. This includes both the surface and subsurface sediment layers. At a flow of 4.5 cfs, the armor layer of Cross Section 3 is winnowing, but there is not significant channel degradation because the subsurface is not mobilized. The surface and subsurface layers at Cross Section 3 will be mobilized when the flow increases to 7.2 cfs. Sediment transport of the subsurface layer in Reach 3 causes the toe erosion and subsequent hillslope failures that increase sediment supply to Reach 4.

In summary, minor amounts of sediment are mobilized at flows around 4.5 cfs, but when the flows reach 7.2 cfs, the channel has the ability to transport the relatively large quantities of sediment stored in the channel bed of Reach 3 and initiate hillslope failures.

Fish Passage

For comparison to the geomorphically determined flow targets, fish passage flow rates through artificial structures were calculated following the Washington Department of Fish and Wildlife regional, seasonal regression equation for Region 2 of Washington as defined by the Washington Department of Fish and Wildlife (WDFW 2013). Empirical formulas for seasonal fish passage flows calculate the 10-percent exceedance flow for the months of January and May (i.e., the flow with the maximum velocity in a culvert that is not exceeded more than 10 percent of the time during the months of fish migration). January was selected to represent the month of highest flow when adult salmonids are passing upstream. May represents the most critical month for upstream passage of juvenile salmonids. Other months are considered important; however, these biannual periods of passage represent two extreme conditions for design considerations. Results are summarized in Table 9.

TABLE 9.
FISH PASSAGE DESIGN FLOW

Location	Fish Passage Flow (cfs)	–SE (cfs)*	+SE (cfs)*
January	11.0	5.4	16.4
May	2.8	1.4	4.2

*Standard Error (SE) developed from regional regression equation.

GEOLOGIC CHARACTERIZATION

Geotechnical and hydrogeological investigations were performed to characterize subsurface geology in the Perrinville Creek watershed and evaluate infiltration feasibility. The findings are used to predict the performance of proposed BMPs and inform the preliminary design of retrofit projects. The work included the following:

- Review of available geologic literature
- Review of past geologic work in the area
- Completion of six soil borings
- Installation of a groundwater monitoring well
- Excavation of an exploration pit and infiltration testing
- Seasonal high groundwater level monitoring to establish depth to seasonal high groundwater
- Geologic studies to assess the type, thickness, distribution and physical properties of the subsurface sediments and groundwater conditions, and to evaluate infiltration feasibility at specific sites within the Perrinville Basin.

The work also incorporated recently completed field and subsurface investigations at the site of the Lynndale Elementary School. Detailed presentation of the methods, data collected and findings are provided in Appendix H. The results were used in evaluating the effects of proposed BMPs on discharges to Perrinville Creek and in the preliminary design of selected BMPs.

Subsurface Exploration

Field study to gain information about subsurface conditions in the Perrinville Basin included drilling six exploration borings, with one completed as a monitoring well, and conducting an infiltration test in a test pit using a modification of the Pilot Infiltration Test (PIT) method, as described in the 2009 King County Storm Water Design Manual (KCSWDM). The types of sediments and groundwater, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix H. The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. A summary of exploration locations and types is presented in Table 10;

Figure *13* identifies the locations of the explorations. All explorations were conducted between April 14 and May 15, 2014.

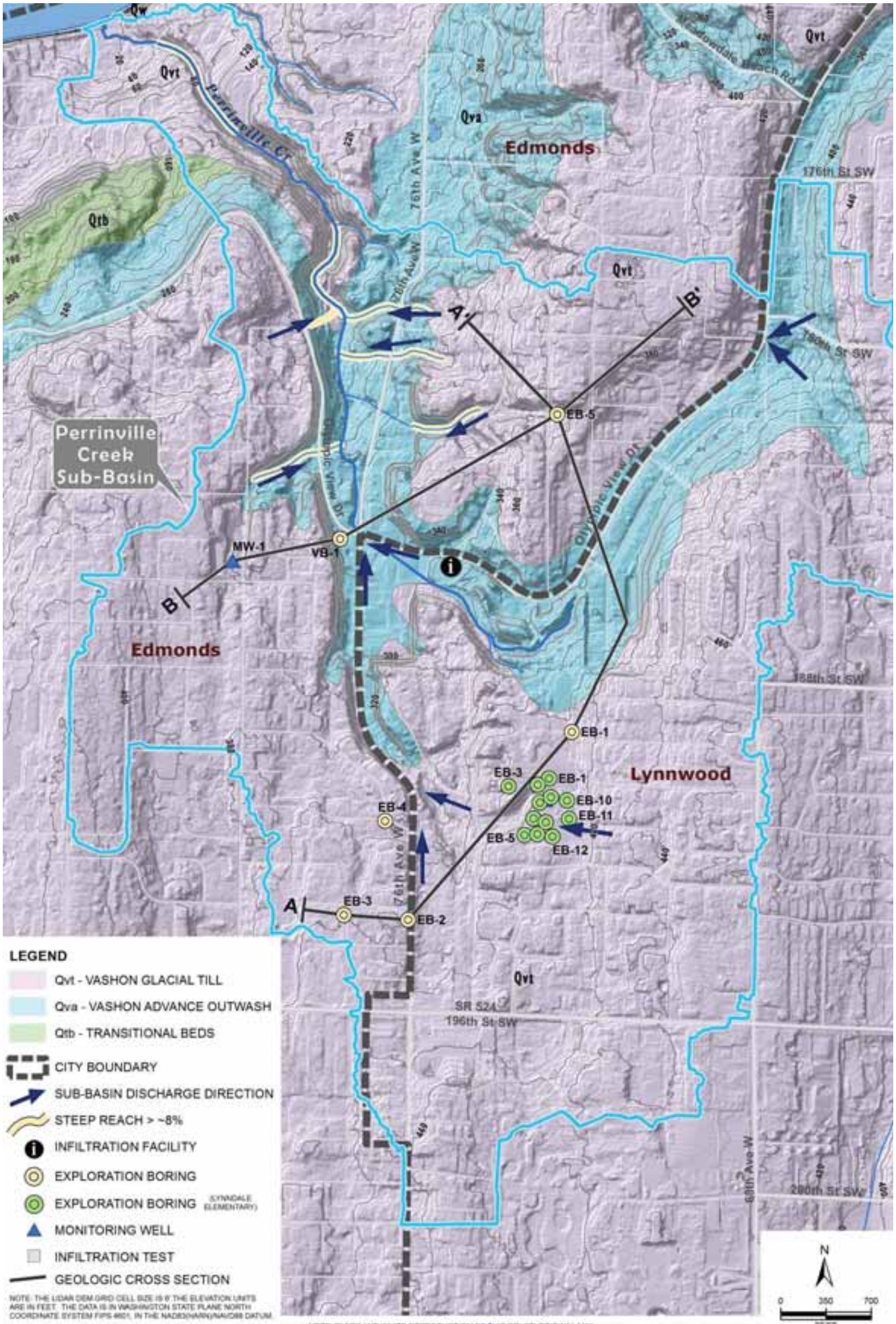

Figure 13. Geotechnical Exploration Locations

TABLE 10.
SUMMARY OF EXPLORATION LOCATIONS AND TYPES

Exploration Name	Location	Depth of Boring (feet)
EB-1	Lynndale Park Southeast Parking Lot	41
EB-2	193rd Place Southwest & 76th Avenue West	50.5
EB-3	193rd Place Southwest & 77th Avenue West	31.5
EB-4	191st Street Southwest & Dellwood Drive	30.5
EB-5	180th Street Southwest & 73rd Avenue West	41.5
VB-1	Olympic View Drive & 76th Avenue West	5.5
IT-1	Blue Ridge Neighborhood Detention Pond (Infiltration Test Pit)	15
MW-1	Seaview Park Parking Lot (completed as a monitoring well)	87
EB-1 [(L)]	Lynndale Elementary Ball Fields	26.5
EB-2 [(L)]	Lynndale Elementary Ball Fields	20.5
EB-3 [(L)]	Lynndale Elementary Ball Fields	20.5
EB-5 [(L)]	SW Lynndale Elementary Campus	50.5

[(L)] Exploration performed as part of the Lynndale Elementary School project and approved for use in this study.

Subsurface Conditions

Most of the surficial geology in the project area is shown in the regional geologic map as Vashon lodgement till (Qvt) overlying Vashon advance outwash (Qva). This mapping is consistent with field observations and interpretations of the explorations made for this study. A thick sequence of regionally extensive permeable Vashon advance outwash is present beneath the low-permeability lodgement till and underlies the entire upland portion of the Perrinville watershed. In some low-elevation locations, Qva exists at the ground surface, without a cap of the lodgement till (see the blue shaded areas in

Figure *13*). In some locations, Qva can be found at the surface in areas that are regionally mapped as lodgement till. Two examples are Exploration EB-4 at the intersection of Dellwood Drive and 191st Street SW and Exploration MW-1 in the Seaview Park parking lot.

The transition from the overlying lodgement till to advance outwash is generally gradual, with the till cap thinning to take the form of silty outwash in thicknesses between 5 and 10 feet below the base of the till. This silty Qva has a lower permeability than the Vashon outwash, but greater permeability than the till. The Vashon outwash is the target receptor for infiltrated stormwater runoff.

Groundwater

Groundwater in the Vashon advance outwash was encountered in multiple explorations, and the regional water table aquifer was confirmed at an elevation of about 267 feet above sea level, which corresponds to water levels observed in Perrinville Creek near the intersection of Olympic View Drive and 76th Avenue W. Monitoring indicates that the groundwater level remained relatively constant over the period of observation from April 16 to July 2, 2014.

Regionally, Vashon advance outwash sediments are mapped as underlying Vashon lodgement till beneath most of the Edmonds area. Groundwater flow in the outwash sediments in the Perrinville Creek watershed is generally to the northwest toward Puget Sound. Discharge from the outwash occurs as seeps that supply base flows to Perrinville Creek. Recharge to the Vashon advance outwash occurs from rainfall slowly infiltrating through the glacial till sediments and through windows of advance soils exposed at the ground surface.

Infiltration Evaluation

The subsurface soils consist of about 15 to 25 feet of low-permeability, fine-grained Vashon lodgement till at ground surface in much of the upland area, underlain by 5 to 10 feet of silty Vashon advance outwash, and finally by relatively clean and permeable sandy Vashon advance outwash. From a geotechnical and hydrogeological standpoint, stormwater infiltration into the clean Vashon advance outwash is feasible in the Perrinville Basin, based on the results of the subsurface exploration, grain-size testing, and groundwater level monitoring. The relatively low amounts of silt in the advance outwash, beginning about 10 feet into the Qva, indicate that it will perform well as a receptor soil for stormwater infiltration. Optimum infiltration can be achieved if the stormwater bypasses the till and silty Qva and is directed to the underlying clean Qva for infiltration.

Groundwater within the advance outwash is deep beneath the southern upland areas, and the thickness of the unsaturated outwash beneath the southern uplands is between 60 and 100 feet under most of the basin. The exploration program and laboratory grain-size analysis indicate that stormwater infiltration is feasible for select sites in the Perrinville watershed. Figure 14 depicts generally the areas where advance outwash is found at the surface, within 5 or 10 feet of the surface, and deeper.

Direct infiltration of surface runoff is feasible in areas where the advance outwash is present at the surface or near-surface. In such locations, the use of bioretention facilities, including rain gardens, can be highly effective in reducing surface water discharges to the creek. Where the surface geology is lodgement till, bioretention facilities are generally recommended to be lined to avoid the risk of infiltrated water moving laterally toward basements or other improvements.

Where there is a relatively thin layer of till overlying the advance outwash, there are means by which storm runoff can bypass the till and access the outwash receptor. Pit drains are trenches, typically between 10 and 20 feet deep, intended to penetrate through a thin cap of till or silty outwash to access the advance outwash and thereby maximize infiltration capacity. Dimensions vary according to site-specific infiltration requirements, but are generally on the order of 2 to 4 feet wide (excavator bucket width) and 6 to 10 feet long. It is typical to install a bioretention or sand filter system above pit drains to meet water quality criteria before infiltration. The bioretention facility can also act as a conduit by conveying and storing stormwater collected over a large surface area to the underlying pit drain. The details of a specific pit drain facility will determine whether the facility must follow the Department of Ecology's Underground Injection Control (UIC) guidelines for registration and/or design requirements (http://www.ecy.wa.gov/biblio/0510067.html).

Where the advance outwash is overburdened by a thicker layer of lodgement till, the outwash can be accessed using the drilled drain concept, which acts as a conduit to convey storm runoff to the receptor layer where it can infiltrate. The drain is drilled and cased through the low-permeability till to the outwash using solid-stem augur style drilling equipment. The remainder of the hole drilled into the outwash is typically uncased. The boring is backfilled with a permeable media extending the full depth of the hole. Like pit drains, drilled drains are typically installed with a rain garden or other storage facility above to maximize their capacity.

Figures schematically depicting the pit drain and drilled drain concepts are found in the geotechnical report provided in Appendix H.

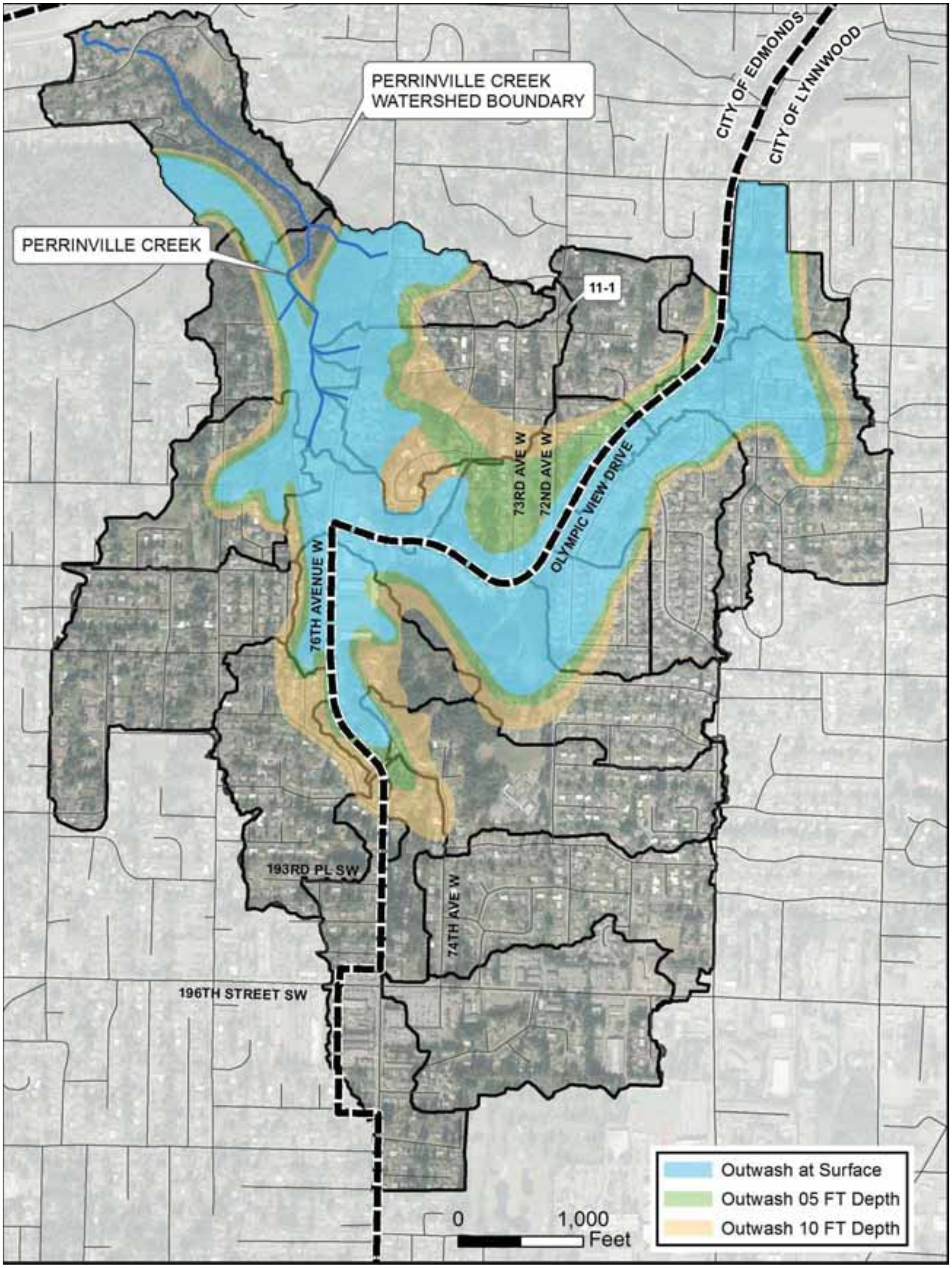

Figure 14. Generalized Estimate of Depth to Vashon Advance Outwash

FLOW REDUCTION OPPORTUNITIES

As discussed earlier, the core objectives of this study are to reduce the stream channel degradation in Perrinville Creek and to mitigate the risk of increased sedimentation and flooding in the creek's lower reaches if the existing 30-inch culvert under Talbot Road is replaced with a fish-friendly box culvert to permit access to upstream habitat. Both objectives can be addressed by reducing the rate and duration of storm discharges in the creek through basin-wide improvements to infiltrate and attenuate peak flows.

Stormwater flow reduction opportunities encompass an array of methods (detention, infiltration, and impervious area reduction), means (capital improvements, maintenance upgrades, site redevelopment, private initiative), scales (from site, neighborhood, or regional), and location (public rights of way, and public and private parcels). With few exceptions, the watershed was developed without stormwater runoff flow controls. Redevelopment of the watershed under state-of-the-practice flow control standards will redress the effects of development from some of the basin; such redevelopment is anticipated to occur over the span of several decades.

The scope of this retrofit plan focuses on **capital improvements** to be situated in public rights of way and on city-owned parcels over a shorter time period than redevelopment offers. The identification of specific capital project opportunities emphasizes sites in the City of Edmonds as the sponsor for this study; however, several projects were identified in Lynnwood, particularly cost effective structural retrofits to existing flow control facilities. This analysis identified 30 discrete flow reduction opportunities within public rights of way and on public properties (parks). The features, effectiveness and costs of these projects are discussed under the subheading Candidate Site Evaluation.

In areas of the watershed that were not analyzed for discrete capital improvements, primarily in the subbasins occupying the eastern portion of the watershed, Tetra Tech developed subbasin-scale estimates of the potential for stormwater flow reductions using BMPs in public rights-of-way. The applied analytical methods and the resulting estimated flow reduction potential are described below the subheading **Basin-wide LID Retrofit**.

It should be noted that city (Edmonds and Lynnwood) owned and controlled properties, consisting of road rights-of-way and parks, account for approximately 13 percent of the Perrinville Creek watershed, with the balance owned by private businesses and individuals or other public entities (such as school districts, community college). Because most of the urban uses in the watershed were developed in the absence of stormwater flow control or water quality treatment standards, there is a large collective opportunity for flow reduction and water quality improvement in the basin as these properties **redevelop** under modern technical standards. In addition to occasions of redevelopment, **private initiatives** such as Edmonds' Raingarden program are underway in Edmonds to improve flow control and water quality of runoff. Both redevelopment and private initiatives can improve conditions in Perrinville Creek, but as their timing and scope are indeterminate, their benefits to the creek are not modeled in this study.

Finally, with this study's understanding of the basin hydrology, the cities of Edmonds and Lynnwood can appropriately consider **flow control enhancements** as they make improvements to drainage systems over time. Examples of these types of interventions include:

- Oversizing storm drainage system replacements to incorporate storage and flow control of smaller events
- Incorporating bioretention or infiltration systems and pervious pavements, and/or reducing in impervious areas when reconstructing roadways

- Collaborating with redeveloping property owners to expand flow control capacity beyond that strictly required for their project.

Again, the hydrologic effect on Perrinville Creek from such improvements over time has not been quantified in this study.

Capital Project Site Identification

By analyzing GIS data from the City of Edmonds and the City of Lynnwood, Tetra Tech identified areas presenting opportunities for reducing the peak discharge or volume of runoff entering Perrinville Creek. The following characteristics were used to identify improvements with the best potential:

- Tributary drainage area
- Subsurface geology
- Location within basin (proximity to the creek)
- Surficial soils
- Suitable site characteristics (space/grades).

The identification of potential sites focused on publicly owned properties and rights-of-way because there is greater certainty of the projects being implemented; where the city controls the property, projects can be put into place more readily. There are opportunities for flow reduction on private property across the watershed, but projects on these sites are expected to require additional lead time to coordinate with property owners. However, existing private facilities identified as having the potential for an effective retrofit are included in the list of candidates. Candidate areas were considered throughout the watershed, in both Edmonds and Lynnwood.

The analysis queried the GIS for land with slopes of 4 percent and less as an initial screen of site suitability. These locations were then overlaid with the drainage system to identify the tributary areas to each location and associated impervious areas. The locations were reviewed with the corresponding surface soil and subsurface geology mapping to identify how a project would be able to access infiltrative soil horizons and thereby have a meaningful impact on flow reduction. Figure 15 presents an example of the GIS data and associated tributary area delineations used in the analysis identifying suitable candidate locations based on slope, tributary area and geology.

Additional sites were identified through record drawings for regional stormwater facilities obtained from the Cities of Edmonds and Lynnwood. Retrofit opportunities were added for locations that were identified as having existing maintenance issues.

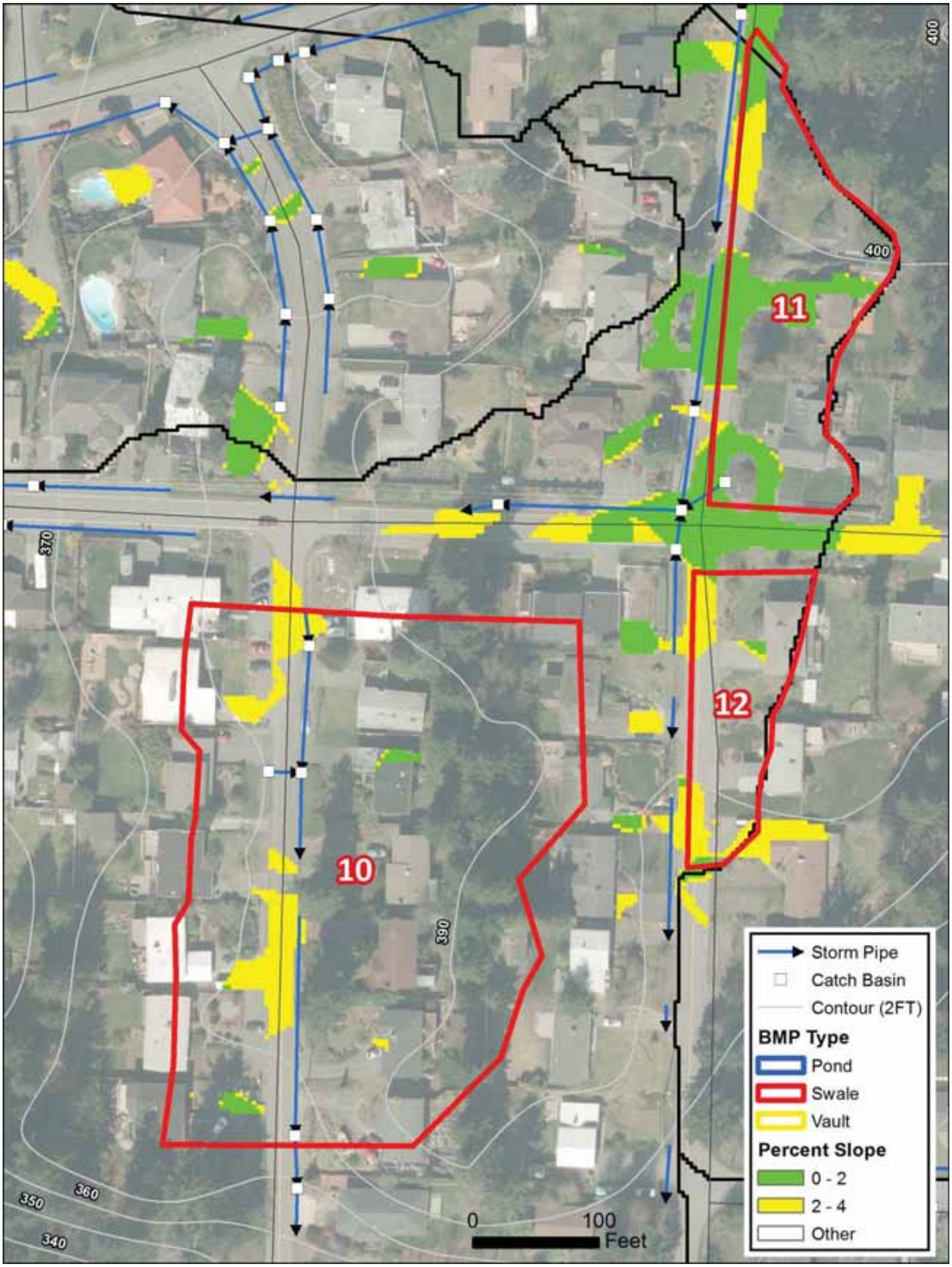

Figure 15. GIS Analysis Sample

Improvement Project Types

Categories of flow reduction improvements considered include the following:

- Public right-of-way LID/BMP retrofit (bio-retention, gravel gallery, other)
- Private property LID/BMP retrofit (rain gardens in appropriate locations)
- Modify existing detention facility storage volume or outlet structure
- Modify existing detention facility to infiltrate
- Modify existing infiltration facility to increase infiltration capacity
- New detention facility (pond or vault)
- New surface infiltration, pit drain or drilled drain facility
- Surface storage (i.e., parking, street, open space).

Capital Project Candidates Evaluation

Based on the GIS screening for areas with mild slopes and significant tributary area, initial concepts were identified for retrofit locations. After sites were identified, a field review was conducted of the candidate areas to confirm site characteristics for potential retrofit projects.

Facility performance was evaluated by incorporating them into a WWHM model representing mitigated conditions. A 2-year level of service, i.e. the effectiveness in reducing the 2-year frequency peak discharge, was selected as the targeted performance in order to minimize the project footprint and maximize facility efficiency in reducing sediment-mobilizing flows that occur frequently during smaller storms. The 2-year peak discharge was also selected as an efficient analytical surrogate for estimating the respective abilities of each candidate project to reduce erosive flows in the creek channel.

Concept-level cost estimates were prepared to aid in identifying the most efficient opportunities. Summary sheets were developed describing each retrofit opportunity, its location, features and estimated cost. The summary sheets are provided in Appendix I. Projects were further evaluated based on the cost per amount of flow reduced, site suitability, overall flow reduction, site location impact, feasibility, and input from the City of Edmonds and the City of Lynnwood. Table 11 lists 30 sites identified as feasible facility locations based on analysis and subsequent field visits. This table describes site attributes for each facility. Facility performance is reported in terms of the reduction in the 2-year return peak discharge. The site numbers listed in this table are cross-referenced to identifiers shown in Figure 16. Projects were considered good opportunities if they were found to have the following:

- A project cost below $450,000 per cfs of 2-year peak flow reduction
- An overall 2-year peak flow reduction greater than 0.15 cfs
- Limited siting and construction constraints.

Based on a comparative review of the 30 candidate projects, it is recommended that the cities of Edmonds and Lynnwood implement 12 of the projects presenting the greatest benefit to the Perrinville Creek system with the highest cost efficiency. The highlighted projects shown in Table 11 are recommended for implementation.

Retrofit ID	Retrofit Type	New / Modified Facility	Address	City	Total Tributary Area (ac)	Impervious Tributary Area (ac)	2-Year Return Peak Discharge (CFS) Existing Conditions	With Project	Flow Reduction	Estimated Cost	Cost/CFS Reduction
2-1	Bio-Retention	New	7903 191st St SW	Edmonds	0.38	0.17	0.11	0.00	0.11	$ 57,000	$ 519,000
2-3	Bio-Retention	New	19108 Dellwood Dr	Edmonds	0.51	0.24	0.13	0.00	0.13	$ 100,000	$ 770,000
3-1	Bio-Retention	New	7805 192nd Pl SW	Edmonds	0.38	0.13	0.05	0.00	0.05	$ 82,000	$ 1,640,000
4-2	Bio-Retention	New	7712 193rd Pl SW	Edmonds	0.38	0.12	0.07	0.00	0.07	$ 100,000	$ 1,516,000
7-1	Bio-Retention	New	19423 74th Ave W	Lynnwood	1.43	0.43	0.20	0.08	0.12	$ 18,000	$ 150,000
7-2	Bio-Retention	New	19417 74th Ave W	Lynnwood	6.60	2.26	0.90	0.70	0.20	$ 42,000	$ 210,000
7-3	Channel Restoration	Modify	19417 74th Ave W	Lynnwood	6.60	2.26	0.90	0.89	0.01	$ 46,000	$ 4,600,000
7-4	Bio-Swale	New	19405 74th Ave W	Lynnwood	0.75	0.28	0.13	0.07	0.06	$ 19,000	$ 317,000
7-5	Bio-Swale	New	19428 73rd Ave W	Lynnwood	0.45	0.25	0.10	0.07	0.03	$ 20,000	$ 667,000
7-6	Bio-Swale	New	19427 73rd Ave W	Lynnwood	0.35	0.20	0.10	0.03	0.07	$ 28,000	$ 418,000
8-1	Bio-Retention	New	19117 74th Ave W	Lynnwood	6.27	1.84	0.71	0.48	0.23	$ 57,000	$ 248,000
10-1	Bio-Retention	New	18027 73rd Ave W	Edmonds	1.87	0.56	0.27	0.09	0.18	$ 89,000	$ 495,000
11-1	Bio-Retention	New	17922 72nds Ave W	Edmonds	0.80	0.35	0.19	0.01	0.18	$ 37,000	$ 206,000
12-1	Bio-Retention	New	18032 72nd Ave W	Edmonds	0.70	0.30	0.14	0.01	0.13	$ 34,000	$ 262,000
13-1	Bio-Retention	New	7418 Ridge Way	Edmonds	3.47	1.62	0.31	0.07	0.24	$ 77,000	$ 321,000
14-1	Vault	New	181st St SW & Homeview Dr	Edmonds	1.77	0.71	0.25	0.19	0.06	$ 92,000	$ 1,534,000
16-1	Infiltration Facility	New	Seaview Park	Edmonds	52.80	12.30	5.00	1.50	3.50	$ 841,000	$ 241,000
17-1	Infiltration Facility	New	76th Ave W & 194th St SW	Edmonds	92.02	34.04	11.30	11.10	0.20	$ 430,000	$ 2,150,000
19-1	Vault	New	7300 196th St SW	Lynnwood	35.67	16.26	5.75	1.25	4.50	$ 1,123,000	$ 250,000
20-1	Pond	Modify	Copper Ridge Pond	Lynnwood	3.84	1.73	0.60	0.22	0.38	$ 22,000	$ 58,000
22-1	Pond	Modify	Blue Ridge Pond	Lynnwood	55.2	14.5	5.77	3.22	2.55	$ 22,000	$ 9,000
24-1	Bio-Retention	New	7332 192nd Pl SW	Lynnwood	1.21	0.50	0.28	0.06	0.22	$ 45,000	$ 205,000
24-2	Bio-Swale	New	19323 72nd Pl W	Lynnwood	0.30	0.17	0.10	0.02	0.08	$ 27,000	$ 338,000
24-3	Bio-Swale	New	19328 72nd Pl W	Lynnwood	1.50	0.64	0.24	0.17	0.07	$ 27,000	$ 386,000
24-4	Bio-Swale	New	19323 72nd Pl W	Lynnwood	0.60	0.29	0.13	0.08	0.05	$ 35,000	$ 700,000
25-1	Bio-Retention	New	7226 182nd St SW	Edmonds	1.30	0.54	0.29	0.01	0.28	$ 96,000	$ 343,000
26-1	Vault	New	7332 192nd Pl SW	Lynnwood	28.07	11.51	4.20	2.81	1.39	$ 286,000	$ 206,000
27-1	Pond	Modify	Olympic View Crest Pond	Edmonds	3.07	1.23	0.43	0.11	0.32	$ 74,000	$ 232,000
28-1	Infiltration Facility	Modify	Lynndale Park	Lynnwood	82.10	20.30	0.33	0.13	0.20	$ 22,000	$ 110,000
29-1	Infiltration Facility	New	Olympic View Dr & 76th Ave W	Edmonds	4.04	1.26	0.44	0.19	0.25	$ 233,000	$ 932,000

Note: Rows highlighted in green indicate a recommended project.

Table 11. Attribute Table for Retrofit Projects Evaluated for Perrinville Creek Watershed

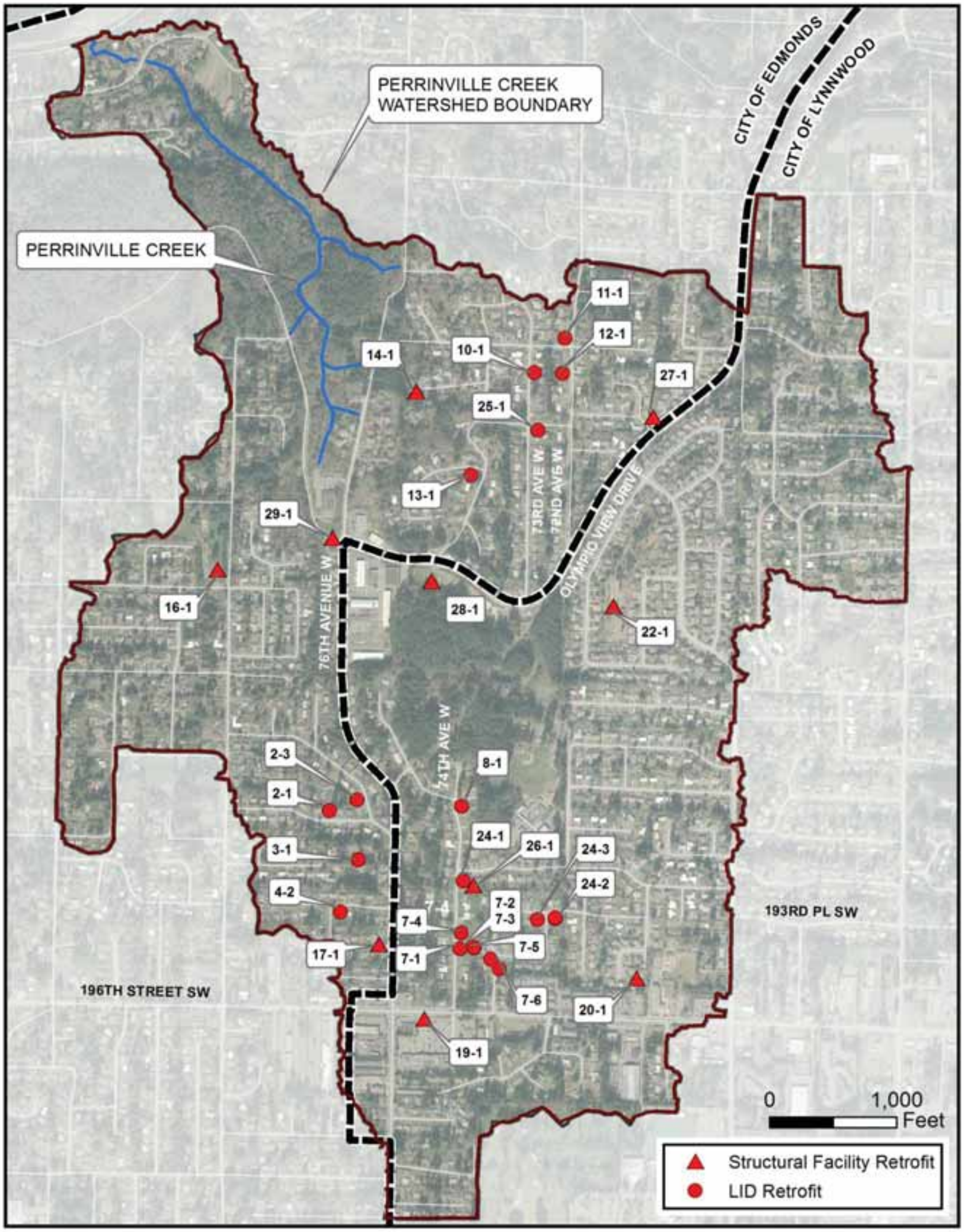

Figure 16. Location Map for Retrofit Projects Evaluated for Perrinville Creek Basin

Basin-Wide LID Retrofit Evaluated

To better estimate the potential for flow reduction from LID retrofits throughout the Perrinville Creek Watershed, a basin-wide LID retrofit was also studied in those subbasins where discrete project opportunities were not investigated, largely in the easternmost portions of the watershed. Two types of bioretention retrofits were modeled using WWHM—one based on good infiltrative soils and a second assuming a lined system installed in lodgement till soils with an underdrain and associated outlet pipe connection. Using a typical retrofit tributary area of 0.5 acres, a facility size of 5'x20' was assumed for the evaluation.

The effective impervious area for each subbasin was segregated based on the infiltrative capabilities of soils. Using these effective impervious areas, a goal was set for each subbasin for lined and infiltrative retrofits. Soils identified as glacial outwash in areas not impacted by high groundwater were assumed to have good infiltrative soils and provide good opportunities for infiltrative bioretention BMPs. All other areas were considered appropriate for lined bioretention BMPs. Due to the siting difficulties associated with connecting the facility underdrain for lined systems, a goal was set to manage only 5% of the effective impervious area for each subbasin that would require lined systems. Since infiltrative retrofits do not rely on a below-grade discharge to existing storm drains, but can rather overflow at surface grades, they are easier to site and the goal for basins that would use infiltrative systems was set at 12% of the effective impervious area.

Based on this analysis a basin-wide goal of 24 infiltration retrofits and 63 lined/piped retrofits was established. Using the cost estimates for similar projects from the retrofit project list on Table 11, and applying them to the retrofits sized for the 0.5-acre tributary area, the costs were estimated to be $24,200 for an infiltration retrofit and $35,600 for a lined/piped retrofit. The total basin-wide retrofit cost was thus estimated to be $2.8 million. There are many benefits of LID retrofits that should be considered when evaluating overall costs against more typical gray-water solutions; these benefits include water quality improvements, flooding reduction, groundwater recharge, air quality improvements, neighborhood traffic calming effects, reduction of urban heat island effect, and increased property values.

Although many studies indicate that LID retrofits have lower maintenance costs than conventional gray-water systems, municipalities sometimes hesitate to implement LID because when the retrofits are not maintained it is more obvious to the public than unmaintained gray-water systems, which are generally out of public view. It is therefore imperative to incorporate costs for maintaining these amenities into annual budgets. Engaging the public to coordinate volunteer programs for routine maintenance can offset LID maintenance costs.

Flow Reduction Results

The hydraulic effects on the stream channel from implementing the various candidate projects were evaluated using the calibrated hydrologic model developed for this study. The future conditions modeling did not forecast changes in land use, since the watershed is nearly fully built out. Two retrofit scenarios were modeled as follows to better understand the corresponding effects. These scenarios are as follows:

- Recommended Projects - This scenario evaluates the effects from only incorporating the 12 capital projects recommended for immediate implementation. The results from this scenario indicate the level of benefits to the creek that is achievable over the short-term.
- All Projects + Basin Wide LID retrofit – This scenario evaluates the effect of incorporating all 30 candidate capital projects plus the target for LID retrofits basin-wide. This scenario

represents what is achievable through more comprehensive retrofitting of city rights-of-way throughout the watershed.

Flood Reduction Effects

Results from the modeled scenarios, summarized in Table 12, indicate an average 20% reduction in the **magnitude** of peak flood flows for 2-year through the 100-year return period. When a comparison is made between existing conditions and retrofitted conditions, it is observed that the **frequency of flooding** at any given rate is reduced roughly by half; by example, the current 25-year flood flow of 99 cfs approximates the 50-year flood flow under the retrofitted condition. This represents a substantial reduction in flooding risk with the recommended projects implemented.

TABLE 12.
PEAK FLOOD FLOW REDUCTION AT TALBOT ROAD CROSSING

Return Period	Existing Conditions (CFS)	Retrofit with Recommended Projects (CFS)	Reduction	All Projects + Basin-wide Retrofit (CFS)	Pre-Developed Forested Condition (CFS)
2-Year	41	31	26%	28	6.9
5-Year	64	51	22%	51	11.1
10-Year	77	59	25%	56	13.5
25-Year	99	87	14%	80	16.0
50-Year	126	100	22%	99	17.4
100-Year	135	115	15%	105	18.6

Table 12 also indicates that implementing additional BMPs basin-wide provides limited additional flood flow reduction beyond that of the recommended projects.

Peak Flow Duration Reduction

As discussed in the Geomorphic Analysis section of the report, scour and sediment transport in Perrinville Creek occur at flows lower than the 2-year return discharge. The generation of new sediment material occurs when discharge in the stream channel exceeds the mobilization flow rate of approximately 7.2 cfs. Reducing the amount of time that flows exceed this erosive threshold represents reductions in the amounts of damage to the stream channel, new sediment generated in the stream, and sediment deposited in the lower reaches. Project performance and the occurrence of sediment generation and transport are best represented using a flow duration curve framework. Flow duration curves represent the percent of time a flow record is likely to equal or exceed a given discharge. Figure 17 compares the shift in the flow duration curve from the existing condition to the recommended project implementation scenario, and to the recommended projects plus basin-wide retrofit scenario.

At the right of Figure 17, the base flow of 1.5 cfs is shown as present or exceeded 100 percent of the time, and on the left side of the figure the higher flow rates are exceeded less often; hence, documenting the intuitive conclusion that duration of high flows is less than that for low flows.

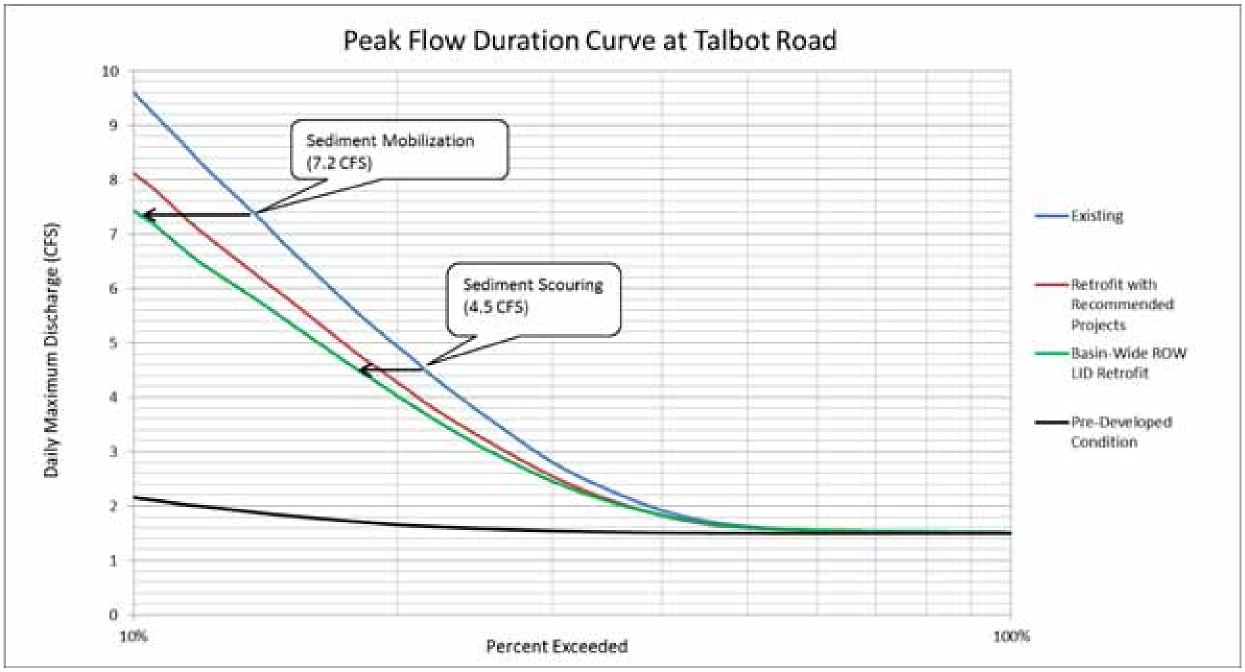

Figure 17. Flow Duration Curve Comparison for Perrinville Creek.

Flow duration curves for the two retrofit scenarios are shifted left from the existing conditions curve, indicating that the duration of any given flow rate is reduced from the current conditions. Figure 17 shows that implementing the recommended projects would reduce the duration of scouring flow exceeding 7.2 cfs from 14 percent of the time to 11 percent. While a 3% reduction would not appear to be significant, this represents a 21% reduction in the duration of erosive flows, and roughly corresponds to a reduction in the amount of material deposited in the lower reach of the stream and the amount of material requiring removal from the City sediment control facility.

Similarly, the threshold at which sediment existing in the creek channel is transported downstream is reduced from 22 percent to 18 percent of the 60-year period of record used in the model. This represents an 18% reduction in the duration of sediment transporting flows. The percent exceedances are summarized below in Table 13..

TABLE 13.
SUMMARY OF FLOW DURATION CURVE EXCEEDANCES

Flow (CFS)	Existing Conditions	Retrofit with Recommended Projects	Reduction in Duration Exceeding Threshold Flow	Recommended Projects + Basin-wide Retrofit
4.5	22%	18%	21%	17%
7.2	14%	11%	18%	10%

RECOMMENDATIONS

The scope of this stormwater retrofit plan focuses on capital improvements in public rights-of-way and on city-owned parcels. The identification of specific capital project opportunities emphasizes sites in the City of Edmonds; however, several projects were identified in Lynnwood, particularly cost effective structural retrofits to existing flow control facilities. This analysis identified 30 discrete flow reduction opportunities within public rights-of-way and on public properties (specifically park lands). Evaluating the 30 candidate opportunities, it recommended that 12 projects be advanced to design and implementation in the near term, listed in Table 14. The estimated cost of these 12 projects totals $2.9M.

Table 14. Recommended Project Summary

Retrofit ID	Retrofit Type	New / Modified Facility	Location	City	Total Tributary Area (ac)	2-year Peak Flow Reduction (CFS)	Estimated Cost
10-1	Bio-Retention	New	18027 73rd Ave W	Edmonds	1.87	0.18	$ 89,000
11-1	Bio-Retention	New	17922 72nds Ave W	Edmonds	0.80	0.18	$ 37,000
13-1	Bio-Retention	New	7418 Ridge Way	Edmonds	3.47	0.24	$ 77,000
16-1	Infiltration Facility	New	Seaview Park	Edmonds	52.80	3.50	$ 841,000
19-1	Vault	New	7300 196th St SW	Lynnwood	35.67	4.50	$ 1,123,000
20-1	Pond	Modify	Copper Ridge Pond	Lynnwood	3.84	0.38	$ 22,000
22-1	Pond	Modify	Blue Ridge Pond	Lynnwood	55.2	2.55	$ 22,000
25-1	Bio-Retention	New	7226 182nd St SW	Edmonds	1.30	0.28	$ 96,000
26-1	Vault	New	7332 192nd Pl SW	Lynnwood	28.07	1.39	$ 286,000
27-1	Pond	Modify	Olympic View Crest Pond	Edmonds	3.07	0.32	$ 74,000
28-1	Infiltration Facility	Modify	Lynndale Park	Lynnwood	82.10	0.20	$ 22,000
29-1	Infiltration Facility	New	Olympic View Dr & 76th Ave W	Edmonds	4.04	0.25	$ 233,000

Two of the recommended projects, No. 16-1 in Seaview Park and No. 26-1 at 74th Avenue W and 192nd Place SW, are in preliminary design as part of this project.

Results from the modeled scenarios, summarized earlier in Table 12, indicate an average 20% reduction in the **magnitude** of peak flood flows for 2-year through the 100-year return period for the 12 recommended projects. When a comparison is made between existing conditions and those following implementation of the 12 recommended projects, it is observed that the **frequency of flooding** at any given rate is reduced roughly by half; by example, the current 25-year flood flow of 99 cfs approximates the 50-year flood flow under the retrofitted condition. This represents a substantial reduction in flooding risk with the recommended projects implemented.

Implementing the recommended projects will reduce flood flows sufficiently to allow replacement of the fish barrier culvert without increasing flood risk to properties downstream of Talbot Road. Sufficient flood flow reduction will be achieved to mitigate removal of the existing culvert by construction of two of the most highly effective of the recommended projects: Project 16-1 (Seaview Park facility) and Project 22-1 (Blue Ridge Pond modifications).

Implementing the recommended near-term projects will also reduce the amount of scour along the Perrinville Creek channel. The generation of new sediment material occurs when discharge in the stream channel exceeds the mobilization flow rate of approximately 7.2 cfs. Reducing the amount of time that flows exceed this erosive threshold represents reductions in the amounts of damage to the stream channel, new sediment generated in the stream, sediment deposited in the lower reaches, and sediment needing removal from the City's sediment control facility. The recommended projects would reduce erosive flows by 18%.

Similarly, the time when sediment existing in the creek channel is transported downstream is reduced from 22 percent to 18 percent of the 60-year period of record used in the model. This represents an 18% reduction in the duration of sediment transporting flows. The percent exceedances were summarized earlier in Table 13..

It should be noted that city-owned and controlled properties, consisting of road rights-of-way and parks, account for only approximately 13 percent of the Perrinville Creek watershed, with the balance owned by private businesses and individuals or other public entities (such as school districts, community college). Because most of the watershed area was developed in the absence of stormwater flow control or water quality treatment standards, there is a large collective opportunity for flow reduction and water quality improvement in the basin as these properties redevelop under modern technical standards. Hence, it is recommended that a flow control standard be developed and placed into effect for the Perrinville Creek watershed to reduce the erosive flows.

The first step in developing a flow control standard would be to evaluate if the flow control standard in the Department of Ecology's 2012 Stormwater Management Manual for Western Washington is adequate for this creek. If not, a stricter flow control standards should be developed and implemented throughout the Perrinville Creek watershed. In addition, flow control requirements should strongly promote infiltration of runoff, particularly in areas of the watershed where outwash soils can be accessed within 10 feet of the ground surface, as mapped in this study. This mimics the predevelopment condition by reducing the amount of surface runoff entering the creek which, in turn, supports beneficial base flows in the stream. To be most effective, similar standards should be implemented throughout the watershed in both Edmonds and Lynnwood.

In addition to occasions of redevelopment, private initiatives such as a rain garden program can improve flow control and water quality of runoff. Both redevelopment and private initiatives can improve conditions in Perrinville Creek, but as their timing and scope are indeterminate, their benefits to the creek are not modeled in this study.

This study has located those reaches of Perrinville Creek that are most prone to scour during erosive flows. These areas, however, are predominately located within a deep canyon in the undeveloped Snohomish County Park and immediately below the park. While it may be beneficial to stabilize these areas, thus potentially raising the threshold flow rates where scour and transport occur, the inaccessibility of these areas likely makes this work very costly. Further study of options for stabilizing these areas may be warranted.

Finally, with this study's understanding of the basin hydrology, the cities of Edmonds and Lynnwood can appropriately consider flow control enhancements as they make improvements to drainage systems over time. Examples of these types of interventions include:

- Oversizing storm drainage system replacements to incorporate storage and flow control of smaller events
- Incorporating bioretention or infiltration systems and pervious pavements, and/or reducing in impervious areas when reconstructing roadways
- Collaborating with redeveloping property owners to expand flow control capacity beyond that strictly required for their project.

The recommended improvements involve substantial investment to redress the hydrologic effects of historical urbanization in the watershed. The benefits to accrue to the community, however, are several:

- The sediment loading to the City's bypass facility that protects the lower reaches of the stream will be reduced, and bring a corresponding reduction in maintenance costs for cleaning the facility
- The degradation of the stream channel and hillslope failures through public and private properties will be slowed, and stream reaches will become more stable
- The risk of blockage to the existing Talbot Road culvert will be reduced, and with it the risk of overtopping the roadway (and damaging city-owned water, sewer, and stormwater infrastructure).
- Flood flow magnitudes will be reduced, lowering risk of damage to Talbot Road and properties below and immediately above the road
- Flood frequencies will be reduced by one-half
- The rate of sediment deposited in the lower reaches of Perrinville Creek and at the shoreline of Browns Bay will be reduced, along with the associated damage to aquatic habitat
- The reduction in flood magnitudes will allow construction of the fish-friendly culvert proposed for Talbot Road without increasing flood risks.

These benefits align with regional, statewide and national objectives to protect and improve water quality and habitat function in coastal ecosystems. This alignment promotes the eligibility of the recommended projects for continued outside funding support.

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APPENDIX A.
HYDROLOGIC MODELING SOURCE DATA

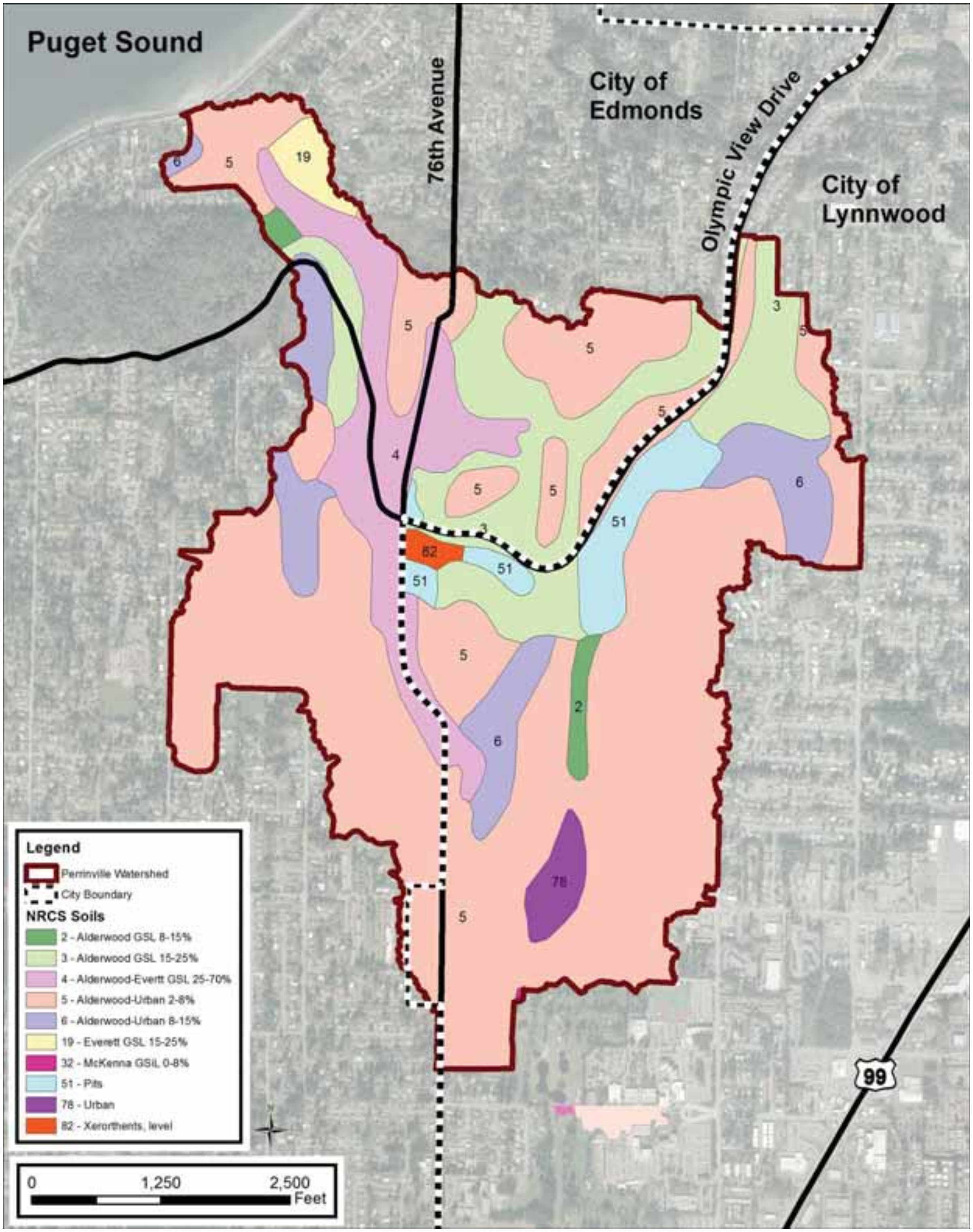
October 2014

Hydrologic Models Considered

Model Name	Brief Description	Advantages	Disadvantages
HSPF	• Continuous hydrologic simulation model based on physical watershed characteristics	• Flexible design • Industry standard	• Time consuming for pipe networks • Many input parameters required • Post-processing required for hydrologic statistics
WWHM	• HSPF front-end to provide regional input parameters and statistically relevant precipitation and evaporation	• Self-generates land-use and climate inputs • Built-in post processing for hydrologic statistics	• Pipes are hydraulic approximations
LSPC	• Continuous hydrologic simulations model based on HSPF parameters and algorithms	• Easy to change and perform a sensitivity analysis	• Need an '.air' file for climate • Not a HSPF front-end • LID module is less developed
SWMM	• Event simulation model based on physical watershed characteristics	• Strong hydraulic modeling capabilities	• Does not handle long time series efficiently • Built-in hydrologic modeling is event based

External Data Sources

Data	File Type	Description
City of Edmonds		
Building Rooftops	GIS Shape	Outline of Rooftops
Storm Type II CB	GIS Shape	Type II Catch Basin Locations and attributes
Storm Lines	GIS Shape	Gravity Main size, direction, material
Storm Ditch Creek	GIS Shape	Perrinville Creek Location
Edmonds Watersheds	GIS Shape	Perrinville Basin Boundary
Topography	GIS Shape	2-ft Contours of Perrinville Basin
Edmonds Streets	GIS Shape	Street Centerlines for Edmonds & Lynnwood
Aerial	TIF	Basin Aerial for GIS
City of Lynnwood		
Storm drain network	GIS GDB	Drainage Infrastructure for Lynnwood
Olympic View Drive Infiltration Design	PDF	Design memo and plans for facility
Blue Ridge Pond Details	PDF	As-built plans for facility
Other		
Surface soil data	GIS GDB	SSURGO soil data from NRCS
Subsurface soil data	GIS Shape	Digitized from Minard, 1983



NRCS SSURGO surficial soils considered for hydrologic modeling.

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APPENDIX B.
EXISTING CONDITIONS HYDROLOGIC MODEL INPUTS

October 2014

WWHM Land-use parameters

WWHM Land-use Group	WWHM LAND-USE INPUTS (ACRES)						
	BASIN ID						
	1	2	3	4	5	6	7
A/B, Forest, Flat	0.8	2.0	0.3	0.0	0.0	0.0	0.9
A/B, Forest, Mod	2.8	6.3	1.2	0.0	0.0	0.0	1.4
A/B, Forest, Steep	3.3	9.5	1.0	0.0	0.0	0.0	3.5
A/B, Lawn, Flat	0.0	0.4	1.5	0.0	2.8	3.3	0.2
A/B, Lawn, Mod	0.0	2.1	2.3	0.0	6.6	3.3	0.2
A/B, Lawn, Steep	0.0	2.7	3.5	0.0	4.9	2.5	0.1
C, Forest, Flat	2.0	2.2	0.1	0.1	0.0	0.0	1.0
C, Forest, Mod	4.6	4.1	0.3	0.3	0.0	0.0	2.2
C, Forest, Steep	17.6	7.1	1.1	0.3	0.0	0.0	2.0
C, Lawn, Flat	2.3	2.0	7.6	10.3	13.5	6.2	7.3
C, Lawn, Mod	3.4	6.4	9.9	5.7	14.2	5.6	5.4
C, Lawn, Steep	3.6	4.1	8.0	2.2	5.5	2.0	2.0
Impervious (EIA)	5.9	7.8	10.2	4.7	16.7	7.6	6.3
Total Area (ac)	46.5	56.7	46.8	23.8	64.2	30.5	32.5

WWHM Land-use Group	WWHM LAND-USE INPUTS (ACRES)						
	BASIN ID						
	8	9	10	11	12	13	14
A/B, Forest, Flat	0.6	0.0	0.0	0.4	1.6	0.0	0.0
A/B, Forest, Mod	0.4	0.0	0.1	0.6	3.6	0.0	0.0
A/B, Forest, Steep	1.5	0.0	0.3	3.0	5.2	0.0	0.0
A/B, Lawn, Flat	2.3	2.2	1.9	4.3	1.4	0.0	0.0
A/B, Lawn, Mod	1.4	2.8	1.9	2.3	1.8	0.0	0.0
A/B, Lawn, Steep	2.1	5.2	2.2	1.1	1.4	0.0	0.0
C, Forest, Flat	0.4	0.0	0.0	3.8	1.5	0.3	3.0
C, Forest, Mod	0.2	0.0	0.0	4.4	2.4	0.1	1.5
C, Forest, Steep	0.5	0.0	0.0	4.5	3.1	0.1	1.0
C, Lawn, Flat	1.1	5.5	1.2	1.8	9.9	23.8	3.3
C, Lawn, Mod	0.3	6.0	3.0	1.2	5.9	14.7	2.1
C, Lawn, Steep	0.2	3.3	3.1	0.6	0.7	1.5	1.3
Impervious (EIA)	4.2	11.6	4.89	3.8	10.6	12.3	1.5
Total Area (ac)	15.2	36.5	18.6	31.7	49.2	52.8	13.6

WWHM Land-use Group	WWHM LAND-USE INPUTS (ACRES)					
	BASIN ID					
	15	16	17	18	19	**20**
A/B, Forest, Flat	0.0	0.1	0.0	0.0	0.0	0.0
A/B, Forest, Mod	0.0	0.1	0.0	0.0	0.0	0.0
A/B, Forest, Steep	0.0	0.0	0.0	0.0	0.0	0.0
A/B, Lawn, Flat	0.0	0.1	0.0	0.0	0.0	2.5
A/B, Lawn, Mod	0.0	0.0	0.0	0.0	0.0	3.4
A/B, Lawn, Steep	0.0	0.0	0.0	0.0	0.0	4.0
C, Forest, Flat	0.2	3.1	0.0	0.0	0.1	0.0
C, Forest, Mod	0.1	3.3	0.0	0.0	0.1	0.0
C, Forest, Steep	0.0	3.7	0.0	0.0	0.3	0.0
C, Lawn, Flat	19.5	18.7	27.5	26.9	21.5	1.1
C, Lawn, Mod	9.7	8.6	11.8	13.0	11.4	2.2
C, Lawn, Steep	1.8	2.4	2.2	2.4	1.8	1.0
Impervious (EIA)	8.0	5.7	7.5	10.3	5.1	3.7
Total Area (ac)	39.3	45.8	49.0	52.7	40.3	18.0

WWHM RCHRES INPUT PARAMETERS					
RCHRES ID	Downstream ID	Length (ft)	Diameter (ft)	Slope (ft/ft)	Manning's (n)
OVD Wetland	5	-	-	-	-
5	Flow Splitter B	1,200	3.0	0.02	0.013
Flow Splitter B	Flow Splitter C OVD	--	--	--	--
Flow Splitter C	Infiltration OVD	--	--	--	--
OVD	8	--	--	--	--
Blue Ridge	6	--	--	--	--
6	8	2,500	2.5	0.02	0.010
7	8	1,000	3.0	0.02	0.024
9	8	1,200	3.0	0.02	0.024
11	8	2,000	3.5	0.02	0.012
14	8	3,500	2.0	0.02	0.012
8	2	500	4.0	0.02	0.010
15	11	1,800	3.0	0.02	0.012
18	15	1,200	2.5	0.02	0.012
19	11	1,000	2.0	0.02	0.012

WWHM CHANNEL RCHRES INPUT PARAMETERS						
RCHRES ID	Downstream ID	Length (ft)	Width (ft)	Slope (ft/ft)	Manning's (n)	Side Slope (ft/ft)
2	1	2,500	10.0	0.02	0.035	3
1	Terminal	2,500	8.0	0.03	0.035	2

STAGE (FT)	AREA (AC)	STORAGE (AC-FT)	DISCHARGE1	DISCHARGE2
0	0.01	0.00	0.00	0.00
0.1	0.01	0.03	0.20	0.00
0.2	0.01	0.06	0.28	0.00
0.3	0.01	0.10	0.36	0.00
0.4	0.01	0.13	0.41	0.00
0.5	0.01	0.16	0.45	0.00
0.6	0.01	0.20	0.51	0.00
0.7	0.01	0.23	0.54	3.14
0.8	0.01	0.26	0.58	3.34
0.9	0.01	0.29	0.61	3.53
1	0.01	0.33	0.65	3.76
1.1	0.01	0.36	0.68	3.93
1.2	0.01	0.40	0.72	4.14
1.3	0.01	0.43	0.74	4.29
1.4	0.01	0.46	0.77	4.44
1.5	0.01	0.50	0.80	4.63
1.6	0.01	0.53	0.83	4.77
1.7	0.01	0.56	0.85	4.90
1.8	0.01	0.60	0.88	5.07
1.9	0.01	0.63	0.90	5.20
2	0.01	0.66	0.92	5.32
2.1	0.01	0.70	0.95	5.48
2.2	0.01	0.73	0.97	5.59
2.3	0.01	0.75	0.98	5.67
2.4	0.01	0.79	1.01	5.86
2.5	0.01	0.81	1.03	5.96
2.6	0.01	0.83	1.05	6.04
2.7	0.01	0.87	1.08	6.21
2.8	0.01	0.89	1.09	6.31
2.9	0.01	0.91	1.11	6.38
3	0.01	0.95	1.13	6.55
3.1	0.01	0.97	1.15	6.61
3.2	0.01	0.97	1.15	6.61
3.3	0.01	0.97	1.15	6.61
3.4	0.01	0.97	1.15	6.61
3.5	0.01	0.97	1.15	6.61
3.6	0.01	0.97	1.15	6.61
3.7	0.01	0.97	1.15	6.61
3.8	0.01	0.97	1.15	6.61
3.9	0.01	0.97	1.15	6.61
4	0.01	0.97	1.15	6.61
4.1	0.01	0.98	1.15	25.00

WWHM Inputs for Olympic View Drive Control Structure Flow Splitter B

STAGE (FT)	AREA (AC)	STORAGE (AC-FT)	DISCHARGE1	DISCHARGE2
0	0.00	0.00	0.00	0.00
0.1	0.01	0.03	0.03	0.00
0.2	0.01	0.07	0.05	0.00
0.3	0.01	0.10	0.06	0.00
0.4	0.01	0.14	0.07	0.00
0.5	0.01	0.18	0.07	0.00
0.6	0.01	0.21	0.08	0.00
0.7	0.01	0.25	0.09	0.04
0.8	0.01	0.29	0.09	0.05
0.9	0.01	0.32	0.10	0.06
1	0.01	0.36	0.10	0.07
1.1	0.01	0.39	0.11	0.07
1.2	0.01	0.43	0.11	0.09
1.3	0.01	0.47	0.12	0.10
1.4	0.01	0.50	0.12	1.30
1.5	0.01	0.54	0.13	1.83
1.6	0.01	0.58	0.13	1.94
1.7	0.01	0.61	0.14	2.19
1.8	0.01	0.65	0.14	2.52
1.9	0.01	0.69	0.14	2.85
2	0.01	0.72	0.15	3.11
2.1	0.01	0.76	0.15	3.44
2.2	0.01	0.79	0.15	3.69
2.3	0.01	0.83	0.16	4.02
2.4	0.01	0.87	0.16	4.36
2.5	1.01	0.89	0.16	4.53

WWHM Inputs for Olympic View Drive Control Structure Flow Splitter C

STAGE (FT)	AREA (AC)	STORAGE (AC-FT)	DISCHARGE1
0.0	0.00	0.00	0.00
0.2	0.00	0.00	0.02
0.4	0.01	0.01	0.03
0.6	0.01	0.01	0.03
0.8	0.01	0.02	0.04
1.0	0.01	0.02	0.04
1.2	0.01	0.03	0.05
1.4	0.02	0.04	0.05
1.6	0.02	0.04	0.05
1.8	0.02	0.05	0.06
2.0	0.02	0.06	0.06
2.2	0.02	0.07	0.06
2.4	0.03	0.08	0.07
2.6	0.03	0.09	0.07
2.8	0.03	0.10	0.07
3.0	0.03	0.11	0.10
3.2	0.03	0.12	0.11
3.4	0.04	0.13	0.12
3.6	0.04	0.14	0.13
3.8	0.04	0.15	0.21
4.0	0.04	0.16	0.27
4.2	0.04	0.18	0.32
4.4	0.05	0.19	0.36
4.6	0.05	0.20	1.36
4.8	0.05	0.21	4.57
5.0	0.05	0.22	7.17
5.2	0.05	0.23	9.22
5.4	0.06	0.24	10.79
5.6	0.06	0.25	11.94
5.8	0.06	0.26	12.64
6.0	0.06	0.27	12.81
6.2	0.06	0.28	13.04
6.4	0.07	0.29	13.24
6.6	0.07	0.30	13.44
6.8	0.07	0.31	13.63
7.0	0.07	0.32	13.82
7.2	0.07	0.33	14.01
7.4	0.08	0.34	14.20
7.6	0.08	0.35	14.39
7.8	0.08	0.35	14.58
8.0	0.08	0.36	30.00

WWHM Inputs for Olympic View Drive Control Structure Detention

STAGE (FT)	(AREA (AC)	STORAGE (AC-FT)	DISCHARGE1 (CFS)
0.00	0.00	0.00	0.00
1.75	0.00	0.02	4.40
1.85	0.01	0.03	4.52
2.85	0.06	0.07	5.61
4.85	0.22	0.21	7.32
6.85	0.31	0.47	8.70
8.85	0.39	0.83	44.32
10.85	0.48	1.26	108.34
11.85	0.55	1.78	147.55

WWHM Inputs for Blue Ridge Pond Detention Facility

STAGE (FT)	AREA (AC)	STORAGE (AC-FT)	DISCHARGE1
0.00	0.07	0.00	0.00
0.25	0.10	0.02	0.00
0.50	0.11	0.05	0.00
0.75	0.12	0.08	0.00
1.00	0.14	0.12	0.00
1.25	0.15	0.15	2.43
1.50	0.16	0.19	6.89
1.75	0.17	0.24	12.65
2.00	0.17	0.28	19.48

WWHM Inputs for Olympic View Drive Wetland

City Of Edmonds
Perrinville Creek Stormwater Flow Reduction Retrofit Study
Final Report

APPENDIX C.
MODEL VALIDATION ANALYSIS

October 2014

TETRA TECH

To: Perrinville Creek Stormwater Flow Reduction Study Project File

From: Bruce Cleland

Subject: **Hydrology Data Assessment**

Date: October 14, 2013

A key part of the Perrinville Creek stormwater flow reduction retrofit study is the development of a hydrologic model for the watershed. This model is needed to characterize existing flow conditions in Perrinville Creek and assess performance of alternative future scenarios. Streamflow data for Perrinville Creek, which can be used to check the validity of the model, is somewhat limited; particularly in examining patterns over multiple years. However, the U.S. Geological Survey (USGS), Snohomish County, and King County operate a number of stream gages in the area that could be used to examine general performance of the Perrinville model.

The purpose of this technical memorandum is to examine hydrologic conditions in the Perrinville Creek area. Characteristics of current and historic flow information for gages located within 10 miles of Perrinville Creek are summarized. Gages that could be used to support the modeling effort are identified. Basic hydrologic characteristics examined include flow duration statistics, annual average volume, base flow as a percentage of total runoff, stream flashiness, and peak flow history. In evaluating flow data, water level recorder information collected by the City of Edmonds is also summarized.

In addition to assessing characteristics of flow gage information collected in the Perrinville Creek area, preliminary hydrologic model results are examined. The analysis is part of the validation process to ensure that model results are representative of flow conditions observed in the Perrinville Creek area. Rainfall – runoff response patterns are compared to a representative flow gage. Metrics important to target development are also examined including key duration curve and peak flow recurrence values.

Contents

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1. Overview

The City of Edmonds desires to improve the aquatic habitat in the lower reaches of Perrinville Creek, including its mouth at Puget Sound. The 30-inch diameter Perrinville Creek culvert under Talbot Road is a major fish barrier. The City has completed a pre-design report for replacing it with a fish-friendly box culvert to permit access to upstream habitat. However, replacing the culvert would increase sedimentation and flooding risk in the lower reaches of Perrinville Creek.

The primary goal of this project is to mitigate flooding risk in Perrinville Creek by reducing stormwater runoff. The flow reduction will provide multiple hydrologic and biological benefits to both Perrinville Creek and Brown's Bay in the Sound such as: 1) allowing for the replacement of the anadromous fish barrier culvert; 2) reducing erosion and sedimentation that is adversely affecting aquatic habitat and City infrastructure; and 3) reducing the amount of pollutants entering the aquatic environment.

This study will develop a plan to accomplish this goal through implementation of low impact development (LID) best management practices (BMPs) to the extent feasible, other stormwater BMPs (e.g., increased detention), and stream stabilization in Perrinville Creek. Stream flow targets will be determined by assessing existing flow conditions and geomorphic conditions as critical sources of sediment. A hydrologic model is being developed to characterize existing conditions and assess performance of alternative future scenarios.

Flow data for Perrinville Creek, which can be used to check the validity of the model, is somewhat limited; particularly in examining patterns over multiple years. However, Snohomish County and King County operate a number of stream gages in the area that could be used to examine general performance of the Perrinville model. The purpose of this technical memorandum is to summarize hydrologic characteristics of gages located within 10 miles of Perrinville Creek and identify those that could be used to support the modeling effort. Water level recorder information collected by the City of Edmonds is also summarized. In addition to assessing flow gage information, preliminary hydrologic model results are examined.

2. Flow Gaging Information

The potential effect that excess stormwater volume exerts on local streams is most easily identified by examining primary hydrologic characteristics. Hydrologic characteristics of watersheds such as average annual flow and surface runoff can be determined from stream gaging information. To date, flow monitoring in Perrinville Creek consists of water levels recorded at 10-15 minute intervals from November 2012 through September 2013 (excluding 12/22/2012 – 1/24/2013 when the recorder was not operating due to vandalism). However, flow records reported by the U.S. Geological Survey (USGS), Snohomish County, and King County are readily available for several locations within 10 miles of Perrinville Creek *(Figure 2-1 and Table 2-1)*. A quick analysis of this information offers some insight on hydrologic characteristics in the area, which can guide the Perrinville Creek model validation process.

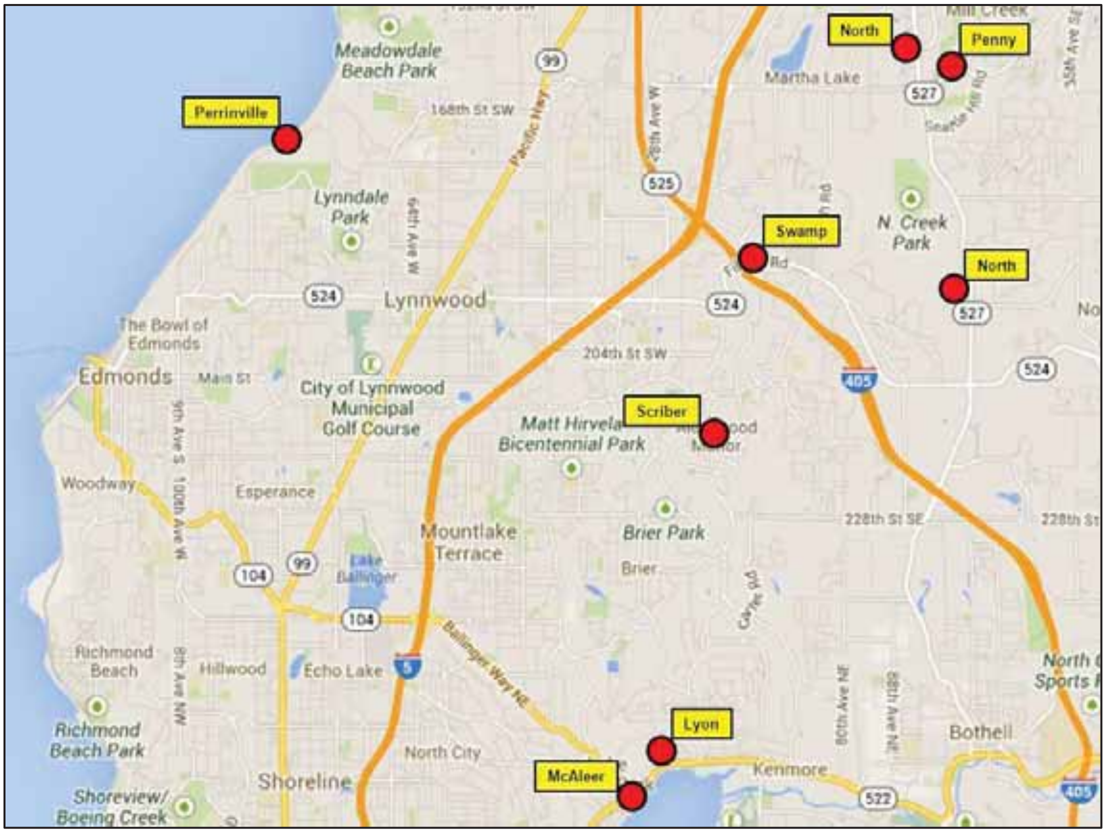


Figure 2-1. Location of gages examined.

Table 2-1. Stream gages examined.

Stream	Area (mi^2)	Site ID		Period of Record
		USGS	County	
North Creek above Penny Creek	6.36		No	2/16/2001-11/6/2012 (SnoCo)
Penny Creek	3.67	12125800	Pe	10/1/1984 - 9/30/1986 (USGS) 2/23/2001 - 3/15/2007 (SnoCo)
North Creek below Penny Creek	14.2	12125900	Nr	10/1/1984 - 9/30/1986 (USGS) 4/24/2001 - 8/2/2011 (SnoCo)
Tambark Creek	4.20	12125950	Tc	10/1/1984 - 9/30/1986 (USGS) 1/12/2000 - 10/20/2000 (SnoCo)
Swamp Creek at I-405	9.55	12126800	Sc	10/1/1984 - 9/30/1986 (USGS) 8/10/1988 - 12/11/2012 (SnoCo)
Scriber Creek	6.14	12126900	So	10/1/1984 - 3/24/1987 (USGS) 2/12/2001 - 12/11/2012 (SnoCo)
Lyon Creek	3.67	12127300	34a **	9/1/1963 - 9/30/1968 (USGS) 10/1/1991 - 4/2/2013 (KingCo **)
McAleer Creek	7.80	12127600	33c **	9/1/1963 - 10/3/1972 (USGS) 3/30/2001 - 10/8/2013 (KingCo **)

2.1 Flow Metrics

Key flow metrics include average annual flow, the distribution of the flow (e.g., base versus surface runoff), flow duration, T_{Qmean} (the fraction of the time that daily average flow is greater than annual average flow), and the R-B flashiness index (flow oscillations relative to total flow based on daily average discharge). Basic annual flow metrics are summarized in Table 2-2, both as unit area discharge (cfs per square mile) and as runoff volume (inches per year). Flow duration curves are another effective method to characterize hydrologic conditions and are an important component of the overall hydrologic analysis. Duration curves provide a quantitative summary that represents the full range of flow conditions, including both magnitude and frequency of occurrence. Figure 2-2 depicts flow duration curves for Scriber, North, Swamp, Lyons, Penny, and McAleer Creeks. These curves are expressed as unit area flows (i.e., cfs / square mile) for direct comparison between sites.

Table 2-2 and Figure 2-2 provide insights, both on the utility of certain flow metrics and on local watershed characteristics. Total runoff, for example, often represents a starting point to understand key hydrologic processes in any given drainage. Watershed specific differences often reflect factors such as watershed impervious cover, as well as the influence of groundwater, wetlands, lakes, and existing stormwater infrastructure (including by-passes). The percentage of total runoff, which is either base flow or surface runoff, is another metric that can be used to evaluate the potential effect of stormwater in a watershed.

Table 2-2. Comparison of runoff characteristics between gages examined.

Location	Area ($mi.^2$)	Gage ID	Average Annual Flow ($cfs/mi.^2$)	Annual Runoff		
				Total (in.)	Base (%)	Surface (%)
North Creek above Penny Creek	6.36	No	1.606	21.8	63%	37%
Penny Creek	3.67	12125800	1.430	19.4	89%	11%
		Pe	1.619	22.0	85%	15%
North Creek below Penny Creek	14.2	12125900	1.387	18.8	80%	20%
		Nr	1.597	21.7	74%	26%
Tambark Creek	4.20	12125950	0.891	12.1	68%	32%
		Tc	Staff only	---	---	---
Swamp Creek at I-405	9.55	12126800	1.117	15.2	72%	28%
		Sc	1.463	19.9	69%	31%
Scriber Creek	6.14	12126900	1.792	24.3	52%	48%
		So	1.527	20.7	57%	43%
Lyon Creek	3.67	12127300	1.717	23.3	73%	27%
		34a	1.272	17.3	70%	30%
McAleer Creek	7.80	12127600	1.897	25.8	88%	12%
		35c	1.683	22.8	86%	14%

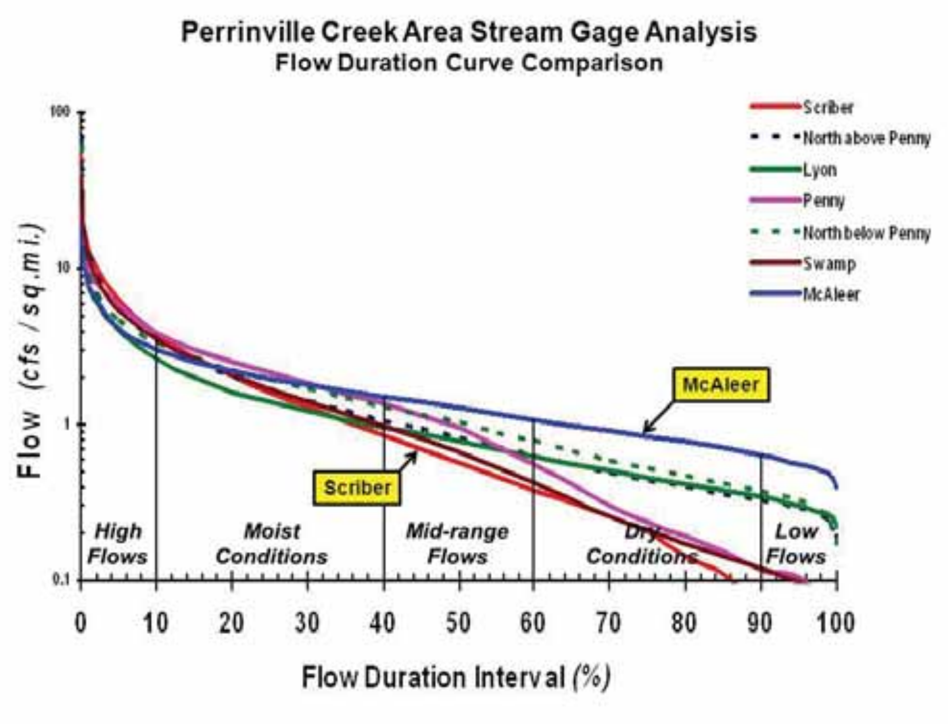


Figure 2-2. Flow duration curves for gages examined.

In addition to total runoff and percentage of base or surface flow, two other metrics (T_{Qmean} and Richards – Baker Flashiness Index) can help examine the effect of stormwater on urban streams (Table 2-3). These indicators have been used in studies that focused on evaluating regional patterns and trends in flow flashiness related to changes in land cover / land use (Konrad and Booth, 2002; Baker, et al., 2004).

T_{Qmean} represents the percentage of time that daily average flows exceed the annual average flow. A higher value represents hydrologic conditions that are closer to being normally distributed (generally, an indication of stable flow regimes). Conversely, lower T_{Qmean} values are typically associated with watersheds that may subjected to rapid changes. T_{Qmean} has been used to detect trends in flow flashiness related to basin urbanization in the Puget Lowland (Konrad and Booth, 2002). R-B Flashiness is an indicator of the frequency and rapidity of short-term changes in stream flow. The R-B Index is typically increases as watershed impervious cover becomes greater.

Clearly, there is significant variation in these metrics for the seven stations listed in Table 2-2 and Table 2-3. Reasons behind these differences, also apparent in the flow duration curves (Figure 2-2), should be considered in the model validation process. For example, the flow duration curve for McAleer Creek is strongly influenced by base flows from Lake Ballinger. The primary goal of this project is to mitigate flooding risk in Perrinville Creek by reducing stormwater runoff. Based on the hydrologic characteristics analysis, Scriber Creek appears to be the site examined that is most influenced by stormwater runoff. It has the greatest percentage of surface runoff relative to total flow and the highest R-B Index value. Furthermore, the headwaters of Scriber Creek are adjacent to Perrinville Creek, providing the added benefit of watershed proximity.

Table 2-3. Comparison of flow metrics for gages examined.

Location	Area ($mi.^2$)	Gage ID	Flow ($cfs/mi.^2$)			Metric Comparison	
			Median	*Average*	*1-day Max.*	T_{Qmean}	*R-B Flashiness*
North Creek abv Penny	6.36	No	0.810	1.606	18.5	*26.2*	*0.510*
Penny Creek	3.67	12125800	1.008	1.430	10.4	*37.8*	*0.135*
		Pe	0.960	1.619	14.5	*33.9*	*0.184*
North Creek blw Penny	14.2	12125900	0.986	1.387	10.0	*32.3*	*0.258*
		Nr	1.015	1.597	12.7	*31.7*	*0.332*
Tambark Creek	4.20	12125950	0.405	0.891	10.0	*28.1*	*0.418*
Swamp Creek at I-405	9.55	12126800	0.618	1.117	12.9	*29.2*	*0.323*
		Sc	0.673	1.463	18.0	*28.9*	*0.365*
Scriber Creek	6.14	12126900	0.782	1.792	25.3	*23.2*	*0.602*
		So	0.564	1.527	18.3	*26.6*	*0.566*
Lyon Creek	3.67	12127300	1.144	1.717	14.6	*29.2*	*0.364*
		34a	0.782	1.272	11.7	*28.3*	*0.418*
McAleer Creek	7.80	12127600	1.410	1.897	9.3	*35.4*	*0.142*
		35c	1.282	1.683	10.4	*33.5*	*0.168*

2.2 Perrinville Flow Data

The City of Edmonds installed a water level recorder on Perrinville Creek at Talbot Road in late 2012. This recorder operated from November 2012 through August 2013 when it was dislodged by high flows resulting from an intense rain event (Note: the recorder was also not operating due to vandalism during the period12/22/2012 – 1/24/2013). Several flow measurements were made at the time of probe deployment and during the periods of operation *(Table 2-4 and Figure 2-3)*.

City staff used this information to develop a quick rating curve by examining both linear and power relationships. City staff recognized the limitations associated with flow measurements that were only taken at the lower end of observed probe depths. However, the linear relationship depicted in Figure 2-3 resulted in a slightly higher correlation coefficient and was used to provide rough flow estimates for screening analysis purposes.

The Scriber Creek gage and the Perrinville Creek water level probe were operating concurrently from November 7 through December 11, 2012. Figure 2-4 compares Scriber Creek flows to Perrinville Creek flow estimates (based on the linear relationship) during this time frame. Precipitation data collected at the Alderwood Water District office in Lynnwood is also shown in Figure 2-4 to provide an indication of stream flow response to rain events.

Table 2-4. Measurements used to develop rating curve for Perrinville Creek at Talbot Road.

Site	Area (mi^2)	Date	Staff Gage (ft)	Probe Depth (ft)	Discharge (cfs)
Perrinville Creek at Talbot Road	1.23	11/7/2012	0.60 [1]	0.588 [1]	1.044
		1/25/2013	0.52 [2]	0.365 [2]	1.547
		2/5/2013	0.57	0.388	2.107
		3/20/2013	0.81	0.597	5.758
		3/26/2013	0.55	0.380	1.388
		4/10/2013	0.71	0.509	3.150
		6/20/2013	0.75	0.467	4.825

Notes: [1] First probe operation (11/7 – 12/21/2012). Probe depths for first period adjusted for comparison to second period based on staff gage readings at time of probe deployment.
[2] Second probe operation (1/25 – 8/29/2013).

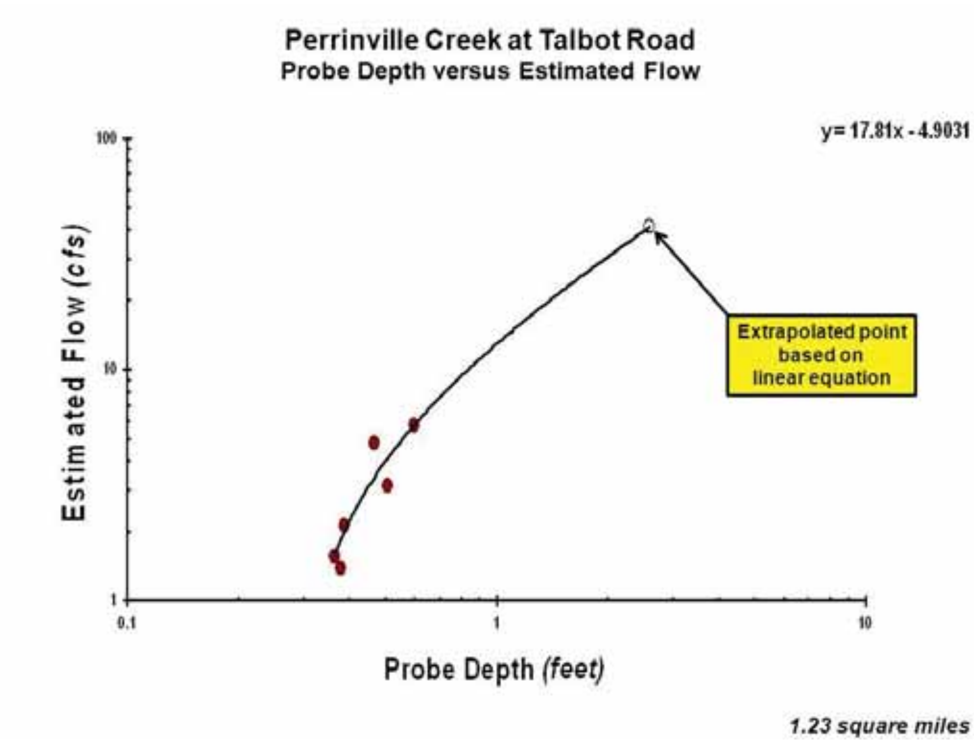


Figure 2-3. Probe depth – estimated flow relationship -- *Perrinville Creek at Talbot Road*.

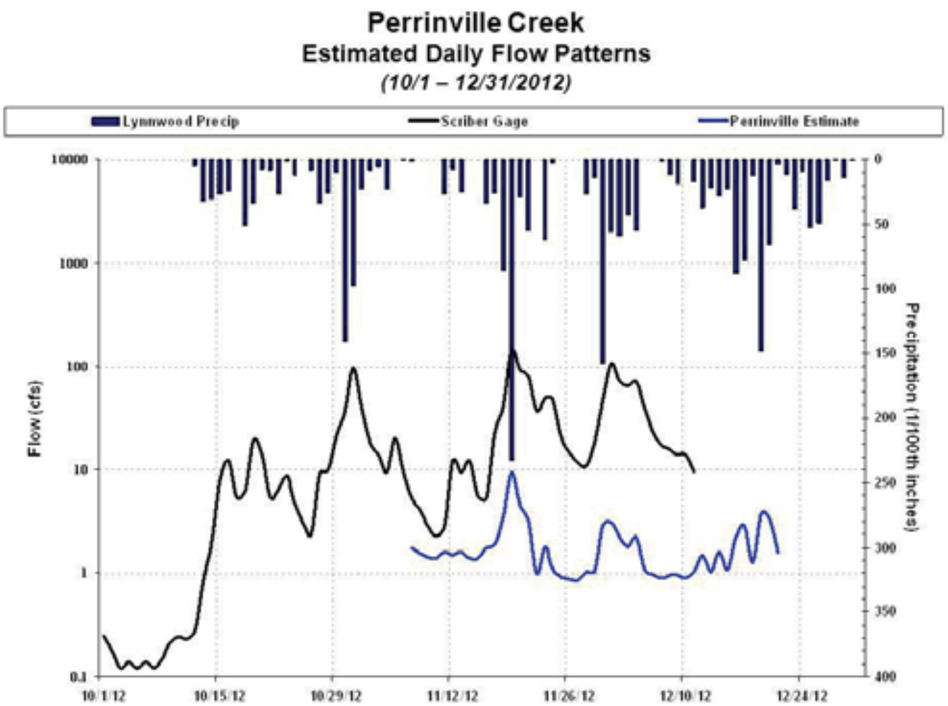


Figure 2-4. Comparison of Scriber Creek discharge to estimated Perrinville Creek flow.

3. Hydrologic Model Data Analysis

The limited analysis comparing stream discharge in Scriber Creek to cursory Perrinville Creek flow estimates indicates that both sites appear to exhibit similar response patterns to rainfall events *(Figure 2-4)*. The next part of this hydrologic assessment involves an analysis of preliminary model results relative to Scriber Creek flow data. This analysis is part of the validation process to ensure that model results are representative of flow conditions observed in the Perrinville Creek area. Rainfall – runoff response patterns are first compared to the Scriber Creek gage. Figure 3-1 through Figure 3-4 show these patterns over the course of a sample one year period using 2008 data.

Patterns shown in these graphs indicate that the model response to precipitation events reasonably coincides with flows recorded at the Scriber Creek gage. One concern that arose during model development, however, is the amount of water in Perrinville Creek that represents base flow. This issue is best illustrated in Figure 3-3, i.e. the summer period. For purposes of this preliminary evaluation, 0.25 cfs was used, which represents the 75 percentile of unit area Scriber Creek flows.

Metrics important to target development are also examined including key duration curve and peak flow recurrence values. Water years 2002 through 2009 are the focus of this portion of the analysis, which represents the common period of available information. Runoff and flow metrics are summarized in Table 3-1 and Table 3-2, while duration curve comparisons are shown in Figure 3-5.

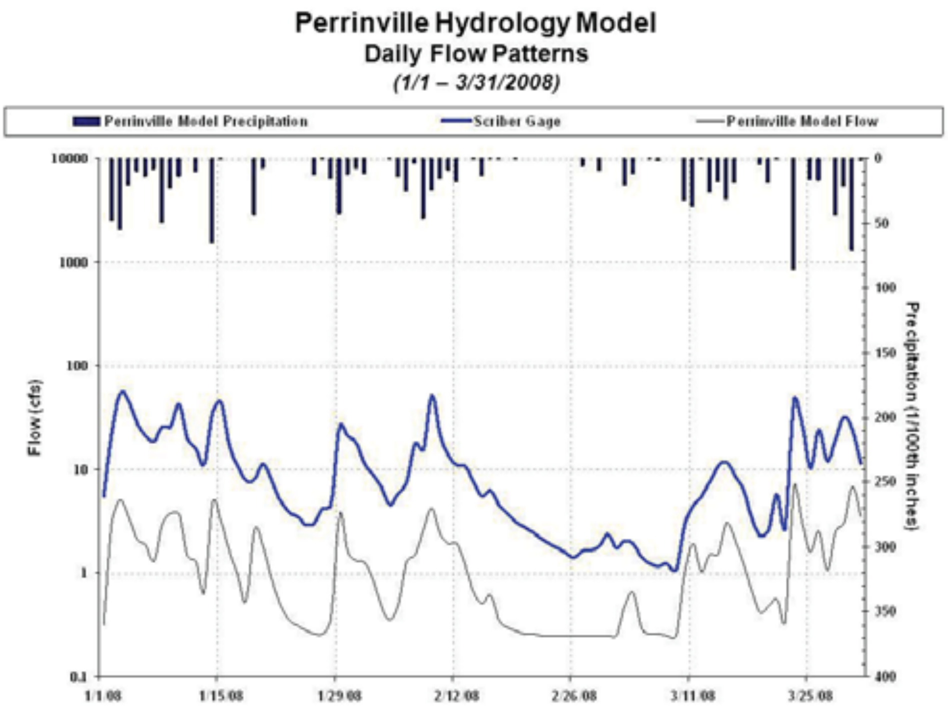


Figure 3-1. Comparison of Perrinville model flow to Scriber Creek discharge *(winter 2008)*.

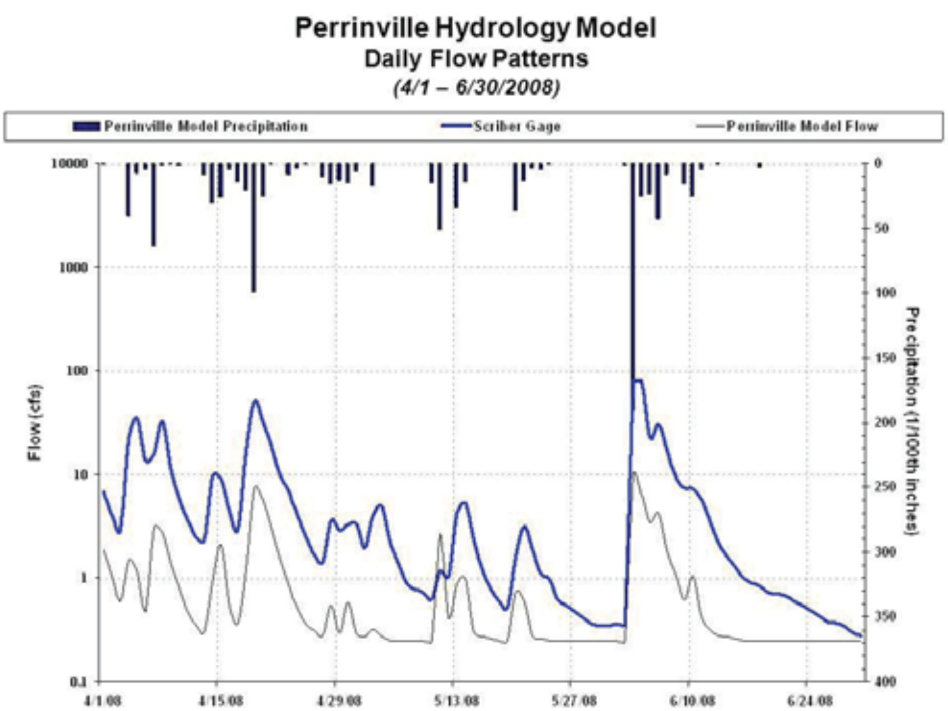


Figure 3-2. Comparison of Perrinville model flow to Scriber Creek discharge *(spring 2008)*.

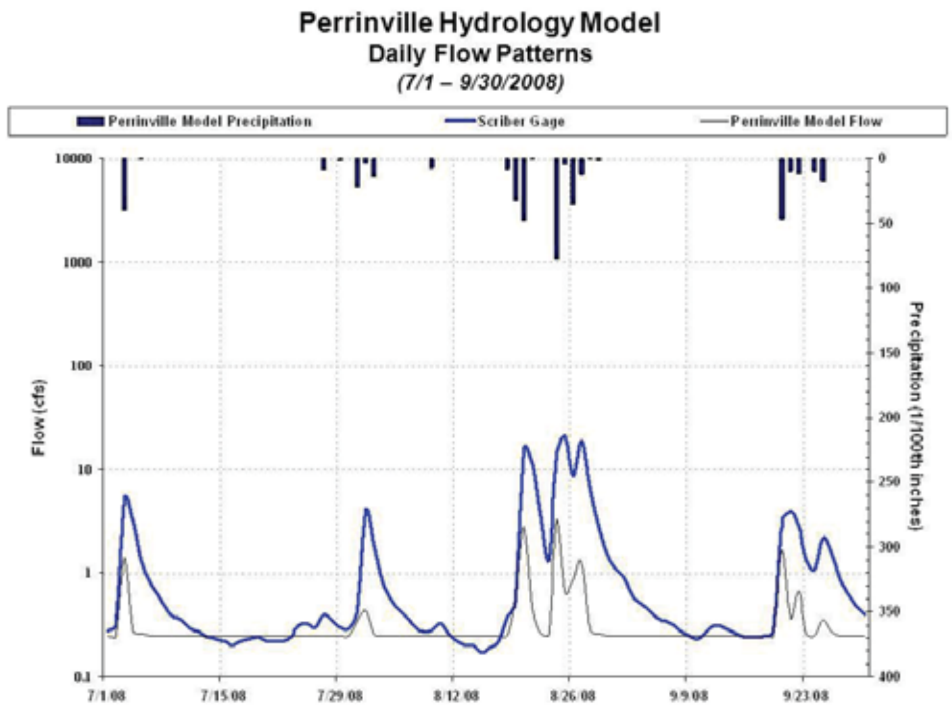


Figure 3-3. Comparison of Perrinville model flow to Scriber Creek discharge *(summer 2008)*.

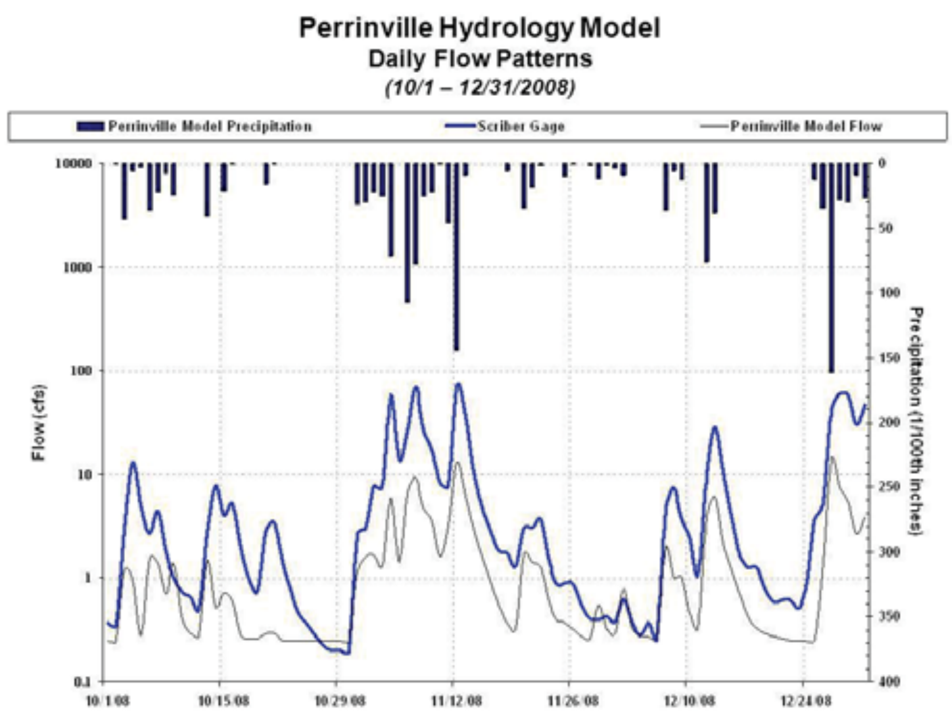


Figure 3-4. Comparison of Perrinville model flow to Scriber Creek discharge *(fall 2008)*.

Table 3-1. Hydrologic model runoff compared to Scriber Creek *(10/1/2001 – 9/30/2009)*.

Location	Area (mi.^{2})	Average Annual Flow (cfs/mi.^{2})	Annual Runoff		
			Total (in.)	Base (%)	Surface (%)
WWHM *(base flow: 0.25 cfs)*	1.23	0.952	12.9	*57%*	*43%*
WWHM *(base flow: 0.50 cfs)*		1.155	15.7	*64%*	*36%*
Scriber Creek	6.14	1.481	20.1	*57%*	*43%*

Table 3-2. Hydrologic model flow metrics compared to Scriber Creek *(10/1/2001 – 9/30/2009)*.

Location	Area (mi.^{2})	Flow (cfs/mi.^{2})			Metric Comparison	
		Median	Average	1-day Max.	T_{Qmean}	R-B Flashiness
WWHM *(base flow: 0.25 cfs)*	1.23	0.286	0.952	11.6	*24.4*	*0.620*
WWHM *(base flow: 0.50 cfs)*		0.436	1.155	11.8	*24.4*	*0.511*
Scriber Creek	6.14	0.552	1.481	18.4	*25.8*	*0.558*

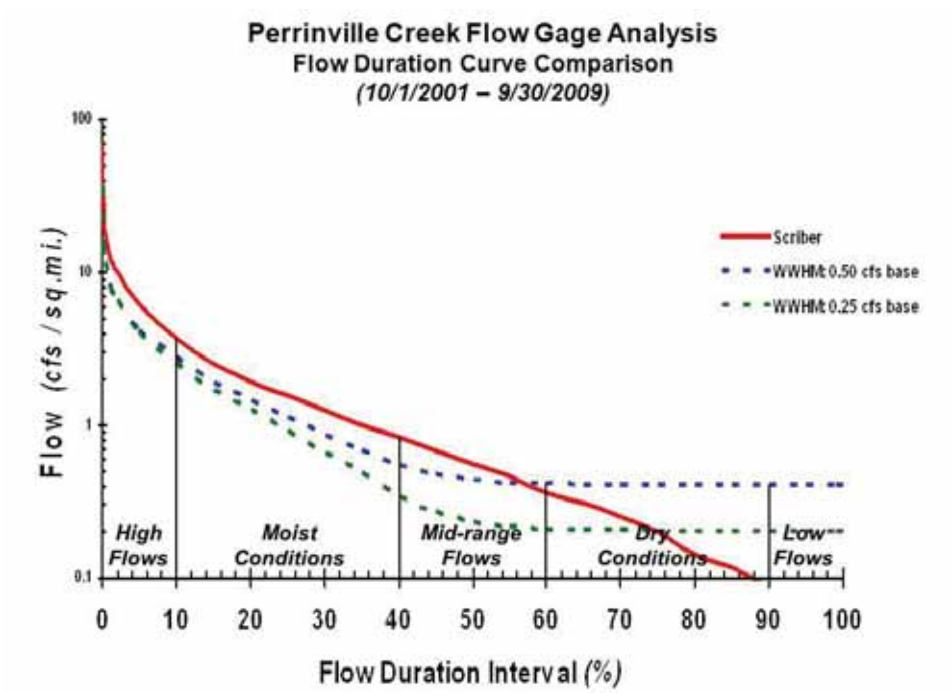


Figure 3-5. Flow duration curve comparison -- Perrinville hydrology model and Scriber Creek.

Another important hydrologic indicator is peak flows. Trends in peak flow history have been used as one method to document the potential effect of stormwater on urban streams *(Figure 3-6)*. This particular example, using data from the Mercer Creek gage, shows annual peak flows relative to a trend line based on the 10-year moving average. This type of analysis can help identify time periods of considerable change, which can often be correlated with urban development (i.e., increased impervious cover) or other watershed activities such as BMP implementation.

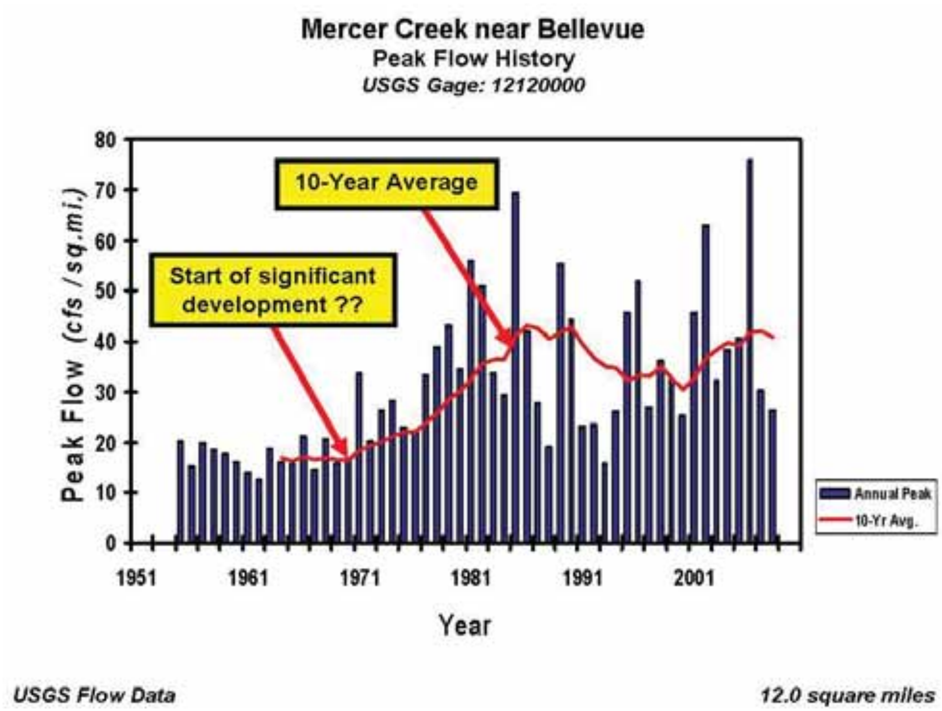


Figure 3-6. Peak flow history -- Mercer Creek.

With respect to Perrinville Creek, a key part of the modeling analysis is the identification of peak flow recurrence intervals; a critical consideration both for development of hydrologic targets and for establishing BMP design conditions. Important recurrence intervals include the 2-year peak (typically associated with the channel forming event and referenced in Ecology's stormwater permits for establishing flow control standards) and the 50-year peak (also referenced in Ecology's stormwater permit). These values are summarized in Table 3-3 and Figure 3-7.

Table 3-3. Perrinville hydrologic model peak flow summary *(WY 1949 – 2009)*.

Recurrence Interval	Peak Flow	
	(cfs)	*(cfs/mi.^{2})*
2-year	55.6	45.2
10-year	101.8	82.7
50-year	146.5	119.1

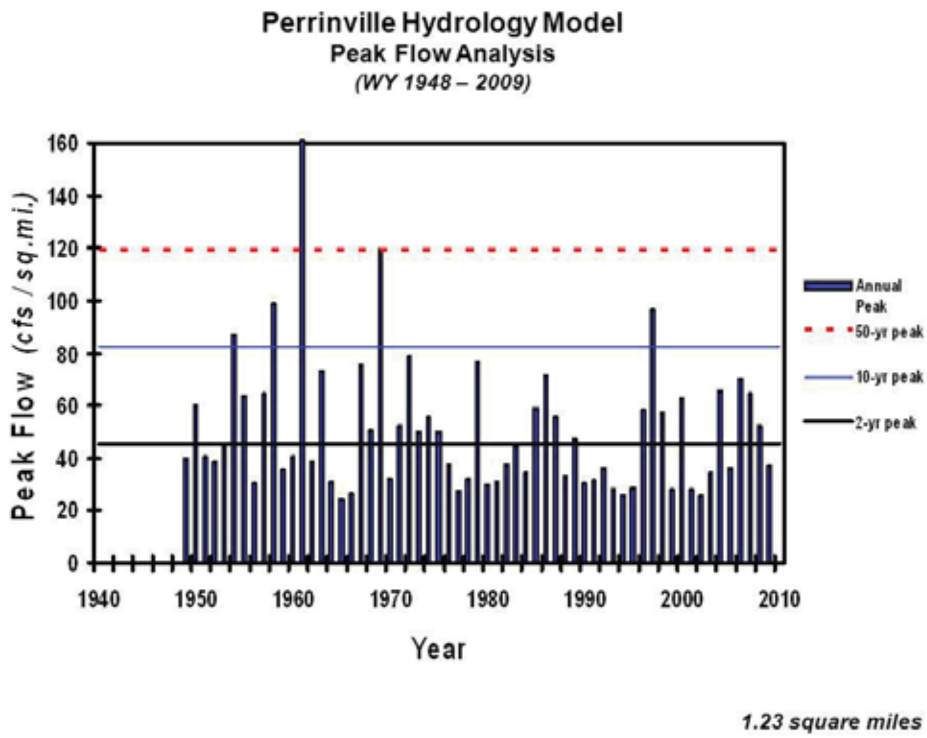


Figure 3-7. Perrinville hydrologic model peak flow summary *(WY 1949 – 2009)*.

4. References

Baker, D.B., R.P. Richards, T.T. Loftus, and J.W. Kramer. 2004. *A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams*. Journal of the American Water Resources Association (JAWRA) 40(2):503-522.

Konrad, C.P. and D.B. Booth. 2002. *Hydrologic Trends Associated With Urban Development for Selected Streams in the Puget Sound Basin, Western Washington*. U.S. Geological Survey Water-Resources Investigations Report 02-4040. Tacoma, WA.

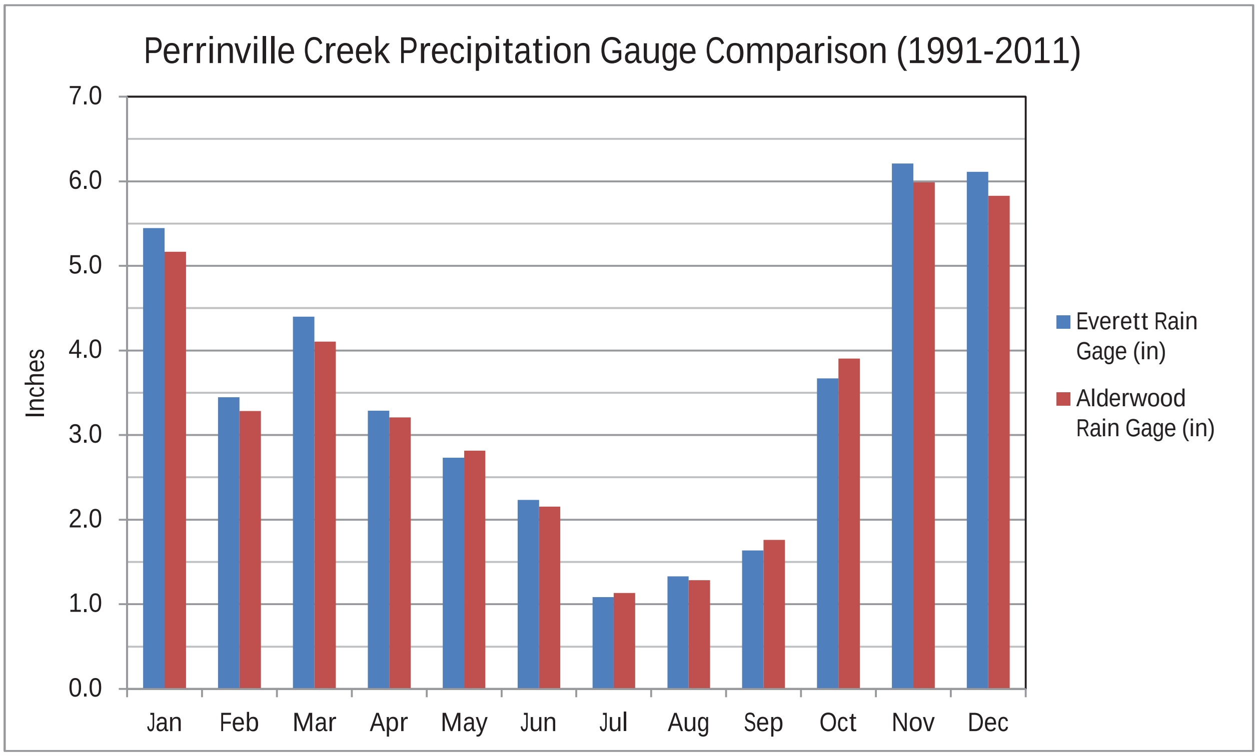
City Of Edmonds
Perrinville Creek Stormwater Flow Reduction Retrofit Study
Final Report

APPENDIX D. FLOW CALIBRATION DATA COLLECTION

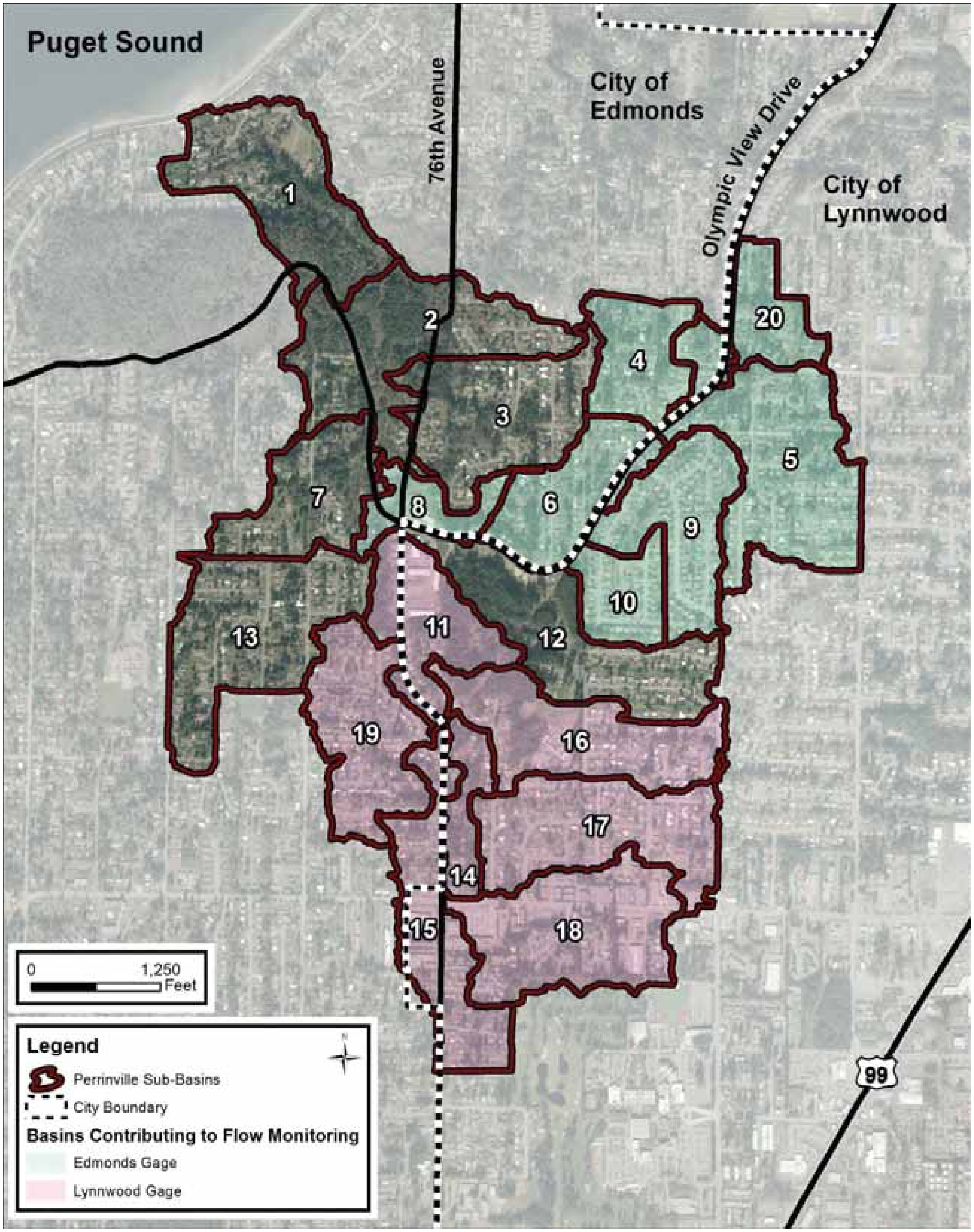
October 2014

Event	Begin Date	End Date	Antecedent Dry Period (hours)	Duration (hours)	Cumulative Event Rain (inches)	Cumulative Peak Volume (in)
1	11/02/13 11:15 AM	11/02/13 02:00 PM	59.3	2.8	0.97	0.51
2	11/07/13 03:45 AM	11/07/13 10:15 AM	31.3	6.5	0.66	0.47
3	11/19/13 01:15 AM	11/19/13 05:00 AM	75.3	3.8	0.73	0.25
4	01/11/14 10:45 AM	01/11/14 01:15 PM	42.0	2.5	1.34	0.33
5	01/28/14 09:45 PM	01/29/14 04:30 AM	391.7	6.8	1.05	0.68
6	02/16/14 04:30 PM	02/17/14 12:15 AM	22.2	7.7	1.02	0.98
7	03/04/14 04:45 AM	03/06/14 02:45 PM	18.7	58.0	2.44	2.38
8	03/08/14 11:45 AM	03/10/14 03:30 AM	45.0	39.7	1.83	1.77
9	03/15/14 04:30 PM	03/17/14 01:45 AM	26.5	33.2	1.71	1.68

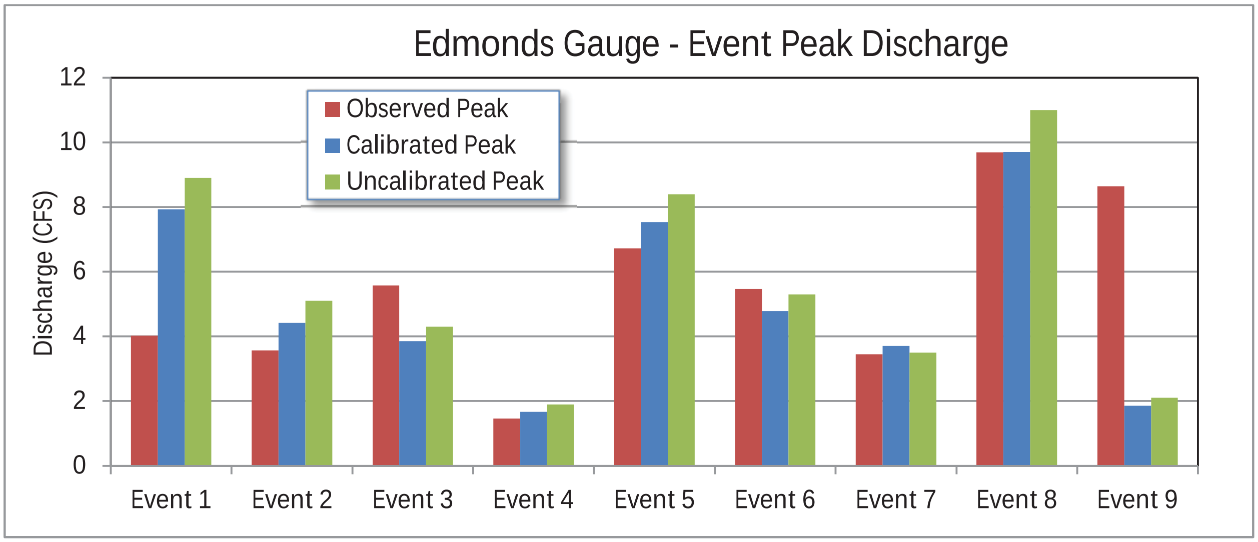
Rainfall events analyzed for WWHM calibration

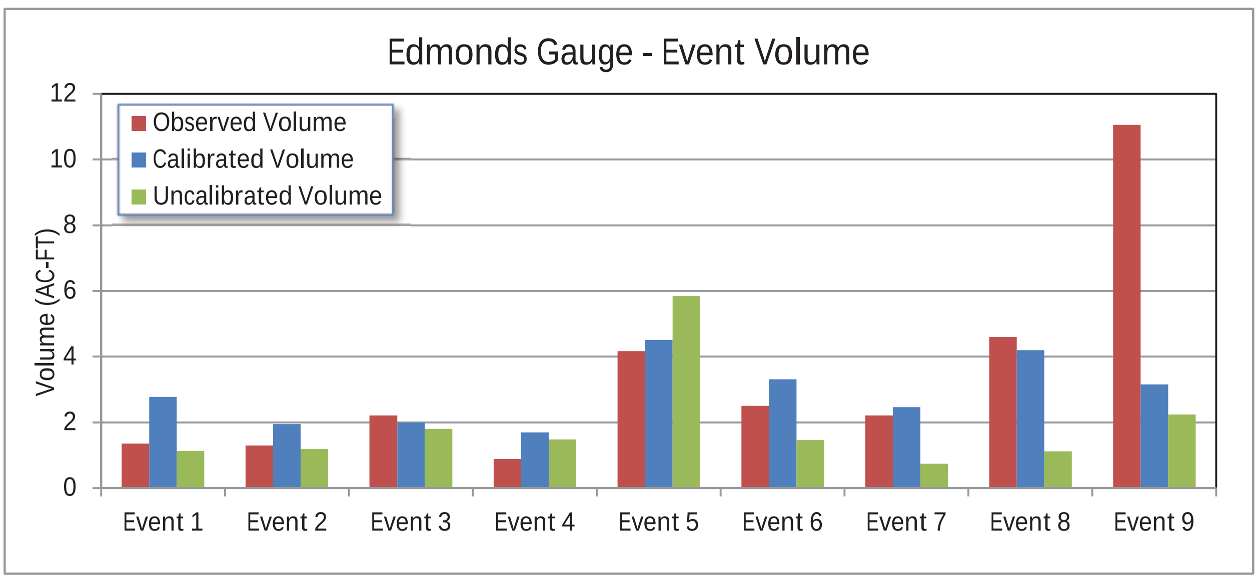


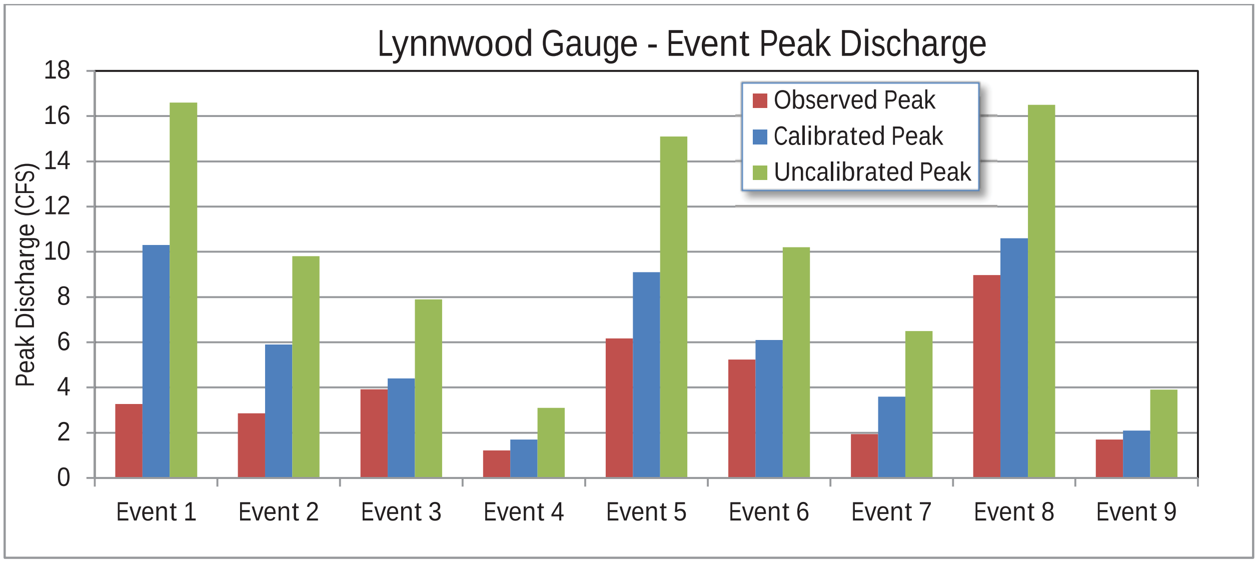
Comparison of long term WWHM Everett Rainfall (in) and Alderwood rainfall

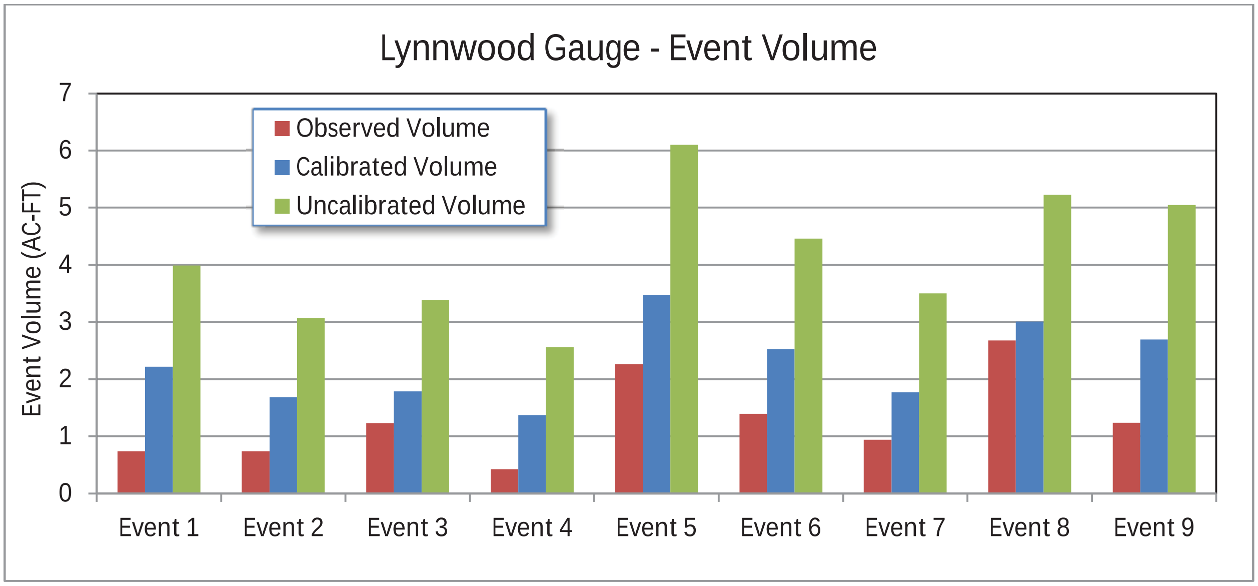


Subbasins Contributing to Independent Flow Monitoring Locations Used for WWHM calibration.


Edmonds Gauge - Event Peak Discharge
Observed Peak
Calibrated Peak
Uncalibrated Peak
Discharge (CFS)
0
2
4
6
8
10
12
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Event 7
Event 8
Event 9


Edmonds Gauge - Event Volume
Observed Volume
Calibrated Volume
Uncalibrated Volume
Volume (AC-FT)
0
2
4
6
8
10
12
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Event 7
Event 8
Event 9

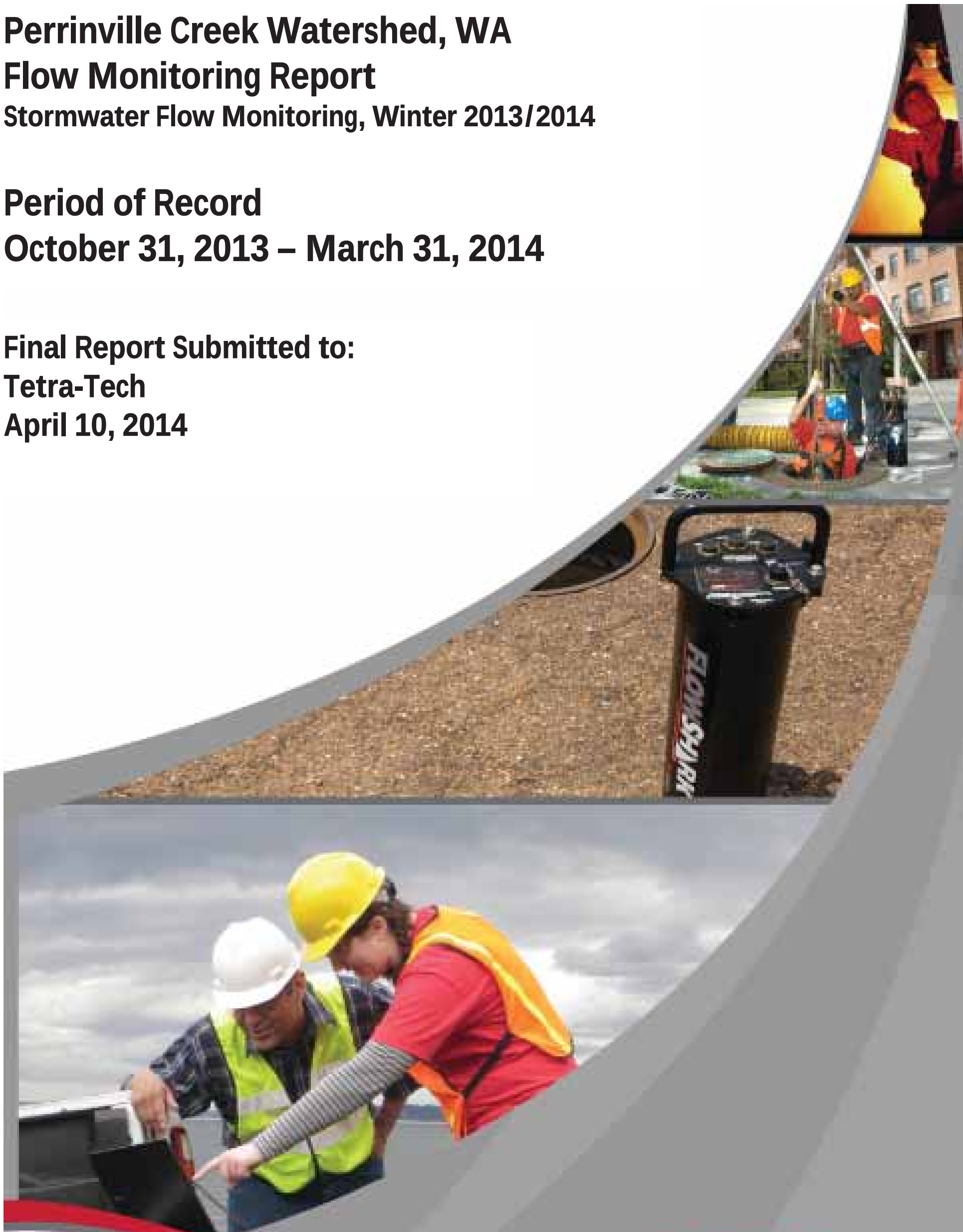

Lynnwood Gauge - Event Peak Discharge
Peak Discharge (CFS)
0
2
4
6
8
10
12
14
16
18
Observed Peak
Calibrated Peak
Uncalibrated Peak
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Event 7
Event 8
Event 9


Lynnwood Gauge - Event Volume
Event Volume (AC-FT)
0
1
2
3
4
5
6
7
Observed Volume
Calibrated Volume
Uncalibrated Volume
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Event 7
Event 8
Event 9

Perrinville Creek Watershed, WA
Flow Monitoring Report
Stormwater Flow Monitoring, Winter 2013/2014

Period of Record
October 31, 2013 – March 31, 2014

Final Report Submitted to:
Tetra-Tech
April 10, 2014



ADS ENVIRONMENTAL SERVICES®
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ADS LLC

4455 South 134th Place • Tukwila, WA 98168
Phone: 206.762.5070 • Fax: 206.762.5077
www.adsenv.com

April 10, 2014

Rick Schaefer
Tetra Tech Inc.
1420 Fifth Ave, Suite 550
Seattle, WA 98101
P: 206.389.4995
rick.schaefer@tetratech.com

Re: Perrinville Creek Stormwater Flow Reduction Retrofit Study Final Report

Dear Mr. Schaefer,

Thank you for the opportunity to complete this flow monitoring work effort in the Perrinville Creek watershed adjacent to Edmonds and Lynnwood WA.

Please find attached the electronic report containing the analysis and results for the data set collected in the City's storm sewer system from October 31, 2013 – March 31, 2014.

Rick, we certainly look forward to other opportunities to work with Tetra Tech on stormwater projects as they arise. If you have any questions regarding the content of this report, please do not hesitate to call Mike Pina at (206) 762 5070.

Sincerely,

Gillian Woodward P.E.
Senior Project Engineer
(206) 255-6904
ADS Environmental Services
gwoodward@idexcorp.com

Edmonds_5-212

Site Access

ADS ENVIRONMENTAL SERVICES®

Site access looking north

Edmonds_5-212

Site Setup

ADS ENVIRONMENTAL SERVICES®

View down MH facing north

Edmonds_5-212

Site Setup

ADS ENVIRONMENTAL SERVICES®

View of inlet and sensors placement

Edmonds_5-212

Site Setup

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View of outlet hydraulics

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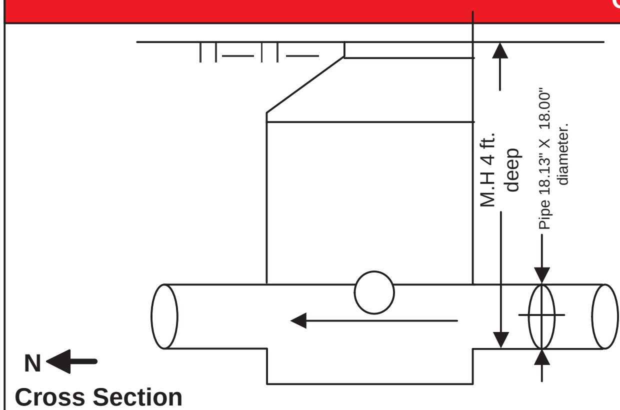
ADS Site Report — Quality Form

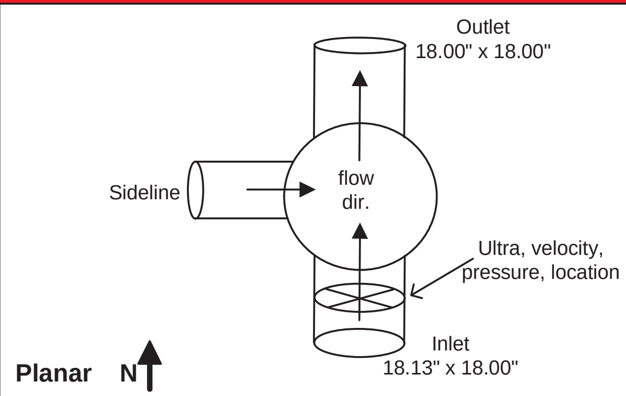
Project Name: Edmonds Storm Water 2013-14	**City / State:** Edmonds, WA	**FM Initials:** SW	
Site Name: Edmonds_5-212	**Monitor Series:** 5000 AG	**Monitor S/N:**	20085
Address/Location: Just North of Post Office (7601 Olympic View Dr) on 76th Ave W		**Manhole #**	5-212
		GPS	47°49'57.84"N,122°20'15.12"W
		Pipe Height:	18.13"
Access: Drive	**Type of System:** Sanitary [ ] Storm [X] Combined [ ]	**Pipe Width:**	18.00"
		IP Address:	166.219.168.145

Investigation Information: / Manhole Information:

Date/Time of Investigation:	10/30/13 @ 11:20	**Manhole Depth:**	4'
Site Hydraulics:	Clear low flow with ripples	**Manhole Material / Condition**	Concrete / Good
Upstream Input: (L/S, P/S)	Catch basin and storm drains	**Pipe Material / Condition:**	Concrete / Good
Upstream Manhole:	1 inlet / 1 outlet	**Mini System Character:**	Residential [X] Commercial [X] Industrial [ ] Trunk [ ]
Downstream Manhole:	2 inlets / 1 outlet (catch basin)	**Telephone Information:**	Does not apply
Depth of Flow:	1.25" +/- 0.25"	**Access Pole #:**	Does not apply
Range (Air DOF):	16.88"+/- 0.25"	**Distance From Manhole:**	Does not apply Feet
Peak Velocity:	0.50 fps	**Road Cut Length:**	Does not apply Feet
Silt:	0.00" Inches	**Trench Length:**	Does not apply Feet

Other Information:





Installation Information	Backup	Yes	No	?	Distance
Installation Type: Standard	Trunk	[ ]	[ ]	[ ]	
Sensors Devices: U, V, P	Lift / Pump Station	[ ]	[ ]	[ ]	
Surcharge Height: 3 Feet	WWTP	[ ]	[ ]	[ ]	
Rain Guage Zone: NA	Other	[ ]	[ ]	[X]	D/S storm outfall

Additional Site Information / Comments:

Flow Monitoring Site Safety Plan

Project Name: Edmonds Stormwater 2013-14 | **Site ID:** Edmonds_5-212 | **Site Classification:** (see below)

Note: Class 5 Site Safety Plans must be approved by the Corporate Safety Manager

*** Hazards found at this site (Discuss checked items below)**

Type	#	Special Hazard	
Communications	1	The site is in a communications "Dead-Zone"	☐
Traffic	2	The site is located in or adjacent to an intersection	☐
	3	The site is located on hill, curve, or where motorists visibility of the site or other vehicles is reduced	☐
	4	The site is located ina high speed (>45MPH) or high density roadway roadway	☐
	5	Site traffic is congested at peak hours	☐
Access	6	Site has access obstacles (rough terrain, fences, deep easement, etc.)	☐
Worksite	7	Worksite contains hazards (terrain, slope, obstructions, etc.)	☐
	8	Elevated work requiring a ladder / work near an unguarded edge. Raised manhole (indicate height below)	☐
	9	Pedestrian control necessary as the site is located in or near a walkway, school, playground, etc.	☐
	10	Work may be performed during darkness; requiring additional site lighting	☐
	11	Site is located in a high crime area (check with client & local authorities if unsure)	☐
Confined Space	12	Confined Space does not have useable rungs	☐
	13	Confined Space depth is greater than 50 feet	☐
	14	Confined Space has internal platforms, weirs or other obstructions that interfere with or prevent unobstructed vertical retrieval	☐
	15	Work requires lateral movement that would interfere with or prevent unobstructed vertical retrieval	☐
	16	Flow is hazardous due to depth, velocity, pipe diameter, or is industrial process flow	☐
	17	Confined Space subject to surcharge during / after a rain event	X
	18	CO, H2S, low O2 or other toxic / flammable gases present or anticipated	☐
	19	Confined Space has active drop connections	☐

*** Hazards found at this site (Discuss checked items below)**

Drain line is subject to surcharge contact Field Manager during or immediately after a rain event for permission to enter site

*** Site Classification**

	Class	Description
X	1	2-person crew. Standard procedures and equipment. No special requirements
☐	2	Worksite (non-traffic) with access obstacles and or worksite hazards
☐	3	Traffic site requiring special scheduling, additional personnel and / or traffic control equipment, or outsourcing
☐	4	Confined Space Entry requiring special scheduling, additional personnel and / or safety equipment
☐	5	Special Operation requiring a separate safety plan. *Must be approved by Corporate Safety Manager*

*** Site Specific Safety Requirements. Must Complete for any site Class 2 & Above**

No Site Specific Safety Requirements

Traffic Control Plan

Note: All worksites located in a roadway or immediately adjacent to a roadway, where the operation may impede the normal flow of traffic, are required to have a Traffic Control Plan. Standard Traffic Control Plans are to be carried in the vehicle and referred to when setting up the worksite. Special Traffic Control Plans are to be are to be developed when required by clients or regulating agencies or when a standard Traffic Control Plan is not sufficient to control traffic at the worksite.

☐ This worksite does NOT require a traffic control Plan

☐ Standard Traffic Control Plan is to be used at this work site

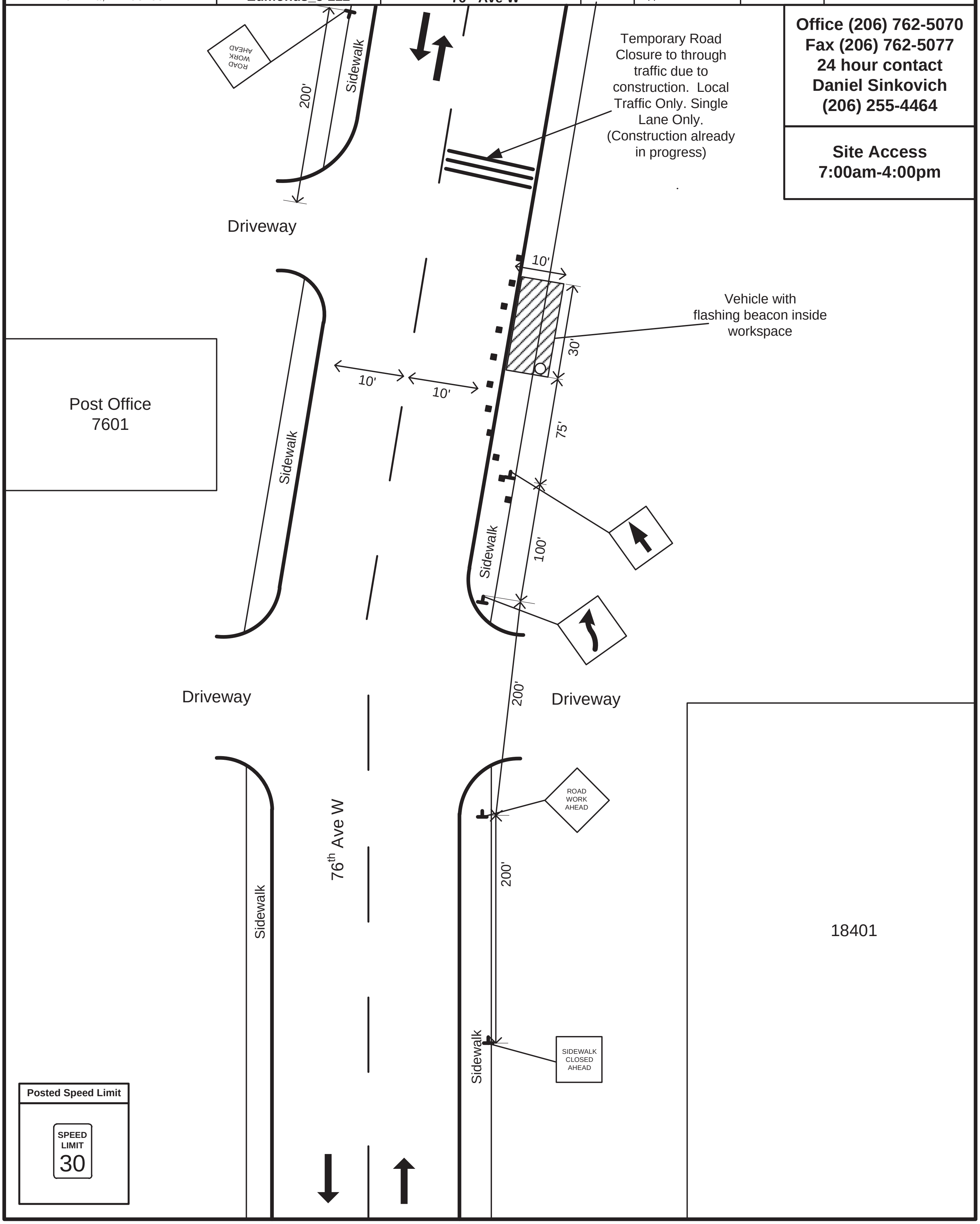
X This site requires a special Traffic Control Plan which is attached

Approved	**Reviewed**
Field Mgr Name: Sean Winder	Project Mgr Name: Mike Pina
Signature: Signed copy can be obtained from ADS	Signature: Signed copy can be obtained from ADS
Date: 10/10/13	Date: 10/10/13

ADS ENVIRONMENTAL SERVICES® 4455 South 134th Place Tukwila, WA 98168	Site Name: Edmonds_5-212 MH #: Edmonds_5-212	Address: Just North of Post Office (7601 Olympic View Dr) on 76th Ave W	N	Drawn: 10/22/13 Submitted: 10/22/13 Approved:	Rev. 0	Pg. 1 of 1 Not to Scale	Edmonds, WA Temporary Flow Monitoring

Office (206) 762-5070
Fax (206) 762-5077
24 hour contact
Daniel Sinkovich
(206) 255-4464

Site Access
7:00am-4:00pm



Edmonds_5-212

Monitoring Period: October 31, 2013 – March 31, 2014
Located At: See attached site report for details
Pipe Dimensions: 18.13" x 18.00"
Finalized Silt Level: 0"

Site Data Characteristics: This site is located in a stormwater pipe, and the equipment type was an ADS FlowShark. Based upon the quality and consistency of the observed flow depth and velocity data, the Continuity equation was used to calculate the flow rate for the monitoring period.

Analysis of Hydrograph: The hydrograph indicates a storm event dependent flow pattern.

Analysis of Scattergraph: The majority of the data are grouped above Fr=1 indicating supercritical flow however the low flow data do cross Fr=1 resulting in a slight hydraulic jump. No other unusual characteristics are noted.

Site Data Bias & Editing: The depth and velocity measurements recorded by the flow monitor were consistent with field confirmations conducted to date and supported the relative accuracy of the flow monitor at this location. The finalized depth data utilized the down looking ultrasonic sensor. For the finalized velocity data "drops" (outside the normal data set) were flagged.

Site Data Uptime: The raw and finalized data uptime achieved during the monitoring period is provided in the table below and this information is based on a 15-minute sample interval.

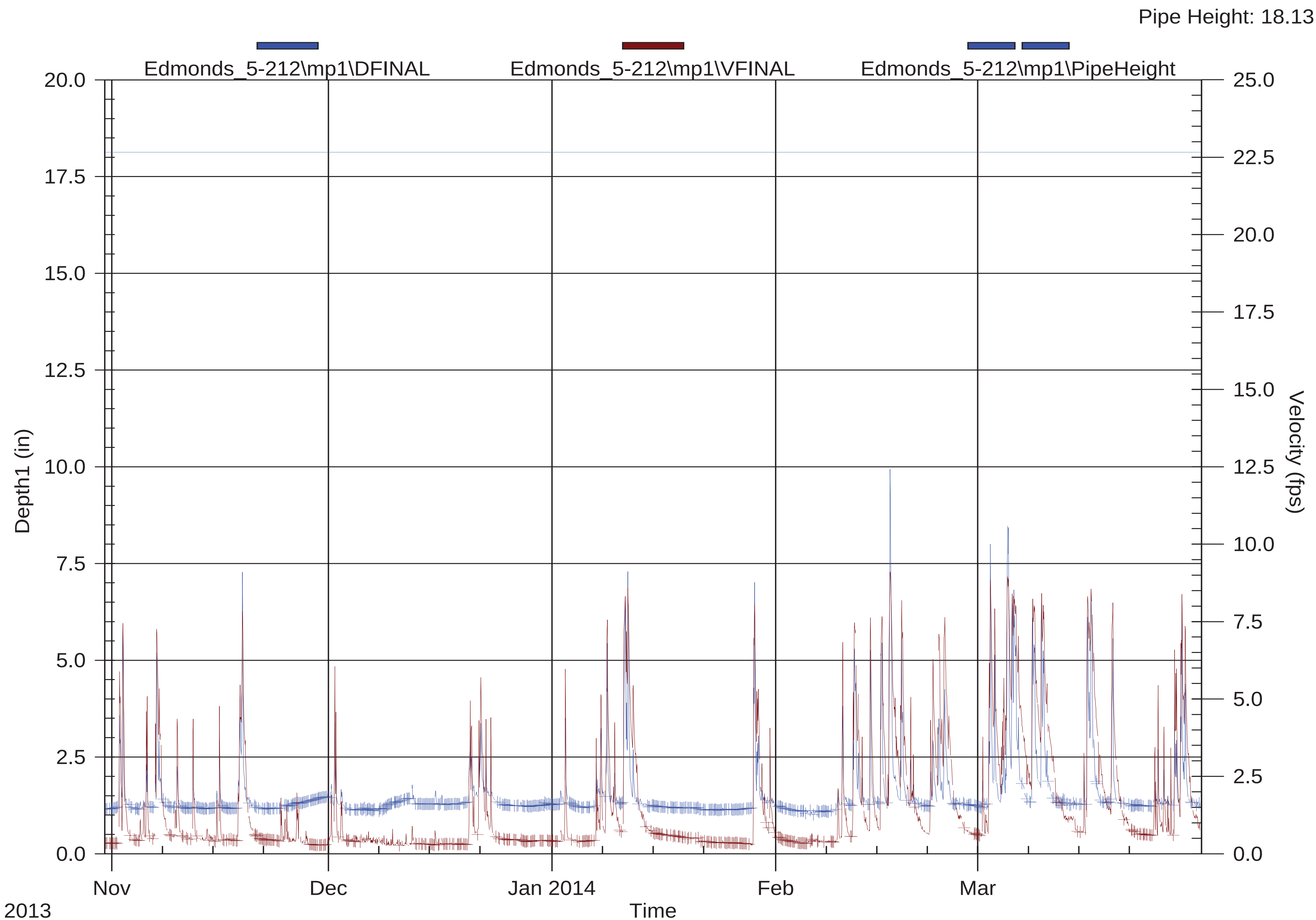
Entity	Percentage Uptime Raw	Percentage Uptime Final
Depth (in)	100.00%	100.00%
Velocity (ft/s)	100.00%	99.56%
Quantity (MGD)	100.00%	99.56%

Site Data Summary: The average flow depth, velocity, and quantity data observed during the monitoring period along with observed minimum and maximum data, are provided in the following table. The minimum and maximum rates recorded in the tables are based on a 15-minute data interval.

Item	Depth (in)	Velocity (ft/s)	Quantity (MGD)
Minimum	0.98	0.23	0.01
Maximum	10.37	9.23	6.26
Average	1.55	1.52	0.16

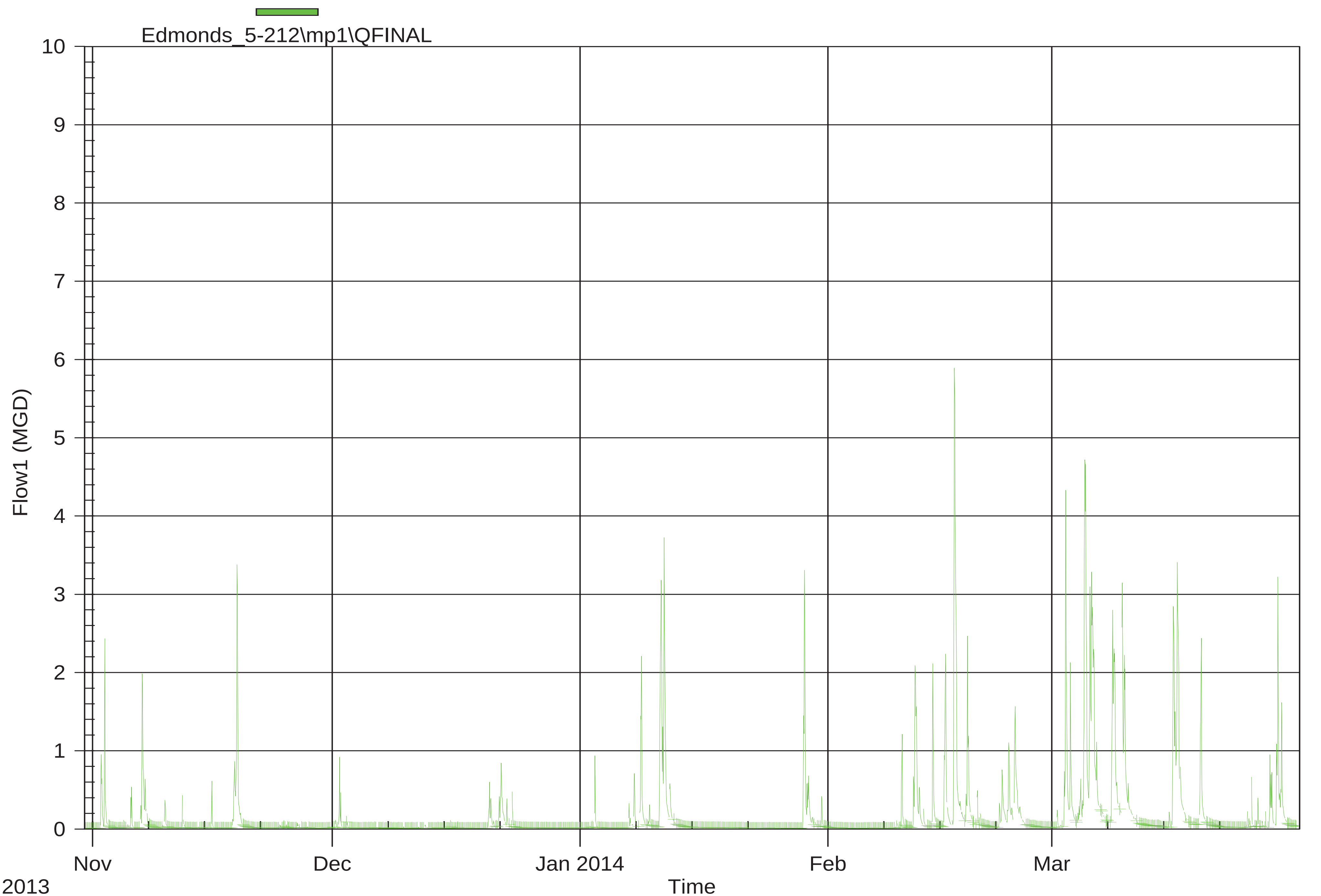
Hydrographs: The flow depth, velocity, and quantity data are plotted on the following hydrographs using an hourly average for ease of viewing.

ADS Environmental Services



ADS Environmental Services

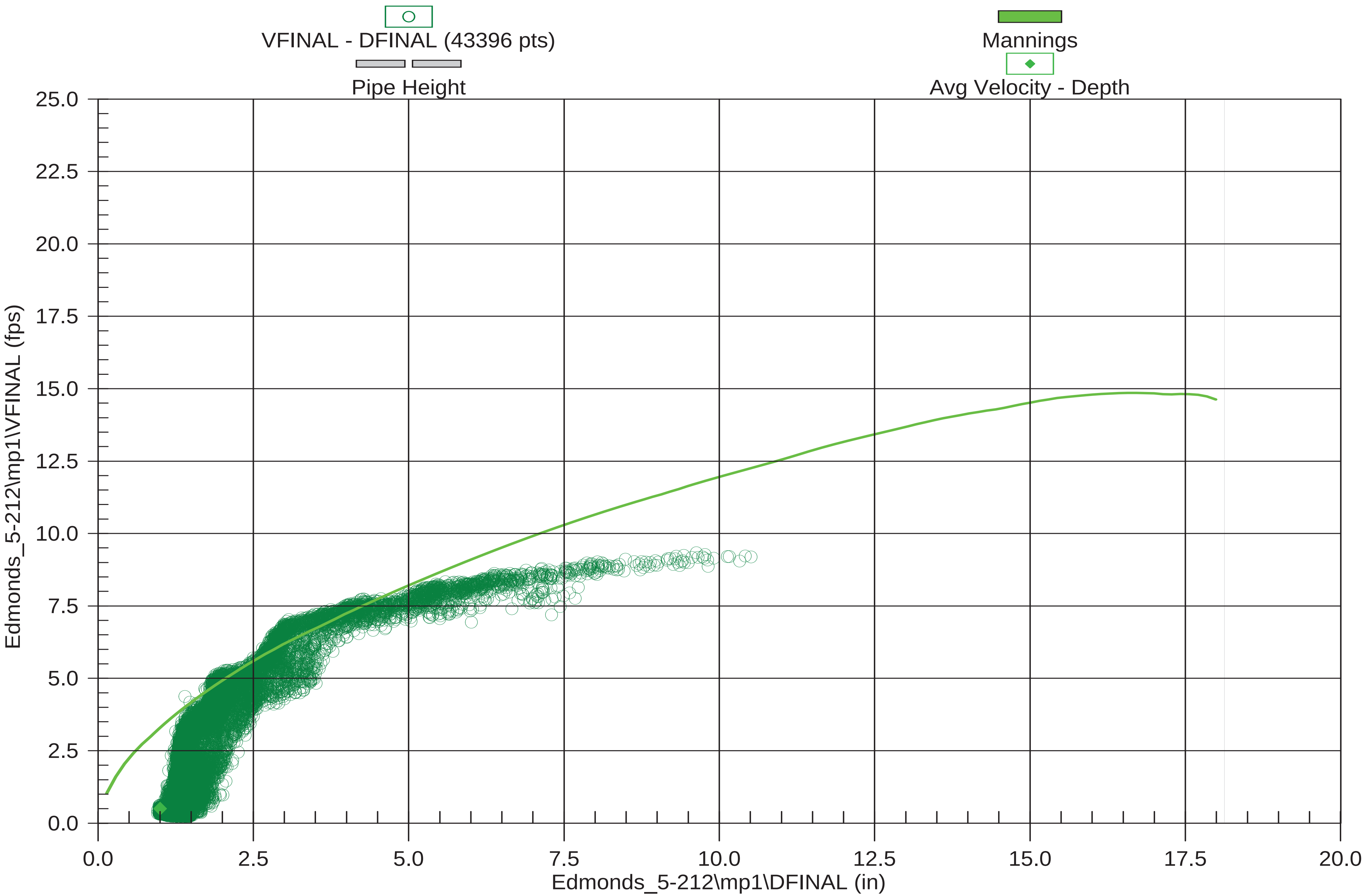
Pipe Height: 18.13



ADS Environmental Services

10/31/2013 12:00:00 AM - 3/31/2014 11:59:59 PM

Pipe Height: 18.13



Lynwood_10

Site Access

Site access looking north

Lynwood_10

Site Setup

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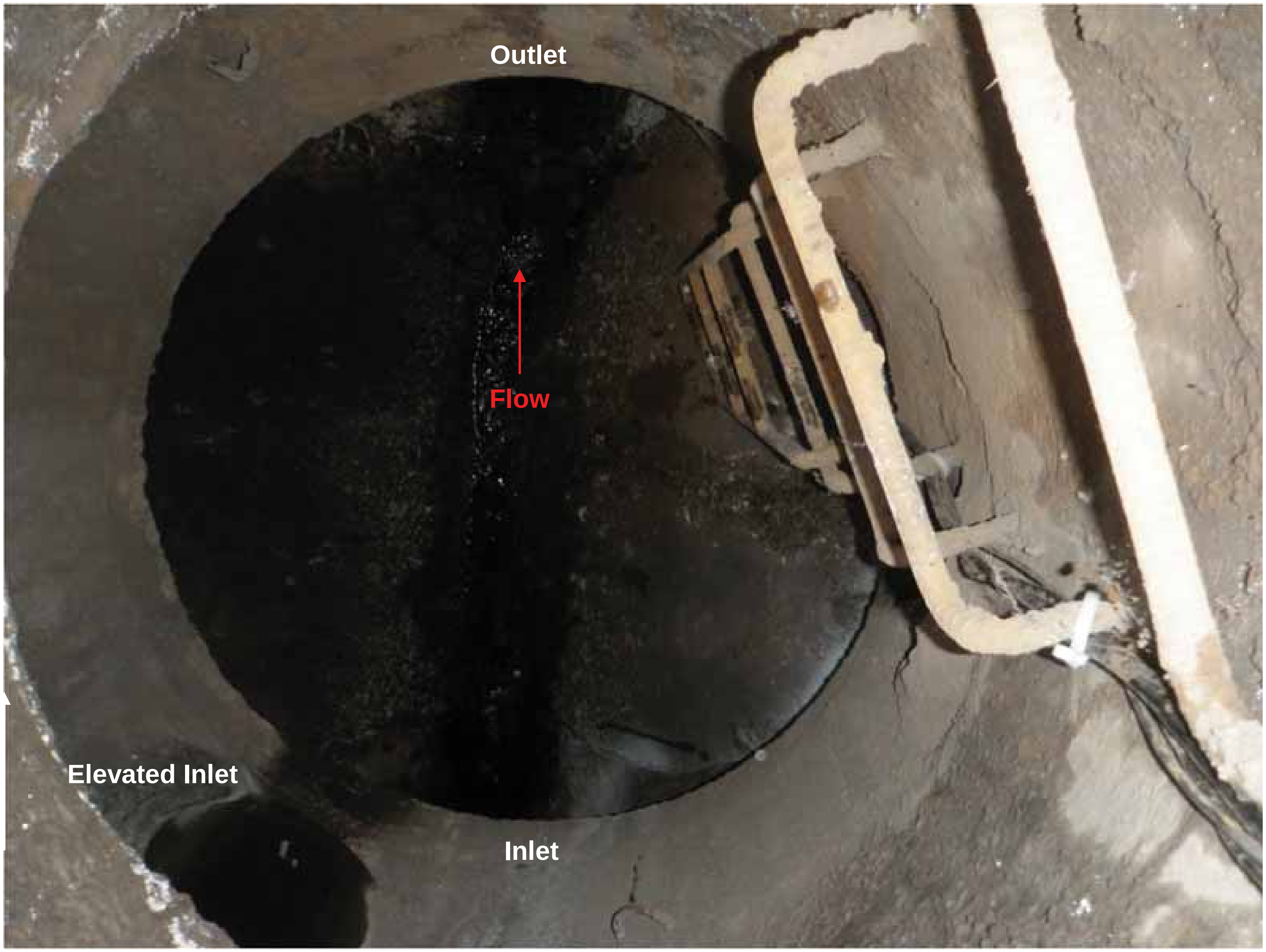


View down MH facing north

Lynwood_10

Site Setup

ADS ENVIRONMENTAL SERVICES®

View of inlet and sensors placement

Lynwood_10

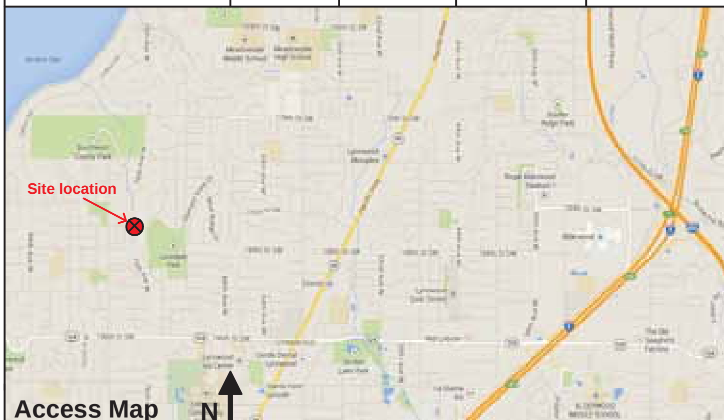
Site Setup

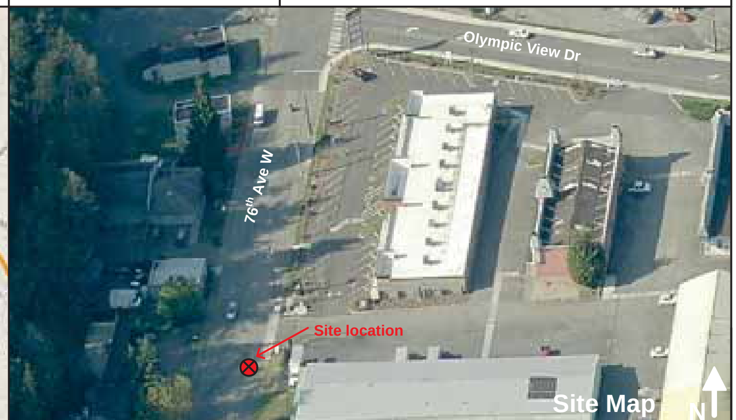
ADS ENVIRONMENTAL SERVICES®

View of outlet hydraulics

ADS Environmental Services — ADS Site Report — Quality Form

Project Name: Edmonds Storm Water 2013-14	**City / State:** Lynwood, WA		**FM Initials:** SW
Site Name: Lynwood_10	**Monitor Series:** 5000 AG	**Monitor S/N:**	20069
Address/Location: 18604 76th Ave W		**Manhole #**	10
		GPS	47°49'49.52"N,122°20'15.67"W
		Pipe Height:	35.38"
Access: Drive	**Type of System:** Sanitary [ ] Storm [X] Combined [ ]	**Pipe Width:**	35.38"
		IP Address:	166.219.49.181

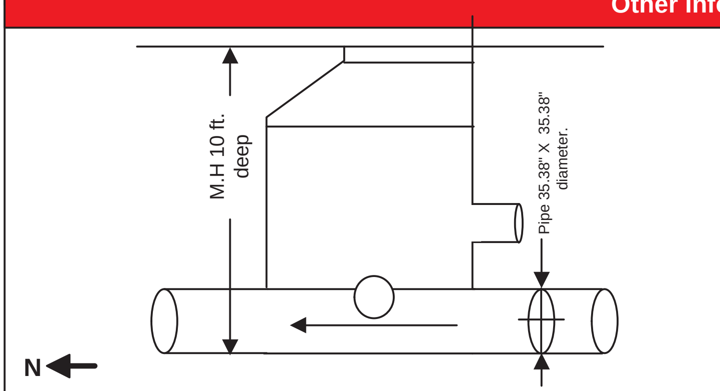




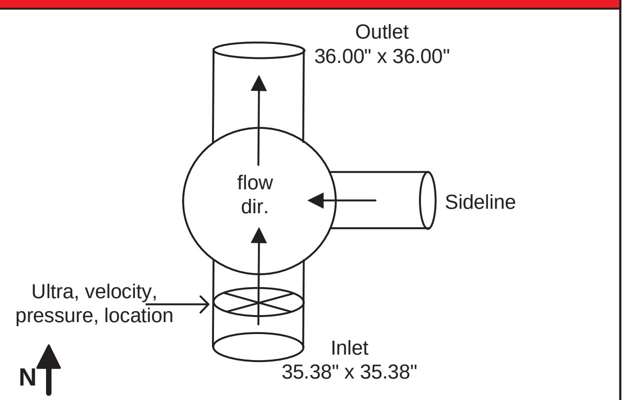
Investigation Information: / Manhole Information:

Date/Time of Investigation:	10/10/13 @ 12:30	**Manhole Depth:**	10'
Site Hydraulics:	Clear low flow with ripples	**Manhole Material / Condition**	Concrete / Good
Upstream Input: (L/S, P/S)	Catch basin and storm drains	**Pipe Material / Condition:**	Concrete / Good
Upstream Manhole:	1 inlet / 1 outlet	**Mini System Character:**	Residential [X] Commercial [X] Industrial [ ] Trunk [ ]
Downstream Manhole:	1 inlet / 1 outlet	**Telephone Information:**	Does not apply
Depth of Flow:	0.25" +/- 0.25"	**Access Pole #:**	Does not apply
Range (Air DOF):	35.13"+/- 0.25"	**Distance From Manhole:**	Does not apply Feet
Peak Velocity:	1.00 fps	**Road Cut Length:**	Does not apply Feet
Silt:	0.00" Inches	**Trench Length:**	Does not apply Feet

Other Information:



Cross Section



Planar

Installation Information	Backup	Yes	No	?	Distance
Installation Type: Standard	Trunk	[ ]	[ ]	[ ]	
Sensors Devices: U, V, P	Lift / Pump Station	[ ]	[ ]	[ ]	
Surcharge Height: 0 Feet	WWTP	[ ]	[ ]	[ ]	
Rain Guage Zone: NA	Other	[ ]	[ ]	[X]	D/S storm outfall

Additional Site Information / Comments:

ADS Site Report

Quality Form

Flow Monitoring Site Safety Plan

Project Name: Edmonds Stormwater 2013-14 **Site ID:** Lynwood_10 **Site Classification:** (see below)

Note: Class 5 Site Safety Plans must be approved by the Corporate Safety Manager

*** Hazards found at this site (Discuss checked items below)**

Type	#	Special Hazard	
Communications	1	The site is in a communications "Dead-Zone"	☐
Traffic	2	The site is located in or adjacent to an intersection	☐
	3	The site is located on hill, curve, or where motorists visibility of the site or other vehicles is reduced	☐
	4	The site is located ina high speed (>45MPH) or high density roadway roadway	☐
	5	Site traffic is congested at peak hours	☐
Access	6	Site has access obstacles (rough terrain, fences, deep easement, etc.)	☐
Worksite	7	Worksite contains hazards (terrain, slope, obstructions, etc.)	☐
	8	Elevated work requiring a ladder / work near an unguarded edge. Raised manhole (indicate height below)	☐
	9	Pedestrian control necessary as the site is located in or near a walkway, school, playground, etc.	☐
	10	Work may be performed during darkness; requiring additional site lighting	☐
	11	Site is located in a high crime area (check with client & local authorities if unsure)	☐
Confined Space	12	Confined Space does not have useable rungs	☐
	13	Confined Space depth is greater than 50 feet	☐
	14	Confined Space has internal platforms, weirs or other obstructions that interfere with or prevent unobstructed vertical retrieval	☐
	15	Work requires lateral movement that would interfere with or prevent unobstructed vertical retrieval	☐
	16	Flow is hazardous due to depth, velocity, pipe diameter, or is industrial process flow	☐
	17	Confined Space subject to surcharge during / after a rain event	X
	18	CO, H2S, low O2 or other toxic / flammable gases present or anticipated	☐
	19	Confined Space has active drop connections	☐

*** Hazards found at this site (Discuss checked items below)**

Drain line is subject to surcharge contact Field Manager during or immediately after a rain event for permission to enter site

*** Site Classification**

	Class	Description
X	1	2-person crew. Standard procedures and equipment. No special requirements
☐	2	Worksite (non-traffic) with access obstacles and or worksite hazards
☐	3	Traffic site requiring special scheduling, additional personnel and / or traffic control equipment, or outsourcing
☐	4	Confined Space Entry requiring special scheduling, additional personnel and / or safety equipment
☐	5	Special Operation requiring a separate safety plan. *Must be approved by Corporate Safety Manager*

*** Site Specific Safety Requirements. Must Complete for any site Class 2 & Above**

No Site Specific Safety Requirements

Traffic Control Plan

Note: All worksites located in a roadway or immediately adjacent to a roadway, where the operation may impede the normal flow of traffic, are required to have a Traffic Control Plan. Standard Traffic Control Plans are to be carried in the vehicle and referred to when setting up the worksite. Special Traffic Control Plans are to be are to be developed when required by clients or regulating agencies or when a standard Traffic Control Plan is not sufficient to control traffic at the worksite.

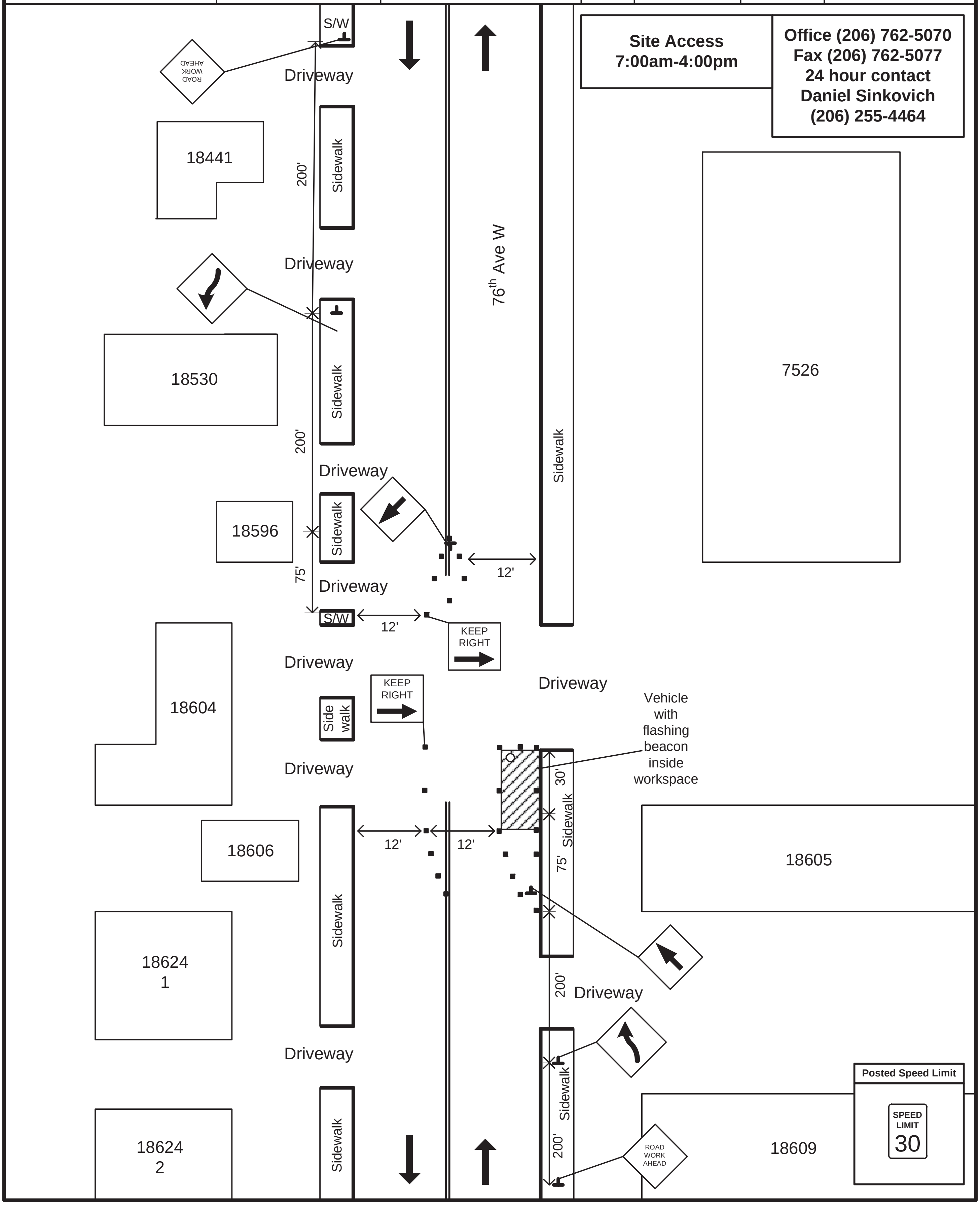
☐ This worksite does NOT require a traffic control Plan

☐ Standard Traffic Control Plan is to be used at this work site

X This site requires a special Traffic Control Plan which is attached

Approved	**Reviewed**
Field Mgr Name: Sean Winder	Project Mgr Name: Mike Pina
Signature: Signed copy can be obtained from ADS	Signature: Signed copy can be obtained from ADS
Date: 10/10/13	Date: 10/10/13

ADS ENVIRONMENTAL SERVICES® 4455 South 134th Place Tukwila, WA 98168	Site Name: Lynnwood_10 MH #: Lynnwood_10	Address: 18604 76th Ave W Lynnwood, WA	N	Drawn: 10/22/13	Rev. 0	Pg. 1 of 1	Edmonds, WA Temporary Flow Monitoring
				Submitted: 10/22/13	Not to Scale		
				Approved:			



Lynwood_10

Monitoring Period: October 31, 2013 – March 31, 2014
Located At: See attached site report for details
Pipe Dimensions: 35.38" x 35.38"
Finalized Silt Level: 0"

Site Data Characteristics: This site is located in a stormwater pipe, and the equipment type was an ADS FlowShark. Based upon the quality and consistency of the observed flow depth and velocity data, the Continuity equation was used to calculate the flow rate for the monitoring period.

Analysis of Hydrograph: The hydrograph indicates a storm event dependent flow pattern.

Analysis of Scattergraph: The majority of the data are grouped above Fr=1 indicating supercritical flow however the low flow data do cross Fr=1 resulting in a slight hydraulic jump. No other unusual characteristics are noted.

Site Data Bias & Editing: The depth and velocity measurements recorded by the flow monitor were consistent with field confirmations conducted to date and supported the relative accuracy of the flow monitor at this location. The finalized depth data utilized the downlooking ultrasonic sensor during normal flow conditions and the pressure sensor during surcharge conditions. Data points "drops and pops" (outside the normal data set) were flagged. For the finalized velocity data "drops" (outside the normal data set) were flagged.

Site Data Uptime: The raw and finalized data uptime achieved during the monitoring period is provided in the table below and this information is based on a 15-minute sample interval.

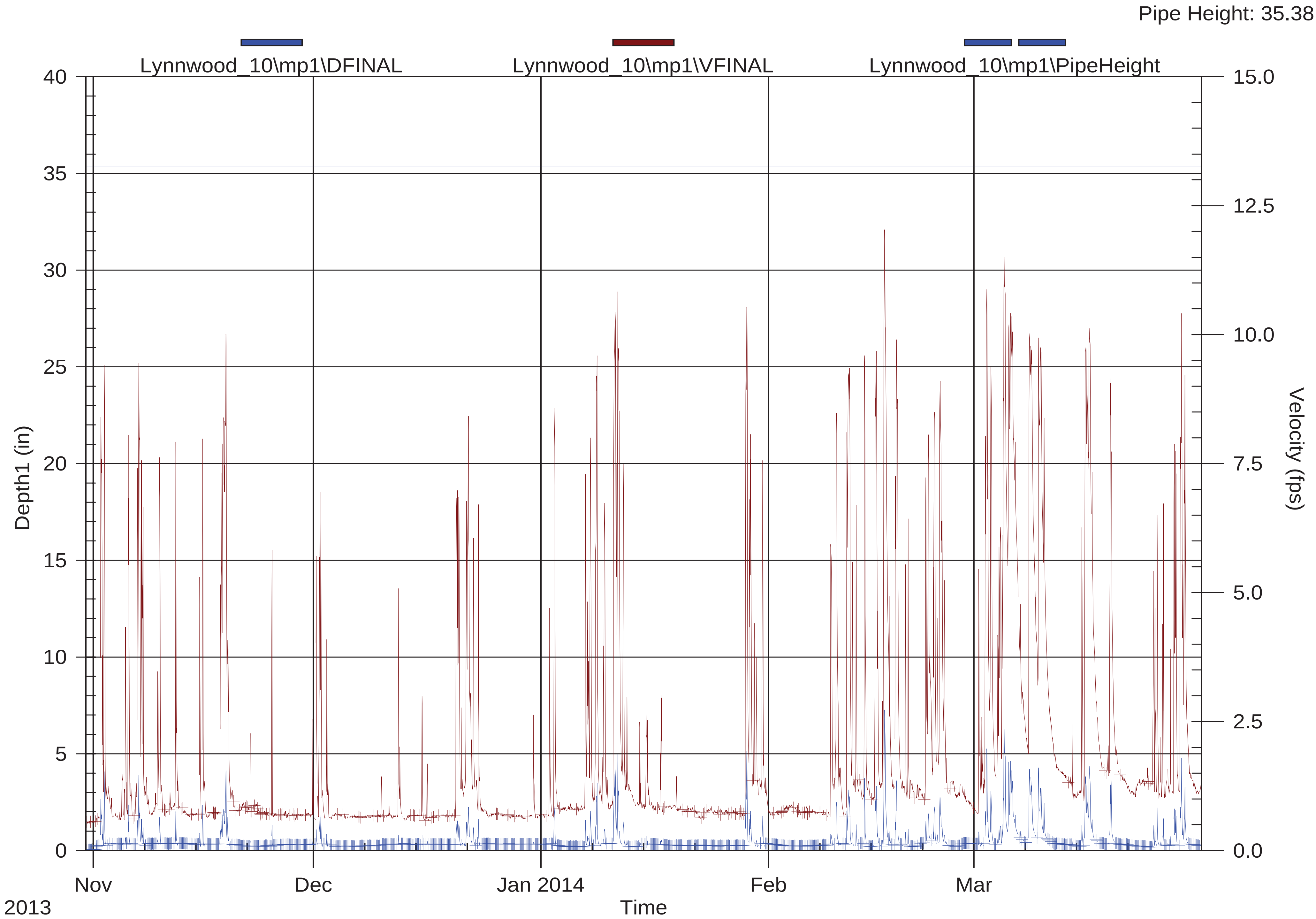
Entity	Percentage Uptime Raw	Percentage Uptime Final
Depth (in)	100.00%	99.97%
Velocity (ft/s)	100.00%	99.97%
Quantity (MGD)	100.00%	99.97%

Site Data Summary: The average flow depth, velocity, and quantity data observed during the monitoring period along with observed minimum and maximum data, are provided in the following table. The minimum and maximum rates recorded in the tables are based on a 15-minute data interval.

Item	Depth (in)	Velocity (ft/s)	Quantity (MGD)
Minimum	0.02	0.47	0.00
Maximum	7.94	12.34	8.98
Average	0.51	1.85	0.12

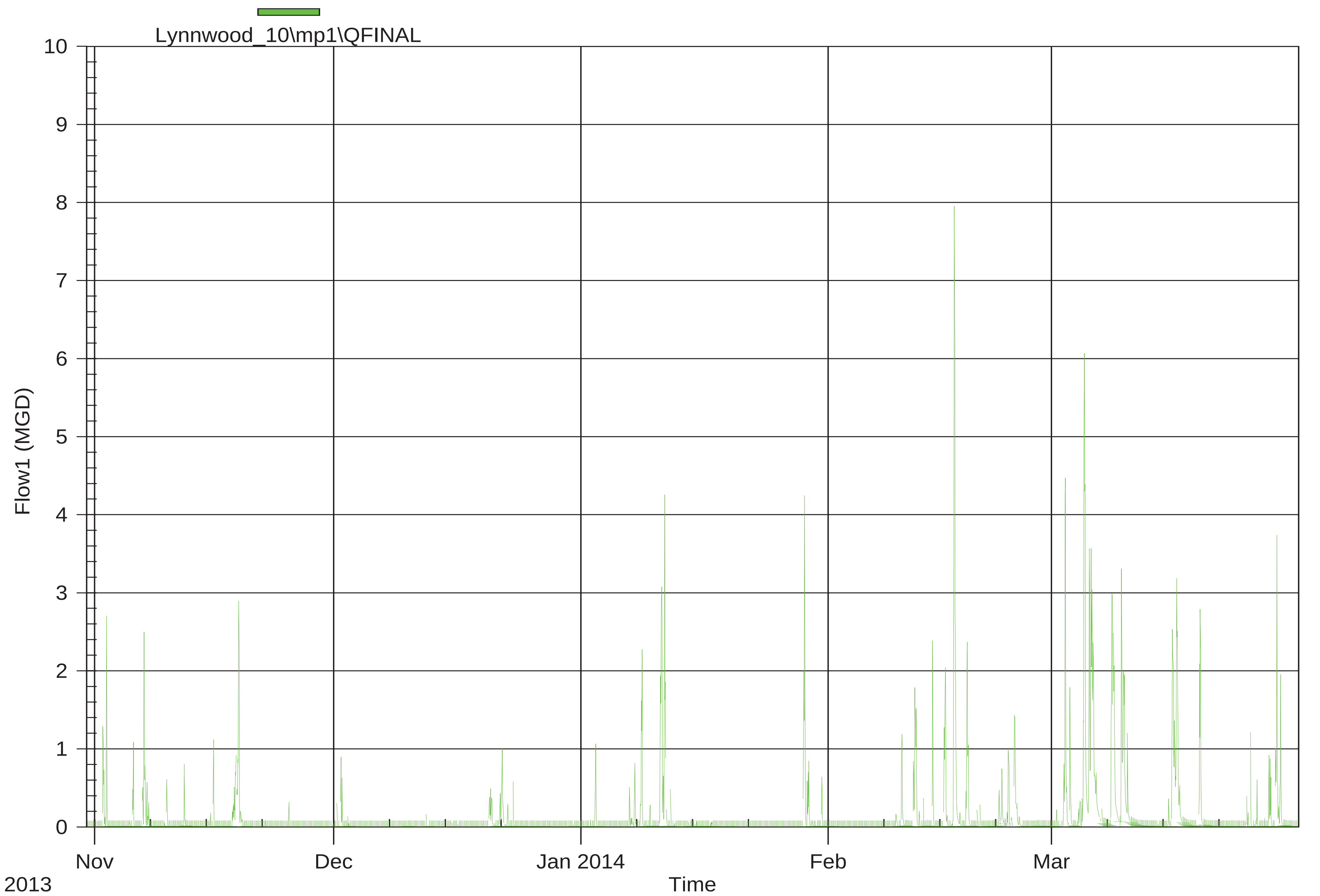
Hydrographs: The flow depth, velocity, and quantity data are plotted on the following hydrographs using an hourly average for ease of viewing.

ADS Environmental Services



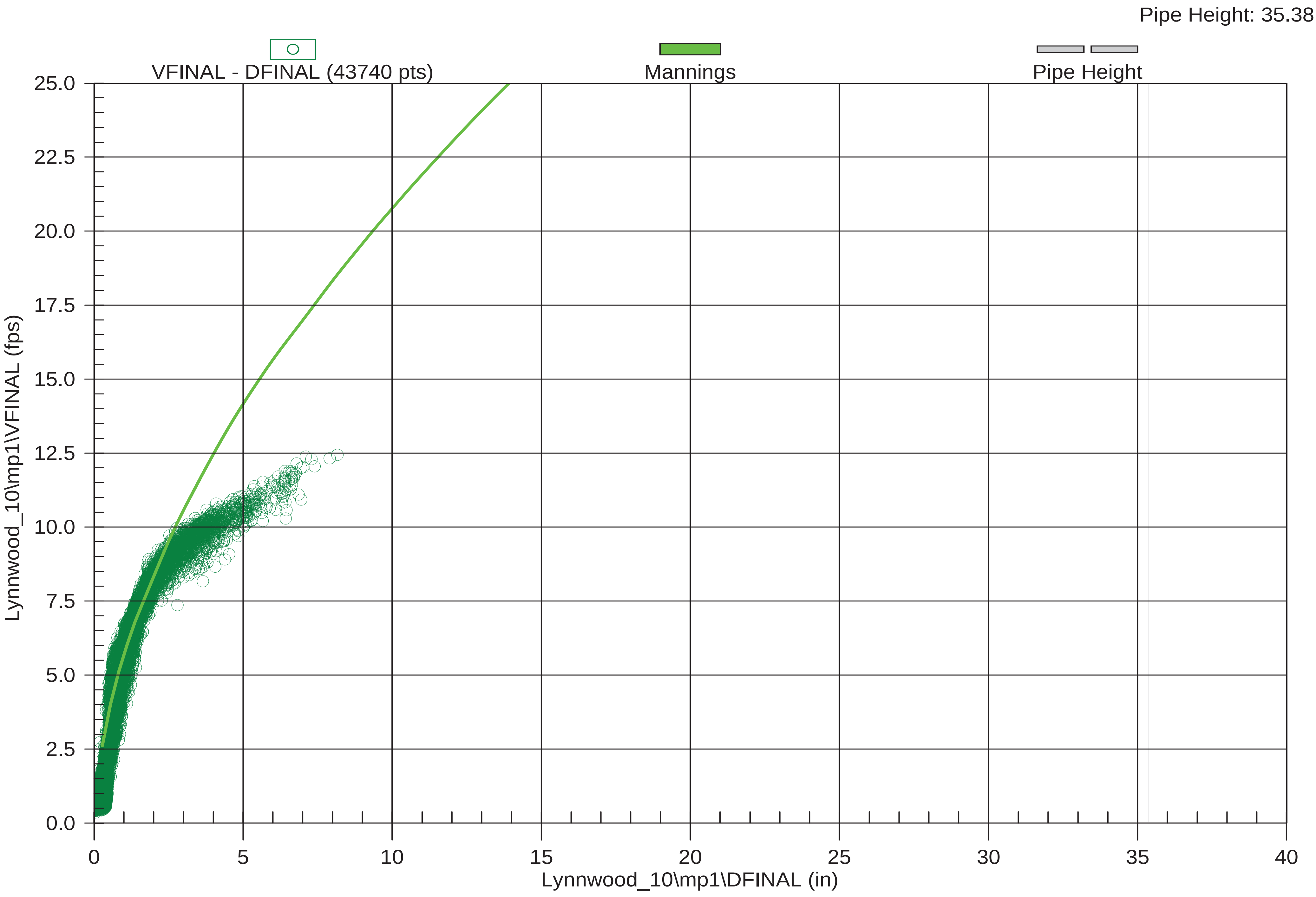
ADS Environmental Services

Pipe Height: 35.38



ADS Environmental Services

10/31/2013 12:00:00 AM - 3/31/2014 11:59:59 PM



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APPENDIX E.
HYDROLOGIC MODELING RESULTS

October 2014

WWHM RESULTS - BASIN RUNOFF UNROUTED					
Basin ID	Area (ac)	Modeled Runoff Results (CFS)			
		2-Year	10-Year	25-Year	100-Year
1	46.5	2.4	4.4	5.7	8.0
2	56.2	3.0	5.5	7.1	10.0
3	46.8	4.1	8.0	10.6	15.5
4	23.8	2.5	5.3	7.3	11.1
5	64.2	6.4	11.9	15.5	22.1
6	30.5	2.9	5.3	6.8	9.7
7	32.5	2.5	4.7	6.2	8.9
8	15.2	1.4	2.3	2.9	3.9
9	34.7	4.2	7.5	9.6	13.4
10	18.6	4.1	8.0	10.6	15.5
11	13.7	1.7	3.0	3.8	5.1
12	49.2	3.9	7.0	9.0	12.7
13	52.9	5.1	10.0	13.3	19.6
14	13.6	0.8	1.7	2.2	3.2
15	37.2	4.1	7.9	10.5	15.2
16	45.8	3.3	6.5	8.7	12.8
17	47.0	4.3	8.6	11.7	17.4
18	53.7	5.4	10.5	13.9	20.2
19	40.3	3.1	6.5	8.8	13.2
20	17.9	1.9	2.4	3.0	4.1

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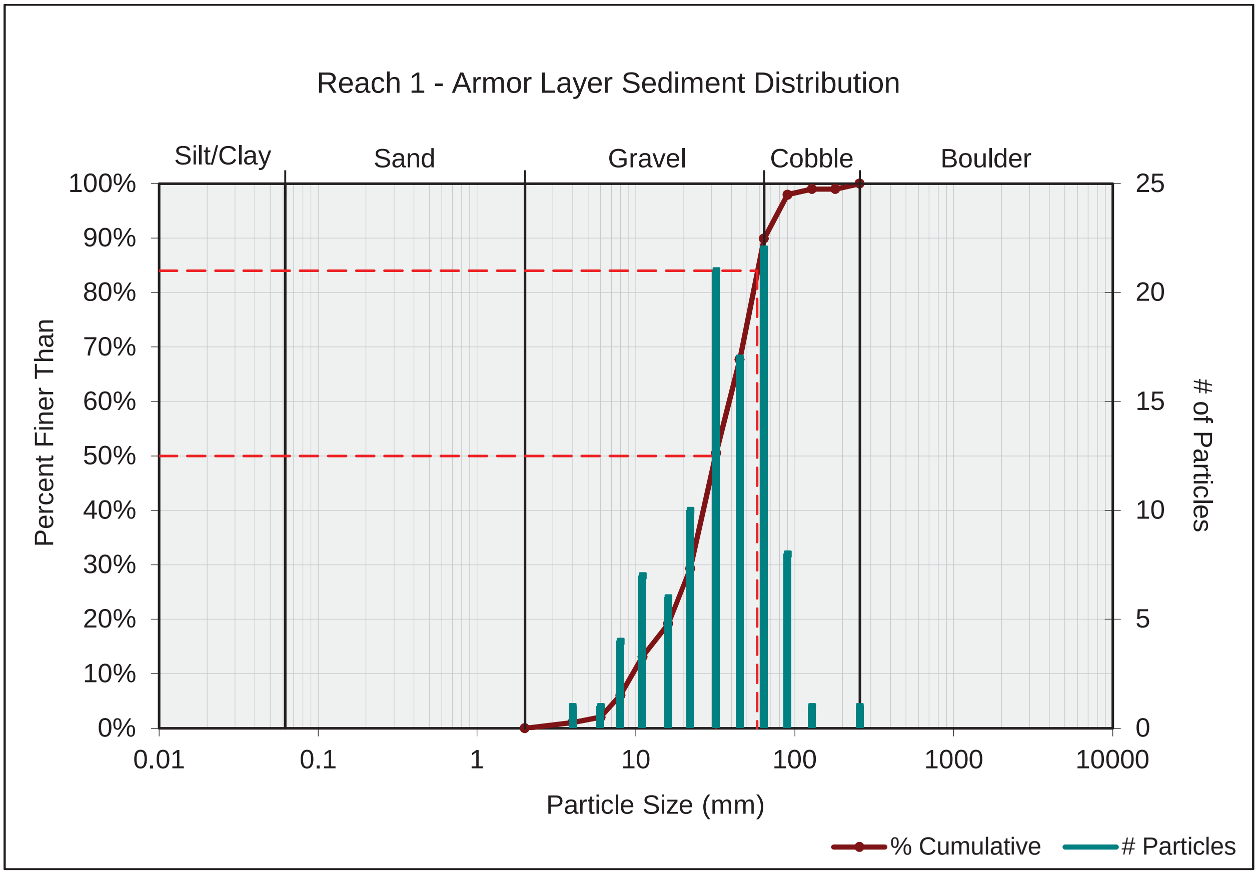
APPENDIX F.
COLLECTED GEOMORPHIC REACH DATA

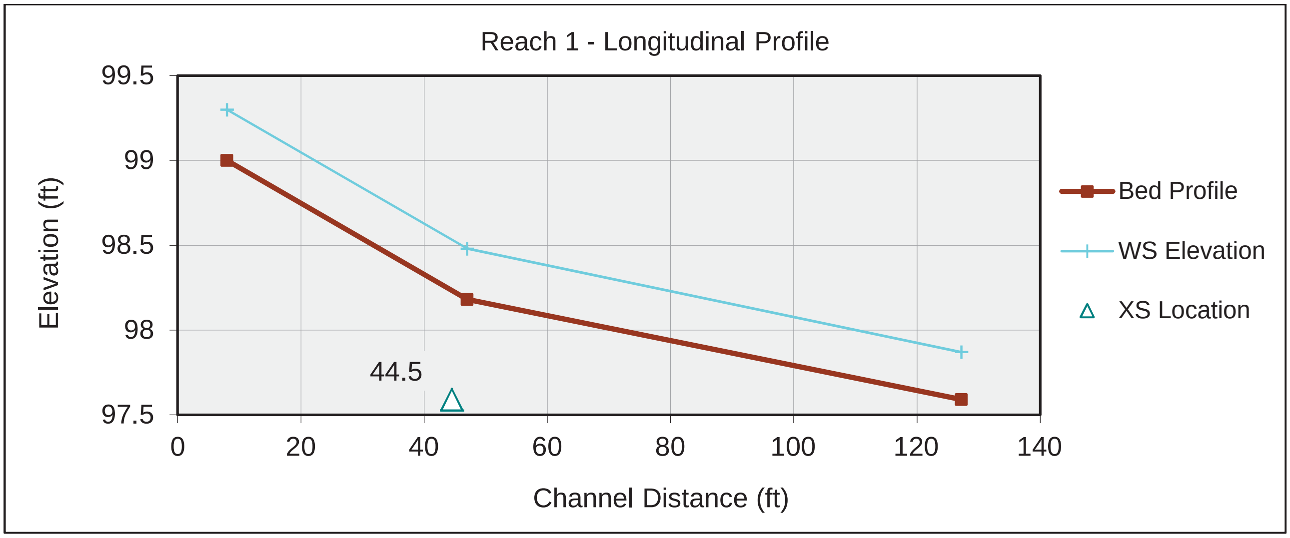
October 2014

Reach 1

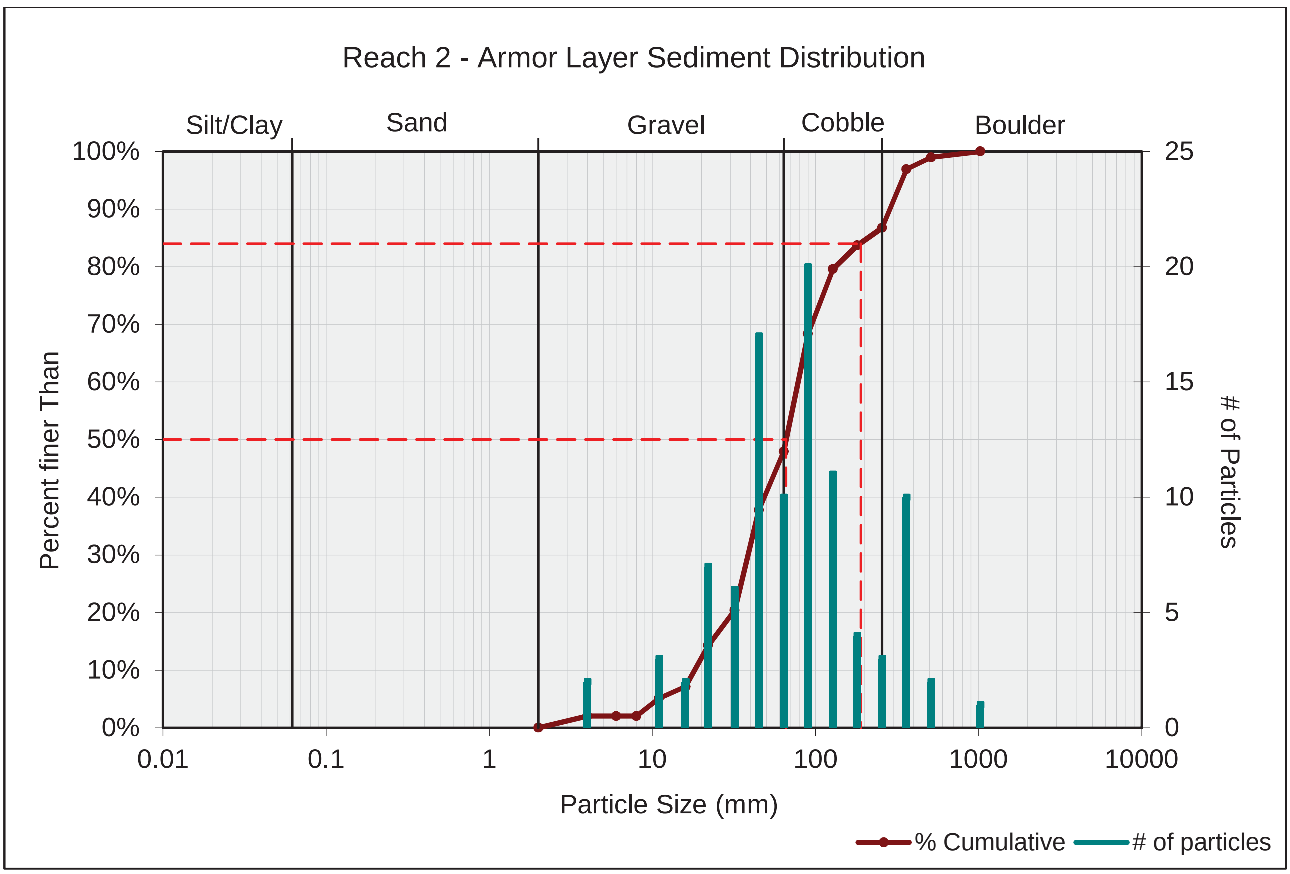


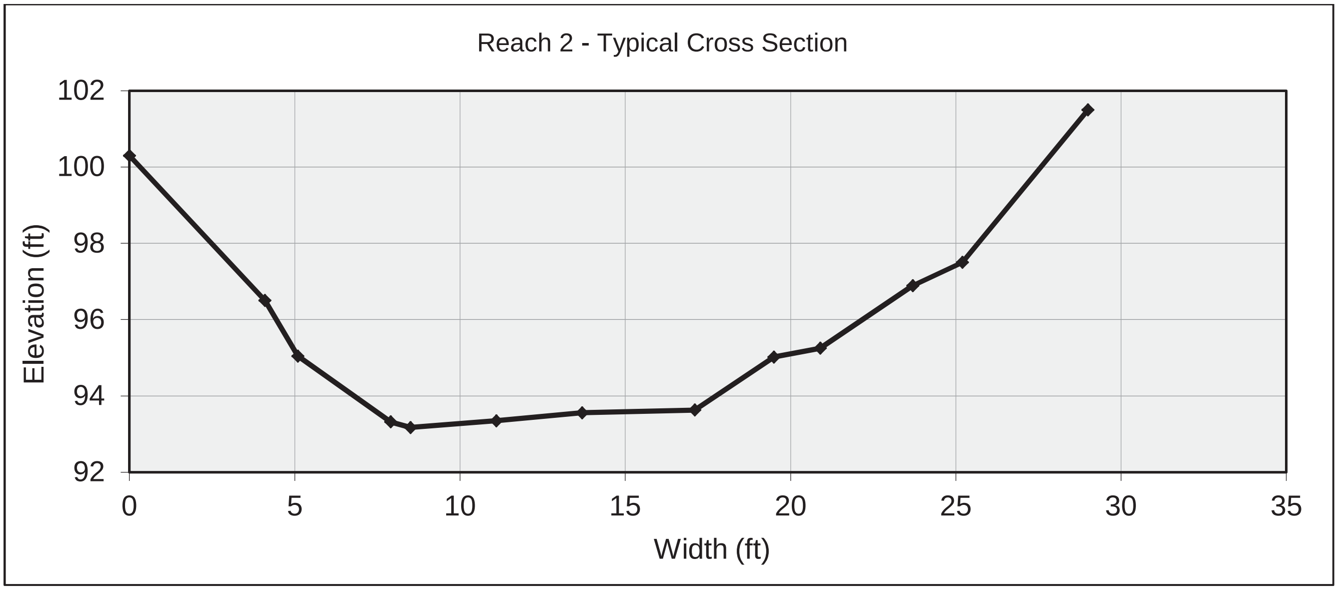
Reach 1 - Armor Layer Sediment Distribution
Silt/Clay
Sand
Gravel
Cobble
Boulder
Percent Finer Than
# of Particles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
0
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
% Cumulative
# Particles

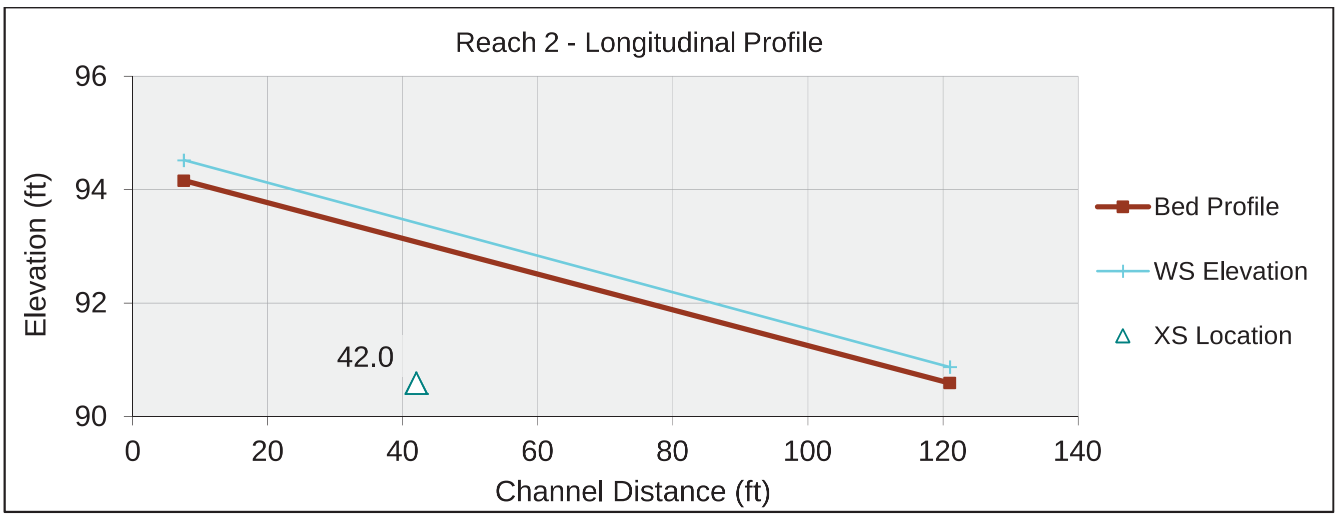
Reach1 - Typical Cross-Section
Elevation (ft)
108
106
104
102
100
98
96
0
10
20
30
40
50
60
70
80
Width (ft)


Reach 1 - Longitudinal Profile
Elevation (ft)
99.5
99
98.5
98
97.5
44.5
0
20
40
60
80
100
120
140
Channel Distance (ft)
Bed Profile
WS Elevation
XS Location

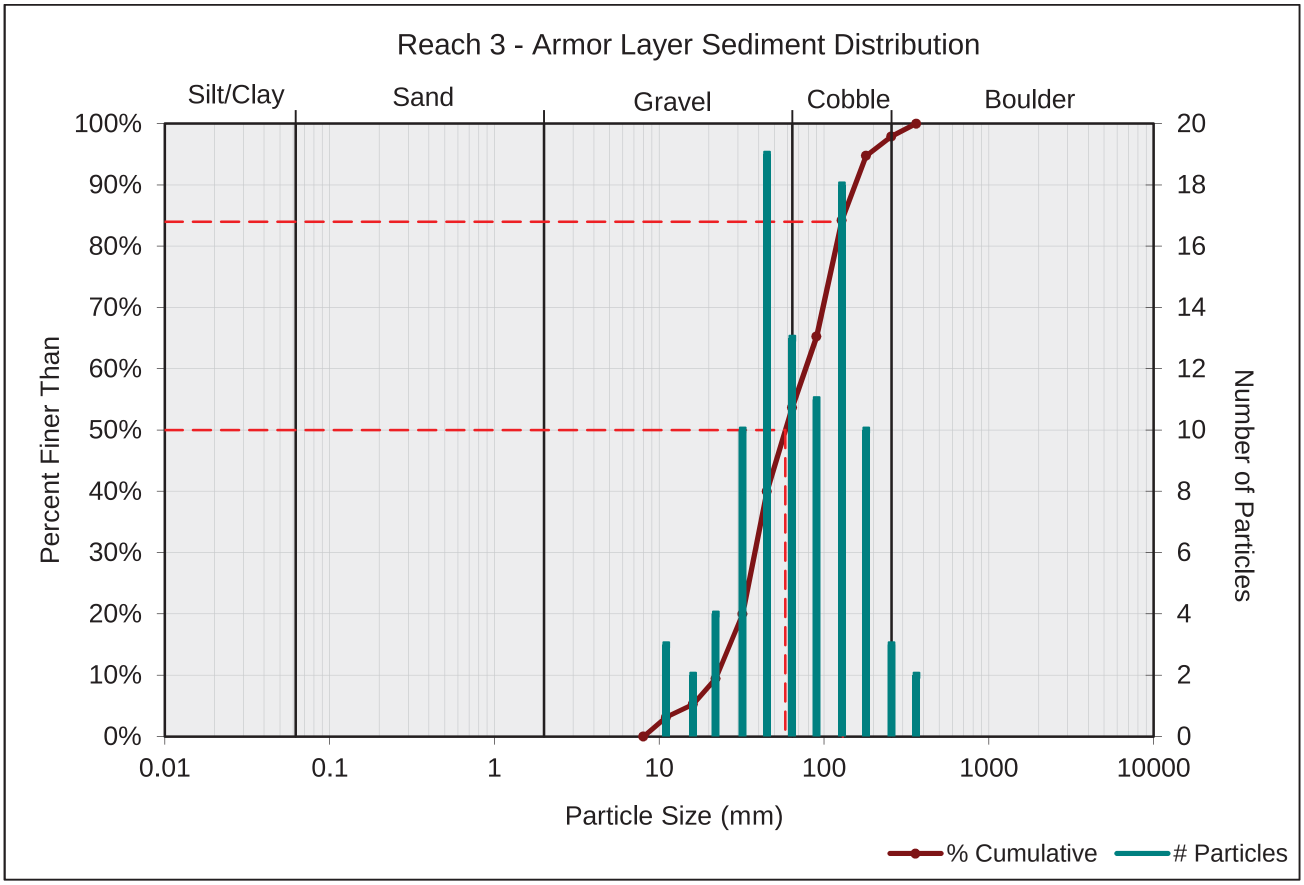
Reach 2

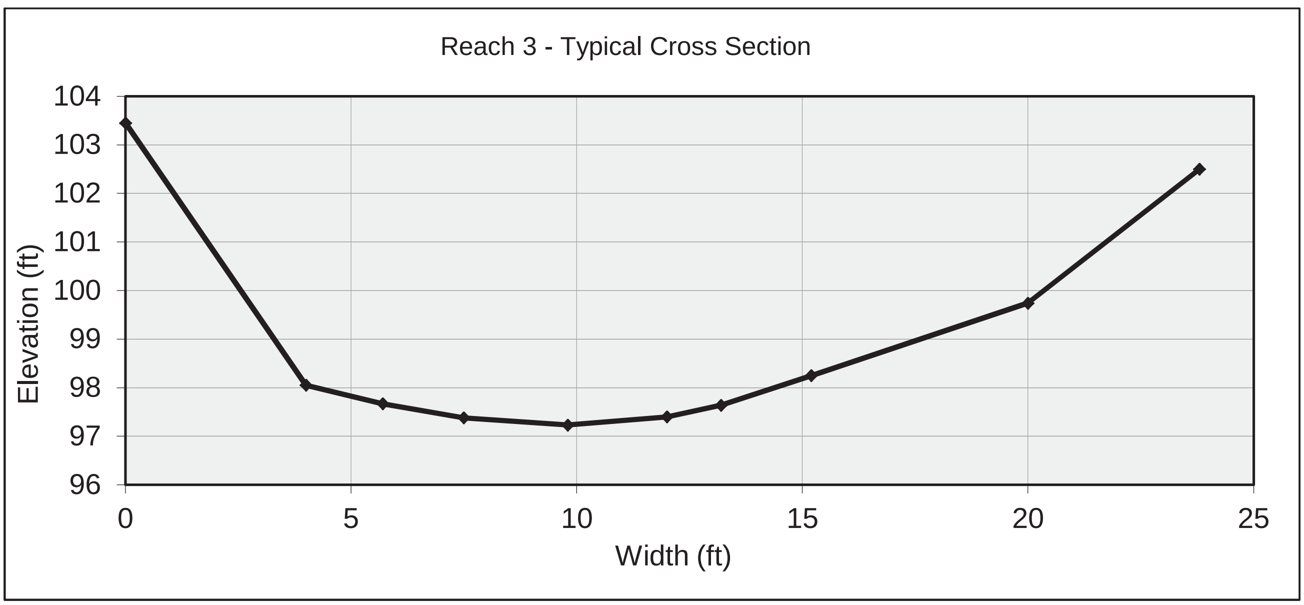

Reach 2 - Armor Layer Sediment Distribution
Silt/Clay
Sand
Gravel
Cobble
Boulder
Percent finer Than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
0
# of Particles
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
% Cumulative
# of particles

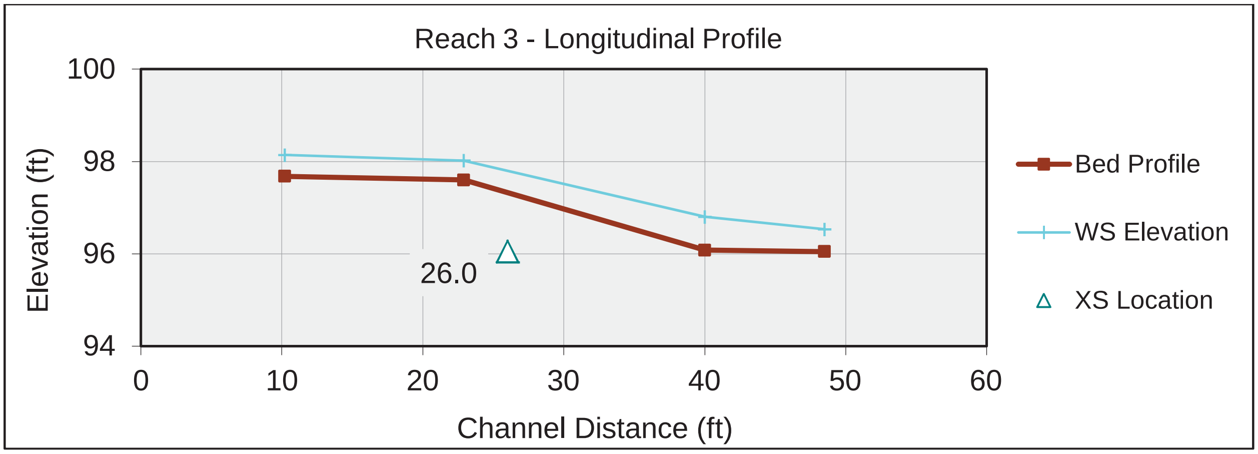

Reach 2 - Typical Cross Section
102
100
98
96
94
92
Elevation (ft)
0
5
10
15
20
25
30
35
Width (ft)


Reach 2 - Longitudinal Profile
96
94
92
90
Elevation (ft)
42.0
0
20
40
60
80
100
120
140
Channel Distance (ft)
Bed Profile
WS Elevation
XS Location

Reach 3

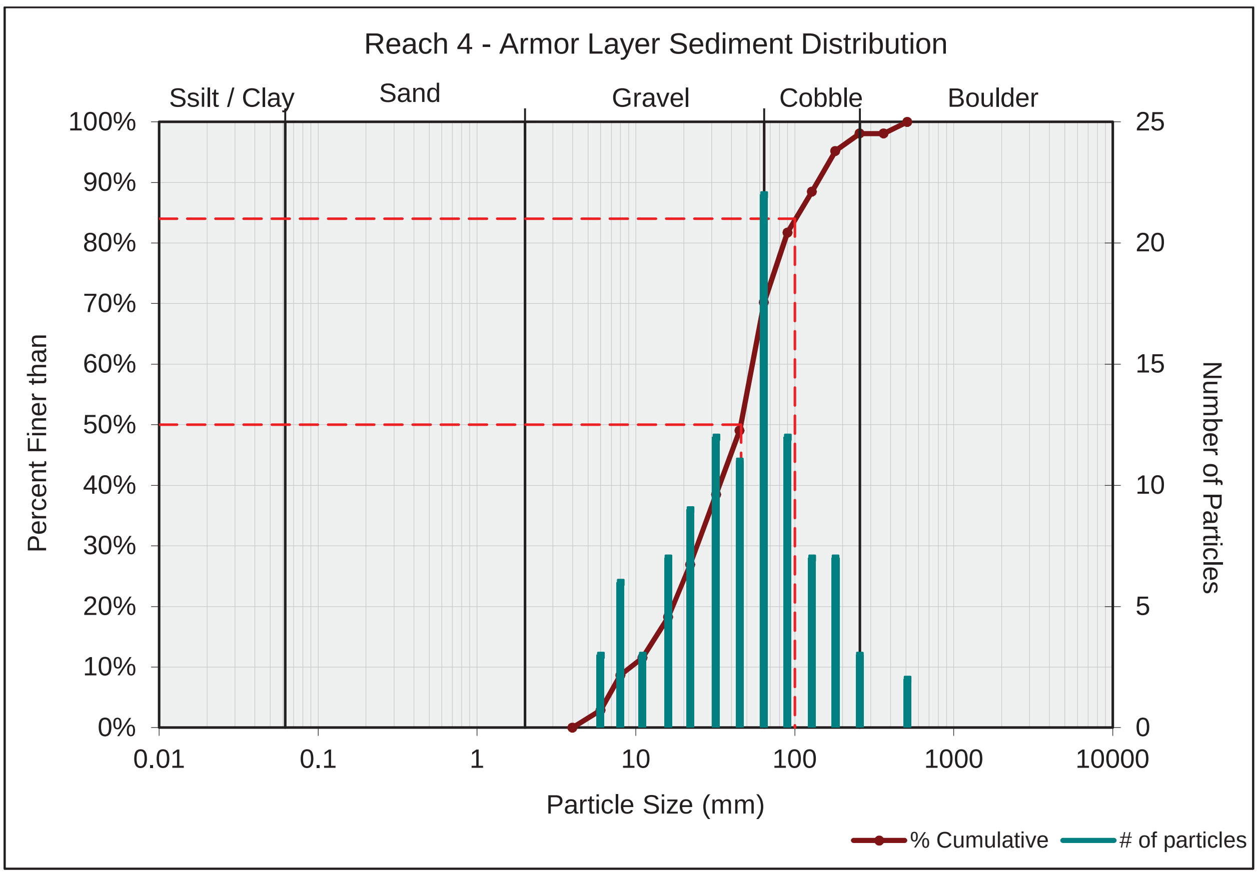

Reach 3 - Armor Layer Sediment Distribution
Silt/Clay
Sand
Gravel
Cobble
Boulder
Percent Finer Than
Number of Particles
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20
18
16
14
12
10
8
6
4
2
0
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
% Cumulative
# Particles


Reach 3 - Typical Cross Section
Elevation (ft)
104
103
102
101
100
99
98
97
96
0
5
10
15
20
25
Width (ft)

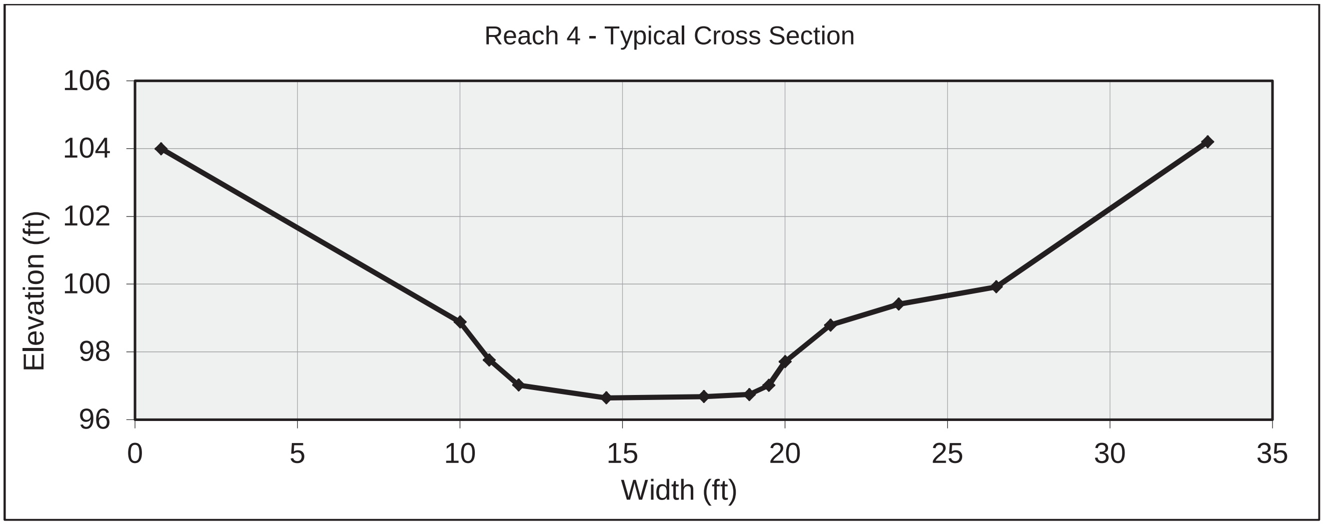


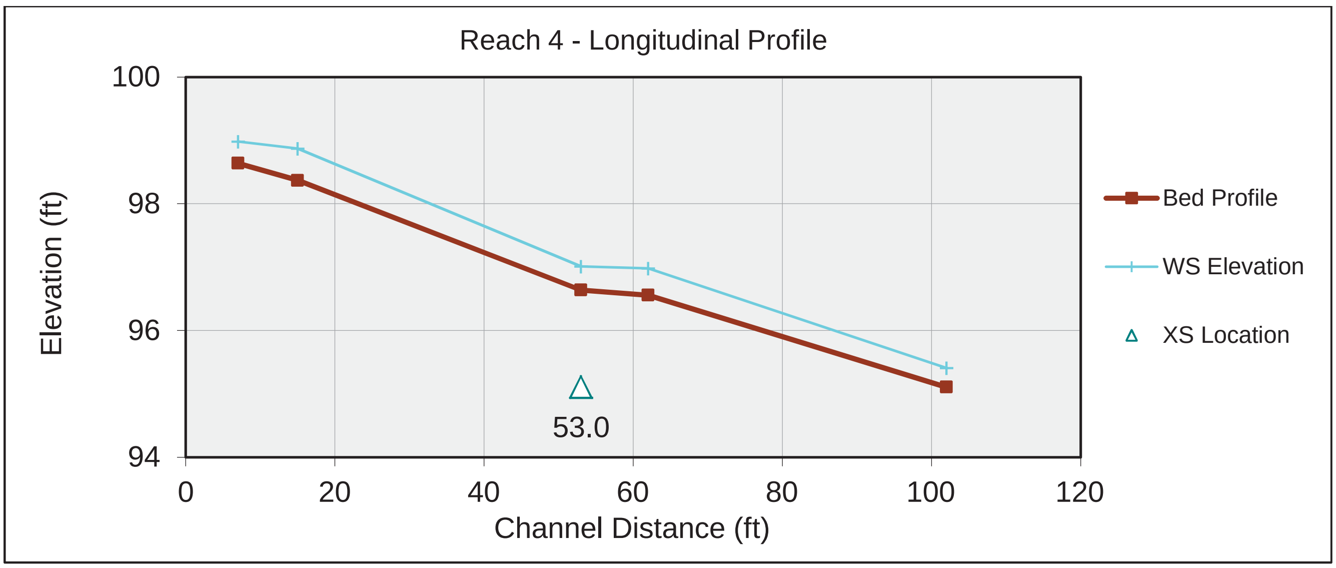
Reach 3 - Longitudinal Profile
100
98
96
94
Elevation (ft)
26.0
0
10
20
30
40
50
60
Channel Distance (ft)
Bed Profile
WS Elevation
XS Location

Reach 4



Reach 4 - Armor Layer Sediment Distribution
Ssilt / Clay
Sand
Gravel
Cobble
Boulder
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Finer than
25
20
15
10
5
0
Number of Particles
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)
% Cumulative
# of particles


Reach 4 - Typical Cross Section
Elevation (ft)
106
104
102
100
98
96
0
5
10
15
20
25
30
35
Width (ft)


Reach 4 - Longitudinal Profile
Elevation (ft)
100
98
96
94
0
20
40
60
80
100
120
Channel Distance (ft)
53.0
Bed Profile
WS Elevation
XS Location

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APPENDIX G. GEOMORPHIC CALCULATIONS

October 2014

Cross Section 4

$$\boldsymbol{\tau_c = \tau_c^* \, (\gamma_s - \gamma) D_{50}}$$

$\boldsymbol{\tau_c}$	**critical shear stress**	
τ_c^*	critical dimensionless shear stress	set to 0.029
γ_s	unit weight of sediment	~165 lb/ft^3
γ	unit weight of water	62.4 lb/ft^3
D_{50}	median particle size	46 mm / 304.8 mm/ft

$\tau_c = 0.45$ lb/ft^2

$$\boldsymbol{\tau_* = \tau' / \tau_c}$$

$\boldsymbol{\tau'}$	**grain shear stress**	
τ_*	normalized grain shear stress	set to 1.5
τ_c	critical shear stress	0.45 lb/ft^2

$\tau' = 0.68$ lb/ft^2

$$\boldsymbol{\tau' = \gamma \, Y' S}$$

$\boldsymbol{Y'}$	**portion of the total hydraulic depth associated with grain resistance**	
γ	unit weight of water	62.4 lb/ft^3
τ'	grain shear stress	0.68 lb/ft^2
S	local energy slope (approximated by the surveyed water surface profile)	0.034 ft/ft

$Y' = 0.32$ ft

$$\boldsymbol{V'_* = \sqrt{g Y' S}}$$

$\boldsymbol{V'_*}$	**shear velocity due to grain roughness**	
g	gravity constant	32.17 ft/sec^2
Y'	hyd. depth assoc. w/grain resist.	0.32 ft
S	local energy slope	0.034 ft/ft

$V'_* = 0.59$ ft/sec

$$\boldsymbol{\frac{V}{V'_*} = 6.25 + 5.75 \, \log\left(\frac{Y'}{k_s}\right)}$$

$\boldsymbol{V}$	**channel velocity at which significant sediment mobilizes**	
V'_*	shear velocity due to grain rough.	0.59 ft/sec
Y'	hyd. depth assoc. w/grain resist.	0.32 ft
k_s	characteristic roughness height of channel bed	approximated as 3.5 D84 = 3.5 × 100 mm / 304.8 mm/ft

$V = 1.78$ ft/sec

$$\frac{\boldsymbol{V}}{\boldsymbol{V_*}} = \frac{\boldsymbol{V}}{\sqrt{\boldsymbol{g R_h S}}} = \mathbf{5.75\ log}\left(\frac{\boldsymbol{a\, R_h}}{\boldsymbol{k_s}}\right)$$

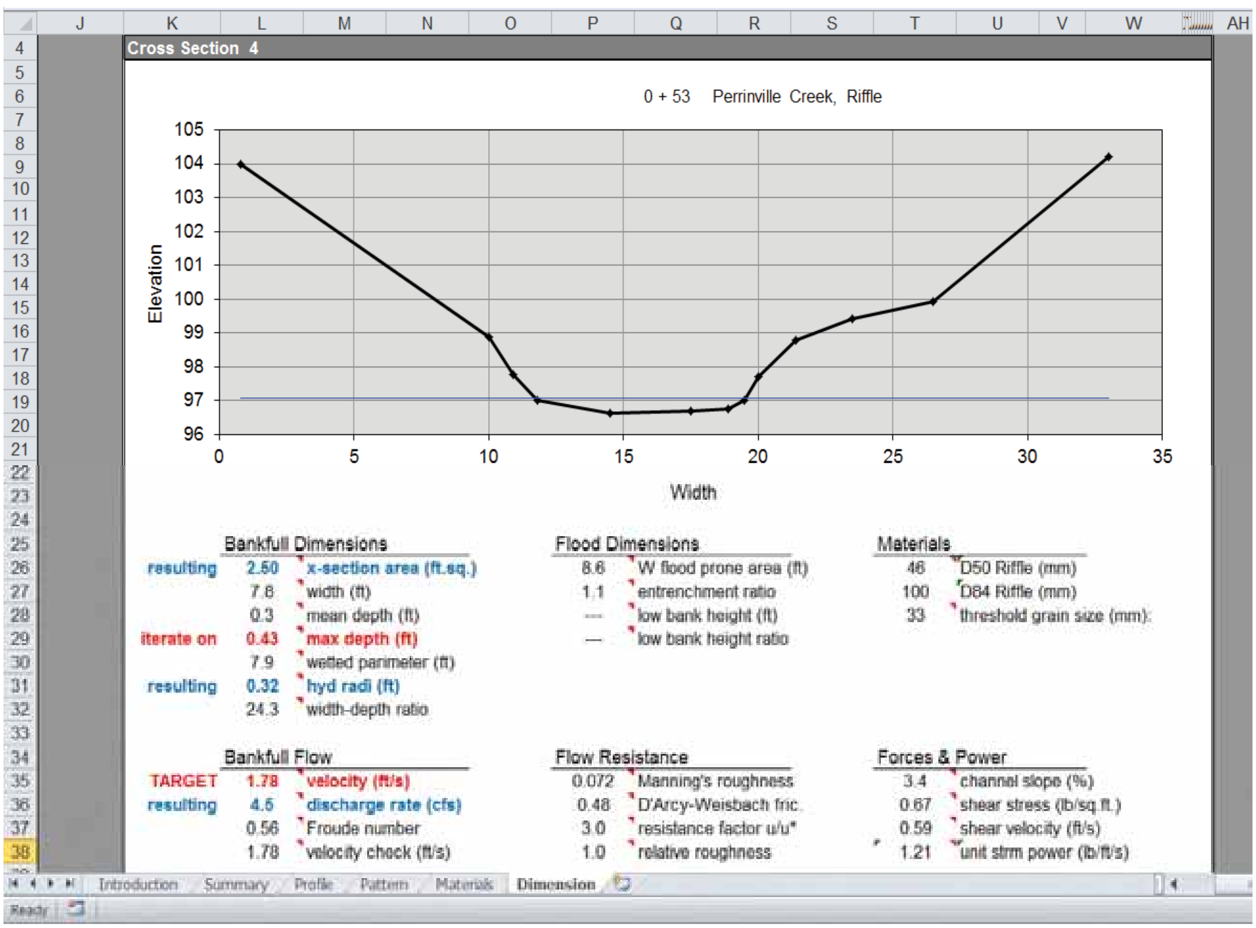
$\boldsymbol{R_h}$	**hydraulic radius**	
V	channel velocity	1.78 ft/sec
V_*	shear velocity	
g	gravity constant	32.17 ft/sec^2
S	local energy slope	0.034 ft/ft
k_s	characteristic roughness height	1.15 ft
a	channel cross section shape factor	$a = 11.1\left(\frac{R_h}{d_m}\right)^{-0.314}$
d_m	maximum depth at cross section	determined iteratively = 0.43 ft

$R_h = 0.32$ ft/sec

$\boldsymbol{Q = VA}$

$\boldsymbol{Q}$	**streamflow rate at which significant sediment mobilizes**	
V	channel velocity	1.78 ft/sec
A	channel cross sectional area	2.50 ft^2 from geometry associated with d_m and R_h

$Q = 4.5$ ft^3/sec



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APPENDIX H.
GEOTECHNICAL/GEOLOGIC TECHNICAL REPORT

October 2014

associated earth sciences incorporated

July 17, 2014
Project No. KH130422A

Tetra Tech, Inc.
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101

Attention: Mr. Rick Schaefer

Subject: Subsurface Exploration, Infiltration Assessment, and Geotechnical Engineering Report
Perrinville Creek Stormwater Flow Reduction Study
Edmonds, Washington

Dear Mr. Schaefer:

Associated Earth Sciences, Inc. (AESI) is pleased to provide this letter-report presenting the results of our subsurface exploration and infiltration assessment for the Perrinville Creek Stormwater Flow Reduction Study, for the Perrinville Basin within Edmonds, Washington (Figure 1). Our understanding of the project and site is based on discussions with both Tetra Tech, Inc. (Tetra Tech) and the City of Edmonds (City), aerial and light detection and ranging (LiDAR) imagery of the Perrinville Basin, our subsurface exploration program, and our work on other Low Impact Development (LID) and Green Stormwater Infrastructure (GSI) projects in the Puget Sound region. It is our understanding that this project would be developed under the 2005 Washington State Department of Ecology *Stormwater Management Manual for Western Washington,* (Ecology Manual) (Ecology, 2005), and the *Phase II Western Washington Municipal Stormwater Permit*, issued in 2007, and adopted by the City of Edmonds.

PURPOSE AND SCOPE

The purpose of this study was to perform geotechnical and hydrogeological investigations within the Perrinville Basin to characterize subsurface geology and evaluate infiltration feasibility for purposes of informing the preliminary design of the retrofit project. This study included a review of selected available geologic literature, a review of our past geologic work in the area, advancing six soil borings and installing a ground water monitoring well, excavating an exploration pit and conducting an infiltration test, conducting ground water level monitoring to establish depth to seasonal high ground water, and performing geologic studies to assess the type, thickness, distribution, and physical properties of the subsurface sediments and ground water conditions, and to evaluate infiltration feasibility at specific sites within Perrinville Basin. This letter-report summarizes our current fieldwork and offers infiltration rate recommendations based on our present understanding of the project. AESI also recently completed field and subsurface investigations at the nearby Lynndale Elementary School. Results from that study contributed to our understanding of subsurface conditions of the Perrinville Basin.

AUTHORIZATION

Authorization to proceed with this study was granted by means of Tetra Tech, Inc.'s Subconsultant Professional Services Agreement, signed by Rick Schaefer July 29, 2013. This letter-report has been prepared for the exclusive use of Tetra Tech and its agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted hydrogeology and geology practices in effect in this area at the time our letter-report was prepared. No other warranty, express or implied, is made. Our observations, findings, and opinions are a means to identify and reduce the inherent risks to the owner.

PROJECT SUMMARY

We understand that the City desires to improve the aquatic habitat in the lower reaches of Perrinville Creek, including replacing the 30-inch Perrinville Creek culvert under Talbot Road. However, replacing the culvert would increase sedimentation and flooding risk in the lower reaches of Perrinville Creek. From speaking with the City, we understand that stormwater runoff causes erosion and siltation in Perrinville Creek due to undetained/underdetained storm drainage systems that convey flow from residential developments in Edmonds and Lynnwood.

Based on this, the City has retained Tetra Tech to conduct a flow reduction study for the Perrinville Creek watershed with the primary goal to reduce peak flow rates and their durations through a combination of LID/GSI and conventional stormwater retrofits. AESI has been contracted as a subconsultant to Tetra Tech to complete geotechnical investigations in the basin to improve model simulation of existing and proposed stormwater best management practices (BMPs). AESI's site-specific geotechnical investigations at the project site will inform the preliminary design.

SITE DESCRIPTION

The project site consists of multiple locations within Perrinville Basin, located in Sections 17 and 18, Township 27 North, Range 4 East, in the City of Edmonds, Washington (Figure 1). Exploration sites are primarily within right-of-ways (ROWs) within the City of Edmonds, or in City of Lynnwood and City of Edmonds parks. Streets and alleys between primary streets are primarily asphalt, with occasional grass-lined ditches or shoulders. Land use in the area includes both single-family residential and light commercial properties. The ground slopes generally northwestward, eventually draining to the Puget Sound. Steep slopes, landslide blocks, landslide debris, and highly incised drainages are present within the Perrinville Basin, and predominantly within the Perrinville Creek ravine. Outside of the Perrinville Creek's ravine, topography in Perrinville is generally flat within the upland glacial drumlinized surface. All elevations referenced in this report are relative to mean sea level, and all referenced depths are relative to existing ground surface unless otherwise indicated. Regional geology and topography derived from LiDAR mapping is presented on Figure 2.

SUBSURFACE EXPLORATION

Our field study included drilling six exploration borings, with one completed as a monitoring well, and conducting an infiltration test in a test pit using a modification of the Pilot Infiltration Test (PIT) method, as described in the 2009 *King County Storm Water Design Manual* (KCSWDM), to gain information about the subsurface conditions of Perrinville Basin. The various types of sediments and ground water, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix A. The depths indicated on the logs where conditions changed may represent gradational variations between sediment types in the field. If changes occurred between sample intervals in our exploration pits and borings, they were interpreted. The locations of our explorations were approximately located in the field by measuring from known site features and are shown on Figure 2. Selected exploration boring locations from Lynndale Elementary School are also included on Figure 2, and exploration logs are included in Appendix A. A summary of exploration locations and types is presented in Table 1.

Table 1
Summary of Exploration Locations and Types

Exploration Name	Date Performed	Location or Nearest Intersection	Depth of Boring (feet)
EB-1	4/15/14	Lynndale Park Southeast Parking Lot	41
EB-2	4/15/14	193rd Place Southwest & 76th Avenue West	50.5
EB-3	5/2/14	193rd Place Southwest & 77th Avenue West	31.5
EB-4	5/2/14	191st Street Southwest & Dellwood Drive	30.5
EB-5	5/2/14	180th Street Southwest & 73rd Avenue West	41.5
VB-1	4/14/14	Olympic View Drive & 76th Avenue West	5.5
IT-1	4/17/14	Blue Ridge Neighborhood Detention Pond	15
MW-1	4/14/14	Seaview Park Parking Lot	87
EB-1 (L)	5/15/14	Lynndale Elementary Ball Fields	26.5
EB-2(L)	5/15/14	Lynndale Elementary Ball Fields	20.5
EB-3(L)	5/15/14	Lynndale Elementary Ball Fields	20.5
EB-5(L)	5/15/14	SW Lynndale Elementary Campus	50.5

(L) Exploration performed as part of the Lynndale Elementary School project and approved for use in this study.

The conclusions and recommendations presented in this letter-report are based on the exploration pits and borings completed for this study. The number, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, extrapolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions may sometimes be present due to the random nature of deposition and the alteration of topography by past grading and/or filling. The nature and extent of any variations between the field explorations may not become fully evident until construction. If variations are observed at that time, it may be necessary to re-evaluate specific recommendations in this letter-report and make appropriate changes.

Vactor Boreholes

Prior to advancing hollow-stem auger borings within the ROW, we advanced vactor boreholes in the footprint of selected exploration locations to clear for utilities. We performed vactor clearing for EB-2, EB-4, EB-5, and VB-1.

Vactor boreholes were completed using a vactor truck operated by the Applied Professional Services (APS) Locates. The vactor holes permitted direct, visual observation of subsurface conditions. The vactor suction pipe and high-pressure air hose were used to excavate an approximate 8-inch-diameter hole. The air jet was used to loosen sediment and the vactor suction pipe removed the loosened sediment from the hole. The vactor suction pipe was removed every 2.5 feet for observation of borehole wall conditions, and to allow for probing and sample collection. Samples were collected using a 4-inch-diameter hand auger with extension rods. Relative densities were determined in the field by probing the soil with a ½-inch-diameter steel probe into undisturbed soil. Materials encountered in the vactor holes were studied and classified in the field by a geotechnical engineer from AESI. Immediately after soil examination and logging, all vactor boreholes were backfilled with crushed gravel to within about 4 inches of pavement surface, and covered with cold-patch asphalt. Samples were labeled and placed in sealed plastic bags and then transported to our laboratory for further visual classification and testing, as necessary.

Our vactor exploration VB-1, at the corner of Olympic View Drive and 76th Avenue West, was advanced in order to confirm the presence of Vashon advance outwash and to assess the feasibility of performing an infiltration test in that location. Our exploration encountered ground water at 5.3 feet below ground surface. When we relayed this to the client, it was decided to not perform the scheduled infiltration test in that location, as results would not be indicative of realistic infiltration rates within the unsaturated advance outwash.

Exploration Borings and Boring Completed as Monitoring Well

Exploration borings were advanced and completed on April 15, 2014 (EB-1 and EB-2), and May 2, 2014 (EB-3, EB-4, EB-5). Exploration boring MW-1 was advanced and completed as a monitoring well April 14, 2014. The exploration borings were completed by advancing a 4.25-inch, inside-diameter, hollow-stem auger with a trailer-mounted drill rig. During the drilling process, samples were obtained at generally 2.5- to 5.0-foot-depth intervals, and drilling was continuously observed and samples logged by a geotechnical engineer from our firm.

Disturbed but representative samples were obtained by using the Standard Penetration Test procedure in accordance with *American Society for Testing and Materials* (ASTM):D 1586. This test and sampling method consists of driving a standard 2-inch outside-diameter split-barrel sampler a distance of 18 inches into the soil with a 140-pound hammer free-falling a distance of 30 inches. The number of blows for each 6-inch interval is recorded and the number of blows required to drive the sampler the final 12 inches is known as the Standard Penetration Resistance (“N”) or blow count. If a total of 50 is recorded within one 6-inch interval, the blow count is recorded as the number of blows for the corresponding number of inches of penetration. The resistance, or N-value, provides a measure of the relative density of granular soils or the relative consistency of cohesive soils; these values are plotted on the attached boring logs.

The samples obtained from the split-barrel sampler were classified in the field and representative portions were labeled and placed in sealed plastic bags. The samples were then transported to our laboratory for further visual classification and laboratory testing, as necessary. Additional information on the various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in Appendix A.

Boring MW-1 was completed as a 2-inch-diameter monitoring well with 10 feet of machine slotted Schedule 40 polyvinyl chloride (PVC) well screen and a flush-ground monument. The well is completely screened below the water table. The sand pack materials consisted of 10/20 Colorado Silica Sand. The well was sealed with a combination of bentonite chips and concrete, and was developed using mechanical pumping techniques. Well construction details are presented on the geologic and monitoring well log in Appendix A. After the well was developed, a data logger and pressure transducer were installed in MW-1 to record hourly water level data. Hand water level data will be collected on a monthly basis during transducer downloading events, and started after the well was developed on April 25, 2014.

Infiltration Test Pit

The infiltration test pit was excavated using a track-mounted back-hoe provided by Northwest Excavating and Trucking on April 18, 2014. The pit permitted direct, visual observation of subsurface conditions. Materials encountered in the infiltration test pit were studied and classified in the field by a geotechnical engineer from our firm. The pit was attended continuously while open for the duration of the infiltration test, and backfilled following completion of the test and overexcavation. Selected samples were then transported to our laboratory for further visual classification. Copies of laboratory testing data sheets are included in Appendix B.

Infiltration Testing

An infiltration test was completed at the location noted on Figure 2 as IT-1, in the Blue Ridge neighborhood. The test was conducted within an exploration pit of measured dimensions as a low-head infiltration test, generally with a head between 0.5 and 1 foot. This test is a modification of the Washington State Department of Ecology (Ecology) PIT methodology. The test in IT-1 was conducted at a depth of 7 feet in what was interpreted as fill materials, discovered after the infiltration test pit was deepened. Mottled silt-rich fill soils, bark fragments, and rootlets were encountered beneath the infiltration test base. Additional details on fill soils encountered in this study are presented below ("Subsurface Conditions"). Fill soils are generally not recommended for infiltration due to high silt contents and high soil variability over short horizontal and vertical distances. Infiltration rates obtained through field infiltration testing are likely not representative of conditions underlying the majority of the site since fill soils are highly variable and we cannot provide a reliable infiltration rate for the soils even though some infiltration did occur. Installation of a staff gauge and stormwater inflow measurement monitoring over a longer period of time could more accurately provide an effective long-term design infiltration rate that could be expected for current subsurface conditions.

SUBSURFACE CONDITIONS

Geologic conditions at the multiple sites and within the overall Perrinville Basin were evaluated using: 1) data obtained from AESI's fieldwork, 2) discussions with local earthwork contractors, and 3) review of selected regional geologic maps, well logs, LiDAR maps, and other documents. Surficial geologic conditions within the study area are presented on Figure 2. Subsurface geology and ground water conditions are illustrated on two schematic hydrogeologic cross sections through the site, including Section A-A', which is a roughly southwest-northeast section that crosses Olympic View Drive and Perrinville Creek (Figure 3), and Section B-B', which is a roughly south-north section that extends from near the intersection of 76th Avenue West and 196th Street SW, across Olympic View Drive, north to Homeview Drive (Figure 4). Cross-section locations are shown on Figure 2.

We reviewed regional geology information from the geologic map titled *Geologic Map of the Edmonds East and part of the Edmonds West Quadrangles, Washington* (J.P. Minard, 1983).

Most of the surficial geology in the project area is shown on the regional geologic map as Vashon lodgement till (Qvt) overlying Vashon advance outwash (Qva). Based on the results of AESI's explorations for this project, AESI's interpretation of geologic conditions at the site is consistent with the regional mapping. As shown on the exploration logs, a thick sequence of regionally extensive permeable Vashon advance outwash (Qva) is present beneath the low-permeability lodgement till and underlies the entire upland portion of the Perrinville Basin. In some low-elevation locations, Qva exists at ground surface, without a cap of lodgement till. The thickness of unsaturated "receptor" soils encountered within Qva generally ranges from 90 feet in the south to about 60 feet in the north, though silt- and clay-rich deposits interpreted to represent an interbed within the Qva zone in EB-5 caused perched ground water to mound about 40 feet higher than the regional water table. Additional description is included under the "Vashon Advance Outwash" section of this letter-report.

The transition from overlying lodgement till to advance outwash throughout the project area was generally not abrupt, which manifested itself as silty outwash in most explorations ranging in thickness between 5 and 10 feet below the base of the lodgement till. This silty Qva has a lower permeability than the "cleaner" sands encountered deeper in the Qva and will thus have lower infiltration rates compared to the deeper, "cleaner" material.

Fill was encountered in some explorations within the Perrinville Basin. With the exception of IT-1 which was completed in fill soils, the native sediments extended to the full depth of all explorations completed by AESI in the project area. All exploration logs completed for this study and selected logs completed by AESI for studies at Lynndale Elementary School are included in Appendix A.

The geologic mapping at the published scale only shows large-scale trends in sediment type, and the boundaries between units and sediment types in any given area are sometimes mapped approximately. Our interpretation of the sediments encountered is in general agreement with the regional geologic mapping. However, we encountered Vashon advance outwash at ground surface in both EB-4 and MW-1, both of which are mapped as Vashon lodgement till. Other areas within the Perrinville Basin could experience the same discrepancies. The following section presents more detailed subsurface information organized from the youngest to the oldest sediment types.

Stratigraphy

<u>Pavement and Crushed Gravel Base Course</u>

The thickness of the asphalt encountered within the roadway and/or parking lot at exploration borings EB-1, EB-2, EB-5, and MW-1 was about 2 inches. Immediately below the pavement in each exploration was about 4 inches of crushed gravel base course.

Topsoil and Sod

Topsoil consisting of a loose, moist, dark brown mixture of silt and fine sand with varying organic content ranged in depth between 2 to 6 inches and was encountered at the ground surface in exploration borings EB-3 and EB-4. Topsoil is not considered suitable for infiltration.

Fill

Man-placed fill consisting of loose to medium dense, gray to brown, silty sand or sandy silt was encountered in the detention pond tract in Blue Ridge Neighborhood. The fill soils in this area of the site extended beyond the maximum depth of 15 feet explored in exploration IT-1. The fill appears to have been generated from site grading activities using native Vashon lodgement till soils encountered near the site, as evidenced by intact till chunks and silt-rich soils encountered in the exploration pit. Wood chips and other organic material were present at depth, further indicating that the soil was fill material.

Speaking with local contractors, we confirmed that there had been a sand and gravel quarry in this location in the 1970's and 1980's, mining Vashon advance outwash as a pit run. The entrance to the mine was at least 10 to 15 feet lower than the current pond elevation, off of Olympic View Drive, and mining operations removed material below the road grade. When mining stopped, upland Vashon lodgement till was pushed out from the upland area to the south and east and pushed into the depression left from mining. Based on current elevations of the neighborhood and vicinity to Olympic View Drive, we estimate that there could be as much as 30 feet of fill in the Blue Ridge neighborhood in the vicinity of IT-1. The existing fill in the pond is not recommended as a receptor soil for infiltration due to its high silt content and variability within short horizontal and vertical distances.

Vashon Lodgement Till (Qvt)

Sediments encountered near ground surface in most explorations consisted of dense to very dense, grayish brown, silty sand with gravel. We interpret these sediments to be representative of Vashon lodgement till. Basin-wide, where encountered at ground surface, the till ranged in thickness from 15 to 24 feet.

Vashon lodgement till was deposited directly from basal, debris-laden, glacial ice during the Vashon Stade of the Fraser Glaciation, approximately 12,500 to 15,000 years ago. Compaction from about 3,000 feet of ice in the vicinity of the project site consolidated this material during the last glacial advance. This process resulted in a compact soil possessing high-strength, low-compressibility, and low-permeability characteristics. Till soils typically contain a substantial fine-grained soil fraction, which makes them moisture-sensitive and susceptible to disturbance when wet site or weather conditions exist. Due to the high density and fine-grained nature of till, we do not recommend it as a receptor soil for infiltration.

Vashon Advance Outwash (Qva)

Advance outwash sediments were deposited during the last glacial age as outwash from rivers flowing from the base of the southward advancing glacial front. The advance outwash was subsequently overridden by about 3,000 feet of ice resulting in a dense to very dense, competent soil mass. Glacial till was deposited at the base of the overlying ice sheet, and represents the ground moraine of the southward advancing glacier. It is generally encountered above the advance outwash but can sometimes be scoured away by post-glacial alluvial processes in lower-elevation areas.

Medium dense to very dense, moist, grayish brown, fine to medium sand with little to trace silt interpreted as Vashon advance outwash was encountered in every exploration except IT-1. The advance outwash was exposed at ground surface in explorations MW-1 and EB-4, and found underlying a 15- to 24-foot-thick mantle of lodgement till in EB-1, EB-2, EB-3, and EB-5.

The Vashon advance outwash in the southern portion of the Perrinville Basin is relatively consistent both laterally and vertically and regional trends in composition are observed throughout most of our explorations. Immediately below the lodgement till cap, extending about 5 to 10 feet below the till-outwash contact, advance outwash soils are typically silt-rich, with silt contents decreasing below this zone. Grain size consisted primarily of fine to medium sand to the maximum depth explored of 87 feet in MW-1. Outwash grain size and composition was also similar laterally between explorations in the southern portion of the Perrinville Basin; however, the till-outwash contact decreases in elevation from south to north in the study area. In the south, the contact between the two units is about 378 feet above sea level (asl). This contact drops to the north, with elevations of the contact illustrated on Cross-Section B-B' around 340 feet asl.

Soils encountered in EB-5, within the northeastern plateau of the Perrinville Basin, were not consistent with soils from other explorations. In EB-5, we encountered a silt- and clay-rich unsorted deposit below saturated outwash. We interpreted this to be an ice-contact deposit or a laterally discontinuous zone of low-energy deposition within the advance outwash. Extents are unknown but may be expected to exist discontinuously in the northeastern plateau area. This zone likely resulted from deposition of silt- and clay-size particles in a low-energy depositional environment, away from the main advance outwash meltwater rivers and streams. Over time, the rivers and streams traversed back over the site, depositing more typical outwash sands and gravels over the silt-rich layer. The silty zone is less transmissive than the overlying fine to medium sand, as evidenced by the perched water zone. The net effect is that this zone limits vertical infiltration and causes water to mound and spread laterally, at a higher elevation than the regional water table.

Unsaturated advance outwash is suitable for infiltration in most settings. Infiltration facilities would need to be designed to convey water through or past the lodgement till and penetrate silty Qva to the "clean" advance outwash.

Transitional Beds (Qtb)

Minard (1983) mapped the transitional beds in the northwest portion of the basin. We did not encounter this formation below advance outwash in our explorations.

Transitional beds are a unit encompassing both glacial and non-glacial sediments present below the Vashon advance outwash. Fine-grained layers were deposited in lakes some distance from the ice-front, and also in fluvial streams prior to the advance of ice in the area. The contact between transitional beds generally grades upward into the Vashon advance outwash, but can be abrupt in some locations. Transitional beds are mapped about 30 to 65 feet thick in exposures in the Edmonds area. High water content in the formation, coupled with jointing, results in potentially unstable slopes. The beds have been involved in numerous landslides, including the Meadowdale landslide located north of Perrinville Basin. The fine-grained transitional beds are not suitable for use as a receptor soil for infiltration.

Laboratory Analysis

We selected samples from the explorations for mechanical grain-size analysis testing, in accordance with ASTM:D 2488, to characterize the sediment and to assess the suitability of the soils for stormwater infiltration. The laboratory data sheets are included as Appendix B.

GROUND WATER CONDITIONS

Ground Water within the Vashon Advance Outwash

Ground water in Vashon advance outwash, the target receptor for stormwater infiltration, was encountered in well MW-1, VB-1, and boring EB-5, as shown on Figures 3 and 4, "Schematic Hydrogeologic Cross-Sections". The regional water table aquifer was encountered in both MW-1 and EB-1 at an elevation of about 267 feet asl, which corresponds to water levels observed in nearby Perrinville Creek. Monitoring well MW-1 was screened completely within the regional water table. A perched water table was encountered in EB-5 at an elevation of about 335 feet asl at time of drilling, above a fine-grained deposit within the advance outwash. Approximate ground water elevations were evaluated by measuring the depth to water in the monitoring well both before and after the well was developed and computing elevations relative to sea level based on site LiDAR topography. Water level in EB-5 was estimated by observing water quantities within SPT sample tubes recovered from depth.

The ground water elevation in MW-1 has remained relatively constant over the period of observation from April 16, 2014 to July 2, 2014, varying between 268.2 and 269.05 feet asl (Table 2). A ground water hydrograph covering this period of time is included in Appendix C. The dark blue line represents the MW-1 water table elevation in feet asl from April to July. The light blue line represents daily rainfall (in inches) recorded by a King County rain gauge installed at Boeing Field. The hydrograph shows ground water levels during this period are increasing slightly. Peak ground water levels in deep aquifers such as the Qva typically lag behind peak rainfall by several months. This lag occurs because of the time it takes water to infiltrate from the surface into the subsurface and create a recharging effect in the deep aquifer.

Ground water measurements will be collected monthly from MW-1 in order to establish seasonal high ground water conditions. Ground water conditions should be expected to vary with changes in season, on- and off-site land usage, and other factors.

Table 2
Summary of Static, Hand-Collected Ground Water Level Measurements in Well MW-1

Date	MW-1 Depth to Water (feet)	MW-1 Approximate Elevation of Ground Water
04/14/14	66.8	268.2
04/25/14	66.20	268.80
05/09/14	66.11	268.89
06/05/14	66.01	268.99
07/02/14	65.95	269.05

Regionally, Vashon advance outwash sediments are mapped as underlying Vashon lodgement till beneath most of the Edmonds area. Ground water flow in the Vashon advance outwash sediments in the Perrinville Creek Basin is likely generally to the northwest, towards the Puget Sound. Discharge from the Vashon advance outwash likely occurs within the Perrinville Creek Basin as seeps within the creek. Recharge to the Vashon advance outwash occurs from rainfall slowly infiltrating through the glacial till sediments and through windows of advance soils exposed at the surface.

HYDROGEOLOGIC CRITICAL AND SENSITIVE AREAS

Critical and sensitive areas reviewed for the proposed stormwater retrofit include critical aquifer recharge areas (CARAs), steep slopes, and other areas that are hydrogeologically sensitive.

Critical Aquifer Recharge Areas (CARAs)

CARAs are areas in Snohomish County that overlie significant ground water resources and are particularly susceptible to ground water contamination, usually due to permeable soil units present at the ground surface. They are protected as critical areas under the Washington State

Growth Management Act. However, no areas meeting the criteria for CARAs exist in the vicinity of the City of Edmonds. Thus, additional specific recommendations for protection of this critical area type are not discussed within this report.

Steep Slopes and Hydrogeological Problem Areas

The 1991 *Edmonds Drainage Basin Studies, Edmonds Way, Perrinville, and Meadowdale Basins*, by R.W. Beck and Associates, identifies sensitive areas within the Perrinville Basin. Areas of steep slopes are shown on Figure 5, with slopes between 15 to 25 percent having moderate erosion potential, and slopes greater than 25 percent susceptible to high erosion. The upper reaches of Perrinville Creek, upstream of Olympic View Drive (OVD) and 76th Avenue West, are classified as moderate erosion potential. Downstream of OVD and 76th, erosion potential becomes high in the immediate vicinity of the creek. Other isolated areas of moderate and steep slopes are identified in Figure 5. When infiltrating stormwater into Vashon advance outwash, care should be taken to avoid infiltrating near a slope where the Qva contact with the underlying transitional beds would cause ground water to daylight. In such a setting, ground water discharge from the Vashon advance outwash at the contact could seep out and over the slope, thereby increasing erosion and/or landslide hazard potential.

Hydrogeologic “problem” areas, as classified by R.W. Beck, include areas of severe sedimentation or erosion, areas of heavy ground water emergence, and landslide complexes (Figure 6). Though R.W. Beck did not map major landslide complexes within Perrinville Basin, the Meadowdale Basin, immediately north of Perrinville, has a large landslide complex and is mapped as a hydrogeologic problem area. Within Perrinville Basin, the only mapped problem area is the severe sedimentation and erosion and smaller scale landslides that occur in the lower reaches of Perrinville Creek, downstream of OVD and 76th Avenue West. This study seeks to reduce the severity of erosion in that area by identifying infiltration opportunities upstream.

Based on available data, the proposed projects evaluated for this study should not cause additional erosion or increase landslide hazard potential. This opinion is based on the understanding that infiltration locations are located a sufficient lateral distance from steep slopes where Qva contacts the underlying transitional beds to avoid potential impacts. After infiltration system designs and locations have been finalized by the City, we recommend that AESI be allowed to review the final design to provide updated recommendations and hazard analysis.

INFILTRATION EVALUATION

The subsurface soils consist of about 15 to 25 feet of low-permeability, fine-grained Vashon lodgement till at ground surface in much of the upland area, underlain by 5 to 10 feet of silty Vashon advance outwash, and finally by relatively “clean” and permeable, sandy Vashon advance outwash. It is our opinion that, from a geotechnical and hydrogeological standpoint, stormwater infiltration into the "clean" Vashon advance outwash is feasible in the Perrinville Basin based on the results of our subsurface exploration, grain-size testing, and ground water level monitoring. The relatively low amounts of silt in the advance outwash, beginning about 10 feet into the Qva, indicate that it will perform well as a receptor soil for stormwater infiltration. Optimum infiltration can be achieved if the stormwater bypasses the till and silty Qva and is directed instead to the underlying "clean" Qva for infiltration. Depth to ground water within the advance outwash is deep beneath the southern upland areas, and the thickness of the unsaturated outwash beneath the southern uplands is between 60 and 100 feet under most of the basin.

Based on conversations with Tetra Tech, and our knowledge of the project, the City seeks to reduce peak flow rates and their durations through a combination of LID/GSI and conventional stormwater retrofits in the Perrinville Basin. Reducing the quantity of water diverted to storm drains by utilizing subsurface infiltration opportunities within the basin can help achieve these goals.

Our exploration program and laboratory grain-size analysis indicate that stormwater infiltration is feasible for select sites in the Perrinville Basin.

Sieve Analysis and Preliminary Infiltration

Mechanical sieve analyses were conducted on 10 samples of the Vashon advance outwash from multiple exploration borings and depths in the Perrinville Basin study area. An additional four sieves were completed for our work at Lynndale Elementary School. Sieve results for both projects are included in Appendix A. Some samples were taken immediately below the till-outwash contact, where silt-rich outwash was encountered. Some of the sieved samples were obtained between 20 to 30 feet below the contact, in relatively clean advance outwash sands. Copies of the sieve results are included in Appendix B.

Appendix D contains a plot of sieve results from AESI's in-house database. The results are presented as: a data envelope encompassing 97 samples (solid blue lines), the calculated median grain-size distribution (dashed blue line), and individual Perrinville Basin samples. The Perrinville Basin samples are further divided into silty Qva (black dashed lines), and "clean" Qva from greater depths (solid black lines). The plot indicates that the Perrinville Basin grain-size distribution is relatively close to the median grain size of the full Qva data set. Perrinville samples have less coarse and medium sand than the average, but have about the same silt content.

Also in Appendix D is a histogram of Underground Injection Control (UIC) well flow rate information from AESI's database. Flow rates range from 330 gallons per minute (gpm) to 5 gpm. In general, high flow rates were obtained from coarse-grained Qva deposits with trace silt and thick unsaturated zones. Low flow rates were observed in silty fine sands with thin unsaturated intervals.

The Perrinville sieve data and thick unsaturated zone beneath the southern uplands indicate that flow rates from properly constructed UIC wells should be near the average for the data set. In our opinion, **preliminary** planning level flow rates ranging from about 20 to 60 gpm (per Drain) are reasonable for properly constructed Pit Drains or Drilled Drains. These two infiltration options are discussed below. Pit Drains should penetrate a minimum thickness of 10 feet of "clean" Qva. Drilled Drains should penetrate a minimum thickness of 20 feet of "clean" Qva. Ultimately, in-situ flow testing will be required to provide infiltration design rates as the project civil design plans are developed.

DEEP INFILTRATION CONSIDERATIONS

The available subsurface data indicates shallow infiltration, such as in conventional rain gardens, is feasible in locations where Vashon advance outwash outcrops at the surface (such as in EB-4 and MW-1). However, shallow infiltration is not recommended in our other exploration areas (EB-1, EB-2, EB-3, and EB-5) due to the presence of low-permeability till at ground surface. In the areas of EB-1, EB-2, and EB-3, deep infiltration into the underlying Vashon advance outwash is feasible and recommended. Deeper infiltration in the vicinity of EB-5 is expected to be limited by the perched ground water encountered in the Vashon advance outwash. Infiltration beneath the footprint of proposed infiltration facility locations, to be finalized as the project progresses, can be accomplished through LID/GSI stormwater retrofits. This includes Pit Drains where the till is thin, generally less than 10 feet or through the use of Drilled Drains where the till is about 20 to 30 feet thick.

PIT DRAIN CONCEPT

Pit drains are trenches, typically between 10 and 20 feet deep, intended to provide moderately deep infiltration opportunities by penetrating past a thin cap of till and/or silty Qva, and accessing the "clean" Vashon advance outwash in order to maximize infiltration potential. Dimensions vary according to site-specific infiltration requirements, but are generally on the order of about 2 to 4 feet wide (excavator bucket width) and about 6 to 10 feet long. It is typical to install a rain garden or sand filter system above pit drains to meet water quality criteria before infiltration. The rain gardens also act as a conduit by conveying stormwater collected over a large surface area to the underlying pit drain. A pit drain is excavated parallel and in the footprint of the overlying rain garden. These drains allow an infiltration facility to use a greater volume of the native outwash sediments for infiltration by penetrating through the less-permeable silty sand horizons and allowing infiltrated stormwater to contact a greater cross section of the receptor sediments (Qva).

Pit Drain Design Considerations

Pit drains can be excavated to depths between about 10 and 20 feet below the bottom of rain gardens and should be backfilled in accordance with the “Pit Drain Detail,” Figure 7. Backfill should be free-draining granular material, as detailed later in this report. Prior to placement of the 4 x 8 sand referenced below, the pea gravel must be water-settled to minimize settlement of the pea gravel backfill once the facility is “on-line.”

The pea gravel or equivalent material should be brought up to a level that accommodates the minimum recommended thicknesses of overlying layers, as presented on Figure 7. A minimum 18-inch-thick layer of 4 x 8 graded sand media or equivalent, as determined by the geotechnical engineer, will be placed on top of the pea gravel. The 4 x 8 sand minimizes migration of the finer-grained “water quality” filter sand into the pea gravel. “Water quality” filter sand should be placed from the top of the 4 x 8 sand and brought to a minimum depth of 18 inches across the infiltration structure bottom. A geotechnical engineer or engineering geologist should be present during advancement and backfilling of the pit drains.

Pit Drain Materials, Gradations, and Details

Pea gravel gradation should be in accordance with 2008 Washington State Department of Transportation (WSDOT) *Standard Specifications for Road, Bridge and Municipal Construction*, M41-10, Specification 9-03.12(4).

4 x 8 sand media is used to minimize the migration of fine-grained “water quality” filter sand into pea gravel, and is described as “sediment size passes the No. 4 sieve but is retained on the No. 8 sieve.”

According to the 2005 Ecology Manual, water quality can be achieved through the use of a “water quality” sand filter. The sand filter must consist of a minimum of 18 inches of filter sand.

The sand filter must consist of a medium sand meeting the size gradation (by weight) given in Table 3. The contractor must obtain a grain-size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. Periodic inspection and grain-size analysis should be performed to verify the composition of the filter sand.

Table 3
Medium Sand Specification

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: Washington State Department of Ecology *Stormwater Management Manual for Western Washington*, 2005, p. 8-16, after *King County Surface Water Design Manual*, September 1998.

Drain Infiltration Rate Testing During Construction

At the time of construction, infiltration rate testing should be completed on a representative number of pit drains to confirm the facility meets design infiltration rates. In summary, the infiltration testing should utilize a continuous water supply source to obtain steady state flow conditions during the test period. If feasible, the head level should be maintained near the top of the pit drain to mimic fully saturated conditions. Water levels in the pit drain can be monitored via a 2-inch PVC sounding tube, and flow rates from the water supply should be metered to obtain both instantaneous rates and total volume. The data collected during testing can then be analyzed to determine the effective infiltration rate of the pit drain.

DRILLED DRAIN CONCEPT

Drilled Drains are a type of UIC well constructed by drilling through the low-permeability till and penetrating into the underlying permeable Vashon advance outwash sands using solid-stem auger style drilling equipment. Surface casing would be advanced to the base of the low-permeability till and the remaining portion of the boring would typically be drilled as an open hole or with temporary casing. The boring is backfilled with a permeable media extending from the base of the boring to ground surface. The Drilled Drains act as a conduit by conveying treated stormwater runoff from an overlying rain garden vertically down past the low-permeability till into the receptor horizon where the water can infiltrate into the unsaturated Vashon advance outwash. Figure 8 is a schematic cross-section profile illustrating the Drilled Drain well configuration beneath a bioretention swale.

Drilled Drains can be installed to access an "intermediate depth" receptor horizon of advance outwash to achieve stormwater infiltration beneath low-permeability till deposits. The term "intermediate depth" is intended to apply to a permeable unit encountered at depths of about 20 to 30 feet below ground surface. Drilled Drains are designed to access an unsaturated interval thickness of about 20 to 30 feet. The combined thickness of 20 to 30 feet of low-permeability material and about 20 to 30 feet of infiltration receptor results in a "typical" Drilled Drain depth of about 40 to 60 feet. This depth range is generally considered too deep for Pit Drain construction in roadside rain garden applications, but is shallow enough that construction of a water well style UIC well is not necessary. Drilling equipment used to construct "intermediate depth" Drilled Drains has a 'reach' or depth capability of about 40 to 60 feet. Larger drilling equipment can achieve greater depths, but due to work space requirements may not be well suited to work within arterial ROWs. Drilled Drains could be located along shoulders of ROWs where explorations indicate suitable depth to receptor soil, and should be hydraulically connected to the overlying bioretention swale.

DESIGN CONSIDERATIONS

Key design considerations for Drilled Drains include well design, including surface seal requirements, observation during drilling, backfill specifications, flow testing, and well protection.

Well Design

The means and methods of drilling are the responsibility of the contractor. However, Drilled Drain wells are commonly constructed using a solid-stem auger drill rig to complete the boring and install either permanent or temporary well casing. Backfill consisting of a select import media such as pea gravel or granulithic is placed inside the boring using a chute, tremie pipe, or other methods. A typical well design includes a 36-inch-diameter cased surface hole extending from ground surface to the base of the low-permeability unit, and is completed open hole from the top of the infiltration receptor horizon (Vashon advance outwash) to total depth.

Ecology does not require installation of a surface seal if the drilled drains are located beneath the water quality treatment cell. This assumes only treated stormwater can flow into the Drilled Drain well. Alternative designs can be considered. However, a surface seal may be required as part of Drilled Drain construction to meet Ecology well construction standards. A surface seal, if required, would likely extend through the full thickness of the low-permeability unit, and would terminate near the top of the receptor horizon. Permanent surface casing will be required assuming a surface seal is installed. Permanent casing would be cut flush with the design subgrade elevation of the bioretention cell.

Observation

Drilling and well completion activities should be observed by a qualified representative of the owner who is independent of the contractor. The representative would observe drilling activities, review samples collected during drilling, and generate a descriptive log of materials encountered during drilling. The representative would provide recommendations to the owner regarding total depth of drilling if unanticipated subsurface conditions are encountered at the time of drilling.

Backfill Specifications

Backfill media must be free draining while limiting the potential for migration of native formation fines into the backfill. Pea gravel, granulithic, or other suitable backfill media specification should be determined during the exploration/design phase of the project. A monitoring pipe constructed of Schedule 80 PVC casing that is 2 inches in diameter and flush-threaded must be installed to the base of the Drilled Drain prior to backfill. The bottom 10 feet of the PVC casing should consist of machine-slotted screen (0.010-inch slot width) with an end cap to facilitate water level monitoring during testing and for the life of the well. Backfill media must be water-settled after placement. Water-settling is typically conducted as a part of flow testing, discussed below.

Flow Testing

Flow testing should be conducted in Drilled Drains to confirm the design flow rates are achieved. Flow testing should be conducted by the owner's qualified representative with assistance from the contractor. Depending on design requirements and subsurface conditions observed during construction, the number of flow tests may include all Drilled Drains or a subset of the total number of Drilled Drains.

Well Protection

Following construction of the Drilled Drains, the drilled drains must be protected from contamination during subsequent construction phases and during permanent operation of the system. Means and methods are the responsibility of the contractor. Previous methods of protection have included placement of 12-inch or thicker layer of medium sand or temporary placement of plastic sheeting or other impermeable material to prevent migration of fines into the backfill. Welded steel lids have also been used. The permanent design should consider the potential for migration of fines from the amended soils placed in the bioretention cell. This consideration may require a modification of standard bioretention cell design criteria.

OPERATIONS AND MAINTENANCE

AESI can provide additional guidance on infiltration system operation and maintenance. If requested, AESI could provide recommendations on maintenance timelines, inspection elements and purposes, and a long-term maintenance plan discussing inspections, performance testing, and eventual Drilled Drain rehabilitation or replacement if siltation of the Drilled Drain occurs.

RECOMMENDATIONS FOR ADDITIONAL STUDY AND CLOSING

The information presented in this report is preliminary and the intended use is to provide guidance for initial planning level design. Site-specific subsurface information should be obtained as design plans and concepts are developed. Many factors influence infiltration facility designs including actual infiltration rate at the specific facility location, depth to ground water, proximity to surface water features including spring discharge zones, proximity to downgradient built infrastructure and other factors. Specific hydrogeologic and geotechnical studies should be performed for each selected block or project area during future design stages. These studies may include but are not limited to subsurface exploration and flow testing, UIC well design details, block or project specific geotechnical design recommendations for construction of vaults, trenches, rain gardens or other infiltration elements. Geotechnical construction monitoring during UIC well installation and earthwork related activities is also recommended.

We have enjoyed working with you on this study and are confident that these preliminary recommendations will aid in the successful completion of your project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington

State of Washington
Hydrogeologist
496
Licensed Geologist
Curtis J. Koger

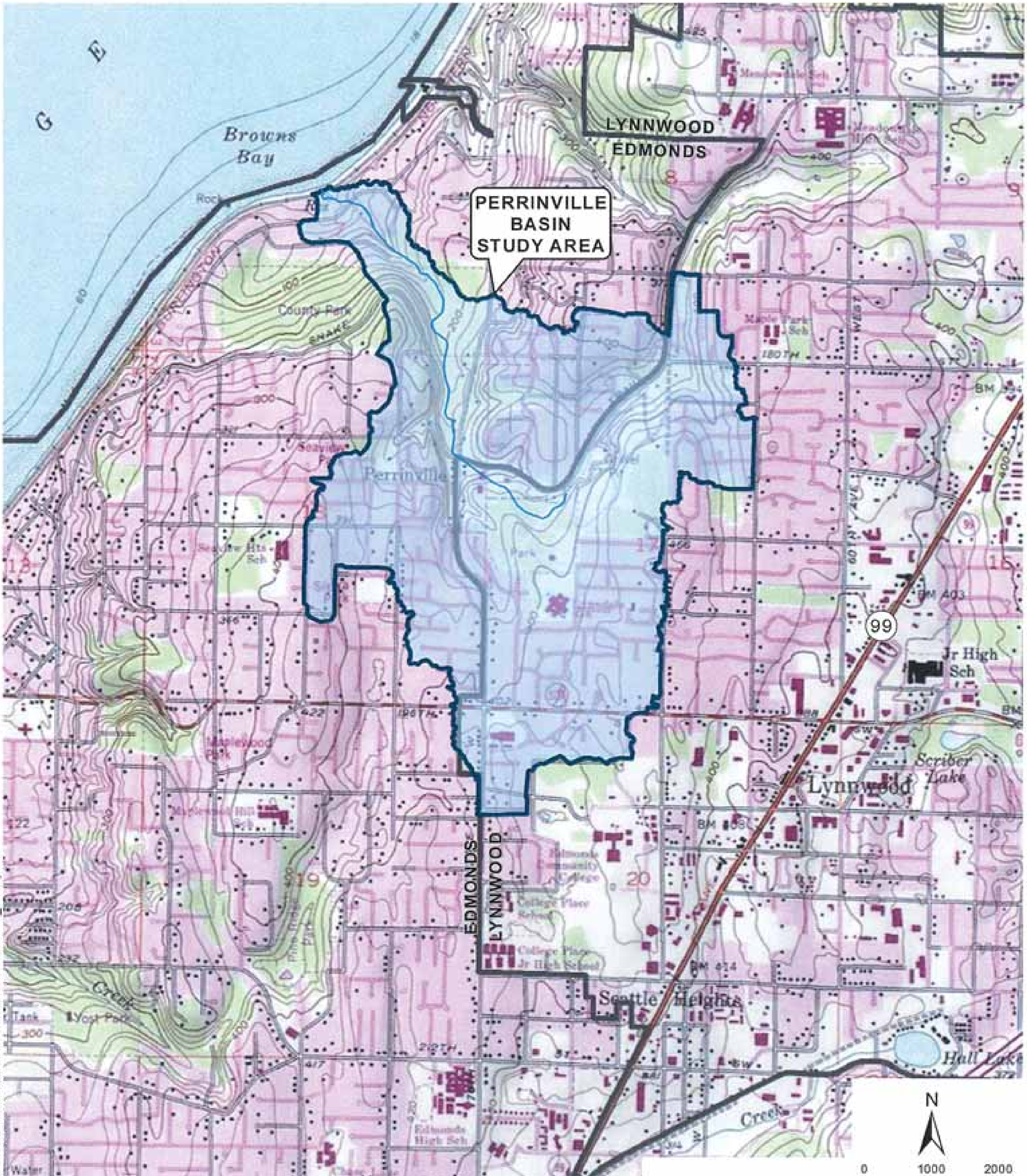
7/17/14

(for)

Danika M. Globokar, E.I.T., G.I.T.
Senior Staff Geotechnical Engineer

Curtis J. Koger, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

Attachments:	Figure 1:	Vicinity Map
	Figure 2:	Site and Explorations
	Figure 3:	Schematic Hydrogeologic Cross Section A-A'
	Figure 4:	Schematic Hydrogeologic Cross Section B-B'
	Figure 5:	Sensitive Areas: Steep Slopes
	Figure 6:	Sensitive Areas: Hydrogeologic Problem Areas
	Figure 7:	Conceptual Pit Drain Detail
	Figure 8:	Conceptual Design of Drilled Drain
	Appendix A:	Exploration Logs
	Appendix B:	Grain-Size Analysis
	Appendix C:	MW-1 Hydrograph
	Appendix D:	Grain Size and Flow Rate Relationship Analysis



REFERENCE: USGS, SNOHOMISH CO

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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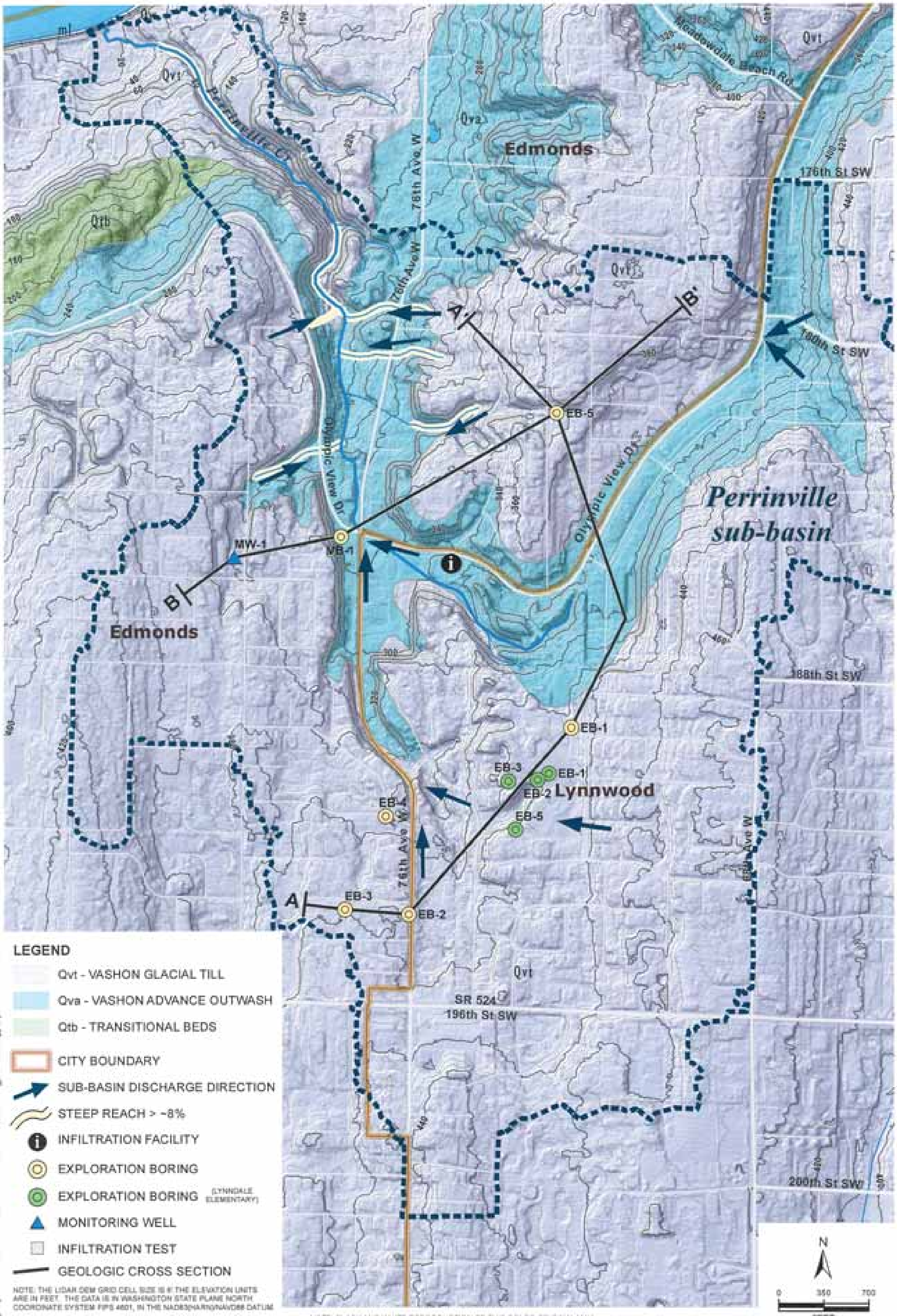
VICINITY MAP

PERRINVILLE CREEK
EDMONDS, WASHINGTON

FIGURE 1

DATE 7/14

PROJ. NO. KE130422A



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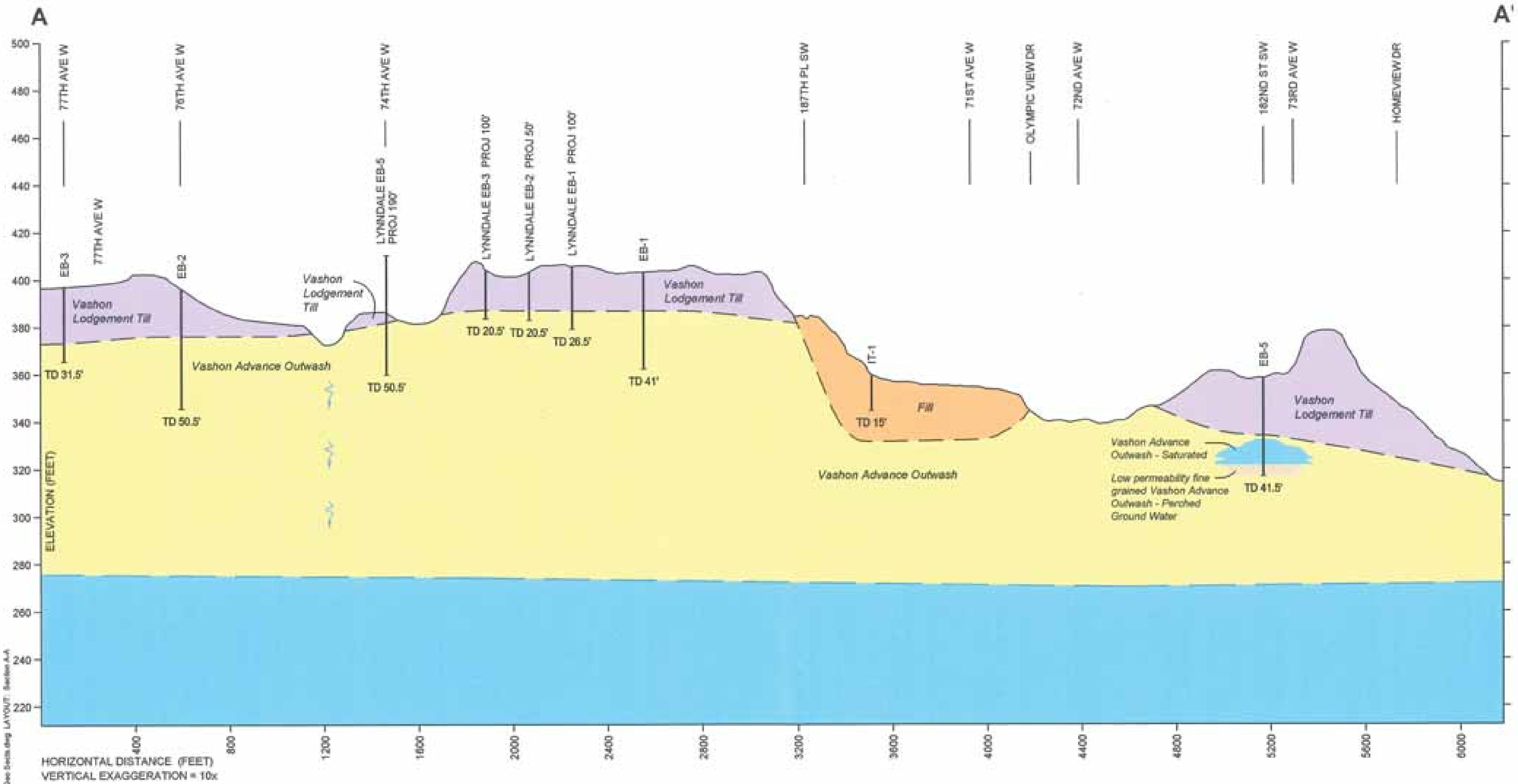
SURFACE GEOLOGY AND EXPLORATION SITES
PERRINVILLE CREEK
SNOHOMISH CO, WASHINGTON

FIGURE 2
DATE 7/14
PROJ. NO. KH130422A



130422 Perrinville Basin \ 130422 Geo Sects.dwg LAYOUT: Section A-A

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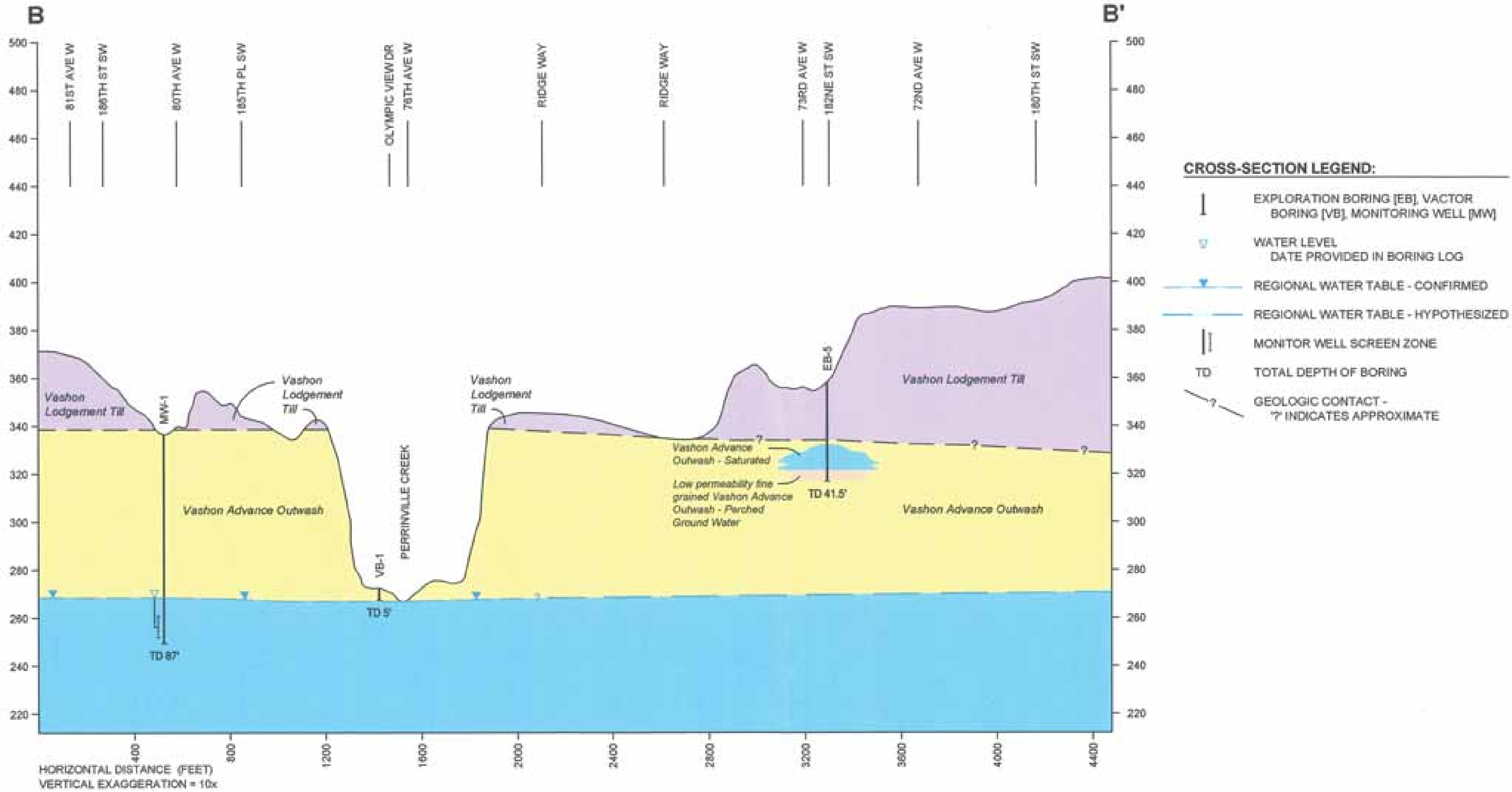
SCHEMATIC GEOLOGIC CROSS-SECTION A - A'
PERRINVILLE
EDMONDS, WASHINGTON

FIGURE 3
DATE 5/14
PROJECT NO. KH130422A



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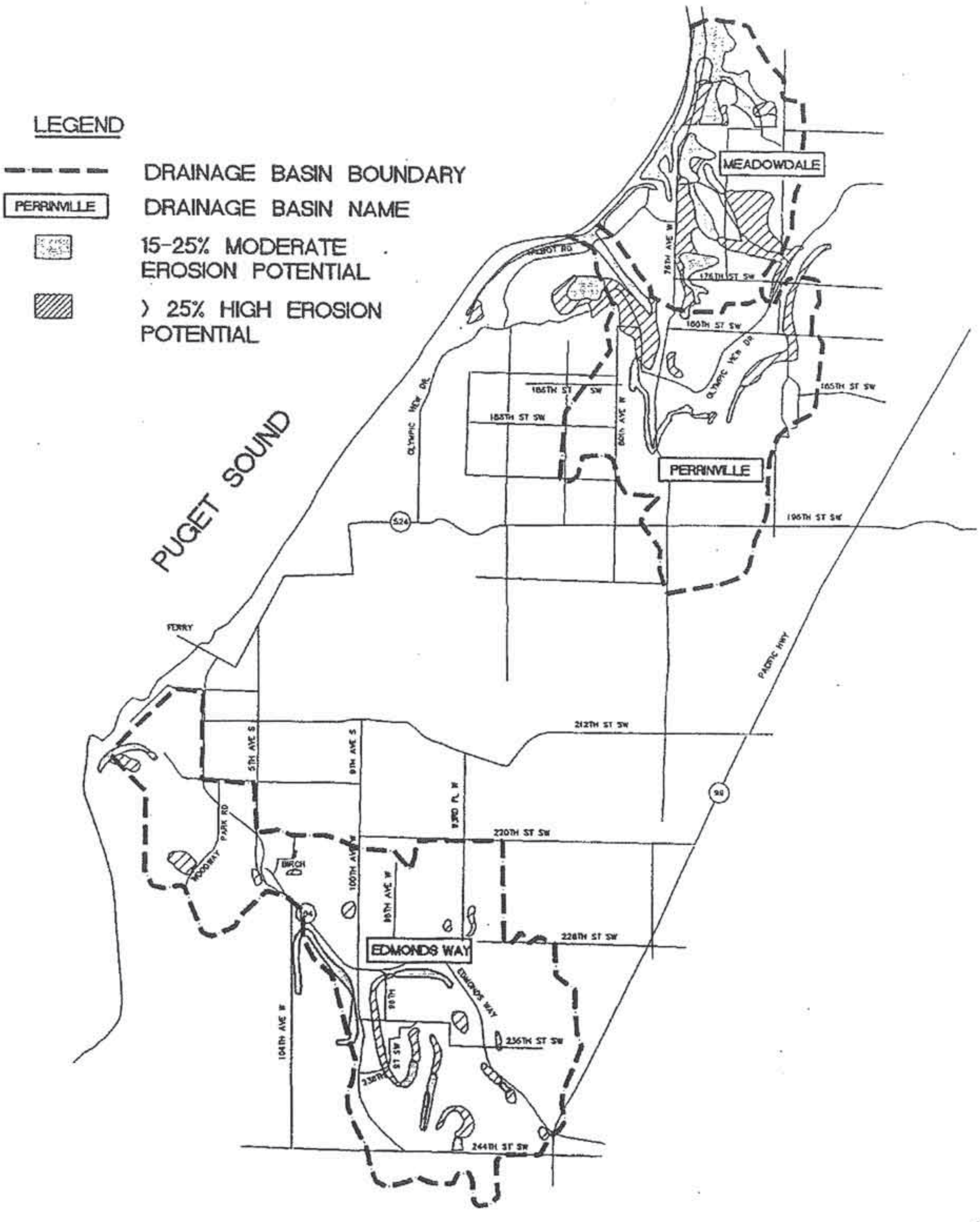
SCHEMATIC GEOLOGIC CROSS-SECTION B - B'
PERRINVILLE
EDMONDS, WASHINGTON

FIGURE 4
DATE 5/14
PROJECT NO. KH130422A



N

0 2000 4000
FEET - APPROXIMATE

REFERENCE: R.W. BECK AND ASSOC.

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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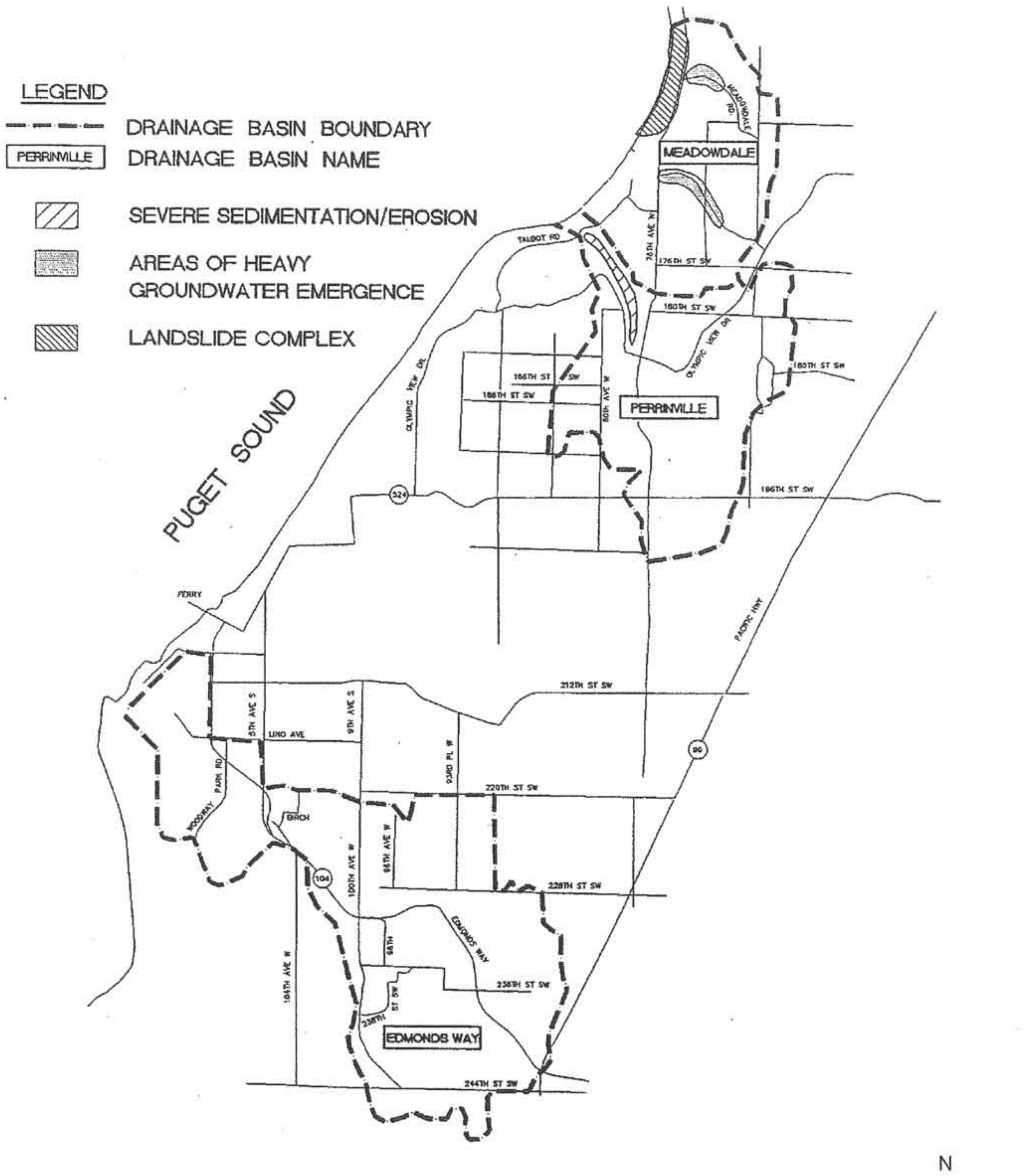
SENSITIVE AREAS - STEEP SLOPES

PERRINVILLE CREEK STORMWATER FLOW REDUCTION STUDY
SNOHOMISH COUNTY, WASHINGTON

FIGURE 5
DATE 5/14
PROJ. NO. KH130422A

130422 Perrinville Basin \ 130422 Sensitive Areas.cdr PAGE 1: Slopes



REFERENCE: R.W. BECK AND ASSOC.

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SENSITIVE AREAS - HYDROGEOLOGIC PROBLEM AREAS

PERRINVILLE CREEK STORMWATER FLOW REDUCTION STUDY

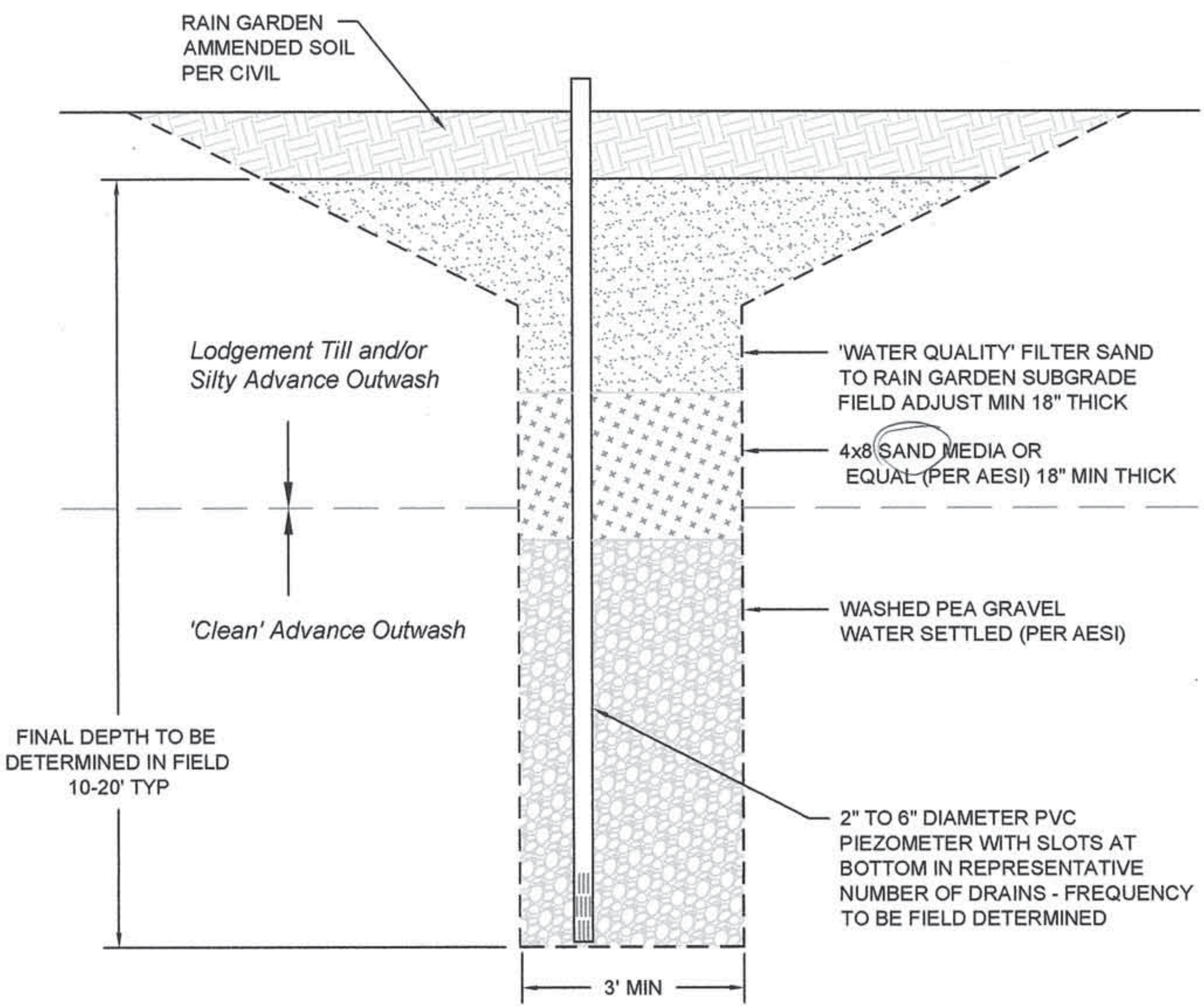
SNOHOMISH COUNTY, WASHINGTON

FIGURE 6

DATE 5/14

PROJ. NO. KH130422A

130422 Perrinville Basin \ 130422 Sensitive Areas.cdr PAGE 2: HydroGeo



NOTE: AN AESI REPRESENTATIVE MUST BE PRESENT AT ALL TIMES DURING ADVANCEMENT AND BACKFILLING OF THE PIT DRAINS.

130422 Perrinville Basin \ 130422 fineger drain.dwg LAYOUT: Pit Drain

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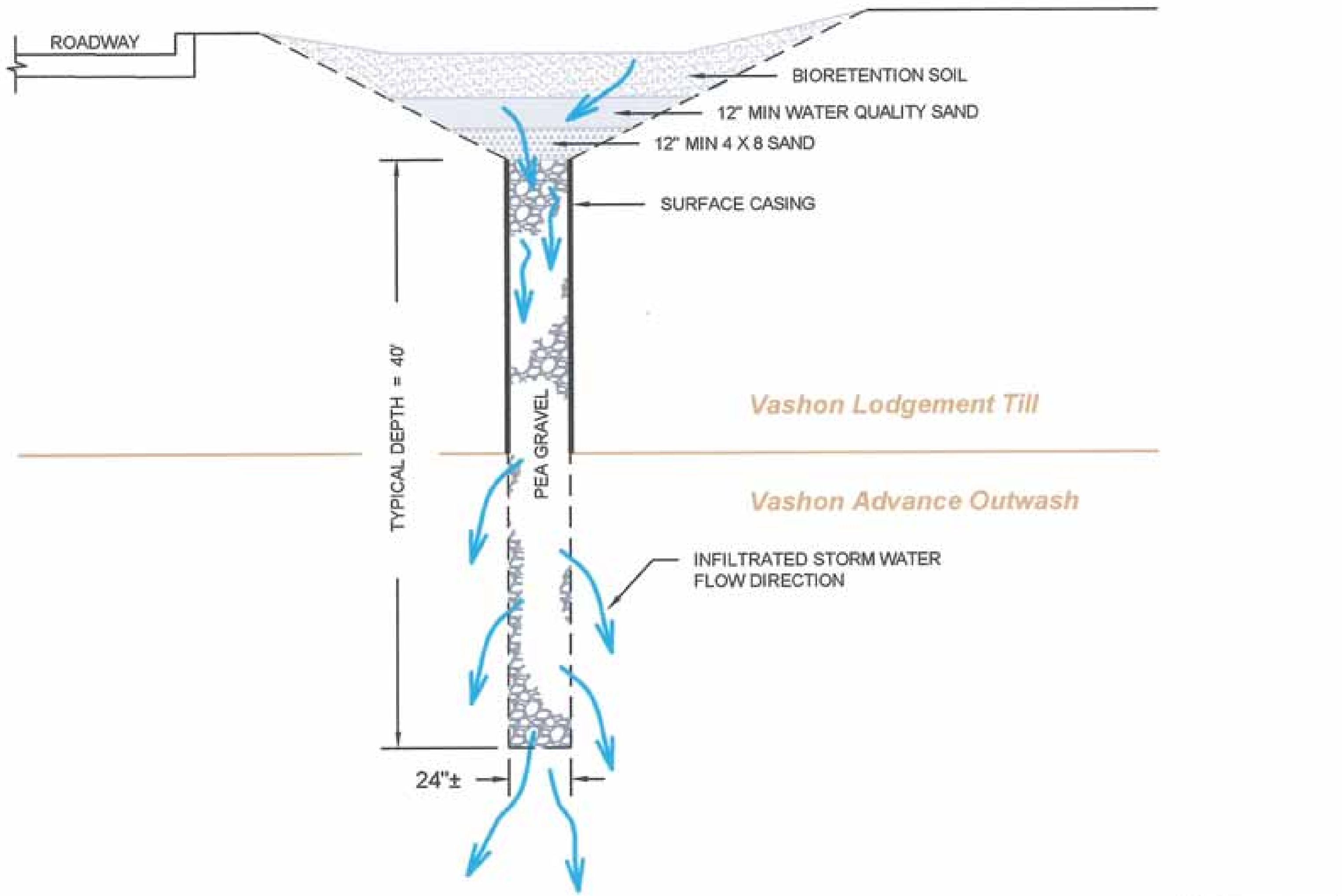
CONCEPTUAL PIT DRAIN DETAIL

PERRINVILLE CREEK STORMWATER FLOW REDUCTION STUDY
EDMONDS, WASHINGTON

FIGURE 7
DATE 5/14
PROJ. NO. KH130422A



NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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DRILLED DRAIN INFILTRATION SCHEMATIC CROSS-SECTION

PERRINVILLE CREEK STORMWATER FLOW REDUCTION STUDY
EDMONDS, WASHINGTON

FIGURE 8
DATE 5/14
PROJECT NO. KH130422A

130422 Perrinville Basin \ 130422 Pit Drain.dwg LAYOUT: 130422 Drilled Drain 5-14

APPENDIX A

Exploration Logs

Major Division	Subdivision	Fines	Symbol	Description
Coarse-Grained Soils - More than 50%(1) Retained on No. 200 Sieve	Gravels - More than 50%(1) of Coarse Fraction Retained on No. 4 Sieve	≤5% Fines(5)	GW	Well-graded gravel and gravel with sand, little to no fines
			GP	Poorly-graded gravel and gravel with sand, little to no fines
		≥15% Fines(5)	GM	Silty gravel and silty gravel with sand
			GC	Clayey gravel and clayey gravel with sand
	Sands - 50%(1) or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines(5)	SW	Well-graded sand and sand with gravel, little to no fines
			SP	Poorly-graded sand and sand with gravel, little to no fines
		≥15% Fines(5)	SM	Silty sand and silty sand with gravel
			SC	Clayey sand and clayey sand with gravel
Fine-Grained Soils - 50%(1) or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50		ML	Silt, sandy silt, gravelly silt, silt with sand or gravel
			CL	Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			OL	Organic clay or silt of low plasticity
	Silts and Clays Liquid Limit 50 or More		MH	Elastic silt, clayey silt, silt with micaceous or diatomaceous fine sand or silt
			CH	Clay of high plasticity, sandy or gravelly clay, fat clay with sand or gravel
			OH	Organic clay or silt of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

Terms Describing Relative Density and Consistency

	Density	SPT(2) blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50

	Consistency	SPT(2) blows/foot
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Chemical
DD = Dry Density
K = Permeability

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

(3) Estimated Percentage

Component	Percentage by Weight
Trace	<5
Few	5 to 10
Little	15 to 25
With	- Non-primary coarse constituents: ≥ 15% - Fines content between 5% and 15%

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch
Slightly Moist - Perceptible moisture
Moist - Damp but no visible water
Very Moist - Water visible but not free draining
Wet - Visible free water, usually from below water table

Symbols

Sampler Type

Blows/6" or portion of 6"

10
15
20

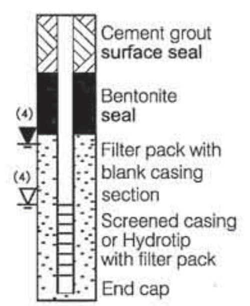
2.0" OD Split-Spoon Sampler (SPT)

Bulk sample

Grab Sample

Sampler Type Description

3.0" OD Split-Spoon Sampler
3.25" OD Split-Spoon Ring Sampler
3.0" OD Thin-Wall Tube Sampler (including Shelby tube)
Portion not recovered



(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of ground water
▼ ATD = At time of drilling
▽ Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 15%

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

Associated Earth Sciences, Inc.

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH130422A	-MW-1	1 of 3

Project Name: Perrinville
Elevation (Top of Well Casing): 335
Water Level Elevation: 268
Drilling/Equipment: Geologic Drill / Trailer Rig
Hammer Weight/Drop: 140# / 30"

Location: Edmonds, WA
Surface Elevation (ft): 335.00
Date Start/Finish: 4/14/14,4/14/14
Hole Diameter (in): 8 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Flush mount monument Concrete seal 0 to 1.5 feet				**Asphalt - 2 inches** **Crushed gravel - 4 inches** **Vashon Advance Outwash**
		Bentonite grout 1.5 to 71 feet				
5		2-inch I.D. PVC blank: 0 to 75 feet		3 4 4		Loose, moist, gray to grayish brown with occasional orange mottling, silty fine SAND, few to trace medium sand, little gravel; unsorted (SM).
10				3 3 2		Loose, moist, grayish brown with occasional orange mottling, fine to medium SAND, few to little silt, little gravel, with thin beds of silt; charcoal present in beds; thinly stratified (SM/ML)
						Driller notes soil is firming up.
15				9 12 17		Medium dense, moist, light brown, medium SAND, few coarse sand, few silt; massive (SP).
20				13 23 31		Very dense, slightly moist, light grayish brown, fine to medium SAND, trace coarse sand, few gravel, few silt; faintly stratified (SP).
				9 13 24		Dense, slightly moist, light grayish brown, fine SAND, few medium sand, few silt, trace coarse sand; stratified to thinly stratified (SP).
25				17 26 33		Very dense, slightly moist, light grayish brown, fine to medium SAND, little to few gravel, few silt; massive (SP).
				17 27 27		Very dense, slightly moist, light grayish brown, fine to medium SAND, few gravel, few silt; stratified (6 to 8 inch beds) (SP).

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH130422A	-MW-1	2 of 3

Project Name: Perrinville
Elevation (Top of Well Casing): 335
Water Level Elevation: 268
Drilling/Equipment: Geologic Drill / Trailer Rig
Hammer Weight/Drop: 140# / 30"

Location: Edmonds, WA
Surface Elevation (ft): 335.00
Date Start/Finish: 4/14/14,4/14/14
Hole Diameter (in): 8 inches

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
				8 12 13		Medium dense, slightly moist to moist grayish brown, fine SAND, little medium sand, little silt, few gravel; thin beds (1 to 2 inch beds) of medium sand, fine sand to silt (SM-SP).
				13 29 33		Very dense, slightly moist, light grayish brown, fine SAND, few medium sand, trace gravel, few to trace silt; stratified (4 to 8 inch beds) (SP).
35				23 33 37		Very dense, slighty moist to moist, light grayish brown, fine to medium SAND, few gravel, few silt; massive (SP).
				23 33 43		Very dense, slightly moist, light grayish brown, fine SAND, few to little medium sand, few gravel, few silt; massive (SP).
40				23 35 35		Very dense, slightly moist, light grayish brown, fine to medium SAND, few to trace gravel, few silt; massive (SP).
45				24 30 33		Very dense, slightly moist to moist, light grayish brown, fine to medium SAND, few coarse sand, few gravel, few silt, beds (3 to 8 inches) of fine sand and fine to medium sand; stratified (SP).
50				30 43 43		Very dense, slightly moist to moist, light grayish brown, fine to medium SAND, few gravel, few coarse sand, few silt; faintly stratified (6 inch beds) (SP).
55				18 29 50/5.5"		As above, beds (4 to 8 inches) of fine sand, little silt, and fine to medium sand (SP).

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
Water Level ()
Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KH130422A	-MW-1	3 of 3

Project Name	Perrinville	Location	Edmonds, WA
Elevation (Top of Well Casing)	335	Surface Elevation (ft)	335.00
Water Level Elevation	268	Date Start/Finish	4/14/14,4/14/14
Drilling/Equipment	Geologic Drill / Trailer Rig	Hole Diameter (in)	8 inches
Hammer Weight/Drop	140# / 30"		

Depth (ft)	Water Level	WELL CONSTRUCTION	S T	Blows/ 6"	Graphic Symbol	DESCRIPTION
				16 23 27		Very dense, slightly moist to moist, light grayish brown, fine SAN D, little medium sand, few to trace silt; massive (SP).
65				18 28 42		Very dense, very moist, grayish brown, fine to medium SAND, few gravel, few silt, beds (4 to 8 inches) of fine sand, and fine to medium sand; faintly stratified (SP).
70		10/20 sand 71 to 85 feet		12 24 35		Very dense, wet, grayish brown, fine to medium SAND, few gravel, few silt; stratified (4 to 6 inch beds) (SP).
75		2-inch I.D. PVC well screen: 0.020-inch slot width, 75 to 85 feet		25 50/6"		Driller adding water to reduce heave at 75 feet; 13 inches heave. Very dense, wet, grayish brown, fine SAND, few medium sand, few silt, trace gravel; faintly stratified (SP).
80				6 12 26		6 inches heave. Dense, wet, grayish brown, fine SAND, few medium to coarse sand, few silt, trace gravel; massive (SP). Driller notes blow counts are likely overstated due to heave.
85		Slip cap; Native slough		12 24 50/6"		12 inches heave. Very dense, wet, grayish brown with occasional orange mottling, fine to medium SAND, few silt, trace gravel, micaceous; massive (SP).
		Well tag # BIJ-463				Boring terminated at 87 feet. Well completed at 85 feet on 4/14/14.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG

Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-1	1 of 2

Project Name	Perrinville	Ground Surface Elevation (ft)	402
Location	Edmonds, WA	Datum	N/A
Driller/Equipment	Geologic Drill / Trailer Rig	Date Start/Finish	4/14/14,4/14/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	8 inches

Depth (ft)	ST	Samples	DESCRIPTION	Blows/6"	Blows/Foot
			Asphalt - 2 inches		
			Crushed gravel - 4 inches		
			Vashon Lodgement Till		
5		S-1	Very dense, slightly moist to dry, light brown, fine to medium SAND, with gravel, with silt, with gravel; unsorted (SM).	32 38 35	73
10		S-2	Hard, slightly moist, grayish brown, SILT, with fine sand, with fractured gravel; unsorted (ML).	12 32 35	67
			Driller notes lots of gravel.		
			Vashon Advance Outwash - Silty		
15		S-3	Very dense, very moist, grayish brown with light brown mottling, silty medium to coarse SAND, little gravel; massive (SM).	24 33 50/5.5"	83/11.5"
20		S-4	Very dense, very moist, grayish brown with occasional orange mottling, fine to medium SAND, with silt, with gravel; massive (SM).	24 35 50/5"	85/11"
			Driller notes change in drilling at 23 feet.		
			Vashon Advance Outwash		
25		S-5	Very dense, moist to very moist, grayish brown, medium SAND, little fine sand, few silt, few gravel; stratified; 6 inches medium sand; 1 inch fine sand, little silt (SM-SP).	22 50/5"	50/5"

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-1	2 of 2

Project Name: Perrinville
Location: Edmonds, WA
Driller/Equipment: Geologic Drill / Trailer Rig
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 402
Datum: N/A
Date Start/Finish: 4/14/14,4/14/14
Hole Diameter (in): 8 inches

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
	S-6	Very dense, moist, grayish brown, fine to medium SAND, few coarse sand, few to little gravel, few silt; massive (SP).	30 50/6"	50/6"
35	S-7	Very dense, moist, grayish brown, fine to medium SAND, trace gravel, few silt, thin interbed of silty fine sand contains perched water; otherwise stratified (SM-SP).	24 50/6"	50/6"
		Driller notes larger gravel.		
40	S-8	Very dense, moist, grayish brown, fine to medium SAND, little gravel, few silt; massive (SP).	32 50/5"	50/5"
		Bottom of exploration boring at 41 feet No ground water encountered.		
45				
50				
55				

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-2	1 of 2

Project Name	Perrinville	Ground Surface Elevation (ft)	397
Location	Edmonds, WA	Datum	N/A
Driller/Equipment	Geologic Drill / Trailer Rig	Date Start/Finish	4/14/14,4/15/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	8 inches

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
0		**Asphalt / Crushed Gravel**		
		Fill		
	S-1	Medium dense, moist, grayish brown, fine to coarse SAND, little silt, trace to few gravel, trace cobbles; unsorted (SM).		
		Vashon Lodgement Till		
5	S-2	As above, dense to very dense.		
	S-3	Hard, moist, grayish brown, SILT, little to few fine sand, few gravel; unsorted (ML).	16 32 37	69
10	S-4	Hard, moist, grayish brown, SILT, little to few fine sand, few to little gravel; unsorted; diamict texture (ML).	7 42 47	89
15	S-5	As above, little fine sand.	27 50/5"	50/5"
20		**Vashon Advance Outwash**		
	S-6	Very dense, moist, grayish brown, fine to medium SAND, with silt, with fractured gravel; massive (SM).	25 28 30	58
25	S-7	Driller notes auger is bouncing on rock. Very dense, moist, grayish brown, gravelly fine to medium SAND, few silt; gravel is fractured; massive (SP). Large gravel stuck in sampler tip.	50/5"	50/5"

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG

Approved by:

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-2	2 of 2

Project Name	Perrinville	Ground Surface Elevation (ft)	397
Location	Edmonds, WA	Datum	N/A
Driller/Equipment	Geologic Drill / Trailer Rig	Date Start/Finish	4/14/14,4/15/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	8 inches

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
	S-8	Very dense, moist, grayish brown, medium SAND, few fine sand, few gravel, few to trace silt, beds (~3 inches thick) of fine to medium sand and medium to coarse sand (SP).	30 50/6"	50/6"
35	S-9	Very dense, moist, grayish brown, fine SAND, with medium sand, trace gravel, few to trace silt; massive (SP).	21 24 34	58
40	S-10	Driller notes auger is bouncing on rock - disturbed sample. Very dense, moist, grayish brown, gravelly medium SAND, few coarse sand, few fine sand, few silt; massive (SP).	50/3"	50/3"
45	S-11	Very dense, moist, grayish brown, fine to medium SAND, trace gravel, few to trace silt, beds (2 to 4 inches) of fine sand and fine to medium sand (SP).	24 36 50/6"	86/12"
50	S-12	Very dense, moist, grayish brown, medium to coarse SAND, little gravel, trace silt (SP).	50/6"	50/6"
		Bottom of exploration boring at 50.5 feet No ground water encountered.		
55				

Other column headings: S T, Graphic Symbol, Well Completion, Water Level, Other Tests. Blows/Foot scale: 10 20 30 40

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-3	1 of 1

Project Name	Perrinville	Ground Surface Elevation (ft)	397
Location	Edmonds, WA	Datum	N/A
Driller/Equipment	Boretec	Date Start/Finish	5/2/14,5/2/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	8

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
		Sod		
		Vashon Lodgement Till		
5	S-1	Dense, moist, grayish brown, silty fine SAND, little gravel; unsorted (SM).	13 21 16	37
10	S-2	As above, very dense.	50/5"	50/5"
15	S-3	As above.	31 50/3"	50/3"
	S-4	Hard, moist, grayish brown with occasional orange mottling, SILT, with fine sand, with gravel; unsorted (ML).	37 50/8"	50/8"
20	S-5	As above.	50/6"	50/6"
	S-6	Very dense, moist, grayish brown, silty fine to medium SAND, with gravel, trace coarse sand; unsorted (SM).	50/4"	50/4"
		Vashon Advance Outwash		
25	S-7	Very dense, moist grayish brown, silty fine to medium SAND, little gravel; massive (SM).	30 50/3"	50/3"
		Driller notes less gravel.		
30	S-8	Very dense, moist to very moist, grayish brown, fine to medium SAND, with silt, few gravel; massive (SM).	26 34 37	71
		Bottom of exploration boring at 31.5 feet No ground water encountered.		
35				

Column headings also include: S T, Graphic Symbol, Well Completion, Water Level, Other Tests. Blows/Foot scale: 10 20 30 40.

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG

Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-4	1 of 1

Project Name	Perrinville	Ground Surface Elevation (ft)	385
Location	Edmonds, WA	Datum	N/A
Driller/Equipment	Boretec	Date Start/Finish	5/2/14,5/2/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	8

Depth (ft)	S T	Samples	DESCRIPTION	Blows/6"	Blows/Foot
0			**Sod and Topsoil** **Vashon Advance Outwash**		
5	Grab		Medium dense, moist, grayish brown, fine to medium SAND, with to little silt, little gravel; bedding not visible in hand sample (SM).		
10	SPT	S-1	Medium dense, moist to very moist, grayish brown with occasional orange mottling, silty fine SAND, trace medium sand, few gravel; thinly bedded with occasional silt beds (SM).	10 11 16	27
15	SPT	S-2	Dense, moist to very moist, grayish brown, fine SAND, little silt, few medium sand; thinly bedded (1 inch thick beds of light orange, silty fine sand) (SM-SP).	13 22 23	45
20	SPT	S-3	Very dense, very moist, grayish brown with occasional orange mottling, fine to medium SAND, little silt, little gravel; thinly bedded (occasional thin silty beds) (SM-SP). Rock stuck in sampler tip. Blow counts may be overstated.	25 50/5"	50/5"
25	SPT	S-4	Very dense, very moist, grayish brown, fine SAND, few medium sand, little to few silt, trace gravel; thinly bedded (beds of fine sand with silt and fine to medium sand) (SM-SP).	14 23 32	55
30	SPT	S-5	As above. Large gravel in sample tip; blow counts likely overstated. (SM-SP).	50/5"	50/5"
			Bottom of exploration boring at 30.5 feet No ground water encountered.		
35					

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-5	1 of 2

Project Name: Perrinville
Location: Edmonds, WA
Driller/Equipment: Boretec
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 360
Datum: N/A
Date Start/Finish: 5/2/14,5/2/14
Hole Diameter (in): 8

Depth (ft)	S T	Samples	DESCRIPTION	Water Level	Blows/6"	Blows/Foot
			Asphalt and Gravel Base Course			
			Vashon Lodgement Till			
5	Grab		Very dense, moist, grayish brown, SILT, with fine tomeidum sand little to few gravel; unsorted (ML).			
10		S-1	Hard, moist, grayish brown with occasional orange mottling, SILT, few sand, few gravel; unsorted (ML).		31 35 47	82
15		S-2	As above (ML).		37 50/3"	50/3"
20		S-3	Hard, moist to very moist, grayish brown, SILT, with fine sand, few gravel; unsorted (ML).		35 25 34	59
			Vashon Advance Outwash	ATD		
25		S-4	Very dense, wet, grayish brown, fine to medium SAND, with gravel, little to few silt; bedded (SM-SP).		24 26 28	54
30		S-5	Very dense, wet, grayish brown, fine to medium SAND, with silt, little to few gravel; bedded (silty fine sand and fine to medium sand) (SM). Clay lens (2 inches thick).		25 25 28	53
35		S-6	Dense, wet, grayish brown, silty fine to medium SAND, little to few gravel; thinly bedded, occasional silty lenses (SM).		19 21 20	41

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	EB-5	2 of 2

Project Name: Perrinville
Location: Edmonds, WA
Driller/Equipment: Boretec
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 360
Datum: N/A
Date Start/Finish: 5/2/14,5/2/14
Hole Diameter (in): 8

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
		S-7		Very dense, wet, silty fine SAND, few gravel; thinly bedded (SM).			49 50/5"	50/5"	
				Hard, moist, SILT, little fine sand, few gravel; unsorted (ML).					
				Bottom of exploration boring at 41.5 feet Heave encountered from 30 to 40 feet.					
45									
50									
55									
60									
65									
70									
75									

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
Water Level ()
Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	IT-1	1 of 1

Project Name: Perrinville
Location: Edmonds, WA
Driller/Equipment: Geologic Drill / Trailer Rig
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 358
Datum: N/A
Date Start/Finish: 4/17/14,4/17/14
Hole Diameter (in): 8' x 8' pit

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Sod / Topsoil					
				Weathered Till Fill Medium dense, moist, grayish brown, silty fine to medium SAND, little gravel; unsorted (SM).					
	Grab	S-1		**Till Fill** As above, gray.					
5									
	Grab	S-2		Medium dense, moist, gray, fine to medium SAND, with gravel, little to few silt (SM-SP).					
10	Grab	S-3		As above, mixed with brown soil.					
	Grab	S-4		As above, occasional rootlets and wood debris.					
15				Bottom of exploration boring at 15 feet Moderate overland water flow into pit. Slight seepage from sidewall at 6.8 feet. Infiltration test at 7 feet. Minor caving 2 to 4 feet.					
20									
25									

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: DMG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KH130422A	VB-1	1 of 1

Project Name: Perrinville
Location: Edmonds, WA
Driller/Equipment: APS Locates (Air Vactor)
Hammer Weight/Drop: N/A

Ground Surface Elevation (ft): 272
Datum: N/A
Date Start/Finish: 4/14/14,4/14/14
Hole Diameter (in): 7

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Crushed Rock Fill					
				Vashon Advance Outwash Medium dense to dense, moist to wet, grayish brown with occasional orange mottling, fine to coarse SAND, little to trace silt, trace gravel; bedding not visible in vactor sample (SM-SP).					
5									
				Bottom of exploration boring at 5.5 feet Moderate seepage at 5.3 feet. Light caving at 5.3 feet.					
10									
15									
20									
25									
30									
35									

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: FSM
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE140220A	EB-1	1 of 1

Project Name	Lynndale Elementary School	Ground Surface Elevation (ft)	405
Location	Lynnwood, WA	Datum	PSLC
Driller/Equipment	Boretel / Mini Track	Date Start/Finish	5/15/14,5/15/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	7

Depth (ft)	Samples	DESCRIPTION	Water Level	Blows/6"	Blows/Foot
		Grass and Topsoil			
		Fill			
	S-1	Hand dug to 2 feet. Loose, very moist, brown and mottled brown, fine to medium SAND, with silt, few fine gravel, trace organics (visually estimated 1% or less by weight) (SM).		4 3 3	6
5	S-2	Loose, very moist, mottled gray, fine to coarse SAND, with silt, little fine gravel (SM).		5 4 5	9
10	S-3	Becomes dark brown, with trace organics (visually estimated 0.5 to 1.5 %).		3 4 5	9
		Vashon Lodgement Till / Vashon Advance Outwash Transitional			
		Perched ground water (seepage zone).	ATD		
15	S-4	Dense, wet, mottled gray, fine to medium SAND, with silt, few fine gravel; nonstratified (SM).		9 11 23	34
		Vashon Advance Outwash			
20	S-5	Very dense, moist, brownish gray, fine SAND, few silt; nonstratified (SP-SM).		15 21 29	50
		Perched ground water (seepage zones).	ATD		
25	S-6	Very dense, very moist to wet (varies), gray and brownish gray, fine SAND, few silt, trace fine gravel; gradational stratification mainly with varying silt content, seepage above silty zones (SP-SM).		15 21 40	61
		Bottom of exploration boring at 26.5 feet			
30					
35					

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: BWG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE140220A	EB-2	1 of 1

Project Name: Lynndale Elementary School
Location: Lynnwood, WA
Driller/Equipment: Boretel / Mini Track
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 403
Datum: PSLC
Date Start/Finish: 5/15/14,5/15/14
Hole Diameter (in): 7

Depth (ft)	Samples	DESCRIPTION	Blows/6"	Blows/Foot
0		**Grass and Topsoil**		
		Fill		
		Hand dug to 2 feet.		
	S-1	Loose, very moist, dark brown, fine to medium SAND, with silt, mixed with sticks and roots; nonstratified (SM).	2 3 5	8
5	S-2	Loose, very moist, brown, fine to coarse SAND, with silt, little fine gravel; nonstratified (lodgement till fill) (SM).	2 3 3	6
		Vashon Lodgement Till		
10	S-3	Very dense, very moist, gray, fine to coarse SAND, with silt, little fine gravel; nonstratified (SM).	19 29 46	75
15	S-4	Gradation as above.	29 50/5"	50/5"
20	S-5	Very dense, very moist to wet, gray, fine to coarse SAND, with fine to coarse gravel, with silt; thin seams of clean sand, possible Vashon advance outwash transitional (SM).	50/5"	50/5"
		Bottom of exploration boring at 20.5 feet No ground water encountered.		
25				
30				
35				

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: BWG
Approved by:

Exploration Log

Associated Earth Sciences, Inc.

Project Number	Exploration Number	Sheet
KE140220A	EB-3	1 of 1

Project Name: Lynndale Elementary School
Location: Lynnwood, WA
Driller/Equipment: Boretel / Mini Track
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 403
Datum: PSLC
Date Start/Finish: 5/15/14,5/15/14
Hole Diameter (in): 7

Depth (ft)	S T	Samples	DESCRIPTION	Blows/6"	Blows/Foot
			Grass and Topsoil		
			Fill		
			Hand dug to 2 feet.		
			Vashon Lodgement Till		
		S-1	Very dense, moist, gray, fine to coarse SAND, with silt, little fine gravel; thin seams of clean fine sand, otherwise nonstratified (SM).	20 40 48	88
5		S-2	Gradation as above but without clean sand seams.	24 26 48	74
10		S-3	Grades to little to with fine to coarse gravel.	20 29 50/6"	79
			Drill action suggests gravel returning to fine.		
15		S-4	Very dense, very moist, gray, fine to coarse SAND, with silt, little fine gravel; nonstratified (SM).	50/5"	50/5"
20		S-50	Gradation as above.	50/5"	50/5"
			Bottom of exploration boring at 20.5 feet No ground water encountered.		
25					
30					
35					

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: BWG
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE140220A	EB-5	1 of 2

Project Name	Lynndale Elementary School	Ground Surface Elevation (ft)	410
Location	Lynnwood, WA	Datum	PSLC
Driller/Equipment	Boretel / Mini Track	Date Start/Finish	5/15/14,5/15/14
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	7

Depth (ft)	Samples	DESCRIPTION	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
		Grass and Topsoil				
		Fill				
	S-1			4 4 27	▲31	
		Vashon Lodgement Till				
		Dense, very moist, gray, fine to coarse SAND, with silt, little fine gravel; nonstratified (SM).				
5	S-2	Very dense, very moist, gray, fine to coarse SAND, with silt, little fine gravel; zones of gradational stratification (+/- 2 1/2 inches thick), more / less silt is primary difference (SM).		21 30 35	▲65	
10	S-3	Dense, wet, gray, fine to coarse SAND with silt, little fine gravel, interbedded with fine SAND, few silt, trace fine gravel (SM/SP-SM).		19 16 17	▲33	
		Zone of wet cuttings at surface with auger tip at 13 to 15 feet.				
		Perched ground water (seepage zone).	▼			
15	S-4	Very dense, very moist, gray, fine to coarse SAND, with silt, little fine gravel; nonstratified (SM).		36 50/5"	▲50/5"	
20	S-5	Very dense, very moist to wet, gray fine to coarse SAND, with silt, little fine gravel; with less silty seams (+/- 1 inch thick) that are wet (SM).		43 50/2"	▲50/2"	
		Perched ground water (seepage zone).				
25	S-6	Gradation as above, intermittent wet cuttings	▼	50/3"	▲50/3"	
		Vashon Advance Outwash				
30	S-7	Trace recovery, one gravel clast and small amount of fine sand (looks like Vashon advance outwash).		50/4"	▲50/4"	
		Scattered cobbles based on drill action.				
35	S-8	Very dense, very moist, gray, interbedded fine SAND, with silt, trace fine gravel; fine SAND, few silt, trace fine gravel; fine to coarse SAND, little to with fine gravel, few silt (SM / SP-SM / SW-SM).		45 50/4"	▲50/4"	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- ▽ Water Level ()
- ▼ Water Level at time of drilling (ATD)

Logged by: BWG

Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE140220A	EB-5	2 of 2

Project Name: Lynndale Elementary School
Location: Lynnwood, WA
Driller/Equipment: Boretel / Mini Track
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 410
Datum: PSLC
Date Start/Finish: 5/15/14,5/15/14
Hole Diameter (in): 7

Depth (ft)	S T	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
		S-9		Very dense, moist, gray, fine to medium SAND, little to with fine gravel, few silt; gradational stratification, gravel tends to cluster in distinct layers, silt content varies in ~2 inch intervals (SP-SM).			41 46 50/3"	50/3"	
45		S-10		Gradation as above continues.			50/5"	50/5"	
50		S-11		No gradation change.			50/5"	50/5"	
				Bottom of exploration boring at 50.5 feet					
55									
60									
65									
70									
75									

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: BWG
Approved by:

APPENDIX B

Grain-Size Analysis

KH130422A PERRINVILLE DATA SUMMARY TABLE

No.	Depth	D10 (mm)	ASTM D-2487					Ecology (2005) USDA Soil Texture	Ecology (2005) Long-Term Infil. Soil Texture Class. (iph)	Ecology (2005) Long-Term Infil. D10 Size (iph)	Nguyen (2013) (iph)	Massmann (2003) Ecology (2005, 2012) (iph)
			Soil Classification	Symbol	%G	%S	%M					
EB-1	20'	0.02	silty SAND with gravel	SM	25	61	14	SANDY CLAY LOAM to LOAMY SAND	No Rate to 0.5	0.0	0.7	14.0
EB-1	25'-30'	0.09	well-graded SAND with silt and gravel	SW-SM	19	72	9	LOAMY SAND to SAND	0.5 to 2	0.8	1.8	26.2
EB-2	20'	0.03	silty SAND with gravel	SM	24	64	12	SANDY LOAM to LOAMY SAND	0.25 to 0.5	0.0	1.0	19.1
EB-2	30'	0.27	poorly-graded SAND with gravel	SP	16	80	5	SAND	2	3.5	6.2	85.6
EB-3	25'	0.01	silty SAND with gravel	SM	17	67	16	SANDY CLAY LOAM to LOAMY SAND	No Rate to 0.5	0.0	0.5	15.6
EB-3	30'	0.04	well-graded SAND with silt and gravel	SW-SM	18	70	12	LOAMY SAND to SAND	0.5 to 2	0.0	1.0	20.2
EB-4	15'	0.02	silty SAND	SM	0	86	14	LOAMY SAND to SAND	0.5 to 2	0.0	0.7	21.3
EB-4	20'	0.01	silty SAND with gravel	SM	24	62	14	SANDY LOAM to LOAMY SAND	0.25 to 0.5	0.0	0.7	14.6
MW-1	15'	0.19	poorly-graded SAND	SP	2	94	4	SAND	2	2.0	5.7	70.0
MW-1	20'	0.15	poorly-graded SAND with silt	SP-SM	11	83	6	SAND	2	2.0	3.8	48.3
MW-1	25'	0.14	poorly-graded SAND with silt	SP-SM	7	86	7	SAND	2	2.0	3.3	48.6
MW-1	30'	0.08	well-graded SAND with silt	SW-SM	5	86	9	SAND	2	0.8	1.9	33.7

Notes: D10 linearly interpolated for EB-1 20', EB-2 20', and all of EB-3 and EB-4.

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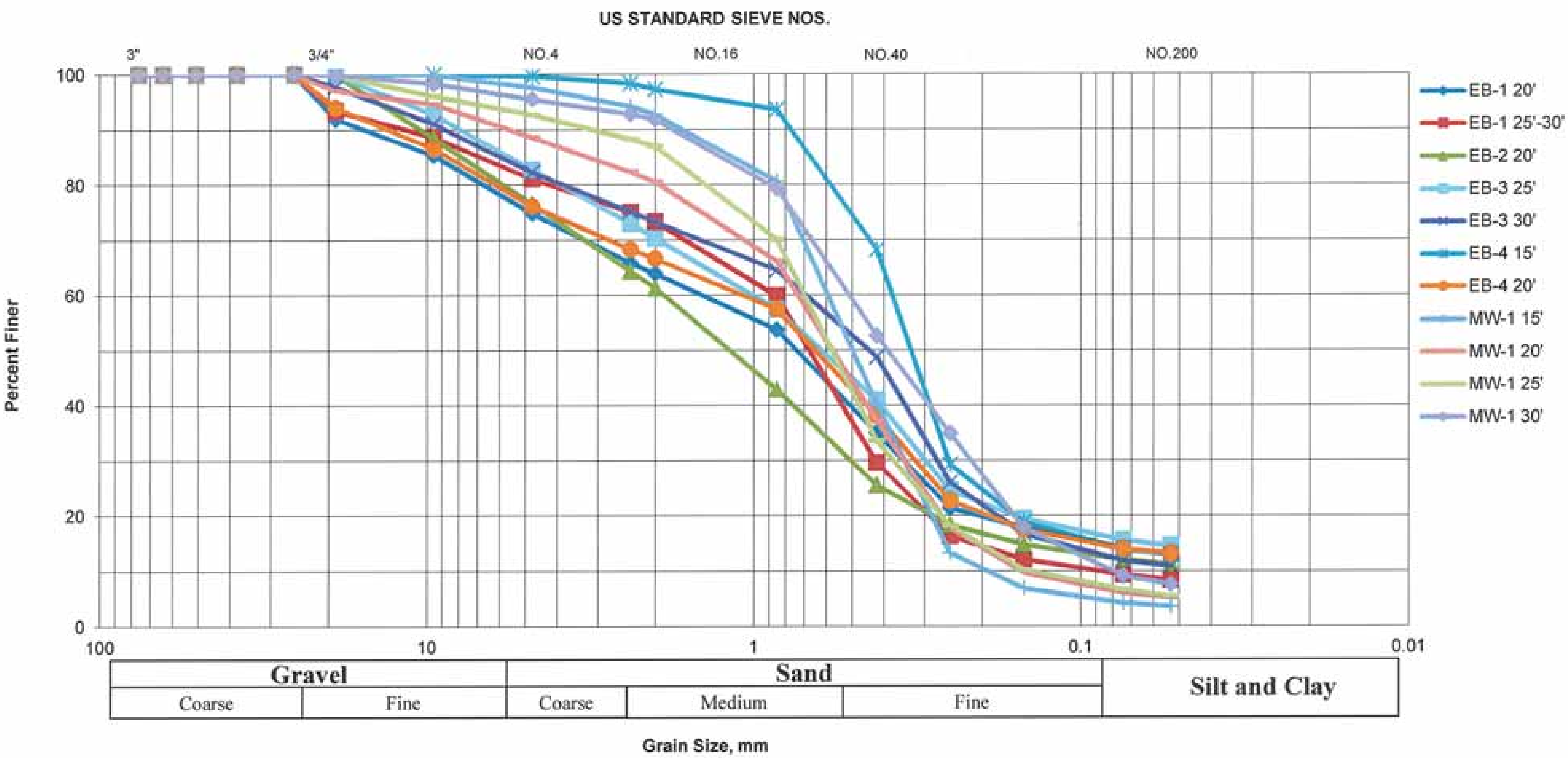
GRAIN SIZE ANALYSIS - MECHANICAL (COMPOSITE SUMMARY)



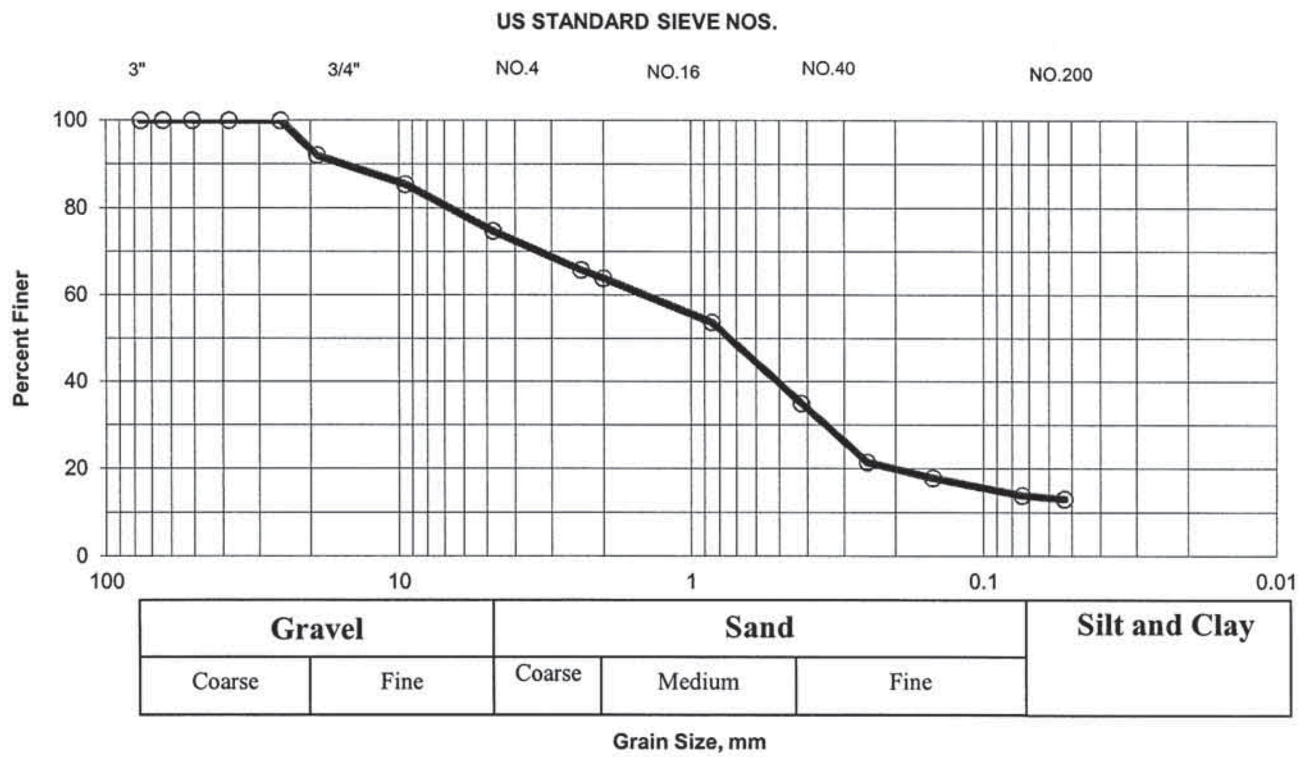
KH130422A Perrinville

GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand with gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-1**	**20'**	

Wt. of moisture wet sample + Tare	317.26	Total Sample Tare	518.46
Wt. of moisture dry Sample + Tare	298.95	Total Sample wt + tare	1121.75
Wt. of Tare	101.12	Total Sample Wt	603.3
Wt. of moisture Dry Sample	197.83	Total Sample Dry Wt	552.2
Moisture %	9%		

					Specification Requirements	
Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	44.16	8.0	92.0		
3/8	9.51	80.7	14.6	85.4		
#4	4.76	139.34	25.2	74.8		
#8	2.38	188.92	34.2	65.8		
#10	2	199.51	36.1	63.9		
#20	0.85	255.65	46.3	53.7		
#40	0.42	358.84	65.0	35.0		
#60	0.25	433.75	78.6	21.4		
#100	0.149	453.75	82.2	17.8		
#200	0.074	475.61	86.1	13.9		
#270	0.053	480.2	87.0	13.0		



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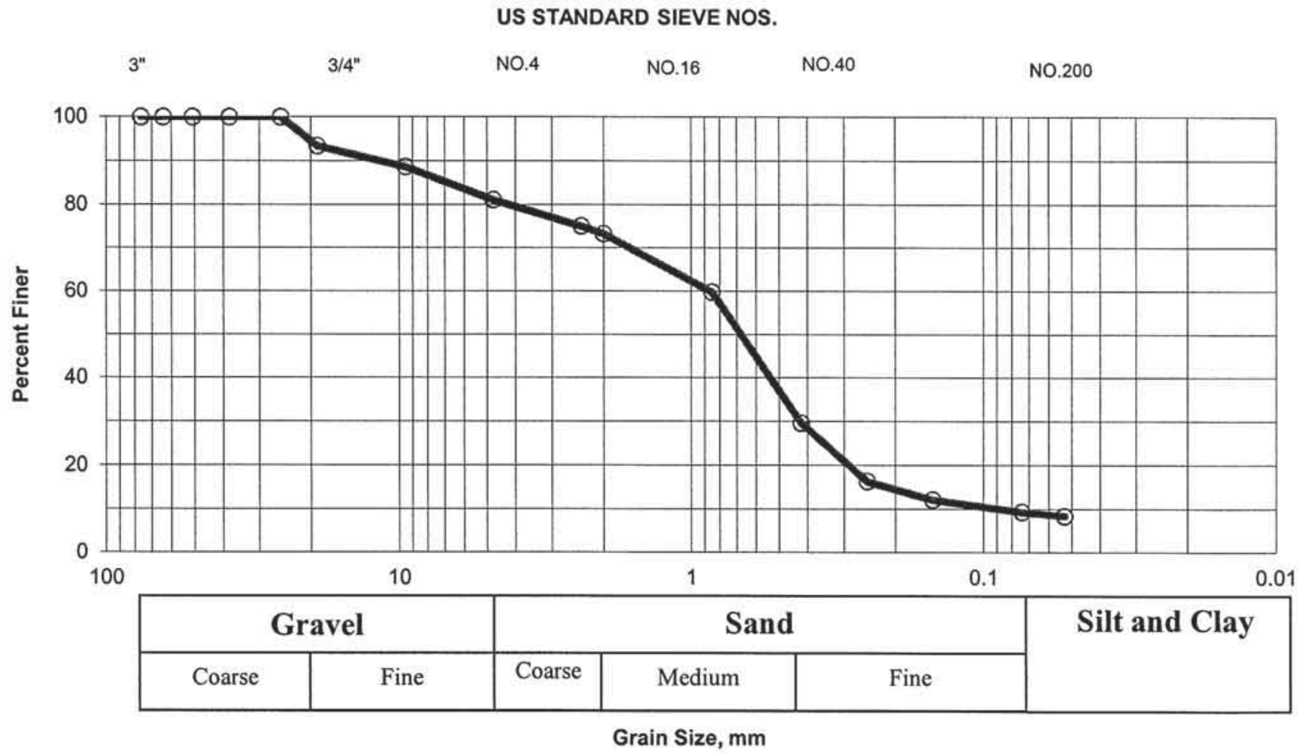
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand little gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-1**	**25-30' Comp.**	

Wt. of moisture wet sample + Tare	267.46	Total Sample Tare	394.42
Wt. of moisture dry Sample + Tare	255.22	Total Sample wt + tare	1097.84
Wt. of Tare	97.74	Total Sample Wt	703.4
Wt. of moisture Dry Sample	157.48	Total Sample Dry Wt	652.7
Moisture %	8%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	43.09	6.6	93.4		
3/8	9.51	73.94	11.3	88.7		
#4	4.76	123.39	18.9	81.1		
#8	2.38	162.89	25.0	75.0		
#10	2	174.43	26.7	73.3		
#20	0.85	262.45	40.2	59.8		
#40	0.42	459.65	70.4	29.6		
#60	0.25	546.18	83.7	16.3		
#100	0.149	573.58	87.9	12.1		
#200	0.074	591.71	90.7	9.3		
#270	0.053	597.79	91.6	8.4		



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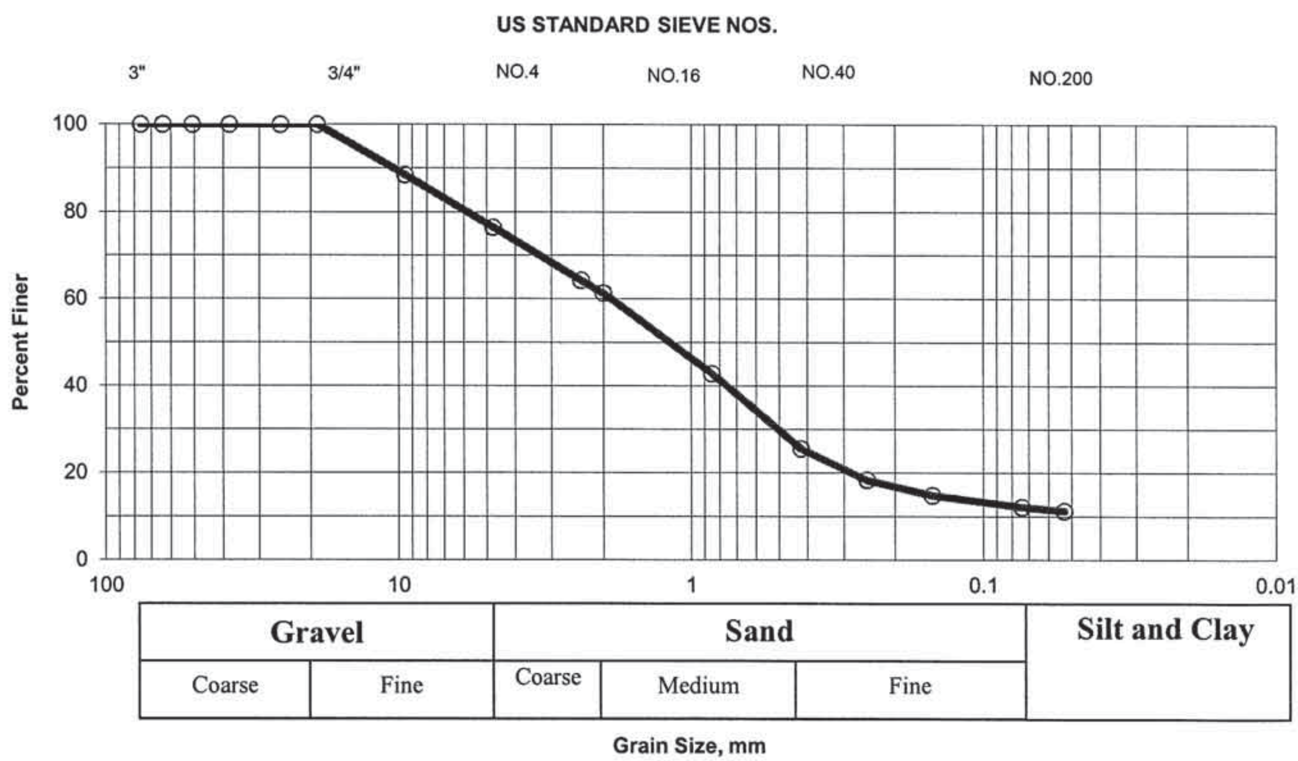
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand little gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-2**	**20'**	

Wt. of moisture wet sample + Tare	312.97	Total Sample Tare	518.78
Wt. of moisture dry Sample + Tare	303.54	Total Sample wt + tare	1074.07
Wt. of Tare	98.18	Total Sample Wt	555.3
Wt. of moisture Dry Sample	205.36	Total Sample Dry Wt	530.9
Moisture %	5%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51	61.12	11.5	88.5		
#4	4.76	124.79	23.5	76.5		
#8	2.38	189.74	35.7	64.3		
#10	2	205.66	38.7	61.3		
#20	0.85	303.14	57.1	42.9		
#40	0.42	395.42	74.5	25.5		
#60	0.25	433.66	81.7	18.3		
#100	0.149	452.28	85.2	14.8		
#200	0.074	466.42	87.9	12.1		
#270	0.053	470.95	88.7	11.3		



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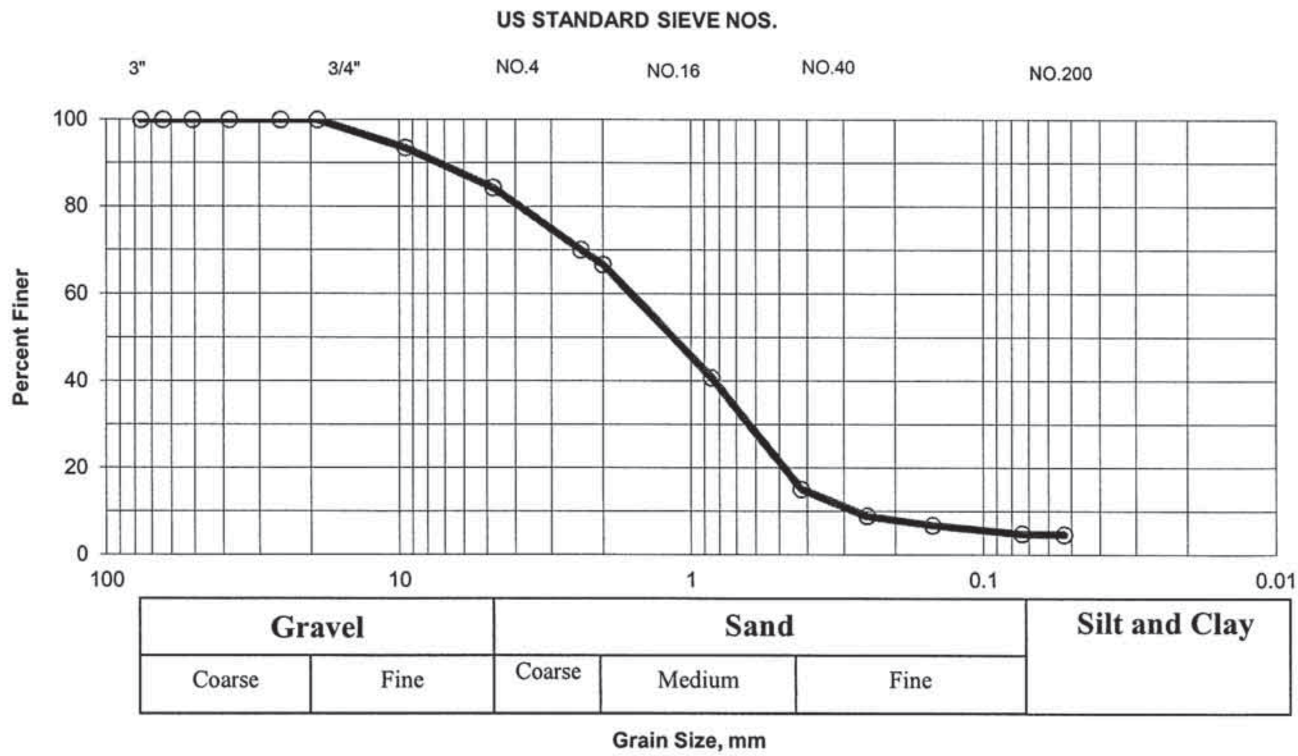
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand little gravel trace silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-2**	**30'**	

Wt. of moisture wet sample + Tare	315.5	Total Sample Tare	408.14
Wt. of moisture dry Sample + Tare	305.91	Total Sample wt + tare	849.9
Wt. of Tare	97.64	Total Sample Wt	441.8
Wt. of moisture Dry Sample	208.27	Total Sample Dry Wt	422.3
Moisture %	5%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51	27.57	6.5	93.5		
#4	4.76	66.42	15.7	84.3		
#8	2.38	126.35	29.9	70.1		
#10	2	140.69	33.3	66.7		
#20	0.85	250.15	59.2	40.8		
#40	0.42	358.78	85.0	15.0		
#60	0.25	384.73	91.1	8.9		
#100	0.149	393.64	93.2	6.8		
#200	0.074	401.96	95.2	4.8		
#270	0.053	402.73	95.4	4.6		



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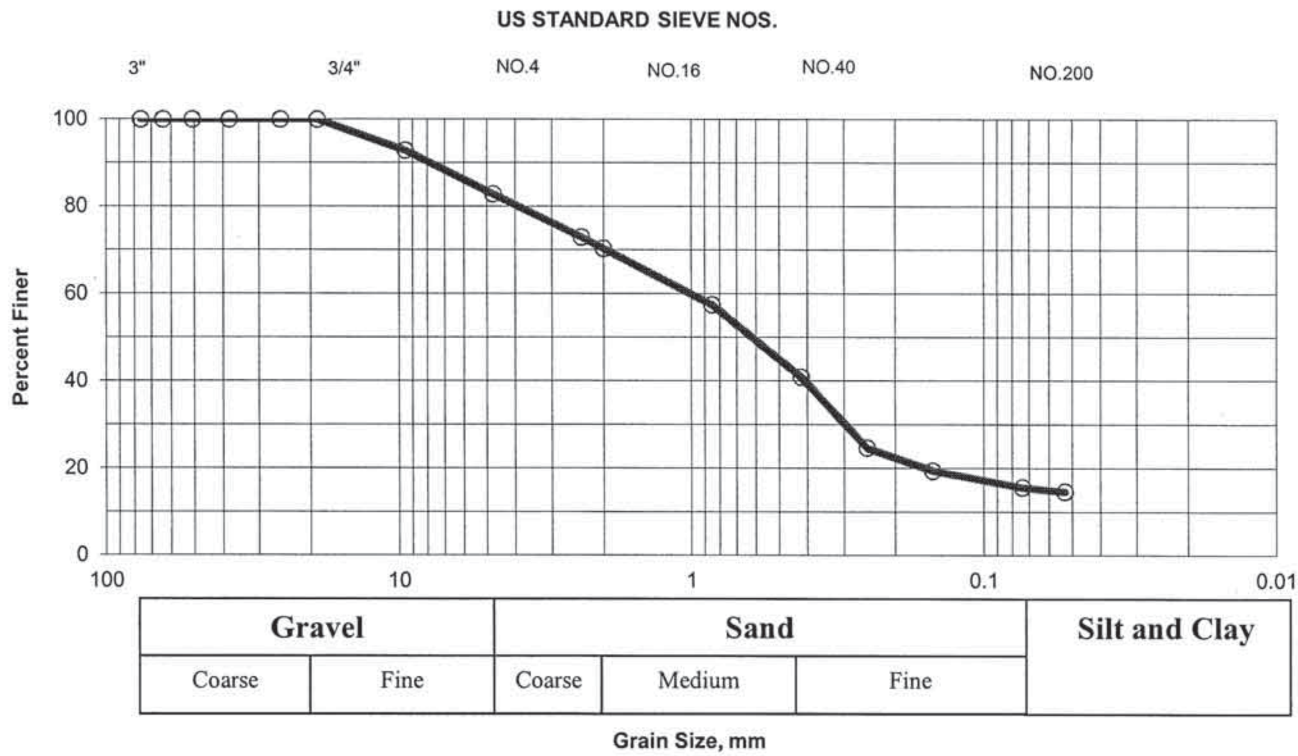
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/2/2014	**Perrinvile**	**KE130422A**		**Sand few silt little gravel**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-3**	**25'**	

Wt. of moisture wet sample + Tare	292.89	Total Sample Tare	342.69
Wt. of moisture dry Sample + Tare	276.76	Total Sample wt + tare	817.87
Wt. of Tare	99.13	Total Sample Wt	475.2
Wt. of moisture Dry Sample	177.63	Total Sample Dry Wt	435.6
Moisture %	9%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51	31.38	7.2	92.8		
#4	4.76	75	17.2	82.8		
#8	2.38	117.83	27.0	73.0		
#10	2	129.26	29.7	70.3		
#20	0.85	185.44	42.6	57.4		
#40	0.42	257.55	59.1	40.9		
#60	0.25	328.28	75.4	24.6		
#100	0.149	351.21	80.6	19.4		
#200	0.074	367.65	84.4	15.6		
#270	0.053	371.95	85.4	14.6		



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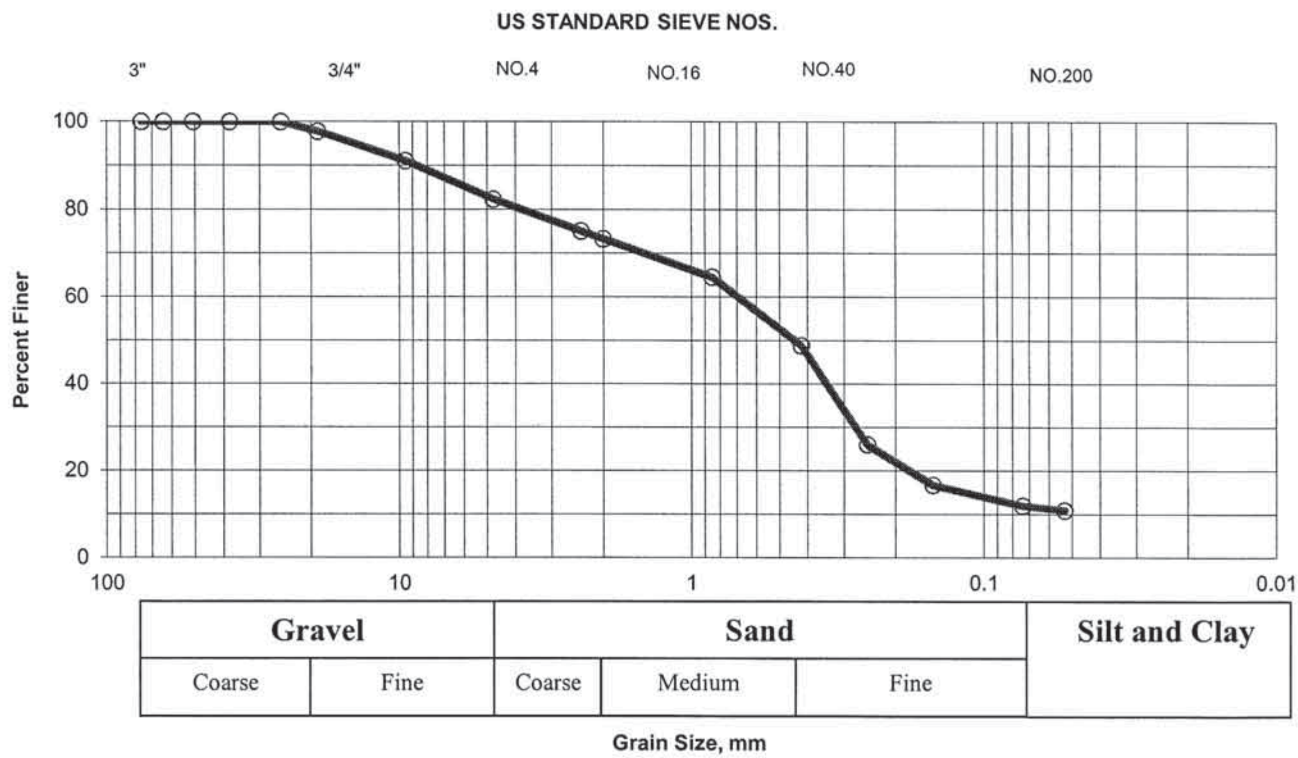
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/2/2014	**Perrinvile**	**KE130422A**		**Sand few silt little gravel**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-3**	**30'**	

Wt. of moisture wet sample + Tare	292.12	Total Sample Tare	394.41
Wt. of moisture dry Sample + Tare	266.77	Total Sample wt + tare	1099.23
Wt. of Tare	101.1	Total Sample Wt	704.8
Wt. of moisture Dry Sample	165.67	Total Sample Dry Wt	611.3
Moisture %	15%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	13.52	2.2	97.8		
3/8	9.51	54.54	8.9	91.1		
#4	4.76	108.25	17.7	82.3		
#8	2.38	152.36	24.9	75.1		
#10	2	163.23	26.7	73.3		
#20	0.85	217.04	35.5	64.5		
#40	0.42	312.77	51.2	48.8		
#60	0.25	452.39	74.0	26.0		
#100	0.149	509.32	83.3	16.7		
#200	0.074	538.3	88.1	11.9		
#270	0.053	544.55	89.1	10.9		



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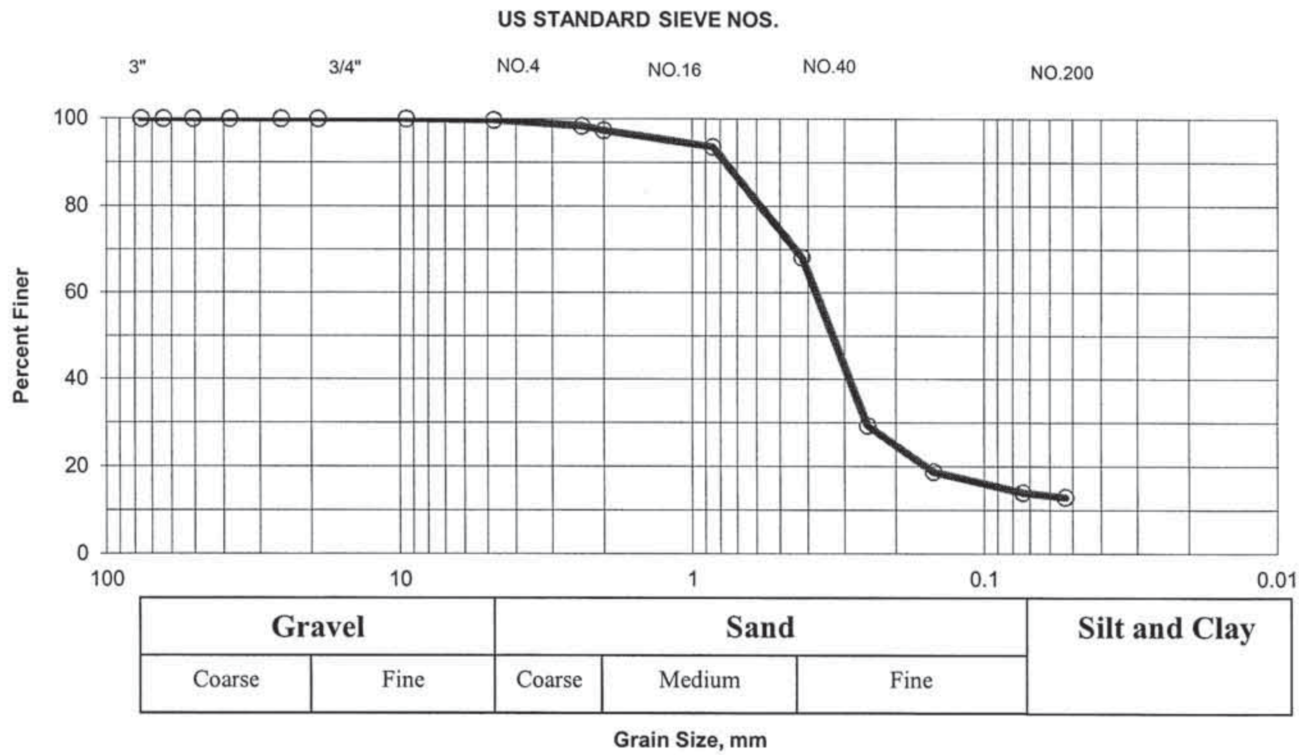
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/2/2014	**Perrinvile**	**KE130422A**		**Sand few silt trace gravel**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-4**	**15'**	

Wt. of moisture wet sample + Tare	298.86	Total Sample Tare	518.64
Wt. of moisture dry Sample + Tare	279.77	Total Sample wt + tare	1027.34
Wt. of Tare	99.7	Total Sample Wt	508.7
Wt. of moisture Dry Sample	180.07	Total Sample Dry Wt	459.9
Moisture %	11%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	1.42	0.3	99.7		
#8	2.38	7.46	1.6	98.4		
#10	2	12.2	2.7	97.3		
#20	0.85	29.59	6.4	93.6		
#40	0.42	146.26	31.8	68.2		
#60	0.25	325.05	70.7	29.3		
#100	0.149	373.68	81.2	18.8		
#200	0.074	395.56	86.0	14.0		
#270	0.053	400.5	87.1	12.9		



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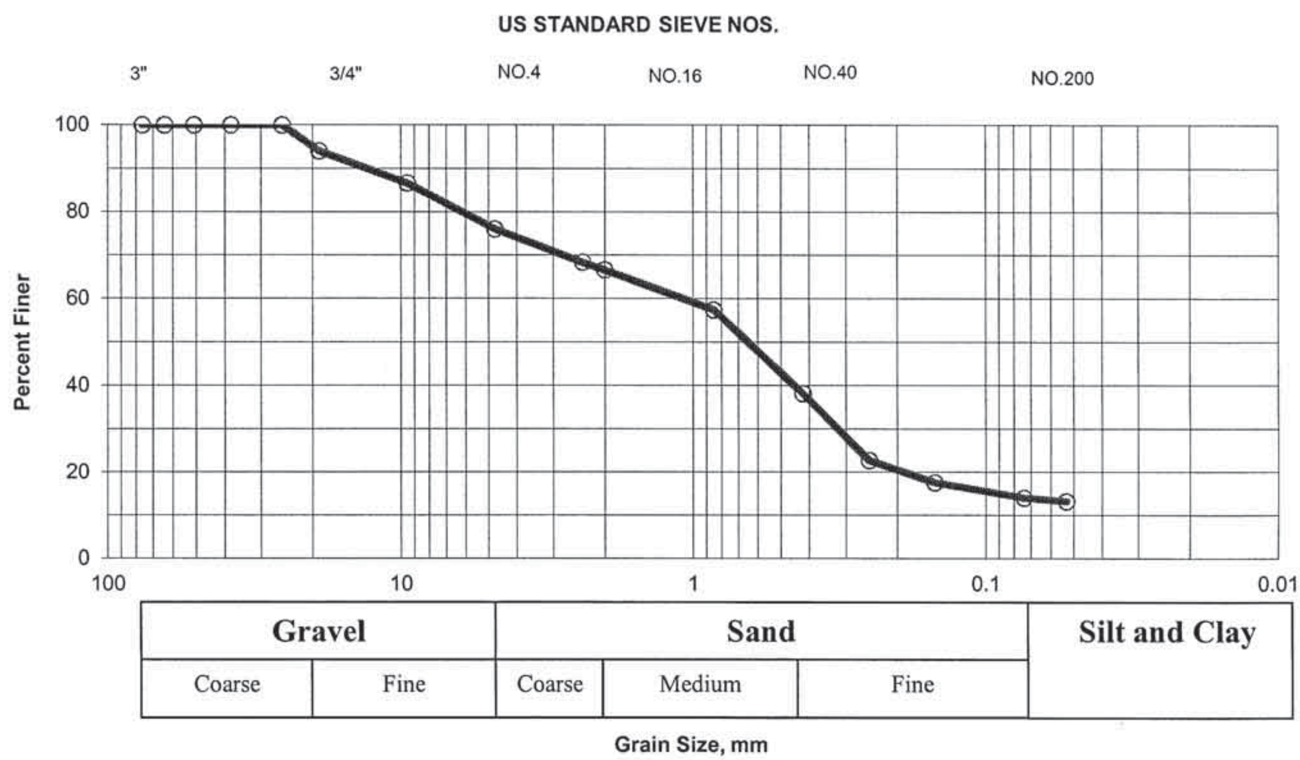
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/2/2014	**Perrinvile**	**KE130422A**		**Sand few silt little gravel**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**EB-4**	**20'**	

Wt. of moisture wet sample + Tare	262.35	Total Sample Tare	295.59
Wt. of moisture dry Sample + Tare	250.78	Total Sample wt + tare	782.49
Wt. of Tare	100.43	Total Sample Wt	486.9
Wt. of moisture Dry Sample	150.35	Total Sample Dry Wt	452.1
Moisture %	8%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	27.09	6.0	94.0		
3/8	9.51	60.51	13.4	86.6		
#4	4.76	108.27	23.9	76.1		
#8	2.38	143.16	31.7	68.3		
#10	2	151.17	33.4	66.6		
#20	0.85	192.56	42.6	57.4		
#40	0.42	279.76	61.9	38.1		
#60	0.25	349.44	77.3	22.7		
#100	0.149	372.84	82.5	17.5		
#200	0.074	388.87	86.0	14.0		
#270	0.053	392.37	86.8	13.2		



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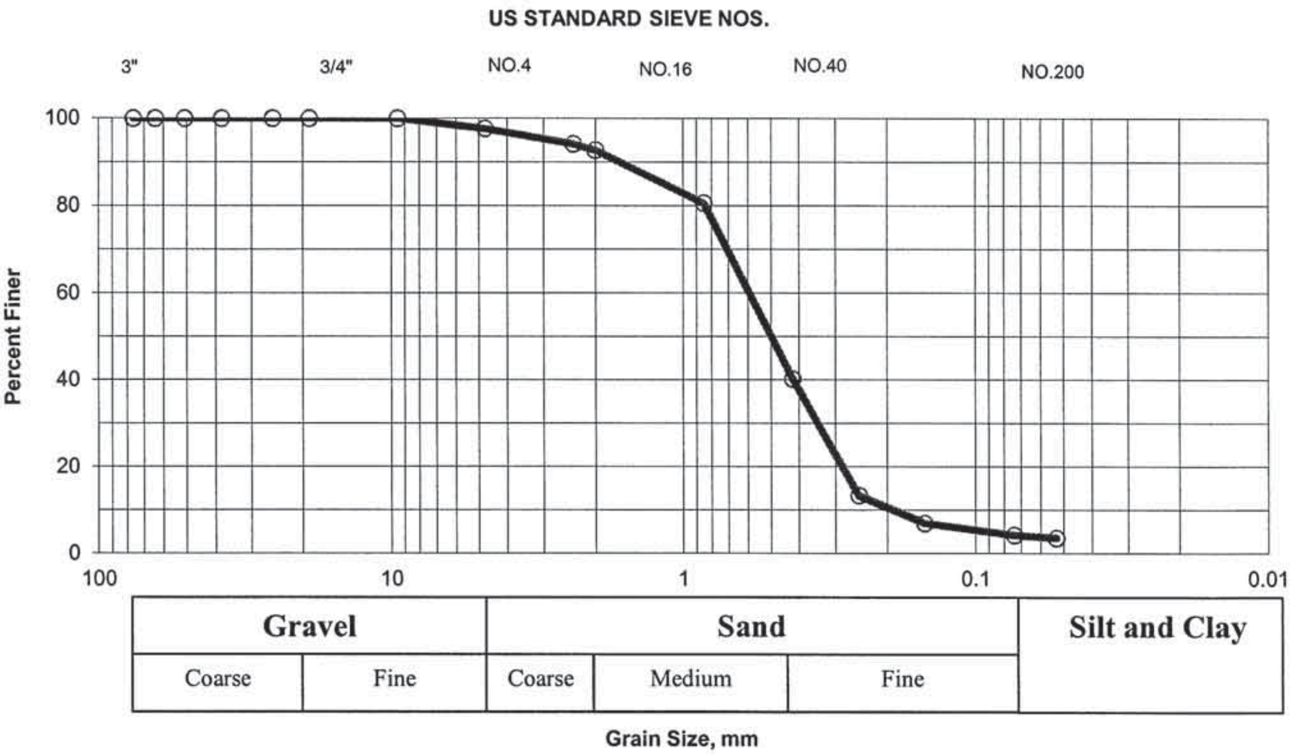
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand trace gravel trace silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**MW-1**	**15'**	

Wt. of moisture wet sample + Tare	331.81	Total Sample Tare	518.74
Wt. of moisture dry Sample + Tare	321.1	Total Sample wt + tare	899.05
Wt. of Tare	100.88	Total Sample Wt	380.3
Wt. of moisture Dry Sample	220.22	Total Sample Dry Wt	362.7
Moisture %	5%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51		0.0	100.0		
#4	4.76	8.43	2.3	97.7		
#8	2.38	21.12	5.8	94.2		
#10	2	26.31	7.3	92.7		
#20	0.85	70.53	19.4	80.6		
#40	0.42	216.91	59.8	40.2		
#60	0.25	314.35	86.7	13.3		
#100	0.149	337.53	93.1	6.9		
#200	0.074	347.44	95.8	4.2		
#270	0.053	349.79	96.4	3.6		



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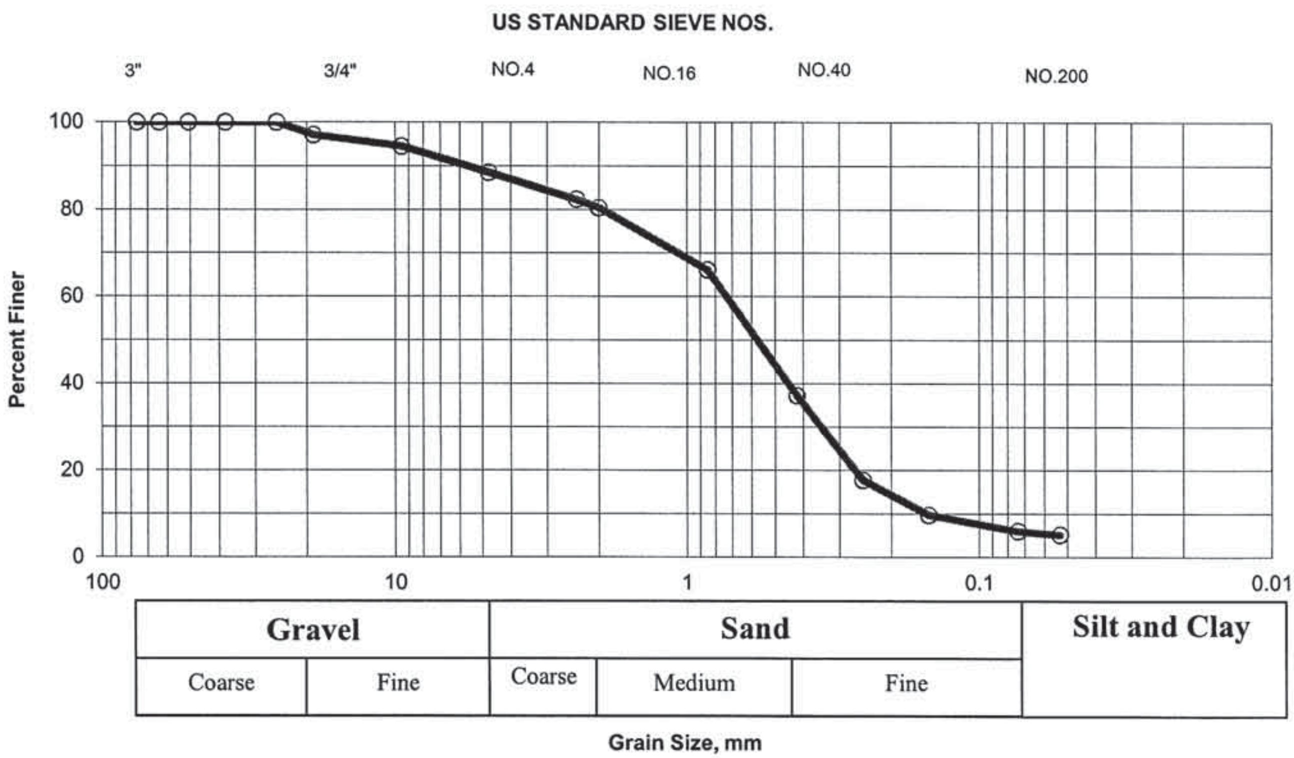
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand few gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**MW1**	**20'**	

Wt. of moisture wet sample + Tare	302.97	Total Sample Tare	518.46
Wt. of moisture dry Sample + Tare	295.29	Total Sample wt + tare	1137.98
Wt. of Tare	99.15	Total Sample Wt	619.5
Wt. of moisture Dry Sample	196.14	Total Sample Dry Wt	596.2
Moisture %	4%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19	17.16	2.9	97.1		
3/8	9.51	32.49	5.4	94.6		
#4	4.76	68.1	11.4	88.6		
#8	2.38	105.35	17.7	82.3		
#10	2	116.47	19.5	80.5		
#20	0.85	202.01	33.9	66.1		
#40	0.42	374.19	62.8	37.2		
#60	0.25	490.25	82.2	17.8		
#100	0.149	538.25	90.3	9.7		
#200	0.074	560.25	94.0	6.0		
#270	0.053	565.11	94.8	5.2		



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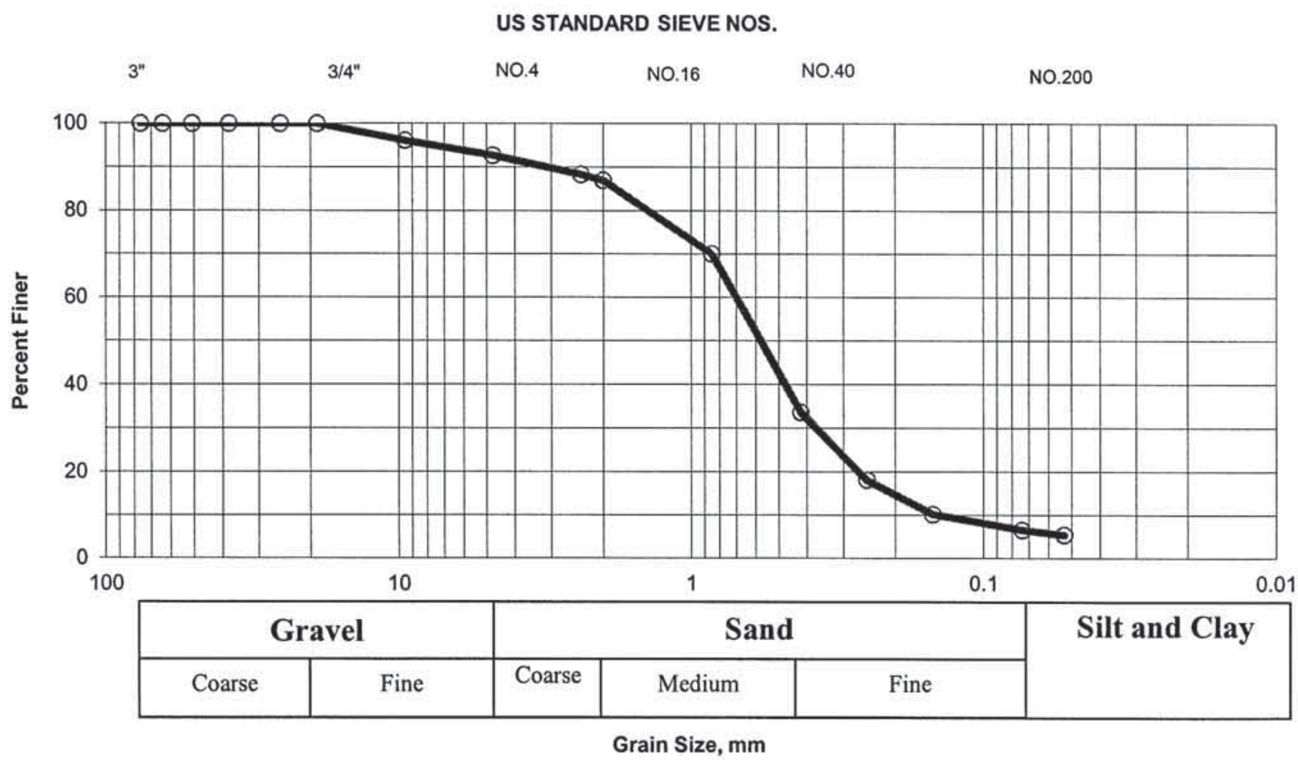
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand few gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**MW1**	**25'**	

Wt. of moisture wet sample + Tare	284.22	Total Sample Tare	343.02
Wt. of moisture dry Sample + Tare	278.87	Total Sample wt + tare	973.91
Wt. of Tare	101.11	Total Sample Wt	630.9
Wt. of moisture Dry Sample	177.76	Total Sample Dry Wt	612.5
Moisture %	3%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51	23.78	3.9	96.1		
#4	4.76	44.75	7.3	92.7		
#8	2.38	71.36	11.7	88.3		
#10	2	79.75	13.0	87.0		
#20	0.85	183.41	29.9	70.1		
#40	0.42	406.44	66.4	33.6		
#60	0.25	501.55	81.9	18.1		
#100	0.149	550.06	89.8	10.2		
#200	0.074	572.33	93.4	6.6		
#270	0.053	579.19	94.6	5.4		



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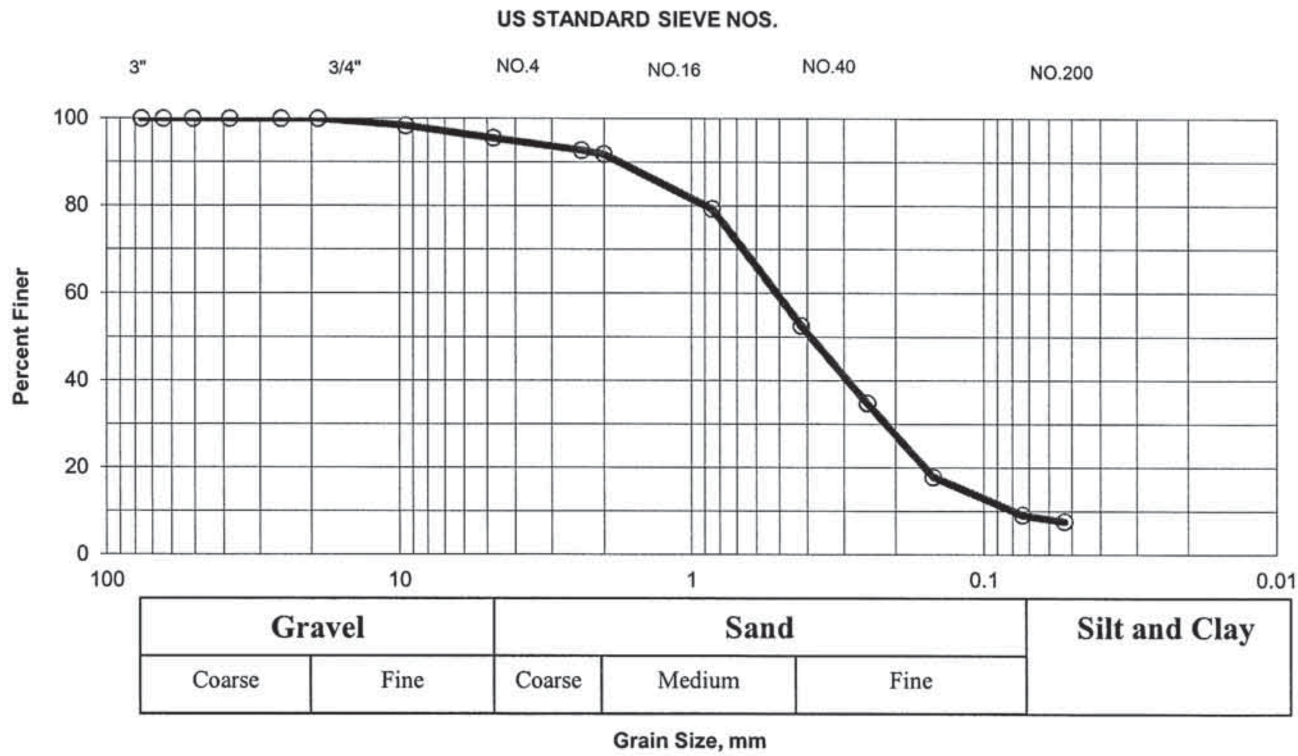
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
4/18/2014	**Perrinville**	**KH130422A**		**Sand trace gravel few silt**
Tested By	Location	EB/EP No	Depth	
MS	**Onsite**	**MW-1**	**30'**	

Wt. of moisture wet sample + Tare	321.74	Total Sample Tare	309.65
Wt. of moisture dry Sample + Tare	304.04	Total Sample wt + tare	916.39
Wt. of Tare	94.85	Total Sample Wt	606.7
Wt. of moisture Dry Sample	209.19	Total Sample Dry Wt	559.4
Moisture %	8%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3	76.1		0.0	100.0	-	-
2.5	64		0.0	100.0	-	-
2	50.8		0.0	100.0	-	-
1.5	38.1		0.0	100.0	-	-
1	25.4		0.0	100.0	-	-
3/4	19		0.0	100.0		
3/8	9.51	9.18	1.6	98.4		
#4	4.76	24.95	4.5	95.5		
#8	2.38	40.5	7.2	92.8		
#10	2	45.67	8.2	91.8		
#20	0.85	115.64	20.7	79.3		
#40	0.42	265.33	47.4	52.6		
#60	0.25	364.38	65.1	34.9		
#100	0.149	459.7	82.2	17.8		
#200	0.074	508.37	90.9	9.1		
#270	0.053	516.66	92.4	7.6		



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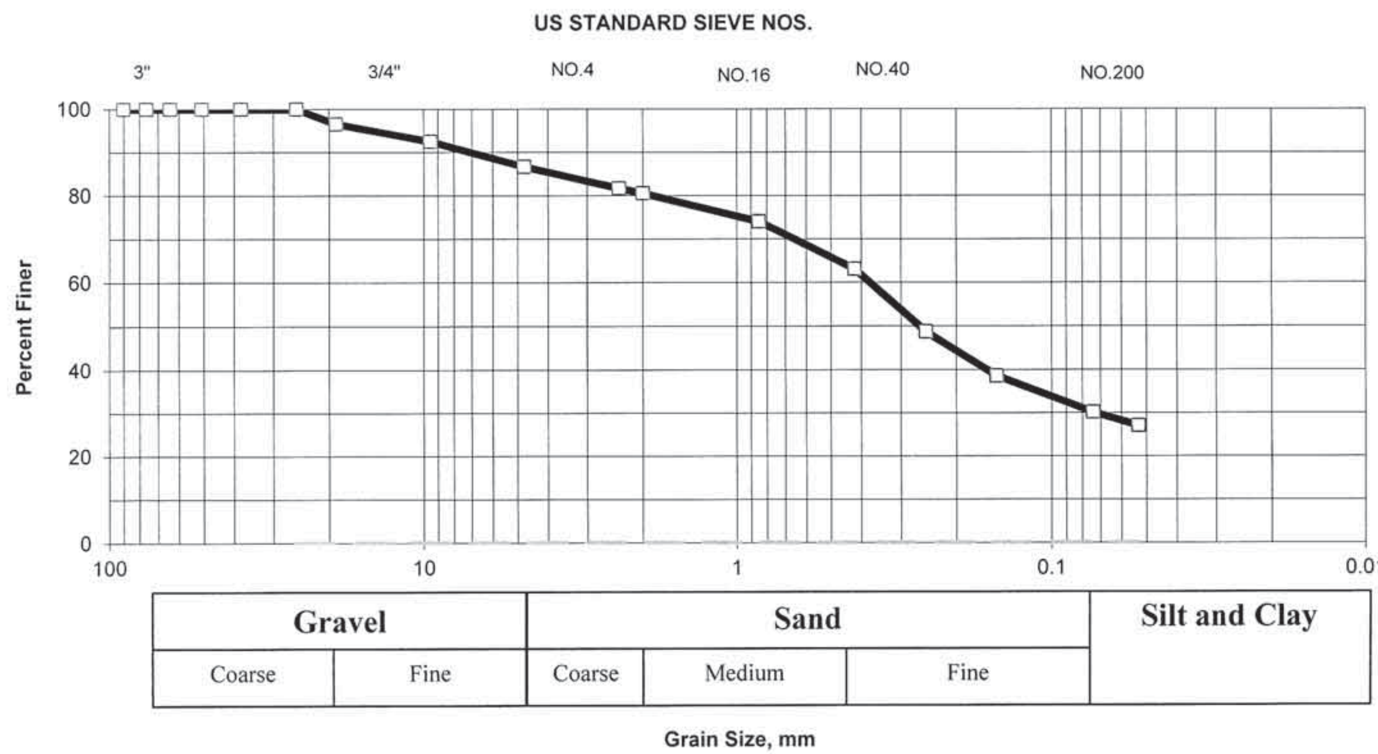
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/15-16/2014	**Lynndale Elementary**	**KE140220A**		**Silty sand, few gravel**
Tested By	Location	EB/EP No	Depth	Intended Use / Specification
GM	**OS**	**EB-4 S-2**	**5'**	

Wt. of moisture wet sample + Tare	186.64	Total Sample Tare	518.49
Wt. of moisture dry Sample + Tare	181.12	Total Sample wt + tare	1117.84
Wt. of Tare	101.14	Total Sample Wt	599.4
Wt. of moisture Dry Sample	79.98	Total Sample Dry Wt	560.7
Moisture %	7%		

					Specification Requirements	
Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Minimum	Maximum
3.5	90	0	-	100.00	-	-
3	76.1	0	-	100.00	-	-
2.5	64	0	-	100.00	-	-
2	50.8	0	-	100.00	-	-
1.5	38.1	0	-	100.00	-	-
1	25.4	0	-	100.00		
3/4	19	19.44	3.47	96.53		
3/8	9.51	42.03	7.50	92.50		
#4	4.76	74.73	13.33	86.67		
#8	2.38	102.83	18.34	81.66		
#10	2	109.17	19.47	80.53		
#20	0.85	145.71	25.99	74.01		
#40	0.42	207.05	36.93	63.07		
#60	0.25	287.44	51.27	48.73		
#100	0.149	344.4	61.43	38.57		
#200	0.074	391.52	69.83	30.17		
#270	0.053	409.11	72.97	27.03		



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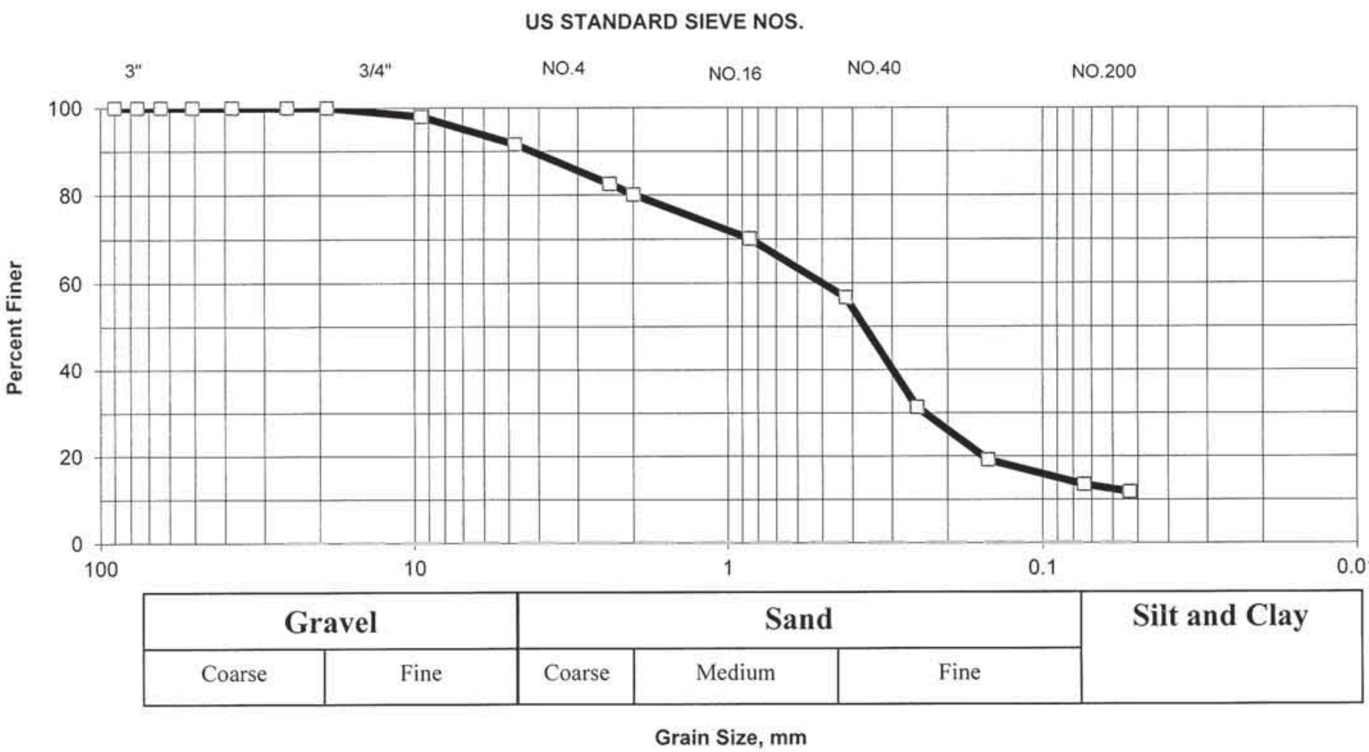
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/15-16/2014	**Lynndale Elementary**	**KE140220A**		**Sand with silt, few gravel**
Tested By	Location	EB/EP No	Depth	Intended Use / Specification
GM	**OS**	**EB-5 S-8**	**35'**	

Wt. of moisture wet sample + Tare	159.26	Total Sample Tare	518.66
Wt. of moisture dry Sample + Tare	155.12	Total Sample wt + tare	954.26
Wt. of Tare	97.64	Total Sample Wt	435.6
Wt. of moisture Dry Sample	57.48	Total Sample Dry Wt	406.3
Moisture %	7%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Specification Requirements Maximum
3.5	90	0	-	100.00	-	-
3	76.1	0	-	100.00	-	-
2.5	64	0	-	100.00	-	-
2	50.8	0	-	100.00	-	-
1.5	38.1	0	-	100.00	-	-
1	25.4	0	-	100.00		
3/4	19	0	-	100.00		
3/8	9.51	8.26	2.03	97.97		
#4	4.76	34.08	8.39	91.61		
#8	2.38	71.06	17.49	82.51		
#10	2	80.82	19.89	80.11		
#20	0.85	121.61	29.93	70.07		
#40	0.42	176.05	43.33	56.67		
#60	0.25	279.06	68.68	31.32		
#100	0.149	328.54	80.85	19.15		
#200	0.074	351.64	86.54	13.46		
#270	0.053	358.4	88.20	11.80		



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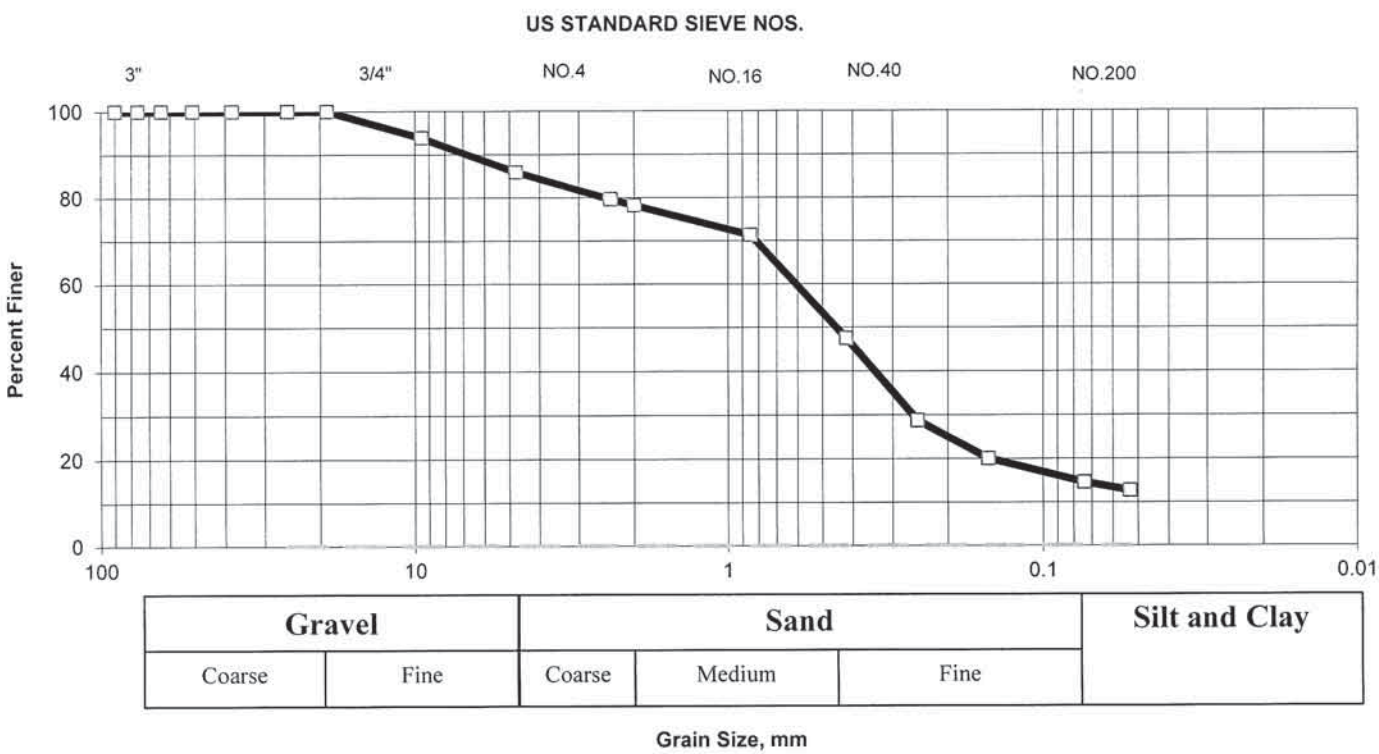
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/15-16/2014	**Lynndale Elementary**	**KE140220A**		**Sand with silt, few gravel**
Tested By	Location	EB/EP No	Depth	Intended Use / Specification
GM	**OS**	**EB-5 S-9**	**40'**	

Wt. of moisture wet sample + Tare	176.98	Total Sample Tare	393.91
Wt. of moisture dry Sample + Tare	172.14	Total Sample wt + tare	788.88
Wt. of Tare	100.64	Total Sample Wt	395.0
Wt. of moisture Dry Sample	71.5	Total Sample Dry Wt	369.9
Moisture %	7%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements	
					Minimum	Maximum
3.5	90	0	-	100.00	-	-
3	76.1	0	-	100.00	-	-
2.5	64	0	-	100.00	-	-
2	50.8	0	-	100.00	-	-
1.5	38.1	0	-	100.00	-	-
1	25.4	0	-	100.00		
3/4	19	0	-	100.00		
3/8	9.51	22.74	6.15	93.85		
#4	4.76	52.24	14.12	85.88		
#8	2.38	75.49	20.41	79.59		
#10	2	80.74	21.83	78.17		
#20	0.85	106.23	28.72	71.28		
#40	0.42	194.22	52.50	47.50		
#60	0.25	263.57	71.25	28.75		
#100	0.149	295.81	79.96	20.04		
#200	0.074	315.92	85.40	14.60		
#270	0.053	322.91	87.29	12.71		



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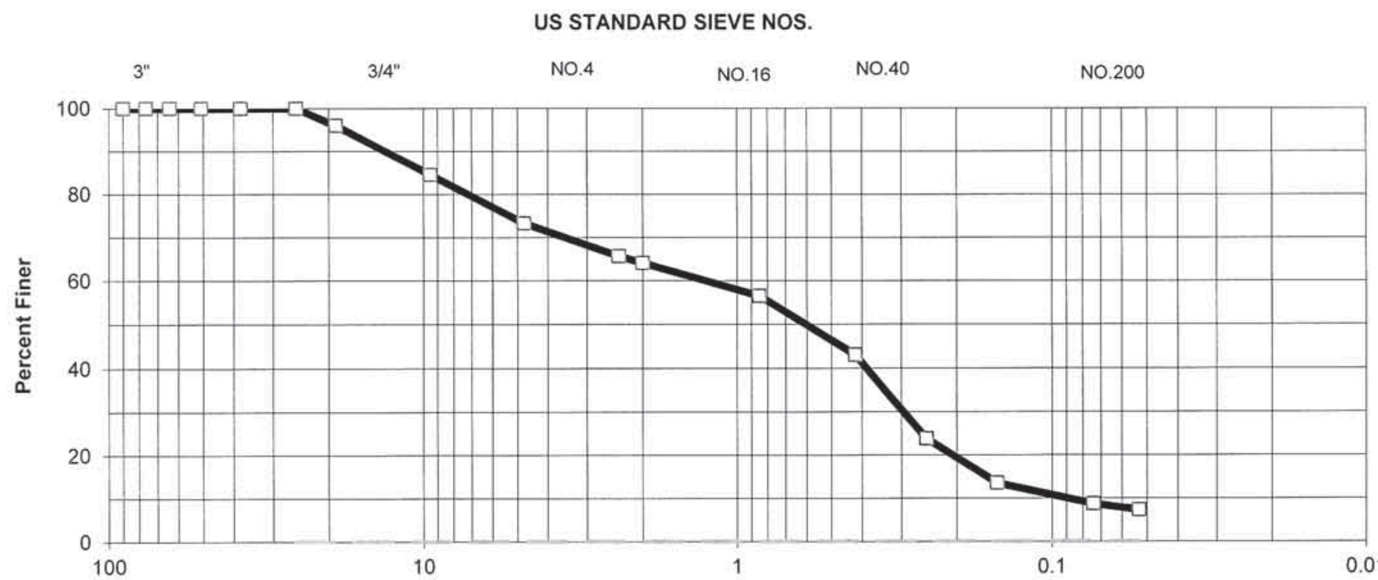
GRAIN SIZE ANALYSIS - MECHANICAL

Date Sampled	Project	Project No.		Soil Description
5/15-16/2014	**Lynndale Elementary**	**KE140220A**		**Gravelly sand, few silt**
Tested By	Location	EB/EP No	Depth	Intended Use / Specification
GM	**OS Composite of S-10 & S-11**	**EB-5 S-10/11**	**45'+50'**	

Wt. of moisture wet sample + Tare	183.49	Total Sample Tare	518.96
Wt. of moisture dry Sample + Tare	179.05	Total Sample wt + tare	1095.72
Wt. of Tare	99.75	Total Sample Wt	576.8
Wt. of moisture Dry Sample	79.3	Total Sample Dry Wt	546.2
Moisture %	6%		

Sieve No.	Diam. (mm)	Wt. Retained (g)	% Retained	% Passing	Specification Requirements Minimum	Maximum
3.5	90	0	-	100.00	-	-
3	76.1	0	-	100.00	-	-
2.5	64	0	-	100.00	-	-
2	50.8	0	-	100.00	-	-
1.5	38.1	0	-	100.00	-	-
1	25.4	0	-	100.00		
3/4	19	21.87	4.00	96.00		
3/8	9.51	84.31	15.44	84.56		
#4	4.76	146.16	26.76	73.24		
#8	2.38	187.58	34.34	65.66		
#10	2	196.28	35.94	64.06		
#20	0.85	237.75	43.53	56.47		
#40	0.42	311.11	56.96	43.04		
#60	0.25	416.25	76.21	23.79		
#100	0.149	472.3	86.47	13.53		
#200	0.074	498.55	91.28	8.72		
#270	0.053	506.1	92.66	7.34		



Gravel		Sand			Silt and Clay
Coarse	Fine	Coarse	Medium	Fine	

Grain Size, mm

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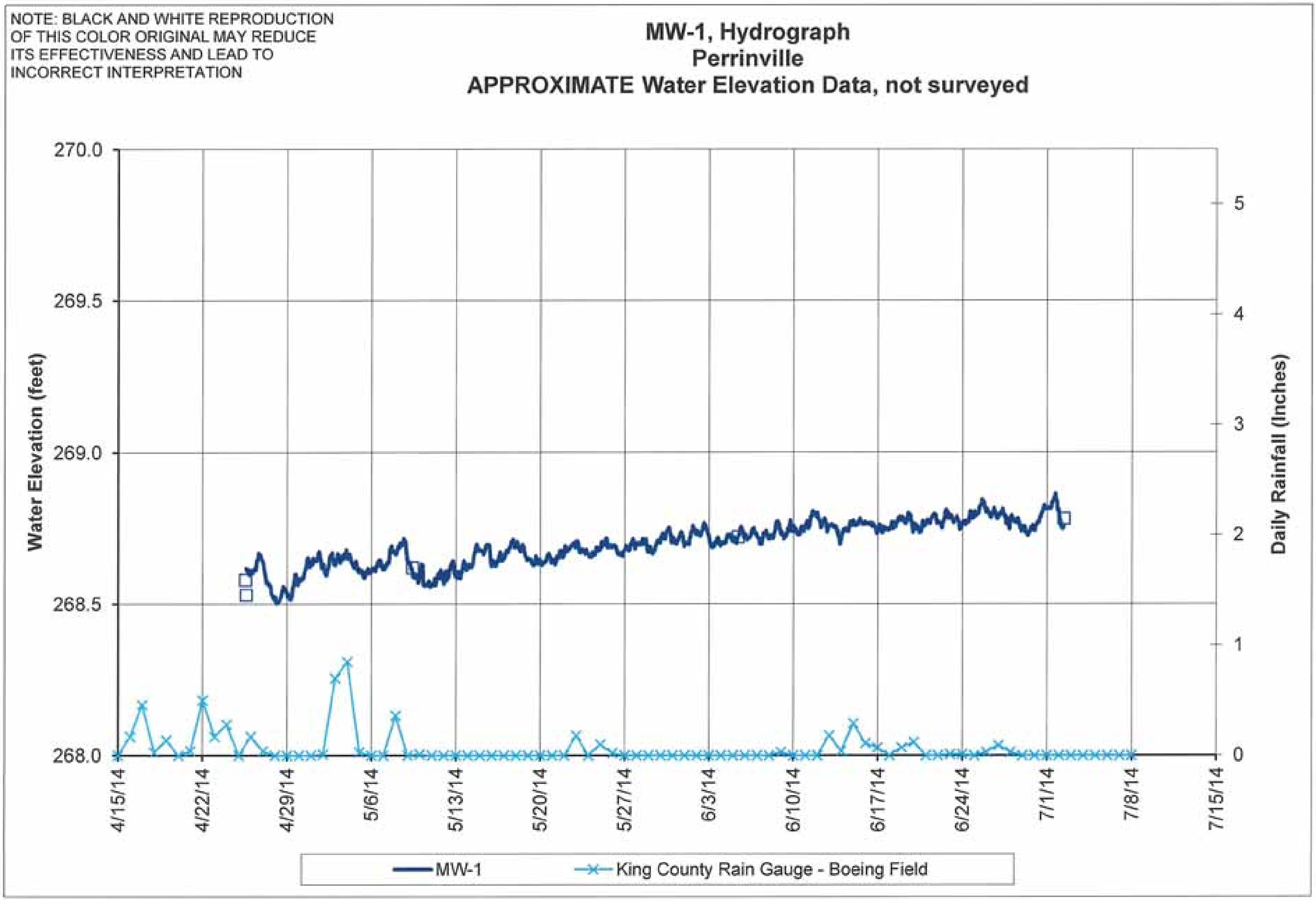
APPENDIX C

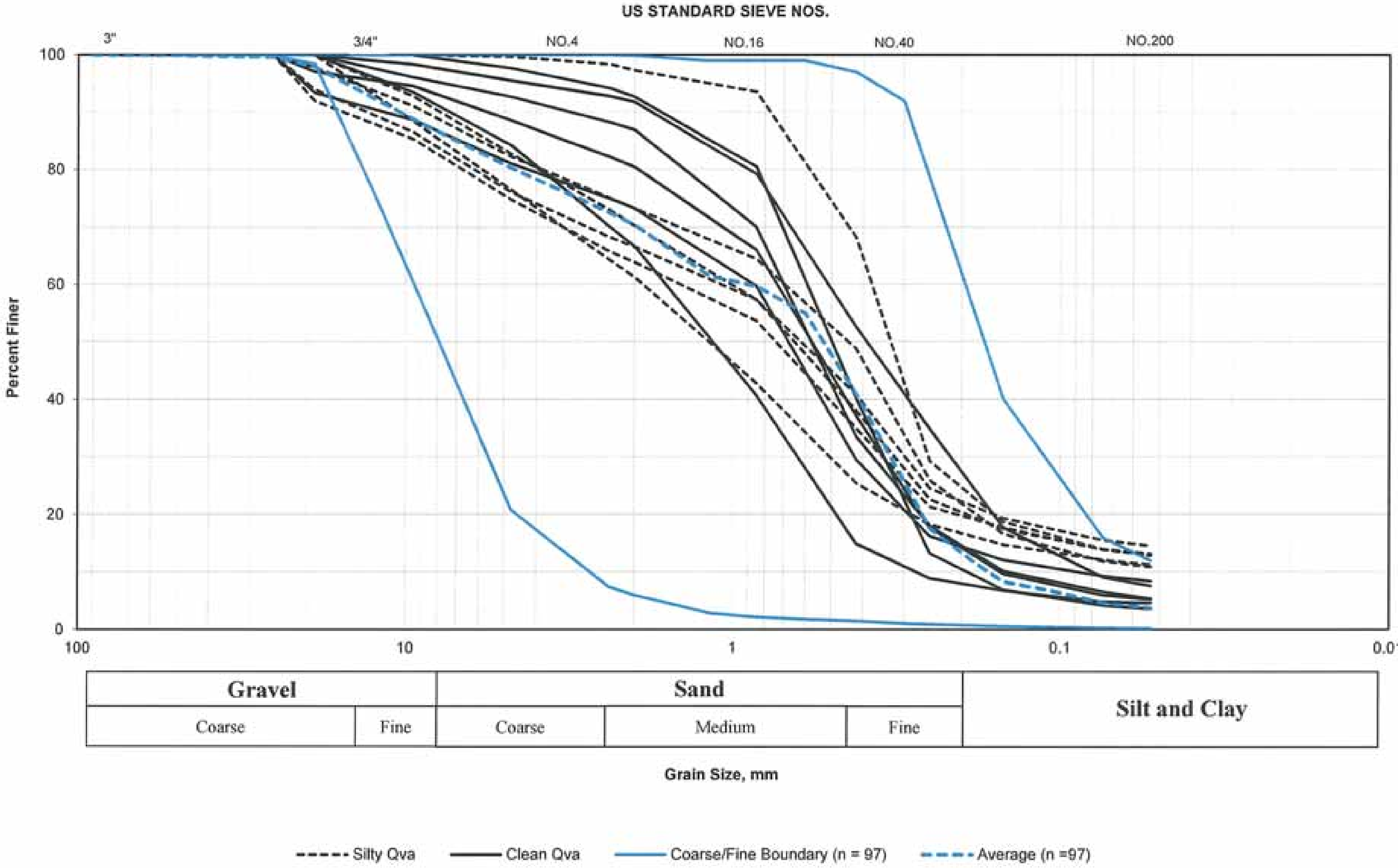
MW-1 Hydrograph


NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION
MW-1, Hydrograph
Perrinville
APPROXIMATE Water Elevation Data, not surveyed
Water Elevation (feet)
270.0
269.5
269.0
268.5
268.0
Daily Rainfall (Inches)
5
4
3
2
1
0
4/15/14
4/22/14
4/29/14
5/6/14
5/13/14
5/20/14
5/27/14
6/3/14
6/10/14
6/17/14
6/24/14
7/1/14
7/8/14
7/15/14
MW-1
King County Rain Gauge - Boeing Field

APPENDIX D

Grain Size and Flow Rate Relationship Analysis

PERRINVILLE VS QVA SAMPLES FROM THE PUGET LOWLAND (n = 97)



Notes:

KH130422A Perrinville

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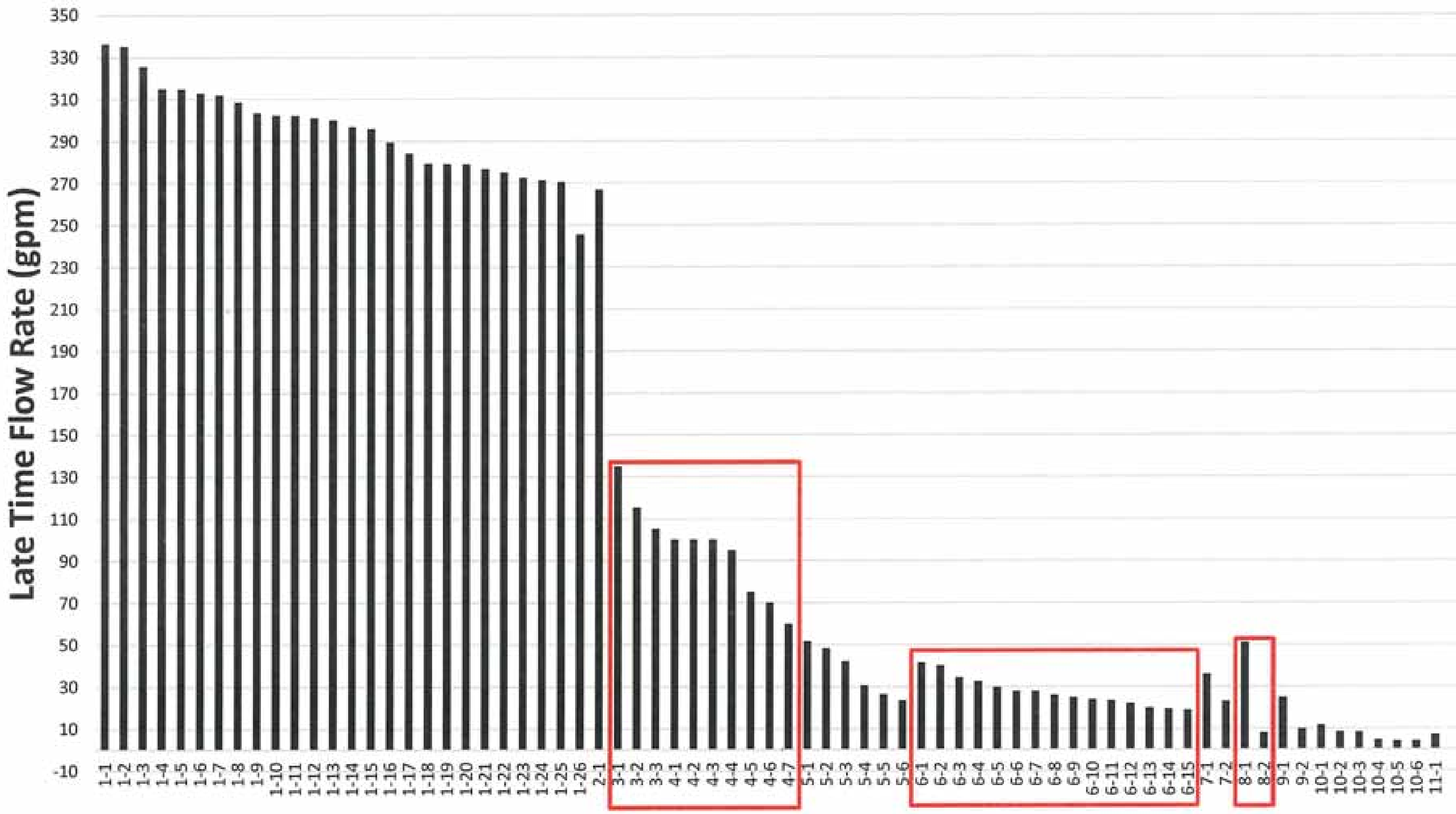
UIC LATE TIME FLOW HISTOGRAM



n = 70

Notes: [red box] = samples with grain-size distributions similar to Perrinville samples

KH130422A Perrinville

City Of Edmonds
Perrinville Creek Stormwater Flow Reduction Retrofit Study
Final Report

APPENDIX I.
CAPITAL PROJECT DESCRIPTIONS

October 2014

TETRA TECH

Bio-retention Site 2-1
Perrinville Creek Stormwater Retrofit

RETROFIT TYPE

Bio-retention

LOCATION

7903 191st St SW
at 78th Pl W, Edmonds

EXISTING USE

Roadside lawn area

TRIBUTARY DRAINAGE AREA

0.38 Acres
0.17 Acres Impervious

SITING NOTES

Proposed system assumes poor soils with lined-system

FLOW REDUCTION

Existing 2-yr	0.11 cfs
Mitigated 2-yr	0.00 cfs
Flow Reduction	0.11 cfs

COST

$57k, $519k per 1 cfs reduced

PROJECT DESCRIPTION

This bio-retention system intercepts sheet flow and roadside drainage from the roadway area to the west prior to entering a catch basin at 78th Pl W. Design consists of converting existing roadside lawn area into a 45' long roadside bio-retention swale to attenuate peak flows through storage and infiltration. The bio-retention swale will have a control structure and overflows to the west with a connection an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to collection of runoff from roadway

SITE CONSTRAINTS/DIFFICULTIES

- Requires new piped connection to existing system near 78th Pl W.

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
Site 2-1					
1	MOBILIZATION (10%)	1	LS	$2,292	$2,292
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$688	$688
3	TESC (5%)	1	LS	$1,092	$1,092
4	SAWCUTTING	60	LF	$2	$90
5	STRUCTURAL EXCAVATION CLASS B INCL HAUL	140	CY	$35	$4,900
6	SCHEDULE A STORM SEWER PIPE 12 IN DIAM	75	LF	$40	$3,000
7	TESTING STORM SEWER PIPE	75	LF	$2	$150
8	UNDERDRAIN PIPE 8 IN. DIAM.	0	LF	$20	$0
9	BIORETENTION SOIL	30	CY	$35	$1,050
10	TILL LINER	0	CY	$15	$0
11	GRAVEL BACKFILL FOR DRAIN	120	CY	$35	$4,200
12	GRAVEL BLANKET	10	CY	$50	$500
13	AREA DRAIN	1	EA	$800	$800
14	FLOW RESTRICTOR	1	EA	$3,000	$3,000
15	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$750	$750
16	PAVEMENT PATCH	1	LS	$0	$0
17	LANDSCAPING	1	L.S.	$1,790	$1,790
18	TRAFFIC CONTROL	1	L.S.	$1,600	$1,600

CONSTRUCTION SUBTOTAL		$25,901
DESIGN CONTINGENCY	50%	$12,951
PERMITTING	5%	$1,295
DESIGN	25%	$6,475
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,295
CONSTRUCTION MANAGEMENT	25%	$6,475
MANAGEMENT RESERVE	10%	$2,590
PROJECT TOTAL COST		**$56,983**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 2-3

Perrinville Creek Stormwater Retrofit

RETROFIT TYPE	
Bio-retention	
LOCATION	
19108 Dellwood Dr. at 191st St SW, Edmonds	
EXISTING USE	
Roadside lawn area	
TRIBUTARY DRAINAGE AREA	
0.51 Acres 0.24 Acres Impervious	
SITING NOTES	
Proposed system assumes poor soils with lined-system	
FLOW REDUCTION	
Existing 2-yr	0.13 cfs
Mitigated 2-yr	0.00 cfs
Flow Reduction	0.13 cfs
COST	
$100k, $770k per 1 cfs reduced	

PROJECT DESCRIPTION

This bio-retention system intercepts sheet flow and roadside drainage from 191st St SW to the west. Design consists of converting existing roadside lawn area into a 75' long roadside bio-retention swale to attenuate peak flows through storage and infiltration. The bio-retention swale will have a control structure with approximately 200' of new piping to connect to an existing storm drain near 76th Ave W.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to collection of runoff from roadway

SITE CONSTRAINTS/DIFFICULTIES

- Requires new piped connection and catch basins to existing system near 78th St W.

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

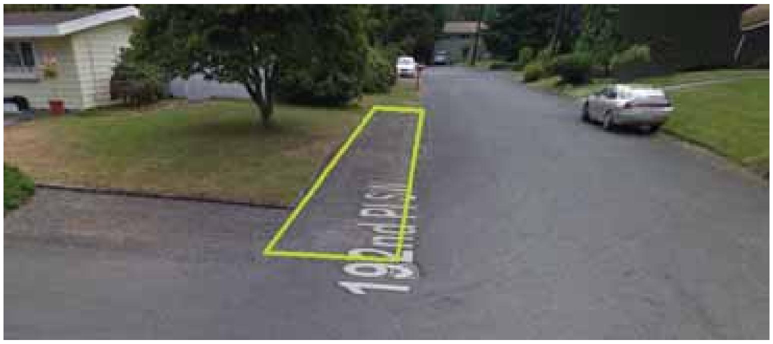
ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
Site 2-3					
1	MOBILIZATION (10%)	1	LS	$4,019	$4,019
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$1,206	$1,206
3	TESC (5%)	1	LS	$1,914	$1,914
4	SAWCUTTING	480	LF	$2	$720
5	STRUCTURAL EXCAVATION CLASS B INCL HAUL	250	CY	$35	$8,750
6	SCHEDULE A STORM SEWER PIPE 12 IN DIAM	200	LF	$40	$8,000
7	TESTING STORM SEWER PIPE	200	LF	$2	$400
8	UNDERDRAIN PIPE 8 IN. DIAM.	70	LF	$20	$1,400
9	BIORETENTION SOIL	50	CY	$35	$1,750
10	TILL LINER	0	CY	$15	$0
11	GRAVEL BACKFILL FOR DRAIN	170	CY	$35	$5,950
12	GRAVEL BLANKET	20	CY	$50	$1,000
13	AREA DRAIN	1	EA	$800	$800
14	FLOW RESTRICTOR	1	EA	$3,000	$3,000
15	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$750	$750
16	PAVEMENT PATCH	1	LS	$1,500	$1,500
17	LANDSCAPING	1	L.S.	$2,660	$2,660
18	TRAFFIC CONTROL	1	L.S.	$1,600	$1,600

CONSTRUCTION SUBTOTAL		$45,419
DESIGN CONTINGENCY	50%	$22,710
PERMITTING	5%	$2,271
DESIGN	25%	$11,355
CITY PROJECT MGMT. ADMINISTRATION	5%	$2,271
CONSTRUCTION MANAGEMENT	25%	$11,355
MANAGEMENT RESERVE	10%	$4,542
PROJECT TOTAL COST		**$99,922**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 3-1
Perrinville Creek Stormwater Retrofit



PROJECT DESCRIPTION

This bio-retention system intercepts sheet flow and roadside drainage from 192nd Pl SW to the east. Design consists of converting the existing roadside area into a 40' long roadside bio-retention area to attenuate peak flows through storage and infiltration. The bio-retention area will be over excavated to reach the outwash layer below and will have a control structure with minimal new piping to connect to an existing storm drain at 78th Pl W.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to collection of runoff from roadway

SITE CONSTRAINTS/DIFFICULTIES

- Requires new piped connection and catch basins to existing system near 78th Pl W.
- Over excavation required to reach soils with good infiltration

RETROFIT TYPE

Bio-retention

LOCATION

7805 192nd Pl SW.
near 78th Pl W, Edmonds

EXISTING USE

Roadside area

TRIBUTARY DRAINAGE AREA

0.38 Acres
0.13 Acres Impervious

SITING NOTES

Existing cul-de-sac pavement in poor condition

FLOW REDUCTION

Existing 2-yr	0.05 cfs
Mitigated 2-yr	0.00 cfs
Flow Reduction	0.05 cfs

COST

$82k, $1,640k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	Site 3-1				
1	MOBILIZATION (10%)	1	LS	$3,316	$3,316
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$995	$995
3	TESC (5%)	1	LS	$1,579	$1,579
4	SAWCUTTING	70	LF	$2	$105
5	STRUCTURAL EXCAVATION CLASS B INCL HAUL	100	CY	$35	$3,500
6	SCHEDULE A STORM SEWER PIPE 12 IN DIAM	25	LF	$40	$1,000
7	TESTING STORM SEWER PIPE	25	LF	$2	$50
8	UNDERDRAIN PIPE 8 IN. DIAM.	40	LF	$20	$800
9	BIORETENTION SOIL	30	CY	$35	$1,050
10	SUPPORT OF EXCAVATION	460	SF	$2	$920
11	GRAVEL BACKFILL FOR DRAIN	440	CY	$35	$15,400
12	GRAVEL BLANKET	10	CY	$50	$500
13	AREA DRAIN	1	EA	$800	$800
14	FLOW RESTRICTOR	1	EA	$3,000	$3,000
15	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$750	$750
16	PAVEMENT PATCH	1	LS	$500	$500
17	LANDSCAPING	1	L.S.	$1,610	$1,610
18	TRAFFIC CONTROL	1	L.S.	$1,600	$1,600

CONSTRUCTION SUBTOTAL		$37,476
DESIGN CONTINGENCY	50%	$18,738
PERMITTING	5%	$1,874
DESIGN	25%	$9,369
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,874
CONSTRUCTION MANAGEMENT	25%	$9,369
MANAGEMENT RESERVE	10%	$3,748
PROJECT TOTAL COST		**$82,446**

All cost estimates are presented in 2014 dollars.

Bio-retention Sites 4-2
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

These lined and interconnected bio-retention systems intercept sheet flow and roadside drainage from 77th Pl SW to the south. Design consists of converting existing roadside lawn area into two 40' long roadside bio-retention swales to attenuate peak flows through storage and infiltration. The swales will have a control structure with and new piping to connect to existing catch basins at 193rd Pl SW.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to collection of runoff from roadway

SITE CONSTRAINTS/DIFFICULTIES

- Requires new piped connections and replacement of existing storm drain between catch basins along 193rd Pl SW.

RETROFIT TYPE

Bio-retention

LOCATION

7712 193rd Pl SW
7711 194th Pl SW
along 77th Pl W, Edmonds

EXISTING USE

Roadside lawn area

TRIBUTARY DRAINAGE AREA

0.38 Acres
0.12 Acres Impervious

SITING NOTES

Proposed system assumes poor soils with lined-system

FLOW REDUCTION

Existing 2-yr	0.07 cfs
Mitigated 2-yr	0.00 cfs
Flow Reduction	0.07 cfs

COST

$100k, $1,516k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
Site 4-2					
1	MOBILIZATION (10%)	1	LS	$4,036	$4,036
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$1,211	$1,211
3	TESC (5%)	1	LS	$1,922	$1,922
4	SAWCUTTING	170	LF	$2	$255
5	STRUCTURAL EXCAVATION CLASS B INCL HAUL	220	CY	$35	$7,700
6	SCHEDULE A STORM SEWER PIPE 12 IN DIAM	150	LF	$40	$6,000
7	TESTING STORM SEWER PIPE	150	LF	$2	$300
8	UNDERDRAIN PIPE 8 IN. DIAM.	75	LF	$20	$1,500
9	BIORETENTION SOIL	50	CY	$35	$1,750
10	TILL LINER	30	CY	$15	$450
11	GRAVEL BACKFILL FOR DRAIN	170	CY	$35	$5,950
12	GRAVEL BLANKET	20	CY	$50	$1,000
13	AREA DRAIN	1	EA	$800	$800
14	FLOW RESTRICTOR	2	EA	$3,000	$6,000
15	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$750	$1,500
16	PAVEMENT PATCH	1	LS	$1,000	$1,000
17	LANDSCAPING	1	L.S.	$2,630	$2,630
18	TRAFFIC CONTROL	1	L.S.	$1,600	$1,600

CONSTRUCTION SUBTOTAL		$45,603
DESIGN CONTINGENCY	50%	$22,802
PERMITTING	5%	$2,280
DESIGN	25%	$11,401
CITY PROJECT MGMT. ADMINISTRATION	5%	$2,280
CONSTRUCTION MANAGEMENT	25%	$11,401
MANAGEMENT RESERVE	10%	$4,560
PROJECT TOTAL COST		**$100,327**

All cost estimates are presented in 2014 dollars.

Bio-retention Site 7-1
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-retention system intercepts sheet flow from an asphalt swale along the roadside to the south prior to entering a catch basin on 74th Ave W near 194th Pl SW. Design consists of removing the raised asphalt edge and converting existing roadside grass area into a bio-retention area to attenuate peak flows through storage and infiltration. This bio-retention area overflows to the west through an existing catch basin.

SITE BENEFITS

- LID is completely within the public right of way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to existing shallow drainage system

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates

RETROFIT TYPE

Bio-retention

LOCATION

19423 74th Ave W
at 194th Pl SW, Lynnwood

EXISTING USE

Roadside drainage ditch
Grass lawn area

TRIBUTARY DRAINAGE AREA

1.43 Acres
0.43 Acres Impervious

SITING NOTES

Replacement of existing roadside lawn area

FLOW REDUCTION

Existing 2-yr	0.20 cfs
Mitigated 2-yr	0.08 cfs
Flow Reduction	0.12 cfs

COST

$18k, $150k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-1				
1	MOBILIZATION (10%)	1	LS	$ 701	$ 701
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 210	$ 210
3	TESC (5%)	1	LS	$ 351	$ 351
4	SAWCUTTING	40	LF	$ 2	$ 80
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	65	CY	$ 35	$ 2,269
6	BIORETENTION SOIL	19	CY	$ 35	$ 681
7	GRAVEL BACKFILL FOR DRAIN	32	CY	$ 35	$ 1,134
8	GRAVEL BLANKET	6	CY	$ 50	$ 324
9	PAVEMENT PATCH	1	LS	$ 500	$ 500
10	LANDSCAPING	1	LS	$ 1,225	$ 1,225
11	TRAFFIC CONTROL	1	LS	$ 800	$ 800

CONSTRUCTION SUBTOTAL		$8,275
DESIGN CONTINGENCY	50%	$4,137
PERMITTING	5%	$414
DESIGN	25%	$2,069
CITY PROJECT MGMT. ADMINISTRATION	5%	$414
CONSTRUCTION MANAGEMENT	25%	$2,069
MANAGEMENT RESERVE	10%	$827
PROJECT TOTAL COST		**$18,204**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 7-2
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-retention system intercepts roadside drainage from a large stormwater system to the east which daylights along 194th Pl SW prior to entering a catch basin at 74th Ave W. Design consists of converting existing roadside drainage ditches into interconnected bio-retention areas to attenuate peak flows through storage and infiltration. The bio-retention area outlets to the west through a control structure to an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to existing shallow drainage system

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Large contributing tributary area may require incorporation of other retrofits or a bypass to ensure bio-retention is not undersized

RETROFIT TYPE

Bio-retention

LOCATION

19417 74th Ave W
at 194th Pl SW, Lynnwood

EXISTING USE

Roadside drainage ditch

TRIBUTARY DRAINAGE AREA

6.60 Acres
2.26 Acres Impervious

SITING NOTES

Replacement of existing grass roadside ditch

FLOW REDUCTION

Existing 2-yr	0.90 cfs
Mitigated 2-yr	0.70 cfs
Flow Reduction	0.20 cfs

COST

$42k, $210k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-2				
1	MOBILIZATION (10%)	1	LS	$ 1,637	$ 1,637
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 491	$ 491
3	TESC (5%)	1	LS	$ 819	$ 819
4	SAWCUTTING	30	LF	$ 2	$ 60
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	120	CY	$ 35	$ 4,213
6	BIORETENTION SOIL	36	CY	$ 35	$ 1,264
7	GRAVEL BACKFILL FOR DRAIN	60	CY	$ 35	$ 2,106
8	GRAVEL BLANKET	12	CY	$ 50	$ 602
9	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
10	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 750	$ 750
11	PAVEMENT PATCH	1	LS	$ 500	$ 500
12	LANDSCAPING	1	LS	$ 2,275	$ 2,275
13	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$19,317
DESIGN CONTINGENCY	50%	$9,658
PERMITTING	5%	$966
DESIGN	25%	$4,829
CITY PROJECT MGMT. ADMINISTRATION	5%	$966
CONSTRUCTION MANAGEMENT	25%	$4,829
MANAGEMENT RESERVE	10%	$1,932
PROJECT TOTAL COST		**$42,497**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Channel Restoration Site 7-3
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This stepped swale system would replace an asphalt lined roadside ditch conveying runoff from a large stormwater system to the east which daylights at the upper end of the asphalt ditch. The proposed design would incorporate a stepped weir system with native plantings and a streambed gravel bottom to slow flows and allow sediment to settle out prior to infiltration at the downstream bio-retention area 7-2.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to shallow existing drainage system

SITE CONSTRAINTS/DIFFICULTIES

- Preservation and protection of existing roadside trees
- Large contributing tributary area may require either incorporation of other retrofits (refer to other options) or a high-flow bypass to ensure conveyance is not undersized

RETROFIT TYPE

Channel restoration and stepped infiltration gallery

LOCATION

19417 74th Ave W
Lynnwood

EXISTING USE

Asphalt Lined Roadside drainage ditch

TRIBUTARY DRAINAGE AREA

6.60 Acres
2.26 Acres Impervious

SITING NOTES

Narrow adjacent roadway and close proximity to existing trees

FLOW REDUCTION

Existing 2-yr	0.90 cfs
Mitigated 2-yr	0.89 cfs
Flow Reduction	0.01 cfs

COST

$46k, negligible flow reduction at two-year – water quality benefits only

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-3				
1	MOBILIZATION (10%)	1	LS	$ 1,785	$ 1,785
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 536	$ 536
3	TESC (5%)	1	LS	$ 893	$ 893
4	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	93	CY	$ 35	$ 3,267
5	GRAVEL BACKFILL FOR DRAIN	93	CY	$ 35	$ 3,267
6	GRAVEL BLANKET	16	CY	$ 50	$ 778
7	WEIR	3	EA	$ 2,000	$ 6,000
8	LANDSCAPING	1	LS	$ 2,940	$ 2,940
9	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$21,064
DESIGN CONTINGENCY	50%	$10,532
PERMITTING	5%	$1,053
DESIGN	25%	$5,266
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,053
CONSTRUCTION MANAGEMENT	25%	$5,266
MANAGEMENT RESERVE	10%	$2,106
PROJECT TOTAL COST		**$46,341**

All cost estimates are presented in 2014 dollars.

Bio-swale Site 7-4

Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-retention system intercepts curb and gutter drainage roadway area to the east prior to entering a catch basin at 74th Ave W. Design consists of converting existing roadside lawn area into a 60' long roadside bio-retention swale to attenuate peak flows through storage and infiltration. The bio-retention swale overflows to the west into an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to collection of curb and gutter flow

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Adjacent lawn area gets steep to the north limiting width
- Adjacent roadway area is narrow

RETROFIT TYPE

Bio-swale

LOCATION

19405 74th Ave W
at 194th Pl SW, Lynnwood

EXISTING USE

Roadside lawn area

TRIBUTARY DRAINAGE AREA

0.75 Acres
0.28 Acres Impervious

SITING NOTES

Concrete curb and gutter and sidewalk area terminate at proposed location

FLOW REDUCTION

Existing 2-yr	0.13 cfs
Mitigated 2-yr	0.07 cfs
Flow Reduction	0.06 cfs

COST

$19k, $317k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-4				
1	MOBILIZATION (10%)	1	LS	$ 721	$ 721
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 216	$ 216
3	TESC (5%)	1	LS	$ 361	$ 361
4	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	67	CY	$ 35	$ 2,333
5	BIORETENTION SOIL	20	CY	$ 35	$ 700
6	GRAVEL BACKFILL FOR DRAIN	33	CY	$ 35	$ 1,167
7	GRAVEL BLANKET	7	CY	$ 50	$ 361
8	LANDSCAPING	1	LS	$ 1,050	$ 1,050
9	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$8,509
DESIGN CONTINGENCY	50%	$4,255
PERMITTING	5%	$425
DESIGN	25%	$2,127
CITY PROJECT MGMT. ADMINISTRATION	5%	$425
CONSTRUCTION MANAGEMENT	25%	$2,127
MANAGEMENT RESERVE	10%	$851
PROJECT TOTAL COST		**$18,720**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-swale Site 7-5

Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-swale system intercepts curb and gutter roadway runoff from the area to the south prior to entering a catch basin at 194th Pl SW. Design consists of converting existing pavement area into a 25' long roadside bio-swale to attenuate peak flows through storage and infiltration. The bio-swale overflows to the north into an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- Minimal grading due to collection of curb and gutter flow
- Reduction of impervious areas
- LID may be incorporated into traffic calming measures

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Results in reduction of parking and possible utility conflicts

RETROFIT TYPE

Bio-swale

LOCATION

19428 73rd Ave W
at 194th Pl SW, Lynnwood

EXISTING USE

Paved Roadway Area

TRIBUTARY DRAINAGE AREA

0.45 Acres
0.25 Acres Impervious

SITING NOTES

Existing roadway widths are approximately 36' – intersection could benefit from traffic calming measures which incorporate LID

FLOW REDUCTION

Existing 2-yr	0.10 cfs
Mitigated 2-yr	0.07 cfs
Flow Reduction	0.03 cfs

COST

$20k, $667k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-5				
1	MOBILIZATION (10%)	1	LS	$ 778	$ 778
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 234	$ 234
3	TESC (5%)	1	LS	$ 389	$ 389
4	SAWCUTTING	35	LF	$ 2	$ 70
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	28	CY	$ 35	$ 972
6	CONCRETE CURB AND GUTTER	35	LF	$ 100	$ 3,500
7	BIORETENTION SOIL	8	CY	$ 35	$ 292
8	GRAVEL BACKFILL FOR DRAIN	14	CY	$ 35	$ 486
9	GRAVEL BLANKET	3	CY	$ 50	$ 139
10	PAVEMENT PATCH	1	LS	$ 1,000	$ 1,000
11	LANDSCAPING	1	LS	$ 525	$ 525
12	TRAFFIC CONTROL	1	LS	$ 800	$ 800

CONSTRUCTION SUBTOTAL		$9,185
DESIGN CONTINGENCY	50%	$4,592
PERMITTING	5%	$459
DESIGN	25%	$2,296
CITY PROJECT MGMT. ADMINISTRATION	5%	$459
CONSTRUCTION MANAGEMENT	25%	$2,296
MANAGEMENT RESERVE	10%	$918
PROJECT TOTAL COST		**$20,207**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-swale Site 7-6
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-swale system intercepts curb and gutter drainage roadway area to the south prior to entering a catch basin at 194th Pl SW. Design consists of converting existing pavement area into a 40' long roadside bio-swale to attenuate peak flows through storage and infiltration. The bio-swale overflows to the north into an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- Minimal grading due to collection of curb and gutter flow
- Reduction of impervious areas
- LID may be incorporated into traffic calming measures

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Results in reduction of parking and possible utility conflicts

RETROFIT TYPE

Bio-swale

LOCATION

19427 73rd Ave W
at 194th Pl SW, Lynnwood

EXISTING USE

Paved Roadway Area

TRIBUTARY DRAINAGE AREA

0.35 Acres
0.20 Acres Impervious

SITING NOTES

Existing roadway widths are approximately 36' – intersection could benefit from traffic calming measures which incorporate LID

FLOW REDUCTION

Existing 2-yr	0.10 cfs
Mitigated 2-yr	0.03 cfs
Flow Reduction	0.07 cfs

COST

$28k, $418k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 7-6				
1	MOBILIZATION (10%)	1	LS	$ 1,076	$ 1,076
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 323	$ 323
3	TESC (5%)	1	LS	$ 538	$ 538
4	SAWCUTTING	50	LF	$ 2	$ 100
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	44	CY	$ 35	$ 1,556
6	CONCRETE CURB AND GUTTER	50	LF	$ 100	$ 5,000
7	BIORETENTION SOIL	13	CY	$ 35	$ 467
8	GRAVEL BACKFILL FOR DRAIN	22	CY	$ 35	$ 778
9	GRAVEL BLANKET	4	CY	$ 50	$ 222
10	PAVEMENT PATCH	1	LS	$ 1,000	$ 1,000
11	LANDSCAPING	1	LS	$ 840	$ 840
12	TRAFFIC CONTROL	1	LS	$ 800	$ 800

CONSTRUCTION SUBTOTAL		$12,699
DESIGN CONTINGENCY	50%	$6,350
PERMITTING	5%	$635
DESIGN	25%	$3,175
CITY PROJECT MGMT. ADMINISTRATION	5%	$635
CONSTRUCTION MANAGEMENT	25%	$3,175
MANAGEMENT RESERVE	10%	$1,270
PROJECT TOTAL COST		**$27,939**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 8-1
Perrinville Creek Stormwater Retrofit

RETROFIT TYPE

Bio-retention

LOCATION

19117 74th Ave W
19123 74th Ave W
near 191st St SW,
Lynnwood

EXISTING USE

Roadside drainage ditch

TRIBUTARY DRAINAGE AREA

6.27 Acres
1.84 Acres Impervious

SITING NOTES

Flows from ravine are known to infiltrate, east of the site

FLOW REDUCTION

Existing 2-yr	0.71 cfs
Mitigated 2-yr	0.48 cfs
Flow Reduction	0.23 cfs

COST

$57k, $248k per 1 cfs reduced

PROJECT DESCRIPTION

This bio-retention area intercepts both roadside drainage along 74rd Ave W and a ravine area which receives runoff from portions of Lynndale Elementary School to the east drain prior to entering a piped system to the north. Design includes interconnected bio-retention areas with a flow control structure at the downstream end.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to shallow existing drainage system

SITE CONSTRAINTS/DIFFICULTIES

- Large tributary area – site may be undersized although much of the flows infiltrate upstream of the site
- Proposed design contingent on good infiltration rates

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
SITE 8-1					
1	MOBILIZATION (10%)	1	LS	$ 2,200	$ 2,200
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 660	$ 660
3	TESC (5%)	1	LS	$ 1,100	$ 1,100
4	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	185	CY	$ 35	$ 6,481
5	BIORETENTION SOIL	56	CY	$ 35	$ 1,944
6	TILL LINER	37	CY	$ 15	$ 556
7	GRAVEL BACKFILL FOR DRAIN	93	CY	$ 35	$ 3,241
8	GRAVEL BLANKET	19	CY	$ 50	$ 926
9	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
10	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 750	$ 750
11	LANDSCAPING	1	LS	$ 3,500	$ 3,500
12	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$25,958
DESIGN CONTINGENCY	50%	$12,979
PERMITTING	5%	$1,298
DESIGN	25%	$6,489
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,298
CONSTRUCTION MANAGEMENT	25%	$6,489
MANAGEMENT RESERVE	10%	$2,596
PROJECT TOTAL COST		**$57,107**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 10-1
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This lined bio-retention system intercepts a catch basin pipe before it outlets into a downstream drainage ditch. Design consists of conversion of drainage ditch and landscaped area into two interconnected bio-retention areas, a control structure, and pipe replacement to the next downstream basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts

SITE CONSTRAINTS/DIFFICULTIES

- Moderate grading difficulty due to raised adjacent yard and interception of pipe
- Soil testing in this vicinity has yielded poor infiltration rates
- Requires removal of existing landscaped area

RETROFIT TYPE

Bio-retention

LOCATION

18027 73^{nd} Ave. W.

EXISTING USE

Roadside ditch
Landscaped yard area

TRIBUTARY DRAINAGE AREA

1.87 Acres
0.56 Acres Impervious

SITING NOTES

Lined system due to soils with low-infiltration and proximity to steep slopes south of site

FLOW REDUCTION

Existing 2-yr	0.27 cfs
Mitigated 2-yr	0.09 cfs
Flow Reduction	0.18 cfs

COST

$89k, $495k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 10-1				
1	MOBILIZATION (10%)	1	LS	$ 3,427	$ 3,427
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 1,028	$ 1,028
3	TESC (5%)	1	LS	$ 1,714	$ 1,714
4	SAWCUTTING	50	LF	$ 2	$ 100
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	232	CY	$ 35	$ 8,110
6	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	188	LF	$ 40	$ 7,520
7	TESTING STORM SEWER PIPE	188	LF	$ 2	$ 376
8	UNDERDRAIN PIPE 6 IN. DIAM.	105	LF	$ 20	$ 2,100
9	BIORETENTION SOIL	59	CY	$ 35	$ 2,074
10	TILL LINER	39	CY	$ 15	$ 583
11	GRAVEL BACKFILL FOR DRAIN	93	CY	$ 35	$ 3,267
12	GRAVEL BLANKET	15	CY	$ 50	$ 741
13	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
14	CONNECTION TO DRINAGE STRUCTURE	2	EA	$ 750	$ 1,500
15	PAVEMENT PATCH	1	LS	$ 500	$ 500
16	LANDSCAPING	1	LS	$ 2,800	$ 2,800
17	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$40,439
DESIGN CONTINGENCY	50%	$20,220
PERMITTING	5%	$2,022
DESIGN	25%	$10,110
CITY PROJECT MGMT. ADMINISTRATION	5%	$2,022
CONSTRUCTION MANAGEMENT	25%	$10,110
MANAGEMENT RESERVE	10%	$4,044
PROJECT TOTAL COST		**$88,966**

All cost estimates are presented in 2014 dollars.

Bio-retention Site 11-1
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-retention system intercepts a pipe just downstream of a catch basin allowing runoff to infiltrate before overflowing to the downstream catch basin at the corner of 180th St SW and 72nd Ave W. Design consists of conversion of the existing gravel shoulder area into a bio-retention area, with a control structure at the downstream end.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading difficulty, flat area

SITE CONSTRAINTS/DIFFICULTIES

- Contingent on soils with good infiltration
- Limited LID footprint area

RETROFIT TYPE

Bio-retention

LOCATION

17922 72nd Ave. W.,
Edmonds

EXISTING USE

Gravel Shoulder

TRIBUTARY DRAINAGE AREA

0.80 Acres
0.35 Acres Impervious

SITING NOTES

Dependent on soils with good infiltration; option for alternate with smaller drainage area to collect sheet flow into shallow bio-retention depression

FLOW REDUCTION

Existing 2-yr	0.19 cfs
Mitigated 2-yr	0.01 cfs
Flow Reduction	0.18 cfs

COST

$37k, $206k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 11-1				
1	MOBILIZATION (10%)	1	LS	$ 1,420	$ 1,420
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 426	$ 426
3	TESC (5%)	1	LS	$ 710	$ 710
4	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	102	CY	$ 35	$ 3,565
5	BIORETENTION SOIL	31	CY	$ 35	$ 1,069
6	GRAVEL BACKFILL FOR DRAIN	51	CY	$ 35	$ 1,782
7	GRAVEL BLANKET	10	CY	$ 50	$ 509
8	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
9	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 750	$ 750
10	LANDSCAPING	1	LS	$ 1,925	$ 1,925
11	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$16,757
DESIGN CONTINGENCY	50%	$8,379
PERMITTING	5%	$838
DESIGN	25%	$4,189
CITY PROJECT MGMT. ADMINISTRATION	5%	$838
CONSTRUCTION MANAGEMENT	25%	$4,189
MANAGEMENT RESERVE	10%	$1,676
PROJECT TOTAL COST		**$36,866**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 12-1
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This lined bio-retention system replaces a roadside ditch as it flows south along the west side of 72nd Ave W. A control structure located at the lower end of the bio-retention area allows for a slow release. Downstream pipe replacement is required to allow for an underdrain connection.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts

SITE CONSTRAINTS/DIFFICULTIES

- Moderate grading difficulty due to raised adjacent yard
- Soil testing in this vicinity has yielded poor infiltration rates
- Limited LID footprint area

RETROFIT TYPE

Bio-retention

LOCATION

18032 72nd Ave. W.,
Edmonds

EXISTING USE

Roadside ditch

TRIBUTARY DRAINAGE AREA

0.70 Acres
0.30 Acres Impervious

SITING NOTES

Lined system due to soils with low-infiltration and proximity to steep slopes south of site

FLOW REDUCTION

Existing 2-yr	0.14 cfs
Mitigated 2-yr	0.01 cfs
Flow Reduction	0.13 cfs

COST

$34k, $262k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 12-1				
1	MOBILIZATION (10%)	1	LS	$ 1,314	$ 1,314
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 394	$ 394
3	TESC (5%)	1	LS	$ 657	$ 657
4	SAWCUTTING	30	LF	$ 2	$ 60
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	52	CY	$ 35	$ 1,815
6	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	60	LF	$ 40	$ 2,400
7	TESTING STORM SEWER PIPE	60	LF	$ 2	$ 120
8	UNDERDRAIN PIPE 6 IN. DIAM.	40	LF	$ 20	$ 800
9	BIORETENTION SOIL	16	CY	$ 35	$ 544
10	TILL LINER	10	CY	$ 15	$ 156
11	GRAVEL BACKFILL FOR DRAIN	26	CY	$ 35	$ 907
12	GRAVEL BLANKET	5	CY	$ 50	$ 259
13	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
14	PAVEMENT PATCH	1	LS	$ 500	$ 500
15	LANDSCAPING	1	LS	$ 980	$ 980
16	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$15,507
DESIGN CONTINGENCY	50%	$7,753
PERMITTING	5%	$775
DESIGN	25%	$3,877
CITY PROJECT MGMT. ADMINISTRATION	5%	$775
CONSTRUCTION MANAGEMENT	25%	$3,877
MANAGEMENT RESERVE	10%	$1,551
PROJECT TOTAL COST		**$34,115**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-retention Site 13-1
Perrinville Creek Stormwater Retrofit

RETROFIT TYPE

Bio-retention

LOCATION

7418 Ridge Way, Edmonds

EXISTING USE

Roadside grass area

TRIBUTARY DRAINAGE AREA

3.47 Acres
1.62 Acres Impervious

SITING NOTES

Lined system due to proximity to steep slopes north of site

May consider tree plantings in tributary area or smaller retrofits at catch basins to the southwest

FLOW REDUCTION

Existing 2-yr	0.31 cfs
Mitigated 2-yr	0.07 cfs
Flow Reduction	0.24 cfs

COST

$77k, $321k per 1 cfs reduced

PROJECT DESCRIPTION

This non-infiltrating, lined bio-retention system intercepts a catch basin pipe before it outlets into a downstream stream to the north. Design consists of conversion of roadside grass area into a bio-retention area, a control structure, and pipe replacement to the next downstream basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts

SITE CONSTRAINTS/DIFFICULTIES

- Moderate grading difficulty due to raised adjacent yard and retaining wall with interception of pipe
- Soil testing in this vicinity has yielded poor infiltration rates
- Need to replace downstream pipe section to allow for positive drainage of underdrain

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

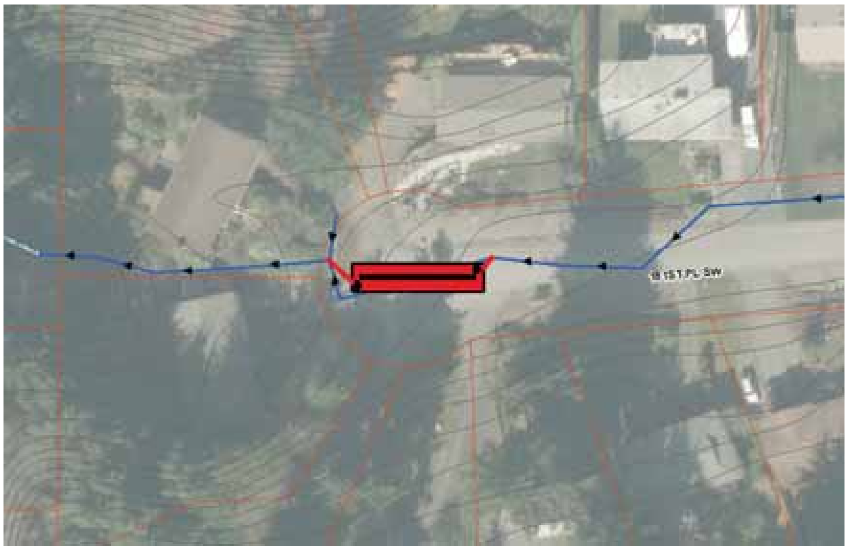
ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 13-1				
1	MOBILIZATION (10%)	1	LS	$ 2,957	$ 2,957
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 887	$ 887
3	TESC (5%)	1	LS	$ 1,478	$ 1,478
4	SAWCUTTING	50	LF	$ 2	$ 100
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	161	CY	$ 35	$ 5,639
6	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	25	LF	$ 40	$ 1,000
7	TESTING STORM SEWER PIPE	25	LF	$ 2	$ 50
8	UNDERDRAIN PIPE 6 IN. DIAM.	110	LF	$ 20	$ 2,200
9	BIORETENTION SOIL	43	CY	$ 35	$ 1,497
10	TILL LINER	29	CY	$ 15	$ 428
11	GRAVEL BACKFILL FOR DRAIN	71	CY	$ 35	$ 2,495
12	GRAVEL BLANKET	14	CY	$ 50	$ 713
13	AREA DRAIN	2	EA	$ 800	$ 1,600
14	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
15	CATCH BASIN	1	EA	$ 4,000	$ 4,000
16	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 750	$ 750
17	PAVEMENT PATCH	1	LS	$ 1,000	$ 1,000
18	LANDSCAPING	1	LS	$ 2,695	$ 2,695
19	TRAFFIC CONTROL	1	LS	$ 2,400	$ 2,400

CONSTRUCTION SUBTOTAL		$34,889
DESIGN CONTINGENCY	50%	$17,445
PERMITTING	5%	$1,744
DESIGN	25%	$8,722
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,744
CONSTRUCTION MANAGEMENT	25%	$8,722
MANAGEMENT RESERVE	10%	$3,489
PROJECT TOTAL COST		**$76,757**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Detention Pipe
Homeview Drive & 181st Pl SW 14-1
City of Edmonds Stormwater Retrofit



PROJECT DESCRIPTION

Proposed system consists of two 36” diameter detention pipes near the west end of 181st Pl SW within the roadway area. The proposed detention pipes would replace the existing storm piping and provide a flow control orifice with a connection to the downstream catch basin. The storage of peak flow volumes with slow release will attenuate the peak flows contributing to the creek, located just to the west of the proposed site.

SITE BENEFITS

- Retrofit is completely within the Right-of-Way.
- No change in current parking use.
- Easy to route contributing area.
- Minimal traffic impact - located near residential cul-de-sac.

SITE CONSTRAINTS/DIFFICULTIES

- Existing utilities within street would need to be avoided.
- Initial screening of the soils in this vicinity indicates poor infiltration capability.

RETROFIT TYPE

Detention Facility

LOCATION

181st Place SW near Homeview Drive, Edmonds

EXISTING USE

Roadway area

TRIBUTARY DRAINAGE AREA

1.77 Acres
0.71 Acres Impervious

SITING NOTES

HDPE detention gallery under existing paved roadway.

FLOW REDUCTION

Existing 2-yr	0.25 cfs
Mitigated 2-yr	0.19 cfs
Flow Reduction	0.06 cfs

COST

$92k, $1,534k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 14-1				
1	MOBILIZATION (10%)	1	LS	$ 3,503	$ 3,503
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 1,051	$ 1,051
3	TESC (5%)	1	LS	$ 1,752	$ 1,752
4	TRAFFIC CONTROL (2%)	1	LS	$ 701	$ 701
5	SAWCUTTING	160	LF	$ 2	$ 320
6	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	157	CY	$ 35	$ 5,496
7	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	20	LF	$ 40	$ 800
9	CORRUGATED POLYETHYLENE STORM SEWER PIPE	120	LF	$ 75	$ 9,000
12	GRAVEL BACKFILL FOR DRAIN	12	CY	$ 35	$ 415
15	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
16	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 1,000	$ 1,000
17	CATCH BASIN TYPE 2	1	EA	$ 5,000	$ 5,000
18	PAVEMENT PATCH	1	LS	$ 10,000	$ 10,000

CONSTRUCTION SUBTOTAL		$42,037
DESIGN CONTINGENCY	50%	$21,019
PERMITTING	5%	$2,102
DESIGN	25%	$10,509
CITY PROJECT MGMT. ADMINISTRATION	5%	$2,102
CONSTRUCTION MANAGEMENT	25%	$10,509
MANAGEMENT RESERVE	10%	$4,204
PROJECT TOTAL COST		**$92,482**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Infiltration Facility Site Seaview Park 16-1
City of Edmonds Stormwater Retrofit

PROJECT DESCRIPTION

Proposed system is a 70'w x 125' l x 6'd infiltration gallery located in an existing grass area of Seaview Park. Stormwater would be diverted near 186th St SW and 80th Ave W and routed to a presettling/wetvault located at the north side of the Seaview Park parking lot before entering the infiltration gallery composed of a manifold system of 6' diameter perforated pipes. A high flow bypass would convey larger events to the existing stormwater system.

Conceptual sizing of the system indicates flow control for tributary area can be provided in this system to meet Department of Ecology flow control requirements. The runoff from the tributary area can be detained and released to match pre-developed forested levels. Additional features could be added to the system to provide various levels of water quality treatment while enhancing aesthetic value in park features.

SITE BENEFITS

- Available site area to provide flow control for entire basin to meet 2005 Ecology flow control requirements.
- Site within Seaview Park and City owned property.
- Soil testing indicates highly infiltrative soils.
- No change in current park use.
- Park setting allows for water quality treatment options that can be integrated with park landscaping.
- Rainwater/stormwater harvesting options for park irrigation.

SITE CONSTRAINTS/DIFFICULTIES

- Replacement of existing park features impacted by construction. Public use of park would be interrupted and/or limited.

RETROFIT TYPE

Infiltration Facility

LOCATION

186th St SW & 80th Ave W

EXISTING USE

Seaview Park lawn area

TRIBUTARY DRAINAGE AREA

52.8 Acres
12.3 Acres Impervious

SITING NOTES

Infiltration gallery under grass lawn - gravel filled or HDPE pipes.

FLOW REDUCTION

Existing 2-yr	5.0 cfs
Mitigated 2-yr	1.5 cfs*
Flow Reduction	3.5 cfs

*Flow reduction based on the Ecology maximum long term infiltration rate of 2 in/hr. Soil testing confirms this will be easily achievable. Mitigated flow meets Ecology flow control standards for forested pre-developed conditions.

Site is large enough to meet Ecology Flow Control Requirements for all of Basin 13.

COST

$841k, 241k per 1 cfs reduced.

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE SEAVIEW PARK 16-1				
1	MOBILIZATION (10%)	1	LS	$ 39,377	$ 39,377
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 11,813	$ 11,813
3	TESC (5%)	1	LS	$ 19,688	$ 19,688
4	TRAFFIC CONTROL (2%)	1	LS	$ 7,875	$ 7,875
5	SAWCUTTING	50	LF	$ 2	$ 100
6	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	3015	CY	$ 35	$ 105,519
7	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	200	LF	$ 40	$ 8,000
8	INFILTRATION PIPE / CHAMBERS	1000	LF	$ 250	$ 250,000
9	GRAVEL BACKFILL FOR DRAIN	119	CY	$ 35	$ 4,148
10	CONNECTION TO DRAINAGE STRUCTURE	1	EA	$ 1,000	$ 1,000
11	CATCH BASIN TYPE 2	1	EA	$ 5,000	$ 5,000
12	PAVEMENT PATCH	1	LS	$ 10,000	$ 10,000
13	LANDSCAPING	1	LS	$ 10,000	$ 10,000

CONSTRUCTION SUBTOTAL		$472,520
DESIGN CONTINGENCY	30%	$141,756
PERMITTING	5%	$23,626
DESIGN	15%	$70,878
CITY PROJECT MGMT. ADMINISTRATION	3%	$14,176
CONSTRUCTION MANAGEMENT	15%	$70,878
MANAGEMENT RESERVE	10%	$47,252
PROJECT TOTAL COST		**$841,086**

All cost estimates are presented in 2014 dollars.

Infiltration Facility Site 17-1
City of Edmonds Stormwater Retrofit

TETRA TECH

RETROFIT TYPE

Infiltration Facility

LOCATION

194th St SW & 76th Ave W

EXISTING USE

Roadway Area

TRIBUTARY DRAINAGE AREA

92.02 Acres
34.04 Acres Impervious

SITING NOTES

Infiltration well with underground storage pipe in 194th St. preceding infiltration well.

FLOW REDUCTION

Existing 2-yr	11.30 cfs
Mitigated 2-yr	11.10 cfs
Flow Reduction	0.20 cfs

COST

$430k, $2,150k per 1 cfs reduced.

PROJECT DESCRIPTION

Proposed facility is an infiltration well approximately 2 feet in diameter and 40 feet deep. A six foot diameter by 125 foot long buried pipe would be installed preceding the infiltration well to provide storage and pre-settling before water enters the infiltration well. Stormwater flows would be split off the main line located in 76th Ave W and routed to the underground storage tank and into the infiltration well.

SITE BENEFITS

- All facilities will be underground and no existing land use changes proposed.

SITE CONSTRAINTS/DIFFICULTIES

- Utilities in the area limit site layout options.
- The main storm drain pipe in 76th Ave is 10 feet deep. The buried storage pipe will require significant excavation to provide a gravity flow system.
- Infiltration layer is located below 20 feet of till and will require a deep well to reach good infiltration rates.
- Infiltration rates provide minimal 2 year peak flow reduction.
- Minimal area to construct facilities and will require replacing the pavement on 194th St. W.

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 17-1				
1	MOBILIZATION (10%)	1	LS	$ 16,298	$ 16,298
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 4,889	$ 4,889
3	TESC (5%)	1	LS	$ 8,149	$ 8,149
4	TRAFFIC CONTROL (2%)	1	LS	$ 3,260	$ 3,260
5	SAWCUTTING	650	LF	$ 2	$ 1,300
6	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	950	CY	$ 35	$ 33,250
8	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	100	LF	$ 40	$ 4,000
10	6 FT DIA. UNDERGROUND STORAGE PIPE	150	LF	$ 250	$ 37,500
14	GRAVEL BACKFILL FOR DRAIN	275	CY	$ 35	$ 9,625
15	INFILTRATION WELL GRAVEL	6	CY	$ 50	$ 300
16	INFILTRATION WELL DRILL AND INSTALL	1	LS	$ 50,000	$ 50,000
18	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
19	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$ 1,000	$ 2,000
20	CATCH BASIN TYPE 2	1	EA	$ 5,000	$ 5,000
21	FLOW SPLITTER CB TYPE 2	1	EA	$ 7,000	$ 7,000
22	PAVEMENT RESTORATION	1	LS	$ 10,000	$ 10,000

CONSTRUCTION SUBTOTAL		$195,570
DESIGN CONTINGENCY	50%	$97,785
PERMITTING	5%	$9,779
DESIGN	25%	$48,893
CITY PROJECT MGMT. ADMINISTRATION	5%	$9,779
CONSTRUCTION MANAGEMENT	25%	$48,893
MANAGEMENT RESERVE	10%	$19,557
PROJECT TOTAL COST		**$430,254**

All cost estimates are presented in 2014 dollars.

Pipe Detention Site 19-1
City of Edmonds Stormwater Retrofit

RETROFIT TYPE
Manifold Pipe Detention Facility

LOCATION
7500 196th St SW
near 76th Ave W, Lynnwood

EXISTING USE
QFC parking lot is private property with heavy traffic.

TRIBUTARY DRAINAGE AREA
35.67 Acres
16.26 Acres Impervious

SITING NOTES
Proposed location is private property with moderate slope.

FLOW REDUCTION
Existing 2-yr	5.75 cfs
Mitigated 2-yr	1.25 cfs
Flow Reduction	4.50 cfs

COST
$1,123k, $250k* per 1 cfs reduced.

*These costs do not reflect any cost for easements or private property acquisitions

PROJECT DESCRIPTION

This 8' diameter manifold detention pipe retrofit intercepts drainage which is redirected from the north side of 196th St SW to the Quality Foods Center parking lot. The proposed system would detain and slowly releases runoff back into the storm system in 196th St SW. Because this system is located on private property, it would require coordination/acquisition of property/easements from the owner/developer.

SITE BENEFITS

- Ample area within existing site is available for construction activities
- No parking reduction resulting from retrofit
- All facilities will be underground and no existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Proposed system is within private property
  Poor soils do not allow for infiltration

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

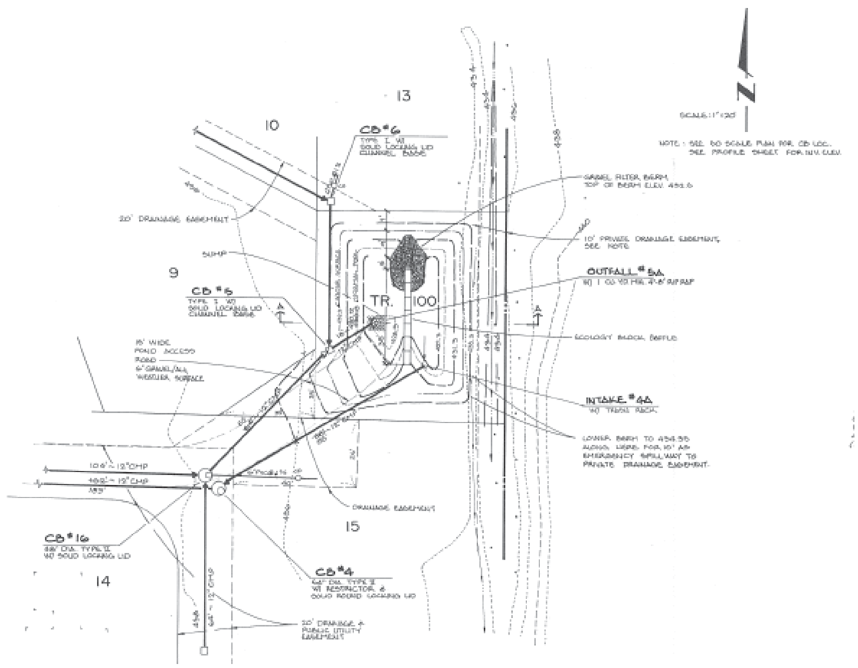
ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 19-1				
1	MOBILIZATION (10%)	1	LS	$ 53,446	$ 53,446
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 16,034	$ 16,034
3	TESC (5%)	1	LS	$ 26,723	$ 26,723
4	SAWCUTTING	1890	LF	$ 2	$ 3,780
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	4504	CY	$ 35	$ 157,630
6	8' DIAM. PIPE DETENTION SYSTEM	900	LF	$ 250	$ 225,000
7	TESTING STORM SEWER PIPE	200	LF	$ 2	$ 400
8	SCHEDULE A STORM SEWER PIPE 24 IN. DIAM.	200	LF	$ 65	$ 13,000
9	GRAVEL BACKFILL FOR DRAIN	3752	TON	$ 22	$ 82,547
10	AREA DRAIN	2	EA	$ 800	$ 1,600
11	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
12	CATCH BASIN	4	EA	$ 4,000	$ 16,000
13	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$ 750	$ 1,500
14	PAVEMENT PATCH	1	LS	$ 10,000	$ 10,000
15	LANDSCAPING	1	LS	$ 10,000	$ 10,000
16	TRAFFIC CONTROL	1	LS	$ 10,000	$ 10,000

CONSTRUCTION SUBTOTAL		$630,659
DESIGN CONTINGENCY	30%	$189,198
PERMITTING	5%	$31,533
DESIGN	15%	$94,599
CITY PROJECT MGMT. ADMINISTRATION	3%	$18,920
CONSTRUCTION MANAGEMENT	15%	$94,599
MANAGEMENT RESERVE	10%	$63,066
PROJECT TOTAL COST		**$1,122,573**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Copper Ridge Pond Site 20-1
City of Edmonds Stormwater Retrofit



PROJECT DESCRIPTION

This retrofit modifies the existing Copper Ridge detention pond orifice control structure.

SITE BENEFITS

- Minimal impact from construction – simple in manhole retrofit
- No parking reduction resulting from retrofit
- All facilities will be underground and no existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Thick till layer does not allow for infiltration retrofit opportunity within existing pond
- Flow control structure is located on private property and detention pond located on City of Lynnwood Property
- Construction would require private owner coordination
- More detailed study of existing pond conditions and hydraulics may be required

RETROFIT TYPE

Orifice Structure Alteration
Detention Pond Facility

LOCATION

7009 196th St SW
near 70th Pl W, Lynnwood

EXISTING USE

Detention Pond Facility

TRIBUTARY DRAINAGE AREA

3.84 Acres
1.73 Acres Impervious

SITING NOTES

Existing control structure is an orifice riser located southwest of the pond

FLOW REDUCTION

Existing 2-yr	0.60 cfs
Mitigated 2-yr	0.22 cfs
Flow Reduction	0.38 cfs

COST

$22k, $58k per 1 cfs reduced.

TETRA TECH

Blue Ridge Pond Site 22-1
City of Edmonds Stormwater Retrofit

PROJECT DESCRIPTION

This retrofit to the flow control structure for the Blue Ridge Pond consists of replacement of the existing orifice with a smaller size to maximize pond storage leading to flow reduction.

SITE BENEFITS

- Flow control structure is wholly within the public right of way
- Minimal impact from construction – simple in manhole retrofit
- Large tributary area with significant flow reduction
- No parking reduction resulting from retrofit
- All facilities will be underground and no existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Thick till layer does not allow for infiltration retrofit opportunity within existing pond

RETROFIT TYPE

Orifice Structure Alteration
Detention Pond Facility

LOCATION

18601 71st Ave W
at 186th St SW, Lynnwood

EXISTING USE

Detention Pond Facility

TRIBUTARY DRAINAGE AREA

55.2 Acres
14.5 Acres Impervious

SITING NOTES

Existing control structure is a 11.25” orifice riser located in a manhole at the intersection of 71st Ave W and 186th St SW

FLOW REDUCTION

Existing 2-yr	5.77 cfs
Mitigated 2-yr	3.22 cfs
Flow Reduction	2.55 cfs

COST

$22k, $9k per 1 cfs reduced.

Bio-retention Site 24-1
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-retention system intercepts roadway runoff which collects in an asphalt swale to the north and south prior to entering a catch basin located in the shoulder area. Design consists of converting a roadside lawn area into a bio-retention area to attenuate peak flows through storage and infiltration. The bio-retention area will overflow to an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- Minimal grading due to collection of curb and gutter flow
- Results in reduction of parking and possible utility conflicts
- No reduction in parking or apparent utility conflicts

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates

RETROFIT TYPE

Bio-retention

LOCATION

7332 192nd Pl SW
at 74th Ave W, Lynnwood

EXISTING USE

Roadside lawn area

TRIBUTARY DRAINAGE AREA

1.21 Acres
0.50 Acres Impervious

SITING NOTES

Wide grass shoulder area

FLOW REDUCTION

Existing 2-yr	0.28 cfs
Mitigated 2-yr	0.06 cfs
Flow Reduction	0.22 cfs

COST

$45k, $205k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 24-1				
1	MOBILIZATION (10%)	1	LS	$ 1,729	$ 1,729
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 519	$ 519
3	TESC (5%)	1	LS	$ 865	$ 865
4	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	181	CY	$ 35	$ 6,319
5	BIORETENTION SOIL	54	CY	$ 35	$ 1,896
6	GRAVEL BACKFILL FOR DRAIN	90	CY	$ 35	$ 3,160
7	GRAVEL BLANKET	18	CY	$ 50	$ 903
8	LANDSCAPING	1	LS	$ 3,413	$ 3,413
9	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$20,403
DESIGN CONTINGENCY	50%	$10,201
PERMITTING	5%	$1,020
DESIGN	25%	$5,101
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,020
CONSTRUCTION MANAGEMENT	25%	$5,101
MANAGEMENT RESERVE	10%	$2,040
PROJECT TOTAL COST		**$44,886**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-swale Site 24-2
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

This bio-swale system intercepts curb and gutter roadway runoff from the east prior to entering a catch basin at 72nd Pl W. Design consists of converting existing pavement area into a 40' long roadside bio-swale to attenuate peak flows through storage and infiltration. The bio-swale overflows to the west into an existing catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- Minimal grading due to collection of curb and gutter flow
- Reduction of impervious areas
- LID may be incorporated into traffic calming measures

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Results in reduction of parking

RETROFIT TYPE

Bio-swale

LOCATION

19323 72nd Pl W
at 193rd Pl SW, Lynnwood

EXISTING USE

Paved Roadway Area

TRIBUTARY DRAINAGE AREA

0.30 Acres
0.17 Acres Impervious

SITING NOTES

Roadway longitudinal slope steep to the east

FLOW REDUCTION

Existing 2-yr	0.10 cfs
Mitigated 2-yr	0.02 cfs
Flow Reduction	0.08 cfs

COST

$27k, $338k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE		TOTAL COST	
	SITE 24-2						
1	MOBILIZATION (10%)	1	LS	$	1,045	$	1,045
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$	313	$	313
3	TESC (5%)	1	LS	$	522	$	522
4	SAWCUTTING	50	LF	$	2	$	100
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	44	CY	$	35	$	1,556
6	CONCRETE CURB AND GUTTER	50	LF	$	100	$	5,000
7	BIORETENTION SOIL	13	CY	$	35	$	467
8	GRAVEL BACKFILL FOR DRAIN	22	CY	$	35	$	778
9	GRAVEL BLANKET	4	CY	$	50	$	222
10	PAVEMENT PATCH	1	LS	$	1,000	$	1,000
11	LANDSCAPING	1	LS	$	525	$	525
12	TRAFFIC CONTROL	1	LS	$	800	$	800

CONSTRUCTION SUBTOTAL		$12,328
DESIGN CONTINGENCY	50%	$6,164
PERMITTING	5%	$616
DESIGN	25%	$3,082
CITY PROJECT MGMT. ADMINISTRATION	5%	$616
CONSTRUCTION MANAGEMENT	25%	$3,082
MANAGEMENT RESERVE	10%	$1,233
PROJECT TOTAL COST		**$27,121**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Bio-swale Site 24-3 & 24-4
Perrinville Creek Stormwater Retrofit

PROJECT DESCRIPTION

These bio-swales intercept curb and gutter drainage from the roadway area to the south prior to entering a catch basin at 193RD Pl SW. Design consists of converting existing pavement area into two swales within the parking lane which will attenuate peak flows through storage and infiltration. The bio-swale overflows to the north into existing catch basins.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- Minimal grading due to collection of curb and gutter flow
- Reduction of impervious areas
- LID may be incorporated into traffic calming measures

SITE CONSTRAINTS/DIFFICULTIES

- Proposed design contingent on good infiltration rates
- Results in reduction of parking

RETROFIT TYPE

Bio-swale

LOCATION

19328 72nd Pl W (24-3)
19323 72nd Pl W (24-4)
at 193rd Pl SW, Lynnwood

EXISTING USE

Paved Roadway Area

TRIBUTARY DRAINAGE AREA

2.10 Acres
0.93 Acres Impervious

SITING NOTES

Roadway longitudinal slope steep to the east

FLOW REDUCTION

Existing 2-yr	0.37 cfs
Mitigated 2-yr	0.25 cfs
Flow Reduction	0.12 cfs

COST

$62k, $1,086k per 1 cfs reduced

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE		TOTAL COST	
	SITE 24-3						
1	MOBILIZATION (10%)	1	LS	$	1,057	$	1,057
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$	317	$	317
3	TESC (5%)	1	LS	$	528	$	528
4	SAWCUTTING	45	LF	$	2	$	90
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	39	CY	$	35	$	1,361
6	CONCRETE CURB AND GUTTER	45	LF	$	100	$	4,500
7	BIORETENTION SOIL	12	CY	$	35	$	408
8	GRAVEL BACKFILL FOR DRAIN	19	CY	$	35	$	681
9	GRAVEL BLANKET	4	CY	$	50	$	194
10	PAVEMENT PATCH	1	LS	$	1,000	$	1,000
11	LANDSCAPING	1	LS	$	735	$	735
12	TRAFFIC CONTROL	1	LS	$	1,600	$	1,600

CONSTRUCTION SUBTOTAL		$12,472
DESIGN CONTINGENCY	50%	$6,236
PERMITTING	5%	$624
DESIGN	25%	$3,118
CITY PROJECT MGMT. ADMINISTRATION	5%	$624
CONSTRUCTION MANAGEMENT	25%	$3,118
MANAGEMENT RESERVE	10%	$1,247
PROJECT TOTAL COST		**$27,438**

All cost estimates are presented in 2014 dollars.

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 24-4				
1	MOBILIZATION (10%)	1	LS	$ 1,355	$ 1,355
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 406	$ 406
3	TESC (5%)	1	LS	$ 677	$ 677
4	SAWCUTTING	60	LF	$ 2	$ 120
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	56	CY	$ 35	$ 1,944
6	CONCRETE CURB AND GUTTER	60	LF	$ 100	$ 6,000
7	BIORETENTION SOIL	17	CY	$ 35	$ 583
8	GRAVEL BACKFILL FOR DRAIN	28	CY	$ 35	$ 972
9	GRAVEL BLANKET	6	CY	$ 50	$ 278
10	PAVEMENT PATCH	1	LS	$ 1,000	$ 1,000
11	LANDSCAPING	1	LS	$ 1,050	$ 1,050
12	TRAFFIC CONTROL	1	LS	$ 1,600	$ 1,600

CONSTRUCTION SUBTOTAL		$15,986
DESIGN CONTINGENCY	50%	$7,993
PERMITTING	5%	$799
DESIGN	25%	$3,997
CITY PROJECT MGMT. ADMINISTRATION	5%	$799
CONSTRUCTION MANAGEMENT	25%	$3,997
MANAGEMENT RESERVE	10%	$1,599
PROJECT TOTAL COST		**$35,170**

All cost estimates are presented in 2014 dollars.

Bio-retention Site 25-1
Perrinville Creek Stormwater Retrofit

RETROFIT TYPE
Bio-retention
LOCATION
7226 182nd St SW at 73rd Ave W
EXISTING USE
Roadside drainage ditch
TRIBUTARY DRAINAGE AREA
1.30 Acres 0.54 Acres Impervious
SITING NOTES
Preliminary soils testing yield poor results
FLOW REDUCTION
Existing 2-yr 0.29 cfs Mitigated 2-yr 0.01 cfs Flow Reduction 0.28 cfs
COST
$96k, $343k per 1 cfs reduced

PROJECT DESCRIPTION

This lined bio-retention system intercepts roadside drainage along 73rd Ave W prior to entering a catch basin which eventually outlets to a stream west of the site. Design consists of rerouting flows from the west side of 73rd Ave W to a bio-retention area in place of an existing roadside grass ditch. The bio-retention area outlets to the west through a control structure with new piping to the next downstream catch basin.

SITE BENEFITS

- LID is completely within the Public Right of Way
- Ample available area for construction
- Ample readily available contributing area
- Easy to route contributing area to LID location
- No reduction in parking or apparent utility conflicts
- Minimal grading due to shallow existing drainage system

SITE CONSTRAINTS/DIFFICULTIES

- Soil testing has yielded poor infiltration rates
- Need to replace downstream pipe section to allow for positive drainage of underdrain
- Potential existing utility service connection conflicts/protection required

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 25-1				
1	MOBILIZATION (10%)	1	LS	$ 3,681	$ 3,681
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 1,104	$ 1,104
3	TESC (5%)	1	LS	$ 1,840	$ 1,840
4	SAWCUTTING	100	LF	$ 2	$ 200
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	241	CY	$ 35	$ 8,426
6	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	50	LF	$ 40	$ 2,000
7	TESTING STORM SEWER PIPE	50	LF	$ 2	$ 100
8	UNDERDRAIN PIPE 6 IN. DIAM.	110	LF	$ 20	$ 2,200
9	BIORETENTION SOIL	61	CY	$ 35	$ 2,139
10	TILL LINER	41	CY	$ 15	$ 611
11	GRAVEL BACKFILL FOR DRAIN	102	CY	$ 35	$ 3,565
12	GRAVEL BLANKET	20	CY	$ 50	$ 1,019
13	AREA DRAIN	1	EA	$ 800	$ 800
14	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
15	CATCH BASIN	1	EA	$ 4,000	$ 4,000
16	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$ 750	$ 1,500
17	PAVEMENT PATCH	1	LS	$ 1,000	$ 1,000
18	LANDSCAPING	1	LS	$ 3,850	$ 3,850
19	TRAFFIC CONTROL	1	LS	$ 2,400	$ 2,400

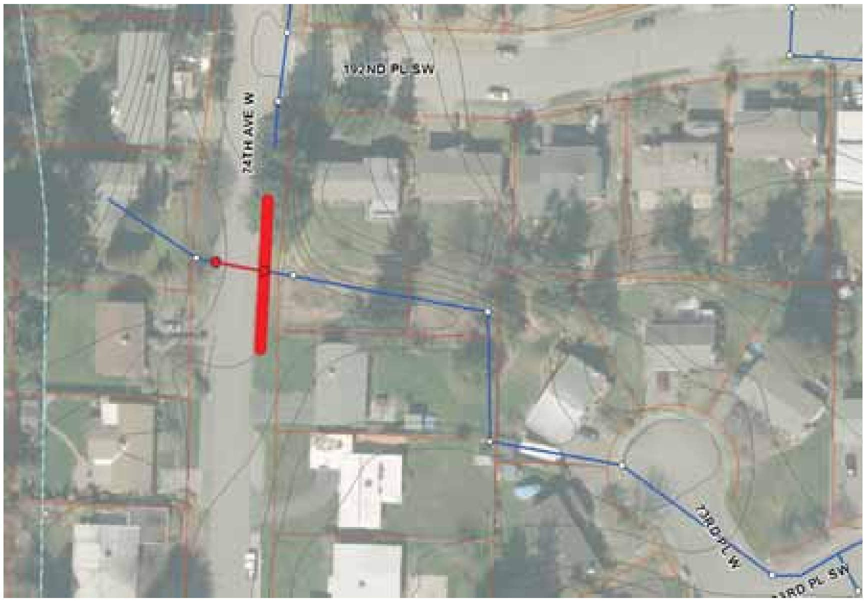
CONSTRUCTION SUBTOTAL		$43,435
DESIGN CONTINGENCY	50%	$21,717
PERMITTING	5%	$2,172
DESIGN	25%	$10,859
CITY PROJECT MGMT. ADMINISTRATION	5%	$2,172
CONSTRUCTION MANAGEMENT	25%	$10,859
MANAGEMENT RESERVE	10%	$4,343
PROJECT TOTAL COST		**$95,557**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Pipe Detention Site 26-1

City of Edmonds Stormwater Retrofit



RETROFIT TYPE

Pipe Detention Facility

LOCATION

7332 192nd Pl SW
on 74th Ave W, Lynnwood

EXISTING USE

Roadside grass area

TRIBUTARY DRAINAGE AREA

28.07 Acres
11.51 Acres Impervious

SITING NOTES

Steep slopes to east and west

FLOW REDUCTION

Existing 2-yr	4.20 cfs
Mitigated 2-yr	2.81 cfs
Flow Reduction	1.39 cfs

COST

$286k, $206k per 1 cfs reduced.

PROJECT DESCRIPTION

This 8' diameter detention pipe retrofit intercepts drainage from a residential area to the east and detains and slowly releases runoff. Proposed location for the detention pipe is a wide grass shoulder area along 74th Ave W. Stormwater release is through a flow control orifice with overflow to attenuate peak flows.

SITE BENEFITS

- Proposed system is completely within the Public Right of Way
- Wide shoulder area with ample area available for construction
- No parking reduction resulting from retrofit
- All facilities will be underground and no existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Adjacent steep slopes to east and west do not allow for infiltration
- Pipe replacement downstream may be needed to allow for deeper invert connection
- Option to expand or relocate facility to natural drainage course within private properties to the east

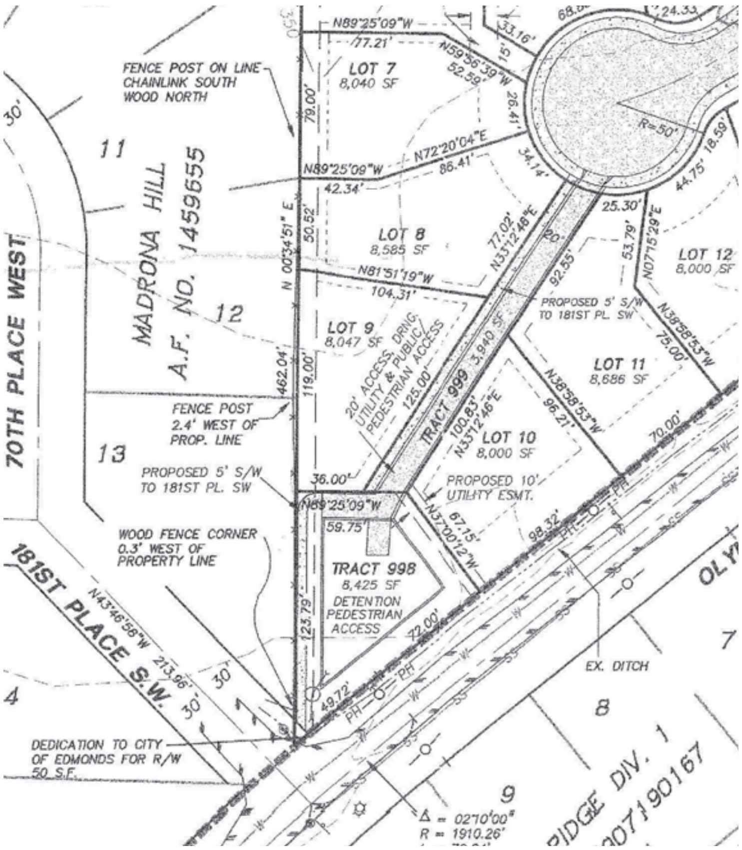
City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 26-1				
1	MOBILIZATION (10%)	1	LS	$ 11,019	$ 11,019
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 3,306	$ 3,306
3	TESC (5%)	1	LS	$ 5,510	$ 5,510
4	SAWCUTTING	140	LF	$ 2	$ 280
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	541	CY	$ 35	$ 18,926
6	8' DIAM. PIPE DETENTION SYSTEM	130	LF	$ 250	$ 32,500
7	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	50	LF	$ 40	$ 2,000
8	GRAVEL BORROW INCLUDING HAUL	799	TON	$ 22	$ 17,585
9	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
10	CATCH BASIN	2	EA	$ 4,000	$ 8,000
11	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$ 750	$ 1,500
12	PAVEMENT PATCH	1	LS	$ 10,000	$ 10,000
13	LANDSCAPING	1	LS	$ 10,000	$ 10,000
14	TRAFFIC CONTROL	1	LS	$ 6,400	$ 6,400

CONSTRUCTION SUBTOTAL		$130,025
DESIGN CONTINGENCY	50%	$65,012
PERMITTING	5%	$6,501
DESIGN	25%	$32,506
CITY PROJECT MGMT. ADMINISTRATION	5%	$6,501
CONSTRUCTION MANAGEMENT	25%	$32,506
MANAGEMENT RESERVE	10%	$13,002
PROJECT TOTAL COST		**$286,055**

All cost estimates are presented in 2014 dollars.

Olympic View Crest Pond Site 27-1
City of Edmonds Stormwater Retrofit



RETROFIT TYPE

Soil Amendment Alteration
Detention Pond Facility

LOCATION

18111 69th Pl W
near 181st Pl SW, Edmonds

EXISTING USE

Detention Pond Facility

TRIBUTARY DRAINAGE AREA

3.07 Acres
1.23 Acres Impervious

SITING NOTES

Existing concrete lined pond has a relatively small footprint with vertical walls

FLOW REDUCTION

Existing 2-yr	0.43 cfs
Mitigated 2-yr	0.11 cfs
Flow Reduction	0.32 cfs

COST

$74k, $232k per 1 cfs reduced

PROJECT DESCRIPTION

This retrofit to the Olympic View Crest Detention Pond consists of removal and replacement of the existing concrete-lined bottom with pervious soils and drainage stone to allow infiltration prior to entering the existing drainage system along Olympic View Drive. Preliminary findings indicate that soils in this vicinity consist of Glacial Outwash with good infiltration rates.

SITE BENEFITS

- Facility is located on publicly owned property
- Minimal impact from construction – simple in manhole retrofit
- No parking reduction resulting from retrofit
- No existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Maintenance/Access drive is shared with adjacent residential properties

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

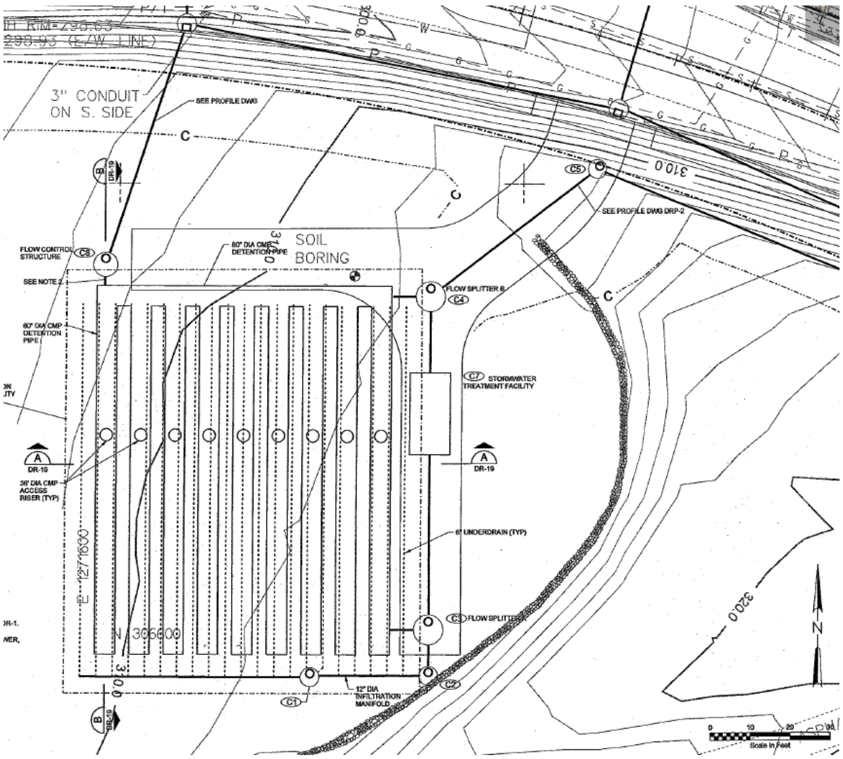
ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 27-1 OLYMPIC VIEW CREST				
1	MOBILIZATION (10%)	1	LS	$ 2,787	$ 2,787
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 836	$ 836
3	TESC (5%)	1	LS	$ 1,394	$ 1,394
4	TRAFFIC CONTROL (2%)	1	LS	$ 557	$ 557
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	426	CY	$ 35	$ 14,907
6	BIORETENTION SOIL	111	CY	$ 35	$ 3,889
7	GRAVEL BACKFILL FOR DRAIN	259	CY	$ 35	$ 9,074

CONSTRUCTION SUBTOTAL		$33,444
DESIGN CONTINGENCY	50%	$16,722
PERMITTING	5%	$1,672
DESIGN	25%	$8,361
CITY PROJECT MGMT. ADMINISTRATION	5%	$1,672
CONSTRUCTION MANAGEMENT	25%	$8,361
MANAGEMENT RESERVE	10%	$3,344
PROJECT TOTAL COST		**$73,578**

All cost estimates are presented in 2014 dollars.

TETRA TECH

Lynndale Park Infiltration Facility 28-1
City of Edmonds Stormwater Retrofit



PROJECT DESCRIPTION

This retrofit to the Infiltration Facility at Lynnwood Park consists of modification of an orifice on a flow splitter to allow utilization of additional infiltration capacity of the underlying soils.

SITE BENEFITS

- Facility is located on publicly owned property
- Minimal impact from construction – simple manhole retrofit
- No parking reduction resulting from retrofit
- No existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- n/a

RETROFIT TYPE

Orifice Structure Alteration
Detention/Infiltration Facility

LOCATION

7512 Olympic View Dr.
near Homeview Dr,
Lynnwood

EXISTING USE

Park Area with
Detention/Infiltration Facility

TRIBUTARY DRAINAGE AREA

82.10 Acres
20.30 Acres Impervious

SITING NOTES

Existing facility is located in park area south of Olympic View Drive

FLOW REDUCTION

Existing 2-yr*	0.33 cfs
Mitigated 2-yr*	0.13 cfs
Flow Reduction	0.20 cfs

COST

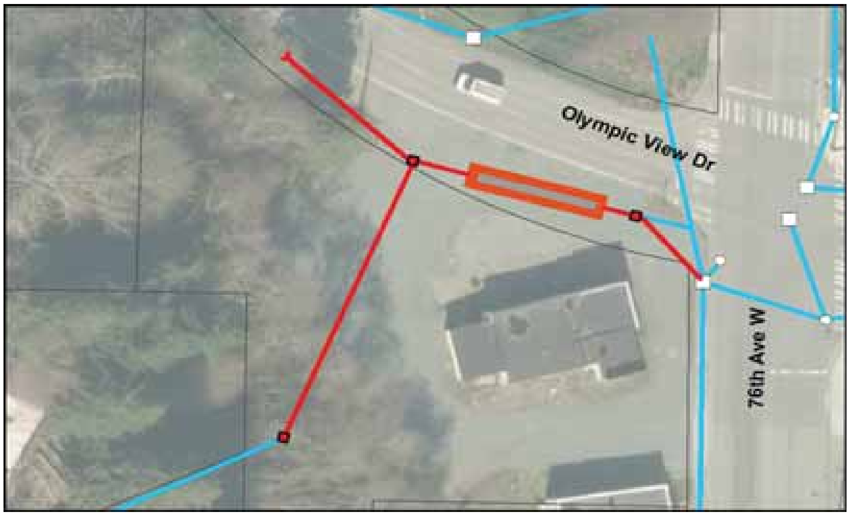
$22k, $110k per 1 cfs reduced

*Flow rates represent the flows that are returned to the closed-pipe detention facility.

TETRA TECH

Pipe Detention Site 29-1

City of Edmonds Stormwater Retrofit



RETROFIT TYPE

Manifold Pipe Detention Facility

LOCATION

76th Avenue W & Olympic View Drive

EXISTING USE

Private property gravel lot

TRIBUTARY DRAINAGE AREA

4.04 Acres
1.26 Acres Impervious

SITING NOTES

Proposed location is on vacant lot private property

FLOW REDUCTION

Existing 2-yr	0.44 cfs
Mitigated 2-yr	0.19 cfs
Flow Reduction	0.25 cfs

COST

$233k, $932k* per 1 cfs reduced.

*These costs do not reflect any cost for easements or private property acquisitions

PROJECT DESCRIPTION

This 8' diameter manifold detention pipe retrofit receives drainage from 185th Place SW and to the west along Olympic View Drive. A new catch basin and 12-inch pipe will capture water that is currently discharge freely at the bottom of the hillside and causing erosion in the receiving gravel lot. Stormwater along Olympic View Drive is collected along the existing roadside ditch on the south side of the road; the existing ditch will be re-graded near the gravel lot with a receiving 12-inch pipe installed to route water from the ditch to the detention manifold and eliminate overland flow.

SITE BENEFITS

- Eliminate erosion on in the gravel lot at the base of 185th Pl SW.
- All facilities will be underground and no existing land use changes proposed

SITE CONSTRAINTS/DIFFICULTIES

- Proposed system will require construction within private property
- A high-water table does not allow for localized infiltration

City of Edmonds
LID Retrofits for Perrinville Creek
Planning Level Estimate

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL COST
	SITE 29-1				
1	MOBILIZATION (10%)	1	LS	$ 8,537	$ 8,537
2	CONTRACTOR PROVIDED SURVEY (3%)	1	LS	$ 2,561	$ 2,561
3	TESC (5%)	1	LS	$ 4,268	$ 4,268
4	CLEARING AND GRUBBING	1	LS	$ 5,000	$ 5,000
5	STRUCTURAL EXCAVATION CLASS B INCL. HAUL	411	CY	$ 35	$ 14,385
6	8' DIAM. PIPE DETENTION SYSTEM	50	LF	$ 200	$ 10,000
7	SCHEDULE A STORM SEWER PIPE 12 IN. DIAM.	295	LF	$ 40	$ 11,800
8	GRAVEL BORROW INCLUDING HAUL	512	TON	$ 22	$ 11,264
9	FLOW RESTRICTOR	1	EA	$ 3,000	$ 3,000
10	CATCH BASIN TYPE 1	2	EA	$ 4,000	$ 8,000
11	CATCH BASIN TYPE 2 (48")	1	EA	$ 5,000	$ 5,000
12	CONNECTION TO DRAINAGE STRUCTURE	2	EA	$ 750	$ 1,500
13	SEEDING AND FERTILIZING	28	SY	$ 15	$ 420
14	LANDSCAPING	1	LS	$ 10,000	$ 10,000
15	TRAFFIC CONTROL	1	LS	$ 10,000	$ 10,000

CONSTRUCTION SUBTOTAL		$105,735
DESIGN CONTINGENCY	50%	$52,868
PERMITTING	5%	$5,287
DESIGN	25%	$26,434
CITY PROJECT MGMT. ADMINISTRATION	5%	$5,287
CONSTRUCTION MANAGEMENT	25%	$26,434
MANAGEMENT RESERVE	10%	$10,574
PROJECT TOTAL COST		**$232,618**

All cost estimates are presented in 2014 dollars.