Council Meeting Date: June 15, 2015 **Agenda Item:** 9(a)

CITY COUNCIL AGENDA ITEM

CITY OF SHORELINE, WASHINGTON

AGENDA TITLE:	Thornton Creek Low Impact Development Project and Basin Plan Update
DEPARTMENT:	Public Works
PRESENTED BY:	Dan Repp, Utilities and Operations Manager Uki Dele, Surface Water and Environmental Services Manager
ACTION:	____ Ordinance ____ Resolution ____ Motion __X_ Discussion ____ Public Hearing

PROBLEM/ISSUE STATEMENT:

The City has completed several Low Impact Development (LID) projects in the Thornton Creek Basin known as the North Fork LID Project (NFLP). The NFLP was largely funded using a grant from the Department of Ecology (Ecology). The City Council has asked staff about the possibility of continuing to install LID projects in the Thornton Creek Basin or in other areas in the City. The NFLP identified several sites in Thornton Creek where more LID projects could be constructed; however, the decision to continue with installing LID projects is a question of priorities within the Surface Water Utility (SWU).

The infrastructure condition assessments performed during basin planning efforts have identified 36,870 lineal feet (6.9 miles) of pipe with severe defects. The defective pipes may pose a risk to the public and may require attention as soon as possible. Approximately half of the known defective pipes are being addressed by the Stormwater Pipe Repair and Replacement Program in the SWU capital improvement plan (CIP). This is a seven year program with a budget of $5,289,000. With several basins having unfinished infrastructure condition assessments, staff expects the amount of defective infrastructure to increase. In addition deflective infrastructure, the basin plans have identified several other capital improvement projects that are not yet included in the SWU CIP.

Staff is using asset management principals to prioritize the repair and improvement needs based on potential risk and consequence of failure. Decisions regarding the amount and timing of additional LID projects should be made once the infrastructure needs are quantified and the priorities are set.

The purpose of this Staff Report is to review the NFLP and the infrastructure needs identified by the SWU basing planning effort.

RESOURCE/FINANCIAL IMPACT:

There is no financial impact in presenting tonight's information. This report is to provide the City Council with an update of the North Fork LID Project and Basin Planning effort.

However, there will be a future financial impact to the SWU when infrastructure repair and improvements are made based on the condition assessments and priorities set by the Council.

Below is a summary of the North Fork LID Project Funding:

EXPENDITURES

Grant Expenditures	$595,429
Surface Water Utility Expenditures	$198,476
Total Project Cost	**$793,905**

SURFACE WATER CAPITAL IMPROVEMENT PROGRAM BUDGET

Ecology Grant	$630,000
Surface Water Utility Funds	$198,476
Total Budget	**$828,476**

As well, the 2014-2019 Capital Improvement Program includes $660,000 for the McAleer Basin Plan and Ballinger Creek Drainage Study.

EXPENDITURES

Osborne Consulting, Inc. Basin Plan Contract	$619,560
Total Project Cost	**$619,560**

SURFACE WATER CAPITAL IMPROVEMENT PROGRAM BUDGET

McAleer Basin Plan	$450,000
Ballinger Creek Drainage Study/Basin Plan	$210,000
Total Budget	**$660,000**

RECOMMENDATION

No action is required by the City Council at this time. This report is to provide the City Council with an update of the North Fork LID Project and Basin Planning effort.

Approved By: City Manager ***DT*** City Attorney ***MK***

BACKGROUND

North Fork LID Project (NFLP)

The NLFP was developed to improve stormwater retention and water quality in the upper Thornton Creek Basin. The project applied LID practices in order to help address water quality and flooding problems identified in the 2009 Thornton Creek Watershed Plan. The City won a Department of Ecology grant in the amount of $630,000 to help fund the project. A significant challenge for the project was how to retrofit existing drainage systems while staying within City right of way and still have effective water quality treatment and flow control. Staff evaluated 164 sites before selecting 40 preferred sites. In the end, 17 facilities were constructed based on available funding. A report of the North Fork Thornton Creek LID Stormwater Retrofit Project is attached to this staff report as Attachment A and a site location map of the project is attached as Attachment B.

The Staff Report linked below, which was presented to the City Council in March 2012, summarizes the project and provides a detailed financial impact discussion:
K:\Staff Reports\2012\20120326\20120326 SR - N Fork Thornton Creek LID Project.docx

Basin Planning Effort

The basin planning effort is a continuation of the City Council's direction to provide strong and fiscally responsible management to the Surface Water Utility for addressing drainage infrastructure needs. In 2011 the City Council adopted a Surface Water Master Plan that emphasized the role of basin planning as an appropriate mechanism to improve the management of the City's surface water infrastructure. Beginning the basin planning work was the jump off point for the City to start understanding and quantifying drainage system and infrastructure needs in a systematic and disciplined approach. Based on preliminary pipe inspection results from early basin planning work that found significant amounts of pipe deterioration, the City Council authorized a $5.29 million pipe repair and replacement capital improvement project. As the basin planning work continues staff is finding more repair and replacement needs which are discussed later in this report.

The City has 11 surface water basins as shown in Surface Water Basin Map, which is attached to staff report as Attachment C. Some of these basins are small and represent either small drainage areas (such as the Puget Sound basins) or are pieces of larger basin that extend into the jurisdictional boundaries of other cities (such as Densmore and Edmonds Way basins). The larger basins are associated with larger streams and include the Boeing Creek, Storm Creek, and Thornton Creek basins. The basins represent distinct drainage areas within the City, and as such, form convenient planning units to address SWU issues. The basin planning objectives include pipe inspections, as well as assessing various elements in each basin including drainage capacity, erosion, infrastructure condition, water quality, and aquatic habitat. One of the key outcomes of the basin plans is documentation of pipe repair and replacement needs in each basin. The plans also identify other types of opportunities for improvement within the basins. To date, approximately 130 recommendations have been made, ranging from major flood control projects to invasive plant removal. The completed plans can be found at the following links:

Boeing Creek Basin Plan:
http://cityofshoreline.com/home/showdocument?id=12539

Storm Creek Basin Plan:
http://cityofshoreline.com/home/showdocument?id=12545

Thornton Creek Basin Plan:
http://cosweb.ci.shoreline.wa.us/uploads/attachments/pwk/swes/final%20thornton%20creek%20watershed%20plan/Watershed%20Plan%20Final.pdf

The basin planning effort is approximately 70% complete. The City has completed the Thornton Creek, Storm Creek, and Boeing Creek Basin Plans. Staff is currently reviewing the Lyon Creek and McAleer Creek Basin Plans and expects to have them finished by July 2015. The planning effort for the six remaining basins is in scheduled to begin in July 2015and staff expects to have them completed by second quarter of 2016. Table 1 shows the status of basin plan development by noting the date when plans were completed or are expected to be completed.

Table 1. Basin Planning Status Summary.

Basin Name	Completed	In Progress	Not Started
Boeing Creek	2012		
Densmore			2016
Edmonds Way			2016
Lyon Creek		2015	
McAleer Creek		2015	
Puget Sound (Highlands)			2016
Puget Sound (Innis Arden)			2016
Puget Sound (Richmond Beach)			2016
Storm Creek	2012		
Thornton Creek	2009		
West Lake Washington			2016

DISCUSSION

North Fork LID Project

The North Fork Thornton Creek LID Stormwater Retrofit Project provides improved flow control and water quality treatment for discharges from this drainage basin using two LID facility types – Bioretention Cells and Gravel Galleries. The goal of the project is to improve stormwater flow control and water quality in an urban watershed that has experienced both flooding and significant water quality problems. The project retrofitted the existing stormwater drainage system with LID facilities in a residential sub-basin located at the headwaters of the North Fork of Thornton Creek.

The project identified 40 preferred sites. Project funding allowed for the design and construction of 17 Bioretention Cells and two Gravel Galleries. The facilities are located within existing right-of-way. A before and after photograph for a typical bioretention

facility are provided in Figure1 below. There are 23 sites where more LID projects could be built in the NFLP area.

Performance monitoring was not included as part of this project and therefore quantifying the benefits on flow control and water quality is not possible. However, visual observations during rainfall events confirm that the improvements are accommodating storm flows and no flooding is occurring. The vegetation in the bioretention cells is also well established.

Figure 1. Bioretention Cell Before and After Project Photo.

Basin Planning Findings

A major focus of the basin planning projects is to inspect and evaluate the condition of both the above ground and buried (pipes) conveyance system. The above ground system generally includes ditches, stream channels, and impoundments (i.e. ponds). Evaluating the condition of the above ground systems includes observing channel stability indicators such erosion, capacity restrictions such sediment deposits and/or overgrown vegetation, and alterations such as filling or unauthorized construction.

For the buried conveyance system, pipe inspections were made using closed circuit television camera systems where an operator codes defect observations according to a standardized methodology. The defect codes capture structural condition, operational and maintenance condition, construction features, and miscellaneous features such as water levels and shape and size changes. The coded observations are analyzed using a system developed by the National Association of Sewer Service Companies (NASSCO) to develop a condition score for each pipe segment. To date, out of the

732,000 feet of pipes inventoried, approximately 255,000 feet (48.3 miles) of pipe in four basins have been inspected (see Table 2). To keep inspection costs reasonable, staff did not inspect small diameter pipe (less than 12 inches in diameter) and pipes less than 50 feet in length.

The Thornton Creek Basin (TCB) is the largest basin in the City and was the first basin plan to be completed. The focus of the TCB plan was to address flooding problems and therefore, the plan did not include a pipe inspection and condition assessment for the basin. Staff has started a three year effort to inspect and assess the condition of the infrastructure in the TCB beginning in 2015.

Table 2. Basin Plan Pipe Inspection Summary.

Basin Name	Pipe Inventory (linear feet)	Pipe Inspected (linear feet)[1]	Percent of Inspection Complete
Boeing Creek	205,293	11,3042	55%
Densmore	2,654	0	0
Edmonds Way	6,674	0	0
Lyon Creek	22,683	19,021	84%
McAleer Creek	127,578	95,444	75%
Puget Sound (Highlands)	1,113	0	0
Puget Sound (Innis Arden)	28,851	0	0
Puget Sound (Richmond Beach)	52,745	0	0
Storm Creek	33,575	27,400	82%
Thornton Creek[2]	243,939	0	0
West Lake Washington	6,659	0	0
Totals	**731,763**	**254,907**	**34.8%**

To date, the condition analysis found approximately 36,870 feet of pipe with severe defects needing attention. The Stormwater Pipe Repair and Replacement CIP Program includes16,790 feet of the 36,870 feet, leaving 20,080 feet of defective pipe to address. Staff is in the process of reviewing the 20,080 feet of defective pipes according to asset management principals to determine the priority for repair and replacement. The priorities are based on a risk assessment which considers the consequence of failure for each pipe. In other words what would happen if the pipe can no longer perform its intended function? Some important risk considerations include who or what gets flooded if the pipe is blocked, what damage can occur if a pipe collapses due to structural problems, and could there be regulatory penalties as a result of a known defect. While setting priorities to minimize risk is important and prudent, eventually all pipes with severe defects will need to be addressed.

[1] Inspection conducted on pipes 12” diameter or greater and longer than 50 feet.
[2] Pipe inspection was not included during basin planning but is a future work item.

The cost estimate to address the 20,080 feet of defective pipe is approximately $5,568,000. The estimate is based on construction costs for similar projects completed in 2014, resulting in a per linear foot cost of $315. Table 3 below compares the current pipe repair and replacement capital project with the defective pipe found during the recent basin plan inspections. While similar in both cost and the length needing to be repaired or replaced, the newly identified defective pipe is not included in the SWU capital plan and is not funded at this time.

Table 3. Comparison of the Existing Pipe Repair and Replacement Project with Recently Identified Defective Pipe.

Pipe Repair and Replacement Status	Linear Feet	Cost Estimate
Current Pipe Repair and Replacement Project	16,790	$5,289,000
Defective pipes found during recent basin plan inspections	20,080	$5,568,000

The observed rate of defective pipe being found during basin plan inspections suggests that uninspected basins will result in more repair and replacement needs. Staff has inspected about 35% of the total pipe inventory and so it's reasonable to expect more deficiencies to be discovered during future inspections. Given the potential for risk exposure to the City, quantifying defective pipe needs and completing repair and replacement projects should be a high priority for the SWU. Developing a funding strategy for priority repair and replacement projects is also a high priority for the SWU. Until a repair and replacement funding strategy is developed, staff recommends suspending construction of additional LID projects.

COUNCIL GOAL(S) ADDRESSED

This project supports Council Goal No. 2, provide safe, efficient and effective infrastructure to support our land use, transportation and surface water plans. This is achieved by identifying and prioritizing projects out of the basin plans that will repair or replace the City's storm water infrastructure.

RESOURCE/FINANCIAL SUMMARY

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ATTACHMENTS

Attachment A – North Fork Thornton Creek LID Stormwater Retrofit Project Report
Attachment B – North Fork LID Site Location Map
Attachment C – Surface Water Basin Map

LID STORMWATER REPORT

Perteet Inc.

TO: **City of Shoreline**

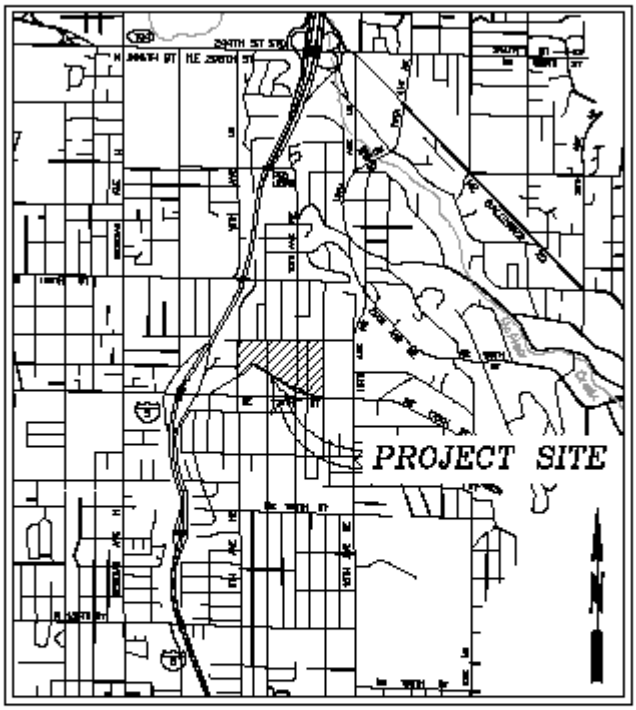
FROM: **Jason Shrope, PE**

DATE: **July 10, 2013**

RE: **North Fork Thornton Creek LID Stormwater Retrofit Project**

Executive Summary

This LID Stormwater Report provides a summary of the low impact development (LID) facilities and the project benefits provided within the North Fork Thornton Creek Drainage Basin. The information included consists of a project and site assessment, hydraulic analysis of each LID facility, and documentation of the Flow Control and Water Quality Treatment provided.



VICINITY MAP

Project Description

The North Fork Thornton Creek LID Stormwater Retrofit Project provides improved flow control and water quality treatment for discharges from this drainage basin using two LID facility types – Bioretention Cells and Gravel Galleries. The project will retrofit existing stormwater drainage infrastructure with LID facilities in a residential sub-basin located at the headwaters of North Fork Thornton Creek. These facilities will improve stormwater retention and water quality in an urban watershed that is water quality impaired for multiple parameters. 17 Bioretention Cells and 2 Gravel Galleries were designed in accordance with the Washington State Department of Ecology Stormwater Management Manual for Western Washington (2005). The facilities are located within existing City of Shoreline right-of-way and will treat and infiltrate contributing runoff from adjacent streets and private yards. These facilities will reduce the volume of runoff contributing to downstream ponds, Ronald Bog, and Thornton Creek. In addition, water quality treatment will be provided where none currently exists.

Existing Conditions

The North Fork Thornton Creek Basin is located in the City of Shoreline neighborhood of North City (See Vicinity Map on previous page). The drainage basin is a highly urbanized basin and is located at the headwaters of Thornton Creek. Thornton Creek has a record of poor water quality and frequent flooding both in the open channel reaches and the piped sections. Thornton Creek is listed as 303d impaired for temperature, dissolved oxygen, and bacteria.

The North Fork Thornton Creek Basin consists of primarily single family residential lots with approximately 40% impervious surface coverage and 60% grass coverage. The existing stormwater system consists of sheet flow to intermittent ditch, culvert, and pipe system. There is no curb and gutter for the majority of the drainage basin.

Existing Soil Characteristics

The geotechnical investigation found both Outwash and Till soils at the project site with greater infiltration potential at the western edge (location of Gravel Galleries 1 & 2). Based on testing and analysis, the design infiltration rates for the proposed bioretention cells range from approximately 0.3 to 2.6 in/hr. The design infiltration rate for Gravel Galleries 1 & 2 is approximately 2 to 2.3 in/hr. The location of Gravel Galleries 1 & 2 contains some advance outwash soils at depths of seven to ten feet, and appears promising for infiltration of stormwater. Most of the bioretention cells are located above glacial till, weathered till, and fill soils with limited infiltration capacity. See Appendix B for the Infiltration Evaluations.

The native soil at the location of Gravel Galleries 1 & 2 was tested to determine the ability to provide water quality treatment. In order for soil to be considered appropriate for water quality treatment, the soil must have a Cation Exchange Capacity (CEC) of 5 meq/100g or greater. The native soil at the location of Gravel Galleries 1 & 2 was determined to have a CEC of 4.94 meq/100g. Based on this CEC and the depth to groundwater of over 12', there will be no negative impact to groundwater based on the stormwater runoff infiltrated at the gravel galleries. See Appendix B for Soil Analysis.

Design Requirements

The LID facilities were designed per the Washington State Department of Ecology Stormwater Management Manual for Western Washington (2005). Since this is a retrofit project and not associated with roadway or site improvements, there are no specific requirements for the amount of Flow Control or Water Quality Treatment to be provided. The facilities are designed to provide Flow Control and Water Quality Treatment to the maximum extent feasible.

Proposed LID Facilities

The contributing area to the Gravel Galleries is approximated at 10 acres in order to calculate the flow reduction and treatment benefits provided. The contributing areas to each Bioretention Cell are shown in Appendix C.

Gravel Gallery #1			
Length = 135'	Contributing Areas		
8.0' wide x 4.0' deep	Approximate	5	acres
24 inches for ponding	Approximate	5	acres

Gravel Gallery #2			
Length = 113'	Contributing Areas		
8.0' wide x 4.0' deep	Approximate	5	acres
24 inches for ponding	Approximate	5	acres

Bioretention Cell #1			
Bottom area = 2’ x 45’ = 90 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1955 sf	0.045	acres
12 inches for ponding	Grass = 1675 sf	0.039	acres

Bioretention Cell #2			
Bottom area = 2’ x 35’ = 70 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1275 sf	0.029	acres
12 inches for ponding	Grass = 1070 sf	0.025	acres

Bioretention Cell #3			
Bottom area = 2’ x 23’ = 46 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 835 sf	0.019	acres
12 inches for ponding	Grass = 770 sf	0.018	acres

Bioretention Cell #4			
Bottom area = 2’ x 64’ = 128 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1955 sf	0.045	acres
6 inches for ponding	Grass = 1075 sf	0.025	acres

Bioretention Cell #5			
Bottom area = 2’ x 55’ = 110 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1835 sf	0.042	acres
6 inches for ponding	Grass = 980 sf	0.023	acres

Bioretention Cell #6			
Bottom area = 2’ x 55’ = 110 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 2535 sf	0.058	acres
12 inches for ponding	Grass = 465 sf	0.011	acres

Bioretention Cell #7			
Bottom area = 2’ x 17.5’ = 35 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1045 sf	0.024	acres
12 inches for ponding	Grass = 170 sf	0.004	acres

Bioretention Cell #8			
Bottom area = 2’ x 45’ = 90 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1345 sf	0.031	acres
12 inches for ponding	Grass = 270 sf	0.006	acres

Bioretention Cell #9			
Bottom area = 2’ x 40’ = 80 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 2110 sf	0.048	acres
6 inches for ponding	Grass = 965 sf	0.022	acres

Bioretention Cell #10			
Bottom area = 2’ x 30’ = 60 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 2010 sf	0.046	acres
6 inches for ponding	Grass = 920 sf	0.021	acres

Bioretention Cell #11			
Bottom area = 2’ x 20’ = 40 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1675 sf	0.039	acres
6 inches for ponding	Grass = 760 sf	0.017	acres

Bioretention Cell #12			
Bottom area = 2’ x 35’ = 70 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1775 sf	0.041	acres
6 inches for ponding	Grass = 795 sf	0.018	acres

Bioretention Cell #13			
Bottom area = 2’ x 38’ = 76 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 2295 sf	0.053	acres
12 inches for ponding	Grass = 1175 sf	0.027	acres

Bioretention Cell #14			
Bottom area = 2’ x 45’ = 90 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 2775 sf	0.064	acres
12 inches for ponding	Grass = 2285 sf	0.053	acres

Bioretention Cell #15			
Bottom area = 2’ x 45’ = 90 sf	Contributing Areas		
2:1 side slopes	Pavement = 870 sf	0.020	acres
6 inches for ponding	Grass = 715 sf	0.016	acres

Bioretention Cell #16			
Bottom area = 2’ x 18’ = 36 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 795 sf	0.018	acres
12 inches for ponding	Grass = 685 sf	0.016	acres

Bioretention Cell #17			
Bottom area = 2’ x 28’ = 56 sf	Contributing Areas		
2.5:1 side slopes	Pavement = 1335 sf	0.031	acres
12 inches for ponding	Grass = 945 sf	0.022	acres

Flow Control and Water Quality Treatment Summaries

See summaries on next 2 pages.

Thornton Creek
Drainage Calculations
LID Facility Benefit Summary - Flow Reduction

Gravel Gallery Summary

	Flow Reduction per Design Storm (cfs)		
Gallery #	2yr	10yr	50yr
1	0.089	0.089	0.089
2	0.074	0.074	0.074
Total Flow Reduction	0.16	0.16	0.16

Bioretention Cell Treatment Summary

	Flow Reduction per Design Storm (cfs)		
Cell #	2yr	10yr	50yr
1	0.0025	0.0033	0.0026
2 - 3	0.0108	0.0065	0.0041
4	0.0068	0.0044	0.0038
5	0.0046	0.0038	0.0032
6	0.0059	0.0030	0.0030
7	0.0012	0.0009	0.0010
8	0.0086	0.0050	0.0025
9	0.0059	0.0029	0.0022
10	0.0037	0.0018	0.0017
11	0.0018	0.0012	0.0011
12	0.0064	0.0054	0.0019
13	0.0129	0.0091	0.0050
14	0.0142	0.0090	0.0066
15	0.0064	0.0044	0.0022
16	0.0006	0.0005	0.0004
17	0.0010	0.0008	0.0006
Total Flow Reduction	0.09	0.06	0.04

LID Facility Summary

Total Flow Reduction	0.26	0.23	0.20

Thornton Creek
Drainage Calculations
LID Facility Benefit Summary - Water Quality Treatment

Gravel Gallery Summary

Gallery #	Percent Infiltrated / Treated	Contributing Area (acres) Impervious	Pervious	
1	63.0%	5.0	5.0	6.30 acres
2	57.5%	5.0	5.0	5.75 acres

Total 12.05 acres

Bioretention Cell Treatment Summary

Cell #	Percent Treated	Contributing Area (acres) Impervious	Pervious	
1	78.0%	0.045	0.039	0.066 acres
2 - 3	98.2%	0.048	0.043	0.089 acres
4	98.9%	0.045	0.025	0.069 acres
5	98.5%	0.042	0.023	0.064 acres
6	97.7%	0.058	0.011	0.067 acres
7	90.0%	0.024	0.004	0.025 acres
8	99.7%	0.031	0.006	0.037 acres
9	98.2%	0.048	0.022	0.069 acres
10	95.9%	0.046	0.021	0.064 acres
11	91.9%	0.039	0.017	0.051 acres
12	98.5%	0.041	0.018	0.058 acres
13	99.6%	0.053	0.027	0.080 acres
14	99.0%	0.064	0.053	0.116 acres
15	99.8%	0.020	0.016	0.036 acres
16	91.6%	0.018	0.016	0.031 acres
17	91.2%	0.031	0.022	0.048 acres

Total 0.97 acres

Note: Area Totals = Percent Treated x Contributing Area

Appendices:

- **Appendix A – LID Hydraulic Analysis**
- **Appendix B – Geotechnical Information**
- **Appendix C – Bioretention Cells – Contributing Areas**

Appendix A – LID Hydraulic Analyses

- **Gravel Gallery 1**
- **Gravel Gallery 2**
- **Bioretention Cell 1**
- **Bioretention Cells 2-3**
- **Bioretention Cell 4**
- **Bioretention Cell 5**
- **Bioretention Cell 6**
- **Bioretention Cell 7**
- **Bioretention Cell 8**
- **Bioretention Cell 9**
- **Bioretention Cell 10**
- **Bioretention Cell 11**
- **Bioretention Cell 12**
- **Bioretention Cell 13**
- **Bioretention Cell 14**
- **Bioretention Cell 15**
- **Bioretention Cell 16**
- **Bioretention Cell 17**

Gravel Gallery Summary
April 16, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the gravel gallery or model output. Impervious and pervious surface areas for predeveloped conditions have been approximated in the modeling in order to show the reduced flow benefits provided by each facility

Gravel Gallery #1 **Infil rate = 2.02**

Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	1.6750 cfs	1.5860 cfs	0.0890 cfs
5 Year	2.1230 cfs	2.0350 cfs	0.0880 cfs
10 Year	2.5630 cfs	2.4740 cfs	0.0890 cfs
25 Year	3.3660 cfs	3.2770 cfs	0.0890 cfs
50 Year	3.6430 cfs	3.5550 cfs	0.0880 cfs
100 Year	3.8980 cfs	3.8100 cfs	0.0880 cfs
		2 Year to 50 Year Sum =	**0.4430 cfs**

Gravel Gallery #2 **Infil rate = 2.02**

Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	1.6750 cfs	1.6010 cfs	0.0740 cfs
5 Year	2.1230 cfs	2.0490 cfs	0.0740 cfs
10 Year	2.5630 cfs	2.4890 cfs	0.0740 cfs
25 Year	3.3660 cfs	3.2920 cfs	0.0740 cfs
50 Year	3.6430 cfs	3.5690 cfs	0.0740 cfs
100 Year	3.8980 cfs	3.8250 cfs	0.0730 cfs
		2 Year to 50 Year Sum =	**0.3700 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 06/24/2013 5:39 PM

Input File Name: Gravel Gallery 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: Gravel Gallery 1
Comments: 8 foot wide trench

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	5.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	5.000
Subbasin Total	10.000

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	5.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	5.000
Subbasin Total	10.000

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: Gallery
Link Type: Infiltration Trench
Downstream Link: None

Trench Type	:	Trench at Toe of Embankment
Trench Length (ft)	:	135.00
Trench Width (ft)	:	8.00
Trench Depth (ft)	:	3.00
Trench Bottom Elev (ft)	:	96.00
Trench Rockfill Porosity (%)	:	40.00

Constant Infiltration Option Used
Infiltration Rate (in/hr): 2.02

**********FLOOD FREQUENCY AND DURATION STATISTICS**********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	614.601
Total:	614.601

Total Post Developed Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Post Developed	614.601
Link: Gallery	2021.021
Total:	2635.623

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 3.890 ac-ft/year, Post Developed: 16.681 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: Gallery **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 3207.94
Total Runoff Infiltrated (ac-ft): 2021.02, 63.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 63.00%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: Gallery

***** Point of Compliance Flow Frequency Data *****

Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.675	2-Year	1.586
5-Year	2.123	5-Year	2.035
10-Year	2.563	10-Year	2.474
25-Year	3.366	25-Year	3.277
50-Year	3.643	50-Year	3.555
100-Year	3.898	100-Year	3.810
200-Year	4.711	200-Year	4.623

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-30.7%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-15.5%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	0.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-52.5%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-30.2%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 06/24/2013 5:36 PM

Input File Name: Gravel Gallery 2.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: Gravel Gallery 2
Comments: 8 foot wide trench

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	5.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	5.000
Subbasin Total	10.000

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	5.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	5.000
Subbasin Total	10.000

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: Gallery
Link Type: Infiltration Trench
Downstream Link: None

Trench Type	:	Trench at Toe of Embankment
Trench Length (ft)	:	113.00
Trench Width (ft)	:	8.00
Trench Depth (ft)	:	3.00
Trench Bottom Elev (ft)	:	96.00
Trench Rockfill Porosity (%)	:	40.00

Constant Infiltration Option Used
Infiltration Rate (in/hr): 2.02

**********FLOOD FREQUENCY AND DURATION STATISTICS**********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	614.601
Total:	614.601

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		614.601
Link:	Gallery	1844.819
Total:		2459.420

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 3.890 ac-ft/year, Post Developed: 15.566 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: Gallery **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 3207.94
Total Runoff Infiltrated (ac-ft): 1844.82, 57.51%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 57.51%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: Gallery

***** Point of Compliance Flow Frequency Data *****

Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.675	2-Year	1.601
5-Year	2.123	5-Year	2.049
10-Year	2.563	10-Year	2.489
25-Year	3.366	25-Year	3.292
50-Year	3.643	50-Year	3.569
100-Year	3.898	100-Year	3.825
200-Year	4.711	200-Year	4.637

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-26.9%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-13.0%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	0.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-45.9%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-26.3%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #1	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0146 cfs	0.0121 cfs	0.0025 cfs
5 Year	0.0188 cfs	0.0174 cfs	0.0014 cfs
10 Year	0.0224 cfs	0.0191 cfs	0.0033 cfs
25 Year	0.0292 cfs	0.0254 cfs	0.0038 cfs
50 Year	0.0311 cfs	0.0285 cfs	0.0026 cfs
100 Year	0.0339 cfs	0.0322 cfs	0.0018 cfs
		2 Year to 50 Year Sum =	**0.0136 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/11/2013 3:35 PM

Input File Name: BRC#1_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #1 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.039
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.045
Subbasin Total	0.084

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.039
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.045
Subbasin Total	0.084

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #1
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 408.15
Riser Crest Elevation (ft) : 409.15
Storage Depth (ft) : 1.00
Bottom Length (ft) : 45.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 90.
Area at Riser Crest El (sq-ft) : 350.
(acres) : 0.008
Volume at Riser Crest (cu-ft) : 270.
(ac-ft) : 0.006

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 0.29

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.15 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.78
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.460E-02
5-Year	1.876E-02
10-Year	2.236E-02
25-Year	2.919E-02
50-Year	3.112E-02
100-Year	3.391E-02
200-Year	4.046E-02

********** Link: BRC #1 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.460E-02

5-Year	1.876E-02
10-Year	2.236E-02
25-Year	2.919E-02
50-Year	3.112E-02
100-Year	3.391E-02
200-Year	4.046E-02

********** Link: BRC #1 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.816
1.11-Year	407.821
1.25-Year	407.825
2.00-Year	407.836
3.33-Year	407.845
5-Year	407.849
10-Year	407.851
25-Year	407.860
50-Year	407.865
100-Year	407.871

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	4.794
Total:	4.794

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		4.794
Link:	BRC #1	22.226
Total:		27.020

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.030 ac-ft/year, Post Developed: 0.171 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #1 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 28.50
Total Runoff Infiltrated (ac-ft): 22.23, 78.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 78.00%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #1

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.460E-02	2-Year	1.206E-02
5-Year	1.876E-02	5-Year	1.741E-02
10-Year	2.236E-02	10-Year	1.906E-02
25-Year	2.919E-02	25-Year	2.541E-02
50-Year	3.112E-02	50-Year	2.852E-02
100-Year	3.391E-02	100-Year	3.215E-02
200-Year	4.046E-02	200-Year	4.032E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-52.9%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-27.9%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-26.7%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-76.6%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-52.9%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #2&3	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0157 cfs	0.0049 cfs	0.0108 cfs
5 Year	0.0201 cfs	0.0147 cfs	0.0054 cfs
10 Year	0.0240 cfs	0.0175 cfs	0.0065 cfs
25 Year	0.0314 cfs	0.0234 cfs	0.0081 cfs
50 Year	0.0336 cfs	0.0295 cfs	0.0041 cfs
100 Year	0.0364 cfs	0.0318 cfs	0.0046 cfs
		2 Year to 50 Year Sum =	**0.0349 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 1:45 PM

Input File Name: BRC#2_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #2 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.043
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.048
Subbasin Total	0.091

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.043
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.048
Subbasin Total	0.091

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #2
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 408.10
Riser Crest Elevation (ft) : 409.10
Storage Depth (ft) : 1.00
Bottom Length (ft) : 58.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 116.
Area at Riser Crest El (sq-ft) : 441.
(acres) : 0.010
Volume at Riser Crest (cu-ft) : 344.
(ac-ft) : 0.008

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 0.79

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.10 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.82
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.570E-02
5-Year	2.009E-02
10-Year	2.399E-02
25-Year	3.144E-02
50-Year	3.359E-02
100-Year	3.644E-02
200-Year	4.361E-02

********** Link: BRC #2 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.570E-02

5-Year	2.009E-02
10-Year	2.399E-02
25-Year	3.144E-02
50-Year	3.359E-02
100-Year	3.644E-02
200-Year	4.361E-02

********** Link: BRC #2 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.543
1.11-Year	407.686
1.25-Year	407.833
2.00-Year	407.855
3.33-Year	407.871
5-Year	407.882
10-Year	407.889
25-Year	407.896
50-Year	407.907
100-Year	407.910

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	5.286
Total:	5.286

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		5.286
Link:	BRC #2	30.326
Total:		35.612

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.033 ac-ft/year, Post Developed: 0.225 ac-ft/year

*************Water Quality Facility Data **************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #2 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 30.87
Total Runoff Infiltrated (ac-ft): 30.33, 98.24%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 98.24%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #2

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.570E-02	2-Year	4.932E-03
5-Year	2.009E-02	5-Year	1.470E-02
10-Year	2.399E-02	10-Year	1.746E-02
25-Year	3.144E-02	25-Year	2.336E-02
50-Year	3.359E-02	50-Year	2.947E-02
100-Year	3.644E-02	100-Year	3.182E-02
200-Year	4.361E-02	200-Year	4.174E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-89.3%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-73.8%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-60.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-97.3%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-89.3%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #4	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0137 cfs	0.0069 cfs	0.0068 cfs
5 Year	0.0177 cfs	0.0131 cfs	0.0047 cfs
10 Year	0.0212 cfs	0.0168 cfs	0.0044 cfs
25 Year	0.0261 cfs	0.0219 cfs	0.0043 cfs
50 Year	0.0274 cfs	0.0237 cfs	0.0038 cfs
100 Year	0.0312 cfs	0.0279 cfs	0.0033 cfs
		2 Year to 50 Year Sum =	**0.0239 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 2:32 PM

Input File Name: BRC#4_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #4 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.025
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.045
Subbasin Total	0.070

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.025
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.045
Subbasin Total	0.070

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #4
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 408.70
Riser Crest Elevation (ft) : 409.20
Storage Depth (ft) : 0.50
Bottom Length (ft) : 64.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 128.
Area at Riser Crest El (sq-ft) : 299.
(acres) : 0.007
Volume at Riser Crest (cu-ft) : 183.
(ac-ft) : 0.004

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 2.00

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.20 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.53
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.374E-02
5-Year	1.770E-02
10-Year	2.115E-02
25-Year	2.614E-02
50-Year	2.743E-02
100-Year	3.116E-02
200-Year	3.592E-02

********** Link: BRC #4 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.374E-02

5-Year	1.770E-02
10-Year	2.115E-02
25-Year	2.614E-02
50-Year	2.743E-02
100-Year	3.116E-02
200-Year	3.592E-02

********** Link: BRC #4 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.467
1.11-Year	407.505
1.25-Year	407.544
2.00-Year	407.571
3.33-Year	407.582
5-Year	407.588
10-Year	407.597
25-Year	407.603
50-Year	407.608
100-Year	407.615

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	3.073
Total:	3.073

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		3.073
Link:	BRC #4	25.806
Total:		28.879

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.019 ac-ft/year, Post Developed: 0.183 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #4 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 26.08
Total Runoff Infiltrated (ac-ft): 25.81, 98.94%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 98.94%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #4

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.374E-02	2-Year	6.949E-03
5-Year	1.770E-02	5-Year	1.305E-02
10-Year	2.115E-02	10-Year	1.678E-02
25-Year	2.614E-02	25-Year	2.186E-02
50-Year	2.743E-02	50-Year	2.367E-02
100-Year	3.116E-02	100-Year	2.790E-02
200-Year	3.592E-02	200-Year	3.213E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-90.7%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-77.6%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-24.6%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-99.0%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-90.7%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #5	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0128 cfs	0.0082 cfs	0.0046 cfs
5 Year	0.0165 cfs	0.0126 cfs	0.0039 cfs
10 Year	0.0197 cfs	0.0160 cfs	0.0038 cfs
25 Year	0.0243 cfs	0.0206 cfs	0.0037 cfs
50 Year	0.0255 cfs	0.0223 cfs	0.0032 cfs
100 Year	0.0290 cfs	0.0262 cfs	0.0028 cfs
		2 Year to 50 Year Sum =	**0.0192 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 2:39 PM

Input File Name: BRC#5_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #5 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.023
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.042
Subbasin Total	0.065

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.023
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.042
Subbasin Total	0.065

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #5
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	409.10
Riser Crest Elevation (ft)	:	409.60
Storage Depth (ft)	:	0.50
Bottom Length (ft)	:	55.0
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	110.
Area at Riser Crest El (sq-ft)	:	259.
(acres)	:	0.006
Volume at Riser Crest (cu-ft)	:	158.
(ac-ft)	:	0.004

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 2.00

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.60 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.94
Diameter (in) : 12.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.281E-02
5-Year	1.650E-02
10-Year	1.972E-02
25-Year	2.432E-02
50-Year	2.554E-02
100-Year	2.901E-02
200-Year	3.342E-02

********** Link: BRC #5 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.281E-02

5-Year	1.650E-02
10-Year	1.972E-02
25-Year	2.432E-02
50-Year	2.554E-02
100-Year	2.901E-02
200-Year	3.342E-02

********** Link: BRC #5 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.904
1.11-Year	407.936
1.25-Year	407.962
2.00-Year	407.979
3.33-Year	407.985
5-Year	407.990
10-Year	407.996
25-Year	408.002
50-Year	408.008
100-Year	408.013

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.827
Total:	2.827

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.827
Link:	BRC #5	23.831
Total:		26.658

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.018 ac-ft/year, Post Developed: 0.169 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #5 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 24.19
Total Runoff Infiltrated (ac-ft): 23.83, 98.53%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 98.53%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #5

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.281E-02	2-Year	8.188E-03
5-Year	1.650E-02	5-Year	1.264E-02
10-Year	1.972E-02	10-Year	1.596E-02
25-Year	2.432E-02	25-Year	2.064E-02
50-Year	2.554E-02	50-Year	2.230E-02
100-Year	2.901E-02	100-Year	2.622E-02
200-Year	3.342E-02	200-Year	3.016E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-88.3%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-74.6%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-23.5%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-98.6%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-88.3%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #6	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0168 cfs	0.0109 cfs	0.0059 cfs
5 Year	0.0214 cfs	0.0174 cfs	0.0040 cfs
10 Year	0.0246 cfs	0.0216 cfs	0.0030 cfs
25 Year	0.0288 cfs	0.0254 cfs	0.0034 cfs
50 Year	0.0318 cfs	0.0288 cfs	0.0030 cfs
100 Year	0.0360 cfs	0.0335 cfs	0.0025 cfs
		2 Year to 50 Year Sum =	**0.0194 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/11/2013 2:56 PM

Input File Name: BRC#6_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #6 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.011
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.058
Subbasin Total	0.069

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.011
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.058
Subbasin Total	0.069

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #6
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 408.60
Riser Crest Elevation (ft) : 409.60
Storage Depth (ft) : 1.00
Bottom Length (ft) : 55.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 110.
Area at Riser Crest El (sq-ft) : 420.
(acres) : 0.010
Volume at Riser Crest (cu-ft) : 327.
(ac-ft) : 0.008

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.60 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.60
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.682E-02
5-Year	2.138E-02
10-Year	2.458E-02
25-Year	2.879E-02
50-Year	3.177E-02
100-Year	3.603E-02
200-Year	3.943E-02

********** Link: BRC #6 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.682E-02

5-Year	2.138E-02
10-Year	2.458E-02
25-Year	2.879E-02
50-Year	3.177E-02
100-Year	3.603E-02
200-Year	3.943E-02

********** Link: BRC #6 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.609
1.11-Year	407.627
1.25-Year	407.635
2.00-Year	407.653
3.33-Year	407.662
5-Year	407.669
10-Year	407.675
25-Year	407.680
50-Year	407.686
100-Year	407.693

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	1.352
Total:	1.352

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		1.352
Link:	BRC #6	28.213
Total:		29.565

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.009 ac-ft/year, Post Developed: 0.187 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #6 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 28.87
Total Runoff Infiltrated (ac-ft): 28.21, 97.74%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 97.74%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #6

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.682E-02	2-Year	1.089E-02
5-Year	2.138E-02	5-Year	1.735E-02
10-Year	2.458E-02	10-Year	2.156E-02
25-Year	2.879E-02	25-Year	2.537E-02
50-Year	3.177E-02	50-Year	2.876E-02
100-Year	3.603E-02	100-Year	3.350E-02
200-Year	3.943E-02	200-Year	3.642E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-87.2%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-70.2%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-15.6%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-97.7%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-87.2%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #7	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0069 cfs	0.0057 cfs	0.0012 cfs
5 Year	0.0088 cfs	0.0076 cfs	0.0012 cfs
10 Year	0.0100 cfs	0.0091 cfs	0.0009 cfs
25 Year	0.0118 cfs	0.0107 cfs	0.0011 cfs
50 Year	0.0131 cfs	0.0121 cfs	0.0010 cfs
100 Year	0.0148 cfs	0.0140 cfs	0.0008 cfs
		2 Year to 50 Year Sum =	**0.0053 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/11/2013 3:28 PM

Input File Name: BRC#7_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #7 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.004
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.024
Subbasin Total	0.028

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.004
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.024
Subbasin Total	0.028

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #7
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	408.30
Riser Crest Elevation (ft)	:	409.30
Storage Depth (ft)	:	1.00
Bottom Length (ft)	:	17.5
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	35.
Area at Riser Crest El (sq-ft)	:	158.
(acres)	:	0.004
Volume at Riser Crest (cu-ft)	:	113.
(ac-ft)	:	0.003

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.30 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.00
Diameter (in) : 12.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	6.917E-03
5-Year	8.787E-03
10-Year	1.008E-02
25-Year	1.177E-02
50-Year	1.306E-02
100-Year	1.480E-02
200-Year	1.614E-02

********** Link: BRC #7 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	6.917E-03

5-Year	8.787E-03
10-Year	1.008E-02
25-Year	1.177E-02
50-Year	1.306E-02
100-Year	1.480E-02
200-Year	1.614E-02

********** Link: BRC #7 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.023
1.11-Year	407.024
1.25-Year	407.026
2.00-Year	407.032
3.33-Year	407.035
5-Year	407.038
10-Year	407.041
25-Year	407.045
50-Year	407.048
100-Year	407.053

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	0.492
Total:	0.492

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		0.492
Link:	BRC #7	10.563
Total:		11.055

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.003 ac-ft/year, Post Developed: 0.070 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #7 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 11.73
Total Runoff Infiltrated (ac-ft): 10.56, 90.05%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 90.05%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #7

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	6.917E-03	2-Year	5.669E-03
5-Year	8.787E-03	5-Year	7.628E-03
10-Year	1.008E-02	10-Year	9.142E-03
25-Year	1.177E-02	25-Year	1.073E-02
50-Year	1.306E-02	50-Year	1.210E-02
100-Year	1.480E-02	100-Year	1.400E-02
200-Year	1.614E-02	200-Year	1.518E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-73.5%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-54.5%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-16.7%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-89.1%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-73.5%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #8	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0090 cfs	0.0004 cfs	0.0086 cfs
5 Year	0.0114 cfs	0.0062 cfs	0.0053 cfs
10 Year	0.0132 cfs	0.0082 cfs	0.0050 cfs
25 Year	0.0154 cfs	0.0124 cfs	0.0030 cfs
50 Year	0.0170 cfs	0.0145 cfs	0.0025 cfs
100 Year	0.0193 cfs	0.0172 cfs	0.0021 cfs
		2 Year to 50 Year Sum =	**0.0243 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 1:50 PM

Input File Name: BRC#8_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #8 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.006
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.031
Subbasin Total	0.037

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.006
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.031
Subbasin Total	0.037

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #8
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 408.60
Riser Crest Elevation (ft) : 409.60
Storage Depth (ft) : 1.00
Bottom Length (ft) : 45.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 90.
Area at Riser Crest El (sq-ft) : 350.
(acres) : 0.008
Volume at Riser Crest (cu-ft) : 270.
(ac-ft) : 0.006

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.60 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 407.60
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	8.994E-03
5-Year	1.144E-02
10-Year	1.316E-02
25-Year	1.542E-02
50-Year	1.700E-02
100-Year	1.928E-02
200-Year	2.111E-02

********** Link: BRC #8 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	8.994E-03

5-Year	1.144E-02
10-Year	1.316E-02
25-Year	1.542E-02
50-Year	1.700E-02
100-Year	1.928E-02
200-Year	2.111E-02

********** Link: BRC #8 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	407.354
1.11-Year	407.426
1.25-Year	407.509
2.00-Year	407.605
3.33-Year	407.632
5-Year	407.639
10-Year	407.645
25-Year	407.656
50-Year	407.662
100-Year	407.668

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	0.738
Total:	0.738

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		0.738
Link:	BRC #8	15.728
Total:		16.465

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.005 ac-ft/year, Post Developed: 0.104 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #8 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 15.77
Total Runoff Infiltrated (ac-ft): 15.73, 99.74%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 99.74%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #8

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	8.994E-03	2-Year	4.060E-04
5-Year	1.144E-02	5-Year	6.171E-03
10-Year	1.316E-02	10-Year	8.178E-03
25-Year	1.542E-02	25-Year	1.238E-02
50-Year	1.700E-02	50-Year	1.453E-02
100-Year	1.928E-02	100-Year	1.721E-02
200-Year	2.111E-02	200-Year	1.865E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-96.1%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-88.8%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-40.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-99.6%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-96.1%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #9	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0145 cfs	0.0086 cfs	0.0059 cfs
5 Year	0.0186 cfs	0.0141 cfs	0.0045 cfs
10 Year	0.0220 cfs	0.0191 cfs	0.0029 cfs
25 Year	0.0268 cfs	0.0243 cfs	0.0025 cfs
50 Year	0.0283 cfs	0.0261 cfs	0.0022 cfs
100 Year	0.0323 cfs	0.0305 cfs	0.0018 cfs
		2 Year to 50 Year Sum =	**0.0180 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 1:56 PM

Input File Name: BRC#9_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #9 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.022
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.048
Subbasin Total	0.070

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.022
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.048
Subbasin Total	0.070

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #9
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	409.60
Riser Crest Elevation (ft)	:	410.10
Storage Depth (ft)	:	0.50
Bottom Length (ft)	:	40.0
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	80.
Area at Riser Crest El (sq-ft)	:	191.
(acres)	:	0.004
Volume at Riser Crest (cu-ft)	:	115.
(ac-ft)	:	0.003

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 410.10 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 408.90
Diameter (in) : 8.00
Orientation : Horizontal
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.454E-02
5-Year	1.858E-02
10-Year	2.202E-02
25-Year	2.675E-02
50-Year	2.833E-02
100-Year	3.232E-02
200-Year	3.681E-02

********** Link: BRC #9 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.454E-02

5-Year	1.858E-02
10-Year	2.202E-02
25-Year	2.675E-02
50-Year	2.833E-02
100-Year	3.232E-02
200-Year	3.681E-02

********** Link: BRC #9 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	408.868
1.11-Year	408.900
1.25-Year	408.900
2.00-Year	408.901
3.33-Year	408.901
5-Year	408.901
10-Year	408.902
25-Year	408.902
50-Year	408.902
100-Year	408.903

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.704
Total:	2.704

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.704
Link:	BRC #9	25.857
Total:		28.561

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.017 ac-ft/year, Post Developed: 0.181 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #9 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 26.34
Total Runoff Infiltrated (ac-ft): 25.86, 98.17%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 98.17%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #9

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.454E-02	2-Year	8.624E-03
5-Year	1.858E-02	5-Year	1.413E-02
10-Year	2.202E-02	10-Year	1.910E-02
25-Year	2.675E-02	25-Year	2.426E-02
50-Year	2.833E-02	50-Year	2.611E-02
100-Year	3.232E-02	100-Year	3.047E-02
200-Year	3.681E-02	200-Year	3.462E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-87.0%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-70.4%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-33.3%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-97.8%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-87.0%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #10	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0139 cfs	0.0103 cfs	0.0037 cfs
5 Year	0.0178 cfs	0.0151 cfs	0.0027 cfs
10 Year	0.0211 cfs	0.0193 cfs	0.0018 cfs
25 Year	0.0256 cfs	0.0238 cfs	0.0019 cfs
50 Year	0.0271 cfs	0.0255 cfs	0.0017 cfs
100 Year	0.0310 cfs	0.0296 cfs	0.0014 cfs
		2 Year to 50 Year Sum =	**0.0117 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 1:58 PM

Input File Name: BRC#10_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #10 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.021
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.046
Subbasin Total	0.067

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.021
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.046
Subbasin Total	0.067

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #10
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	409.40
Riser Crest Elevation (ft)	:	409.90
Storage Depth (ft)	:	0.50
Bottom Length (ft)	:	30.0
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	60.
Area at Riser Crest El (sq-ft)	:	146.
(acres)	:	0.003
Volume at Riser Crest (cu-ft)	:	87.
(ac-ft)	:	0.002

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.90 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 408.70
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.394E-02
5-Year	1.780E-02
10-Year	2.108E-02
25-Year	2.562E-02
50-Year	2.713E-02
100-Year	3.095E-02
200-Year	3.525E-02

********** Link: BRC #10 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.394E-02

5-Year	1.780E-02
10-Year	2.108E-02
25-Year	2.562E-02
50-Year	2.713E-02
100-Year	3.095E-02
200-Year	3.525E-02

********** Link: BRC #10 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	408.726
1.11-Year	408.731
1.25-Year	408.739
2.00-Year	408.751
3.33-Year	408.759
5-Year	408.763
10-Year	408.772
25-Year	408.777
50-Year	408.781
100-Year	408.787

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.581
Total:	2.581

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.581
Link:	BRC #10	24.046
Total:		26.627

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.016 ac-ft/year, Post Developed: 0.169 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #10 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 25.06
Total Runoff Infiltrated (ac-ft): 24.05, 95.94%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 95.94%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #10

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.394E-02	2-Year	1.027E-02
5-Year	1.780E-02	5-Year	1.511E-02
10-Year	2.108E-02	10-Year	1.925E-02
25-Year	2.562E-02	25-Year	2.375E-02
50-Year	2.713E-02	50-Year	2.547E-02
100-Year	3.095E-02	100-Year	2.957E-02
200-Year	3.525E-02	200-Year	3.360E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-79.4%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-55.4%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-26.7%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-95.6%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-79.4%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #11	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0118 cfs	0.0100 cfs	0.0018 cfs
5 Year	0.0150 cfs	0.0137 cfs	0.0013 cfs
10 Year	0.0177 cfs	0.0165 cfs	0.0012 cfs
25 Year	0.0215 cfs	0.0203 cfs	0.0012 cfs
50 Year	0.0229 cfs	0.0218 cfs	0.0011 cfs
100 Year	0.0261 cfs	0.0252 cfs	0.0009 cfs
		2 Year to 50 Year Sum =	**0.0067 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 2:05 PM

Input File Name: BRC#11_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #11 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.017
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.039
Subbasin Total	0.056

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.017
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.039
Subbasin Total	0.056

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #11
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 409.20
Riser Crest Elevation (ft) : 409.70
Storage Depth (ft) : 0.50
Bottom Length (ft) : 20.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 40.
Area at Riser Crest El (sq-ft) : 101.
(acres) : 0.002
Volume at Riser Crest (cu-ft) : 59.
(ac-ft) : 0.001

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.70 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 408.50
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.179E-02
5-Year	1.502E-02
10-Year	1.774E-02
25-Year	2.152E-02
50-Year	2.285E-02
100-Year	2.609E-02
200-Year	2.962E-02

********** Link: BRC #11 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.179E-02

5-Year	1.502E-02
10-Year	1.774E-02
25-Year	2.152E-02
50-Year	2.285E-02
100-Year	2.609E-02
200-Year	2.962E-02

********** Link: BRC #11 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	408.532
1.11-Year	408.536
1.25-Year	408.540
2.00-Year	408.551
3.33-Year	408.556
5-Year	408.560
10-Year	408.567
25-Year	408.572
50-Year	408.575
100-Year	408.581

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.090
Total:	2.090

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.090
Link:	BRC #11	19.283
Total:		21.373

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.013 ac-ft/year, Post Developed: 0.135 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #11 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 20.99
Total Runoff Infiltrated (ac-ft): 19.28, 91.89%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 91.89%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #11

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.179E-02	2-Year	1.005E-02
5-Year	1.502E-02	5-Year	1.369E-02
10-Year	1.774E-02	10-Year	1.652E-02
25-Year	2.152E-02	25-Year	2.028E-02
50-Year	2.285E-02	50-Year	2.177E-02
100-Year	2.609E-02	100-Year	2.517E-02
200-Year	2.962E-02	200-Year	2.853E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-68.5%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-37.5%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-17.1%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-91.3%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-68.5%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #12	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0124 cfs	0.0060 cfs	0.0064 cfs
5 Year	0.0158 cfs	0.0112 cfs	0.0046 cfs
10 Year	0.0187 cfs	0.0133 cfs	0.0054 cfs
25 Year	0.0227 cfs	0.0205 cfs	0.0022 cfs
50 Year	0.0240 cfs	0.0221 cfs	0.0019 cfs
100 Year	0.0275 cfs	0.0258 cfs	0.0017 cfs
		2 Year to 50 Year Sum =	**0.0205 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 06/24/2013 9:40 AM

Input File Name: BRC#12_Scenario 1 6-24-13.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #12 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.018
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.041
Subbasin Total	0.059

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.018
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.041
Subbasin Total	0.059

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #12
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	409.20
Riser Crest Elevation (ft)	:	409.70
Storage Depth (ft)	:	0.50
Bottom Length (ft)	:	35.0
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	70.
Area at Riser Crest El (sq-ft)	:	169.
(acres)	:	0.004
Volume at Riser Crest (cu-ft)	:	101.
(ac-ft)	:	0.002

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.90

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 409.70 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 408.50
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

********** Link: BRC #12 ********** Link WSEL Stats
WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	408.435
1.11-Year	408.507
1.25-Year	408.523
2.00-Year	408.538
3.33-Year	408.551
5-Year	408.554
10-Year	408.559
25-Year	408.572
50-Year	408.576
100-Year	408.582

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.213
Total:	2.213

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.213
Link:	BRC #12	22.022
Total:		24.235

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.014 ac-ft/year, Post Developed: 0.153 ac-ft/year

*************Water Quality Facility Data **************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #12 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 22.36
Total Runoff Infiltrated (ac-ft): 22.02, 98.50%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 98.50%

*************Compliance Point Results **************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #12

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.240E-02	2-Year	6.022E-03
5-Year	1.581E-02	5-Year	1.118E-02
10-Year	1.867E-02	10-Year	1.328E-02
25-Year	2.266E-02	25-Year	2.048E-02

50-Year	2.404E-02	50-Year	2.214E-02
100-Year	2.745E-02	100-Year	2.584E-02
200-Year	3.118E-02	200-Year	2.927E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-89.1%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-75.5%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-23.4%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-98.1%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-89.1%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #13	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0161 cfs	0.0032 cfs	0.0129 cfs
5 Year	0.0207 cfs	0.0124 cfs	0.0084 cfs
10 Year	0.0247 cfs	0.0157 cfs	0.0091 cfs
25 Year	0.0302 cfs	0.0219 cfs	0.0083 cfs
50 Year	0.0318 cfs	0.0268 cfs	0.0050 cfs
100 Year	0.0362 cfs	0.0287 cfs	0.0075 cfs
		2 Year to 50 Year Sum =	**0.0435 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 2:48 PM

Input File Name: BRC#13_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #13 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.027
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.053
Subbasin Total	0.080

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.027
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.053
Subbasin Total	0.080

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #13
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft)	:	410.50
Riser Crest Elevation (ft)	:	411.50
Storage Depth (ft)	:	1.00
Bottom Length (ft)	:	38.0
Bottom Width (ft)	:	2.0
Side Slopes (ft/ft)	:	L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft)	:	76.
Area at Riser Crest El (sq-ft)	:	301.
(acres)	:	0.007
Volume at Riser Crest (cu-ft)	:	230.
(ac-ft)	:	0.005

Infiltration on Bottom only Selected

Soil Properties

Biosoil Thickness (ft)	:	1.50
Biosoil Saturated Hydraulic Conductivity (in/hr)	:	2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.74

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 411.50 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 410.50
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.610E-02
5-Year	2.070E-02
10-Year	2.473E-02
25-Year	3.020E-02
50-Year	3.182E-02
100-Year	3.621E-02
200-Year	4.152E-02

********** Link: BRC #13 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	1.610E-02

5-Year	2.070E-02
10-Year	2.473E-02
25-Year	3.020E-02
50-Year	3.182E-02
100-Year	3.621E-02
200-Year	4.152E-02

********** Link: BRC #13 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	410.016
1.11-Year	410.178
1.25-Year	410.368
2.00-Year	410.526
3.33-Year	410.543
5-Year	410.557
10-Year	410.564
25-Year	410.574
50-Year	410.583
100-Year	410.586

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	3.319
Total:	3.319

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		3.319
Link:	BRC #13	29.396
Total:		32.715

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.021 ac-ft/year, Post Developed: 0.207 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #13 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 29.50
Total Runoff Infiltrated (ac-ft): 29.40, 99.63%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 99.63%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #13

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	1.610E-02	2-Year	3.202E-03
5-Year	2.070E-02	5-Year	1.235E-02
10-Year	2.473E-02	10-Year	1.568E-02
25-Year	3.020E-02	25-Year	2.194E-02
50-Year	3.182E-02	50-Year	2.684E-02
100-Year	3.621E-02	100-Year	2.867E-02
200-Year	4.152E-02	200-Year	3.764E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-94.1%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-84.9%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-64.7%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-98.7%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-94.1%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #14	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0205 cfs	0.0063 cfs	0.0142 cfs
5 Year	0.0266 cfs	0.0184 cfs	0.0082 cfs
10 Year	0.0316 cfs	0.0226 cfs	0.0090 cfs
25 Year	0.0410 cfs	0.0293 cfs	0.0117 cfs
50 Year	0.0436 cfs	0.0370 cfs	0.0066 cfs
100 Year	0.0477 cfs	0.0399 cfs	0.0078 cfs
		2 Year to 50 Year Sum =	**0.0497 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 06/24/2013 9:28 AM

Input File Name: BRC#14_Scenario 1 6-24-13.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #14 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.053
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.064
Subbasin Total	0.117

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.053
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.064
Subbasin Total	0.117

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #14
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 410.50
Riser Crest Elevation (ft) : 411.50
Storage Depth (ft) : 1.00
Bottom Length (ft) : 45.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 90.
Area at Riser Crest El (sq-ft) : 350.
(acres) : 0.008
Volume at Riser Crest (cu-ft) : 270.
(ac-ft) : 0.006

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.74

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 411.50 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 410.50
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

********** Link: BRC #14 ********** Link WSEL Stats
WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	410.129
1.11-Year	410.273
1.25-Year	410.449
2.00-Year	410.539
3.33-Year	410.557
5-Year	410.571
10-Year	410.577
25-Year	410.584
50-Year	410.598
100-Year	410.602

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	6.515
Total:	6.515

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		6.515
Link:	BRC #14	39.283
Total:		45.797

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.041 ac-ft/year, Post Developed: 0.290 ac-ft/year

*************Water Quality Facility Data **************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #14 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 39.68
Total Runoff Infiltrated (ac-ft): 39.28, 99.01%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 99.01%

*************Compliance Point Results **************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #14

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	2.054E-02	2-Year	6.262E-03
5-Year	2.656E-02	5-Year	1.837E-02
10-Year	3.156E-02	10-Year	2.259E-02
25-Year	4.099E-02	25-Year	2.934E-02

50-Year	4.358E-02	50-Year	3.697E-02
100-Year	4.774E-02	100-Year	3.989E-02
200-Year	5.674E-02	200-Year	5.253E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-91.0%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-76.8%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-60.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-98.1%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-91.0%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #15	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0064 cfs	0.0000 cfs	0.0064 cfs
5 Year	0.0083 cfs	0.0036 cfs	0.0047 cfs
10 Year	0.0098 cfs	0.0054 cfs	0.0044 cfs
25 Year	0.0127 cfs	0.0095 cfs	0.0032 cfs
50 Year	0.0135 cfs	0.0113 cfs	0.0022 cfs
100 Year	0.0148 cfs	0.0131 cfs	0.0018 cfs
		2 Year to 50 Year Sum =	**0.0208 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 06/24/2013 9:30 AM

Input File Name: BRC#15_Scenario 1 6-24-13.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #15 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.016
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.020
Subbasin Total	0.036

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.016
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.020
Subbasin Total	0.036

********** **LINK DATA** **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** **LINK DATA** **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #15
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 411.60
Riser Crest Elevation (ft) : 412.10
Storage Depth (ft) : 0.50
Bottom Length (ft) : 45.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.00 L2= 2.00 W1= 2.00 W2= 2.00
Bottom Area (sq-ft) : 90.
Area at Riser Crest El (sq-ft) : 188.
(acres) : 0.004
Volume at Riser Crest (cu-ft) : 123.
(ac-ft) : 0.003

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.74

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 412.10 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 410.50
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

********** Link: BRC #15 ********** Link WSEL Stats
WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	410.182
1.11-Year	410.217
1.25-Year	410.285
2.00-Year	410.477
3.33-Year	410.512
5-Year	410.528
10-Year	410.536
25-Year	410.548
50-Year	410.554
100-Year	410.558

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	1.967
Total:	1.967

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		1.967
Link:	BRC #15	12.865
Total:		14.831

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.012 ac-ft/year, Post Developed: 0.094 ac-ft/year

*************Water Quality Facility Data **************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #15 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 12.89
Total Runoff Infiltrated (ac-ft): 12.86, 99.78%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 99.78%

*************Compliance Point Results **************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #15

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	6.366E-03	2-Year	3.768E-06
5-Year	8.260E-03	5-Year	3.621E-03
10-Year	9.816E-03	10-Year	5.430E-03
25-Year	1.269E-02	25-Year	9.488E-03

50-Year	1.346E-02	50-Year	1.127E-02
100-Year	1.481E-02	100-Year	1.306E-02
200-Year	1.755E-02	200-Year	1.542E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-96.8%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-88.9%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-48.5%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-99.8%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-96.8%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #16	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0059 cfs	0.0053 cfs	0.0006 cfs
5 Year	0.0075 cfs	0.0069 cfs	0.0006 cfs
10 Year	0.0090 cfs	0.0085 cfs	0.0005 cfs
25 Year	0.0118 cfs	0.0113 cfs	0.0005 cfs
50 Year	0.0126 cfs	0.0122 cfs	0.0004 cfs
100 Year	0.0136 cfs	0.0135 cfs	0.0002 cfs
		2 Year to 50 Year Sum =	**0.0026 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 3:20 PM

Input File Name: BRC#16_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #16 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.016
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.018
Subbasin Total	0.034

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.016
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.018
Subbasin Total	0.034

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #16
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 433.30
Riser Crest Elevation (ft) : 434.30
Storage Depth (ft) : 1.00
Bottom Length (ft) : 18.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 36.
Area at Riser Crest El (sq-ft) : 161.
(acres) : 0.004
Volume at Riser Crest (cu-ft) : 116.
(ac-ft) : 0.003

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.12

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 434.30 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 432.24
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS*********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	5.878E-03
5-Year	7.527E-03
10-Year	8.980E-03
25-Year	1.176E-02
50-Year	1.256E-02
100-Year	1.364E-02
200-Year	1.631E-02

********** Link: BRC #16 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	5.878E-03

5-Year	7.527E-03
10-Year	8.980E-03
25-Year	1.176E-02
50-Year	1.256E-02
100-Year	1.364E-02
200-Year	1.631E-02

********** Link: BRC #16 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	432.262
1.11-Year	432.265
1.25-Year	432.268
2.00-Year	432.276
3.33-Year	432.279
5-Year	432.281
10-Year	432.286
25-Year	432.292
50-Year	432.296
100-Year	432.299

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	1.967
Total:	1.967

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		1.967
Link:	BRC #16	10.513
Total:		12.480

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.012 ac-ft/year, Post Developed: 0.079 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #16 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 11.48
Total Runoff Infiltrated (ac-ft): 10.51, 91.59%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 91.59%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #16

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	5.878E-03	2-Year	5.250E-03
5-Year	7.527E-03	5-Year	6.925E-03
10-Year	8.980E-03	10-Year	8.458E-03
25-Year	1.176E-02	25-Year	1.129E-02
50-Year	1.256E-02	50-Year	1.220E-02
100-Year	1.364E-02	100-Year	1.346E-02
200-Year	1.631E-02	200-Year	1.598E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-63.2%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-32.6%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	0.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-90.6%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-63.2%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Thornton Creek
Drainage Calculations
Bioretention Cell Summary

Bioretention Cells
April 11, 2013

Bioretention Cell Flow Reduction Summary

Note: Predeveloped conditions do not affect the performance of the bioretention cell or model output. Impervious and pervious surfaces have been used for predeveloped conditions in the modeling in order to show actual existing conditions at the site and in order to show the reduced flow benefits provided by the facility.

Bioretention Cell #17	**With Underdrain**		
Storm Event	Predeveloped Flows	Postdeveloped Flows	Flow Reduction
2 Year	0.0097 cfs	0.0087 cfs	0.0010 cfs
5 Year	0.0125 cfs	0.0116 cfs	0.0009 cfs
10 Year	0.0150 cfs	0.0142 cfs	0.0008 cfs
25 Year	0.0191 cfs	0.0183 cfs	0.0007 cfs
50 Year	0.0201 cfs	0.0195 cfs	0.0006 cfs
100 Year	0.0224 cfs	0.0221 cfs	0.0003 cfs
		2 Year to 50 Year Sum =	**0.0040 cfs**

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.29
Program License Number: 200310001
Run Date: 04/12/2013 3:25 PM

Input File Name: BRC#17_Scenario 1.fld
Project Name: North Thornton Creek LID Stormwater Retrofit
Analysis Title: BRC #17 with underdrain
Comments: Scenario 1

PRECIPITATION INPUT

Computational Time Step (Minutes): 60

Extended Precipitation Timeseries Selected
Climatic Region Number: 13

Full Period of Record Available used for Routing
Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097
Evaporation Station : 961040 Puget East 40 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Pre-Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.022
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.031
Subbasin Total	0.053

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1

---------- Subbasin : Post Developed ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.022
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User 2	0.000
Impervious	0.031
Subbasin Total	0.053

********** LINK DATA **********

----------SCENARIO: PREDEVELOPED
Number of Links: 0

********** LINK DATA **********

----------SCENARIO: POSTDEVELOPED
Number of Links: 1

Link Name: BRC #17
Link Type: Bioretention Facility
Downstream Link: None

Base Elevation (ft) : 433.30
Riser Crest Elevation (ft) : 434.30
Storage Depth (ft) : 1.00
Bottom Length (ft) : 28.0
Bottom Width (ft) : 2.0
Side Slopes (ft/ft) : L1= 2.50 L2= 2.50 W1= 2.50 W2= 2.50
Bottom Area (sq-ft) : 56.
Area at Riser Crest El (sq-ft) : 231.
(acres) : 0.005
Volume at Riser Crest (cu-ft) : 173.
(ac-ft) : 0.004

Infiltration on Bottom only Selected

Soil Properties
Biosoil Thickness (ft) : 1.50
Biosoil Saturated Hydraulic Conductivity (in/hr) : 2.00

Biosoil Porosity (Percent) : 40.00
Native Soil Hydraulic Conductivity (in/hr) : 1.12

Riser Geometry
Riser Structure Type : Circular
Riser Diameter (in) : 12.00
Common Length (ft) : 0.000
Riser Crest Elevation : 434.30 ft

Hydraulic Structure Geometry

Number of Devices: 1

---Device Number 1 ---
Device Type : Circular Orifice
Control Elevation (ft) : 432.31
Diameter (in) : 8.00
Orientation : Vertical
Elbow : Yes

**************************FLOOD FREQUENCY AND DURATION STATISTICS********************

----------SCENARIO: PREDEVELOPED
Number of Subbasins: 1
Number of Links: 0

----------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 1

************ Subbasin: Post Developed ************

Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	9.708E-03
5-Year	1.253E-02
10-Year	1.502E-02
25-Year	1.907E-02
50-Year	2.009E-02
100-Year	2.240E-02
200-Year	2.629E-02

********** Link: BRC #17 ********** Link Inflow Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	9.708E-03

5-Year	1.253E-02
10-Year	1.502E-02
25-Year	1.907E-02
50-Year	2.009E-02
100-Year	2.240E-02
200-Year	2.629E-02

********** Link: BRC #17 ********** Link WSEL Stats

WSEL Frequency Data(ft)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	WSEL Peak (ft)
1.05-Year	432.339
1.11-Year	432.343
1.25-Year	432.347
2.00-Year	432.357
3.33-Year	432.362
5-Year	432.365
10-Year	432.371
25-Year	432.378
50-Year	432.382
100-Year	432.386

*************Groundwater Recharge Summary **************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: Pre-Developed	2.704
Total:	2.704

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: Post Developed		2.704
Link:	BRC #17	16.968
Total:		19.672

Total Predevelopment Recharge is Less than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 0.017 ac-ft/year, Post Developed: 0.125 ac-ft/year

*************Water Quality Facility Data ***************

----------SCENARIO: PREDEVELOPED

Number of Links: 0

----------SCENARIO: POSTDEVELOPED

Number of Links: 1

********** Link: BRC #17 **********

Infiltration/Filtration Statistics----------
Total Runoff Volume (ac-ft): 18.60
Total Runoff Infiltrated (ac-ft): 16.97, 91.21%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Percent Treated (Infiltrated+Filtered)/Total Volume: 91.21%

*************Compliance Point Results ***************

Scenario Predeveloped Compliance Subbasin: Pre-Developed

Scenario Postdeveloped Compliance Link: BRC #17

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	9.708E-03	2-Year	8.702E-03
5-Year	1.253E-02	5-Year	1.162E-02
10-Year	1.502E-02	10-Year	1.421E-02
25-Year	1.907E-02	25-Year	1.833E-02
50-Year	2.009E-02	50-Year	1.953E-02
100-Year	2.240E-02	100-Year	2.212E-02
200-Year	2.629E-02	200-Year	2.577E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than 0%):	-64.2%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than 0%):	-31.9%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	0.0%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	-90.4%	PASS
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	-64.2%	PASS

MEETS ALL LID DURATION DESIGN CRITERIA: PASS

Appendix B – Geotechnical Information

- **Infiltration Evaluation**
- **Soil Analysis**

HWA GeoSciences Inc.

Geotechnical Engineering • Hydrogeology • Geoenvironmental Services • Inspection and Testing

April 5, 2013
HWA Project No. 2012 007

Perteet Inc.
505 Fifth Avenue South, Suite 300
Seattle, WA 98104-3894

Attention: Jason Shrope, P.E.

Subject: **INFILTRATION EVALUATIONS**
North Fork Thornton Creek LID Stormwater Retrofit
Shoreline, Washington

Dear Mr. Shrope:

This report summarizes the results of the HWA GeoSciences Inc. (HWA) storm water infiltration suitability study, conducted for Perteet on behalf of the City of Shoreline, Washington. The purpose of the investigation was to evaluate the study area surface and subsurface conditions and provide recommendations in support of low impact development (LID) stormwater retrofit improvements.

SCOPE OF WORK

In a previous phase of the study, HWA reviewed available geologic data, advanced shallow hand boring explorations, and provided preliminary recommendations for low-impact development stormwater facilities.

In this follow-on phase, HWA's scope of work included the following elements:

- At selected LID sites, drill and sample direct push soil borings to characterize shallow soil and ground water conditions with respect to stormwater infiltration potential.
- Employ a subcontracted licensed drilling contractor to advance the borings.
- Collect and analyze selected soil samples for material properties including grain size distribution.
- Estimate potential infiltration rates per Ecology Stormwater Manual, and provide recommendations for stormwater infiltration at each site based on the technical findings of the investigation.

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www.hwageo.com

SITE GEOLOGY AND SOILS

Geologic information for the project area was obtained from the *Composite Geologic Map of the Sno-King Area: University of Washington, Seattle-Area,* (Booth, et al., 2004). According to Booth, near-surface deposits in the study area consist primarily of Vashon glacial till at the surface over advance outwash. In some areas, advance outwash is present at the surface. Soil types mapped in the project area include the following:

> **Vashon Till (QVt)** covers most of the study area and generally consists of an unsorted compact mixture of clay to boulder sized particles in a fine-grained matrix, deposited at the base of the Cordilleran ice sheet during the latest glaciation. Occasional sand and gravel lenses may be present. Till is commonly referred to as "hardpan" due to its concrete-like texture. Till is generally not water-bearing, and acts as an aquitard that inhibits the flow of ground water, perches water on top of it in surficial fill, and also confines water below it in the advance outwash. In general, the permeability of till ranges from low in weathered surficial deposits to relatively impermeable in very dense non-weathered materials.
>
> **Advance Outwash (QVa)** consists mostly of glaciofluvial (river-deposited) sand and gravel, with some lacustrine (lake deposited) clay and silt deposited during the advance of glaciers. Sandy units are commonly thick, well sorted, and fine grained, with interlayered coarser sand, gravel, cobbles and silt. Advance outwash is typically dense to very dense, having been overridden by glacial ice, and is commonly overlain by till, except where exposed by erosion. The advance outwash represents a local aquifer, with ground water typically occurring under unconfined conditions, although locally confined conditions may be present where the outwash is thin below a confining overlying layer. Ground water in the study area follows local topography and discharges to the Snohomish River to the east, and to the Puget Sound to the west. Where exposed at the surface, the QVa may be unsaturated. Unsaturated surface exposures of QVa are subject to high rates of natural recharge via precipitation.

SITE EXPLORATIONS

On March 12, 2013, a HWA geologist conducted soil explorations within the study area in order to further delineate near-surface soils for stormwater infiltration potential. A total of nine soil borings were advanced with a direct-push drilling rig to depths of up to 13 feet. Boring locations were selected to coincide with proposed facility locations. Figure 2 shows the locations of the borings. Appendix A includes the exploration logs.

Site soil conditions encountered were described by the HWA geologist at each of the locations. Soil samples were collected at selected intervals within each boring and sealed in plastic bags for examination.

LABORATORY TESTING

Laboratory tests were conducted on selected samples obtained from the explorations to characterize relevant engineering and index properties of the project soils. Laboratory tests included determination of in-situ moisture content and grain size distribution. The tests were conducted in general accordance with appropriate American Society of Testing and Materials (ASTM) standards. The test results are presented in Appendix B.

DISCUSSION

Soils encountered generally consisted one to two feet of fill material, likely derived from native soils, in most borings. Deeper fill soils were encountered at borings B-4, B-5 and B-6, likely due to the borings' proximity to utilities. Most of the study area was underlain by silty sand (with variable silt content) believed to be weathered glacial till beneath the fill, to a maximum depth of eight feet below grade. Unweathered glacial till was encountered at depths ranging from three to eight feet. Silty sands, possibly advance outwash deposits, were encountered in boring B-5 and B-9 at depths of eight to nine feet, respectively.

Grain size analyses were performed on selected soil samples. Samples were selected based on proposed depths of the stormwater facilities and field classification. Samples were typically classified as silty sand based on the grain size analysis, although one sample (B7-3) was classified as silt.

The grain size results were initially analyzed by two methods recommended in the Washington State Department of Ecology (Ecology) 2005 *Stormwater Management Manual for Western Washington*: ASTM grain size distribution and USDA textural analysis. These methods assign short term and corrected long term infiltration rates to soils based on grain size distribution data. The results are summarized on Table 1.

Based on these analyses, long-term infiltration rates for most of the soils encountered at the site range were 0.25 in/hr using the USDA method, with one sample (B5, 8 foot depth) as high as 2 in/hr. The ASTM ('D_{10}') method generally classified the soils as 'unsuitable' for infiltration based on the high silt and clay content and resulting low D_{10} values. These methodologies tend to be conservative in their infiltration capacity estimations.

HWA also calculated infiltration capability of the soils using the "detailed approach" method per the 2005 Ecology Manual. This method, taken from Massmann (2003) also uses grain size distribution data. First, the saturated hydraulic conductivity (K) is estimated based on a regression-based formula which includes the D_{10}, D_{60}, D_{90},(where Dn = the particle size where n percent of the sample passes that sieve) and percent fines :

$$\log_{10}(K_{sat}) = -1.57 + 1.90 D_{10} + 0.015 D_{60} - 0.013 D_{90} - 2.08 f_{fines}$$

Table 1
Infiltration Analysis Summary

Boring ID	Proposed Infiltration Facility Type and ID	Approx. Facility Depth (ft bgs)	Approx. Facility Dimensions (ft)	Sample Depth (ft bgs)	Soil Field Description	ASTM Method (Ecology, 2005)			USDA Method (Ecology (2005)		Detailed Method (Ecology. 2005)			
						ASTM Soil Classification	D_{10}* diameter, (mm)	Infiltration Rate	USDA Soil Classification	Short/Long Term Rates (in/hr)	Massmann K_{sat} (in/hr)	Infiltration by Massmann Regression** (in/hr)	Correction factor	Corrected Infiltration rate (in/hr)
B1	Rain Garden #15,16	5-6	3x28, 3x35	6	Till	SM	0.005	Unsuitable	Sandy loam	1/0.25	6.8	1.9	0.6	1.12
B2	Rain Garden #14	5-6	2.5x42	4	Till	SM	0.005	Unsuitable	Sandy loam	1/0.25	7.1	2.0	0.6	1.17
B3	Rain Garden #8, 9	5-6	3x45 (2)	4	Weathered Till	SM	0.005	Unsuitable	Sandy loam	1/0.25	10.8	2.9	0.6	1.74
		5-6	3x45 (2)	7	Till, sandy	SM	0.016	Unsuitable	Sandy loam	1/0.25	11.8	3.2	0.6	1.90
B4	Rain Garden #5, 6,7	5-6	2x45, 2x17, 2x60	3	Fill	SM	0.015	Unsuitable	Sandy loam	1/0.25	11.8	3.2	0.6	1.90
B5	Rain Garden #10,11	5-6	3x75, 3x65	8	Till, sandy	SM	0.06	0.8	Sand	8/2	12.5	3.3	0.6	2.00
		5-6		11	Till, sandy	SM	0.02	Unsuitable	Loamy sand	2/.05	16.5	4.4	0.6	2.61
B6	Rain Garden #3, 4	5-6	3x35, 3x45	6	Fill	SM	0.0075	Unsuitable	Sandy loam	1/0.25	4.7	1.3	0.6	0.79
B7	Rain Garden #1,2	5-6	3x70	3	Till	ML	0.003	Unsuitable	Silt Loam	Unsuitable	1.7	0.5	0.6	0.29
B8	Gallery #1	10-12	6x150	8	Till	SM	0.003	Unsuitable	Sandy loam	1/0.25	5.8	2.0	0.6	1.18
B9	Gallery #2&3	5-7	6x155, 6x122	8	Till, sandy	SM	0.015	Unsuitable	Sandy loam	1/0.25	14.5	3.9	0.6	2.34
	Gallery #2&3	5-7		10	Till	SM	0.015	Unsuitable	Sandy loam	1/0.25	12.3	3.4	0.6	2.02

Notes:
Highlighted - value estimated
* - ASTM D_{10} method not to be used for D_{10}< 0.05mm
** - assumptions, 20 feet to ground water, area based on 60% plan dimensions

Calculated saturated hydraulic conductivities using this method ranged over one order of magnitude (considered a relatively narrow range for this parameter), from 0.0024 feet/ minute (ft/min) (1.7in/hr) for B7 (6 foot sample), to 0.023 ft/min (16.5 in/hr) for B5 (11 foot sample).

The second step in the "detailed approach" involves calculation of the vertical hydraulic gradient, also based on regression of data and computer simulations from multiple infiltration facilities in the Puget Sound area. The vertical gradient for a trench is described by the following relationship: i = (Dwt+Dt) / 78*K0.05, where:

i = vertical gradient
Dwt = depth to water table (or low-permeability layers) – assumed to be 20 feet
Dt = trench depth - (variable – based on 60% project plans)
K = saturated hydraulic conductivity – based on grain size data (above)

The third step in the "detailed approach" includes a variation of Darcy's law, which states Q = k i A, where:

Q = discharge
K = 0.023-0.0024 ft/min (16.5-1.7 in/hr) (above)
i = variable (calculated by above equation)
A = variable (based on 60% project plans)

Solving for discharge and dividing by the area of each proposed infiltration facility yields the final design infiltration rates. The (uncorrected) infiltration rates at the various facility locations range from about 0.5 to 4.4 in/hr (Table 1).

The Stormwater Manual recommends applying an additional correction factor for infiltration facilities to account for biofouling and siltation effects (Ecology, 2005). Based on an assumed low potential for biofouling, and low degree of long-term maintenance/performance monitoring, a reduction factor of 0.6 was used.

The design infiltration rates for the proposed rain gardens and Gallery #1 locations are therefore approximately 0.3 to 2.6 in/hr after applying the correction factor. The design infiltration rate for the proposed gallery #2 and #3 locations is approximately 2 to 2.3 in/hr.

Infiltration via the retrofit of the existing stormwater system will increase on-site stormwater treatment, detention, and infiltration. Infiltration of large storm events may be limited by the fine-grained nature of the receiving soils, as well as fine grained and consolidated soils underlying the receiving areas. Design considerations should include provision for a system overflow discharge, as appropriate.

CONCLUSIONS

Based on the testing and analyses presented herein, design infiltration rates for the proposed rain gardens and Gallery #1 range from approximately 0.3 to 2.6 in/hr, as shown on Table 1 (far right column), and summarized in Table 2 below. The potential infiltration rate for Galleries #2 and #3 is approximately 2 to 2.3 in/hr. This location contains some advance outwash soils at depths of seven to ten feet, and appears promising for infiltration of stormwater. Most of the other rain garden locations are located above glacial till, weathered till, and fill soils with limited infiltration capacity.

Table 2
Infiltration Rate Summary

Boring ID	Proposed infiltration facility type and ID	Design Infiltration rate (in/hr)
B1	Rain Garden #15,16	1.12
B2	Rain Garden #14	1.17
B3	Rain Garden #8, 9	1.74
		1.90
B4	Rain Garden #5, 6,7	1.90
B5	Rain Garden #10,11	2.00
		2.61
B6	Rain Garden #3, 4	0.79
B7	Rain Garden #1,2	0.29
B8	Gallery #1	1.18
B9	Gallery #2&3	2.34
	Gallery #2&3	2.02

REFERENCES

Ecology, Washington State Department of, 2005, *Stormwater Management Manual for Western Washington*, Publications Numbers 05-10-029 through 05-10-033, Water Quality Program, Washington State Department of Ecology

HWA GeoSciences, 2012, *Preliminary Infiltration Evaluation, North Fork Thornton Creek LID Stormwater Retrofit, Shoreline, Washington*, dated September 7.

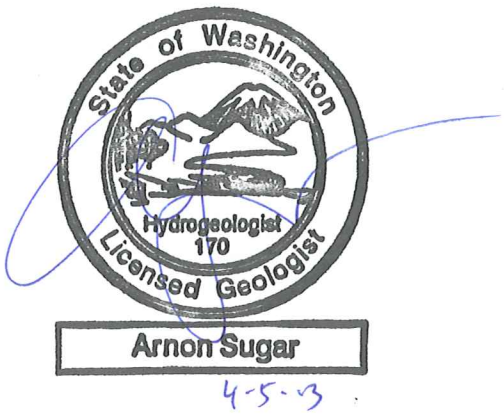
Massmann, Joel W., 2003. *A Design Manual for Sizing Infiltration Ponds*, Prepared for

Washington State Transportation Commission, Department of Transportation and in cooperation with U.S. Department of Transportation Federal Highway Administration, October, 2003.

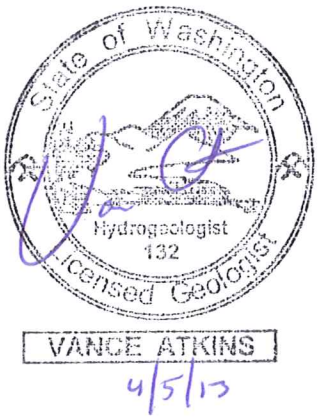
Thank you again for the opportunity to assist Perteet and the City of Shoreline on this project. Should you have any questions regarding this report, or require additional services, please contact us at your convenience.

Sincerely,

HWA GEOSCIENCES INC.



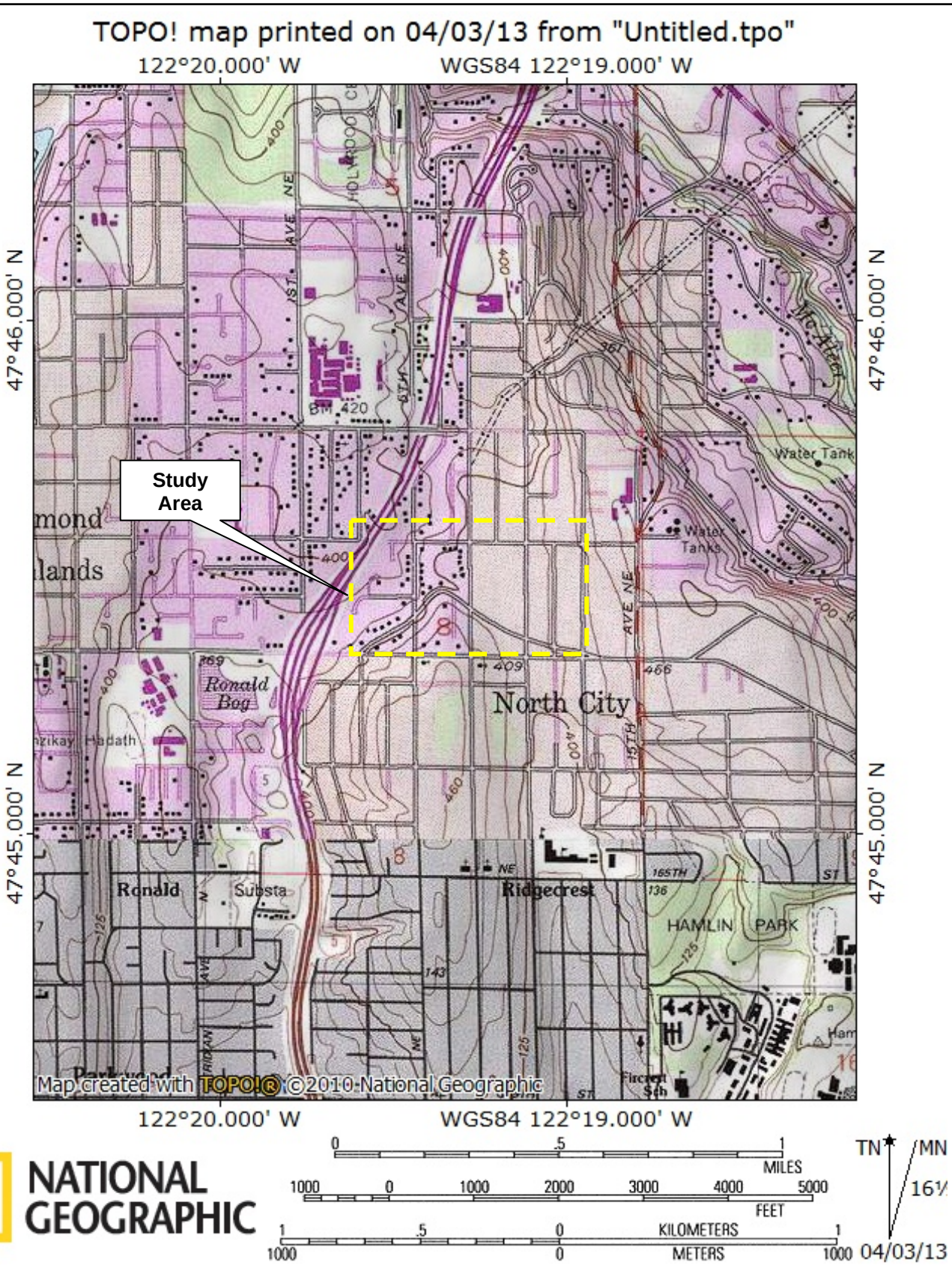
Arnie Sugar, LG, LHG
Hydrogeologist, President



Vance Atkins, LG, LHG
Senior Hydrogeologist

Attachments:

Figure 1- Site Location Map
Figure 2 – Boring Location Map
Table 1 – Infiltration Analysis Summary
Appendix A – Boring Logs
Appendix B – Geotechnical Laboratory Test Results



NATIONAL GEOGRAPHIC

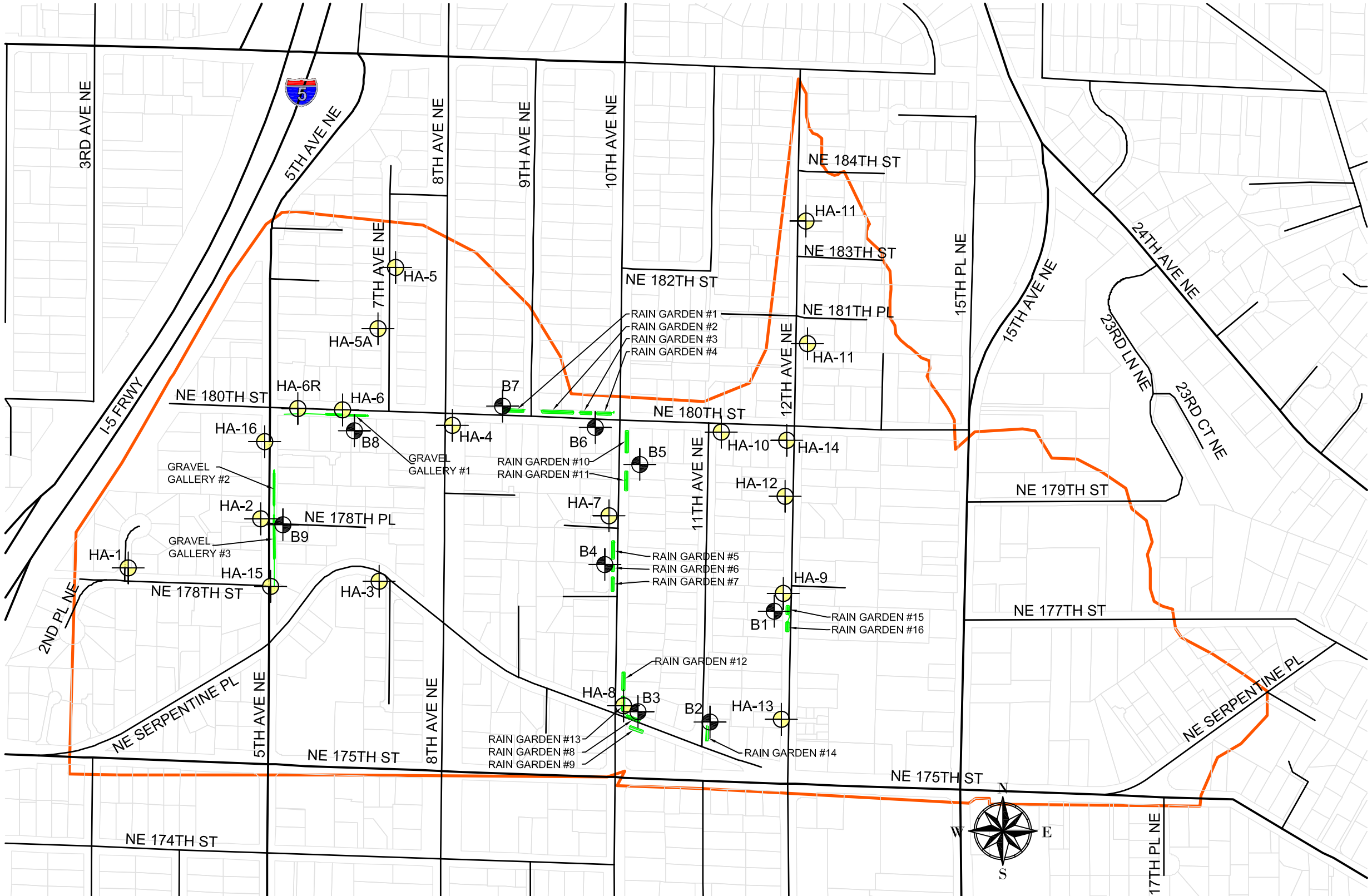
SITE LOCATION MAP

FIGURE NO. 1

HWA GEOSCIENCES INC.

INFILTRATION EVALUATIONS
NORTH FORK THORNTON CREEK LID STORMWATER RETROFIT
SHORELINE, WASHINGTON

PROJECT NO. 2012-007



SCALE: 1" = 400'

400'

HA-16 HAND BORING DESIGNATION AND APPROXIMATE LOCATION

B9 MACHINE BORING DESIGNATION AND APPROXIMATE LOCATION

RAIN GARDENS

GRAVEL GALLERY

BASE MAP PROVIDED BY: PERTEET

HWA GEOSCIENCES INC.

NORTH FORK THORNTON CREEK LID
STORMWATER RETROFIT
SHORELINE, WASHINGTON

SITE AND EXPLORATION PLAN

DRAWN BY	FIGURE #
EFK	2
CHECK BY	PROJECT #
AS	2012-007-21 TASK 0200
DATE: 04.03.13	

S:\2012 PROJECTS\2012-007-22 SHORELINE N THORNTON CK LID\CAD\HWA 2012-007.DWG <Layout1> Plotted: 4/5/2013 2:36 AM

APPENDIX A

BORING LOGS

RELATIVE DENSITY OR CONSISTENCY VERSUS SPT N-VALUE

COHESIONLESS SOILS			COHESIVE SOILS		
Density	N (blows/ft)	Approximate Relative Density(%)	Consistency	N (blows/ft)	Approximate Undrained Shear Strength (psf)
Very Loose	0 to 4	0 - 15	Very Soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Medium Dense	10 to 30	35 - 65	Medium Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	over 50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	over 30	>4000

USCS SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP DESCRIPTIONS	
Coarse Grained Soils	Gravel and Gravelly Soils	Clean Gravel (little or no fines)	GW	Well-graded GRAVEL
			GP	Poorly-graded GRAVEL
	More than 50% of Coarse Fraction Retained on No. 4 Sieve	Gravel with Fines (appreciable amount of fines)	GM	Silty GRAVEL
			GC	Clayey GRAVEL
More than 50% Retained on No. 200 Sieve Size	Sand and Sandy Soils	Clean Sand (little or no fines)	SW	Well-graded SAND
			SP	Poorly-graded SAND
	50% or More of Coarse Fraction Passing No. 4 Sieve	Sand with Fines (appreciable amount of fines)	SM	Silty SAND
			SC	Clayey SAND
Fine Grained Soils	Silt and Clay	Liquid Limit Less than 50%	ML	SILT
			CL	Lean CLAY
			OL	Organic SILT/Organic CLAY
50% or More Passing No. 200 Sieve Size	Silt and Clay	Liquid Limit 50% or More	MH	Elastic SILT
			CH	Fat CLAY
			OH	Organic SILT/Organic CLAY
Highly Organic Soils			PT	PEAT

TEST SYMBOLS

%F	Percent Fines	
AL	Atterberg Limits:	PL = Plastic Limit LL = Liquid Limit
CBR	California Bearing Ratio	
CN	Consolidation	
DD	Dry Density (pcf)	
DS	Direct Shear	
GS	Grain Size Distribution	
K	Permeability	
MD	Moisture/Density Relationship (Proctor)	
MR	Resilient Modulus	
PID	Photoionization Device Reading	
PP	Pocket Penetrometer Approx. Compressive Strength (tsf)	
SG	Specific Gravity	
TC	Triaxial Compression	
TV	Torvane Approx. Shear Strength (tsf)	
UC	Unconfined Compression	

SAMPLE TYPE SYMBOLS

- 2.0" OD Split Spoon (SPT) (140 lb. hammer with 30 in. drop)
- Shelby Tube
- 3-1/4" OD Split Spoon with Brass Rings
- Small Bag Sample
- Large Bag (Bulk) Sample
- Core Run
- Non-standard Penetration Test (3.0" OD split spoon)

GROUNDWATER SYMBOLS

- Groundwater Level (measured at time of drilling)
- Groundwater Level (measured in well or open hole after water level stabilized)

COMPONENT DEFINITIONS

COMPONENT	SIZE RANGE
Boulders	Larger than 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No 4 (4.5mm)
Coarse gravel	3 in to 3/4 in
Fine gravel	3/4 in to No 4 (4.5mm)
Sand	No. 4 (4.5 mm) to No. 200 (0.074 mm)
Coarse sand	No. 4 (4.5 mm) to No. 10 (2.0 mm)
Medium sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

COMPONENT PROPORTIONS

PROPORTION RANGE	DESCRIPTIVE TERMS
< 5%	Clean
5 - 12%	Slightly (Clayey, Silty, Sandy)
12 - 30%	Clayey, Silty, Sandy, Gravelly
30 - 50%	Very (Clayey, Silty, Sandy, Gravelly)
Components are arranged in order of increasing quantities.	

NOTES: Soil classifications presented on exploration logs are based on visual and laboratory observation. Soil descriptions are presented in the following general order:

Density/consistency, color, modifier (if any) GROUP NAME, additions to group name (if any), moisture content. Proportion, gradation, and angularity of constituents, additional comments. (GEOLOGIC INTERPRETATION)

Please refer to the discussion in the report text as well as the exploration logs for a more complete description of subsurface conditions.

MOISTURE CONTENT

DRY	Absence of moisture, dusty, dry to the touch.
MOIST	Damp but no visible water.
WET	Visible free water, usually soil is below water table.

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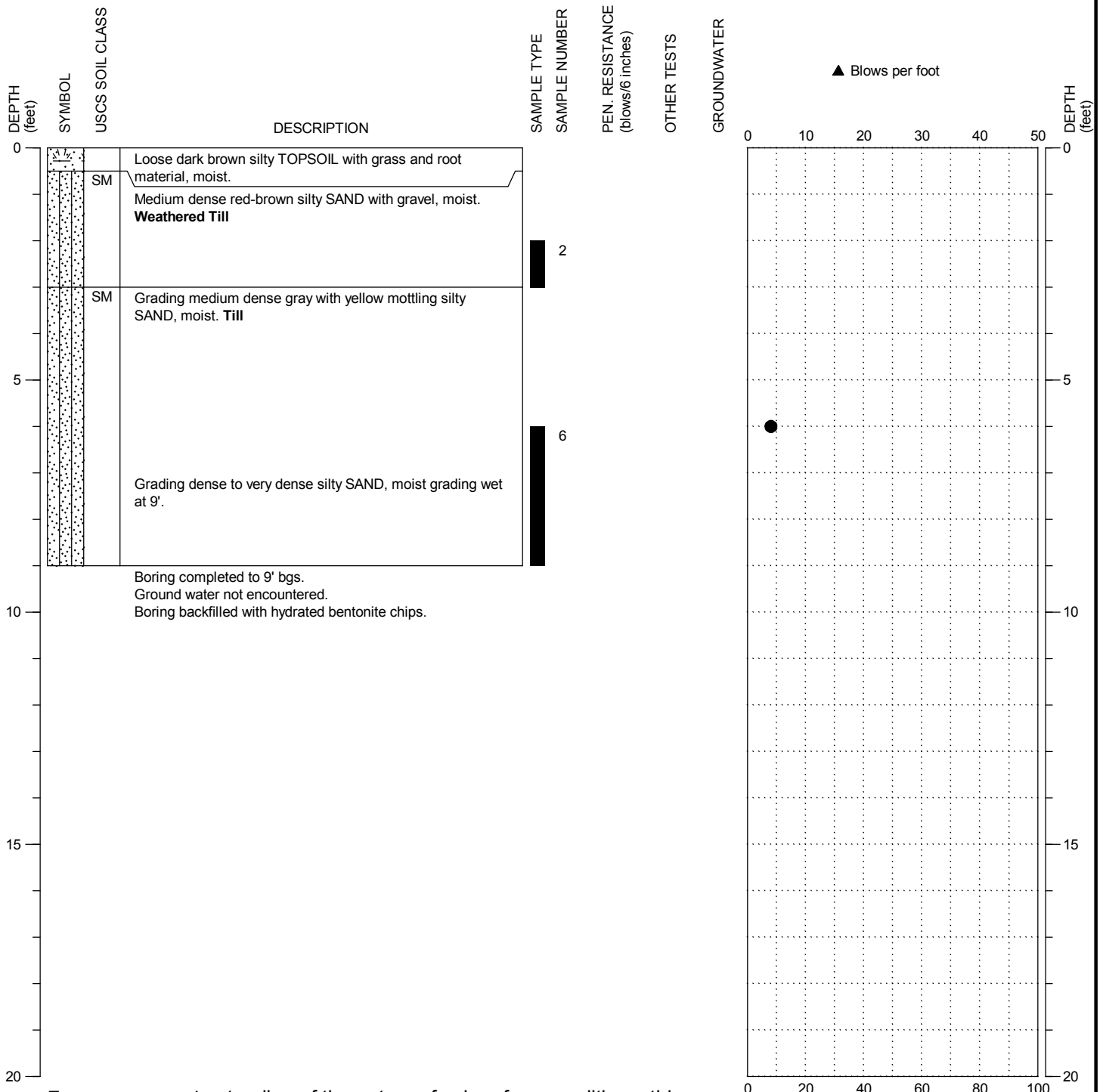
Thornton Creek LID Retrofit
Shoreline
WA

LEGEND OF TERMS AND SYMBOLS USED ON EXPLORATION LOGS

PROJECT NO.: 2012-007 FIGURE: A-1

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17563 12th Ave NE
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-1

PAGE: 1 of 1

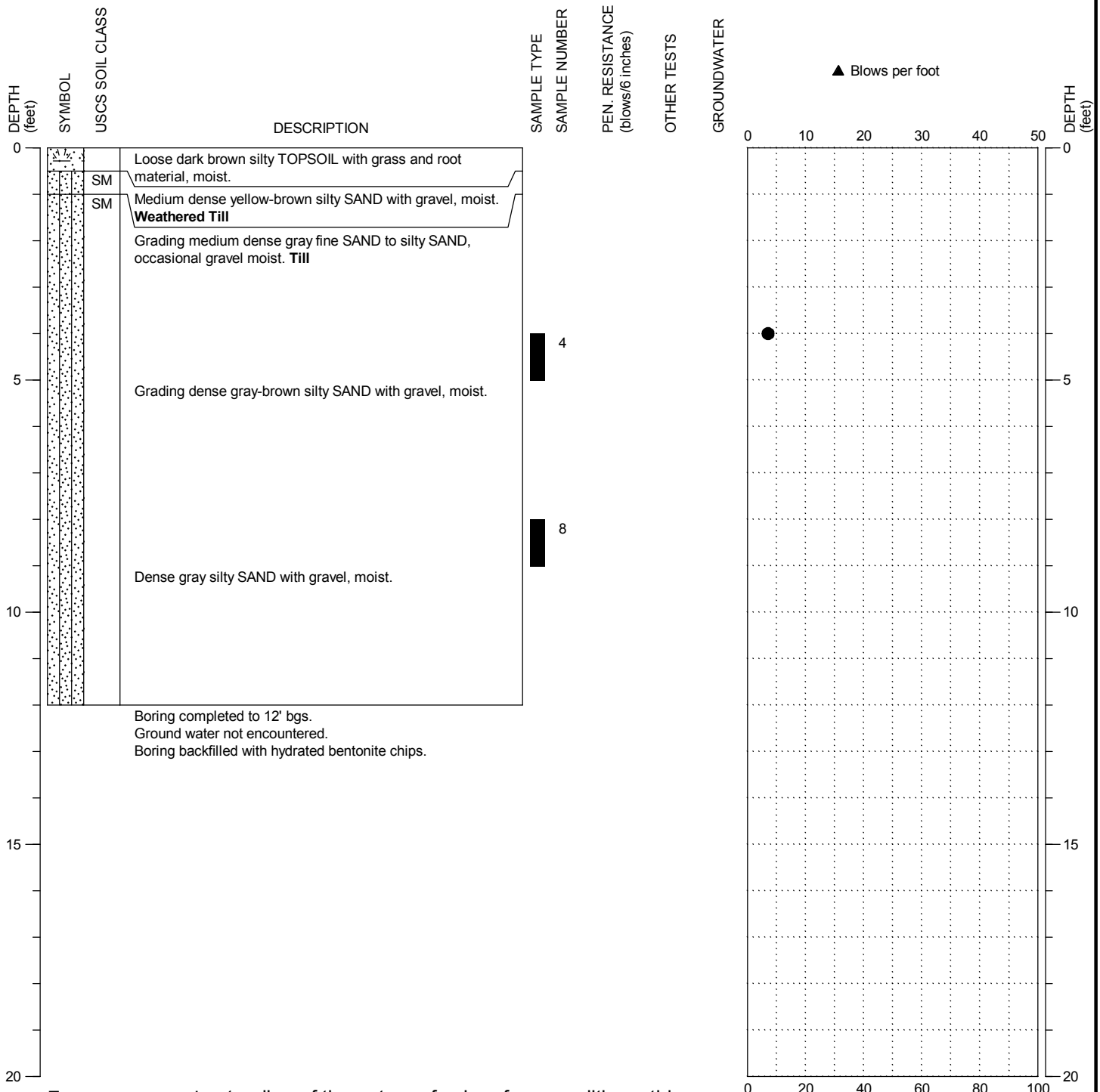
PROJECT NO.: 2012-007

FIGURE: A-2

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17520 11th Ave NE
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins



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NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-2

PAGE: 1 of 1

PROJECT NO.: 2012-007

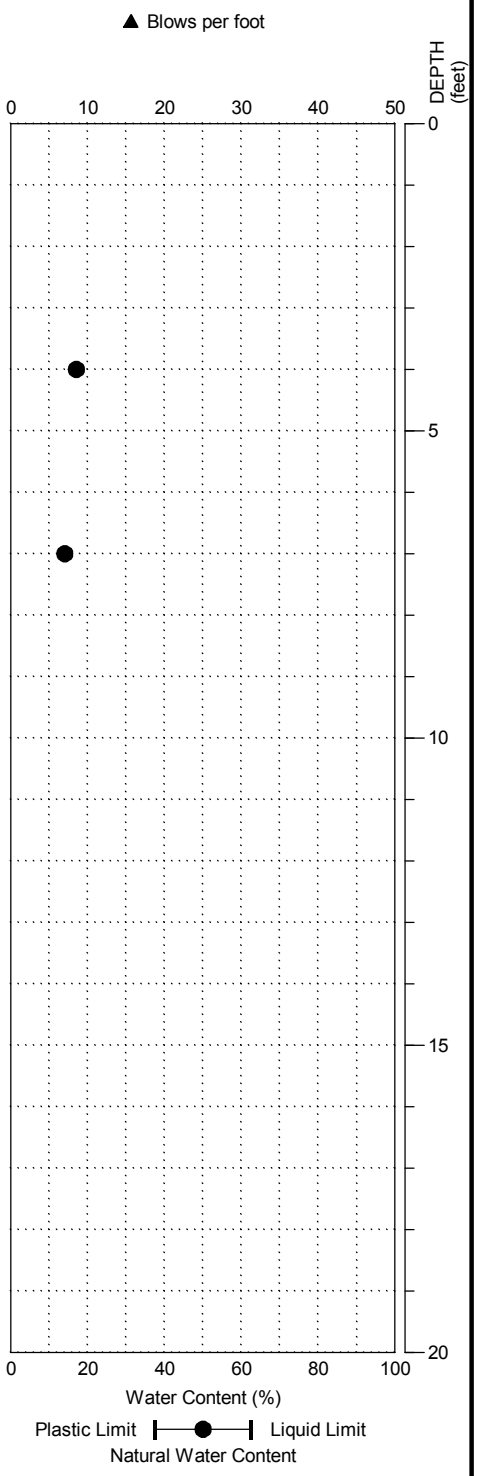
FIGURE: A-3

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 1010 NE Serpentine Pl
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0			Loose dark brown silty TOPSOIL with grass and root material, moist.					
		SM	Medium dense red-brown silty SAND with woody debris, moist. **Fill**					
		SM	Grading medium dense red-brown silty SAND, with fine gravel, trace roots, moist. **Weathered Till**					
		SM	Grading dense yellow-gray fine SAND with silt and gravel, moist.		4			
5			Grading wet, apparent perched water.		7			
		SM	Dense gray silty SAND with gravel, moist.					
10			Moist grading wet, occasional mottling.		10			
			Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.					
15								
20								



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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-3

PAGE: 1 of 1

PROJECT NO.: 2012-007

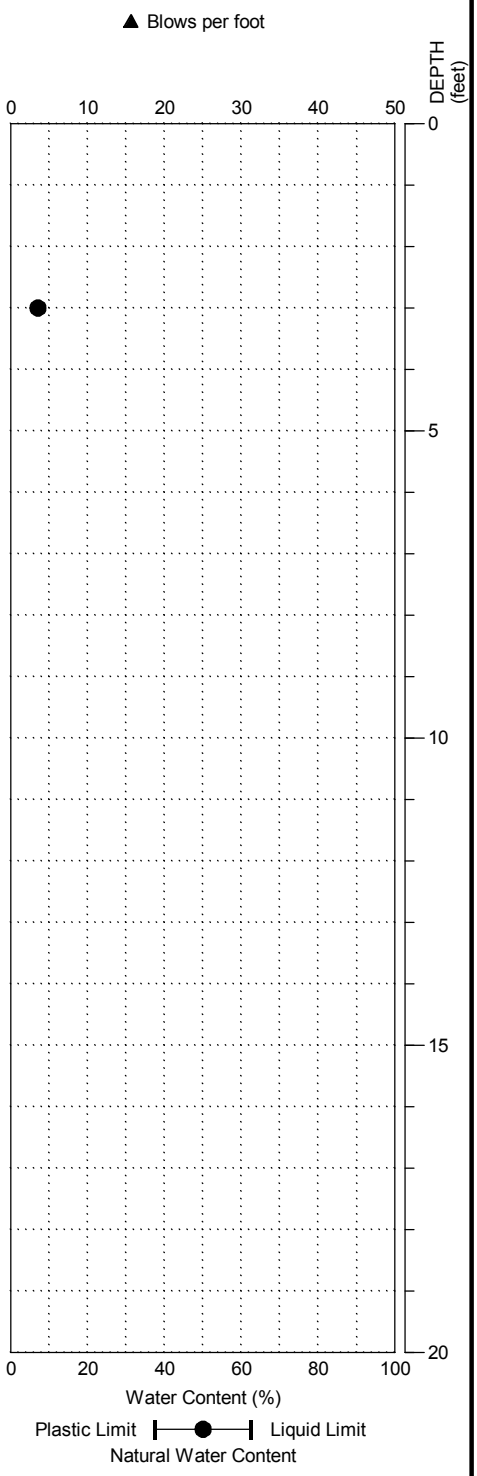
FIGURE: A-4

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17708 10th Ave NE (across Street)
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0			Loose dark brown silty TOPSOIL with gravel, root material, moist.					
		SP SM	Loose to medium dense yellow-red to brown SAND and silty SAND, moist. **Fill**		3			
5		SP	Grading medium dense yellow-red fine SAND, moist. **Weathered Till**					
		SM	Grading medium dense red-brown silty SAND with gravel, moist. **Weathered Till**		6			
		SM	Dense gray silty SAND with gravel, occasional mottling, moist.		8			
10			Gray sand layer					
			Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.					
15								
20								



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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-4

PAGE: 1 of 1

PROJECT NO.: 2012-007

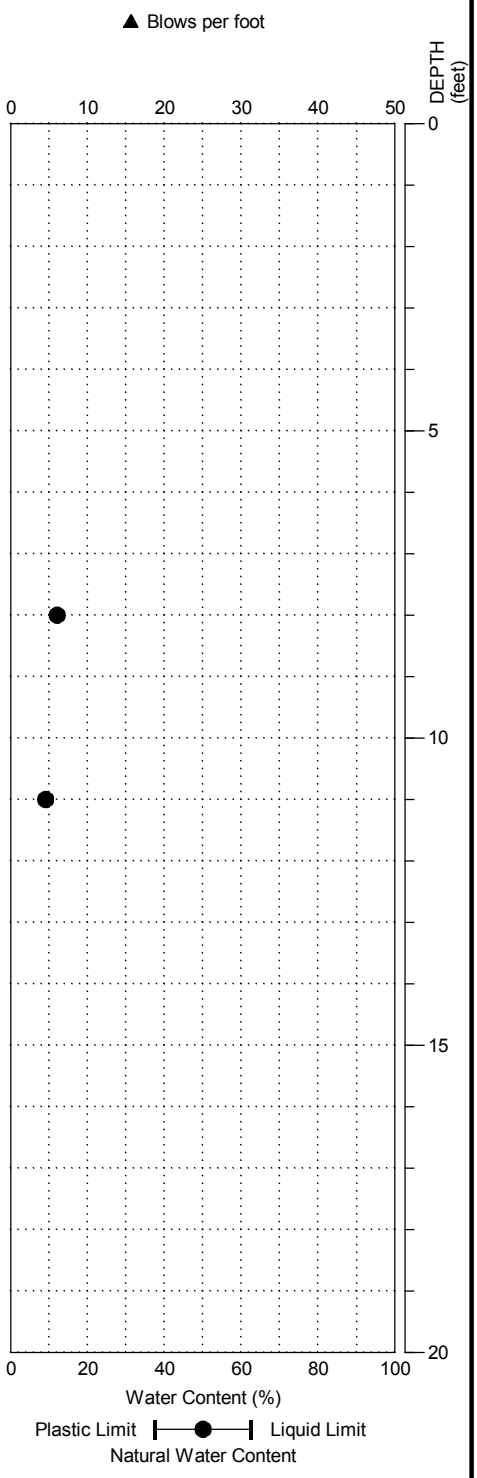
FIGURE: A-5

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17921 10th Ave NE (across Street)
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		SP SM	Loose to medium dense brown to gray SAND with silt and gravel, moist. **Fill**		1			
5		SP	Grading medium dense yellow-red fine SAND, moist. **Weathered Till**		6			
		SM	Medium dense brown silty SAND with organics, roots, moist. **Buried Soil Surface**		8			
		SP SM	Dense gray SAND with SILT to silty SAND with gravel, occasional mottling, moist. **Till**		11			
10		SP	Dense yellow-red fine to medium SAND, moist.					
15			Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.					
20								



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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-5

PAGE: 1 of 1

PROJECT NO.: 2012-007

FIGURE: A-6

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17921 10th Ave NE (across Street)
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		SP SM	Loose to medium dense brown to gray SAND with silt and gravel, moist. **Fill**		1	1		
5		SP	Grading medium dense red-brown fine SAND with silt, moist. **Weathered Till**					
		SM	Medium dense brown silty SAND with organics, roots, moist. **Buried Soil Surface**					
		SP SM	Dense reddish-yellow silty SAND with gravel, occasional mottling, moist. **Weathered Till**					
10		SP	Dense yellow-red fine to medium SAND, moist.					
		SM	Dense to very dense brown grading gray silty SAND, moist. **Till**		12	12		
15			Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.					
20								

▲ Blows per foot

0 10 20 30 40 50

DEPTH (feet) 0 5 10 15 20

0 20 40 60 80 100

Water Content (%)

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

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Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-5A

PAGE: 1 of 1

PROJECT NO.: 2012-007

FIGURE: A-7

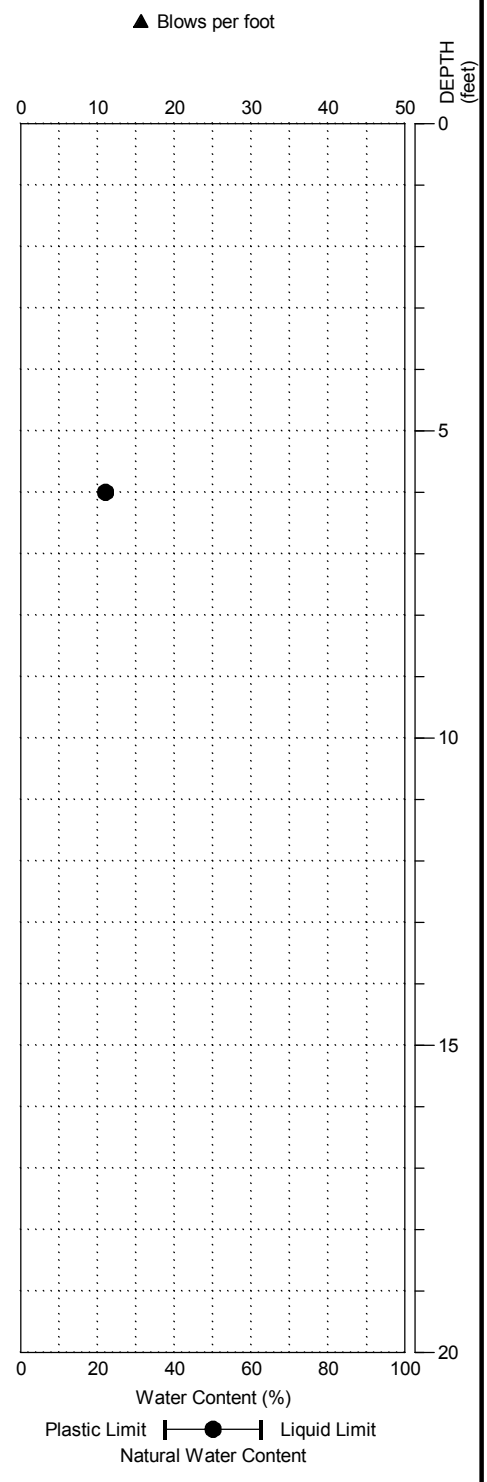
BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 919 NE 180th St
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER
0	SP / SM	Loose to medium dense gray silty SAND and GRAVEL, moist. **Fill**	3
5	SM	Medium dense red-brown silty SAND with sandy lenses and gravel, trace debris, moist. **Fill**	6
	SM	Grading medium dense yellow-red silty SAND, occasional mottling, moist. **Weathered Till**	
10	SM	Grading dense yellow-gray silty SAND, occasional gravel and sandy seams, moist. **Till**	11
15		Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.	
20			

SAMPLE TYPE
PEN. RESISTANCE (blows/6 inches)
OTHER TESTS
GROUNDWATER



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HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-6

PAGE: 1 of 1

PROJECT NO.: 2012-007

FIGURE: A-8

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 820 NE 180th St
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER
0	SP SM	Loose to medium dense gray-brown silty SAND with gravel, moist. **Fill**	
	SM	Medium dense yellow-red silty SAND, occasional mottling, trace gravel, moist. **Weathered Till**	3
5	SM	Grading medium dense to dense gray silty SAND with gravel, moist. **Till**	
		Grading dense to very dense gray silty SAND, moist.	8
10		Boring completed to 9' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.	
15			
20			

SAMPLE TYPE
PEN. RESISTANCE (blows/6 inches)
OTHER TESTS
GROUNDWATER

▲ Blows per foot

0 10 20 30 40 50

DEPTH (feet)

0 20 40 60 80 100

Water Content (%)

Plastic Limit ⊢●⊣ Liquid Limit

Natural Water Content

For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-7

PAGE: 1 of 1

PROJECT NO.: 2012-007

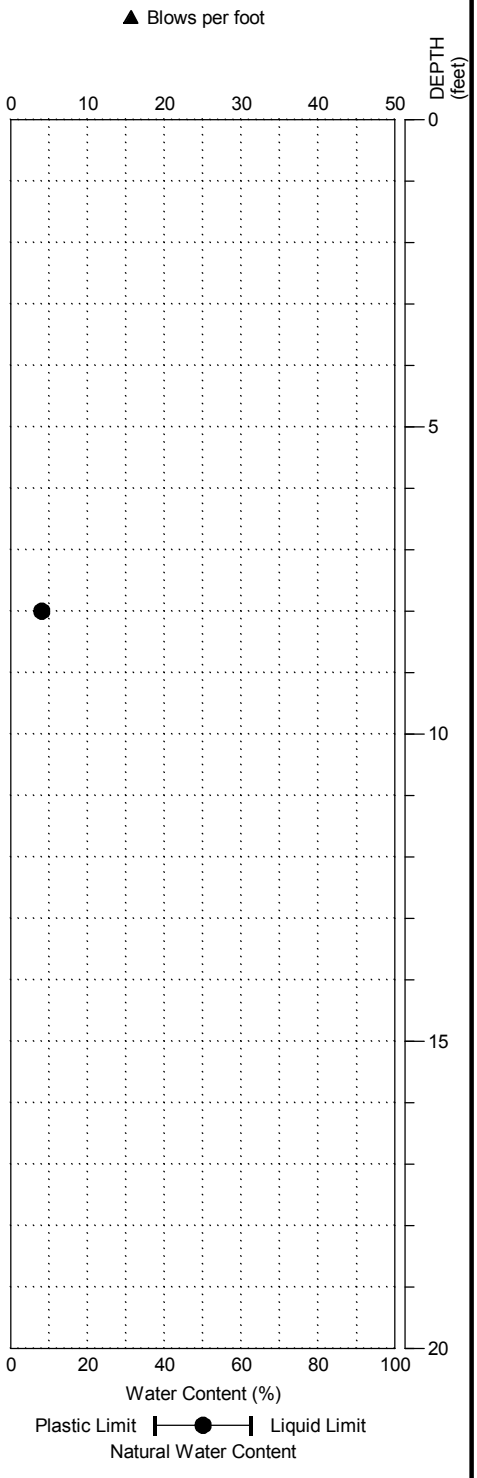
FIGURE: A-9

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 523 NE 180th St
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER
0	SP SM	Loose to medium dense brown silty SAND with gravel, moist. **Fill**	
	SM	Medium dense grading dense gray silty SAND with gravel, moist to wet at 4' (perched?). **Weathered Till**	2
5	SM	Grading dense to very dense gray silty SAND with gravel, moist. **Till** Pullback difficult, refusal.	
		Boring completed to 8' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.	8
10			
15			
20			



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HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-8

PAGE: 1 of 1

PROJECT NO.: 2012-007

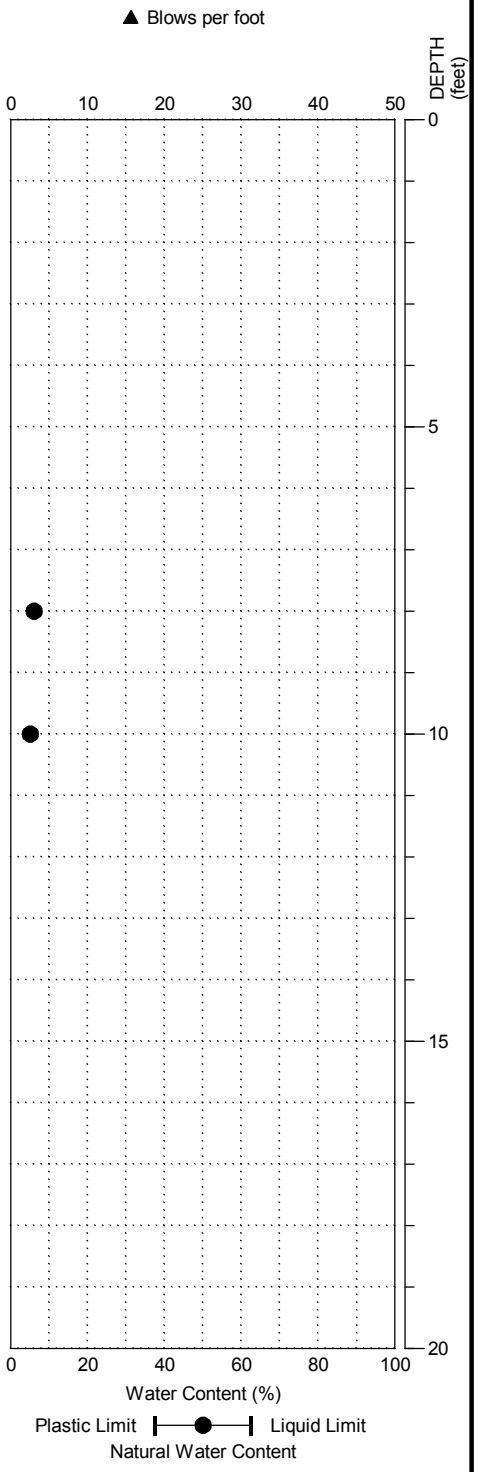
FIGURE: A-10

BORING 2012-007.GPJ 4/3/13

DRILLING COMPANY: ESN Northwest
DRILLING METHOD: GeoProbe
SAMPLING METHOD: 1.25" Macrocore Sampler with HDPE liner
SURFACE ELEVATION: ± feet

LOCATION: 17822 5th Ave NE
DATE STARTED: 3/12/2013
DATE COMPLETED: 3/12/2013
LOGGED BY: V. Atkins

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER
0	SP SM	Medium dense gray silty SAND and SAND with silt and gravel, moist. **Fill**	2
5	SM	Dense gray silty SAND with gravel, moist. **Till**	6
	SM	Dense yellow-gray fine silty SAND, moist.	8
10	SM	Dense to very dense gray silty SAND with gravel, moist.	10
		Boring completed to 12' bgs. Ground water not encountered. Boring backfilled with hydrated bentonite chips.	
15			
20			



For a proper understanding of the nature of subsurface conditions, this exploration log should be read in conjunction with the text of the geotechnical report.

NOTE: This log of subsurface conditions applies only at the specified location and on the date indicated and therefore may not necessarily be indicative of other times and/or locations.

HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
Shoreline
WA

BORING:
B-9

PAGE: 1 of 1

PROJECT NO.: 2012-007

FIGURE: A-11

BORING 2012-007.GPJ 4/3/13

APPENDIX B

GEOTECHNICAL LABORATORY TEST RESULTS

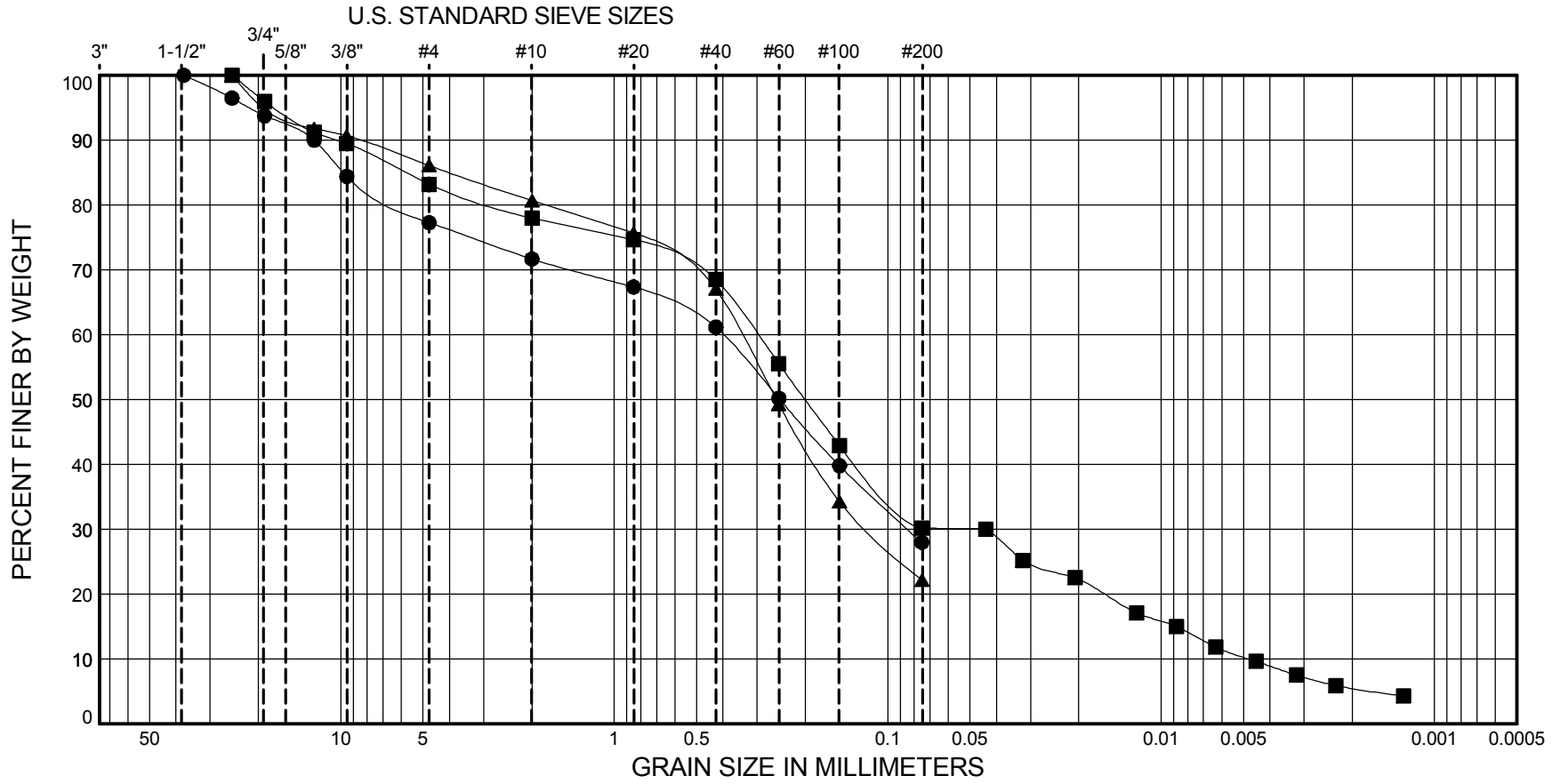
APPENDIX B

LABORATORY TEST RESULTS

The soil samples obtained from the borings were taken to HWA's soils laboratory in Bothell, Washington for testing. Laboratory tests were conducted on selected soil samples to characterize relevant engineering properties of the on-site soils. Laboratory tests, as described below, included determination of moisture content, grain size distributions of representative samples.

MOISTURE CONTENT (BY MASS): The moisture content of selected soil samples were determined in general accordance with ASTM D 2216. Test results are presented on the exploration logs in Appendix A, as appropriate.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle size distribution of material in general accordance with ASTM D422. The results are summarized on the Grain Size Distribution report, Figures B-1 through B-4 which also provides information regarding the classification of the sample and the moisture content at the time of testing. The USDA classifications of selected soil samples are shown on the classification on Figure B-5.



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-1	6	6.0 - 9.0	(SM) Grayish brown, silty SAND with gravel	8				22.7	49.3	28.0
■	B-2	4	4.0 - 5.0	(SM) Olive brown, silty SAND with gravel	7				16.8	53.0	30.2
▲	B-3	4	4.0 - 5.0	(SM) Olive brown, silty SAND	17				13.9	63.9	22.1

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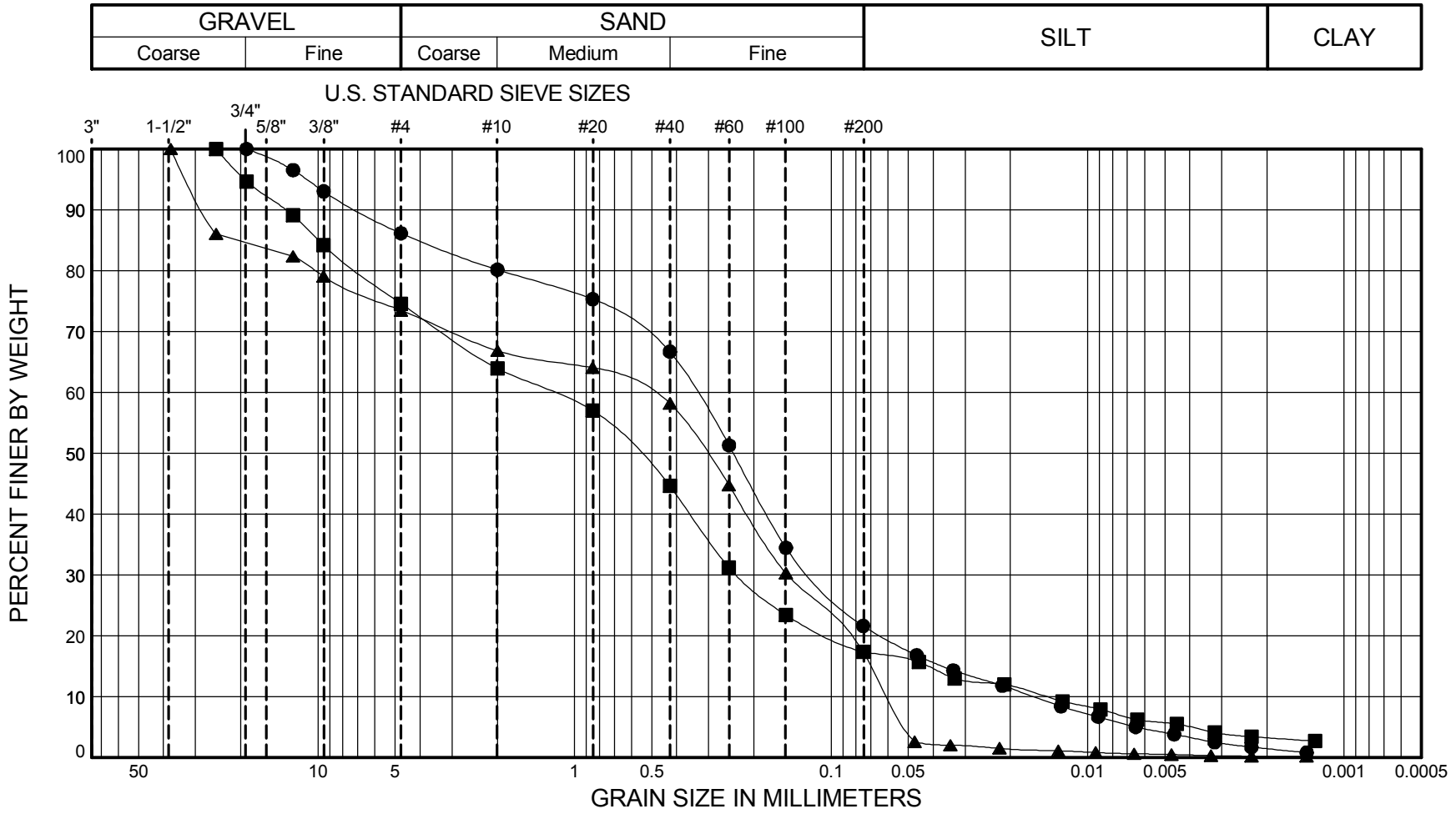
9a-148

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2012-007 FIGURE: B-1



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-3	7	7.0 - 8.0	(SM) Olive brown, silty SAND	14				13.9	64.5	21.6
■	B-4	3	3.0 - 5.0	(SM) Olive brown, silty SAND with gravel	7				25.4	57.2	17.4
▲	B-5	8	8.0 - 9.0	(SM) Olive brown, silty SAND with gravel	12				26.5	56.1	17.3

HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
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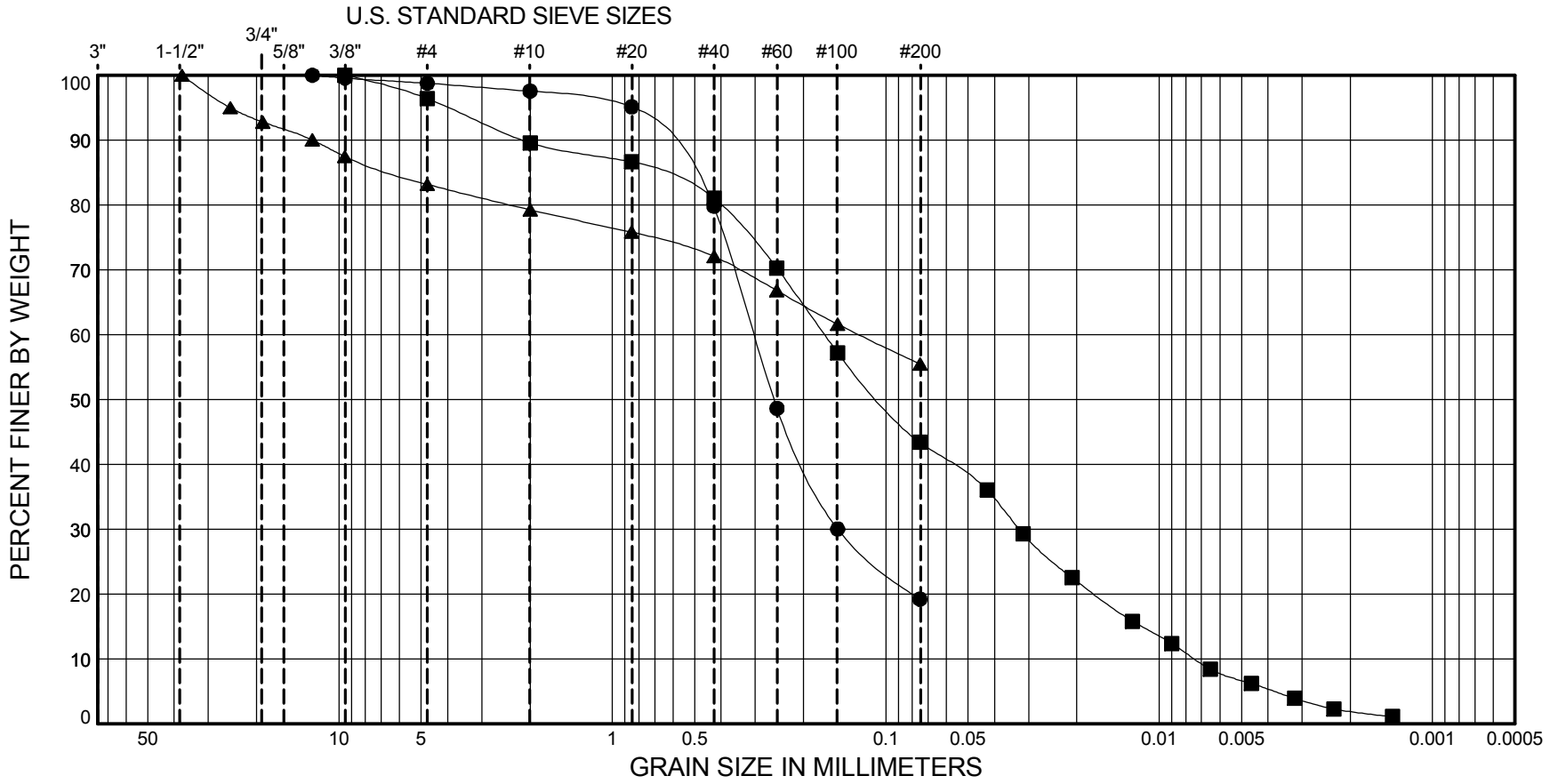
WA
9a-149

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2012-007 FIGURE: B-2



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-5	11	11.0 - 12.0	(SM) Olive brown, silty SAND	9				1.2	79.5	19.2
■	B-6	6	6.0 - 7.0	(SM) Dark yellowish brown, silty SAND	22				3.6	53.0	43.4
▲	B-7	3	3.0 - 4.0	(ML) Yellowish brown, sandy SILT with gravel	13				16.9	27.7	55.5

HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
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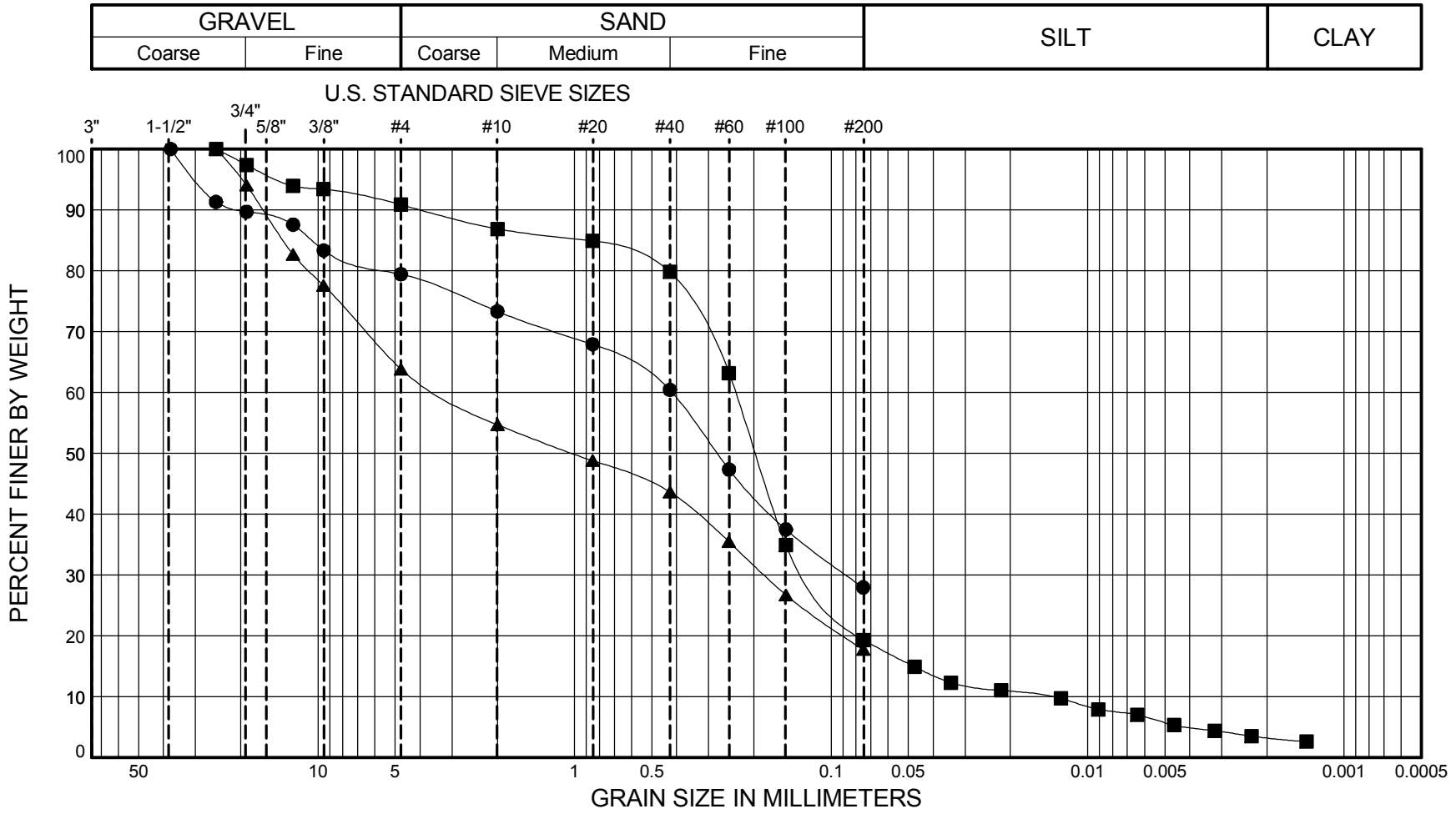
9a-150

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2012-007 FIGURE: B-3



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION OF SOIL- ASTM D2487 Group Symbol and Name	% MC	LL	PL	PI	Gravel %	Sand %	Fines %
●	B-8	8	8.0 - 9.0	(SM) Grayish brown, silty SAND with gravel	8				20.6	51.5	27.9
■	B-9	8	8.0 - 9.0	(SM) Olive brown, silty SAND	6				9.2	71.5	19.3
▲	B-9	10	10.0 - 12.0	(SM) Grayish brown, silty SAND with gravel	5				36.2	46.1	17.8

HWA GEOSCIENCES INC.

Thornton Creek LID Retrofit
Shoreline
WA
9a-151

PARTICLE-SIZE ANALYSIS
OF SOILS
METHOD ASTM D422

PROJECT NO.: 2012-007 FIGURE: B-4

3600 Fremont Ave. N.
Seattle, WA 98103
T: (206) 352-3790
F: (206) 352-7178
info@fremontanalytical.com

HWA GeoSciences, Inc.
Vance Atkins
21312 30th Drive SE, Ste 110
Bothell, Washington 98021

RE: Shoreline Lid
Lab ID: 1306023

June 07, 2013

Attention Vance Atkins:

Fremont Analytical, Inc. received 1 sample(s) on 6/5/2013 for the analyses presented in the following report.

Cation Exchange Capacity

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

M. Clements

Michelle Clements
Sr. Chemist / Lab Manager

Date: *06/07/2013*

CLIENT: HWA GeoSciences, Inc.
Project: Shoreline Lid
Lab Order: 1306023

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1306023-001	B9 (6-7)	06/04/2013 2:00 PM	06/05/2013 9:17 AM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1306023**
Date: **6/7/2013**

CLIENT: HWA GeoSciences, Inc.
Project: Shoreline Lid

I. SAMPLE RECEIPT:
Samples receipt information is recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Analytical Report

WO#: **1306023**
Date Reported: **6/7/2013**

Client: HWA GeoSciences, Inc.
Collection Date: 6/4/2013 2:00:00 PM
Project: Shoreline Lid
Lab ID: 1306023-001
Matrix: Soil
Client Sample ID: B9 (6-7)

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Cation Exchange Capacity				Batch ID: R8784		Analyst: MC
Cation Exchange Capacity	4.94	0		meq/100g	1	6/6/2013 1:47:49 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Fremont Analytical

Date: *6/7/2013*

Work Order: 1306023
CLIENT: HWA GeoSciences, Inc.
Project: Shoreline Lid

QC SUMMARY REPORT

Cation Exchange Capacity

Sample ID: **MB-R8784** SampType: **MBLK** Units: **meq/100g** Prep Date: **6/6/2013** RunNo: **8784**
Client ID: **MBLKS** Batch ID: **R8784** Analysis Date: **6/6/2013** SeqNo: **176301**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Cation Exchange Capacity	ND	0									

Sample ID: **LCS-R8784** SampType: **LCS** Units: **µg/L** Prep Date: **6/6/2013** RunNo: **8784**
Client ID: **LCSS** Batch ID: **R8784** Analysis Date: **6/6/2013** SeqNo: **176302**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Barium	108	0	100.0	0	108	75	125				

Sample ID: **1306023-001ADUP** SampType: **DUP** Units: **meq/100g** Prep Date: **6/6/2013** RunNo: **8784**
Client ID: **B9 (6-7)** Batch ID: **R8784** Analysis Date: **6/6/2013** SeqNo: **176304**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Cation Exchange Capacity	4.99	0						4.940	1.01	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	D	Dilution was required	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits	ND	Not detected at the Reporting Limit
R	RPD outside accepted recovery limits	RL	Reporting Limit	S	Spike recovery outside accepted recovery limits

Sample Log-In Check List

Client Name: **HWA**	Work Order Number: **1306023**
Logged by: **Clare Griggs**	Date Received: **6/5/2013 9:17:00 AM**

Chain of Custody

1.	Were custodial seals present?	Yes	☐	No	☐	Not Required ☑
2.	Is Chain of Custody complete?	Yes	☑	No	☐	Not Present ☐
3.	How was the sample delivered?	Client				

Log In

4.	Coolers are present?	Yes	☐	No	☑	NA ☐
	No cooler present.					
5.	Was an attempt made to cool the samples?	Yes	☐	No	☑	NA ☐
	No cooler/ice present.					
6.	Were all coolers received at a temperature of >0° C to 10.0°C	Yes	☐	No	☑	NA ☐
	Sample was not received at recommended temp.					
7.	Sample(s) in proper container(s)?	Yes	☑	No	☐	
8.	Sufficient sample volume for indicated test(s)?	Yes	☑	No	☐	
9.	Are samples properly preserved?	Yes	☑	No	☐	
10.	Was preservative added to bottles?	Yes	☐	No	☑	NA ☐
11.	Is there headspace present in VOA vials?	Yes	☐	No	☐	NA ☑
12.	Did all sample containers arrive in good condition?(unbroken)	Yes	☑	No	☐	
13.	Does paperwork match bottle labels?	Yes	☑	No	☐	
14.	Are matrices correctly identified on Chain of Custody?	Yes	☑	No	☐	
15.	Is it clear what analyses were requested?	Yes	☑	No	☐	
16.	Were all holding times able to be met?	Yes	☑	No	☐	

Special Handling (if applicable)

17.	Was client notified of all discrepancies with this order?	Yes	☐	No	☐	NA ☑

Person Notified: _____ Date: _____

By Whom: _____ Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person

Regarding: _____

Client Instructions: _____

18. Additional remarks/Disrepancies

Item Information

HWA GeoSciences Inc.

21312 30th Drive SE, Suite 110, Bothell, Washington 98021-7010
Tel 425.774.0106 Fax 425.774.2714 www.hwageo.com

Chain of Custody and Laboratory Anaylsis Request

DATE: 6/4/13
PAGE: 1 of 1

PROJECT NAME: Stanwood LID #:
SAMPLERS NAME: [illegible] PHONE:
SAMPLERS SIGNATURE: DATE:
HWA CONTACT: A. Sugar PHONE:

HWA SAMPLE ID	DATE	TIME	MATRIX	LAB ID	# OF BOTTLE	Cation Exchange Capacity	EDD	REMARKS
B9-(6-7)	6/4/13	1400	Soil		1	X		

ANALYSIS REQUESTED

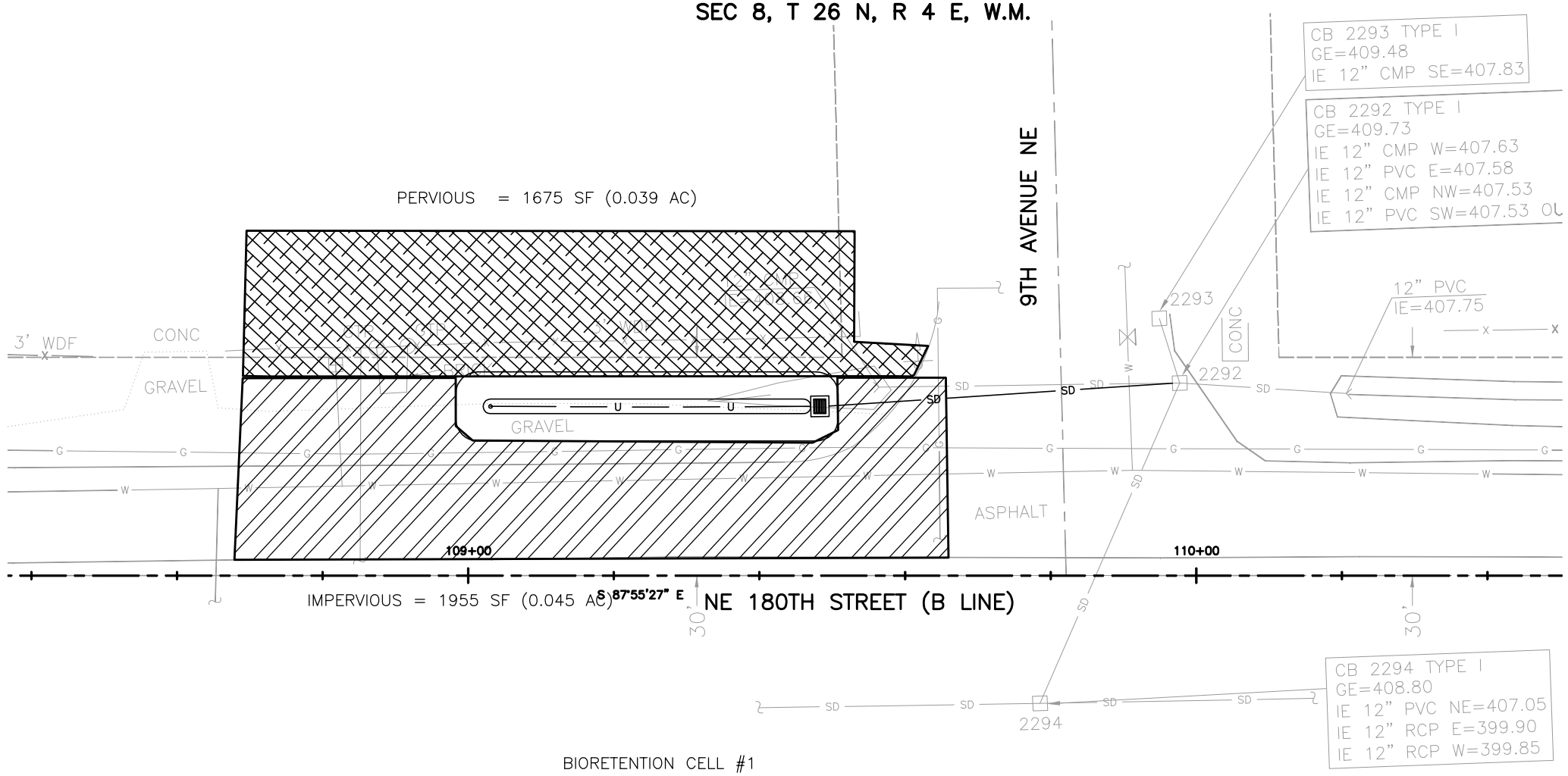
TURNAROUND TIME
2 DAYS
☐ STANDARD

PRINT NAME	SIGNATURE	COMPANY	DATE	TIME	REMARKS
Relinquished by: [illegible]	[illegible]	HWA	6/6/13	917	
Received by: [illegible]	[illegible]	PAI	6/5/13	917	
Relinquished by:					
Received by:					

DISTRIBUTION: WHITE - Return to HWA GeoSciences; YELLOW - Retain by Lab; PINK - Retain by Sampler

Appendix C – Bioretention Cells – Contributing Areas

SEC 8, T 26 N, R 4 E, W.M.



BIORETENTION CELL #1

SCALE
10 0 10 20
FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date	5/2013
Designed By	JTS		5/2013
Checked By	BC		5/2013
Approved By			

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE
N. FORK THORNTON CREEK LID
STORMWATER RETROFIT PROJECT
CONTRIBUTING AREAS

Drawing No. 1
Sheet No. – 33 of Total

9a-160

Jul 09, 2013 - 2:16pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CADD\Exhibits\Contributing Areas.dwg Layout Name: SP2

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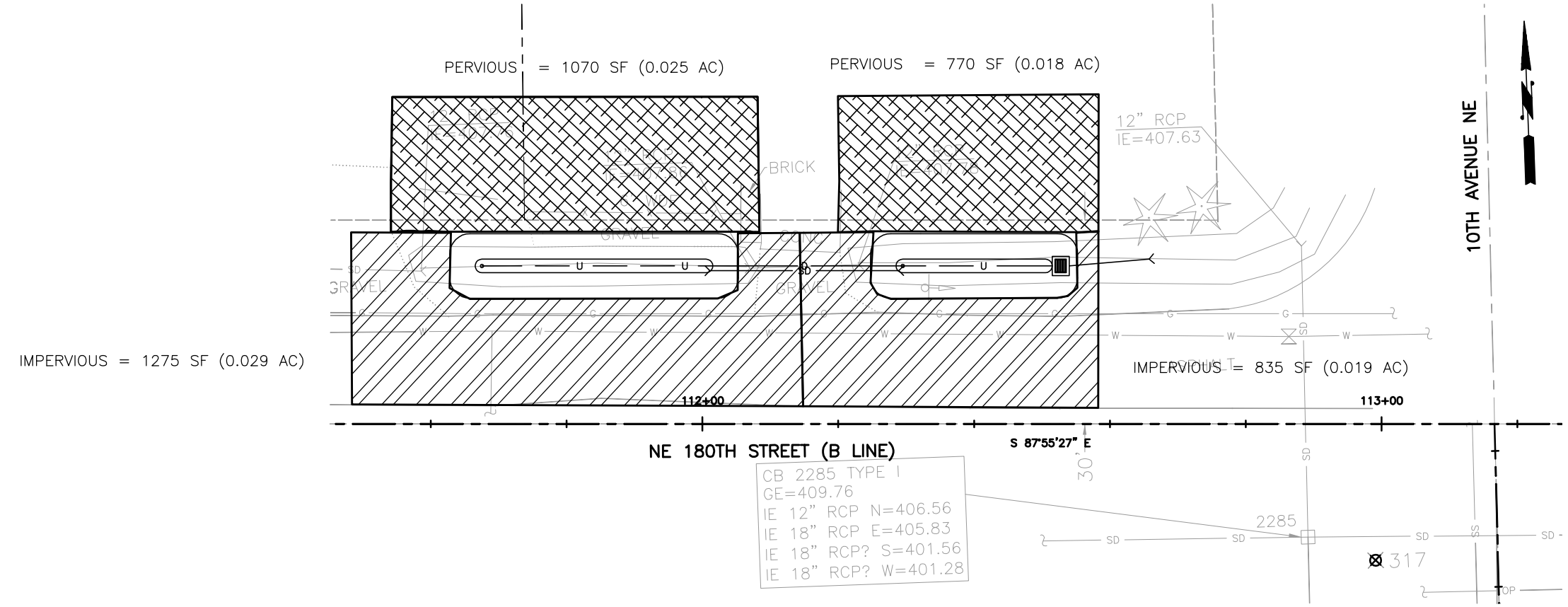

BIORETENTION CELL #2

BIORETENTION CELL #3

SCALE
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FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date	5/2013
Designed By	JTS		5/2013
Checked By	BC		5/2013
Approved By			

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE

N. FORK THORNTON CREEK LID STORMWATER RETROFIT PROJECT

CONTRIBUTING AREAS

Drawing No. 2

Sheet No. – 33 of Total

9a-161

Jul 09, 2013 - 2:18pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CADD\Exhibits\Contributing Areas.dwg Layout Name: SP3

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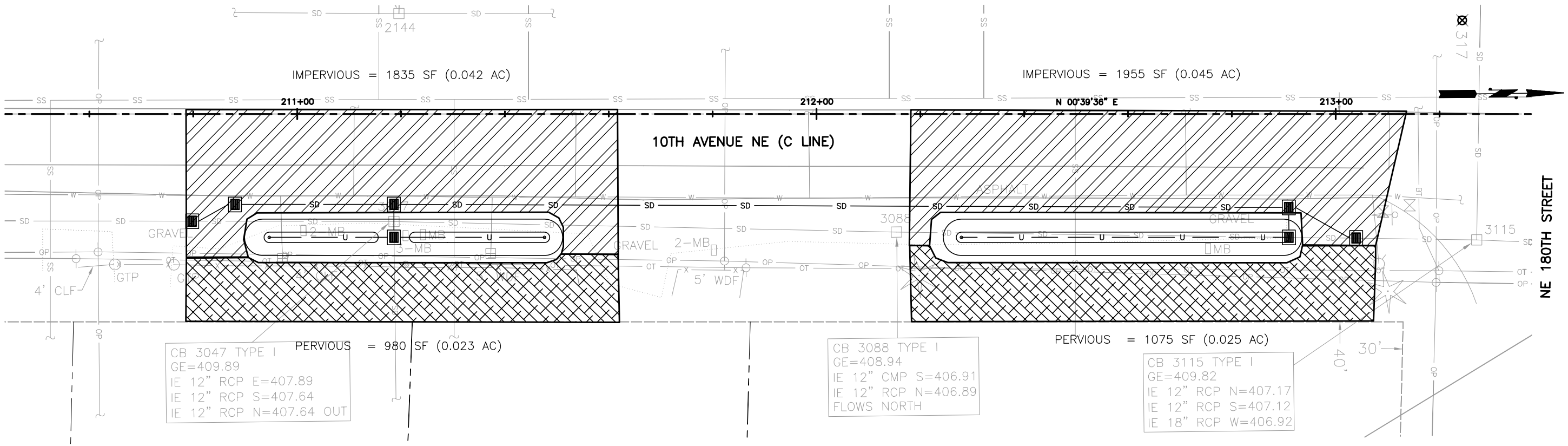

BIORETENTION CELL #5

BIORETENTION CELL #4

SCALE
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FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date	5/2013
Designed By	JTS		5/2013
Checked By	BC		5/2013
Approved By			

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Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE

N. FORK THORNTON CREEK LID
STORMWATER RETROFIT PROJECT
CONTRIBUTING AREAS

Drawing No. 3
Sheet No. – 33 of Total

9a-162

Jul 09, 2013 - 2:19pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CAD\Exhibits\Contributing Areas.dwg Layout Name: SP4

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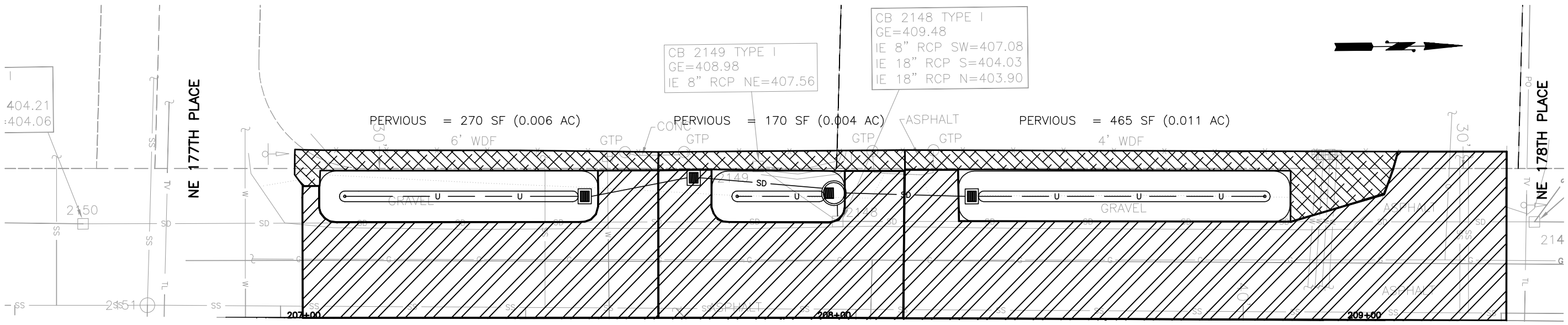

BIORETENTION CELL #8

BIORETENTION CELL #7

BIORETENTION CELL #6

SCALE
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FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date	5/2013
Designed By	JTS		5/2013
Checked By	BC		5/2013
Approved By			

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE

N. FORK THORNTON CREEK LID STORMWATER RETROFIT PROJECT

CONTRIBUTING AREAS

Drawing No. 4

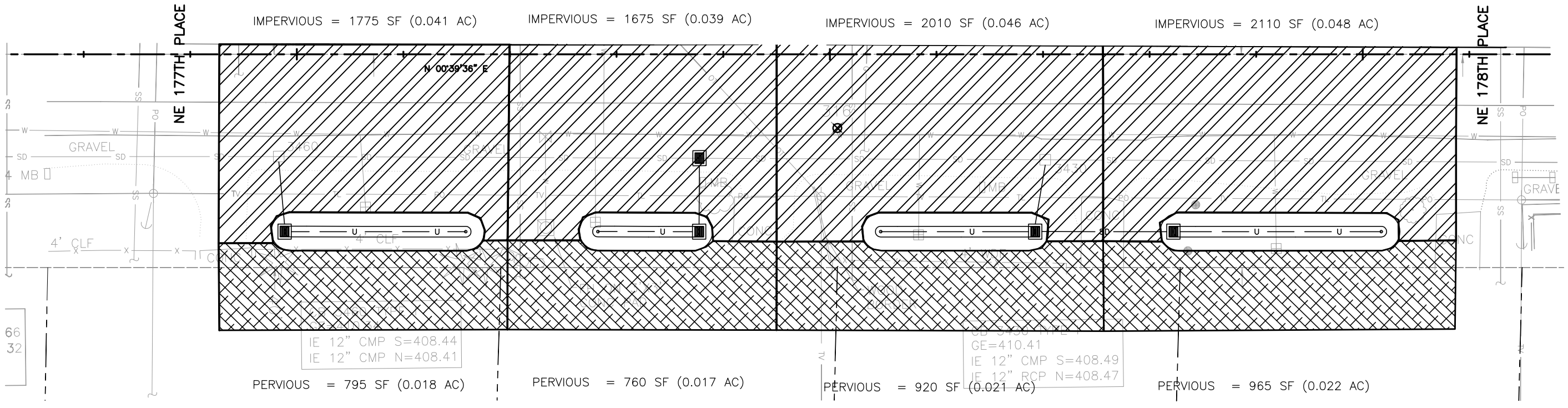
Sheet No. – 33 of Total

9a-163

Jul 09, 2013 - 2:20pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CAD\DExhibits\Contributing Areas.dwg Layout Name: SP5

SEC 8, T 26 N, R 4 E, W.M.

10TH AVENUE NE (C LINE)



BIORETENTION CELL #12

BIORETENTION CELL #11

BIORETENTION CELL #10

BIORETENTION CELL #9

SCALE
10 0 10 20
FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KMC	Date 5/2013
Designed By	JTS	5/2013
Checked By	BC	5/2013
Approved By		

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE
N. FORK THORNTON CREEK LID STORMWATER RETROFIT PROJECT
CONTRIBUTING AREAS

Drawing No. 5
Sheet No. – 33 of Total

9a-164

Jul 09, 2013 - 2:21pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CADD\Exhibits\Contributing Areas.dwg Layout Name: SP6

SEC 8, T 26 N, R 4 E, W.M.

10TH AVENUE NE (C LINE)

IMPERVIOUS = 2065+710=2775 SF (0.064 AC)

IMPERVIOUS = 2295 SF (0.053 AC)

NE SERPENTINE PLACE

PERVIOUS = 450+1835=2285 SF (0.053 AC)

BIORETENTION
CELL #14

PERVIOUS = 1175 SF (0.027 AC)

BIORETENTION
CELL #13

IE 12" CMP S=410.22 IN
PROBABLE CMP STUB IN
IE 12" CMP N=410.18

SSMH 2008
CTR=413.69
FL 8" NW
N CAPPED
FLOWSPREAD
W=404.32

CB 2002 TYPE I
GE=411.77
IE 12" RCP
IE 12" RCP
STANDING H2O OVER PIPES
SE=410.52
N=410.47
S=410.37

SCALE
10 0 10 20
FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

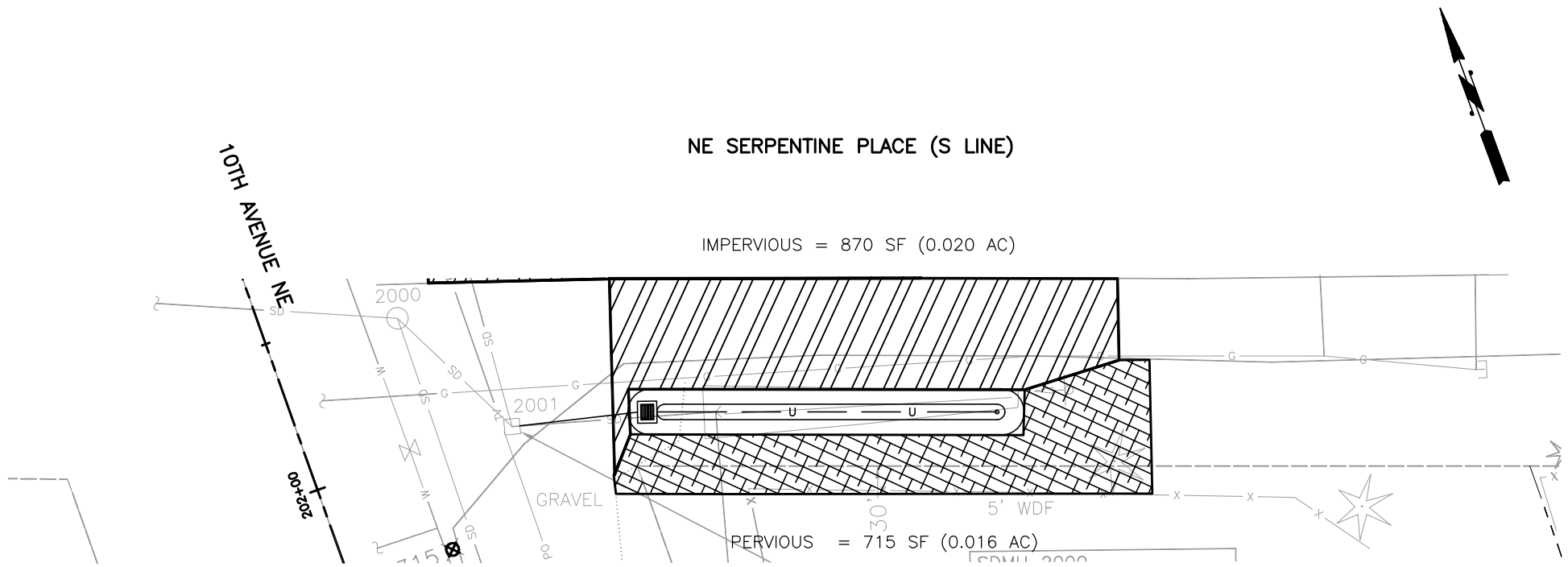
Drawn By	KWC	Date	5/2013
Designed By	JTS		5/2013
Checked By	BC		5/2013
Approved By			

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE
N. FORK THORNTON CREEK LID
STORMWATER RETROFIT PROJECT
CONTRIBUTING AREAS

Drawing No. 6
Sheet No. – 33 of Total

SEC 8, T 26 N, R 4 E, W.M.



BIORETENTION CELL #15

SCALE
10 0 10 20
FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date 5/2013
Designed By	JTS	5/2013
Checked By	BC	5/2013
Approved By		

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

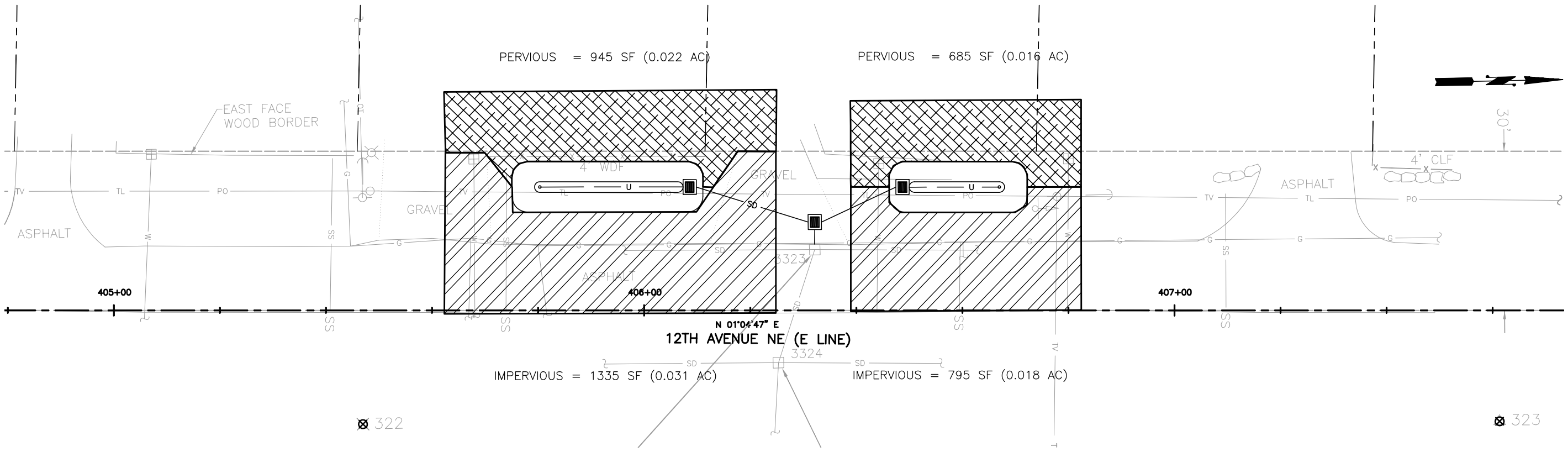
CITY OF SHORELINE

N. FORK THORNTON CREEK LID STORMWATER RETROFIT PROJECT

CONTRIBUTING AREAS

Drawing No. 7
Sheet No. – 33 of Total

SEC 8, T 26 N, R 4 E, W.M.



SCALE
10 0 10 20
FEET

DATUM
NAVD 88

No.	Date	Revision	By	Appr.

Perteet
206-436-0515 I 1-800-615-9900
505 5th Avenue S, Suite 300
Seattle, Washington 98104

SHORELINE

Drawn By	KWC	Date 5/2013
Designed By	JTS	5/2013
Checked By	BC	5/2013
Approved By		

SCALE
Horiz SEE SHEET
Vert SEE SHEET
Project Number 20110051

CITY OF SHORELINE

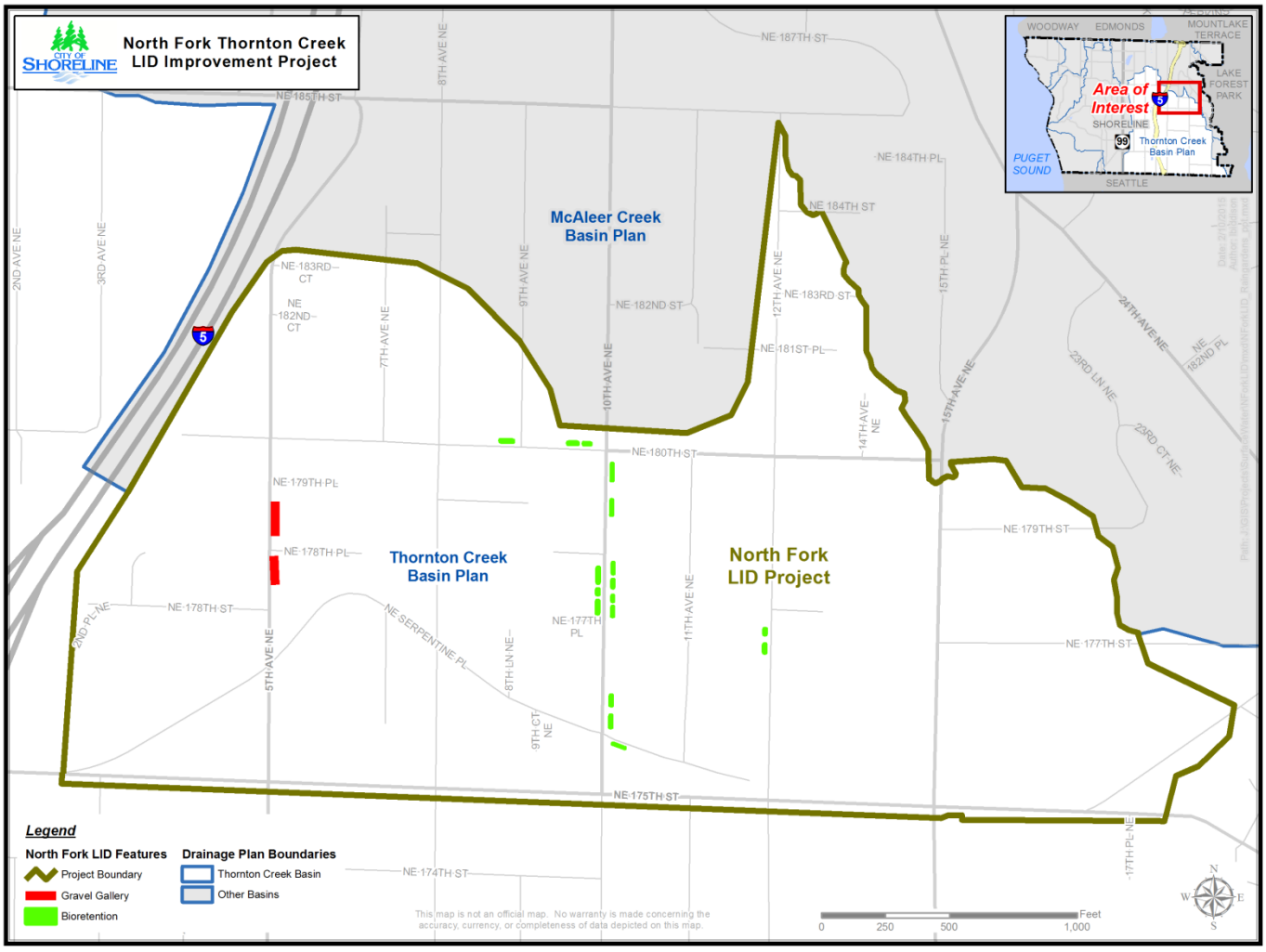
N. FORK THORNTON CREEK LID
STORMWATER RETROFIT PROJECT
CONTRIBUTING AREAS

Drawing No. 8
Sheet No. – 33 of Total

9a-167

Jul 09, 2013 - 2:27pm jshrope X:\Shoreline, City of\Projects\20110051 - North Thornton Creek LID Stormwater Retrofit\CADD\Exhibits\Contributing Areas.dwg Layout Name: SP9

Attachment B
North Fork LID Site Location Map



Attachment C
Surface Water Basin Map