City Center Soil Permeability Study
Lynnwood, Washington

Prepared for
City of Lynnwood

August 13, 2012
17855-00

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CITY CENTER SOIL PERMEABILITY STUDY
LYNNWOOD, WASHINGTON

1.0 INTRODUCTION

This report was prepared on behalf of the City of Lynnwood (City) and presents the results of the City Center Soil Permeability Study in Lynnwood, Washington (Figure 1). The purpose of the study is to evaluate the potential for large-scale subsurface infiltration of stormwater within the City Center project area. The results of this study will support the stormwater management study that is currently being conducted for the City for the City Center project area. Stormwater infiltration is one of several options being evaluated in the stormwater management study.

2.0 SCOPE OF WORK

The scope of work consisted of the four tasks described below.

Task 1—Data Review

- Reviewed existing data in publically-available sources and information provided by the City related to subsurface conditions within the City Center project area.

Task 2—Phase 1 Drilling

The purpose of the Phase 1 drilling program was to identify subsurface conditions favorable for infiltration. Phase 1 consisted of the following activities:

- Coordinated with the City and private property owners to complete explorations.

- Cleared the exploration locations for underground utilities. We used One Call for utilities in the public right-of-way and contracted with a private utility locating contractor to locate utilities on private property.

- Installed traffic controls signs as required by the traffic control plan for drilling sites.

- Completed 7 explorations (HCB-1, -2, -3, -5, -6, -7, -8) to depths ranging from 21 to 53 feet.

- Collected soil samples at 5-foot intervals starting at a depth of 2.5 feet. Additional soil samples were collected from geologic units that appeared to be favorable for infiltration.

- Conducted drilling under the observation of a Hart Crowser geologist and created detailed logs of each exploration. The soils were visually classified in general accordance with ASTM D 2488.

- Collected drill cuttings in 55-gallon steel drums. The drilling contractor hauled the drums off-site for disposal.

- Tested soil samples from each exploration for grain size distribution by mechanical sieve analysis using ASTM D 422.

- Restored the areas surrounding the finished boreholes to conditions similar to those that existed before drilling took place.

Task 3—Phase 2 Drilling

The purpose of Phase 2 drilling program was to further investigate areas that appeared to have favorable conditions for infiltration based on Phase 1 drilling results.

Task 3 included all the activities listed in the scope for Task 2 and the additional activities identified below.

- Coordinated with the Washington State Department of Transportation (WSDOT) to drill boring HCB-11 within WSDOT right-of-way.

- Completed 6 additional explorations (HCB-4, -9, -10, -11, -11A, -12) to depths ranging from 15.1 to 51.5 feet.

- Analyzed one to two soil samples from each exploration for grain size by mechanical sieve analysis using ASTM D 422.

Task 4—Data Analysis and Reporting

The data from the Phase 1 and 2 drilling programs were analyzed, and the results of field investigations and laboratory testing are presented in this report.

3.0 BACKGROUND

The City Center project area is currently a commercial area within the City. The City is designing and developing an urban center within the City's central area called City Center Project (Lynnwood 2012). The purpose of the project is to restructure the City Center's growth toward a more concentrated, mixed-use, pedestrian-friendly, and transit-supportive center; and to create an attractive, functional, and comfortable place for Lynnwood residents to live, work, and play.

3.1 Site Location

The City Center project area is located on the east to southeast portion of the City limits (Figure 1). The general project boundaries are 194th Street to the north, 48th Avenue to the west, and Alderwood Mall Boulevard to the east and south.

Topographic gradients in the project area generally slope slightly to moderately downward to the south. Elevations range from a high of 400 feet to a low of 300 feet.

3.2 Regional Geology

The geology of the Lynnwood area is described by Minard (1983), Yount et. al., (1993), Thomas (1997), and Booth (2004). The geology in the Lynnwood area consists mostly of glacial material derived from repeated glacial advances and retreats over the past two million years. Each advance erased and remodeled the deposits produced since the last advance, resulting in layers of discontinuous lenses of gravel, sand, silty sand, and silt. The Frasier Glaciation was the most recent glacial advance and occurred approximately 12,000 to 16,000 years ago. The most recent of the advance "pulses" of glaciation is referred to as the Vashon Stade.

The following geological units are present in project area.

Fill. Artificial fill material consisting primarily of varying proportions of sand, gravel, and silt. This fill often contains construction debris.

Alluvium. This deposit consists of fluvial and wetland sediments associated with streams. This unit consists mainly of sand and gravel with organic silt and clay, and may include peat deposits.

Vashon recessional outwash. This unit is composed of stratified sand and gravel with minor silt and clay layers, and is mapped at the surface east of the project area. It is derived from the stagnating and receding Vashon glacier.

Vashon Till. This is dense material referred to as "hardpan" and "lodgment till" because it was compacted by overlying ice that may have been as thick as 3,000 feet. This unit consists of poorly sorted mixture of clay, silt, gravels and cobbles and underlies most of the City.

Advanced Outwash. Advanced Outwash underlies the Vashon Till in most areas, and is not exposed at the surface within the City. It consists mostly of clean sand and gravel, although some layers of silt and clay may be present.

Pre-Vashon Deposits. Various glacial and nonglacial occur deposits beneath the Advanced Outwash unit. These older deposits are variable consisting of sand, gravels, silty and clay.

3.3 Surface Water Hydrology

The project area is located within the Scriber Creek basin (Snohomish County, 2002; Herrera 2009). The western portion of the project area drains to Scriber Creek, which originates in the City near Scriber Lake (approximately 0.5 miles west of the project area) and flows southeast along the southern boundary of the project area to Swamp Creek, which flows into the Sammamish River and ultimately discharges into Lake Washington. The eastern portion of the City Center drains to Poplar Creek, which is a tributary of Scriber Creek. The Poplar Creek system begins north of I-5, and flows south toward Scriber Creek.

Approximately 95 percent of the City Center area is covered with impervious surfaces including paved parking lots, building roofs, sidewalks, and streets. Stormwater originating in the project area is currently conveyed through a series of pipes and discharged into Poplar and Scriber Creeks, while stormwater runoff from I-5 and access ramps is captured by and stored in two detention ponds. One detention pond is located near 195th Place SW in the northeastern portion of the project area, and the other is located in a triangle defined by I-5 and the 196th Ave on- and off-ramps to I-5.

3.4 Convention Center Stormwater Infiltration System

The stormwater management system for the recently-completed Lynnwood Convention Center was one of the inspirations for this study. According to Macnoskey (2007), the design of the Convention Center included 4.6 acres of impervious area, which created a significant volume of stormwater. Instead of

constructing large aboveground detention ponds, an alternative approach consisting of a combination of underground detention and infiltration was used. The recently-constructed underground facility consists of a 26-foot-deep, 60-foot-wide, and 100-foot-long excavation backfilled with drainage rock, and an infiltration gallery that appears to tap into a permeable zone below glacial till.

A full-scale test was performed with a flow rate of 1,500 gallons per minute. The duration and ultimate capacity of the system was not provided in the 2007 article. Although the system appears to be a combination of detention and infiltration, the infiltration rates of target infiltration zone were not provided.

4.0 INFILTRATION POTENTIAL FOR THE CITY CENTER PROJECT AREA

Stormwater infiltration is the process through which stormwater penetrates into the soil from the ground surface. Infiltration is one of the preferred methods for stormwater management. Success of an infiltration system depends on the subsurface capacity, the rate of infiltration, and the volume of stormwater.

Based on our data review and site explorations we classified the subsurface infiltration potential for the project area into three categories: favorable, low, and unfavorable. Favorable infiltration conditions are most commonly found in highly-permeable, unsaturated soils that can easily accept stormwater. Low infiltration conditions (where infiltration may be limited) are found in areas of less permeable soils, a higher groundwater table, and/or seasonal fluctuations in the groundwater table. Unfavorable infiltration conditions exist (where infiltration is unlikely) in areas with impermeable soils and a high groundwater table.

For this study, we used four parameters to determine the infiltration potential of the subsurface: (1) field and laboratory soil descriptions; (2) groundwater depth observed at the time of drilling; (3) percent fines content; and (4) D10 values from laboratory grain size analysis. The percent fines content is the amount of silt and clay in the soil, and the D10 value is the grain diameter at which 10 percent of the sediment sample is finer than this size.

The criteria we used for this study are as follows:

- **Favorable Infiltration Potential.** Soils classified as "favorable" include all of the following criteria:
  - permeable sand and gravel;
  - unsaturated (located above the water table);

- a fines content less than 10 percent; and
- a D10 value greater than 0.05 mm.

- **Low Infiltration Potential.** Soils classified as "low" include one or more of the following criteria:
  - silty sand and/or silty gravel;
  - unsaturated;
  - a fines content between 10 and 20 percent; and
  - a D10 value greater than 0.05 mm.

- **Unfavorable Infiltration Potential**. Soils classified as "unfavorable" include:
  - clay, silt, and very silty sand (less permeable);
  - saturated (below the water table);
  - a fines content greater than 20 percent; and
  - a D10 value less than 0.05 mm.

5.0 SUBSURFACE CONDITIONS

Our understanding of the subsurface conditions is based on conditions encountered on 12 borings drilled for this project. Subsurface conditions were interpreted from explorations completed at discrete locations and actual conditions may vary between borings.

5.1 Historical Explorations

We reviewed the publically available information on subsurface explorations near the City Center Project area. Sources reviewed included:

- City project files;
- State of Washington Department of Ecology well database;
- GeoMapNW database; and
- WSDOT reports.

We found very few useful historical explorations within the boundaries of the project area. Most subsurface explorations consist of shallow borings and/or monitoring wells completed for geotechnical and environmental purposes. In the western part of the project area, explorations were typically less than 20 feet deep. Borings completed for geotechnical studies along the I-5 corridor were completed to depths as great as 50 feet or more. The locations of selected historical explorations are shown on Figure B-1 and in Appendix B.

5.2 Drilling Program

The drilling program for the infiltration study was split into two phases. The Phase 1 drilling locations were selected based on data gaps identified during the review of subsurface conditions in the project area. The Phase 2 drilling locations were selected based on the results of the Phase 1 drilling, and focused on areas of potentially-favorable soil conditions in the northeast area of the project site.

Subsurface conditions were explored with 13 soil borings (7 borings during Phase 1, and 6 borings during Phase 2); the approximate locations of these borings are shown on Figure 2. A summary of the soil boring characteristics are provided in Table 1, and the details of the field exploration program and borings logs are provided in Appendix A. Grain size analysis results are summarized in Table 2, and the details of the laboratory testing program are provided in Appendix C.

5.3 Soils

Three geologic units were encountered the explorations. Each unit is briefly described below.

Fill. The Fill unit was observed in 11 of the 13 explorations (not in HCB-4 or HCB-9) and typically consists of silty, gravelly Sand to silty, sandy Gravel. This unit had a thickness ranging from 3.5 to 11 feet.

Glacial Till. The Glacial Till unit underlies the Fill unit and was observed in all the explorations. This soil unit typically consists of dense to very dense, gravelly silty Sand to silty, sandy, Gravel with cobbles. The Glacial Till unit was the predominant unit in the explorations. Grain size analysis of one soil sample (HCB-11A S-2) from this unit indicates that the unit has greater than 30 percent fines, which indicates unfavorable infiltration conditions.

Sand. The Sand unit is usually saturated and underlies the Glacial Till unit, creating confined conditions. This unit was observed in 9 of the 13 explorations and was not observed in the four northwestern explorations (HCB-3, HCB-6, HCB-7, and HCB-8). This soil unit typically consists of Sand, gravelly Sand, and sandy Gravel with varying amounts of silt. Grain size analyses of selected soil samples from this unit indicate the percent fines content ranges between 5 and 43 percent. This wide range of silt content suggests that the Sand unit is highly variable, and subsurface infiltration potential is low.

5.4 Groundwater

Perched and/or regional groundwater was encountered in 12 of the 13 explorations (not observed in exploration HCB-6). Perched groundwater was observed in three explorations (HCB-2, HCB-8, and HCB-12) between the Fill and Glacial Till units. Perched groundwater was observed in exploration HCB-7 in the upper 9 feet of the Glacial Till unit, where an increase in gravels was noted.

Regional groundwater was observed in 10 explorations (HCB-1 through HCB-5, HCB-9 through HCB-12, and HCB-11A) at elevations ranging between 388 and 422 feet.

No wells were installed in any of the explorations; therefore, we can only infer groundwater flow direction based on local topography. In the western part of the study area, we expect shallow groundwater to flow south/southwest towards Scriber Creek. In the eastern part of the project area, we expect shallow groundwater to flow to the south/southeast. We expect that the depth to groundwater could vary seasonally by as much as 5 to 10 feet. It is important to note that groundwater levels may fluctuate due to seasonal changes, rainfall, temperature, and other effects. Perched water may also be present where pervious material is underlain by relatively impervious zones.

6.0 INFILTRATION SUITABILITY

The suitability of the subsurface for stormwater infiltration in the project area is summarized below:

- **Fill.** Because of the wide variability in soil conditions, Fill is generally considered unfavorable for infiltration.

- **Glacial Till.** Based on general nature of soil conditions, Glacial Till unit is generally unfavorable for infiltration. This was the predominant geologic unit encountered in the explorations in the project area. The Glacial Till is unlikely to infiltrate large volumes of stormwater; however, small volumes of stormwater (e.g., from rooftop drains) may potentially be infiltrated.

- **Sand Unit.** The Sand unit in the project area is generally marginal for infiltration. The unit is thin to non-existent in the western and southern explorations (approximate elevation 357 feet) and was observed only at higher elevations in eastern explorations (between 388 and 423 feet). Two explorations (HCB-4 and HCB-12) contained 2 to 5 feet of unsaturated soil in

the Sand and Gravel unit. These explorations are located on the undeveloped school property located south of the Lynnwood Convention Center (Figure 3). The Sand and Gravel unit in these explorations has marginal conditions for infiltration since only the upper 2 to 5 feet is unsaturated and groundwater varies seasonally. In addition, the grain size results analysis for these explorations indicate a fines content of 8 to 11 percent and D10 values of 0.065 to 0.09 mm, which generally correspond to a favorable to low infiltration potential.

6.1 Estimated Infiltration Rates

Infiltration rates were estimated from gain size analysis based on the methods outlined in the Stormwater Management Manual for Western Washington (Ecology 2005). According to the manual, D10 values can be used to estimate design infiltration rates. Table 3 presents our estimated infiltration rates. The field infiltration rate for samples from the Sand unit with fines less than 30 percent is between less than 0.5 and 5 inches/hour. We estimate that the field infiltration rate for the Glacial Till will be less than 0.5 inches/hour.

7.0 RECOMMENDATIONS

Favorable infiltration conditions were not observed within the project area (Table 4); however, low infiltration conditions were observed in the eastern portion of the project area and south of the Convention Center. Stormwater might be managed in this area with individual site-specific subsurface detention/infiltration systems, similar to the system constructed at the Convention Center. The subsurface detention/infiltration system would store the stormwater in the drainage rock and allow it to slowly infiltrate into the surrounding soils.

If the site-specific infiltration system is considered for the stormwater management of the project area, we recommend investigating each site further with the following actions:

- Advance one or more soil boring using sonic drilling methods in order to collect continuous soil cores. The variations in the soil layering and grain size can be better observed by obtaining a continuous core. Collect representative soil samples for grain size analysis and soil permeability testing.

- Install wells to monitor seasonal groundwater levels.

- Perform infiltration tests in borings to estimate infiltration rates.

- Conduct groundwater mounding analyses to determine the rate and volume of water available for infiltration.

8.0 LIMITATIONS

Work for this project was performed, and this report prepared, in accordance with generally accepted professional practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. This report was prepared at the request of the City of Lynnwood and it is intended for the exclusive use of the City of Lynnwood. This report is not meant to represent a legal opinion. No other warranty, express or implied, is made.

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Table 1 - Summary of Soil Boring Characteristics

Boring ID	Ground Surface Elevation in Feet (a)	Boring Bottom Depth in Feet	Depth to Water in Feet	Groundwater Elevation in Feet	Depth to Top of Sand Unit in Feet	Sand Unit Thickness in Feet	Top of Sand Unit Elevation in Feet
HCB-1	372	30.5	15.5	356.5	15.5	1.5	356.5
HCB-2	403	35.5	5 (c)	--	30.5	≥ 5	372.5
			30.5	372.5			
HCB-3	400	21.0	10	390	--	--	--
HCB-4	445	51.5	43.4	401.6	41	≥ 10	404
HCB-5	444	53.0	21	423	21	2	423
					50.5	1.5	393.5
HCB-6	435	40.0	--	--	--	--	--
HCB-7	415	50.3	17 (c)	--	--	--	--
HCB-8	408	51.5	8 (c)	--	--	--	--
HCB-9	428	46.3	38.5	389.5	39	≥ 7.3	389
HCB-10	449	48.8	46	403	45	≥ 3.8	404
HCB-11 (b)	414	29.9	19	395	--	--	--
HCB-11A	414	15.1	11.8	402.2	12	≥ 3	402
HCB-12	426	34.0	7 (c)	--	15	5	411
			27.7	398.3	25.5	≥ 8.5	400.5

Notes:
a = Elevation estimated from Lidar survey. Elevation datum is NAVD88.
b = Soil sample recovery was poor and boring was redrilled 5 feet to the northwest (HCB-11A).
c = Likely represents perched groundwater.
-- = Data not available.

Table 2 - Summary of Grain Size Analysis Results

Boring ID	Sample Number	Depth Interval in Feet	Soil Unit	Material Description	USCS	Percent Gravel	Percent Sand	Percent Fines	D_{60}	D_{30}	D_{10}
HCB-1	S-38A	16.0 to 17.3	S	slightly gravelly, silty SAND	SM	7.0	67.4	25.5	0.312	0.097	--
HCB-2	S-50	32.5 to 33.8	S	slightly silty, slightly gravelly SAND	SP-SM	9.0	85.5	5.4	1.253	0.512	0.241
HCB-4	S-10	45.0 to 46.3	S	slightly silty, slightly gravelly SAND	SP-SM	8.2	83.8	8.0	0.359	0.205	0.090
HCB-5	S-15	20.0 to 21.3	S	slightly gravelly, very silty SAND	SM	5.1	51.9	43.0	0.121	--	--
HCB-9	S-10A	45.0 to 45.4	S	very silty SAND, trace gravel	SM	1.1	66.4	32.5	0.154	--	--
HCB-9	S-10B	45.4 to 45.9	S	slightly silty SAND	SP-SM	0.0	92.7	7.3	0.190	0.130	0.080
HCB-10	S-11	47.5 to 48.8	S	very silty SAND	SM	0.0	69.8	30.2	0.125	--	--
HCB-11A	S-2	10.0 to 11.5	S	silty, very gravelly SAND	SM	39.2	40.9	19.9	4.098	0.170	0.025 (a)
HCB-11A	S-3	12.5 to 14.0	GT	slightly gravelly, very silty SAND	SM	6.1	57.2	36.7	0.226	--	--
HCB-12	S-4	17.5 to 19.0	S	slightly silty SAND, trace gravel	SP-SM	4.4	84.6	11.1	0.507	0.281	0.065 (a)

Note:
a = Extrapolated value from grain size analysis results.
S = Sand unit.
GT = Glacial Till unit.
-- = Data not available.

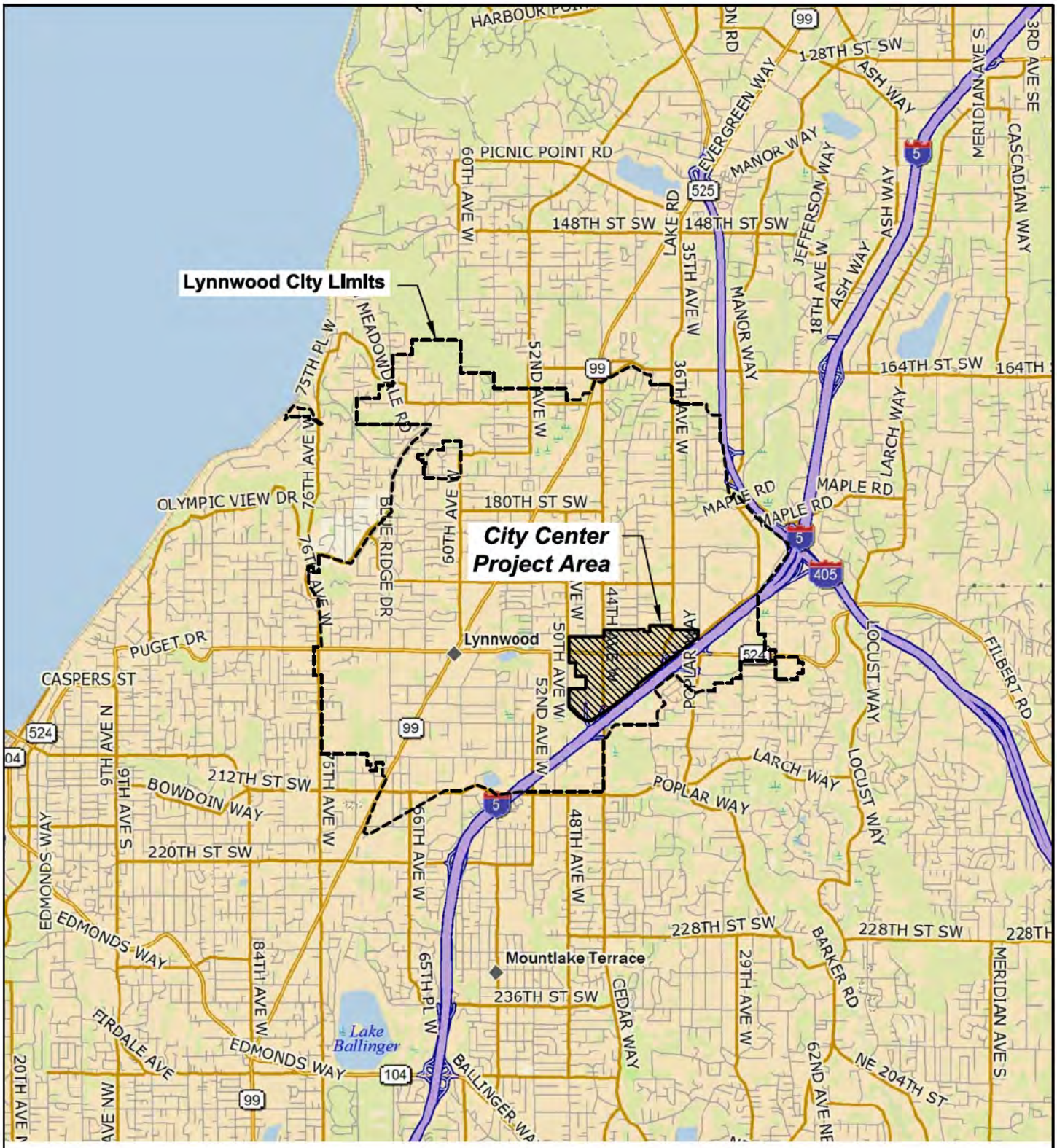
Table 3 - Infiltration Rates Based on Grain Size

Boring ID	Sample #	Soil Unit	USCS	Percent Fines	D_{10}	K_{hz} Ave in ft/min (b)	K_v Ave in ft/min (c)	Field Infil. rate from K_v in in/hr	Infil. Rate in/hr (d)	Inferred Infil. Rate in in/hr (e)
HCB-1	S-38A	S	SM	25.5	--	--	--	--	--	<0.5
HCB-2	S-50	S	SP-SM	5.4	0.241	0.11	0.011	8.2	5	5
HCB-4	S-10	S	SP-SM	8.0	0.090	0.02	0.002	1.1	1.9	1.5
HCB-5	S-15	S	SM	43.0	--	--	--	--	--	<0.5
HCB-9	S-10A	S	SM	32.5	--	--	--	--	--	<0.5
HCB-9	S-10B	S	SP-SM	7.3	0.080	0.013	0.001	0.9	1.6	1
HCB-10	S-11	S	SM	30.2	--	--	--	--	--	<0.5
HCB-11A	S-2	S	SM	19.9	0.025 (a)	0.001	0.0001	0.1	0.3	0.2
HCB-11A	S-3	GT	SM	36.7	--	--	--	--	--	<0.5
HCB-12	S-4	S	SP-SM	11.1	0.065 (a)	0.008	0.0008	0.6	1.2	1

Notes:
a = Extrapolated value from grain size analysis results.
b = Hazen Method. Kh in cm/sec = D_{10}^2
c = Assumed K_v to be 10 percent of K_{hz}.
d = Table 3.8 and Figure 3.28 in Stormwater Management Manual for Western Washington, page 3-78.
e = Estimated field infiltration rates.
S = Sand unit.
GT = Glacial Till unit.
K_{hz} = Horizontal hydraulic conductivity.
K_v = Vertical hydraulic conductivity.

Table 4 - Inferred Infiltration Potential

Boring ID	Sand/Gravel Target Zone Present?	In Target Zone, is the Fines Content Less than 10%?	In Target Zone, is D_{10} Greater than 0.05 mm?	Is Target Zone Unsaturated?	Inferred Infiltration Potential
HCB-1	Y	N	N	N	Unfavorable
HCB-2	Y	Y	Y	N	Unfavorable
HCB-3	N	--	--	--	Unfavorable
HCB-4	Y	Y	Y	Y	Low
HCB-5	Y	N	N	N	Unfavorable
HCB-6	N	--	--	--	Unfavorable
HCB-7	N	--	--	--	Unfavorable
HCB-8	N	--	--	--	Unfavorable
HCB-9	Y	N	N	N	Unfavorable
HCB-10	Y	N	N	N	Unfavorable
HCB-11/11A	Y	N	N	N	Unfavorable
HCB-12	Y	N/Y	Y	Y	Low



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Scale in Miles

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Source: Base map prepared from DeLorme Topo 7.0, 2007.

Lynnwood City Center Soil Permeability Study
Lynnwood, Washington

Vicinity Map

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Figure
1

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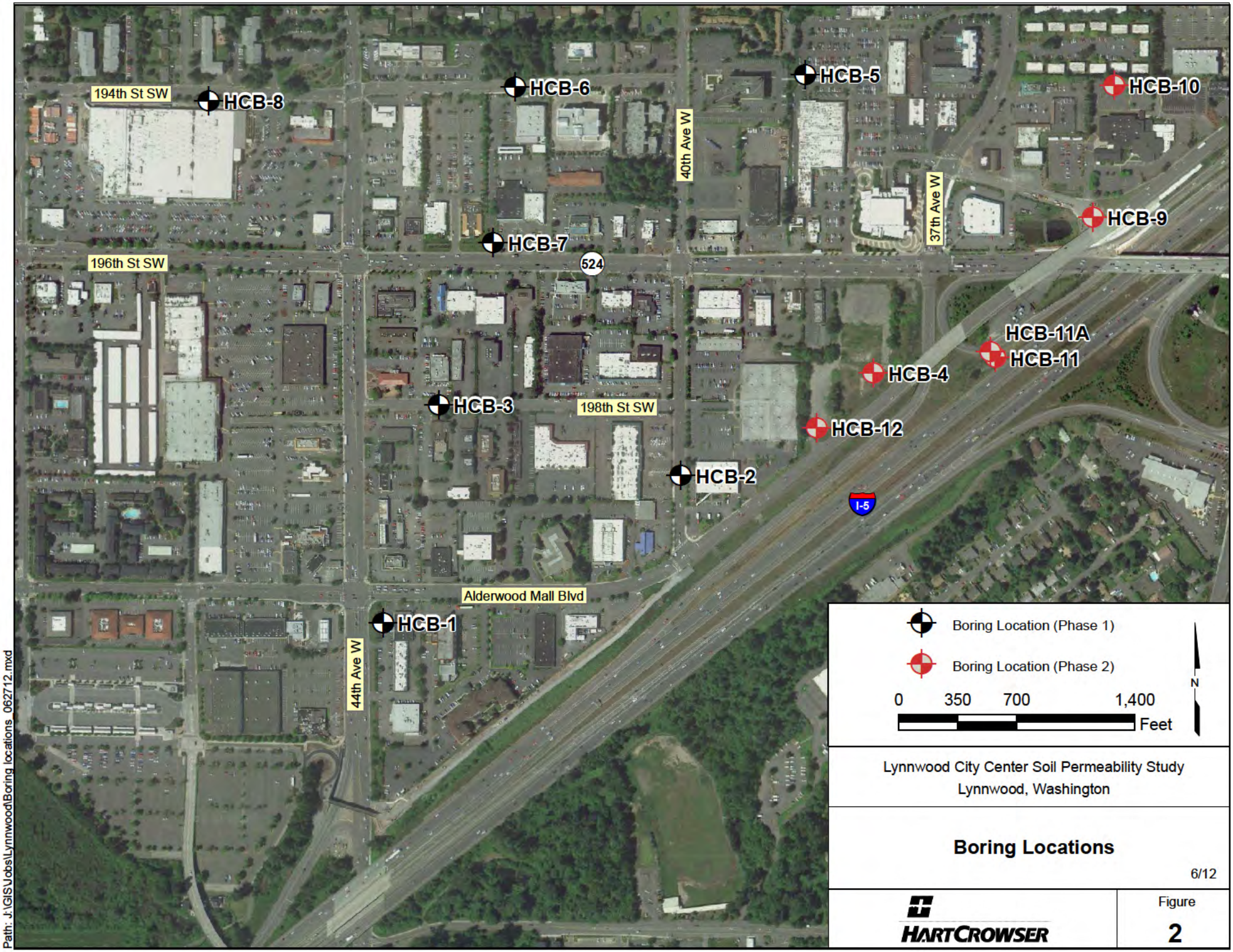

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Lynnwood, Washington

Boring Locations

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Figure
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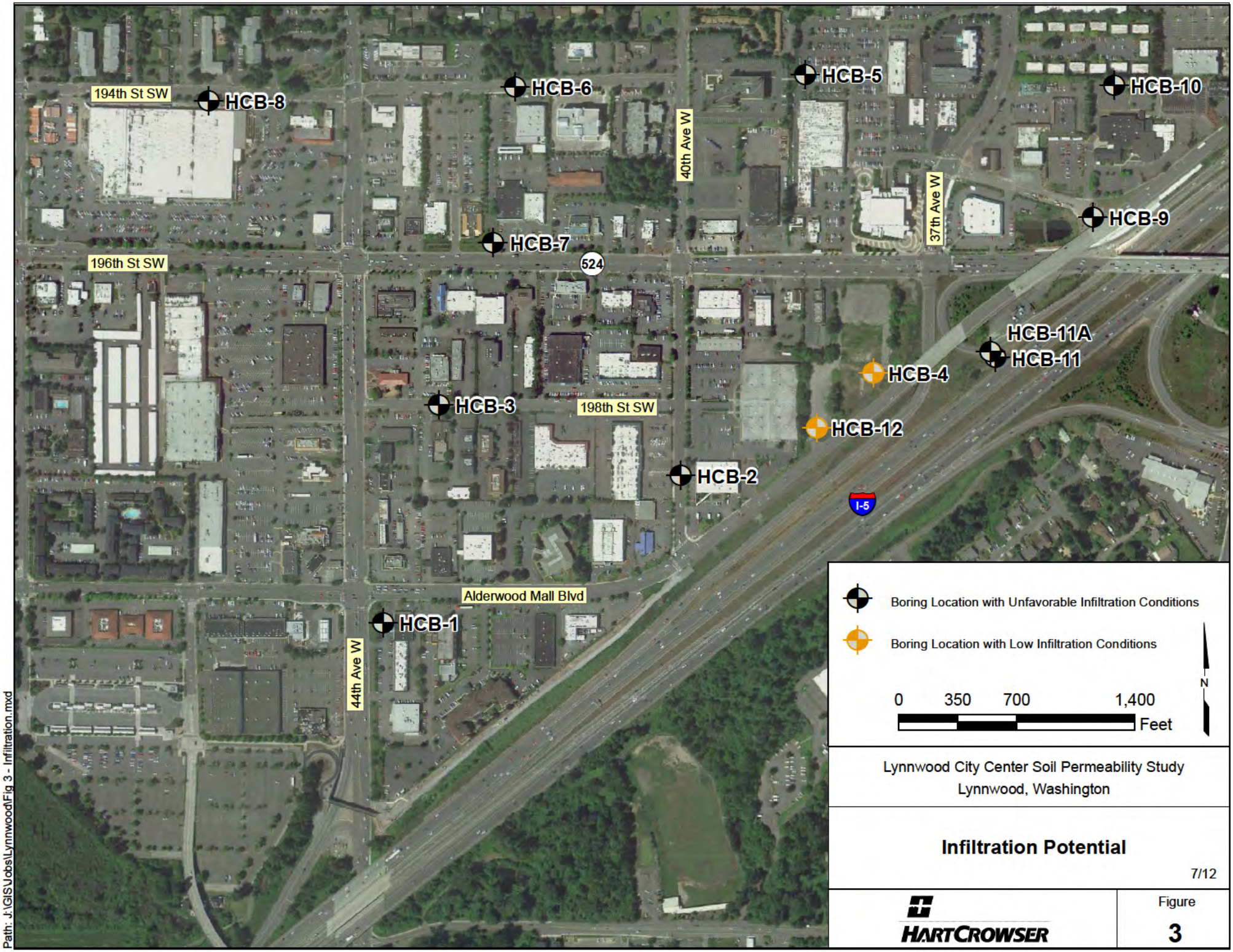

Lynnwood City Center Soil Permeability Study
Lynnwood, Washington

Infiltration Potential

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Figure
3

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APPENDIX A
FIELD METHODS
AND BORING LOGS

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APPENDIX A
FIELD METHODS
AND BORING LOGS

This appendix describes the field exploration methods we used to advance explorations and collect soil samples. The boring logs in this appendix show our interpretation of the exploration sampling and testing data. The logs indicate the depth where the soils change. Note that the change may be gradual. In the field, we classified the samples taken from the explorations according to the methods presented on Figure A-1—Key to Exploration Logs. This figure also provides a legend explaining the symbols and abbreviations used in the logs.

Hollow-Stem Auger Borings

With depths ranging from 15.1 to 53 feet below the ground surface, 13 hollow-stem auger borings (HCB-1 through HCB-12), were drilled on February 22 and 23, 2012, and June 13 and 14, 2012. HCB-11 was re-drilled because of poor sample recovery; the new boring was named HCB-11A. A 4-inch inside diameter hollow-stem auger was advanced with a truck-mounted drill rig subcontracted by Hart Crowser. Using the Standard Penetration Test (SPT), we obtained samples at 2-1/2- to 5-foot-depth intervals. The drilling was continuously observed by a geologist from Hart Crowser who prepared detailed field logs of each boring. The borings logs are presented on Figures A-2 through A-13 at the end of this appendix.

Standard Penetration Test (SPT) Procedures

This test is an approximate measure of soil density and consistency. To be useful, the results must be used in combination with engineering judgment and other tests. The SPT (as described in ASTM D 1586) was used to obtain disturbed samples. This test employs a 3- or 1.5-inch diameter split-spoon sampler, which is driven into the soil for 18 inches using a 140-pound autohammer and free-falling 30 inches. The number of blows required to drive the sampler <u>the last 12 inches only</u> is the Standard Penetration Resistance. This resistance, or blow count, measures the relative density of granular soils and the consistency of cohesive soils. The blow counts are then plotted on the boring logs at their respective sample depths.

Soil samples were recovered from the split-barrel sampler, field classified, and placed into water-tight jars. They were then transported to Hart Crowser's laboratory for further testing.

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BORING LOGS

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Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits and probes is estimated based on visual observation and is presented parenthetically on the logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 to 4	Very soft	0 to 2	<0.125
Loose	4 to 10	Soft	2 to 4	0.125 to 0.25
Medium dense	10 to 30	Medium stiff	4 to 8	0.25 to 0.5
Dense	30 to 50	Stiff	8 to 15	0.5 to 1.0
Very dense	>50	Very stiff	15 to 30	1.0 to 2.0
		Hard	>30	>2.0

Sampling Test Symbols

- 1.5" I.D. Split Spoon
- Grab (Jar)
- 3.0" I.D. Split Spoon
- Shelby Tube (Pushed)
- Bag
- Cuttings
- Core Run

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, likely below optimum
Moist	Likely near optimum moisture content
Wet	Much perceptible moisture, likely above optimum

Minor Constituents	Estimated Percentage
Trace	<5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Laboratory Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits Water Content in Percent Liquid Limit Natural Plastic Limit
PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	In Situ Density in PCF
OT	Tests by Others

Groundwater Indicators

- Groundwater Level on Date or (ATD) At Time of Drilling
- Groundwater Seepage (Test Pits)

Sample Key

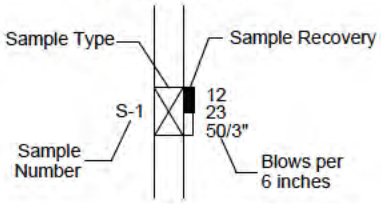

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Figure A-1

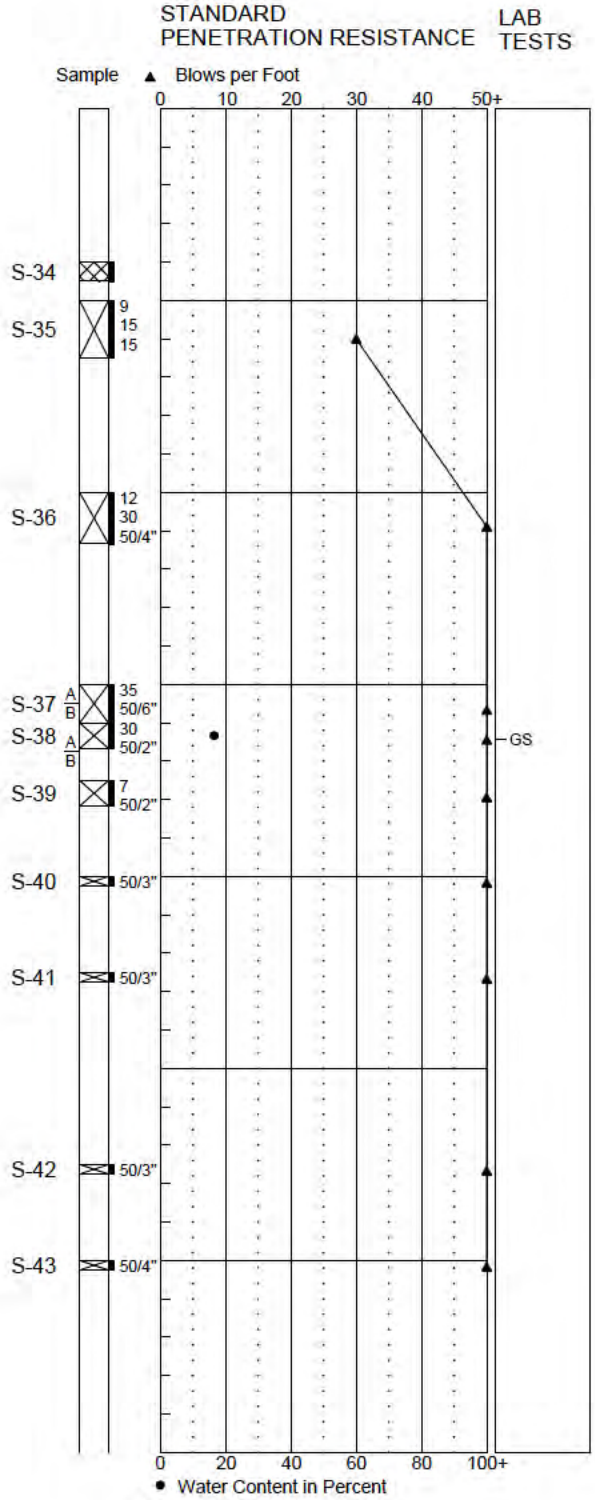
KEY SHEET 1785500-BL.GPJ HC_CORP.GDT 7/5/12

Boring Log HCB-1

Location: See Figure 2.
Approximate Ground Surface Elevation: 371 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		3 inches of Topsoil over (medium dense), moist, brown, gravelly, silty SAND with asphalt debris. (FILL)	0
SM		Dense, moist, gray, gravelly, very silty SAND with iron staining. (Glacial Till)	5
		Grades to very dense with cobbles.	10
SM		Very dense, wet, gray, slightly gravelly, silty, fine to medium SAND.	15 ATD
SM		Very dense, moist, gray, gravelly, very silty SAND with cobbles. (Glacial Till)	20
			25
			30
		Bottom of Boring at 30.5 Feet. Started 02/23/12. Completed 02/23/12.	35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-2

Boring Log HCB-2

Location: See Figure 2.
Approximate Ground Surface Elevation: 403 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SM	8 inches of Asphalt over (dense), moist, brown, gravelly, silty SAND. (FILL)	0
SM	Very dense, moist, gray-brown, slightly gravelly, very silty SAND. (Glacial Till) Grades to wet.	5 (Perched)
	Grades to gravelly with cobbles.	10
		15
		20
	Grades to slightly gravelly.	25
SP	Very dense, wet, gray, slightly gravelly, slightly silty, fine to coarse SAND.	30 (ATD)
		35

STANDARD PENETRATION RESISTANCE — Sample ▲ Blows per Foot (0, 10, 20, 30, 40, 50+)

Sample	Blows	LAB TESTS
S-44	21 42 50/4"	
S-45	50/6"	
S-46	50/5"	
S-47	50/6"	
S-48	50/3"	
S-49 A/B	21 50/3"	
S-50	45 42 50/2"	GS

● Water Content in Percent (0, 20, 40, 60, 80, 100+)

NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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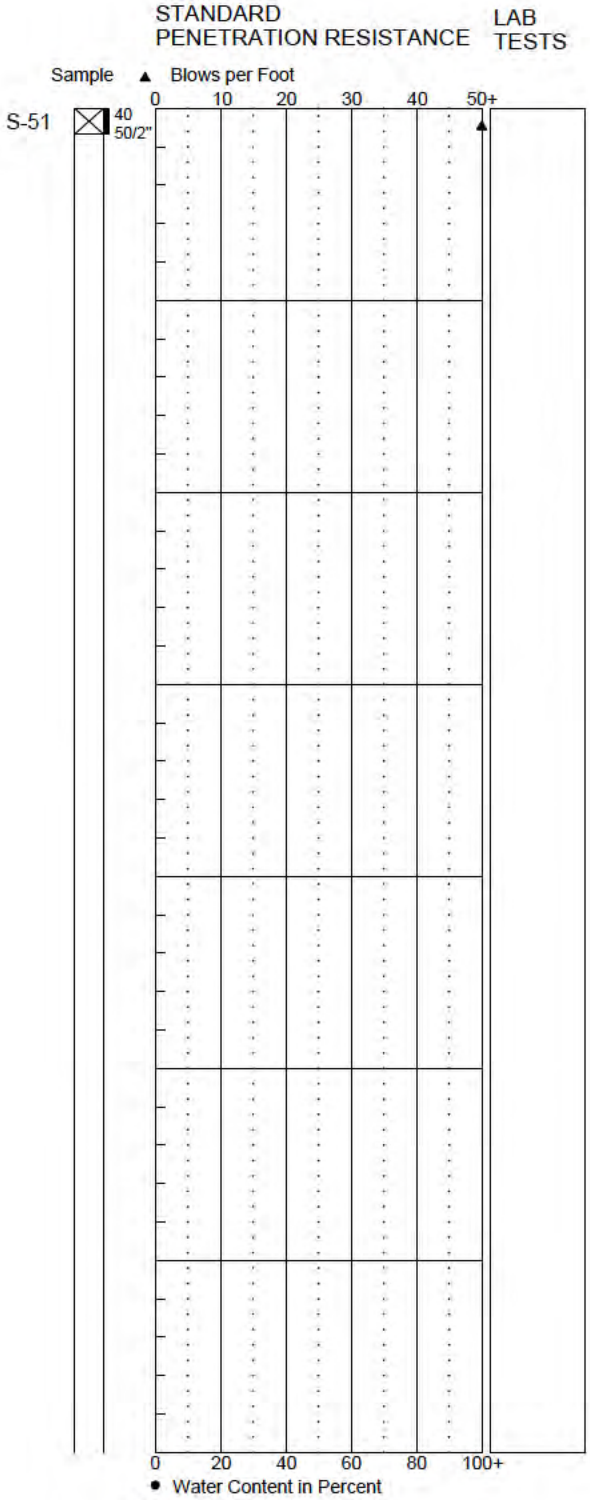
Figure A-3 1/2

Boring Log HCB-2

Location: See Figure 2.
Approximate Ground Surface Elevation: 403 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
		Bottom of Boring at 35.5 Feet. Started 02/23/12. Completed 02/23/12.	35
			40
			45
			50
			55
			60
			65
			70



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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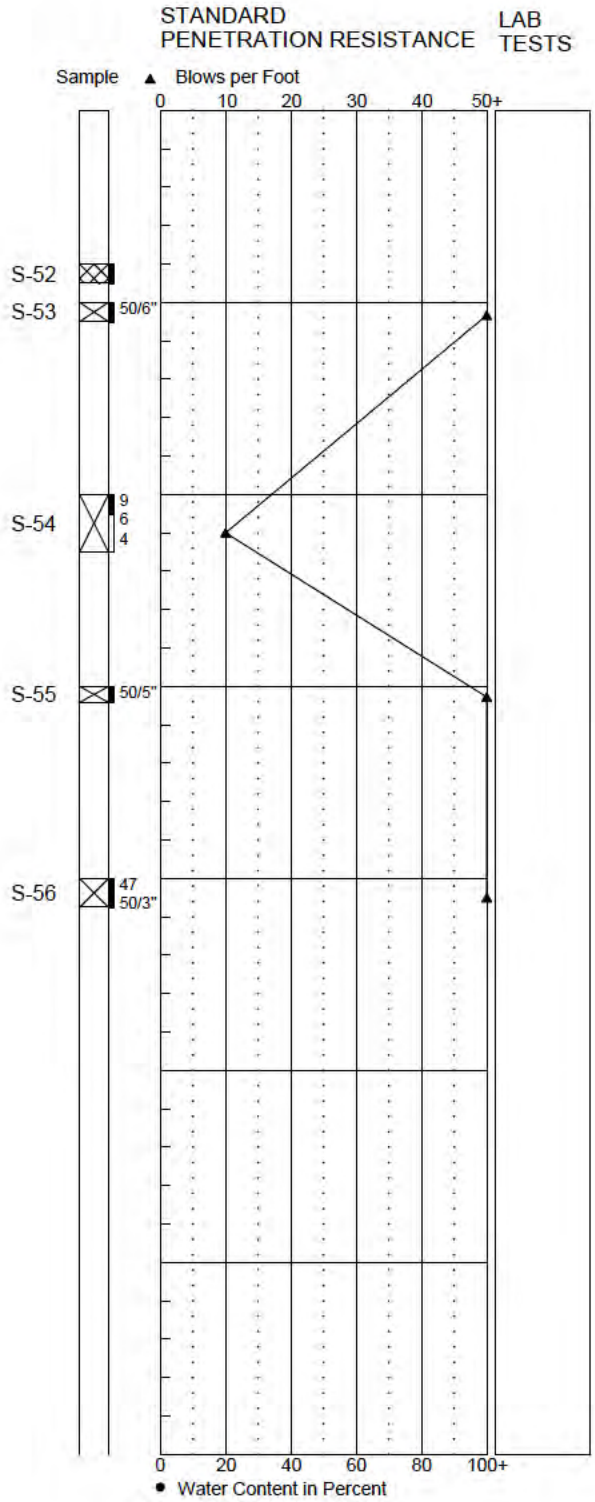
Figure A-3 2/2

Boring Log HCB-3

Location: See Figure 2.
Approximate Ground Surface Elevation: 400 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		4 inches of Asphalt over (medium dense), moist, gray to brown, gravelly, silty SAND. (FILL)	0
SM		Very dense, gray, gravelly, very silty SAND with iron staining at 5.5 feet. (Glacial Till)	5
		Grades to wet and brown.	10 ATD
			15
		Grades to gray and slightly gravelly.	20
		Bottom of Boring at 21.0 Feet. Started 02/23/12. Completed 02/23/12.	25
			30
			35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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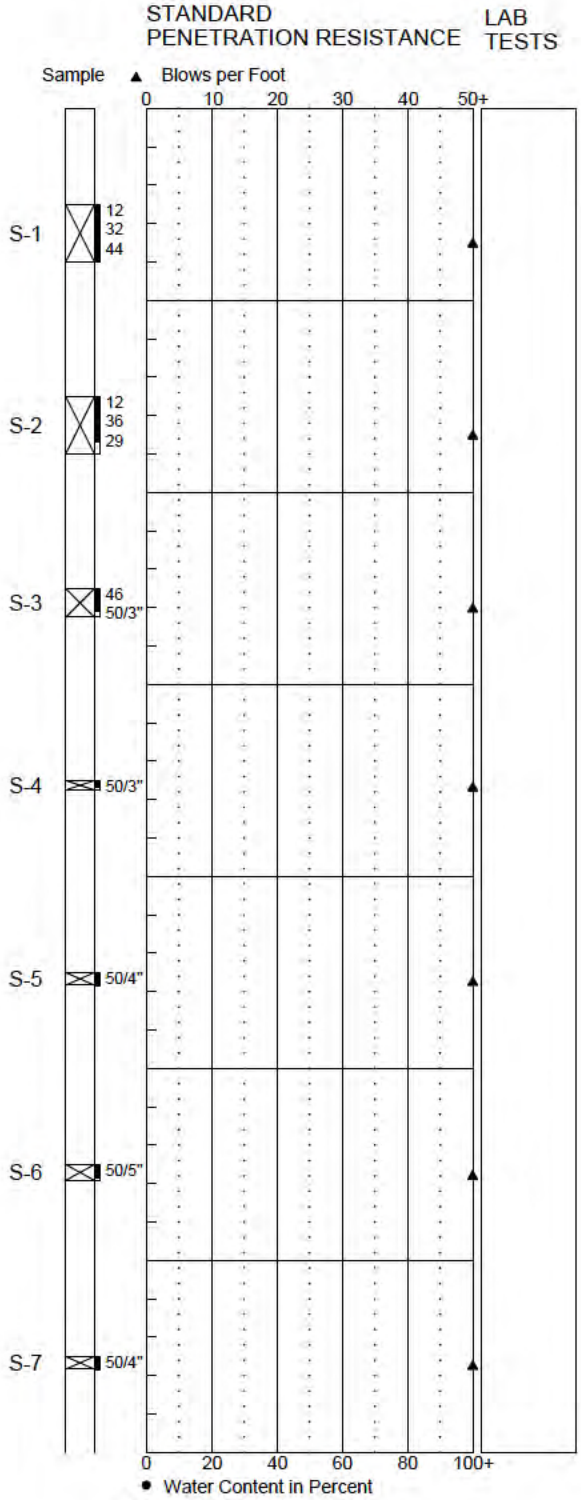
Figure A-4

Boring Log HCB-4

Location: See Figure 2.
Approximate Ground Surface Elevation: 445 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
GM	3 inches of Asphalt over very dense, damp to moist, gray-brown, silty, sandy, fine to coarse GRAVEL. (Glacial Till)	0
SM	Very dense, damp to moist, gray, silty, gravelly, fine to medium SAND. (Glacial Till)	5
GM	Very dense, damp to moist, gray-brown, silty, sandy, fine GRAVEL. (Glacial Till)	10
SM	Very dense, damp to moist, gray, silty, gravelly, fine to medium SAND. (Glacial Till)	15
		20
		25
		30
		35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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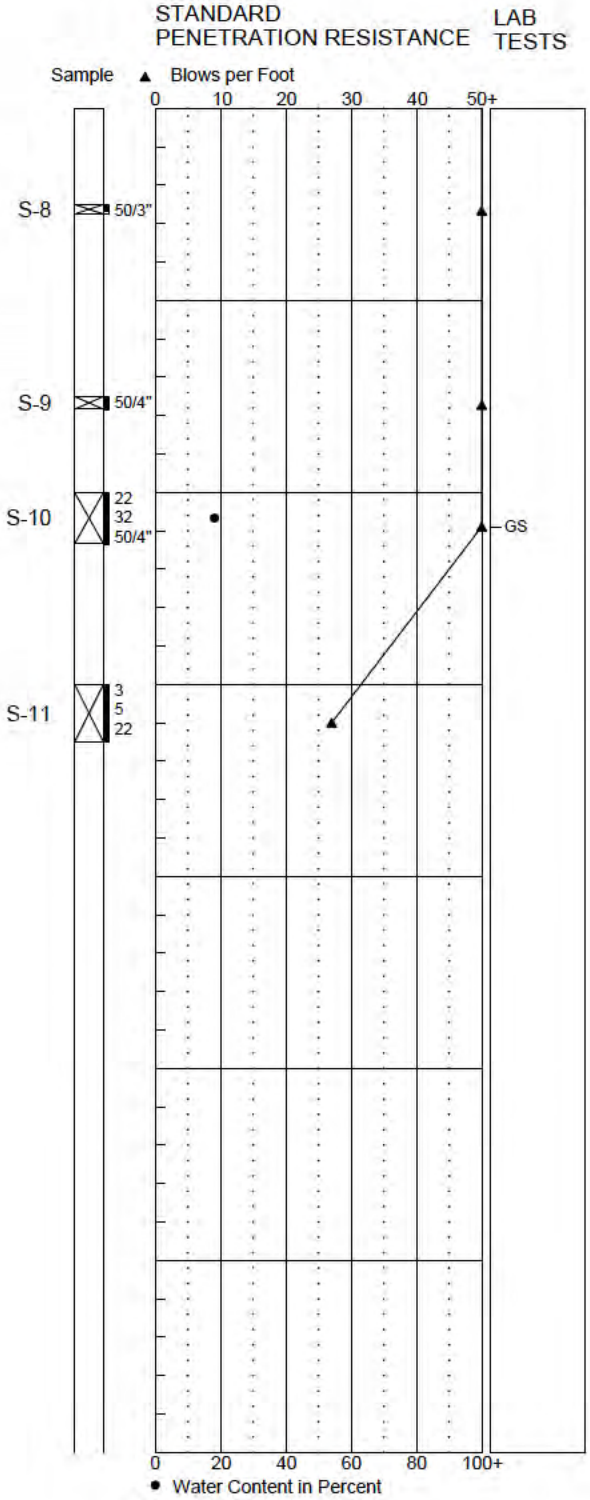
Figure A-5 1/2

Boring Log HCB-4

Location: See Figure 2.
Approximate Ground Surface Elevation: 445 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
GM		Very dense, damp to moist, gray-brown, silty, sandy, fine to coarse GRAVEL. (Glacial Till)	35
			40
SW		Very dense, moist to wet, gray, slightly silty, slightly gravelly, fine to coarse SAND.	
		ATD	45
		Grades to medium dense.	50
		Bottom of Boring at 51.5 Feet. Started 06/13/12. Completed 06/13/12.	
			55
			60
			65
			70



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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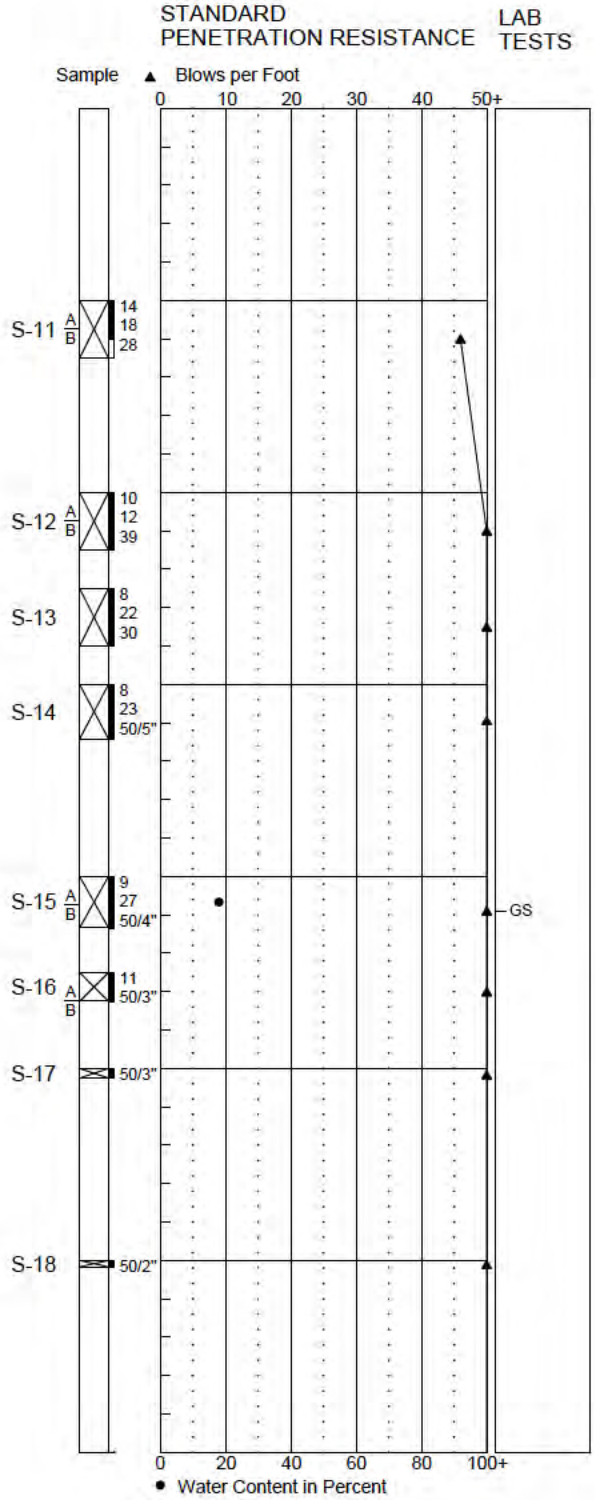
Figure A-5 2/2

Boring Log HCB-5

Location: See Figure 2.
Approximate Ground Surface Elevation: 444 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SP	3 inches of Asphalt over dense, moist, gray, fine to medium SAND with trace silt. (FILL)	0
SM	Very dense, moist, gray, slightly gravelly, very silty, fine to medium SAND. (Glacial Till)	5
	Grades to brown.	10
	Iron staining observed.	
	Iron staining and cobbles observed.	15
SM	Very dense, wet, slightly gravelly to trace gravels, very silty to silty, fine SAND.	20 ATD
SM	Very dense, moist to wet, gravelly, very silty, fine to coarse SAND. (Glacial Till)	25
		30
GM	Very dense, wet, gray, silty, sandy GRAVEL. (Glacial Till)	35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-6 1/2

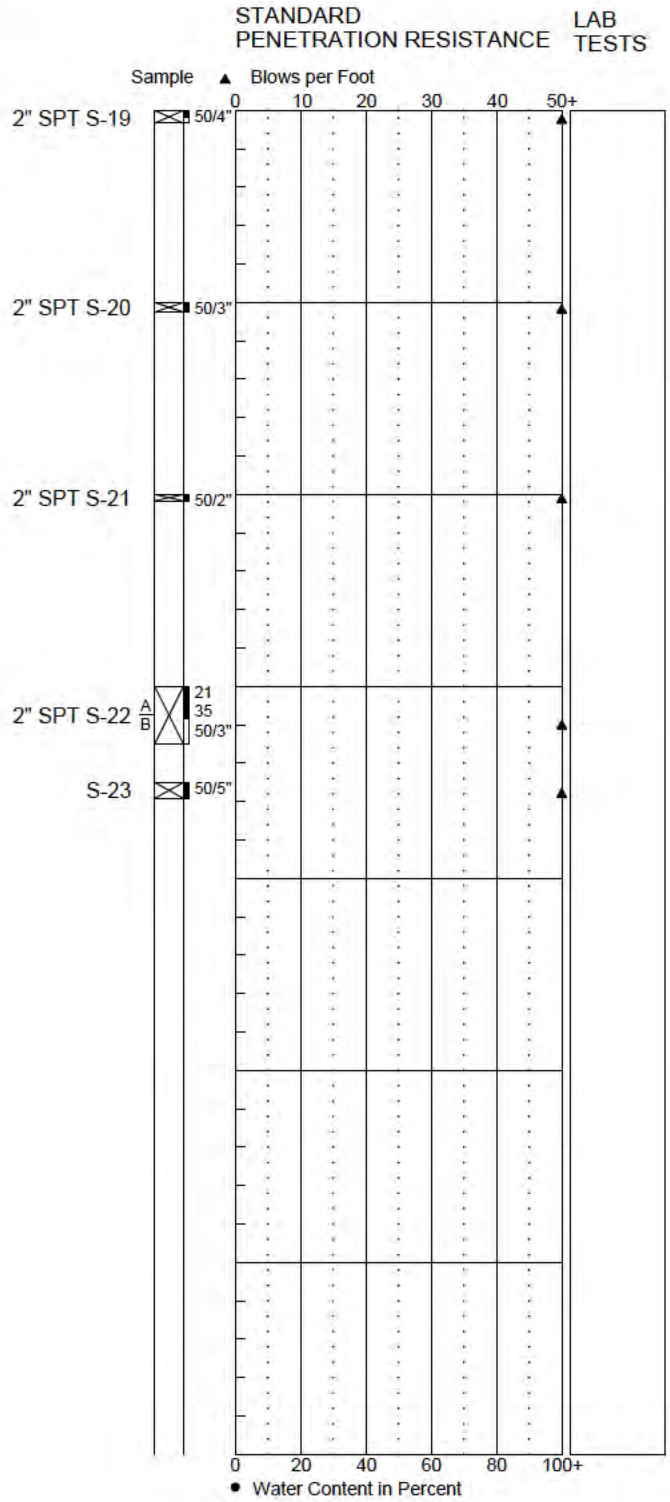
Boring Log HCB-5

Location: See Figure 2.
Approximate Ground Surface Elevation: 444 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
GM	Very dense, wet, gray, silty, sandy GRAVEL. (Glacial Till) (cont'd)	35
SM	Very dense, moist, gray, gravelly to very gravelly, very silty, fine to coarse SAND. (Glacial Till)	40, 45
SP	Very dense, wet, gray, fine to medium SAND with trace silt.	50
SM	Very dense, wet, silty, very gravelly, fine to coarse SAND. (Glacial Till)	

Bottom of Boring at 53.0 Feet.
Started 02/22/12.
Completed 02/22/12.



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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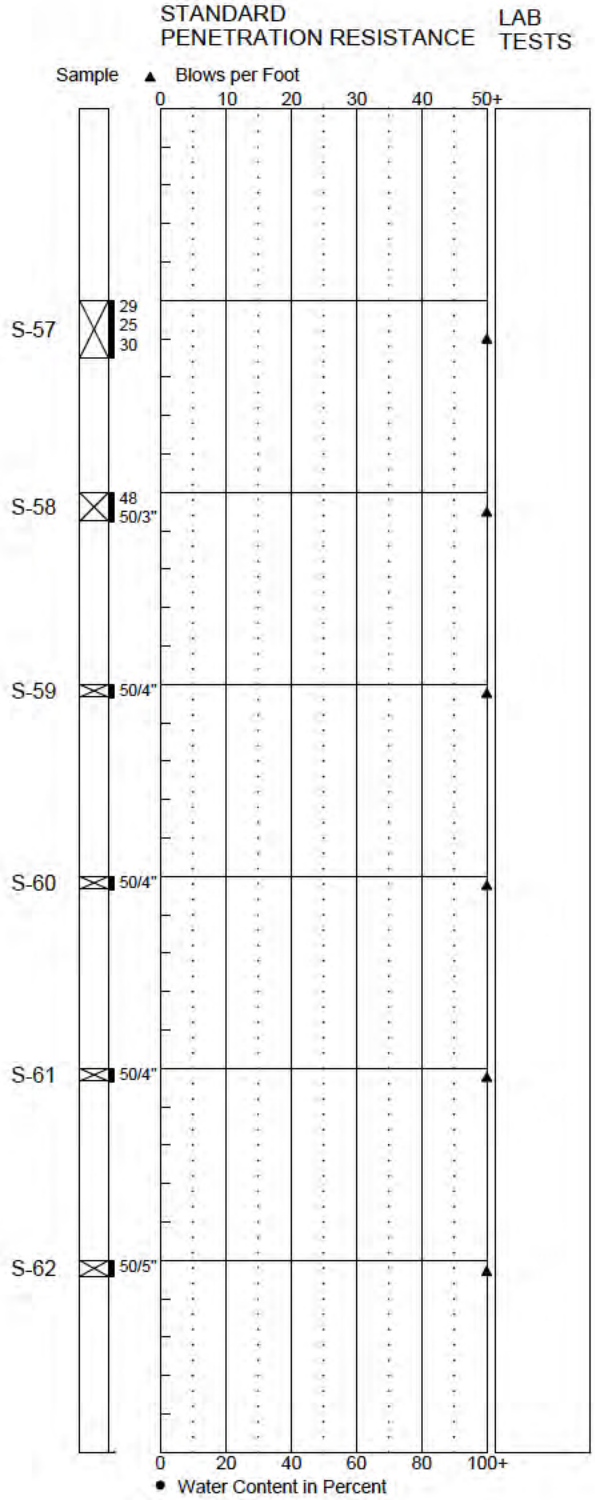
Figure A-6 2/2

Boring Log HCB-6

Location: See Figure 2.
Approximate Ground Surface Elevation: 435 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		12 inches of Asphalt over very dense, moist, brown, silty, very gravelly SAND. (FILL)	0
		Cobbles observed.	10
SM		Very dense, moist, gray, gravelly, very silty SAND. (Glacial Till)	



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-7 1/2

NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

Boring Log HCB-6

Location: See Figure 2.
Approximate Ground Surface Elevation: 435 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		Very dense, moist, gray, gravelly, very silty SAND. (Glacial Till) (cont'd)	35
		Bottom of Boring at 40.0 Feet. Started 02/23/12. Completed 02/23/12.	40
			45
			50
			55
			60
			65
			70

STANDARD PENETRATION RESISTANCE — LAB TESTS

Sample ▲ Blows per Foot (0, 10, 20, 30, 40, 50+)

S-63 50/3"

S-64 50/1"

0 20 40 60 80 100+
● Water Content in Percent

NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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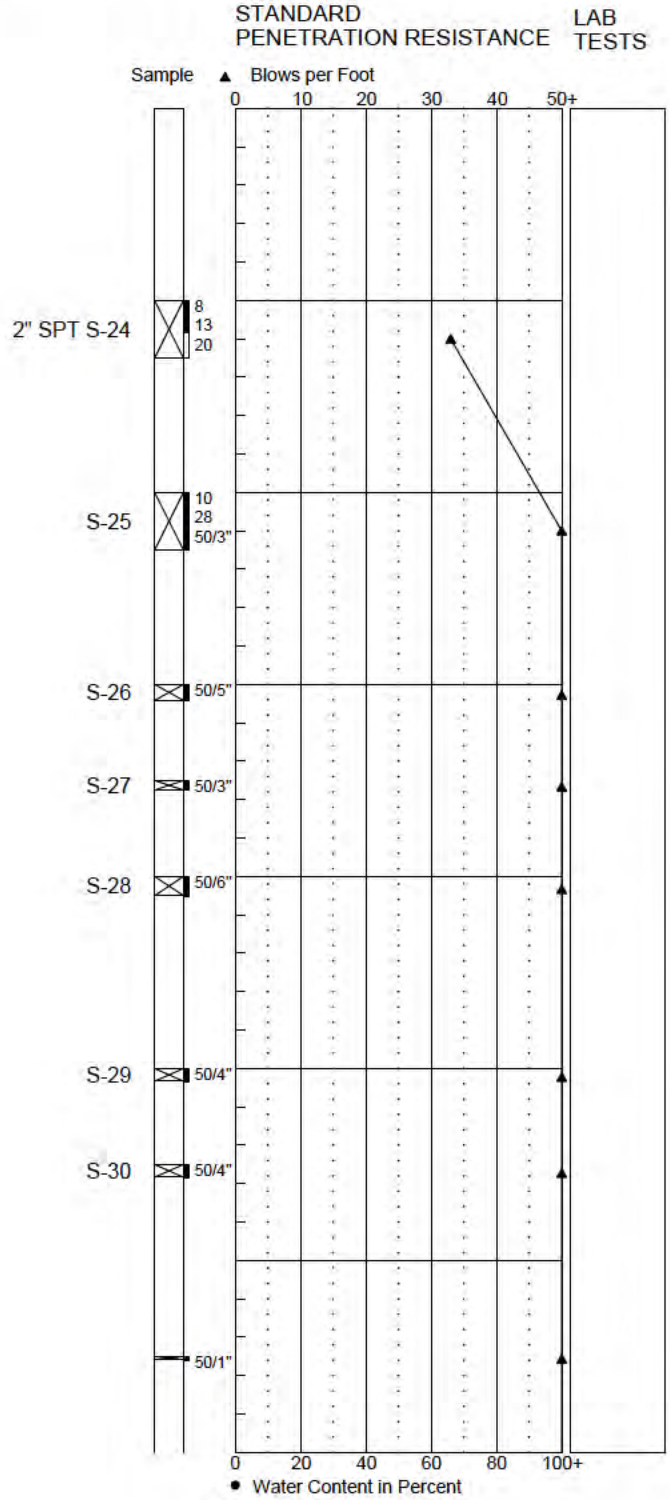
Figure A-7 2/2

Boring Log HCB-7

Location: See Figure 2.
Approximate Ground Surface Elevation: 415 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		3 inches of Asphalt over dense, moist, gray-brown, gravelly, very silty SAND. (FILL)	0
SM		Very dense, moist, gray, very gravelly, very silty SAND with cobbles. (Glacial Till)	5
		Grades to gravelly.	10
		Grades to wet.	15 (Perched)
		Grades to moist.	20
		Grades to very gravelly.	25
		Grades to gravelly.	30
			35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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Figure A-8 1/2

Boring Log HCB-7

Location: See Figure 2.
Approximate Ground Surface Elevation: 415 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		Very dense, moist, gray, very gravelly, very silty SAND with cobbles. (Glacial Till) (cont'd)	35
		Grades to very gravelly.	40
			45
			50
		Bottom of Boring at 50.3 Feet. Started 02/22/12. Completed 02/22/12.	
			55
			60
			65
			70

STANDARD PENETRATION RESISTANCE — LAB TESTS

Sample ▲ Blows per Foot (0, 10, 20, 30, 40, 50+)

Sample	Blows
S-31	50/4"
	50/1"
2" SPT S-32	50/4"
2" SPT S-33	50/3"

● Water Content in Percent (0, 20, 40, 60, 80, 100+)

NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17855-00 2/12

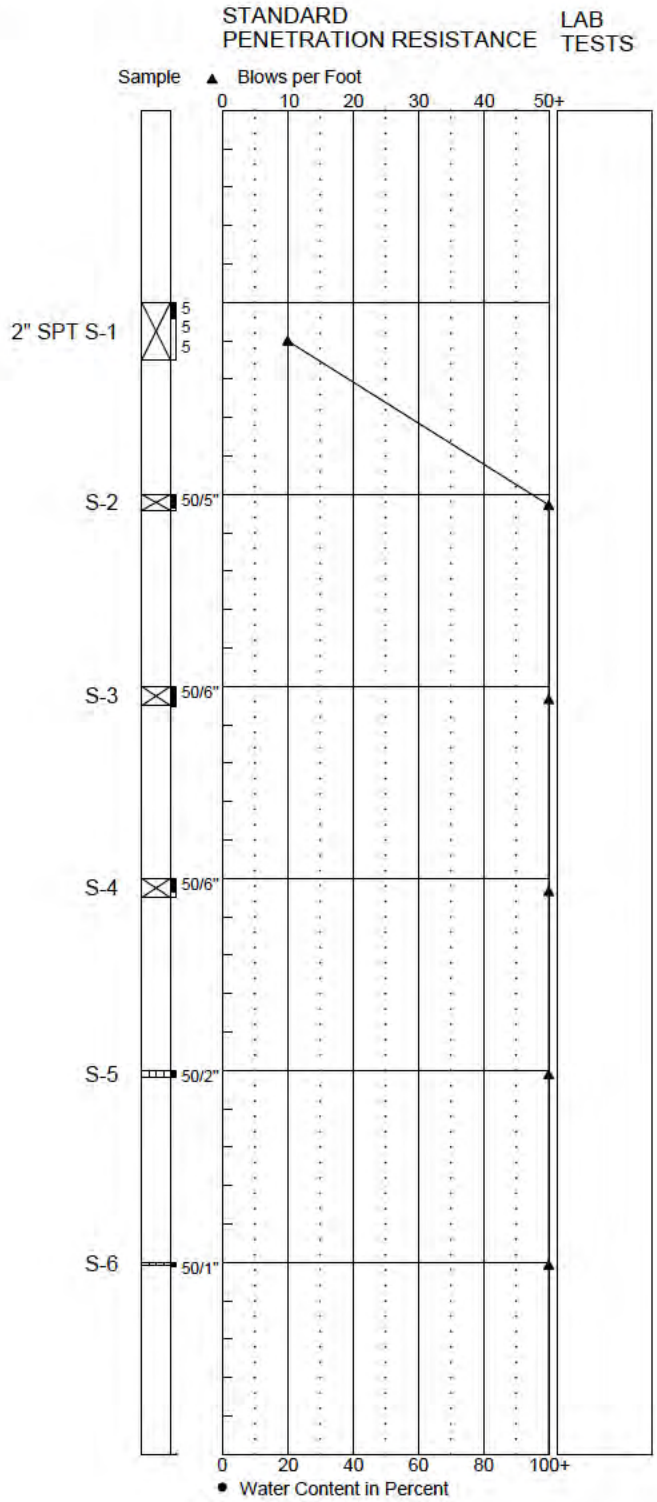
Figure A-8 2/2

Boring Log HCB-8

Location: See Figure 2.
Approximate Ground Surface Elevation: 408 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		4 inches of Asphalt over loose, wet, gray, gravelly, very silty SAND. (FILL)	0
SM		Very dense, moist, gray, very gravelly, very silty, fine to coarse SAND with cobbles. (Glacial Till)	10 (Perched ▽)
		Grades to slightly gravelly.	25



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17855-00 2/12

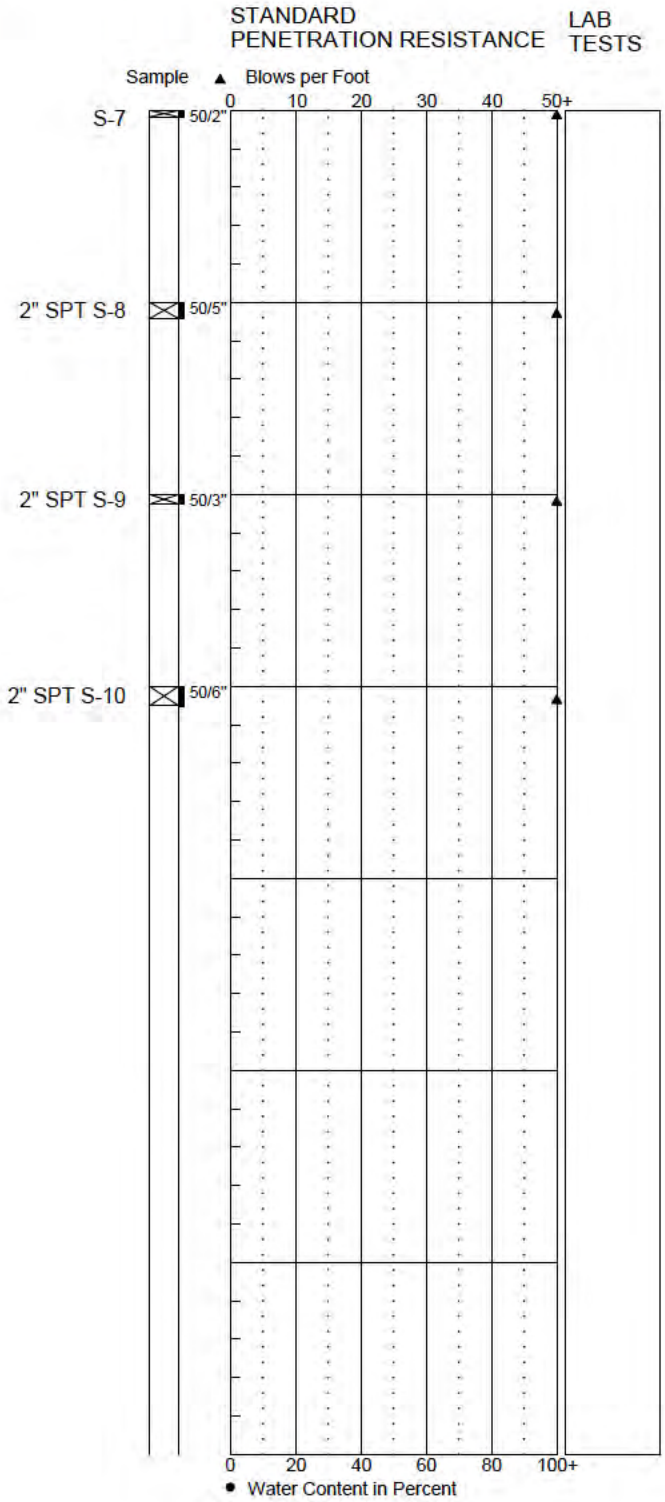
Figure A-9 1/2

Boring Log HCB-8

Location: See Figure 2.
Approximate Ground Surface Elevation: 408 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 3" SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. ole-MoiYoi Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		Very dense, moist, gray, very gravelly, very silty, fine to coarse SAND with cobbles. (Glacial Till) (cont'd)	35
		Grades to gravelly.	40
			45
			50
		Bottom of Boring at 51.5 Feet. Started 02/22/12. Completed 02/22/12.	55
			60
			65
			70



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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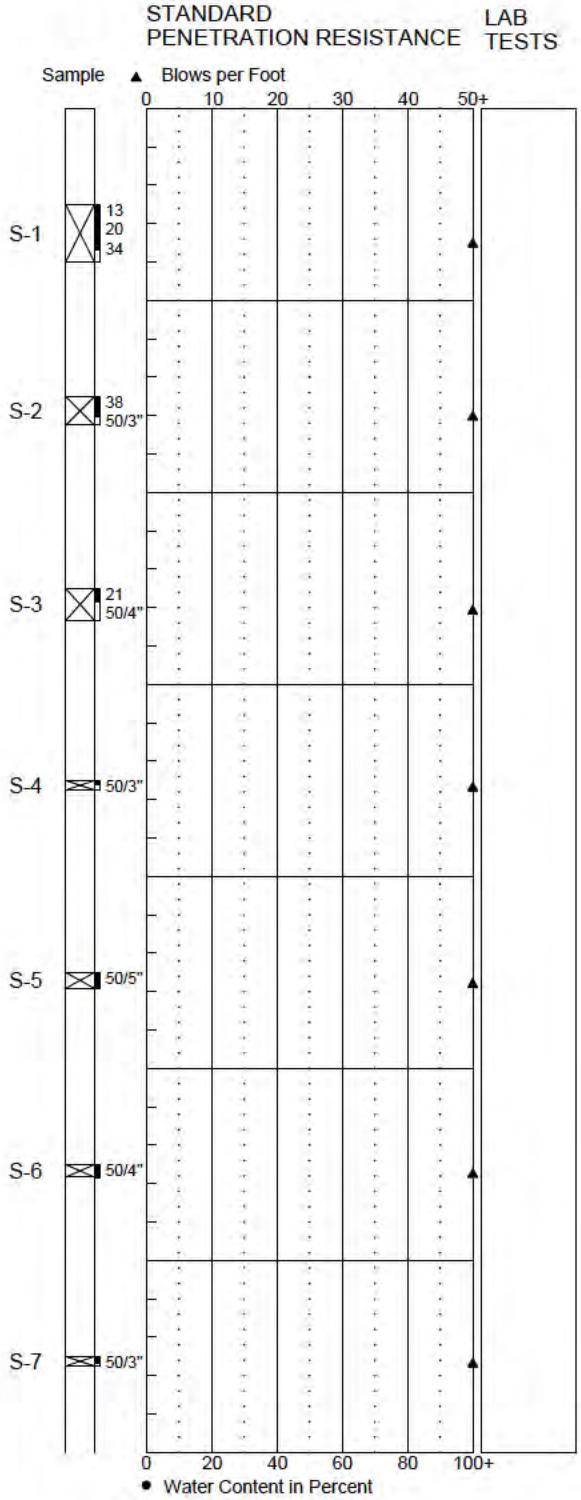
Figure A-9 2/2

Boring Log HCB-9

Location: See Figure 2.
Approximate Ground Surface Elevation: 428 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SM	12 inches of Topsoil over very dense, damp, gray, silty, gravelly, fine to medium SAND with iron staining. (Glacial Till)	0
SM	Very dense, damp, gray, slightly gravelly, silty, fine to medium SAND. (Glacial Till)	5
GM	Very dense, damp, gray-brown, silty, sandy, fine to coarse GRAVEL. (Glacial Till)	10
	Cobbles observed at 15 feet.	15
	Grades to slightly silty.	20
SW	Very dense, moist, gray, gravelly, fine to medium SAND with trace silt. (Glacial Till)	25
	Cobbles observed at 29.5 feet.	30
GM	Very dense, moist, gray, silty, sandy, fine to coarse GRAVEL. (Glacial Till)	35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

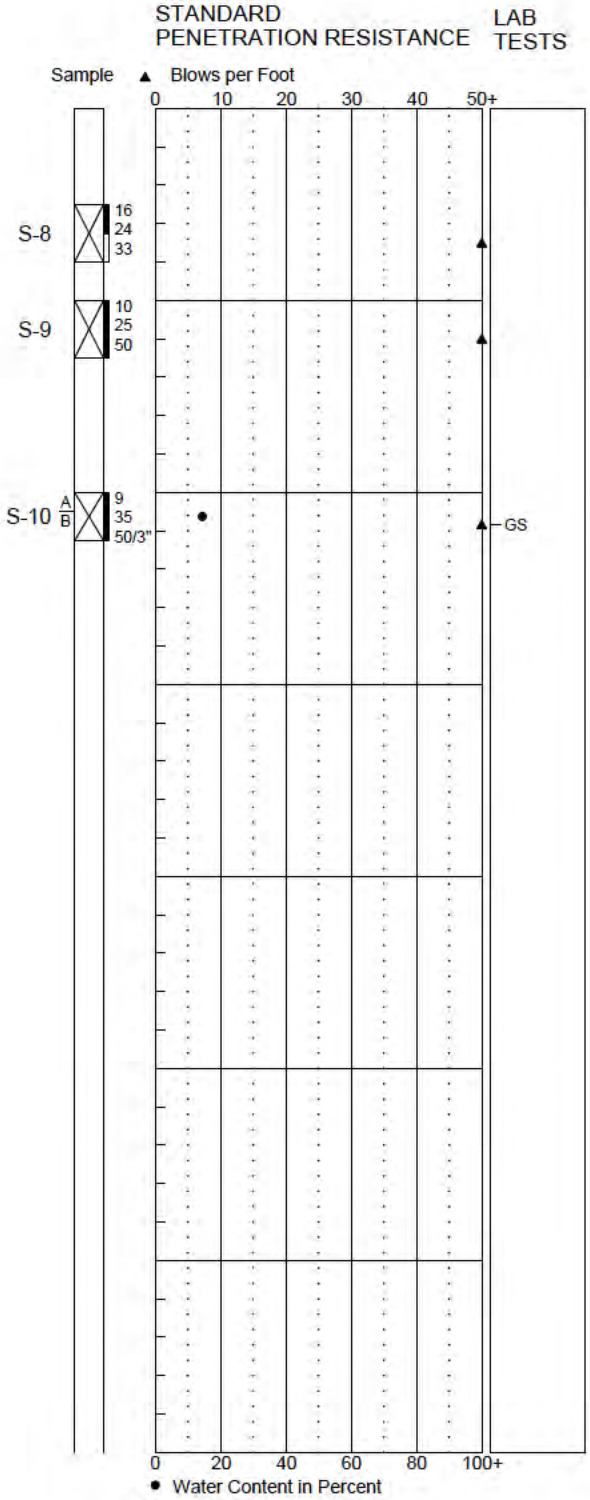
17855-00 6/12
Figure A-10 1/2

Boring Log HCB-9

Location: See Figure 2.
Approximate Ground Surface Elevation: 428 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SM	Very dense, moist to wet, gray, silty, gravelly, fine to medium SAND. (Glacial Till) (cont'd)	35
	ATD	
SP-SM	Very dense, wet, gray, silty, fine to medium SAND. Heaving during drilling affected blow count accuracy.	40
	Grades to no silt.	45
	Grades to silty.	
	Grades to brown and no silt.	
	Bottom of Boring at 46.3 Feet.	
	Started 06/13/12.	
	Completed 06/13/12.	
		50
		55
		60
		65
		70



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

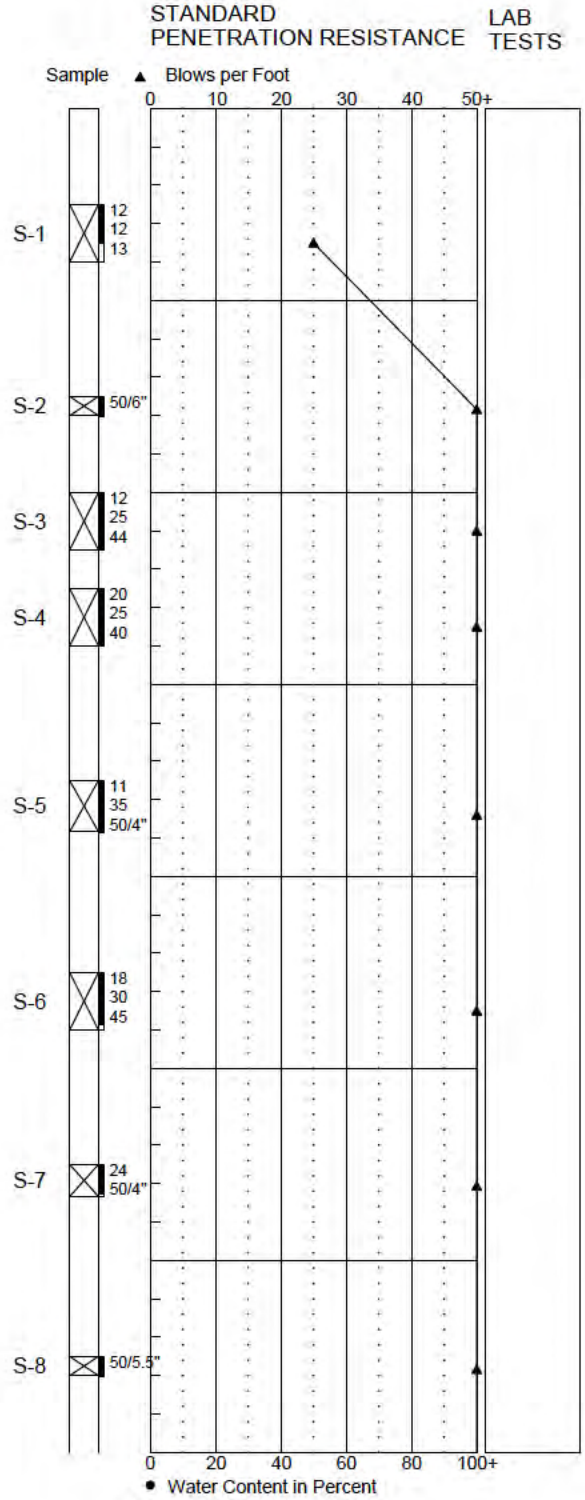
17855-00 6/12
Figure A-10 2/2

Boring Log HCB-10

Location: See Figure 2.
Approximate Ground Surface Elevation: 449 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		2 inches of Asphalt over medium dense, damp to moist, gray-brown, slightly gravelly, silty SAND with iron staining. (FILL)	0
SM		Very dense, moist, gray-brown, gravelly, silty, fine to coarse SAND. (Glacial Till)	5
		Gravels observed at 21 feet.	10, 15, 20
		Grades to damp.	25
		Very hard drilling.	30, 35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

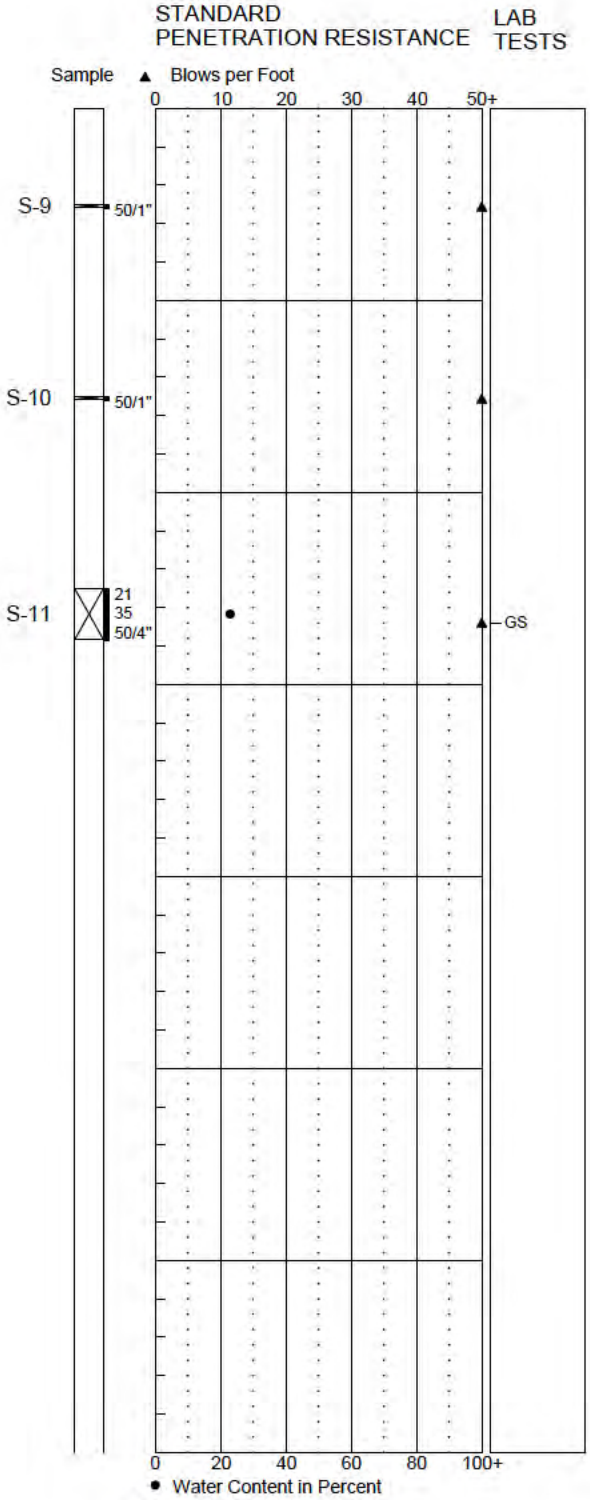
17855-00 6/12
Figure A-11 1/2

Boring Log HCB-10

Location: See Figure 2.
Approximate Ground Surface Elevation: 449 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SM		Very dense, moist, gray-brown, gravelly, silty, fine to coarse SAND. (Glacial Till) (cont'd)	35
		Cobbles observed at 37 feet.	40
SM		Very dense, wet, brown, very silty, fine to medium SAND.	45 ATD
		Bottom of Boring at 48.8 Feet. Started 06/13/12. Completed 06/13/12.	50
			55
			60
			65
			70



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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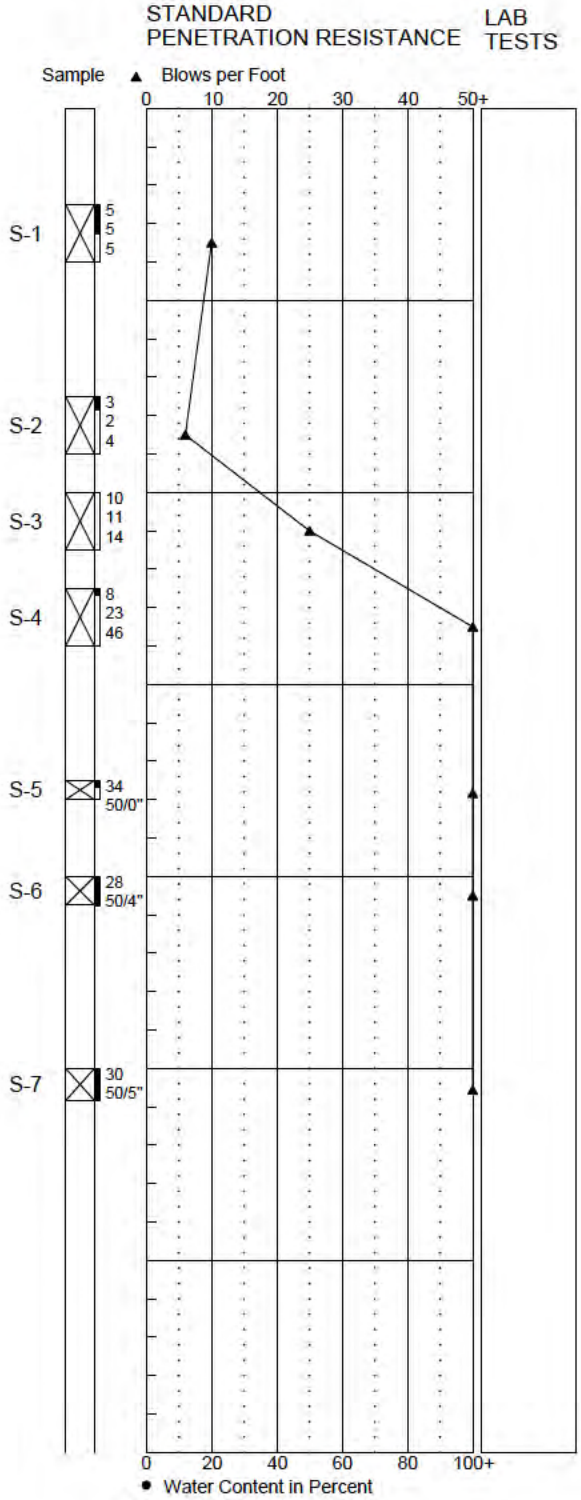
Figure A-11 2/2

Boring Log HCB-11

Location: See Figure 2.
Approximate Ground Surface Elevation: 414 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SM	3 inches of coarse Gravel over medium dense, moist, brown to dark brown, silty, gravelly, fine to coarse SAND. (FILL)	0
SM	Loose to medium dense, wet, red-brown, silty, fine to coarse SAND.	5
	Rock in sampler limiting soil sample recovery. Cuttings indicate silty, fine to medium SAND.	10
	Grades to very dense.	15
SW	Very dense, wet, gray, slightly silty, gravelly, fine to coarse SAND.	ATD 20
SM	Very dense, wet, gray, silty, fine SAND.	25
	Bottom of Boring at 25.9 Feet. Started 06/13/12. Completed 06/13/12. Note: Since recovery was limited, another boring (HCB-11A) was drilled 5 feet northwest of HCB-11.	30 35



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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Figure A-12

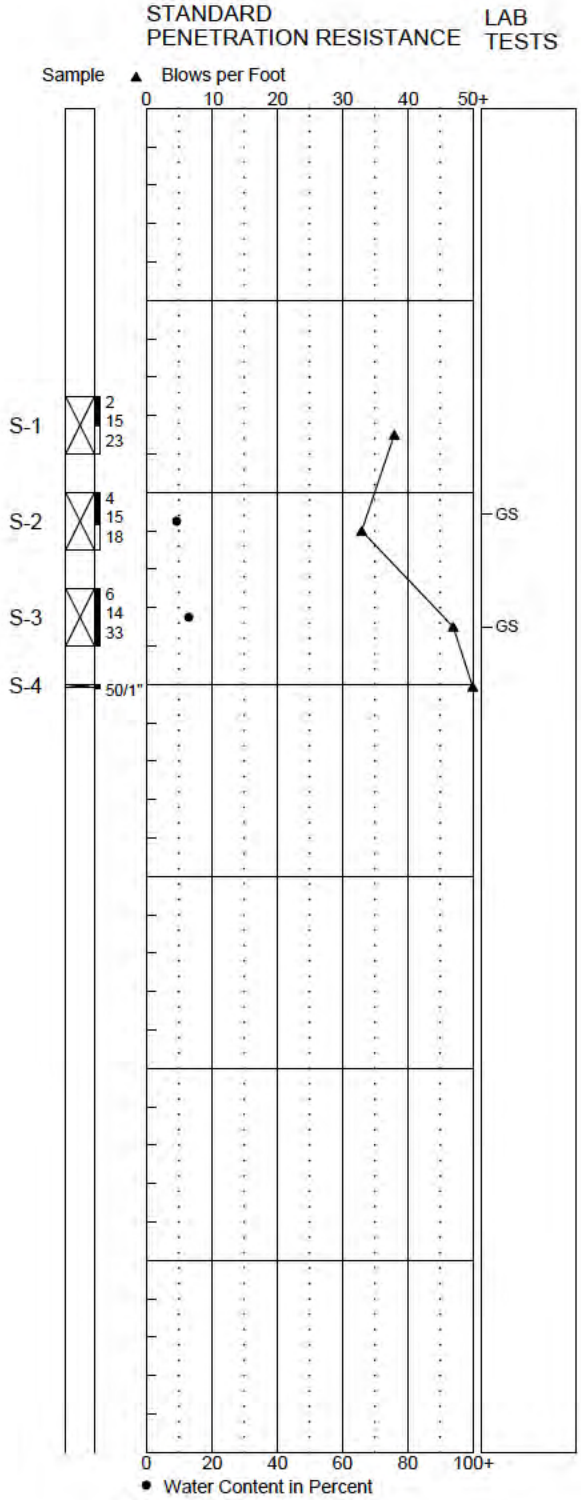
Boring Log HCB-11A

Location: See Figure 2.
Approximate Ground Surface Elevation: 414 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
GM		3 inches of coarse Gravel over dense, moist, red-brown, silty, sandy, fine to coarse GRAVEL. (FILL)	0
SM		Dense, wet, gray-brown, silty, very gravelly, fine to medium SAND. (Glacial Till)	10
SM		Dense, wet, gray-brown, gravelly, very silty SAND.	15
		Bottom of Boring at 15.1 Feet. Started 06/13/12. Completed 06/13/12.	

ATD



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

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Figure A-13

Boring Log HCB-12

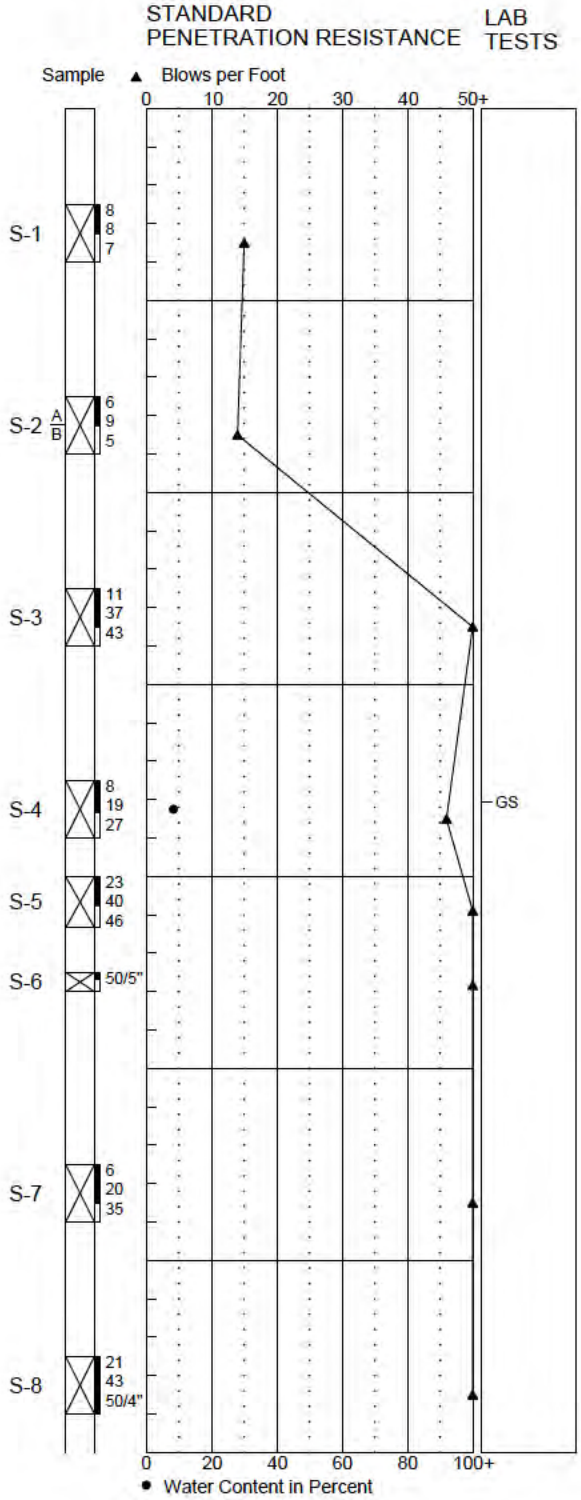
Location: See Figure 2.
Approximate Ground Surface Elevation: 426 Feet
Horizontal Datum:
Vertical Datum: NAVD88

Drill Equipment: Hollow Stem Auger
Hammer Type: 1.5' SPT w/ 140 lb. hammer
Hole Diameter: 8 inches
Logged By: P. Cordell Reviewed By: A. Goodwin

USCS Class	Soil Descriptions	Depth in Feet
SM/GM	3 inches of Asphalt over medium dense, damp to moist, brown to gray, silty, sandy, fine to coarse GRAVEL to silty, gravelly, fine to coarse SAND. (FILL)	0
	Grades to wet.	5
GW SW	Medium dense, moist, brown, sandy, fine to coarse GRAVEL to gravelly SAND with trace silt. (Glacial Till)	10
GM	Very dense, damp to moist, gray-brown, silty, sandy, fine to coarse GRAVEL. (Glacial Till)	15
SP	Dense, moist, light brown, slightly silty, fine to coarse SAND with trace gravels.	20
SW GW	Very dense, moist, gray-brown, slightly silty, gravelly, fine to coarse SAND to sandy, fine to coarse GRAVEL. (Glacial Till)	25
SP GP	Very dense, wet, gray-brown, gravelly, fine to coarse SAND to sandy, fine to coarse GRAVEL with trace silt.	30
	Bottom of Boring at 34.0 Feet. Started 06/13/12. Completed 06/13/12.	35

Perched

ATD



NEW BORING LOG 1785500-BL.GPJ HC_CORP.GDT 7/5/12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

17855-00 6/12

Figure A-14

APPENDIX B
HISTORICAL EXPLORATIONS

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Table B-1 - Summary of Historical Explorations

ID on Figure B-1	Exploration ID	Exploration Type	Northing (a)	Easting (a)	Exploration Depth in Feet	Elevation in Feet	Elevation Source	Elevation Datum	Exploration Log Author (b)	Exploration Date	Exploration Method	Well Installed	Bottom of Fill Depth in Feet	Bottom of Till Depth in Feet	Bottom of Sand Depth in Feet	Depth to Water ATD in Feet
B-1-92	B-1	Boring	301598	1283807	6.5	408	Log	Unknown	GEI	9/24/1992	HSA	No	1.5	4	6.5	None
B-2-92	B-2	Boring	301811	1283796	6.5	418	Log	Unknown	GEI	9/23/1992	HSA	No	1.5	4	6.5	None
B-3-92	B-3	Boring	302049	1283954	23.5	424	Log	Unknown	GEI	9/11/1992	HSA	No	6.5	15.5	23.5	None
B-4-92	B-4	Boring	302156	1284076	53.5	430	Log	Unknown	GEI	9/10/1992	HSA	Yes	6	15	53.5	38
B-5-92	B-5	Boring	302637	1284280	9	417	Log	Unknown	GEI	9/10/1992	HSA	No	1.5	9	--	None
B-6-92	B-6	Boring	302562	1284488	38.5	410	Log	Unknown	GEI	9/9/1992	HSA	Yes	6.5	38.5	--	9
B-7-92	B-7	Boring	302712	1284659	44	414	Log	Unknown	GEI	9/9/1992	HSA	Yes	4	44	--	11
B-8-92	B-8	Boring	302333	1284498	6.5	415	Log	Unknown	GEI	9/23/1992	HSA	No	1.5	6.5	--	None
B-9-92	B-9	Boring	302115	1284593	9	408	Log	Unknown	GEI	9/11/1992	HSA	No	4	9	--	None
B-10-92	B-10	Boring	302360	1285168	32.5	424	Log	Unknown	GEI	9/14/1992	HSA	No	1.5	32.5	--	None
B-11-92	B-11	Boring	303028	1285093	9	431	Log	Unknown	GEI	9/11/1992	HSA	No	2	9	--	None
B-12-92	B-12	Boring	303275	1285449	9	428	Log	Unknown	GEI	9/11/1992	HSA	No	6.5	9	--	None
B-8-91	B-8	Boring	--	--	25	339	Log	Unknown	SW	8/21/1991	HSA	No	11.5	--	25	16
B-9-91	B-9	Boring	--	--	31	344	Log	Unknown	SW	8/21/1991	HSA	No	19	31	28	16.5
B-23-92	B-23	Boring	--	--	35.8	337	Log	Unknown	SW	5/14/1992	HSA	No	4	35.8	7	None
B-24-92	B-24	Boring	--	--	50.5	337	Log	Unknown	SW	5/29/1992	HSA	No	7	40.5	--	None
B-29-92	B-29	Boring	--	--	60.5	361	Log	Unknown	SW	5/21/1992	HSA	No	25.5	58	60.5	27
H-45-62	H-45	Boring	302833	1284963	23.6	427	Log	Unknown	WSDOT	4/18/1962	HSA	No	--	22	23.5	22
H-46-62	H-46	Boring	302834	1285308	47.5	431.5	Log	Unknown	WSDOT	4/19/1962	HSA	No	--	30	42.5	41
H-47-62	H-47	Boring	--	--	32.5	427	Log	Unknown	WSDOT	4/19/1962	HSA	No	--	27	32.5	15
H-7-62	H-7	Boring	300178	1281911	40.1	328	Log	Unknown	WSDOT	5/18/1962	Unknown	No	--	40.1	--	1
H-8-62	H-8	Boring	300194	1281951	35	330	Log	Unknown	WSDOT	5/1/1962	Unknown	No	--	35	--	2.5
H-9-62	H-9	Boring	300135	1281855	35	328	Log	Unknown	WSDOT	5/25/1962	Unknown	No	--	35	--	3
H-61-62	H-61	Boring	300360	1281924	22.5	346	Log	Unknown	WSDOT	5/2/1961	HSA	No	--	22.5	--	None
H-62-62	H-62	Boring	300302	1281911	19	339	Log	Unknown	WSDOT	5/2/1962	HSA	No	--	19	--	10
H-63-62	H-63	Boring	300412	1282057	22.5	340	Log	Unknown	WSDOT	5/2/1962	HSA	No	5	22.5	--	11
H-64-62	H-64	Boring	300271	1282028	18.2	339	Log	Unknown	WSDOT	5/2/1962	HSA	No	--	18.2	--	11
BH-1-95	BH-1	Boring	302740	1284228	21.5	414.3	Log	Unknown	HWA	6/19/1995	HSA	No	6	8.5	17.5	None
BH-2-95	BH-2	Boring	302888	1284369	21.5	412.1	Log	Unknown	HWA	6/21/1995	HSA	No	13.5	21.5	--	13.5
BH-3-95	BH-3	Boring	302330	1284126	41.5	431.9	Log	Unknown	HWA	6/19/1995	HSA	No	--	22	22	35
BH-4-95	BH-4	Boring	302432	1284326	51	420.2	Log	Unknown	HWA	6/21/1995	HSA	No	4.5	13	43.5	30
BH-5-95	BH-5	Boring	302568	1284513	26.5	409.3	Log	Unknown	HWA	6/19/1995	HSA	No	7	26.5	--	16.5
BH-6-95	BH-6	Boring	302709	1284558	26.5	409.4	Log	Unknown	HWA	6/19/1995	HSA	No	7	17	22.5	7.5
BH-7-95	BH-7	Boring	302389	1284242	51	423.1	Log	Unknown	HWA	6/21/1995	HSA	No	4.5	23.5	51	34
BH-8-95	BH-8	Boring	302841	1284840	51.5	422	Log	Unknown	HWA	6/22/1995	HSA	No	4.5	33.5	51.5	35
BH-9-95	BH-9	Boring	302933	1284992	25.5	413	Log	Unknown	HWA	6/20/1995	HSA	No	--	25.5	--	None
BH-10-95	BH-10	Boring	303060	1285248	26	417.1	Log	Unknown	HWA	6/22/1995	HSA	No	--	19	26	None
BH-11-95	BH-11	Boring	303092	1285137	30.5	430.6	Log	Unknown	HWA	6/20/1995	HSA	No	--	13	30.5	None
BH-12-95	BH-12	Boring	303188	1285411	20.5	414.7	Log	Unknown	HWA	6/22/1995	HSA	No	--	20.5	--	None
BH-13-95	BH-13	Boring	302767	1283698	21	422	Log	Unknown	HWA	11/3/1995	HSA	No	--	21	--	None
BH-14-95	BH-14	Boring	302874	1284561	21.5	411	Log	Unknown	HWA	11/2/1995	HSA	No	9	--	21.5	6
BH-15-95	BH-15	Boring	302911	1284876	20.5	424	Log	Unknown	HWA	11/2/1995	HSA	No	--	20.5	--	None
BH-16-95	BH-16	Boring	302872	1285068	30.5	426	Log	Unknown	HWA	11/2/1995	HSA	No	--	23	28	None
BH-17-95	BH-17	Boring	303085	1285352	21	405	Log	Unknown	HWA	11/2/1995	HSA	No	--	12.5	21	18.5
BH-18-95	BH-18	Boring	302578	1284702	26	419.5	Log	Unknown	HWA	11/10/1995	HSA	No	7	22.5	26	22
BH-19-95	BH-19	Boring	302647	1284803	31	422.5	Log	Unknown	HWA	11/10/1995	HSA	No	7	31	--	30 seep

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Table B-1 - Summary of Historical Explorations

ID on Figure B-1	Exploration ID	Exploration Type	Northing (a)	Easting (a)	Exploration Depth in Feet	Elevation in Feet	Elevation Source	Elevation Datum	Exploration Log Author (b)	Exploration Date	Exploration Method	Well Installed	Bottom of Fill Depth in Feet	Bottom of Till Depth in Feet	Bottom of Sand Depth in Feet	Depth to Water ATD in Feet
BH-20-96	BH-20	Boring	302732	1284662	80.5	415.5	Log	Unknown	HWA	3/20/1996	Mud Rotary	No	6.5	24	65-80.5	67?
BH-501-99	BH-501	Boring	302964	1284693	18	412	Log	Unknown	HWA	3/29/1999	HSA	No	11	18	--	10
BH-502-99	BH-502	Boring	302933	1284760	11	413	Log	Unknown	HWA	3/29/1999	HSA	No	7.5	11	--	None
B-4-95	B-4-95	Boring	303219	1285450	39.5	414	Log	Unknown	CivilTech	5/1/1996	HSA	No	--	23.5	39.5	22.5
B-3-95	B-3-95	Boring	303050	1285596	40	400	Log	Unknown	CivilTech	11/17/1995	HSA	No	3	20.5	40	20.5
B-5-95	B-5-95	Boring	303320	1285580	25	411	Log	Unknown	CivilTech	5/1/1996	HSA	No	--	17	25	17
B-1-06	B-1	Boring	--	--	51.5	437	Log	Unknown	Landau	2/13/2006	HSA	No	27.5	51.5	--	34
B-2-06	B-2	Boring	--	--	29.5	438	Log	Unknown	Landau	2/13/2006	HSA	No	19	29.5	--	None
BH-01-99	BH-01	Boring	--	--	33.5	335	Log	Unknown	HWA	10/25/1999	HSA	No	6.5	26	33.5	26
BH-02-99	BH-02	Boring	--	--	46	338	Log	Unknown	HWA	10/25/1999	HSA	No	--	35	41	35
BH-03-99	BH-03	Boring	--	--	60.4	344	Log	Unknown	HWA	11/17/1999	HSA	No	6.5	33	60.4	33
BH-04-99	BH-04	Boring	--	--	60.75	351	Log	Unknown	HWA	11/16/1999	HSA	No	3	48?	60.75	38
BH-05-99	BH-05	Boring	--	--	50.75	362	Log	Unknown	HWA	10/26/1999	HSA	No	19	38	50.75	28
BH-11-99	BH-11	Boring	--	--	31.5	356	Log	Unknown	HWA	5/22/2008	HSA	No	12.5	31	--	None
BH-12-99	BH-12	Boring	--	--	41.5	350	Log	Unknown	HWA	5/22/2008	HSA	No	5	--/25/35	12/30/41.5	9
BH-13-99	BH-13	Boring	--	--	41.5	349	Log	Unknown	HWA	5/23/2008	HSA	No	--	10/35	20/41.5	12.5
B-1-08	B-1	Boring	--	--	21.5	--	--	--	Riley	1/7/2008	HSA	No	--	21.5	--	4 seep
B-2-08	B-2	Boring	--	--	12.5	--	--	--	Riley	1/7/2008	HSA	No	--	12.5	--	None
B-1-78	B-1	Boring	--	--	19.3	395	Log	Unknown	EC	2/24/1978	HSA	No	9.3	19.3	--	8
B-2-78	B-2	Boring	--	--	20	395	Log	Unknown	EC	2/24/1978	HSA	Yes	10.5	20	--	8 ATD
B-3-78	B-3	Boring	--	--	15	400	Log	Unknown	EC	2/27/1978	HSA	No	7	15	--	6
B-1-03	B-1	Boring	--	--	19	432	Log	Unknown	ZZA	2/13/2003	HSA	No	3.5	19	--	None
B-2-03	B-2	Boring	--	--	23.5	436	Log	Unknown	ZZA	2/13/2003	HSA	No	4.5	23.5	--	None
B-3-03	B-3	Boring	--	--	18	434	Log	Unknown	ZZA	2/13/2003	HSA	No	1.5	18	--	None
B-4-03	B-4	Boring	--	--	19	420	Log	Unknown	ZZA	2/13/2003	HSA	No	1	19	--	None
B-5-03	B-5	Boring	--	--	18.5	419	Log	Unknown	ZZA	2/13/2003	HSA	No	1.5	18.5	--	None
B-6-03	B-6	Boring	--	--	14	443	Log	Unknown	ZZA	2/13/2003	HSA	No	1.5	14	--	None
B-1-99	B-1	Boring	--	--	16	450	Log	Unknown	DODDS	9/28/1999	HSA	No	6	16	--	None
B-2-99	B-2	Boring	--	--	16	449	Log	Unknown	DODDS	9/28/1999	HSA	No	8	16	--	None
B-3-99	B-3	Boring	--	--	16.5	447	Log	Unknown	DODDS	9/28/1999	HSA	No	9	16.5	--	None
B-4-99	B-4	Boring	--	--	10.5	429	Log	Unknown	DODDS	9/28/1999	HSA	No	--	10.5	--	None
B-5-99	B-5	Boring	--	--	10.5	429	Log	Unknown	DODDS	9/28/1999	HSA	No	--	10.5	--	None
B-6-99	B-6	Boring	--	--	9	433	Log	Unknown	DODDS	9/28/1999	HSA	No	--	9	--	None
MW-1-93	71946	MW	301099	1281535	12.5	--	--	--	McG	6/18/1993	HSA	Yes	2	12.5	--	9
MW-1-94	R26153	MW	301675	1281838	15	--	--	--	CGI	5/9/1994	HSA	Yes	--	23	--	4
MW-1-90a	22726	MW	301390	1281808	19	--	--	--	G&D	1/22/1990	HSA	Yes	12	19	--	10
MW-1-90b	40671	MW	301830	1281905	28	--	--	--	G&D	4/18/1990	HSA	Yes	--	28	--	--
MW-1-99	43124	MW	302927	1283642	55	--	--	--	EWE	2/18/1999	Unknown	Yes	--	40	55	45

Notes:
-- = Data not available.
HSA = Hollow-Stem Auger.
a = Coordinates are from GeoMapNW.com database.
b = Authors are identified below.
G&D = Geoboring and Development.
McG = McGarret Drilling, Inc.

b = Authors continued:
CGI = Cascade Geotecnical, Inc.
EWE = Environmental West Explorations
DODDS = DODDS Geosciences, Inc.
HWA = Hong West Associates
SW = Shannon & Wilson, Inc.

b = Authors continued:
WSDOT = Washington State Department of Transportation.
CivilTech = CivilTech Corporation.
Riley = The Riley Group, Inc.
Landau = Landau Associates.
EC = Earth Consultants, Inc.

b = Authors continued:
GEI = GeoEngineers, Inc.
ZZA = Zipper Zeman Associates, Inc.

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Lynnwood City Center Soil Permeability Study
Lynnwood, WA

Historical Boring Locations

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Figure
B-1

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APPENDIX C
LABORATORY TESTING PROGRAM

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APPENDIX C
LABORATORY TESTING PROGRAM

A laboratory testing program was performed to evaluate the basic index and geotechnical engineering properties of the site soils. The tests performed and the procedures followed are outlined below.

Soil Classification

Ten soil samples from the explorations were visually classified in the field and then taken to our laboratory, where the classifications were verified in a relatively controlled environment. Field and laboratory observations include density/consistency, moisture condition, and grain size estimates.

The classifications of selected samples were verified with laboratory tests, including grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure C-1.

Water Content Determinations

Water contents were determined for most of the samples recovered from the explorations in general accordance with ASTM D 2216, as soon as possible following their arrival in our laboratory. The results of the water content tests are plotted at the respective sample depth on the exploration logs.

Grain Size Analysis (GS)

Grain size distribution was analyzed on representative samples in general accordance with ASTM D 422. Wet sieve analysis was used to determine the size distribution greater than the U.S. No. 200 mesh sieve. The results of the tests are presented as curves on Figures C-2 through C-5 plotting percent finer by weight versus grain size.

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GRAIN SIZE ANALYSIS

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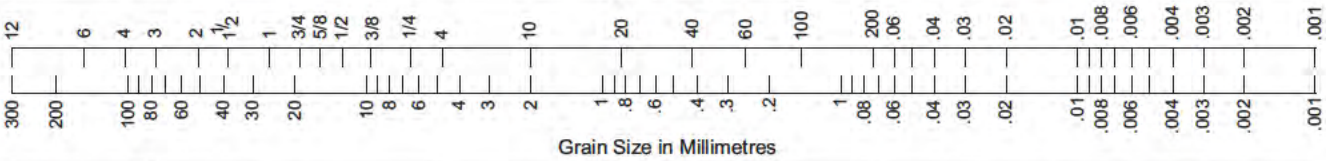
Unified Soil Classification (USC) System
Soil Grain Size

Size of Opening In Inches	Number of Mesh per Inch (US Standard)	Grain Size in Millimetres



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines	*	GRAVEL with >12% fines		Clean SAND <5% fines	*	SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)$ >4 for G W, >6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

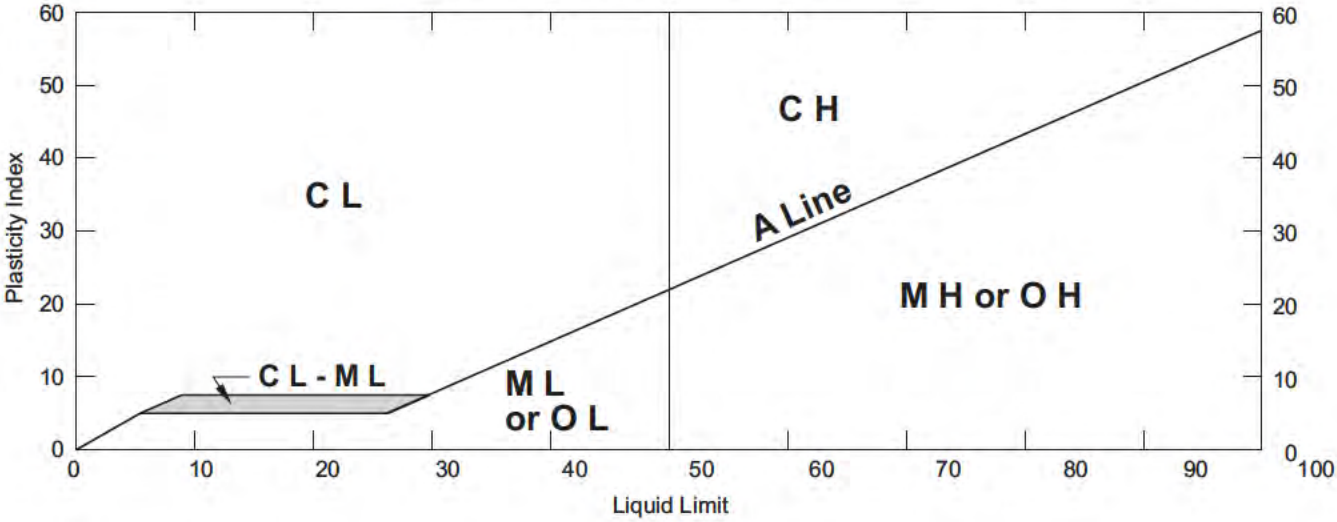


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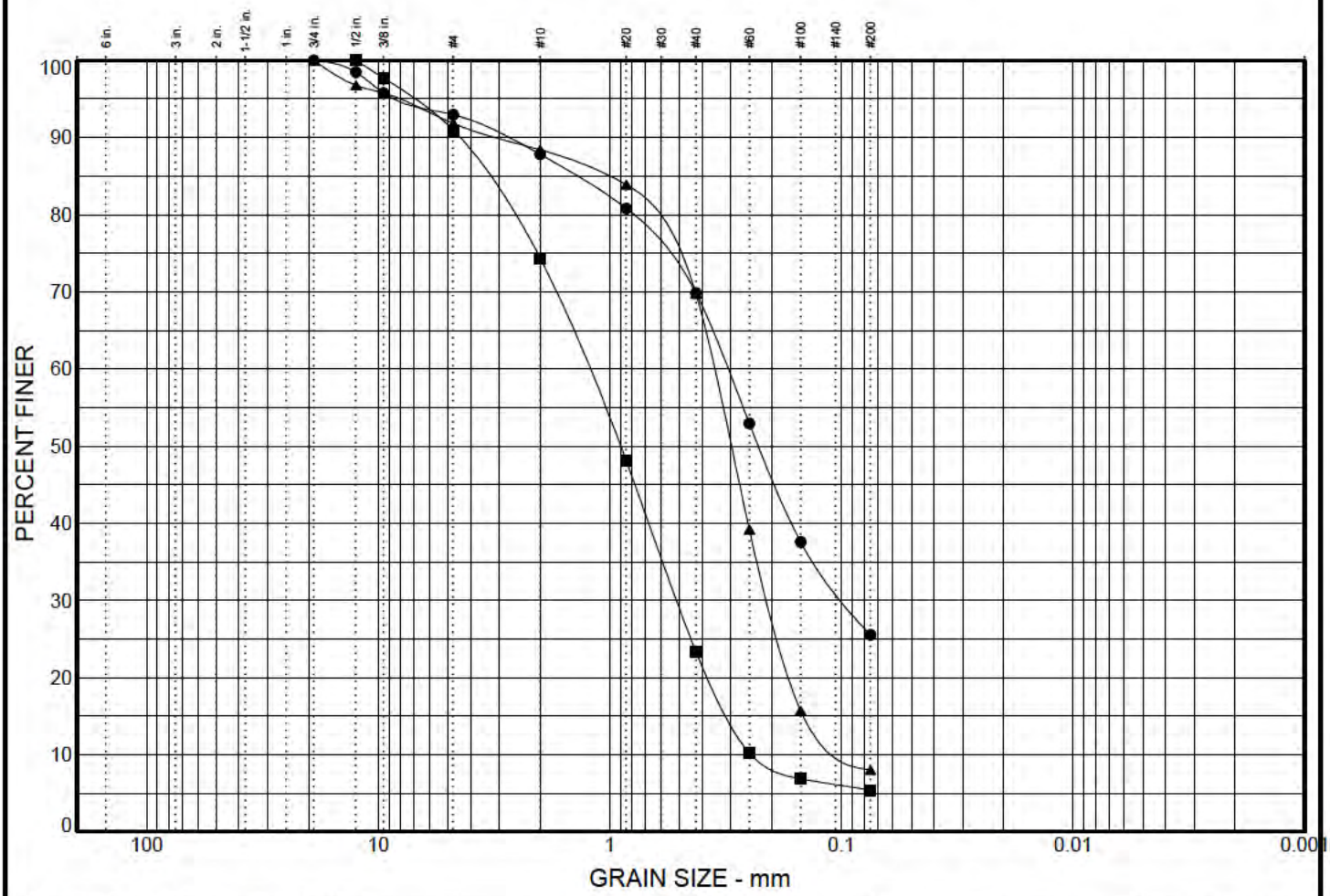
Figure C-1

SRF Grain Size (B-1).cdr 3/06

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	7.0	67.4	25.5	
■	0.0	9.0	85.5	5.4	
▲	0.0	8.2	83.8	8.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			1.417	0.312	0.227	0.097				
■			3.482	1.253	0.904	0.512	0.303	0.241	0.87	5.20
▲			1.049	0.359	0.302	0.205	0.141	0.09	1.30	4.00

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly gravelly, silty SAND	SM	16.5%
■ slightly silty, slightly gravelly SAND	SP-SM	12.0%
▲ slightly silty, slightly gravelly SAND	SP-SM	18.1%

Remarks:

●

■

▲ Description and Classification based on grain size test results only.

Project: Lynnwood Permeability Study

Client:

● Source: HCB- 1 Sample No.: S-38A Depth: 16.0 to 17.3
■ Source: HCB- 2 Sample No.: S-50 Depth: 32.5 to 33.8
▲ Source: HCB- 4 Sample No.: S-10 Depth: 45.0 to 46.3

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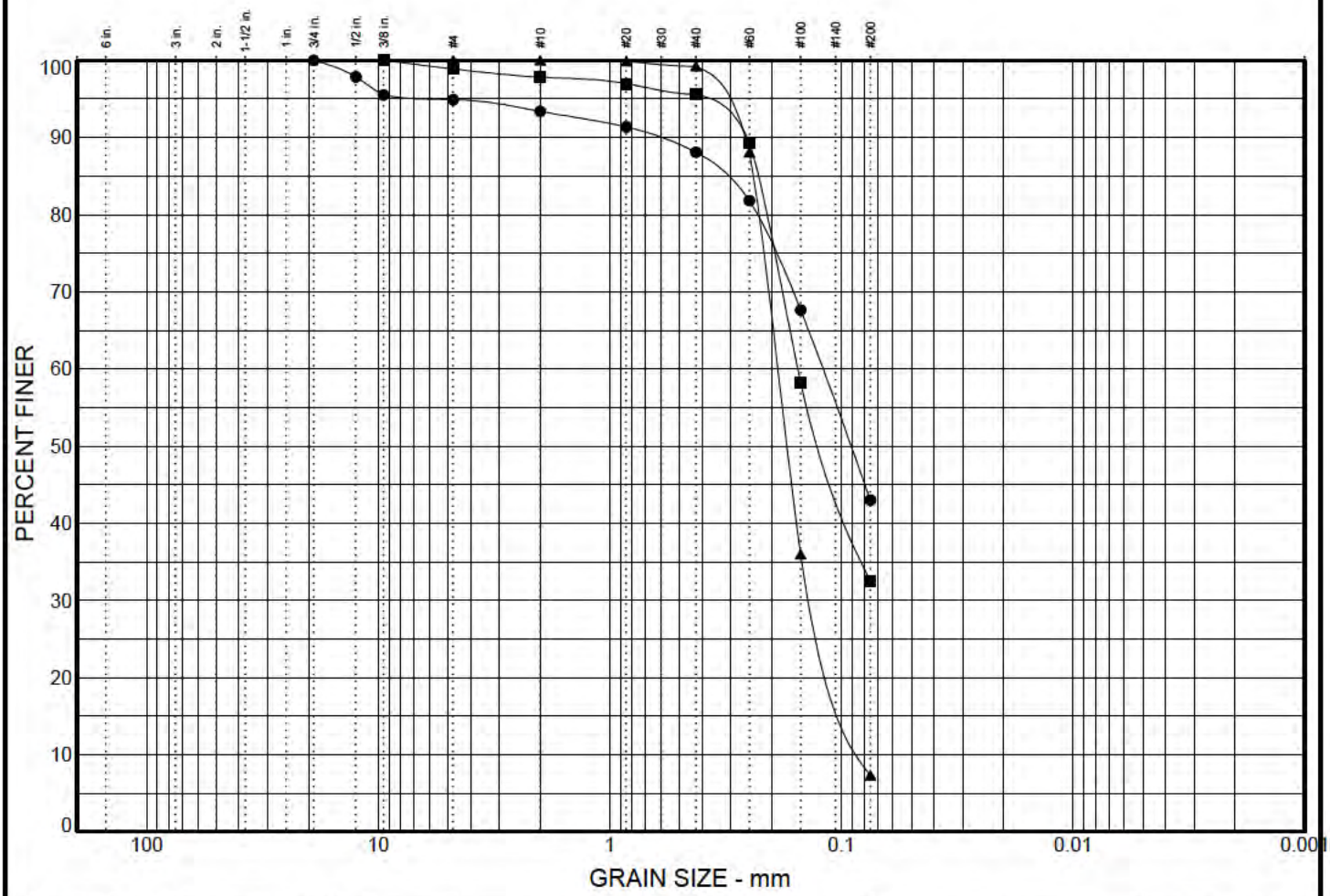
Figure C-2

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	5.1	51.9	43.0	
■	0.0	1.1	66.4	32.5	
▲	0.0	0.0	92.7	7.3	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.327	0.121	0.091					
■			0.233	0.154	0.12					
▲			0.243	0.19	0.172	0.13	0.09	0.08	1.11	2.37

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly gravelly, very silty SAND	SM	17.9%
■ very silty SAND, trace gravel	SM	14.4%
▲ slightly silty SAND	SP-SM	23.9%

Remarks:

●

■ Description and Classification based on grain size test results only.

▲ Description and Classification based on grain size test results only.

Project: Lynnwood Permeability Study

Client:

● Source: HCB- 5 Sample No.: S-15 Depth: 20.0 to 20.5
■ Source: HCB- 9 Sample No.: S-10A Depth: 45.0 to 45.5
▲ Source: HCB- 9 Sample No.: S-10B Depth: 45.4 to 45.9

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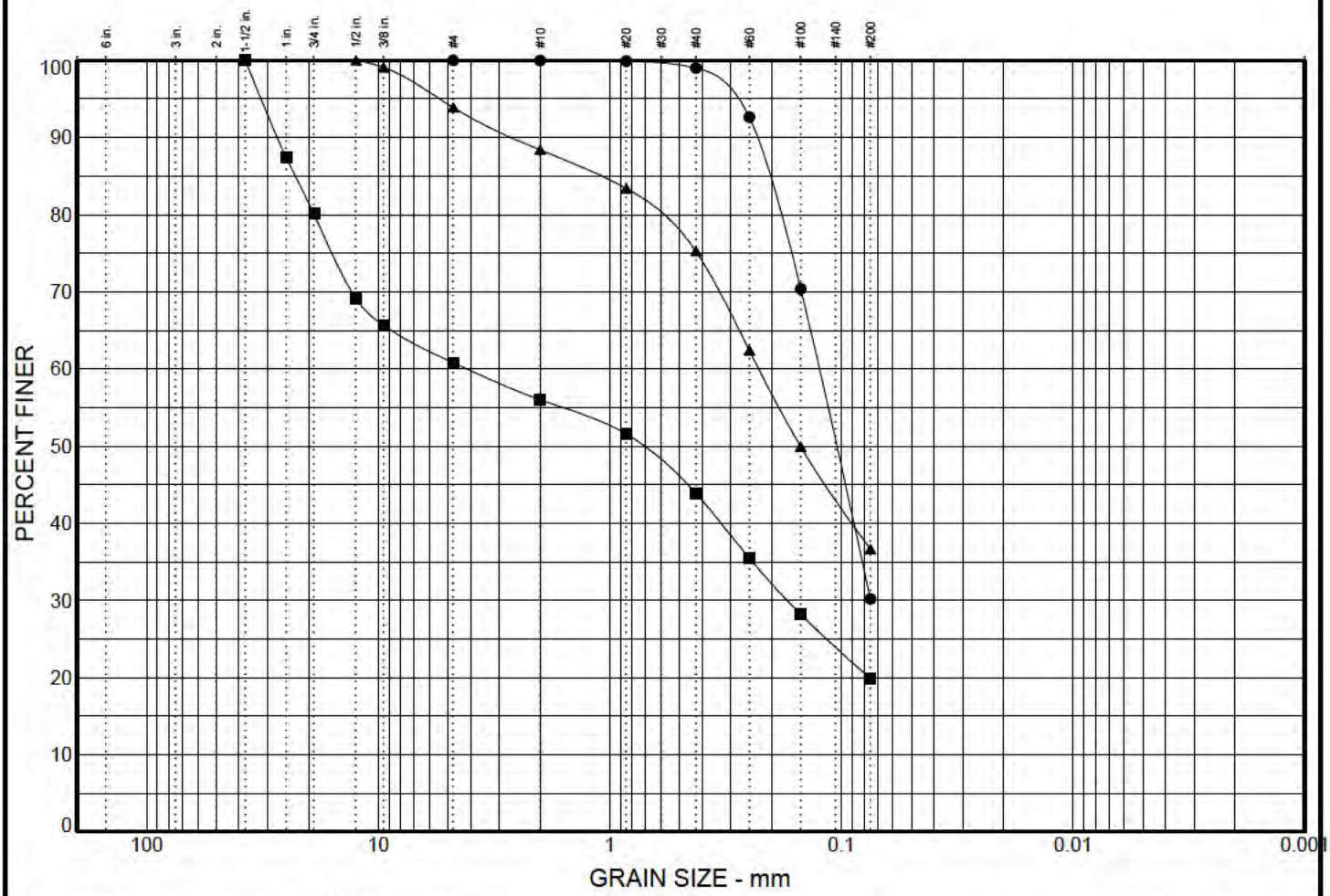
Figure C-3

GRAIN SIZE 1785500-GS.GPJ HC_CORP.GDT 7/5/12

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.0	69.8	30.2	
■	0.0	39.2	40.9	19.9	
▲	0.0	6.1	57.2	36.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.21	0.125	0.106					
■			22.807	4.098	0.738	0.17				
▲			1.118	0.226	0.15					

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● very silty SAND	SM	22.9%
■ silty, very gravelly SAND	SM	9.3%
▲ slightly gravelly, very silty SAND	SM	13.0%

Remarks:

● Description and Classification based on grain size test results only.

■ Description and Classification based on grain size test results only.

▲ Description and Classification based on grain size test results only.

Project: Lynnwood Permeability Study

Client:

● Source: HCB-10 Sample No.: S-11 Depth: 47.5 to 49.0
■ Source: HCB-11A Sample No.: S-2 Depth: 10.0 to 11.5
▲ Source: HCB-11A Sample No.: S-3 Depth: 12.5 to 14.0

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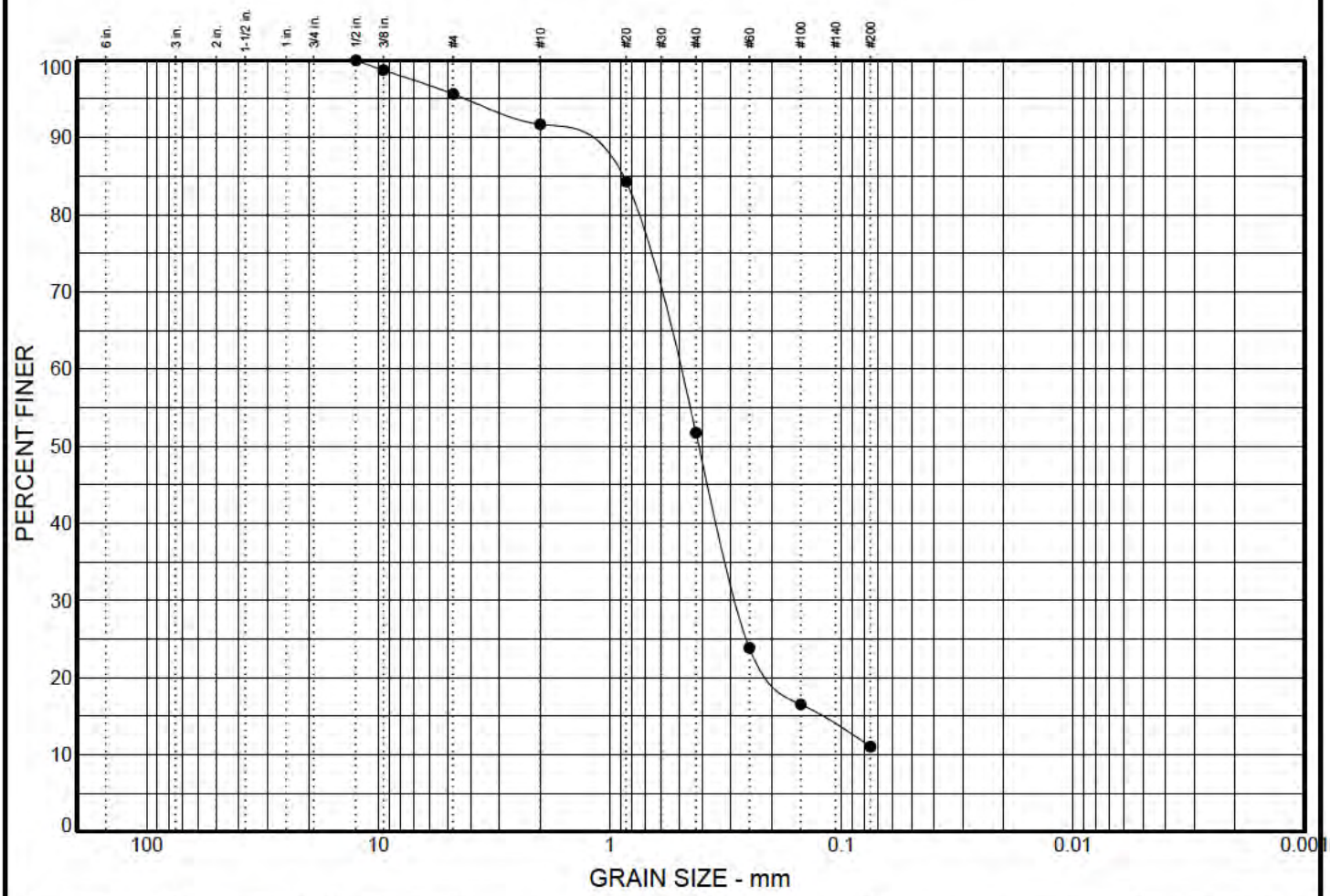
Figure C-4

GRAIN SIZE 1785500-GS.GPJ HC_CORP.GDT 7/5/12

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	4.4	84.6	11.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.924	0.507	0.411	0.281	0.123		2.38	7.74

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly silty SAND, trace gravel	SP-SM	8.3%

Remarks:

● Description and Classification based on grain size test results only.

Project: Lynnwood Permeability Study

Client:

● Source: HCB-12 Sample No.: S-4 Depth: 17.5 to 19.0

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Figure C-5

GRAIN SIZE 1785500-GS.GPJ HC_CORP.GDT 7/5/12

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