October 17, 2014

Clark County Public Works
Attention: Ken Lader
P.O. Box 9810
Vancouver, WA 98666-9810

Re: Infiltration Study
NE 94th Avenue: NE Padden Parkway to NE 99th Street (CRP #350822)
Clark County, Washington
15915-08

Dear Mr. Lader:

Introduction

Project Understanding

This report summarizes the results of our infiltration study for the NE 94th Avenue road improvement project located in unincorporated Clark County, Washington.

This project includes improvements to NE 94th Avenue between NE Padden Parkway to the south and NE 99th Street to the north, such as installation of curbs, gutters, and roadside landscaping. Stormwater improvements will consist of a series of rain gardens and planter strips.

The general location of the project is shown on the Vicinity Map (Figure 1) and the relevant limits of our work area are shown on the Site Plan (Figure 2). Attachment A presents boring logs of the explorations we conducted for this study. Attachment B presents results of our geotechnical laboratory testing program.

This report specifically addresses the infiltration capacity of the site soils. Other items such as earthwork, pavement design, etc., were not part of our work. The recommendations were developed in accordance with Task Order #4 of our County geotechnical on-call contract (No. 664123).

Purpose

The purpose of our work is to provide Clark County Public Works with recommendations related to the design and construction of the infiltration systems for the NE 94th Avenue road improvements project. We present our descriptions, conclusions, and recommendations in the following sections of this report.

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Vancouver, Washington 98660-2927
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Scope of Work

Our scope of work is outlined in our scope and fee estimate provided with Task Order #4 (dated April 4, 2014), and generally includes the following:

- Completed a field exploration program consisting of seven soil borings, installation of two monitoring wells, and completion of eight infiltration tests;
- Collected groundwater level readings in the monitoring wells;
- Completed a limited laboratory testing program;
- Evaluated infiltration characteristics of the site soils; and
- Prepared a draft report (dated July 2, 2014) for your review.
- Prepared this final report summarizing our findings and recommendations.

Use of this Report

This report is for the exclusive use of Clark County Public Works and their design consultants for specific application to the subject project and site. We completed this work in accordance with generally accepted geotechnical engineering practices for the nature and conditions of the work in the same or similar localities at the time the work was performed. We make no other warranty, express or implied.

Please note that the explorations performed for this study reveal subsurface conditions only at discrete locations across the project site, and actual conditions in other areas will vary. Furthermore, the nature and extent of any such variations would not become evident until additional explorations are performed or until construction activities have begun. If significant variations are observed at that time, we may need to modify our conclusions and recommendations accordingly to reflect site conditions.

Site Description

Surface Conditions

The project area includes an approximately 4,000-foot-long section of NE 94th Avenue between NE Padden Parkway to the south and NE 99th Street to the north. Half-width improvements are also being completed to a 540-foot-long section of the southern half of NE 99th Street to the west of NE 94th Avenue.

In the project work area, NE 94th Avenue is mostly a two-lane paved road with unpaved shoulders consisting of crushed rock and paved sidewalks. South of NE 88th Street, NE 94th Avenue is a three lane road with a center turn lane.

NE 94th Avenue is bound by residential properties and open agricultural fields along most of its length. The old Leichner landfill is located to the east of NE 94th Avenue between NE 90th and 95th Streets. Additionally, there is a church east of NE 94th Avenue and south of NE 86th Street.

The site vicinity slopes gently down from north-to-south, from approximate elevation 217 feet above mean sea level (MSL) near the intersection with NE 95th Street to approximately 213 feet MSL at the intersection with NE Padden Parkway.

Geologic and Soils Mapping

Geologic Mapping

The geology of the site is mapped in the Washington Department of Geology and Earth Resources (DGER) *Geologic Map of the Vancouver Quadrangle, Washington* (Phillips 1987). As mapped by Phillips (1987), the site is mantled by the "sand-sized" subdivision of the "Periglacial Deposits from Glacial Outburst Floods of Glacial Lake Missoula." These materials are described as "very coarse to fine sand; horizontally stratified." However, some of the shallow soils encountered during our investigation correspond more closely with the "fine-grained" subdivision of this unit, described by Phillips (1987) as "very fine sand, silt, and clay […] generally massive."

Soils Mapping

The soils at the site are mapped by the U.S. Department of Agriculture in *the Soil Survey of Clark County, Washington* (McGee 1972) as mantled by "Sifton gravelly loam, 0 to 3 percent slopes." Sifton soils are described as somewhat excessively drained, with gravelly loam that grades to very gravelly coarse sand below 16 inches.

The soil unit is classified as hydrologic soil group B, or soils with a generally moderate infiltration rate when thoroughly wet. Specifically, the upper 16 inches of the soil is estimated to have a hydraulic conductivity (permeability) of 0.6 to 2 inches per hour, while below 16 inches the estimated hydraulic conductivity increases to greater than 20 inches per hour.

Sifton soils are reported to have a cation exchange capacity (CEC) ranging from 33 to 66 meq/100g in the upper 16 inches and 0 to 5 meq/100g below 16 inches.

Subsurface Conditions

General

Our understanding of the subsurface conditions is based on our research and information collected from our field explorations completed for this project. The locations of the explorations are shown on Figure 2, and the exploration logs are included in Attachment A.

We completed seven borings (HC-1 through HC-7) along the project alignment, each to a depth 16.5 feet below ground surface (bgs). Eight *in situ* infiltration tests were performed either within or adjacent to these borings at depths of approximately 3 and 5 feet bgs. Four of the infiltration tests were completed in borings (HC-1B, HC-3B, HC-6B, and HC-7B) drilled approximately 3 to 4 feet away from the main borings.

Soils encountered in our explorations included mostly sands, gravelly sands, and slightly silty sands of the coarse-grained Glacial Outburst Flood deposits, though some veneers of fill and silty soil were occasionally encountered. Groundwater was not encountered at the time of drilling. These conditions are described in more detail below.

Asphalt and Soil

All of the borings, except HC-7, penetrated 1.5 to 8 inches of asphalt pavement. HC-7 was drilled off the pavement in an area covered with sod. Beneath these surfacings, borings HC-1, HC-2, HC-5, HC-6, and HC-7 penetrated through 1 to 4.5 feet of fill consisting of slightly silty to silty, sandy gravel and slightly gravelly to gravelly, clean to silty sand. The fill layers were loose to medium dense, with blow counts typically ranging from 8 to 19 blows per foot (bpf). No fill was encountered in borings HC-3 and HC-4. Boring HC-3 encountered a stiff silt layer with trace sand and gravel from the ground surface to approximately 4 feet bgs, while boring HC-4 encountered native gravelly soil beneath the pavement.

Below the fill and silt layers the native soils consist of trace silt to silty, gravelly, coarse sand and sandy, coarse gravel to a depth of 16.5 feet bgs, the maximum depth explored. We interpret this stratified, well-graded coarse gravel and sand as outburst deposits from the Missoula floods. The flood deposits were typically loose to medium dense, with blow counts typically ranging from 6 to 28 bpf, averaging 16 bpf.

Fifteen measured moisture contents of the flood deposits returned values ranging from 6 to 26 percent. Fourteen fines-content tests returned silt and clay content values ranging from 3 to 25 percent. Eight grain size distribution tests measured sand content ranging from 44 to 88 percent and gravel content ranging from 4 to 47 percent. Based on the laboratory testing, we have classified the soils in the proposed infiltration zone as summarized in Table 1.

Table 1 – Fines Content Test Data and Soil Classification

Sample	Fines Content	USCS Soil Type	USDA Soil Textural Classification
HC-1 @ 5 feet	8%	SP-SM (Slightly silty Sand)	Sand
HC-1B @ 3.2 feet	11%	SP-SM (Slightly silty Sand)	Sand
HC-2 @ 4 feet	9%	SP-SM (Slightly silty Sand)	Sand
HC-2 @ 7.5 feet	9%	SP-SM (Slightly silty Sand)	Sand
HC-3 @ 5 feet	25%	SM (Silty Sand)	Loamy Sand
HC-3 @ 7.5 feet	9%	SP-SM (Slightly silty Sand)	Sand
HC-4 @ 5 feet	8%	SP-SM (Slightly silty Sand)	Sand
HC-5 @ 1.5 feet	23%	SM (Silty Sand)	Loamy Sand
HC-5 @ 4 feet	6%	SP-SM (Slightly silty Sand)	Sand
HC-5 @ 7.5 feet	8%	SP-SM (Slightly silty Sand)	Sand
HC-6 @ 5 feet	9%	SP-SM (Slightly silty Sand)	Sand

Sample	Fines Content	USCS Soil Type	USDA Soil Textural Classification
HC-6 @ 7.5 feet	6%	SW-SM (Slightly silty Sand)	Sand
HC-6B @ 3.2 feet	10%	SP-SM (Slightly silty Sand)	Sand
HC-7 @ 5 feet	4%	SP (Sand)	Sand
HC-7B @ 3 feet	3%	SP (Sand)	Sand

Notes:

a. USDA Soil Textural Classification based on the assumption the percent fines distribution consists of 70 percent silt and 30 percent clay particles.

Groundwater

Groundwater was not encountered in any of the borings during drilling, which were terminated at 16.5 feet bgs. Hart Crowser field personnel read the monitoring wells at MW-1 and MW-2 on May 1, 2014 and July 2, and October 13, 2014 and did not measure water in the wells.

Groundwater mapping prepared by Clark County (Swanson and McCarley 1995) estimates that the groundwater along the project alignment is approximately 10 to 20 feet bgs, or at approximately elevation 200 feet above MSL.

Water level data collected between 1987 and the present from monitoring wells at the Leichner landfill property (SCS Engineers, 2014), which borders the central portion of the project alignment, indicates that groundwater levels by the roadway have ranged from approximately 165 to 190 feet since 1987.

A review of nearby water well logs on the Washington State Department of Ecology's (WSDOE) Well Log Viewer website (WSDOE 2014) showed nearby groundwater levels between 23 and 68 feet bgs.

Infiltration Testing

We performed eight *in-situ* infiltration tests. The tests were completed in shallow borings advanced either adjacent to the primary soil borings and within the primary borings. The infiltration tests were performed in general conformance with the methods prescribed in Section 6.6 of the *Clark County Stormwater Manual* (Clark County 2009). The unfactored, field-measured "drawdown" rates (i.e., the vertical drop in the water level with time), as well as the unfactored, calculated hydraulic conductivities (per CCSWM requirements) are shown in Table 2.

Table 2 – Infiltration Test Data

Boring	Approximate Test Depth (feet)	Field Drawdown Rate (inches/hour)	Calculated Hydraulic Conductivity (inches/hour)
HC-1B	3.2	10	1.7
HC-1	5.0	380	100
HC-2	4.0	110	21
HC-3B (see notes)	5.1	0.3	0.01
HC-4	3.5	440	120
HC-5	3.6	90	24
HC-6B	3.2	2	0.4
HC-7B	3.0	1	0.1

Notes:

a. Drawdown rates and hydraulic conductivities are unfactored values.
b. Hydraulic conductivities calculated per CCSWM Section 6.6.
c. The infiltration test at HC-3 appears to have been blocked by a cobble resulting in an invalid result.

Refer to the *Infiltration Analyses and Recommendations* section of this report for a discussion of our findings and recommendations regarding the design of infiltration systems.

Infiltration Analyses and Recommendations

We understand that rain gardens/bioswales are being proposed for treatment and disposal of stormwater along the roadway alignment. Based on our explorations, testing, and analyses, it is our opinion that this is feasible for this project. The depth to groundwater in the project vicinity is generally well over 10 below grade, which will provide the required 5 feet of separation from the base of the systems. We note that the site soils have variable infiltration capacity. However, below a depth of 3.5 feet the calculated hydraulic conductivity is typically 20 inches/hour or higher.

Based on our analysis and experience with the area soils, it is our opinion that an average unfactored hydraulic conductivity of 20 inches per hour with a minimum correction factor (CF) of 4 (base CF = 2 + soil CF = 2) can be used for design of rain gardens **with bases a minimum of 3.5 feet below grade**. This results in a **factored hydraulic conductivity of 5 inches/hour**. Additionally, the bases of the rain gardens should penetrate through pre-existing fill materials.

Due to the high variability of the test results, we recommend that confirmation testing be completed during construction to verify that the subgrade soils exposed in the bases of the infiltration systems have the anticipated infiltration characteristics. If confirmation testing indicates that locally lower than anticipated infiltration rates are present, then localized deepening of the bases of the rain gardens may be required.

We understand that the use of the native soils for treatment of the stormwater is being considered. We tested two soil samples from the upper 2.5 feet for cation exchange capacity and organic content. The results indicate an average CEC of 13.5 meq/100g and organic content of 2.4 percent. (See Attachment B for specific test results.) The designer can evaluate these results to determine what, if any, additives are required to make the native soils suitable for stormwater treatment.

Construction Observation

Satisfactory performance of the stormwater infiltration system depends to a large degree on quality of construction. Sufficient monitoring of the contractor's activities is a key part of determining that the work is completed in accordance with the construction drawings and specifications. Subsurface conditions observed during construction should be compared with those encountered during subsurface explorations. Recognition of changed conditions often requires experience; therefore, Hart Crowser or their representative should visit the site with sufficient frequency to detect whether subsurface conditions change significantly from those anticipated.

As noted above, we recommend that Hart Crowser be retained to monitor construction at the site to confirm that subsurface conditions are consistent with the site explorations and to confirm that the intent of project plans and specifications relating to infiltration system construction are being met. In particular, we recommend that the infiltration trench subgrade be observed and that confirmation infiltration testing be completed by Hart Crowser.

Sincerely,

HART CROWSER, INC.

DANIEL J. TRISLER, PE
Senior Associate, Geotechnical Engineer

TIMOTHY W. BLACKWOOD, PE, LEG
Principal, Geotechnical Engineer

Attachments:
Figure 1 – Vicinity Map
Figure 2 – Exploration Plan
Attachment A – Field Explorations
Attachment B – Laboratory Testing

References

Clark County 2009. *Clark County Stormwater Manual*, November 2009.

McGee, D.A. 1972. *Soil Survey of Clark County, Washington*: U.S. Department of Agriculture Soil Conservation Service, 288p, 64 plates.

Phillips, W.M. 1987. *Geologic Map of the Vancouver Quadrangle, Oregon and Washington*: Washington Division of Geology and Earth Resources, Open File Report 87-10, 32 pp., 1 plate, 1:100,000 scale.

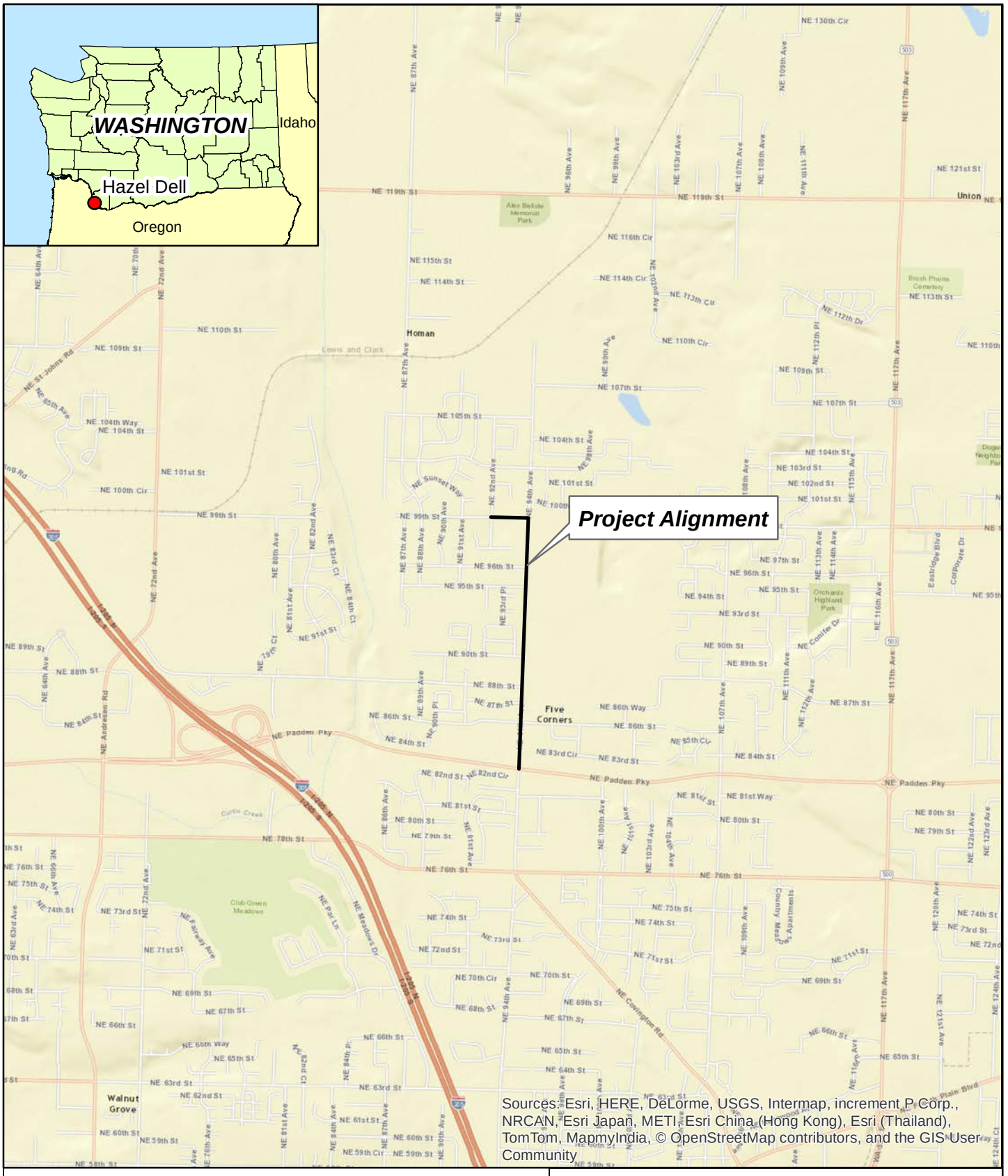
Evarts, R.C. and O'Connor, J.E. 2008. *Geologic Map of the Camas Quadrangle, Clark County, Washington, and Multnomah County, Oregon:* U.S. Geological Survey Scientific Investigations Map 3017, 31 pp., 1:24,000 scale.

SCS Engineers 2014. *2013 Fourth Quarter and Annual Report, Closed Leichner Landfill, Vancouver, Washington, Consent Decree 96-2-03081-7, Facility ID No. 1017,* dated February 27, 2014.

Swanson, R.D. and C. McCarley 1995. *Southwest Clark County Generalized Water Table Altitude and Depth to Groundwater Mapping*, Clark County Water Quality Division, September 1995.

Washington State Department of Ecology (WSDOE) 2014. *Washington State Well Log Viewer*: http://apps.ecy.wa.gov/welllog/.

WSDOE 2012. *2012 Stormwater Management Manual for Western Washington,* August 2012. WSDOE – Water Quality Program, Publication No. 12-10-030.



0 1,000 2,000 4,000 Feet

N

NE 94th Avenue: NE Padden Parkway to NE 99th Street
Clark County, Washington

Vicinity Map

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Figure 1

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Sources: Aerial photograph from ArcGIS Online, 2014

Approximate Exploration Location and Number

MW-1 ● Monitoring Well

HC-1 ⊕ Boring

Proposed Planter Strip

Proposed Rain Gardens

N

0 300 600

Scale in Feet

NE 94th Avenue: NE Padden Parkway to NE 99th Street
Clark County, Washington

Site Plan

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Figure
2

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ATTACHMENT A
Field Explorations

ATTACHMENT A

Field Explorations and Testing

This attachment documents the processes Hart Crowser used to determine the nature (and quality) of the soil and groundwater underlying the project site addressed by this report. The discussion includes information on the following subjects:

- Explorations and their Location;
- Hollow-Stem Auger Borings; and
- Standard Penetration Test (SPT) Procedures.

Explorations and their Location

Subsurface explorations for this project include seven geotechnical borings HC-1 through HC-7, and four infiltration test borings HC-1B, HC-3B, HC-6B, and HC-7B (drilled adjacent to the geotechnical borings approximately 3 to 4 feet way). The exploration logs in this attachment show our interpretation of the drilling, 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.

Figure 2 shows the location of explorations, located using a steel tape measuring from existing physical features. The method used determines the accuracy of the location and elevation of the explorations.

Hollow-Stem Auger Borings

Seven borings designated HC-1 through HC-7 and the adjacent infiltration borings were drilled between April 14, 2014 and April 17, 2014, using a 4-1/4-inch inside diameter (ID), 8-inch outside diameter (OD), hollow-stem auger advanced with a truck-mounted drill rig subcontracted by Hart Crowser. The drilling was continuously observed by a geotechnical engineer from Hart Crowser. Detailed field logs were prepared of each boring. Using the SPT sampler, we obtained samples at 2.5- to 5-foot-depth intervals.

Soil samples were collected by standard penetration test sampler or hand-auger below the infiltration tests. Below the infiltration test at HC-5 (sample S-2) soil was not recovered. The soil cuttings near sample S-2 appeared to be consistent with the sample taken at S-3; therefore, sample S-3 was assumed to be representative of the soil below the infiltration test at HC-5.

The boring logs are presented on Figures A-2 and A-4 through A-9 at the end of this attachment.

Standard Penetration Test (SPT) Procedures

This test is an approximate measure of soil density and consistency. To be useful, the results must be used with engineering judgment in conjunction with other tests. The SPT (as described in ASTM D 1586) was used to obtain disturbed samples. This test employs a standard 2-inch outside diameter split-spoon sampler. Using a 140-pound auto-hammer, free-falling 30 inches, the sampler is driven into the soil for 18 inches. The number of blows required to drive the sampler the last 12 inches only 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 plotted on the boring logs at their respective sample depths.

Soil samples are recovered from the split-barrel sampler, field classified, and placed into watertight bags. They are then taken to Hart Crowser's laboratory for further testing.

Infiltration Test Procedures

We completed eight infiltration tests in general accordance with the Clark County Stormwater Manual (CCSWM) (Clark County 2009) and the applicable sections of the Stormwater Management Manual for Western Washington (WSDOE 2012) referenced by the CCSWM. The infiltration tests were completed in borings located at or adjacent to our "exploration" borings HC-1 through HC-7. Infiltration borings are designated with a "B" after the adjacent exploration boring (e.g. HC-1B). Soil sampling below the infiltration depth was conducted in the appropriate exploration boring.

The tests were completed using two methods:

Method 1: Infiltration tests were performed in exploration borings HC-1, HC-2, HC-4, and HC-5 by advancing the hollow-stem auger to the testing depth, ranging from 3.2 to 5 feet bgs. After removing the inner plug from the auger, the hole was filled with approximately 12 inches of water and was allowed to drain. After 10 minutes, if the auger was not dry, we used Method 2 for the infiltration test. If the water did drain in under 10 minutes, this procedure was repeated three to four times to soak the bottom of the hole. We filled the hole with 12 inches of water and recorded the time it took for the hole to completely drain several time until we obtained consistent readings.

Method 2: Infiltration tests were conducted in adjacent infiltration borings HC-1B, HC-3B, HC-6B, and HC-7B by placing a 4-inch diameter PVC pipe into the boring at the selected depths, ranging from 3 to 5.1 feet bgs. The pipes were embedded approximately 1 to 3 inches into the underlying soil to reduce the potential for water loss around the annulus. The pipes were filled with water and allowed to infiltrate overnight to saturate the soil.

We returned to the site the following day and refilled the pipes to 12 inches above the bottom of the hole. If at the time we arrived the water level in the pipe was still more than 12 inches above the bottom of the hole, the infiltration test was performed at the current water level. The drop in water level was then measured for a minimum of 3 hours.

The collected data were used to calculate the coefficient of permeability at each test location. The field measured drawdown rates and calculated coefficients of permeability are summarized in Table 2.

Water Level Measurement

Water levels in the monitoring wells were measured using an electronic water level probe graduated in 0.01-foot increments. Water level readings were taken on May 1, July 2, and October 13, 2014 at MW-1 and MW-2 and no water was detected in the wells.

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
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE			GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		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
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE			SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		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

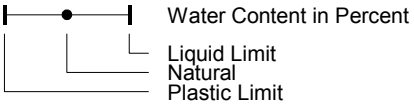
Moisture

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



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

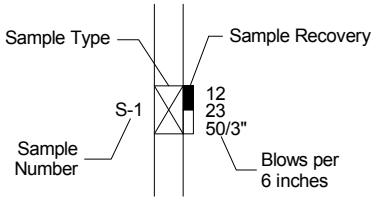


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Figure A-1

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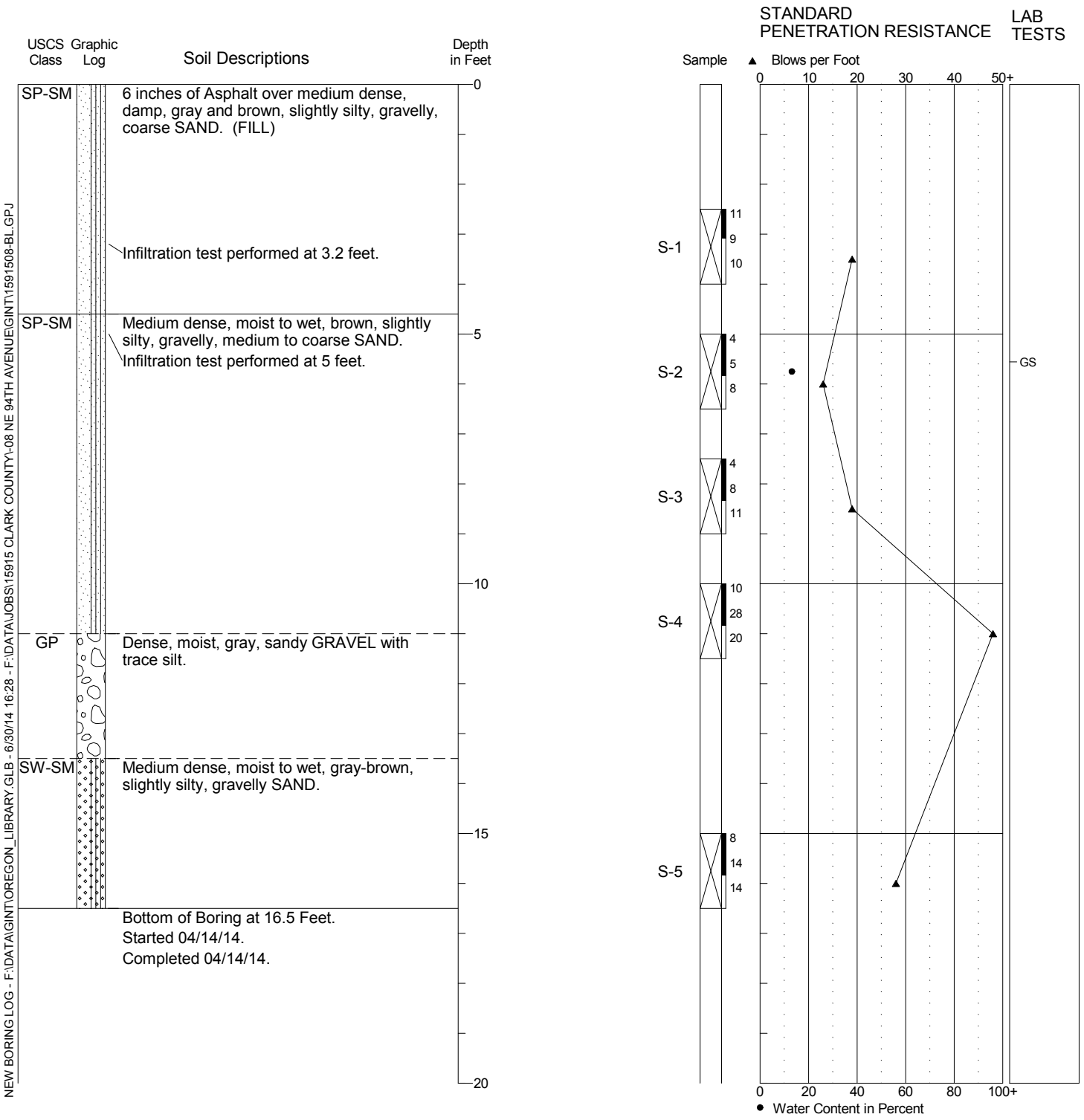
Boring Log HC-1

Location:
Approximate Ground Surface Elevation: 209 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



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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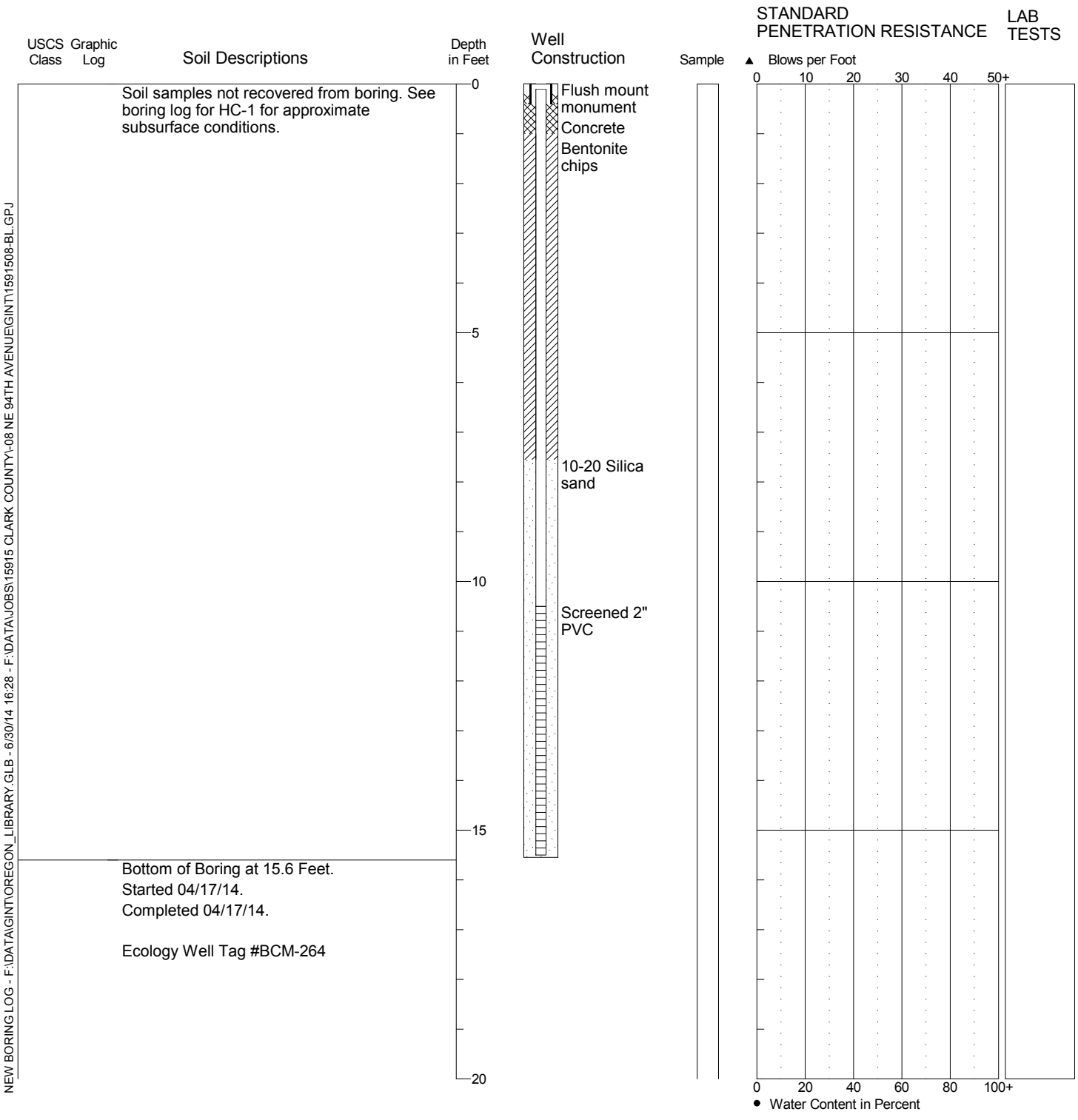
Figure A-2

Monitoring Well Log MW-1

Location:
Approximate Ground Surface Elevation: 208 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



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

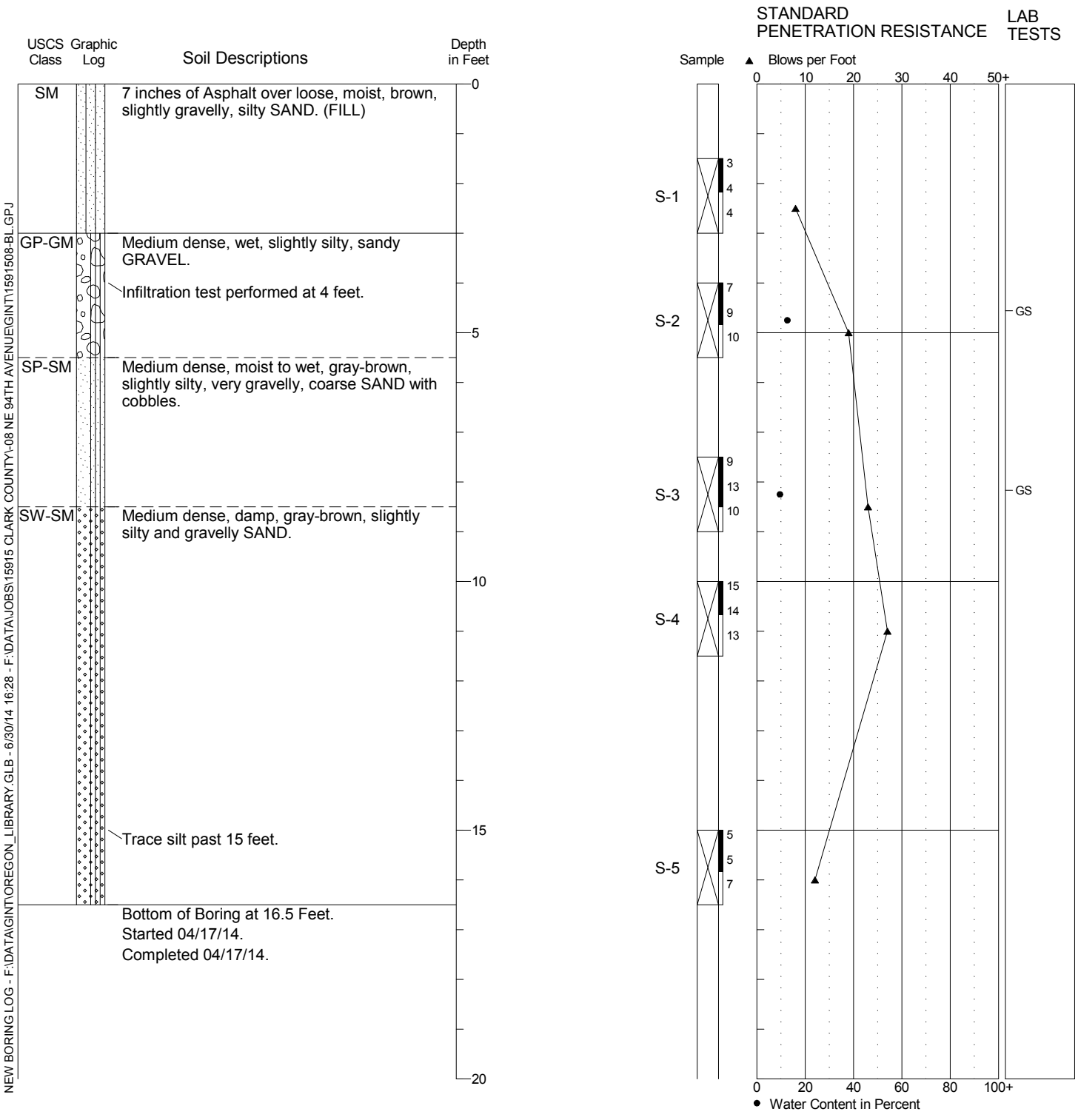
15915-08 ***7/14***

Figure A-3

Boring Log HC-2

Location:
Approximate Ground Surface Elevation: 206 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



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.
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HARTCROWSER

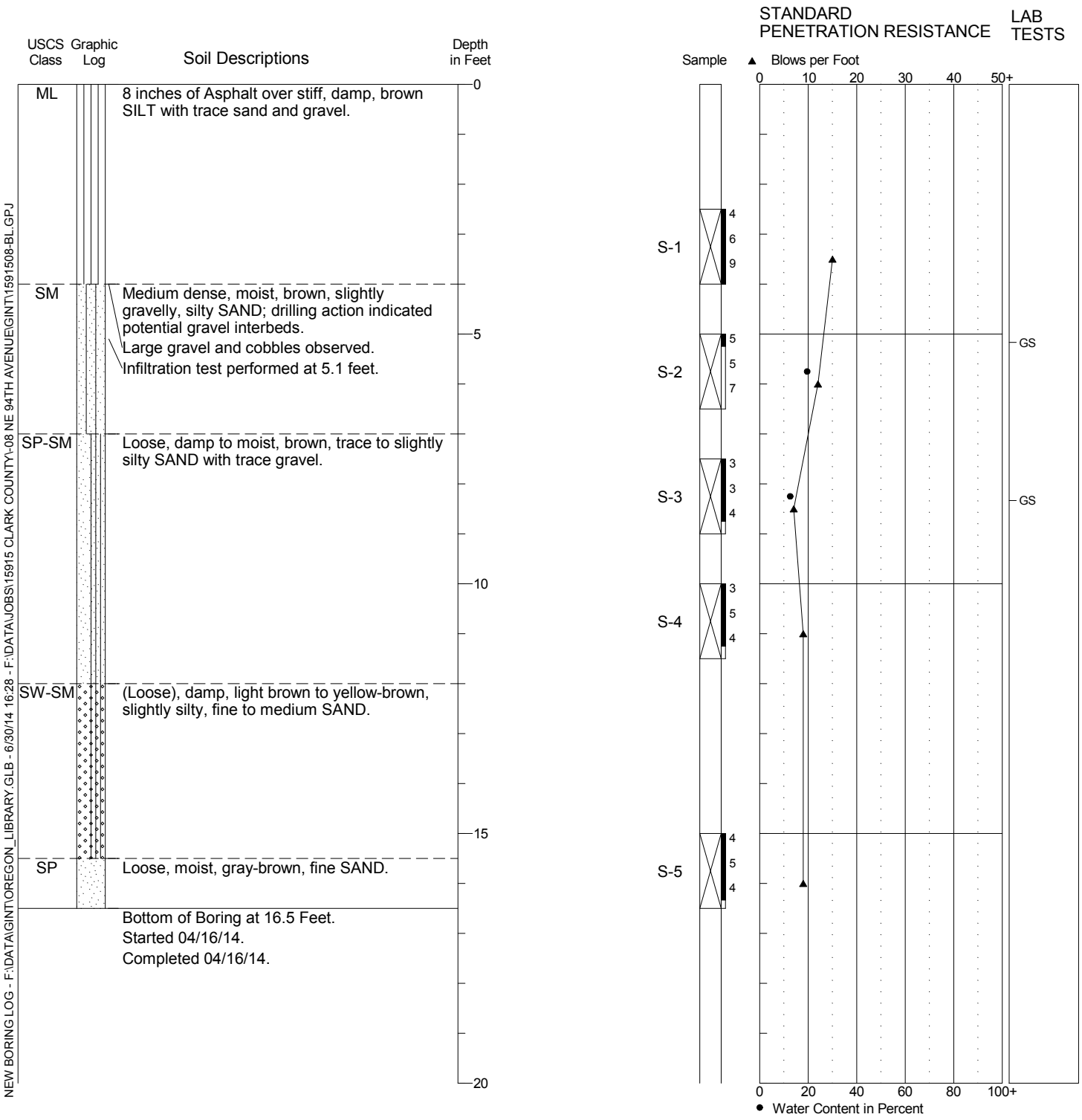
15915-08 ***7/14***

Figure A-4

Boring Log HC-3

Location:
Approximate Ground Surface Elevation: 203 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



NEW BORING LOG - F:\DATA\GINT\OREGON_LIBRARY.GLB - 6/30/14 16:28 - F:\DATA\JOBS\15915 CLARK COUNTY\-08 NE 94TH AVENUE\GINT\1591508-BL.GPJ

1. Refer to Figure A-1 for explanation of descriptions and symbols.
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HARTCROWSER

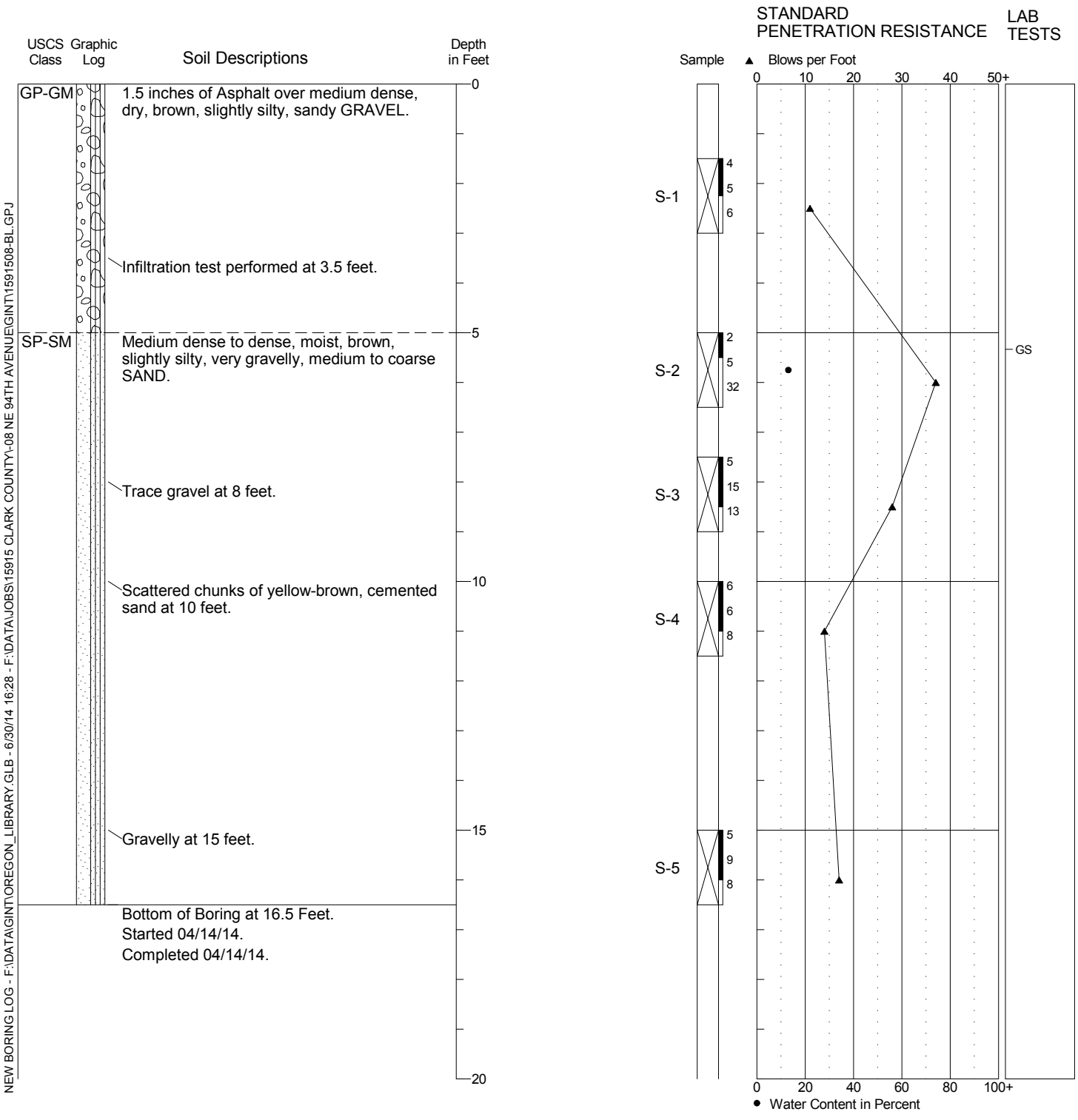
15915-08 ***7/14***

Figure A-5

Boring Log HC-4

Location:
Approximate Ground Surface Elevation: 221 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: M. Higgins Reviewed By: B. Cook



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).
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HARTCROWSER

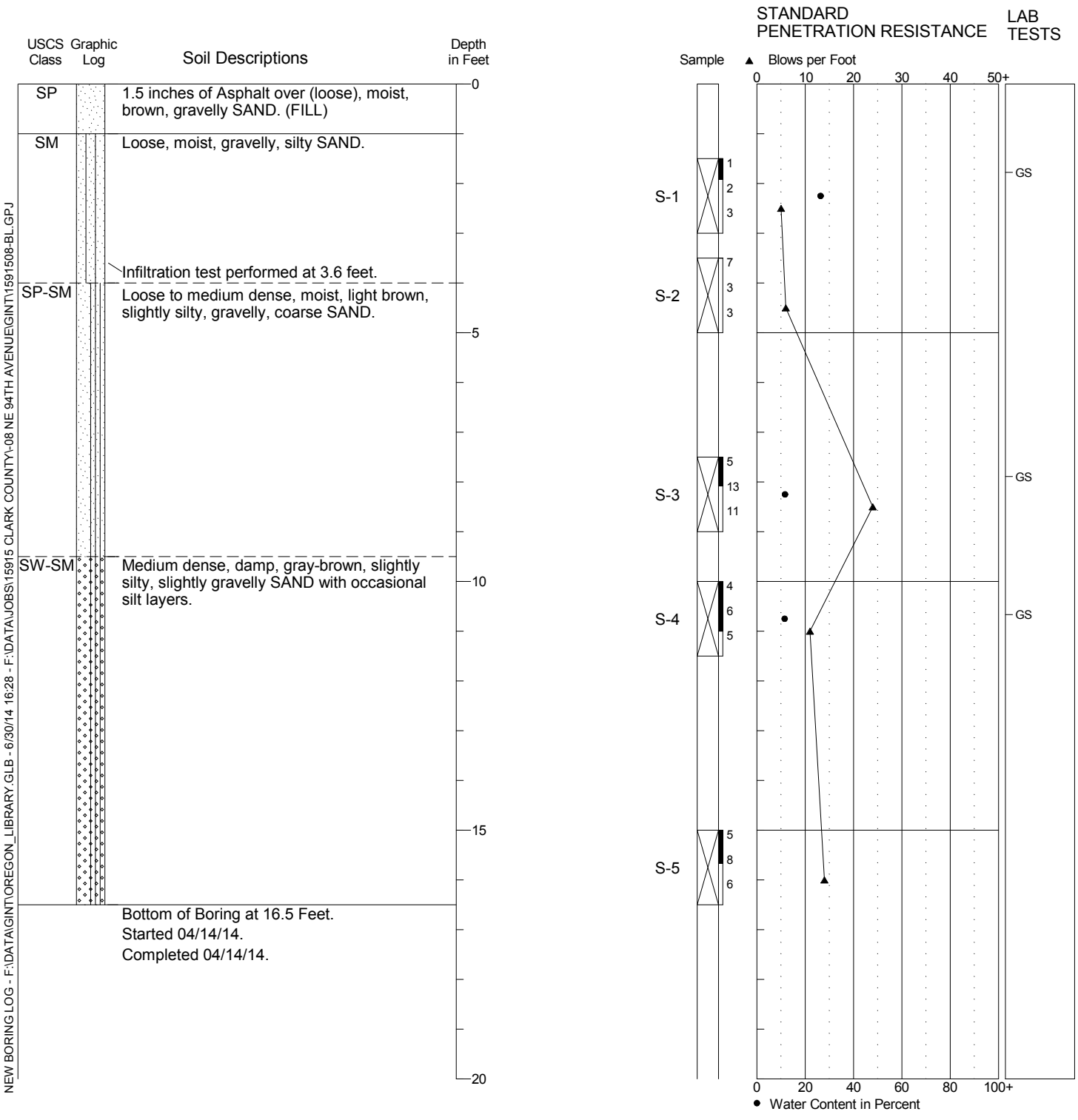
15915-08 ***7/14***

Figure A-6

Boring Log HC-5

Location:
Approximate Ground Surface Elevation: 208 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



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).
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HARTCROWSER

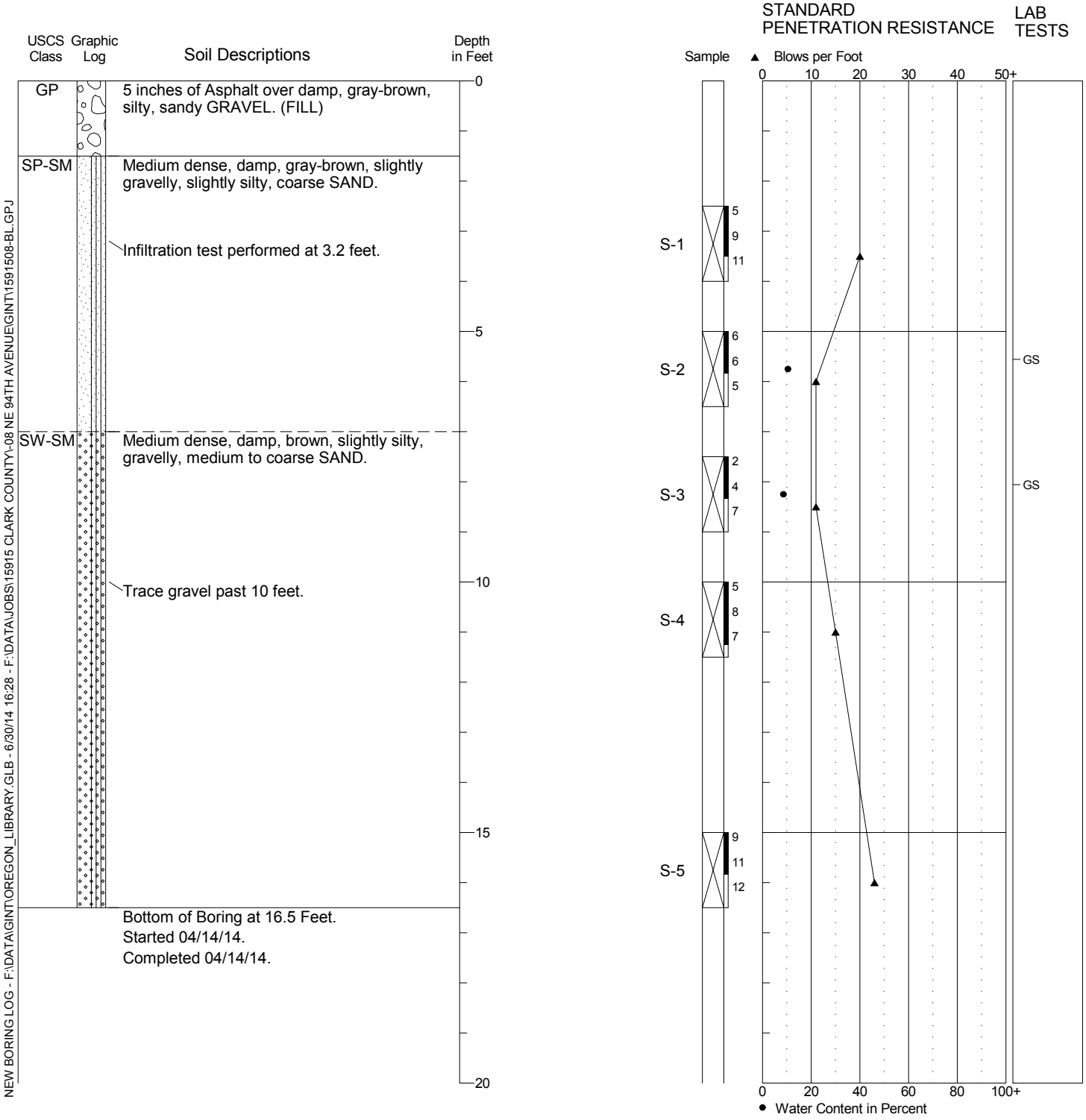
15915-08 ***7/14***

Figure A-7

Boring Log HC-6

Location:
Approximate Ground Surface Elevation: 223 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



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

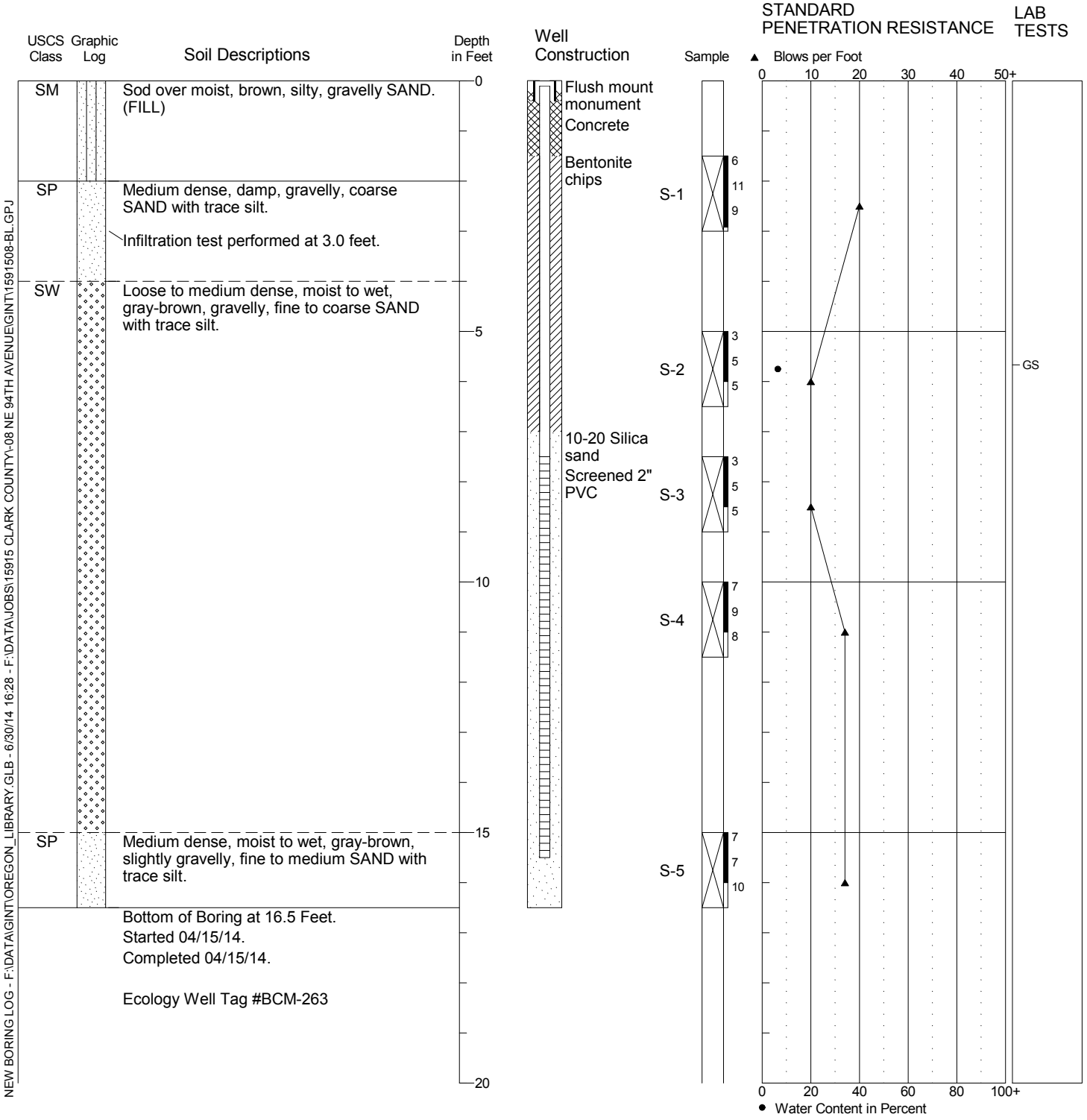
15915-08 ***7/14***

Figure A-8

Boring Log HC-7

Location:
Approximate Ground Surface Elevation: 219 Feet
Horizontal Datum:
Vertical Datum: WGS84

Drill Equipment: CME 75/Hollow-Stem Auger
Hammer Type: SPT w/140 lb. Autohammer
Hole Diameter: 8 inches
Logged By: C. Valdez Reviewed By: B. Cook



1. Refer to Figure A-1 for explanation of descriptions and symbols.
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3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
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HARTCROWSER

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Figure A-9

ATTACHMENT B
Laboratory Testing

ATTACHMENT B

Laboratory Testing

A geotechnical laboratory testing program was performed for this study to evaluate the basic index and geotechnical engineering properties of the site soil. Disturbed samples were tested. The tests performed and the procedures followed are outlined below.

Soil Classification

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 laboratory environment. Field and laboratory observations include density/consistency, moisture condition, and grain size and plasticity estimates.

The classifications of selected samples were checked by laboratory tests, such as water content determinations and grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System and ASTM D 2487.

Water Content Determinations

Water contents were determined for samples recovered in the explorations in general accordance with ASTM D 2216 as soon as possible following their arrival in our laboratory. The results of these tests are plotted at the respective sample depth on the exploration logs included in Attachment A and are also presented on Figure B-1 in this attachment.

Sieve Analysis (Grain Size Distribution)

Sieve analysis tests were performed on selected samples to determine the quantitative distribution of particle sizes in the original sample. The tests were performed in general accordance with ASTM D 6913-04. The test results are summarized on Figure B-2 and shown in detail on Figures B-3 through B-5.

Fines Content Analyses

Fines content analyses were performed to determine the percentage of soils finer than the No. 200 sieve—the boundary between sand and silt size particles. The tests were performed in general accordance with ASTM Test Method D 1140. The test results are summarized on Figure B-2.

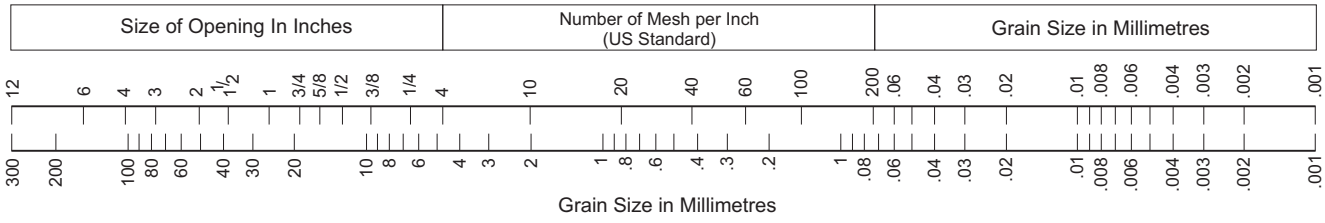
Cation Exchange Capacity and Organic Content

The cation exchange capacity and organic content of select samples was performed by AM Test Laboratories of Kirkland, Washington. Table B-1 lists the tests conducted, the applicable standard followed, and the test results. The results of the testing are also included in this attachment after Figure B-5.

Table B-1 – Specialty Testing Results

Test (Units)	Standard	Sample	
		HC-6 @ 2.5’	HC-4 @ 1.5’
Cation Exchange Capacity (meq/100g)	SW-846 9081	14	13
Organic Content (%)	SM 2540G	2.6	2.2

Unified Soil Classification (USC) System
Soil Grain Size



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

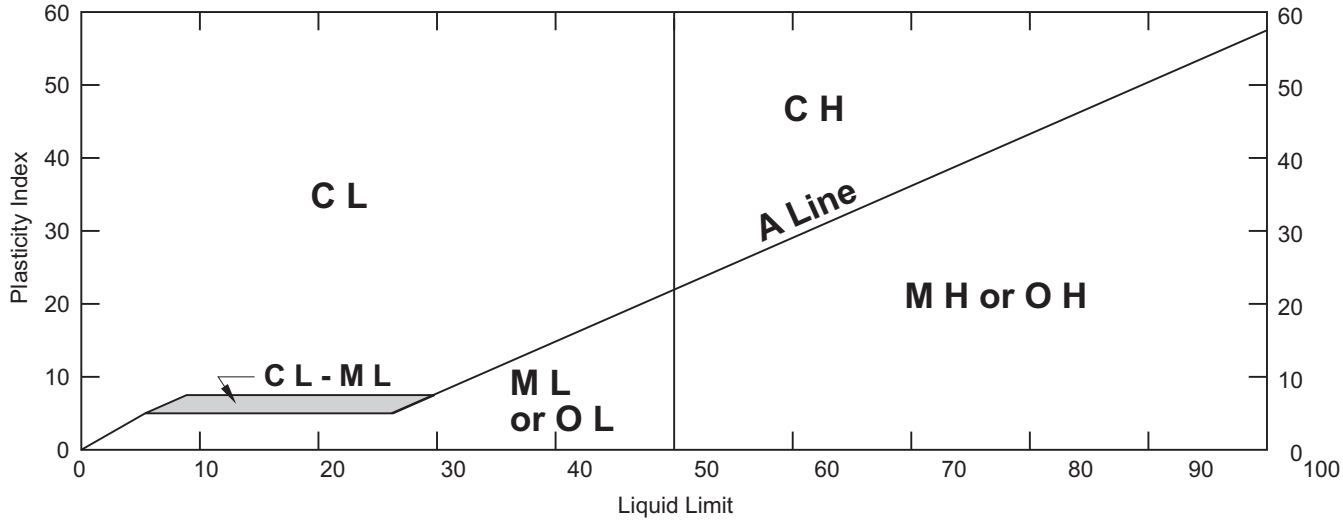
G C and S C Atterberg limits above A Line with PI >7

* 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						



HARTCROWSER

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Figure B-1

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

SUMMARY OF LABORATORY RESULTS

HARTCROWSER

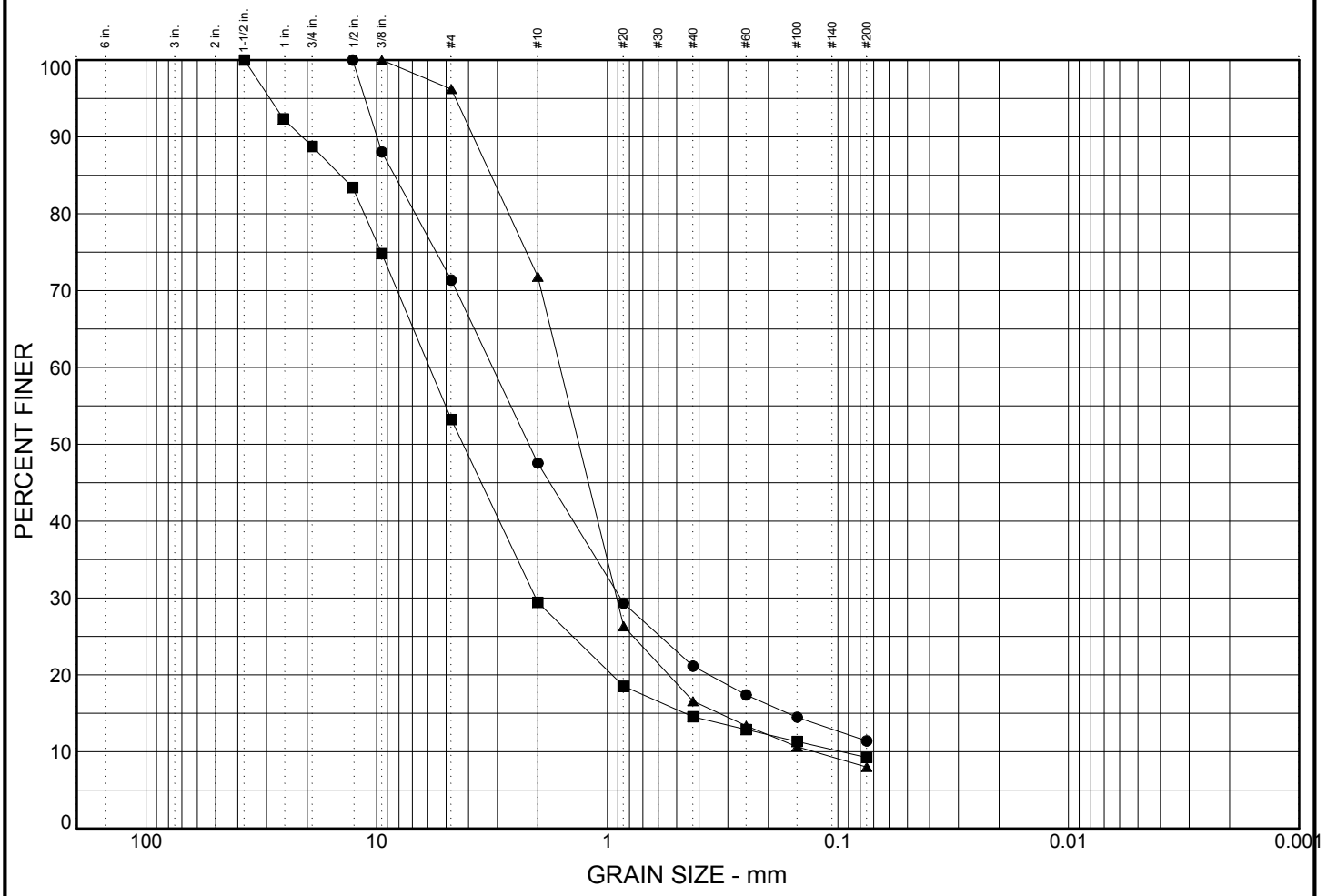
CLIENT Clark County **PROJECT NAME** NE 94th Ave.: NE Padden Pkwy. to NE 99th St.

PROJECT NUMBER 15915-08 **PROJECT LOCATION** Vancouver, WA

Borehole	Sample ID	Depth	% Gravel	% Sand	% Fines	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
HC-1	5	5.0	15.0	77.4	7.7			13.1	SP-SM	slightly silty, gravelly SAND
HC-1B	3.2	3.2	28.6	60.0	11.4			16.7	SP-SM	slightly silty, gravelly SAND
HC-2	4	4.0	46.8	44.0	9.3			12.6	GP-GM	slightly silty, very sandy GRAVEL
HC-2	7.5	7.5	42.0	49.0	9.0			9.5	SP-SM	slightly silty, very gravelly SAND
HC-3	1.5	1.5						17.3		
HC-3	5	5.0	24.4	50.2	25.5			19.6		
HC-3	7.5	7.5	3.8	88.2	8.0			12.6	SP-SM	slightly silty SAND, trace gravel
HC-4	5	5.0	31.6	61.0	7.5			13.0	SP-SM	slightly silty, very gravelly SAND
HC-5	1.5	1.5	23.7	53.3	23.0			26.4	SM	silty, gravelly SAND
HC-5	7.5	7.5	27.8	64.6	7.7			11.6	SP-SM	slightly silty, gravelly SAND
HC-5	10	10.0	6.5	87.3	6.2			11.5	SW-SM	slightly silty, slightly gravelly SAND
HC-6	5	5.0	32.2	58.6	9.3			10.4	SP-SM	slightly silty, very gravelly SAND
HC-6	7.5	7.5	23.6	70.4	6.0			8.6	SW-SM	slightly silty, gravelly SAND
HC-6B	3.2	3.2	20.8	69.7	9.5			16.6	SP-SM	slightly silty, gravelly SAND
HC-7	5	5.0	23.6	72.8	3.6			6.4	SW	gravelly SAND with trace silt
HC-7B	3	3.0	32.9	64.6	2.5			10.7	SP	very gravelly SAND, trace silt

FIGURE B-2

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	28.6	60.0	11.4	
■	0.0	46.8	44.0	9.3	
▲	0.0	3.8	88.2	8.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			8.368	3.143	2.185	0.877	0.164		4.49	57.63
■			14.326	5.903	4.224	2.042	0.458	0.096	7.35	61.41
▲			3.19	1.601	1.327	0.911	0.326	0.126	4.11	12.71

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly silty, gravelly SAND	SP-SM	16.7%
■ slightly silty, very sandy GRAVEL	GP-GM	12.6%
▲ slightly silty SAND, trace gravel	SP-SM	12.6%

Remarks:

●

■

▲

Project: NE 94th Ave.: NE Padden Pkwy. to NE 99th St.

Client: Clark County

● Source: HC-1B	Sample No.: S-1	Depth: 3.2 to 4.7
■ Source: HC-2	Sample No.: S-2	Depth: 4.0 to 5.5
▲ Source: HC-3	Sample No.: S-3	Depth: 7.5 to 9.0

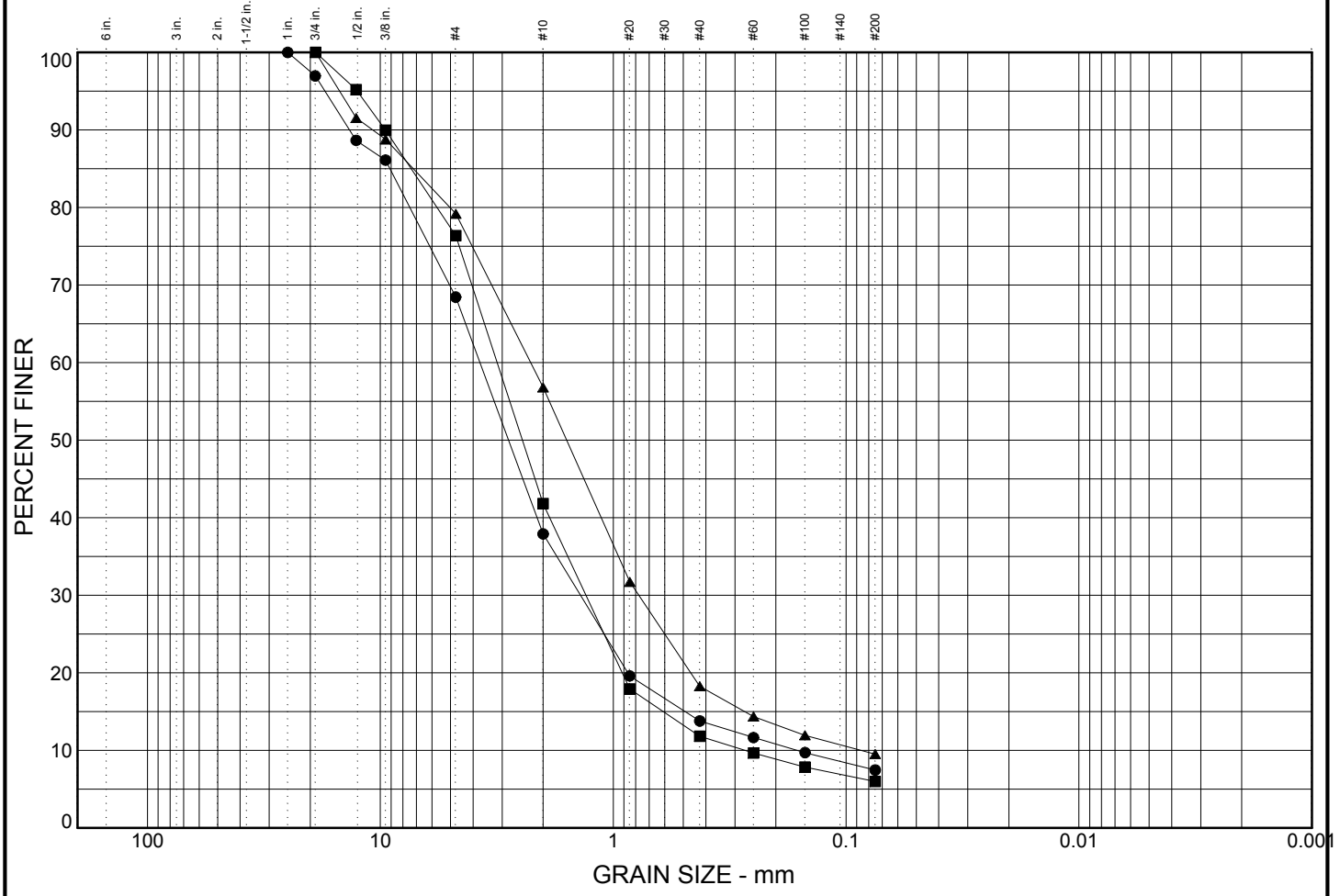
HARTCROWSER

15915-08 *7/14*

Figure B-3

GRAIN SIZE 1591508-BL.GPJ HC_CORP.GDT 6/30/14

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	31.6	61.0	7.5	
■	0.0	23.6	70.4	6.0	
▲	0.0	20.8	69.7	9.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			9.092	3.739	2.817	1.382	0.49	0.162	3.16	23.13
■			7.368	3.152	2.454	1.31	0.61	0.272	2.00	11.59
▲			7.223	2.262	1.585	0.777	0.272	0.086	3.11	26.31

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly silty, very gravelly SAND	SP-SM	13.0%
■ slightly silty, gravelly SAND	SW-SM	8.6%
▲ slightly silty, gravelly SAND	SP-SM	16.6%

Remarks:

●

■

▲

Project: NE 94th Ave.: NE Padden Pkwy. to NE 99th St.

Client: Clark County

●	Source: HC-4	Sample No.: S-2	Depth: 5.0 to 5.5
■	Source: HC-6	Sample No.: S-3	Depth: 7.5 to 8.0
▲	Source: HC-6B	Sample No.: S-2	Depth: 3.2 to 3.7

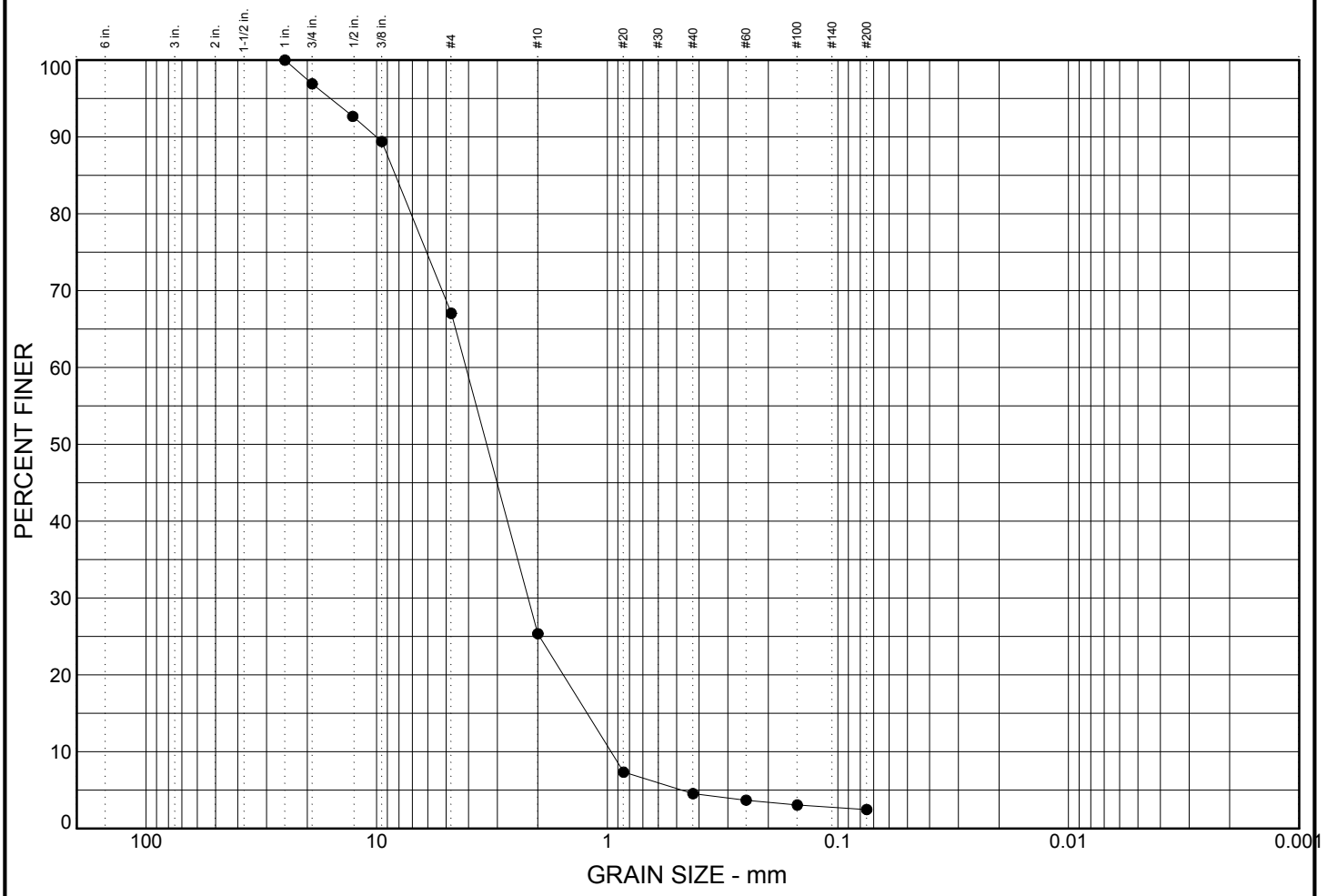
HARTCROWSER

15915-08 *7/14*

Figure B-4

GRAIN SIZE 1591508-BL.GPJ HC_CORP.GDT 6/30/14

Particle Size Distribution Test Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	32.9	64.6	2.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			8.286	4.104	3.335	2.202	1.223	0.964	1.23	4.26

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● very gravelly SAND, trace silt	SP	10.7%

Remarks:
●

Project: NE 94th Ave.: NE Padden Pkwy. to NE 99th St.

Client: Clark County

● Source: HC-7B Sample No.: S-1 Depth: 3.0 to 3.5

HARTCROWSER

15915-08 *7/14*

Figure B-5

GRAIN SIZE 1591508-BL.GPJ HC_CORP.GDT 6/30/14

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

Professional Analytical Services

ANALYSIS REPORT

Hart Crowser
1700 Westlake Ave N
Seattle, WA 98109
Attention: Brenton Cook
Project Name: NE 94th Ave
Project #: 15915-08
All results reported on an as received basis.

Date Received: 04/25/14
Date Reported: 5/13/14

AMTEST Identification Number **14-A006275**
Client Identification **HC-6 S-1**
Sampling Date **04/14/14**

Conventionals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Cation Exchange Capacity	14.	meq/100g		0.5	SW-846 9081	EB	05/05/14

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Organic Matter	2.6	%			SM 2540G	AB	05/06/14

AMTEST Identification Number **14-A006276**
Client Identification **HC-4 S-1**
Sampling Date **04/14/14**

Conventionals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Cation Exchange Capacity	13.	meq/100g		0.5	SW-846 9081	EB	05/05/14

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Organic Matter	2.2	%			SM 2540G	AB	05/06/14

Kathy Fugiel
President