File NR G1-28722
WR Doc ID 5198893

DEPARTMENT OF ECOLOGY
State of Washington

State of Washington
REPORT OF EXAMINATION
FOR WATER RIGHT APPLICATION

PRIORITY DATE	WATER RIGHT NUMBER
3/21/2012	G1-28722

MAILING ADDRESS	SITE ADDRESS (IF DIFFERENT)
SEATTLE STEAM COMPANY 1325 FOURTH AVENUE SUITE 1440 SEATTLE WA 98101	

Quantity Authorized for Withdrawal or Diversion

WITHDRAWAL OR DIVERSION RATE	UNITS	ANNUAL QUANTITY (AF/YR)
250	GPM	404

Purpose

	WITHDRAWAL OR DIVERSION RATE			ANNUAL QUANTITY (AF/YR)		
PURPOSE	ADDITIVE	NON-ADDITIVE	UNITS	ADDITIVE	NON-ADDITIVE	PERIOD OF USE (mm/dd)
Commercial and Industrial	250			404		01/01 - 12/31

REMARKS

This water right allocation allows Seattle Steam to use water from the closed Lake Washington Basin in a location downstream from Lake Washington before it empties to Puget Sound. Historically, Seattle Steam purchased water from Seattle Public Utilities for its steam operations. Removing this large industrial use from Seattle's municipal supply of water relieves pressure on the Tolt/Cedar water supply serving Seattle.

IRRIGATED ACRES		PUBLIC WATER SYSTEM INFORMATION	
ADDITIVE	NON-ADDITIVE	WATER SYSTEM ID	CONNECTIONS
0	0		

Source Location

COUNTY	WATERBODY	TRIBUTARY TO	WATER RESOURCE INVENTORY AREA
KING	GROUNDWATER		8-CEDAR-SAMMAMISH

SOURCE FACILITY/DEVICE	PARCEL	WELL TAG	TWP	RNG	SEC	QQ Q	LATITUDE	LONGITUDE
Well	7666202445	BCS872	25N	04E	31	NW SE		

Datum: NAD83/WGS84

Place of Use (See Attached Map)

PARCELS (NOT LISTED FOR SERVICE AREAS)

7666202445 / 1976200031 / 85191400100

LEGAL DESCRIPTION OF AUTHORIZED PLACE OF USE

Western Steam Plant, Parcel 7666202445: Lots 3 and 4 of Block 177 in the Plat of Seattle Tide Lands, Section 31, Township 25N, Range 4E, W.M.

Biomass Boiler, 1976200031:The Westerly 34.5 ft of Lots 1, 4, and 5 and the Northerly 30 ft of Lot 8, all in Block 178 in Plat of Seattle Tide Lands, Section 31, Township 25N, Range 4E, W.M., less the South 30 feet thereof.

Post Street Steam Plant, 8591400100: A portion Block M and of Block 195 of Terry's 3rd Addition within Section 6, Township 24N Range 4E, W.M. described as follows: Beginning at a point on the Westerly line of Post Street 100 ft Northerly from North Line of Yesler Way, thence West parallel with said North line to Westerly Line of Lot 5 of said block 195, thence Northerly and Northwesterly along said block 195 to Northwesterly Line of Southeastern 15 ft of Lot 2 of said Block 195, thence Northeasterly along said Northwesterly line to Southwesterly line of Post Street thence Southeasterly and Southerly along said street to the beginning, excluding that area defined as historic property in RCW 84.26

Proposed Works

Seattle Steam waterworks includes the well, water purification systems, and boilers to generate steam for transmission throughout the City of Seattle.

Development Schedule

BEGIN PROJECT	COMPLETE PROJECT	PUT WATER TO FULL USE
July 23, 2013	December 31, 2018	December 31, 2023

Measurement of Water Use

How often must water use be measured?	Monthly
How often must water use data be reported to Ecology?	Annually (Jan 31)
What volume should be reported?	Total Annual Volume & Report_Volume
What rate should be reported?	Monthly Peak Rate of Withdrawal (gpm or cfs)

Provisions

Wells, Well Logs and Well Construction Standards

All wells constructed in the state shall meet the construction requirements of WAC 173-160 titled "Minimum Standards for the Construction and Maintenance of Wells" and RCW 18.104 titled "Water Well Construction". Any well which is unusable, abandoned, or whose use has been permanently discontinued, or which is in such disrepair that its continued use is impractical or is an environmental, safety or public health hazard shall be decommissioned.

Flowing wells shall be constructed and equipped with valves to ensure that the flow of water can be completely stopped when not in use. Likewise, the well shall be continuously maintained to prevent the waste of water through leaky casings, pipes, fittings, valves, or pumps -- either above or below land surface.

All wells shall be tagged with a Department of Ecology unique well identification number. If you have an existing well and it does not have a tag, please contact the well-drilling coordinator at the regional Department of Ecology office issuing this decision. This tag shall remain attached to the well. If you are required to submit water measuring reports, reference this tag number.

Installation and maintenance of an access port as described in WAC 173-160- 291(3) is required.

Measurements, Monitoring, Metering and Reporting
An approved measuring device shall be installed and maintained for each of the sources identified by this water right in accordance with the rule "Requirements for Measuring and Reporting Water Use", WAC 173-173.

Ecology is requiring the recording and reporting of meter data as described above to collect seasonal information for water resource planning and compliance.

Recorded water use data shall be submitted via the Internet. To set up an Internet reporting account, contact the Northwest Regional Office. If you do not have Internet access, you can still submit hard copies by contacting the Northwest Regional Office for forms to submit your water use data.

WAC 173-173 describes the requirements for data accuracy, device installation and operation, and information reporting. It also allows a water user to petition the Department of Ecology for modifications to some of the requirements.

Water Level Measurements
In order to maintain a sustainable supply of water, pumping must be managed so that static water levels do not progressively decline from year to year. Static water level is defined as the water level in a well when no pumping is occurring and the water level has fully recovered from previous pumping. Static water levels shall be measured and recorded monthly, using a consistent methodology. Data for the previous year shall be submitted by January 31 to the Department of Ecology.

Static water level data shall be submitted in digital format and shall include the following elements:

Unique Well ID Number
Measurement date and time
Measurement method (air line, electric tape, pressure transducer, etc.)
Measurement accuracy (to nearest foot, tenth of foot, etc.)
Description of the measuring point (top of casing, sounding tube, etc.)
Measuring point elevation above or below land surface to the nearest 0.1 foot
Land surface elevation at the well head to the nearest foot.
Static water level below measuring point to the nearest 0.1 foot.

Chloride Monitoring
By January 31st of each year, the following information shall be submitted in writing to the Department of Ecology.

April and September measurements from the subject well(s) of:

Chloride and conductivity (the chemical analysis shall be performed by a state-accredited laboratory)

The chloride/conductivity sampling and the static water level measurement shall be conducted concurrently.

This data collection will assist the applicant and Ecology in determining if actions are necessary to prevent an increasing trend in chloride concentrations (an indicator of seawater intrusion). Preventative actions may include – reducing the instantaneous pumping rate, reducing the annual volume pumped, scheduling pumping to coincide with low tides, raising the pump intake, and/or limiting the number of service connections.

Water Use Efficiency
The water right holder is required to maintain efficient water delivery systems and use of up-to-date water conservation practices consistent with RCW 90.03.005.

Proof of Appropriation
The water right holder shall file the notice of Proof of Appropriation of water (under which the certificate of water right is issued) when the permanent distribution system has been constructed and the quantity of water required by the project has been put to full beneficial use. The certificate will reflect the extent of the project perfected within the limitations of the permit. Elements of a proof inspection may include, as appropriate, the source(s), system instantaneous capacity, beneficial use(s), annual quantity, place of use, and satisfaction of provisions.

Schedule and Inspections
Department of Ecology personnel, upon presentation of proper credentials, shall have access at reasonable times, to the project location, and to inspect at reasonable times, records of water use, wells, diversions, measuring devices and associated distribution systems for compliance with water law.

Findings of Facts

Upon reviewing the investigator's report, I find all facts, relevant and material to the subject application, have been thoroughly investigated. Furthermore, I concur with the investigator that water is available from the source in question; that there will be no impairment of existing rights; that the purpose(s) of use are beneficial; and that there will be no detriment to the public interest.

Therefore, I ORDER approval of Application No. G1-28722, subject to existing rights and the provisions specified above.

Your Right To Appeal

You have a right to appeal this Order to the Pollution Control Hearings Board (PCHB) within 30 days of the date of receipt of this Order. The appeal process is governed by Chapter 43.21B RCW and Chapter 371-08 WAC. "Date of receipt" is defined in RCW 43.21B.001(2).

To appeal you must do the following within 30 days of the date of receipt of the Order.

File your appeal and a copy of this Order with the PCHB (see addresses below). Filing means actual receipt by the PCHB during regular business hours.

- Serve a copy of your appeal and this Order on Ecology in paper form - by mail or in person. (See addresses below.) E-mail is not accepted.
- You must also comply with other applicable requirements in Chapter 43.21B RCW and Chapter 371-08 WAC.

Street Addresses	Mailing Addresses
Department of Ecology Attn: Appeals Processing Desk 300 Desmond Drive SE Lacey, WA 98503	**Department of Ecology** Attn: Appeals Processing Desk PO Box 47608 Olympia, WA 98504-7608
Pollution Control Hearings Board 1111 Israel RD SW Ste 301 Tumwater, WA 98501	**Pollution Control Hearings Board** PO Box 40903 Olympia, WA 98504-0903

Signed at Bellevue, Washington, this 3 day of March, 2014.

Jacqueline Klug, Section Manager
Water Resources Program, Northwest Regional Office

For additional information visit the Environmental Hearings Office Website: http://www.eho.wa.gov. To find laws and agency rules visit the Washington State Legislature Website: http://www1.leg.wa.gov/CodeReviser.

BACKGROUND

This report serves as the written findings of fact concerning Water Right Application Number G1-28722.

Cost Reimbursement

This application is being processed under an expedited cost reimbursement agreement between the applicant the Department of Ecology. Ecology prepared this report based on findings in the hydrogeologic report written by Robinson & Noble, Inc. in an attachment (Attachment 2) appended to this report.

Table 1 Summary of Requested Water Right

Applicant Name:	Seattle Steam Company
Date of Application:	3/21/2012
Place of Use	King County Parcels 7666202445 / 1976200031 / 85191400100

County	Waterbody	Tributary To	WRIA
King	Groundwater		8-Cedar-Sammamish

Purpose	Rate	Unit	Ac-ft/yr	Begin Season	End Season
Commercial and Industrial	250	GPM	404	01/01	12/31

Source Name	Parcel	Well Tag	Twp	Rng	Sec	QQ Q	Latitude	Longitude
Well			25N	04E	31	NW SE		

CFS = Cubic Feet per Second; Ac-ft/yr = Acre-feet per year; Sec. = Section; QQ Q = Quarter-quarter of a section; WRIA = Water Resource Inventory Area; E.W.M. = East of the Willamette Meridian; Datum: NAD83/WGS84.

Legal Requirements for Approval of Appropriation of Water

Public Notice

RCW 90.03.280 requires that notice of a water right application be published once a week, for two consecutive weeks, in a newspaper of general circulation in the county or counties where the water is to be stored, diverted and used. Notice of this application was published in the Daily Journal of Commerce in Seattle on November 6th and 13th, 2012.

Consultation with the Department of Fish and Wildlife

The Department must give notice to the Department of Fish and Wildlife (WDFW) of applications to divert, withdraw or store water. The impact of the water appropriation described by this report will have a neutral effect on fish and wildlife, according to WDFW, in a letter received January 9, 2014, from Steve Boessow, Water Rights Biologist.

State Environmental Policy Act (SEPA)

A water right application is subject to a SEPA threshold determination (i.e., an evaluation whether there are likely to be significant adverse environmental impacts) if any one of the following conditions are met.

(a) It is a surface water right application for more than 1 cubic foot per second, unless that project is for agricultural irrigation, in which case the threshold is increased to 50 cubic feet per second, so long as that irrigation project will not receive public subsidies;
(b) It is a groundwater right application for more than 2,250 gallons per minute;
(c) It is an application that, in combination with other water right applications for the same project, collectively exceed the amounts above;
(d) It is a part of a larger proposal that is subject to SEPA for other reasons (e.g., the need to obtain other permits that are not exempt from SEPA);
(e) It is part of a series of exempt actions that, together, trigger the need to do a threshold determination, as defined under WAC 197-11-305.

Because this application does not meet any of these conditions, it is categorically exempt from SEPA and a threshold determination is not required.

INVESTIGATION

Proposed Use and Basis of Water Demand

Seattle Steam is a privately-owned utility that provides district heat to approximately 200 buildings in Seattle's Central Business District and First Hill neighborhoods. The company produces thermal energy from five boilers located in two plants in downtown Seattle. The water appropriated by permit will accommodate the plant's base flow requirements, with water purchased from a municipal source to satisfy peak demand and increased business growth.

Other Rights Appurtenant to the Place of Use

G1-*00047SWRIS and G1-*00048SWRIS are groundwater right certificates appurtenant to the property issued to Puget Sound Power and Light and used for steam plant activity. According to the applicant, it has not been put to use since the 50's or 60's, when the steam plant began purchasing water from a municipal source. This water right is likely relinquished. A statement voluntarily relinquishing water right certificates G1-*00047SWRIS and G1-*00048SWRIS is in the master application on file with

Ecology. Ecology and Seattle Steam discussed its status at a meeting (pre-application meeting) occurring before permit application G1-28722 was filed for new, additive water for industrial/commercial use.

Impairment Considerations

Impairment is an adverse impact on the physical availability of water for a beneficial use that is entitled to protection. A water right application may not be approved if it would:

- Interrupt or interfere with the availability of water to an adequately constructed groundwater withdrawal facility of an existing right. An adequately constructed groundwater withdrawal facility is one that (a) is constructed in compliance with well construction requirements and (b) fully penetrates the saturated zone of an aquifer or withdraws water from a reasonable and feasible pumping lift.
- Interrupt or interfere with the availability of water at the authorized point of diversion of a surface water right. A surface water right conditioned with instream flows may be impaired if a proposed use or change would cause the flow of the stream to fall to or below the instream flow more frequently or for a longer duration than was previously the case.
- Interrupt or interfere with the flow of water allocated by rule, water rights, or court decree to instream flows.
- Degrade the water quality of the source to the point that the water is unsuitable for beneficial use by existing users (e.g., via sea water intrusion).

Existing water rights in Township 24 North, Range 04 East, Section 31 include G1-*00049SWRIS for the Diamond Ice Company (now defunct) and S1-28477P, a rainwater catchment permit issued to Seattle Public Utilities. The Diamond Ice certificate is likely statutorily relinquished, and withdrawal by Seattle Steam from a well will not interfere with or impair the rainwater harvesting in Seattle's urban core.

Water Availability

For water to be available for appropriation, it must be both physically and legally available.

Physical availability

For water to be physically available for appropriation there must be ground or surface water present in quantities and quality and on a sufficiently frequent basis to provide a reasonably reliable source for the requested beneficial use or uses. In addition, the following factors are considered:

- Volume of water represented by senior water rights, including federal or tribal reserved rights or claims;
- Water right claims registered under Chapter 90.14 RCW;
- Ground water uses established in accordance with Chapter 90.44 RCW, including those that are exempt from the requirement to obtain a permit; and
- Potential riparian water rights, including non-diversionary stock water.
- Lack of data indicating water usage can also be a consideration in determining water availability, if the department cannot ascertain the extent to which existing rights are consistently utilized and cannot affirmatively find that water is available for further appropriation.

Hokkaido drilling constructed the well under a variance for setback requirements. According to the well report, there exists unconsolidated, low-permeability sediment to 71 feet bgs (below ground surface).

Gravel appears at this depth, and is accompanied by silt and sand to 210 feet bgs. Water is encountered at this interval, but not in the quantity needed by the applicant. Lower permeability clay deposits are encountered until a second water bearing layer is encountered at 263 feet bgs. A clay unit from 301 to 333 feet confines the production aquifer from 333 to 385 feet bgs; the bottom of the borehole.

Robinson & Noble performed the hydrogeologic analysis (Attachment 2) of the impact on the water resource during a pump test performed October 21-23, 2013. A variable pumping rate step test was performed the first two hours, followed by 25 hours of pumping at 416 gpm. Pressure transducers measured and recorded data throughout the test.

Sea level data plotted with water levels show the well is tidally influenced, and water levels mirrored sea level change throughout the 25-hour pump test. The pumping water level is considered static for purposes of the test, and subsequent analysis. Water levels in the well recovered fully approximately 3.5 days after the pump was shut down.

Based on the pumping test data and corroborating analysis in the testing report, water is likely available at the requested rate of 250 gpm.

Legal availability

To determine whether water to be legally available for appropriation, the following factors are considered:

- Regional water management plans – which may specifically close certain water bodies to further appropriation.
- Existing rights – which may already appropriate physically available water.
- Fisheries and other instream uses (e.g., recreation and navigation). Instream needs, including instream and base flows set by regulation. Water is not available for out of stream uses where further reducing the flow level of surface water would be detrimental to existing fishery resources.
- The Department may deny an application for a new appropriation in a drainage where adjudicated rights exceed the average low flow supply, even if the prior rights are not presently being exercised. Water would not become available for appropriation until existing rights are relinquished for non-use by state proceedings.

The well is outside the Lake Washington basin and tributary closure. Water at the Seattle Steam plant is withdrawn downgradient of Lake Washington and won't likely affect this closed basin to the point of impairment.

Beneficial Use

The proposed use of water is defined in statute as a beneficial use (RCW 90.54.020(1)).

Public Interest Considerations

Consideration of Protests and Comments

No protests were filed against this application.

Conclusions

Water is available in the quantity requested and its beneficial industrial/commercial use, which is in the public interest, will not impair existing water right holders.

RECOMMENDATIONS

Based on the above investigation and conclusions, I recommend that this request for a water right be approved in the amounts and within the limitations listed below and subject to the provisions listed above

Purpose of Use and Authorized Quantities

The amount of water recommended is a maximum limit and the water user may only use that amount of water within the specified limit that is reasonable and beneficial:

250 gpm
404 acre-feet per year
Industrial/commercial

Point of Withdrawal

NE¼ SE¼, Section 31, Township 25 North, Range 4 E.W.M.

Place of Use

Legal Desc: Seattle Tide LDS, King County Parcel: 7666202445

02/27/2014

Report Writer: Noel Philip, LHG #2662-
Dept. of Ecology

Date

If you need this publication in an alternate format, please call Water Resources Program at (360) 407-6600. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Seattle Steam Company
Water Right G1-28722
Section 31 T25N R04E W.M.
WRIA 8 - King County

Legend

- Authorized Place of Use
- Authorized Point of Diversion
- Water Body
- Townships
- Parcels
- Sections

0 125 250 500 750 1,000 Feet

DEPARTMENT OF ECOLOGY
State of Washington

Map Date: 1/9/2014

Place of use and point(s) of diversion/withdrawal are as defined on the cover sheet under the headings,'LOCATION OF DIVERSION/WITHDRAWAL' and 'LEGAL DESCRIPTION OF PROPERTY ON WHICH WATER IS TO BE USED.'

ATTACHMENT 1

ATTACHMENT 2

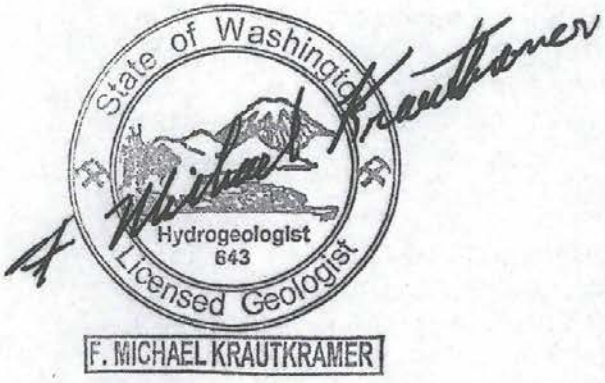
ROBINSON
NOBLE

SEATTLE STEAM COMPANY
WESTERN AVENUE PLANT TEST WELL
CONSTRUCTION AND TESTING REPORT

DECEMBER 2013

by

F. Michael Krautkramer, LHG, RG
Principal Hydrogeologist



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SEATTLE STEAM COMPANY
WESTERN AVENUE PLANT TEST WELL
CONSTRUCTION AND TESTING REPORT
DECEMBER 2013

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Table 2 Chloride, Conductivity, and Hardness Test Results

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Figure 1A Aerial Map

Figure 2 Construction Detail and Geologic Log

Figure 3 Grain-size Distribution Graph

Figure 4 Plant Well Hydrograph

Figure 5 Plant Well Step Test

Figure 6 25-Hour Constant-rate Test Drawdown

Figure 7 25-Hour Constant-Rate Test Recovery

APPENDICES

Preliminary Permit to Drill and Test

Department of Ecology Well Construction Variance

Formation Sample Grain Size Distribution Plots

Water Well Report Form

Manual Water Level Measurements

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CD CONTENT

Full Report with Appendices as PDF

Electronic Pumping Test Data Sets

SEATTLE STEAM COMPANY
WESTERN AVENUE PLANT TEST WELL
CONSTRUCTION AND TESTING REPORT
DECEMBER 2013

Introduction

Seattle Steam Company desired a production well at its Western Avenue Steam Plant (Plant) to serve as a primary water source in lieu of the use of water from the City of Seattle (City). The benefits of developing a source well at the Plant are many. If a suitable groundwater source is developed at the Plant, it will significantly diminish Plant vulnerability in the event of a natural disaster or other interruption of water service within the City's system, operation of a dedicated source will be economically beneficial to Plant operation, and production of deep aquifer groundwater from the discharge end of the watershed (rather than from the City's Cedar or Tolt River surface water sources) will be beneficial to the environment.

Robinson Noble's initial hydrogeologic studies indicated development of a deep aquifer groundwater source may be possible at the Plant site. Subsequent discussion with the Washington State Department of Ecology (Ecology) indicated that a water right could be issued provided the proposed production amount did not cause seawater intrusion into the aquifer. Application was made for a water right (application G1-28722), and a preliminary permit to drill and test was issued by Ecology on June 4, 2013. Specifications for a test/production well were prepared by our hydrogeologists, and Hokkaido Drilling Company (Contractor) of Graham, Washington was contracted to perform the work. Robinson Noble provided hydrogeologic services throughout the drilling project. The test well is located at the Plant site at 1319 Western Avenue, in the City's downtown waterfront area on Elliott Bay, as shown in Figures 1 and 1a. The drill site required a variance from Ecology to reduce the setback requirements for a properly sited well. Copies of the preliminary permit and variance are included as appendices to this report.

Drilling

The Contractor mobilized a Speedstar Model 72 cable-tool drilling rig and other equipment to the site on July 23. Drilling began by placing a 20-inch temporary casing to a depth of 50 feet. A 16-inch casing was placed inside the 20-inch casing, placing its bottom on undisturbed material at 50 feet below ground surface (bgs). To create an artesian flow seal, the 20-inch casing was pulled back with hydraulic jacks while neat cement grout was injected into the 16-20 inch annular space until grout reached the ground surface as the last of the 20-inch casing was removed. The cement was allowed to cure for a full week to assure an effective artesian flow seal had been created. Twelve-inch casing was installed inside the 16-inch surface seal casing and drilling continued to the final depth of 385 feet, which was reached on September 10, 2013. Figure 2 shows the drilling and construction details.

Drilling from land surface first encountered fill material containing bricks and woody materials such as pieces of pilings. The fill persists to 18 feet bgs, where a gray silt, clay and gravel unit was encountered. This unit contains large wood pieces, which were removed in lengths as much as five feet, believed to be piling remnants driven into the natural geologic formation. The wood was encountered from 18 to 23 feet. The gray silty, clayey gravel unit persists to 42 feet,

when a gray clay unit exists. The 16-inch flow-control/surface seal is cemented into this gray clay.

During the initial drilling, three feet of sediments, approximately 15 and 18 feet bgs, contaminated with hydrocarbons, were observed. The drill cuttings (soil) from this zone required chemical characterization by our environmental division before their proper disposal could be determined. The contaminant appears to be from an old spill of bunker fuel. Contaminated cuttings were removed by vacuum truck and taken to a certified disposal site.

The drilling below the surface seal casing encountered a complex series of unconsolidated sediments, as was expected for this location from our initial study. The lithologic log is shown on Figure 2. Low-permeability material persists from 18 feet to 146 feet. This confining unit is dominated by a gray clay unit that exists from 71 to 146 feet. Below 146 feet, somewhat more permeable layers exist, with the most significant being a gray silty sand and gravel encountered between 169 and 208 feet. Though these sediments could be considered an aquifer, their production potential seemed quite low and only minor water entry was observed during drilling. At 208 feet, lower permeability sediments, predominantly silty-clay deposits, were again encountered. These low permeability units persist to 263 feet.

The second layer of water-bearing sediments, consisting of sand and gravel, exists from 263 to 285 feet. The conductivity of the water within this aquifer was measured in the field at 2,100 micro mhos (potable water background levels are typically about 200 micro mhos). This indicates the aquifer is likely brackish, though some of the high conductivity could be the result of the water column during drilling carrying brackish water from the 169 to 208-foot overlying aquifer. Below 301 feet, a clay unit with some gravel was penetrated. These may be pro-glacial lake sediments with ice-rafted gravel. This confining material extends to 333 feet where the production aquifer was penetrated. Drilling was ended at 385 feet, still within water-bearing sediments, on September 10.

The aquifer is believed to extend beyond the 385-foot total depth drilled. However, the aquifer materials are progressively siltier and finer with depth and sufficiently lower in permeability that further drilling was not justified. During drilling, water conductivity from the 354-foot depth was measured at about 200 micro mhos (by pumping approximately 50 gpm from an educator pipe installed to that depth). Though higher conductivity water was also measured during drilling of the aquifer, the measurements obtained while pumping demonstrate the aquifer is not brackish.

Aquifer sediment samples collected between 333 and 380 feet were subjected to grain-size distribution analyses in Robinson Noble's soils laboratory. The grain-size distribution analysis was used in conjunction with our hydrogeologists' observations of the drilling process to determine an appropriate well screen completion design for the well. The grain-size analyses of the aquifer is summarized in Figure 3 and presented for each sample in the appendices. Figure 3 presents the distribution of grain size as three key sizes for each sample presented relative to the depth of the samples. The curves presented on Figure 3, D_{10}, D_{30}, and D_{60}, represent the sizes at which 10%, 30% and 60% of the subject samples are smaller than the identified size. These distribution descriptors are commonly used for design of well screens, and therefore, are common to the industry when discussing grain-size distributions of aquifer material.

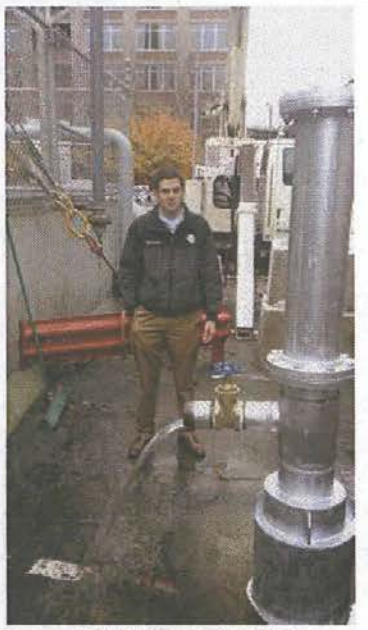
The completion design called for 35 feet of sand-packed, 8-inch pipe-size, 50-slot (0.050 inch) wire-wound stainless-steel screen with a 10-foot tail pipe fitted with a steel-plate bottom. The selected pack material for this aquifer is Colorado Silica 8 x 12 sand. The details of the well screen assembly as built are provided as part of Figure 2.

Construction and Development

The hole was prepared for completion by cutting the 12-inch casing at 372 feet bgs. The drive shoe and casing remnant was left in the hole between 372 and 385 feet. It was backfilled with pea gravel to a depth of 380 feet to provide a stable bottom for the well screen assembly. On October 7, the screen assembly was welded together and set in place on 8-inch casing. The 8-ince casing extends from the top of the screen to 3.5 feet above land surface. The screen was exposed to the formation by pulling the 12-inch casing back to 335 feet with hydraulic jacks. The screen is exposed at depths between 370 feet and 335 feet. Though the 8-inch riser casing is brought to a level above land surface, the well is designed so that the 8-inch casing can be cut off as low as 90 feet below land surface to provide a 12-inch pumping chamber if this becomes desirable at some point in the future.

Subsequent to development and testing, the 12-inch casing was pulled back from its temporary position of 335 feet bgs to a final position a 130 feet bgs. While pulling the casing, a bentonite seal was placed in the 8- to 12-inch annulus to seal the completion aquifer (as required from Ecology) from all overlying materials. The 8- to12-inch annulus is sealed with neat cement from 140 to 95.5 feet. Sealing details are shown on Figure 2.

The 8-inch wellhead assembly extends 6.58 feet above land surface as shown in the attached photo and Figure 2. The 12-inch casing extends to 1.67 feet above land surface and the 16-inch casing is 1.25 feet above land surface. The annular spaces are sealed with cement grout and welded steel rings. Because the static water level is above ground, the wellhead is fitted with an 8- to 4-inch "T" fitting and valve. This will allow water to flow from the well under control conditions when any work is done inside the casing, such as installation of a production pump. The static water level in the well is not expected to rise above the top of the casing even at high tide.



Finished wellhead

Development of the well was accomplished using standard cable-tool surge-and-bail techniques aided by the flowing conditions at the wellhead and, at times, by pumping the well with a centrifugal pump. A rubber surge block was fitted on the cable-tool rig. The drill-rig walking beam used to raise and lower the surge block in a two-foot stroke that alternatively pushes water out of and into the well screen. This action loosens and pulls in fine sand in the aquifer formation around the screen, resulting in a higher permeability outside the screen. The sand developed out of the formation was removed by bailing and by the flow and pumping of the well. The removal of fine aquifer formation sand causes the sand pack around the well screen to settle. Therefore, the pack was replenished during development. Development was accomplished over seven days, whereupon the sand pack had stabilized and the production of sand and turbid water had diminished sufficiently to conclude that the well had been sufficiently developed to warrant testing.

Testing

The water level in the well was monitored using a pressure transducer/data logger deployed on October 18 and retrieved on October 28. A second transducer was set in the annulus between

the 12-inch casing and the 16-inch flow/surface-seal casing. Initial deployment between the 18th and the 21st provided a shut-in tidal response for the 8-inch well and a tidal record for the non-flowing annular water level. The record is continuous for the annular setting, but the water level record in the 8-inch casing was interrupted on the morning of the 21st when the pump was set and again on the 24th when the pump was removed. The full hydrographic records for both the annular transducer and the well transducer are presented as Figure 4.

On October 21, a 40-hp submersible test pump was installed in the Plant well with the intake 110 feet below land surface. The same afternoon, a preliminary (step) test was accomplished. The step test was timed so as to occur near the low tide to minimize tidal reflection in the observed drawdown. The well was pumped at several successively increasing rates as listed in Table 1.

Table 1. Plant Well Pumping Test Results

Date	Discharge Rate (gpm)	Elapsed Time (minutes)	Drawdown (feet)	Specific Capacity (gpm/ft)
10/21	175	40	9.56	18.3
	277	20	16.61	16.7
	440	40	26.97	16.3
	540	20	33.91	15.9
10/22-23	416	1500	35.22	11.8

Pumping water levels measured on a falling tide tend to increase the drawdown measured by some small amount. Though these effects are sufficiently small that corrections were not necessary for the step test, it should be noted that the observed drawdowns are slightly greater than actual drawdown and that effect increases with successive steps. The reported results, therefore, conservatively overstate the drawdown. The results of the step test are presented graphically on Figure 5.

Based on the step test, it was determined that a test rate of about 400 gpm would be suitable for the constant-rate test. The well was pumped starting at 2:00 pm on Tuesday, October 22, and run at a continuous rate of 416 gpm (average from totalizer on meter) until 3:00 pm the following day, a total of 25 hours. Again, the start and stop of the test were timed so as to coincide with the low tide to minimize the effects on the early drawdown and recovery data sets.

The pre-test water level for the 25-hour test was 2.1 feet below the measuring point (top of the 1-inch PVC measuring tube), which was 4.87 feet above land surface. Land surface elevation was surveyed at 15.65 feet. Therefore, the static water level (swl) elevation was 18.42 feet above mean sea level at the start of testing. Water levels were monitored both electronically and manually throughout the test. Manual water level data are included as an appendix. A disc with the electronic data sets is also included with this report.

The transducer in the 12x16-inch annulus did not show any response to the test. The tidal signature in the annulus is nearly identical to the pre-test tidal signature. The well data for the constant-rate test drawdown and recovery was corrected for tidal influence by using the record from the annular transducer and is shown on Figures 6 and 7. Barometric changes were monitored on site throughout the testing period but no significant barometric changes were recorded, and the drawdown pattern and the tidal signature render any barometric changes insignificant to the analyses.

A plot of the drawdown data corrected for tide versus the log of elapsed pumping time is provided as Figure 6. Upon pump shutdown, water-level recovery was monitored manually for 60

minutes. At that time, monitoring was left to the automated equipment. The following day, the pumping equipment was removed from the well, and after a brief hiatus, the transducer was reinstalled in the well to acquire the longer-term recovery data. Recovery was accomplished for an additional four days. The record indicates full recovery was reached within 40 hours of pump shut off, though the tidal variability masks the last 16 hours where a small amount of remaining recovery may have occurred. The plot of tidally corrected recovery versus log of elapsed recovery time is provided as Figure 7.

Transmissivity

Aquifer transmissivity (T) is a measure of the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient of one. The transmissivity was calculated using the Jacob/Theis, modified, non-equilibrium formula from the pumping rate and the slopes of the drawdown graph recovery graphs. The water level in the well showed a drawdown of 35 feet after 25 hours of pumping at 416 gpm. The Cooper-Jacob solution of the Theis equation for the first 200 minutes of the test indicates a near-well transmissivity of approximately 25,000 gpd/ft. The plot of the later data indicates a transmissivity of approximately 13,500 gpd/ft for the more regional expression of the aquifer.

Though no calculation of the storage coefficient can be made without an observation well, the aquifer is confined. Therefore, we suggest an estimated value of 0.001 is appropriate to the setting.

Hydrogeology

The Plant well represents the first exploration of deep-source groundwater in this part of the City, particularly along the shore of Elliott Bay. This drilling demonstrates that the unconsolidated sediments consist of sand and gravel layers separated by substantial layers of fine-grained, low-permeability deposits which serve as regionally effective confining layers. In addition to the near-surface permeable materials, three distinct aquifer zones were encountered.

At the site, the first aquifer is between 146 and 208 feet below land surface. This unit has a substantial silt matrix throughout most of its extent and did not appear to be very productive with the exception of a few relatively thin layers. The preponderance of this aquifer layer is likely comprised of fairly low hydraulic conductivity material. A second, much more productive aquifer exists from 263 to 305 feet. Water in this aquifer may be brackish, but it is possible high conductivity observed during drilling was a carryover effect from the overlying aquifer. This unit is comprised of cleaner sand and gravel than the upper aquifer; its sediments showed signs of relatively high hydraulic conductivity. A seven-foot thick low-permeability layer in the middle of the aquifer zone is speculated to be a lahar deposit. The third aquifer (in which the well is completed) is between 333 and 380 feet bgs. This aquifer is at an elevation equivalent to the deeper portion of Elliott Bay more than 5,000 feet west of the well site. Testing indicates the water in this aquifer is fresh.

The confining layers at the upper portion of the hole and separating the three aquifer zones are all substantially thick. They are formed by low-permeability silt, clay and fine-matrix clastic deposits.

The deeper aquifer, which is the source aquifer for the Plant well, has a static water level between one and six feet above land surface depending upon the tide. It is likely the discharge zone for this aquifer is Puget Sound, within a mile west of the site.

Water Quality

Seattle Steam personnel collected samples for analysis in their laboratory. They report, with treatment, the water is of acceptable quality for the industrial purpose for which it is intended. During testing, the water was clear and sand free with a temperature of 53.5 degrees Fahrenheit.

Saltwater Intrusion Potential

Water conductivity was routinely checked throughout the test using a field conductivity meter. Additionally, samples were taken to be run for chloride, conductivity, and hardness per the requirements of the preliminary permit. No changes in conductivity were observed in the field.

Water samples were collected within the first 30 minutes, at 12 hours, and within one hour of the conclusion of the test. The samples were tested in a certified laboratory (WML Laboratory of Tacoma) for chloride, conductivity, and hardness as (CaCO3). Test results are listed in Table 2. Laboratory test results showed consistent water quality during the 25-hour pumping test.

Table 2. Chloride, Conductivity and Hardness Test Results

Plant Well	Interval	Chloride (mg/L)	Electrical Conductivity (uS/cm)	Hardness (mg/L)
10/22	30 minutes	6	203	43
	12 hours	6	200	43
10/23	24 hours	6	201	41

Though the well itself is capable of producing at sustained rates over 400 gpm, the predicted aquifer response indicates that pumping at that rate is not tenable. Further, concerns about saltwater intrusion make it unwise to pump at a rate where predicted drawdowns in the seaward direction could result in a cone of depression below sea level. Analyses of predicted cones for various pumping rates indicate that a continuous production rate of 250 gpm can likely be maintained without creating a lateral avenue for seawater intrusion. Making reasonable assumptions based on the level of knowledge gained through the drilling and testing program, the predicted elevation of the cone of depression at 250 gpm after 180 days is 4.2 feet 500 feet from the well and 4.4 feet 1,000 feet away. Even with a one-year projection, the predicted water levels remain above sea level at those distances (at 3.2 and 3.4 feet respectively). Details of this analysis are provided in an appendix

Findings

The pending water right for the Plant well is for a maximum instantaneous production rate (Qi) of 250 gpm. This is the practical maximum production rate for the well unless long-term production records support higher withdrawal rates. The Plant well could reliably provide 400 gpm for short duration peak demand (infrequently and less than one day), but sustained production at that rate beyond one day is not advised unless the aquifer responds more favorably than is projected from the 25-hour constant-rate test data. If, after an extended operation period, it is demonstrated that the aquifer can support additional production beyond the current water right application request of 250 gpm and 407 acre feet per year, a higher production rate can be considered and application for additional water rights can be made.

The report of water quality testing in Seattle Steam's laboratory indicates that, with treatment, the water is of acceptable quality for the purpose for which it is intended.

Recommendations

- Robinson Noble recommends installation of a submersible pump to a depth of approximately 90 feet below land surface in the 8-inch casing of the completed wellhead.
- The well is capable of substantial production. The projected aquifer response and the 250-gpm maximum demand indicated in the water right application make a well rating of 250 gpm appropriate at this time. The pump can be sized to provide the pressure necessary to move the water to points of use in the plant if that is the desired mode of operation. The predicted drawdown after 180 days of continuous operation at 250 gpm is just over 32 feet, or about 15 feet below sea level, depending upon the stage of the tide. Land surface elevation is 15.65 feet. A variable-frequency drive submersible pump should be considered to facilitate accommodating the observed aquifer response should the production potential prove to be greater than or less than is predicted from current testing.
- Two one-inch, vertically-accessible water-level sounding tubes should be installed with the pump. The wellhead design is intended to bring the wellhead sufficiently above land surface to preclude flowing conditions at high tide. However, it is best if the wellhead is sealed to preclude flowing in case of an unusually high tide.
- A combination monitoring device capable of monitoring depth to water, specific conductivity, and temperature should be installed in one of the sounding tubes. This unit would ideally be designed to provide data access remotely in the plant. The instrumentation should be set at a depth equivalent to approximately five feet above the top of the submersible pump. The system should be set up to record all parameters at one-hour intervals with the data sent to a computer where it will be automatically stored. Data should be plotted at least monthly through appropriate data-management software.
- Because aquifer response is a key element of the operation of this well, it is recommended that the operation of the well be ramped up to achieve the full 250-gpm maximum operational rate. It may be prudent to initiate pumping at a rate of 150 gpm (or the lowest rate practical for the installed pump if over 150 gpm) for the first few months of operation to verify the predicted aquifer response. Comparison of observed drawdown and the theoretical drawdown pattern through time should be made to determine the most appropriate operational pattern for the well. The production rates and durations during the ramp-up period can be determined in the context of plant operation needs.
- Robinson Noble recommends our hydrogeologists perform an annual review of the water level data collected so that operational changes can be considered.

The statements, conclusions, and recommendations provided in this report are to be exclusively used within the context of this document. They are based upon generally accepted hydrogeologic practices and are the result of analysis by Robinson Noble staff. This report, including any attachments to it, is for the exclusive use of Seattle Steam Company. Unless specifically stated in the document, no warranty, expressed or implied, is made.

FIGURES

ROBINSON NOBLE	Note: Basemap taken from USGS Seattle South Quadrangle	PM: FMK December 2013 2719-001B	King County T 25 N/R 04 E - 31 Scale 1" = 1000'	Figure 1 Vicinity Map Seattle Steam Company

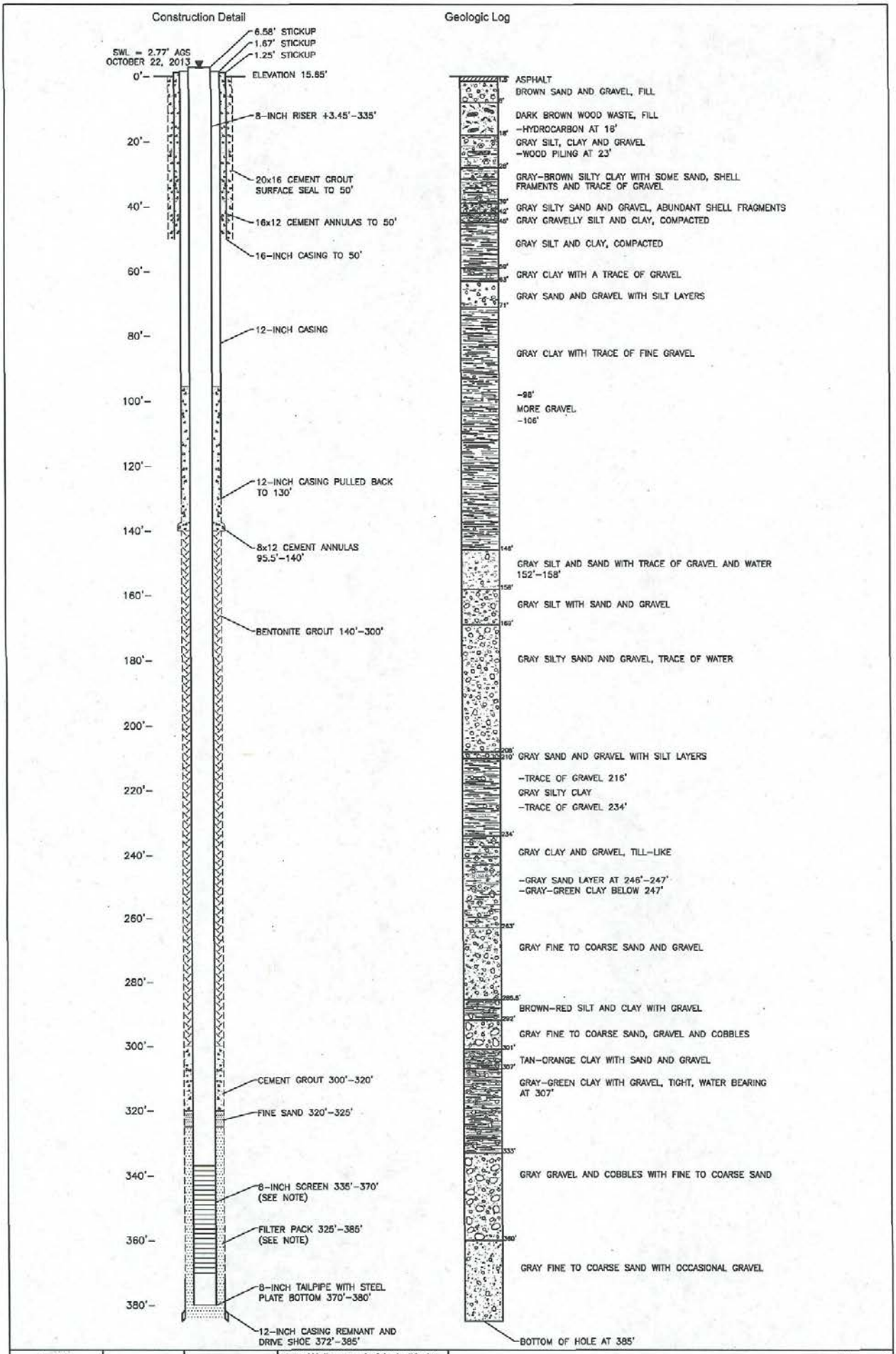
ROBINSON NOBLE

Note: Image from USGS EarthExplorer
Date: March 2012

PM: FMK
December 2013
2719-001B

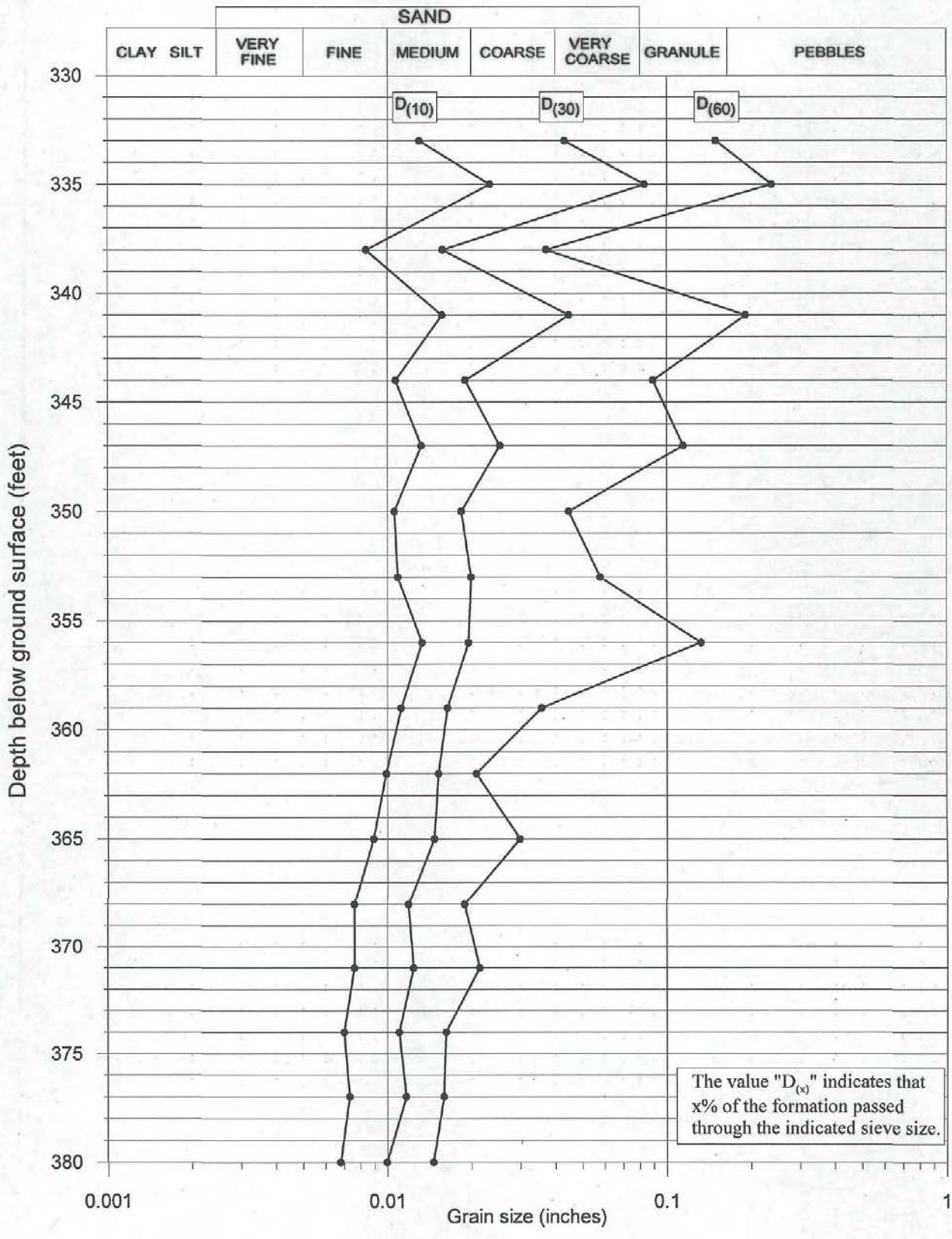
King County
T 25 N/R 04 E - 31
Scale 1" = 100'

Figure 1A
Aerial Map of Site
Seattle Steam Company



ROBINSON NOBLE	PM: FMK December 2013 2719-001B	King County T 25 N/R 04 E - 31 Unique ID: BCS872	Note: Well screen is 8-inch, 50-slot (0.050-inch opening) type 304, standard stainless steel. Filter pack is 8x12 Colorado Silica Sand product.

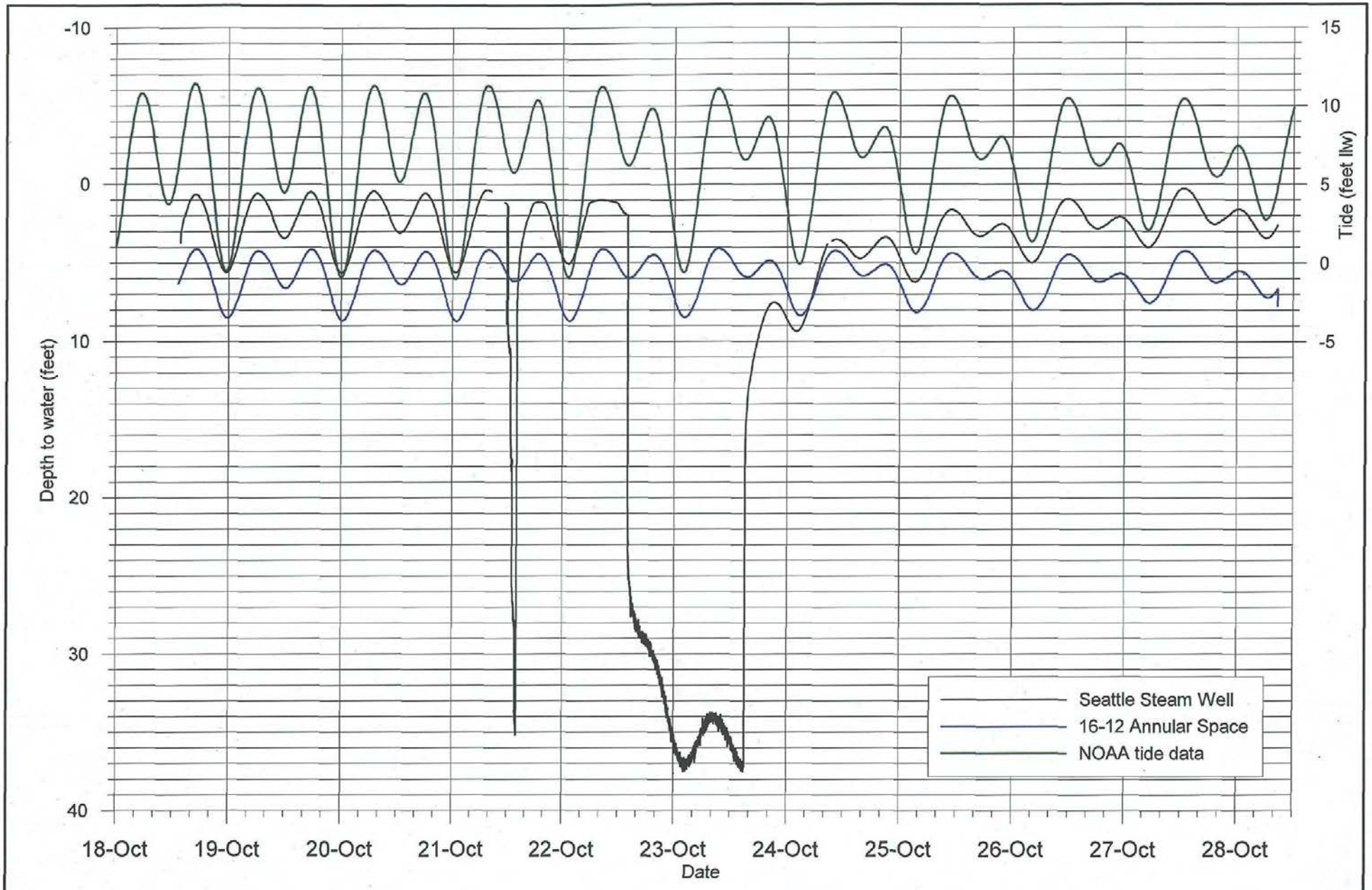
Figure 2
Construction Detail and Geologic Log for Seattle Steam Plant Well
Seattle Steam Company



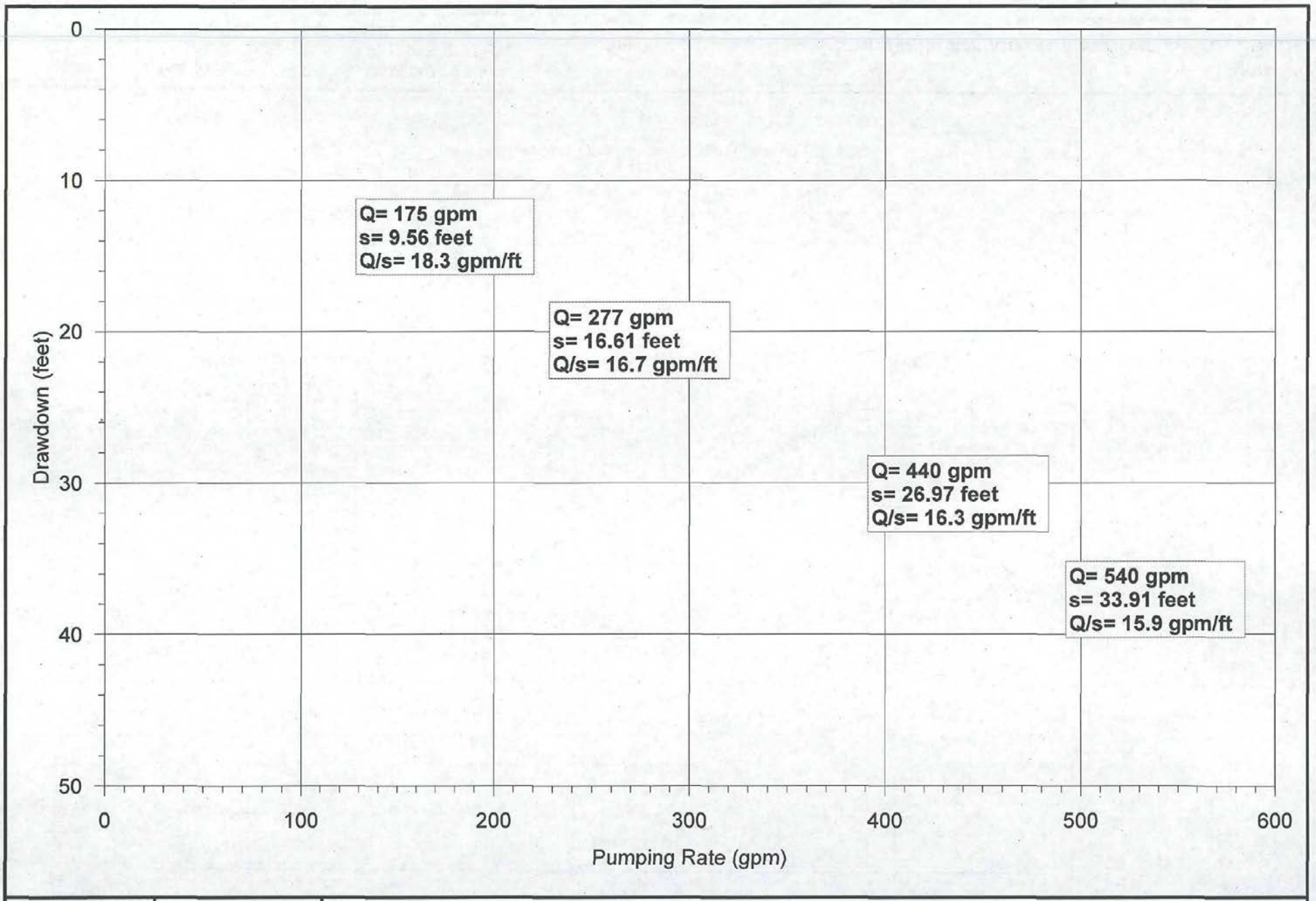
ROBINSON NOBLE

PM: FMK
December 2013
2719-001B

Figure 3
Plant Well Vertical Grain-size Distribution
Seattle Steam Company



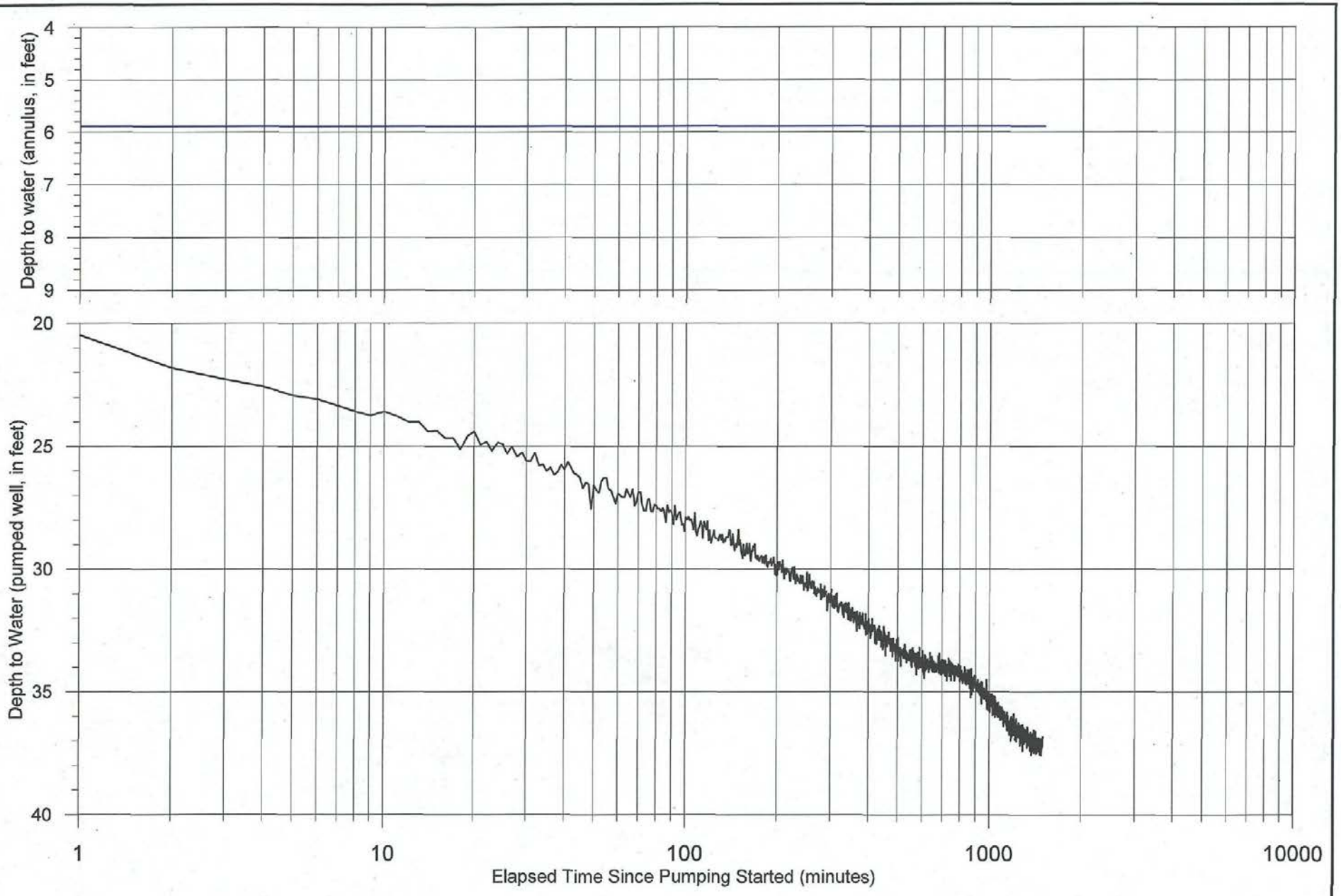
ROBINSON NOBLE	PM: FMK December 2013 2719-001B	October 18-28, 2013	**Figure 4** Plant Well Hydrographs, October 18-28, 2013 Seattle Steam Company



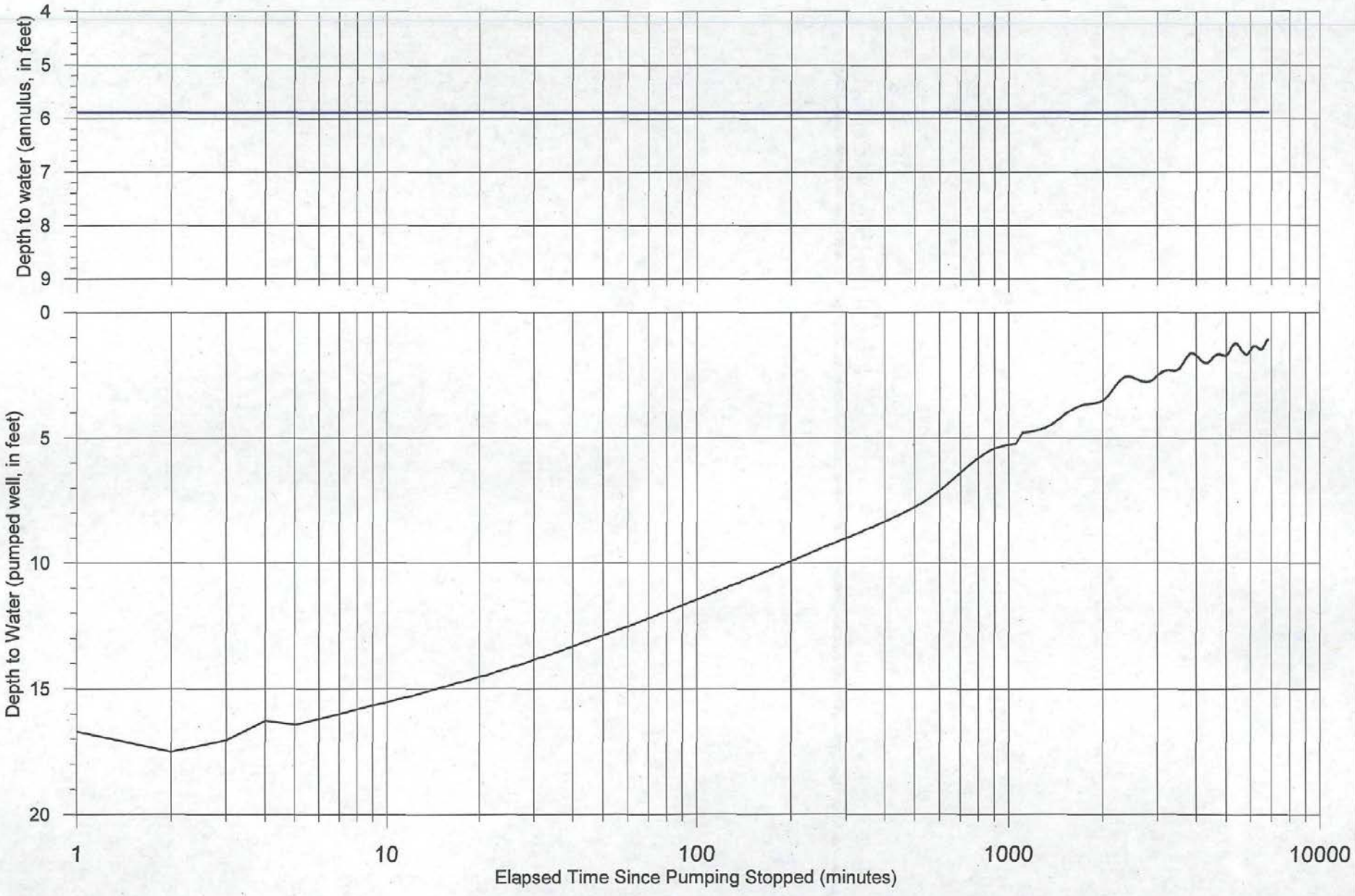
ROBINSON NOBLE

PM: FMK
December 2013
2719-001B

Figure 5
Plant Well Step Test, October 21, 2013
Seattle Steam Company



ROBINSON NOBLE	PM: FMK December 2013 2719-001B	Pre-test DTW = 2.10 feet October 22, 2013, 2:00 PM 416 GPM Constant-rate testing Tidal influence mathematically removed	**Figure 6** Plant Well Drawdown, October 22-23, 2013 Seattle Steam Company



ROBINSON NOBLE	PM: FMK December 2013 2719-001B	Pre-test DTW = 2.10 feet October 22, 2013, 2:00 PM 416 GPM Constant-rate testing Tidal influence mathematically removed	**Figure 7** Plant Well Recovery, October 23-24, 2013 Seattle Steam Company

Preliminary Permit

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Ave SE • Bellevue, WA 98008-5452 • 425-649-7000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

RECEIVED
JUN 05 2013
SEATTLE STEAM COMPANY

JUN 04 2013

Jim Thompson
Brandon Oyer
Seattle Steam Company
1325 Fourth Avenue
Suite 1440
Seattle, WA 98101

Re: PRELIMINARY PERMIT to Drill and Test a Well under Water Right Application G1-28722

Dear Mr. Thompson:

This letter serves as a Preliminary Permit to drill and test a well under Groundwater Application G1-28722. **PLEASE READ THIS LETTER CAREFULLY. In accordance with RCW 90.03.290, failure to comply with the conditions of this Preliminary Permit shall result in the cancellation of the preliminary permit and the associated water right application.**

The above water right application requests the withdrawal of public groundwater at the rate of 250 gallons per minute (gpm) for industrial use from a well in the SE¼ of Section 31, Township 25 North, Range 4 East, W.M. in King County.

The purpose of this preliminary permit is three-fold. First, this permit is intended to provide information that can be used to determine the well's capacity to produce the requested instantaneous quantity, and to determine the ability of the aquifer to transmit water. Second, this permit is intended to provide information regarding the potential for seawater intrusion into the aquifer resulting from the proposed withdrawal. Lastly, this permit is intended to provide information regarding any potential impacts to existing wells due to the operation of the proposed withdrawal.

The Department of Ecology (Ecology) is likely to deny new water right applications in areas where sea water intrusion into the aquifer has been documented. Elevated groundwater chloride concentrations may be attributed to a high level of mineralization, as opposed to intruded by sea water. Because of this, it is important to distinguish between hard groundwater and groundwater that has been impacted by sea water intrusion. The water quality analyses required as part of this preliminary permit are necessary to distinguish between groundwater that has been impacted by sea water and groundwater that is highly mineralized.

Under the authority of RCW 90.03.290 and RCW 90.44.060, Ecology may issue a preliminary permit requiring the applicant to conduct studies, surveys, and investigations necessary to provide the information needed to properly assess the subject application. Given the uncertainties regarding the ability of the aquifer and well to produce the required water volume, and uncertainties regarding the changes in water quality, a pumping test is required to provide the necessary information to address these uncertainties.

You are hereby granted a PRELIMINARY PERMIT to proceed with testing the well you intend to use for your steam power generation operations. This letter serves as a PRELIMINARY PERMIT subject to existing rights and the following conditions:

1. This PRELIMINARY PERMIT becomes effective immediately and will remain in effect until **June 30, 2014,** unless sooner revoked by Ecology.

2. All water wells constructed within the state shall meet the minimum standards for construction and maintenance as provided under chapter 18.104 RCW (Washington Water Well Construction Act of 1971) and chapter 173-160 WAC (Minimum Standards for Construction and Maintenance of Water Wells). If a variance is required for construction, alternate construction shall be approved by request to the department.

3. An access port, as described in the Department of Ecology's Groundwater Bulletin No. 1 (ECY 040-1-3, Rev. 12/90 [copy enclosed]), shall be installed and maintained. In order to facilitate accurate recovery data collection, the system shall incorporate backflow check-valve(s) that will prevent water from flowing back into the well when the pump is shut off.

4. *Background water level data* shall be collected from the pumping well prior to the start of the pump test. *Tidal and barometric pressure data* shall also be collected during this period to evaluate background water level fluctuations.

5. An aquifer test shall be conducted under the supervision of a professional groundwater consultant. The well shall be tested in a manner consistent with best scientific practice to determine whether the well is capable of providing adequate water for its proposed use, without contributing to seawater intrusion into the aquifer. This test may take the form of a step-test (variable pump rate) or constant rate pump test, but only the highest sustained pumping rate may be permitted for purposes of appropriation and final certificating as a water right. The *highest sustained rate* shall be considered the pumping rate maintained with stabilization of the pumping well water level occurring for at least four hours. Stabilization is defined as a drop in water level of less than or equal to 0.1 foot drawdown per hour during pumping.

6. *Tidal and barometric pressure data* shall be collected for the duration of the pump test, as well as during the recovery period.

7. Pumped water produced during the test shall be routed away from the pumping well and all observational wells, and shall be discharged such that this water will not influence the test in any way. This water may also be stored for future use.

8. Water levels in the pumping well and all observational wells shall be monitored and recorded throughout the duration of the aquifer test (which includes the recovery period). Generally more frequent measurements are required at the beginning of the test when the rate of water level change is greatest. Refer to WRIS Information Bulletin No. 30 for the recommended frequency of measurements throughout the aquifer test. Additionally, water levels should be measured in feet, using 10ths and 100ths of a foot rather than inches.

9. At the completion of pumping, recovery data shall be collected from *all* wells until the pumped well nears pre-pumping static conditions and the water level recovery rate is less than 0.1 foot per hour.

10. The following water quality sampling and analyses will be used by the Department of Ecology when evaluating your application. **Please be aware that the state or county health department may require additional testing prior to the approval of your project. If your project involves a public water system, please check with the appropriate health agency to determine what additional testing is required prior to conducting the test.** All water sample analyses conducted pursuant to this PRELIMINARY PERMIT shall be performed by a laboratory accredited by the Washington State Department of Ecology.

    Groundwater sampling and analysis shall occur as follows:

    - For the pumped well, water quality samples shall be collected at the following times during the pump test: *within the first 30 minutes, and within one hour of the conclusion of the test.*

    - All samples shall be analyzed for *chloride, conductivity, and hardness (as $CaCO_3$).*

11. When the aquifer test is complete, the data shall be analyzed and all pertinent information compiled into a completion report and submitted to the Department of Ecology, Northwest Regional Office. This report shall address the following:

    - The distance and time drawdown response within the producing aquifer to the proposed groundwater withdrawal.

    - Aquifer transmissivity.

    - Aquifer storage coefficient or specific yield.

    - The measured and potential effect of the proposed groundwater withdrawal on any existing groundwater and surface water users, wetlands, springs, lakes, streams, etc.

    - Seawater intrusion potential.

    The report shall also include the following:

    - A well construction report (well log for the pumping well and all observation wells, if available). This must include the total depth and screened interval depths for all

wells, as well as the pump intake depth for the pumping well.

- Distance, to the nearest foot, from the pumping well to each observation well and a map indicating all well locations.

- Copies of the original field data sheets and a discussion of the methods and calculations employed during determination of aquifer characteristics and discharge measurements.

- Land surface elevations for all measuring points and method used for determining.

- All water level data collected pursuant to this permit shall be submitted to the Department of Ecology in electronic form (such as a spreadsheet) along with a hard copy, if it exists.

- Tidal fluctuation and barometric pressure data shall be plotted on a graph along with water level data collected during the pump test.

- A copy of any laboratory test results, including chain-of-custody documentation.

12. All expenses, risks, and liabilities incurred during well testing shall be borne by the applicant. If senior water right holders, including those with rights to surface water bodies and wells exempt from permitting under RCW 90.44.050 are adversely affected during any portion of the aquifer test, the test shall be terminated immediately.

This PRELIMINARY PERMIT grants the right to use this well for testing purposes only. No further use will be allowed from the well until such time as specific approval has been granted. Approval will not be considered until such time as the above conditions have been met. The granting of this PRELIMINARY PERMIT shall not be construed, by inference or otherwise, that the subject application will ultimately be approved. **If the applicant fails to comply with the conditions of this PRELIMINARY PERMIT, it and the associated water right application may be canceled.**

You have a right to appeal this action to the Pollution Control Hearing Board (PCHB) within 30 days of the date of receipt of this document. The appeal process is governed by Chapter 43.21B RCW and Chapter 371-08 WAC. "Date of receipt" is defined in RCW 43.21B.001(2).

To appeal, you must do the following within 30 days of the date of receipt of this document:

- File your appeal and a copy of this document with the PCHB (see addresses below). Filing means actual receipt by the PCHB during regular business hours.

- Serve a copy of your appeal and this document on Ecology in paper form - by mail or in person. (See addresses below.) Email is not accepted.

You must also comply with other applicable requirements in Chapter 43.21B RCW and Chapter 371-08 WAC.

Street Addresses	Mailing Addresses
Department of Ecology Attn: Appeals Processing Desk 300 Desmond Drive SE Lacey, WA 98503 Pollution Control Hearings Board Environmental Hearings Office 1111 Israel Road SW, Suite 301 Tumwater, WA 98501	Department of Ecology Attn: Appeals Processing Desk P.O. Box 47608 Olympia, WA 98504-7608 Pollution Control Hearings Board P.O. Box 40903 Olympia, WA 98504-0903

For additional information visit the Environmental Hearings Office Website:
http://www.eho.wa.gov

To find laws and agency rules visit the Washington State Legislature Website:
http://www1.leg.wa.gov/CodeReviser

Should you have any questions regarding this PRELIMINARY PERMIT, please contact Noel Philip at (425) 649-7044 or at noel.philip@ecy.wa.gov.

Sincerely,

Jacqueline Klug
Section Supervisor
Water Resources

jk/dh/mc

By certified mail: 7012 3460 0000 2586 7698

Enclosures: WRIS Information Bulletin 30
Groundwater Bulletin No. 1
Your Right to be Heard

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Water Resources Information System

Aquifer Test Procedures

September 1976
Rev. 6/98
WRIS Information Bulletin No. 30

printed on recycled paper

AQUIFER TEST PROCEDURES

By

WATER RESOURCES INVESTIGATION SECTION
PERSONNEL

September, 1976
Rev. 6/98
Department of Ecology
Olympia, Washington

FORWARD

During our evaluation of ground-water quantity throughout the state we often encounter pump test data which are inadequate for aquifer analysis. In many cases, much time, effort and money were expended but because of failure to record readily available information, or to make accurate measurements, a test that would have yielded much aquifer data, did not. It is the purpose of this paper to point out precautions that must be taken, the tools needed and the recording of data necessary to produce reliable basic data, which can be used for determination of aquifer characteristics.

Aquifer Test Procedures

The primary objective of aquifer tests is to determine the ability of the aquifer to transmit and store water and to determine adverse effects on existing wells created by new withdrawals. It is important that everything possible is done to assure that the data are sufficiently detailed and accurate to determine these parameters.

If possible, other wells or springs in addition to the pumped wells, should be measured for drawdown during the aquifer test. Drawdown measurements in at least two wells are necessary to establish the storage coefficient of the aquifer. These wells must be hydraulically open to the aquifer being tested. An examination of the driller's log, where available, will possibly indicate if the wells have been perforated or screened in the same aquifer.

Observation wells accessible to hand measurement are preferable to airline measurements. The accuracy of airlines is questionable and they should be used only if necessary.

Once the observation wells have been selected, the discharging well should be pumped for several hours before the aquifer test to determine the maximum constant discharged which can be maintained, the approximate extent of drawdown, the method best suited for measurement of discharge and the disposal of the pumped water. A constant rate of discharge is important. An electric pump is preferable to gasoline driven pumps as discharge rates are more constant.

An accurate means of measuring discharge is essential. Orifice buckets, weirs, flow meters, and orifice plates are useful devices. A simple and accurate method makes use of an open bucket or barrel with know capacity and a stopwatch; the water is discharged into the container, and the time taken to fill it to known capacity is measured. A flow meter may be attached to the discharge pipe and used to monitor outflow from the well. For greater accuracy, place the meter at least 10 pipe diameters and at least 5 pipe diameters upstream from any valve controlling the flow or any elbows or pipe structures. Water should be discharged away from the immediate test area so that recharge to the aquifer does not occur. Refer to Johnson, Ground Water and Wells, for additional information.

Operating Procedure

It is critical that pumps, which might affect drawdown in the aquifer being tested, be shut off at least 24 hours before the test is to begin. This allows water in the pumped and observation wells to static or near static conditions. If these nearby pumps cannot be shut down, the pumpage and approximate time of operation should be noted.

It is advisable to record water levels and time of measurements prior to pumping in areas where water levels are affected by tidal movements or barometric changes. These data are used to correct the aquifer test measurements such that the changes in the latter reflect only the effects of the pumping stress. Microbarograph or Paulin System altimeters are useful in cases of barometric changes.

Once the pump is started, discharge should be maintained at a constant rate. The flow, which should initially be less than the pump capacity, is controlled by means of a valve in the discharge pipe.

The actual measurement of water levels during the test should be made with equipment such as standardized electric tapes or steel tapes. Electric tapes are generally used to measure in pumped wells because the wet casing and turbulence make measurement with steel tape difficult. The convenience of the electric tape also allows for more rapid measurements during the initial portion of drawdown and recovery where they are greatest. Steel tapes are more accurate and should be used whenever possible.

Barometric and tidal changes can influence water levels in aquifers and are therefore important parameters to measure before and during the pumping test and recovery period. For example, a barometric pressure change of 1 inch (25.4 mm) of mercury can result in a rise or fall of up to 1 foot in the potentiometric surface for confined aquifers that have high barometric efficiency. Barometric efficiency refers to the aquifer's ability to transmit changes in atmospheric pressure. Tidal changes can affect ground water levels up to several feet in wells near tidally influenced areas.

Because the rate of drawdown is greater during the early part of the test, accurate measurements (to 0.01 feet if possible) are taken with brief intervals between readings (a portable tape recorder may be helpful). The time between measurements is gradually increased as the test progresses. The following table gives a recommended frequency at which measurements should be taken:

Time since pumping started or stopped	Time intervals
0-2 minutes	approx. every 10 seconds
2-5 minutes	30 seconds
5-15 minutes	1 minutes
15-50 minutes	5 minutes
50-100 minutes	10 minutes
100 minutes – 5 hours	30 minutes
5 hours – 48 hours	1 hour
48 hours – 6 days	8 hours
6 days – shutdown	24 hours

If an observation well is some distance from the pumped well, the interval of measurement can be greater as the effect of drawdown on this well will not show for some time.

Recovery measurements should be made in the same manner as the drawdown measurements. Once the pump has been turned off, measurements are taken at the same frequency as prescribed for drawdown until the water in each well nears prepumping static conditions. Recovery data are as, or more important than the pumping data, especially in cases where discharge rates are not constant throughout the pumping test. Recovery data may also be used to check calculations based on drawdown data.

Both drawdown and recovery data should be recorded on forms similar to the example attached to this procedures report. The owner of the well, location, well number, date, type of test (drawdown or recovery), county, measuring point, type of measuring equipment, elevation of measuring point and person recording the data, should all be listed on each page. The data will be entered under the columns: depth – referring to depth in feet to water level, s – (drawdown or recovery) in feet, t – referring to time since pumping was started or stopped, and r – the distance from the pumped well to the observation well. Remarks will include any additional information

such as discharge rate of pumped well (which should be recorded frequently during the early part of the test and later as often as water level measurements are taken), any changes in conditions, or unusual events such as storms, temperature changes, etc.

Duration of the Aquifer Test

The amount of time the aquifer should be pumped is dependent on the type of aquifer, the degree of accuracy needed to establish the storage coefficient and transmissivity and the rate of pumping. Pumping should continue until equilibrium occurs, that is, until the recharge of the aquifer equals the discharge and the water levels in the wells stabilize. This may occur a few hours after pumping starts, or it may be days or weeks. Some aquifer tests may never achieve equilibrium. Although it is not necessary for the pumping to continue until equilibrium is reached, it is recommended that pumping be continued for as long as possible and at least 24 hours. Recovery measurements should be made for a similar period or until pre-pumping water levels have been attained. The costs of running the pump a few extra hours are low compared with the total costs of the test, and the difference in data could be the difference between a conclusive or inconclusive aquifer test.

Summary

The performance of an aquifer test involves at least the following procedure:

1. Standardize tapes – Steel tapes are the most accurate and should be used whenever possible. E-tapes should be calibrated with a steel tape because slippage of the metal taps will give erroneous readings. E-tapes are usually used in pumping wells, cascading wells, or wells with wet casings. Usually, it is best to assign one E-tape for all measurements of a particular well. Avoid airline measurements, or use only when necessary.

2. Synchronize watches – Time is important during the early part of the test. Later, exact time is not needed.

3. Barometric and tidal measurements – Barometric pressure should be recorded throughout the duration of the aquifer test. Tidal effects on the aquifer being tested should also be assessed prior to the test. Drawdown measurements in the pumping and observation wells must be corrected for any tidal effects.

4. Start pump after measuring all static levels – Static levels of all observation wells measured prior to the test are used as the initial static levels. If static levels are changing significantly, measurements should be taken at intervals several days before the test begins to determine the fluctuations such that the measurements taken during the test pumping can be corrected.

5. Measure all wells frequently at first – The most frequent measurements usually are made in the pumped well and in the closest observation wells.

6. Measure pump discharge – Frequent pump discharge measurement with adjustments, if required, assures a constant discharge during the test. As a rule, start the pump discharge at a less than capacity to allow for adjustment.

7. Record data on appropriate forms – Use a clipboard at each well with the data sheets clearly labeled as to which well it applies and exact measuring point. The form of the sheet is unimportant but it should tabulate the necessary drawdown data in a systematic manner.

8. Plot drawdown vs. time on semi-log paper – Plotting of all wells during the test is very useful because this plot will reveal the effects of boundaries or other disturbing influences if they are encountered. It will also give some indication when enough data capable of a solution have been recorded.

9. Measure recovery – It is advisable to obtain recovery measurements. Recovery measurements are more consistent, especially if pump discharge varies. Recovery data are added confirmation of the drawdown data; measurements should be maintained until static water level is reached.

REFERENCES

Edward E. Johnson, Inc., 1972, Ground Water and Wells, Johnson Div., Univ. Oil Prod. Co., St. Paul, Minn., pp. 81-98.

Kruseman, G.P. and de Ridder, N.A., 1970, Analysis and Evaluation of Pumping Test Data: International Institute for Land Reclamation and Improvement, Wageninger, the Netherlands; pp. 23-44.

DEPARTMENT OF ECOLOGY
WATER RESOURCES DIVISION
OLYMPIA, WASHINGTON 98504

AQUIFER TEST

Sheet ____ of ____

Owner__________________ Location______________________ Well No.__________

Date____________ Meas. by________________ Test__________ County__________

Meas. point________________________ Elev. Meas. Point________________________

Meas. equipment____

DTW_o______________ t_o______________ Q______________ r______________

Date	Hour	Water Level			s	t	$\frac{1440r^2}{t}$	Remarks
		Held	Wet	Depth (DTW)				

Ground Water Bulletin No. 1

Access Ports or Pressure Gages for Water-Level Measurements

All wells are required to have either an access port for measuring the depth to water or a pressure gage to measure the shut-in pressure of flowing wells. (WAC 173-160-355)

Determination of the level of the water surface in a well is desirable for the following reasons:

a. To enable a well owner to determine whether or not the water level in the well is below the suction pipe or pump bowls if the pump fails to deliver water.

b. To enable a well owner to determine the efficiencies of the pump and well by means of comparing water levels with pumping rate and power consumption.

c. To allow access to wells for ground water studies. The state regularly collects water levels during different seasons of the year and during pump tests to determine drawdown interference between two or more wells. These studies are conducted for the purpose of safeguarding the continued supply of ground water.

Sketches on the following page show several ways of providing access ports (tapped holes or airlines) and pressure gages, depending on a well's plumbing and pump placement. This sketch is similar to Figure 6 in WAC 173-160-355.

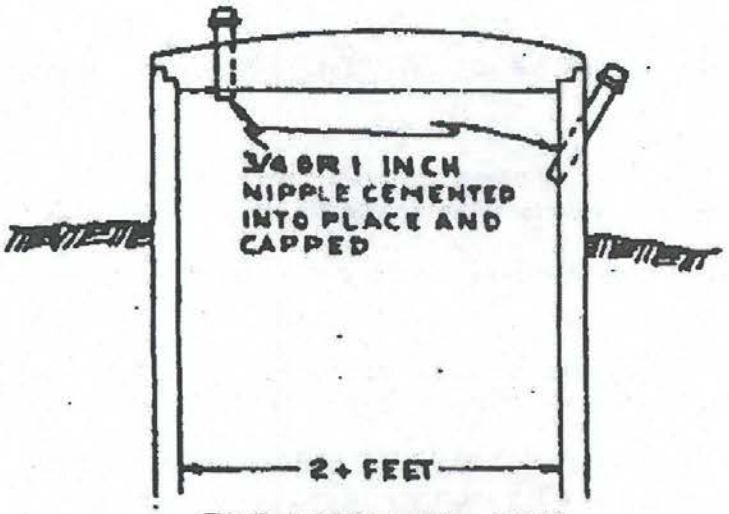
An airline installation is recommended where the water level lies at a considerable depth below land surface. The amount of air pressure that can be built up inside the air line will indicate the depth of water standing above the bottom of the air line. (One pound-per-square-inch pressure equals approximately 2.31 feet of water.) The exact length of the air line is required to obtain an accurate measurement of the water level in the well. The air line length should be conspicuously posted at the well head.

Ecology is an Equal Opportunity and Affirmative Action employer.

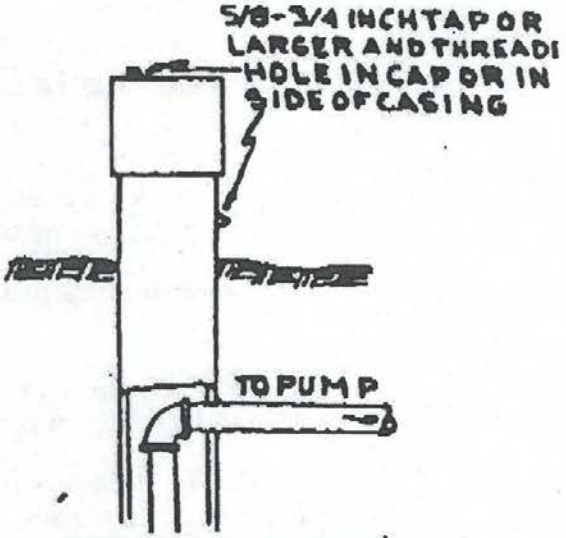
ECY 040-1-3 (Rev. 4/94)

SKETCHES OF ACCESS PORTS TO WATER WELLS

A. WELLS OPEN ABOVE

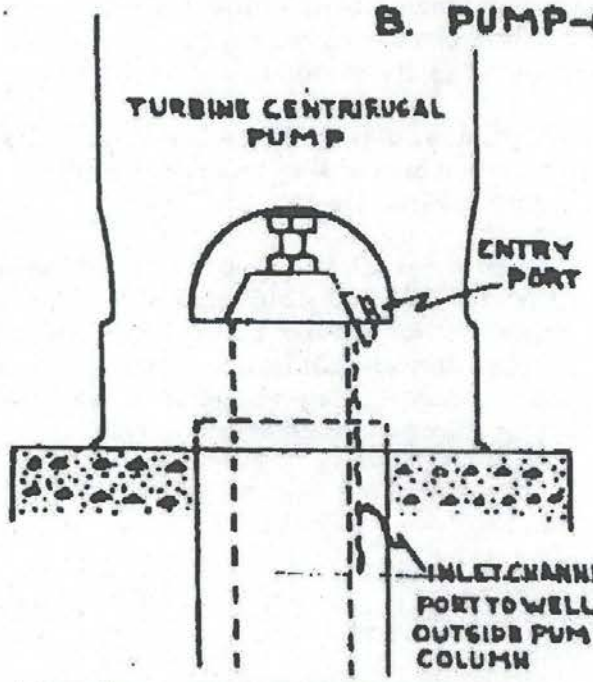


FOR MASONRY WELLS

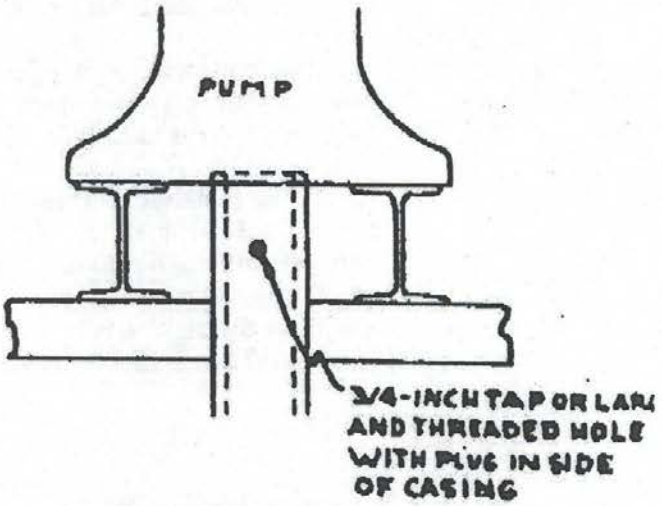


FOR STEEL-CASED WELLS

B. PUMP-COVERED WELLS

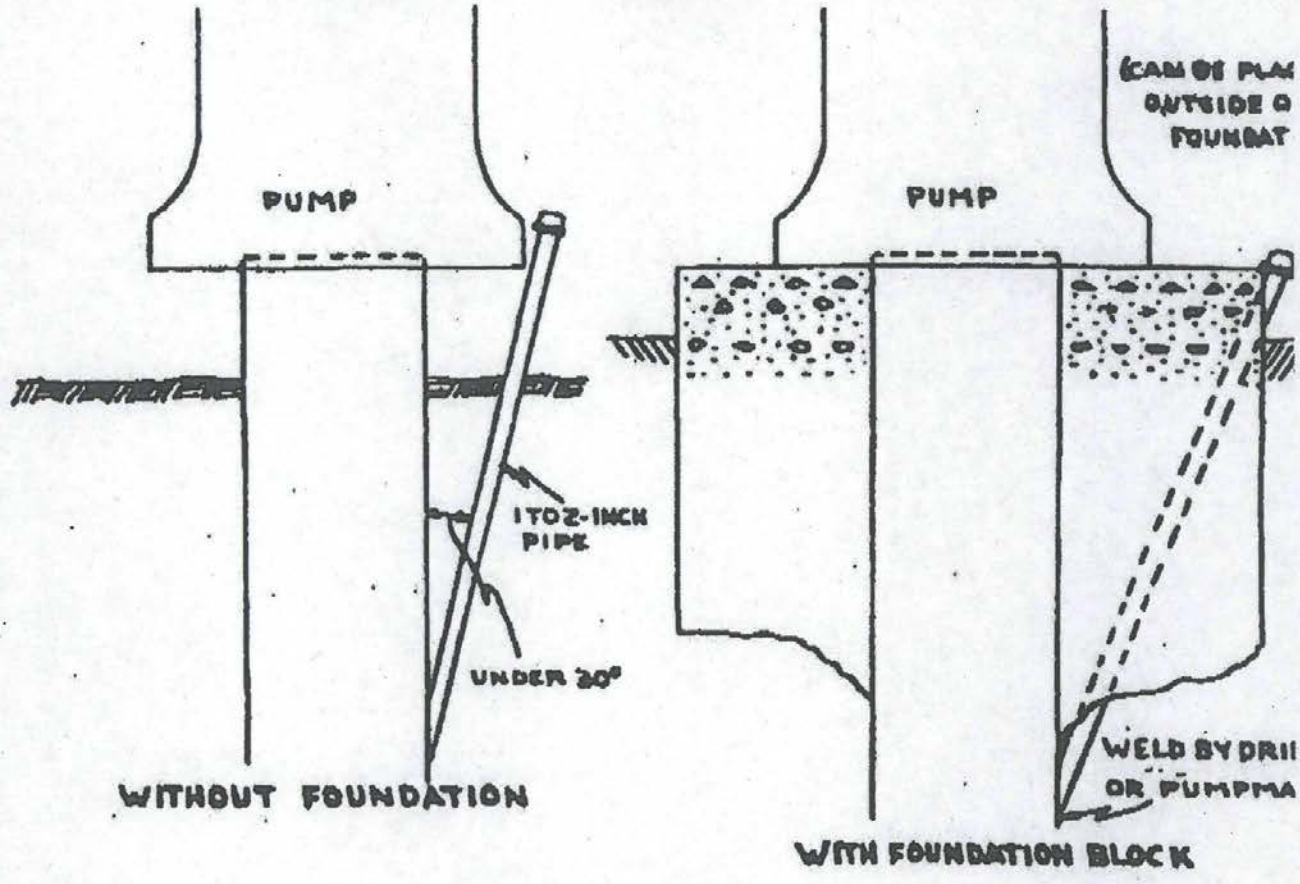


BUILT-IN ENTRANCE TO WATER IN WELL

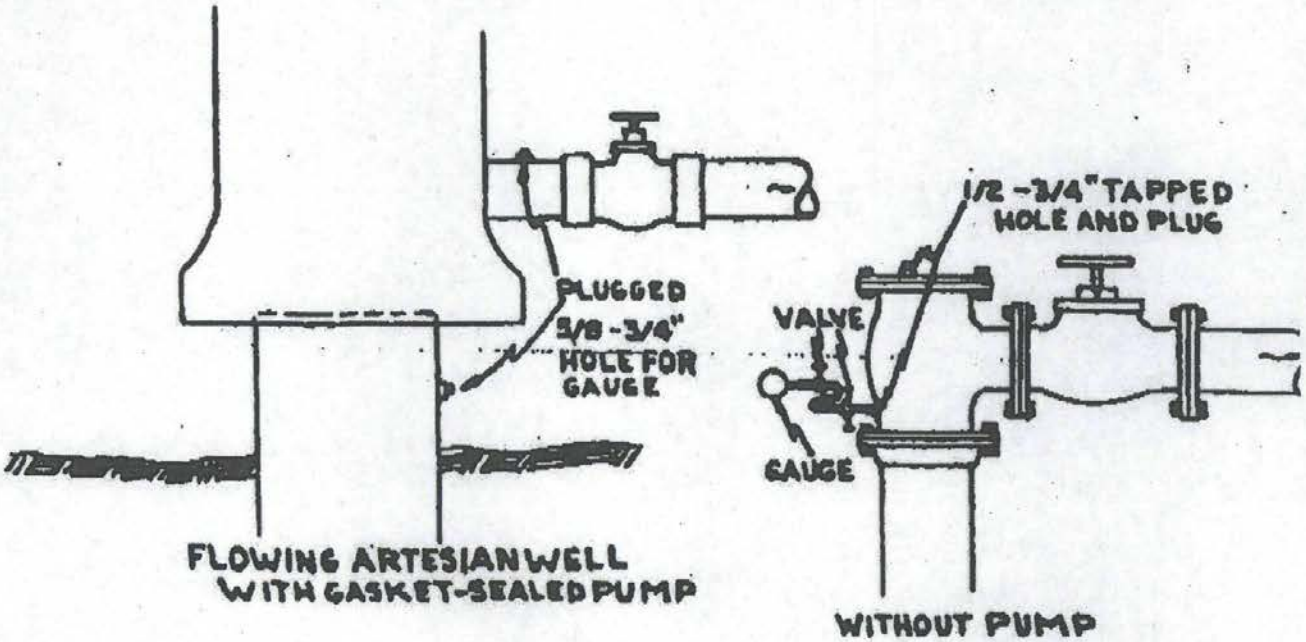


ENTRY BELOW HIGH-SET PUMP

C. EXTERNAL PIPE ENTRY TO WELL CASINGS



D. ENTRY TO ARTESIAN FLOWING WELLS



Well Construction Variance

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office • 3190 160th Ave SE • Bellevue, WA 98008-5452 • 425-649-7000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

MAY 01 2013

RECEIVED
MAY 03 2013
SEATTLE STEAM COMPANY

Jim Thompson
Brandon Oyer, PE
Seattle Steam Company
1325 4th Avenue
Ste. 1440
Seattle, WA 98101

RE: Variance request from Washington Administrative Code (WAC) 173-160-171, requirements for properly siting water wells. The property is located at 1319 Western Avenue, Seattle, in the NW¼ SE¼ of Section 31, Township 25N, Range 04E, in King County.

Dear Messers Thompson and Oyer:

Seattle Steam requested a variance to water well construction standards in WAC 173-160-171 which restricts the placement of water wells.

Department of Ecology (Ecology) received your variance request via email December 02, 2012. Concurrent water rights processing and indeterminate acquisition of permits postponed processing of this request. The request was submitted with the following:

- Attachment A: Descriptive list of potential contamination sources on and near the property
- Attachment B: excerpts from a letter dated December, 2009, written by Department of Ecology, describing the extent of contamination at the site
- Attachment C: results of geotechnical evaluation of the site showing depth to confining/low permeability sedimentary layers
- Site plan for the proposed well (scaled)

According to the request, the property is in an urban setting, and the industrial use of the completed well in conjunction with the steamworks limits possible locations for the well. Further, the site has been subject to contamination, and construction alternatives must be found to locate a well within setbacks of these potential sources of contamination to groundwater.

Your proposed alternative construction is to lengthen the sanitary surface seal to extend five (5) feet into the confining layer found approximately 50 feet below ground surface.

After an investigation, interview, and review of information available, a variance is hereby **granted** in accordance with WAC 173-160-106 to allow for construction of the well with the extended seal, according to the provisions, below. This variance **expires December 31, 2014.**

1. The sanitary surface seal required by WAC 173-160-231 shall extend five (5) feet into a suitable confining layer found approximately 50 feet below ground surface. If no suitable confining layer is found at this depth, the seal shall extend from ground surface to at least 60 feet below ground surface, while meeting the remaining requirements of surface seals.

2. A" Notice of Intent to Construct a Water Well" (Start Card) and fees must be submitted to Ecology (Olympia address).

3. All other minimum construction standards found in WAC 173-160 shall be followed to protect further degradation of the groundwater resource.

4. A well report describing the construction of the well shall be submitted to the Department (Northwest Regional Office) within thirty (30) days after completing the work for the well. Attach a copy of this variance to the well report.

5. Inform Ecology (Noel S. Philip, 425-649-7044) two business days before any work begins. The site must be accessible to Mr. Philip or any county delegate to inspect any and/or all construction work.

6. With the exception of the specific provisions set forth (above) in this variance, all federal, state, and local requirements shall apply.

7. This variance expires **December 31, 2014.** After this date, approval of a new request for variance must be obtained for the work proposed.

You have a right to appeal this action to the Pollution Control Hearing Board (PCHB) within 30 days of the date of receipt of this document. The appeal process is governed by Chapter 43.21B RCW and Chapter 371-08 WAC. "Date of receipt" is defined in RCW 43.21B.001(2).

To appeal, you must do the following within 30 days of the date of receipt of this document:

- File your appeal and a copy of this document with the PCHB (see addresses below). Filing means actual receipt by the PCHB during regular business hours.

- Serve a copy of your appeal and this document on Ecology in paper form - by mail or in person. (See addresses below.) Email is not accepted.

You must also comply with other applicable requirements in Chapter 43.21B RCW and Chapter 371-08 WAC.

Street Addresses	Mailing Addresses
Department of Ecology Attn: Appeals Processing Desk 300 Desmond Drive SE Lacey, WA 98503 Pollution Control Hearings Board Environmental Hearings Office 1111 Israel Road SW, Suite 301 Tumwater, WA 98501	Department of Ecology Attn: Appeals Processing Desk P.O. Box 47608 Olympia, WA 98504-7608 Pollution Control Hearings Board P.O. Box 40903 Olympia, WA 98504-0903

For additional information visit the Environmental Hearings Office Website:
http://www.eho.wa.gov

To find laws and agency rules visit the Washington State Legislature Website:
http://www1.leg.wa.gov/CodeReviser

Your attention to these laws and regulations, and cooperation with the Department of Ecology in this matter is appreciated. Please telephone Noel S. Philip at (425) 649-7044 or email him at noel.philip@ecy.wa.gov if you have any questions concerning this variance.

DATED this 1 day of May, 2013, at Bellevue, Washington.

Sincerely,

Jacqueline Klug
Section Manager
Water Resources Program

jk/np/mc

By certified mail: 7010 3090 0000 1910 5666

Enclosure: Your Right to be Heard

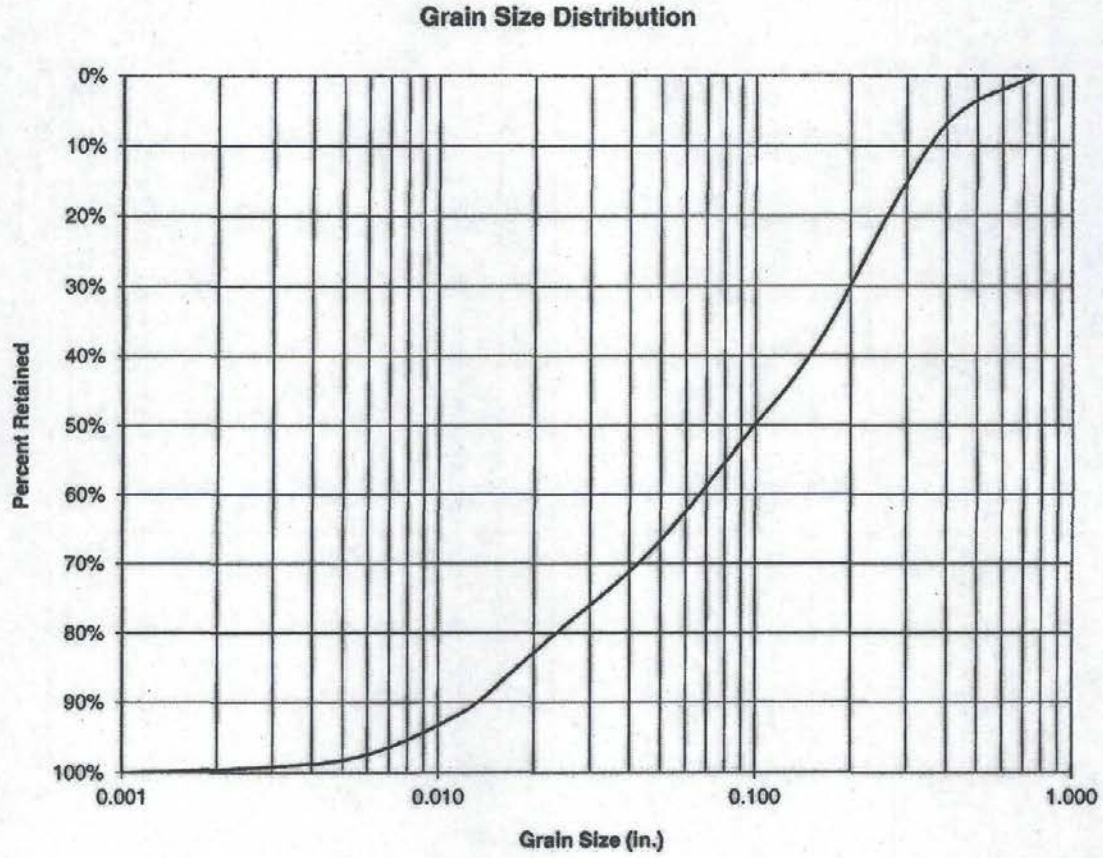
cc: Noel S. Philip, NWRO WR

I certify that I mailed this Order, or an identical copy thereof, postage prepaid, to the above addressee(s) this 1st day of May 2013.
Michelle Cross (SIGNATURE)

Grain-size Distribution Plots

Grain Size Calculations

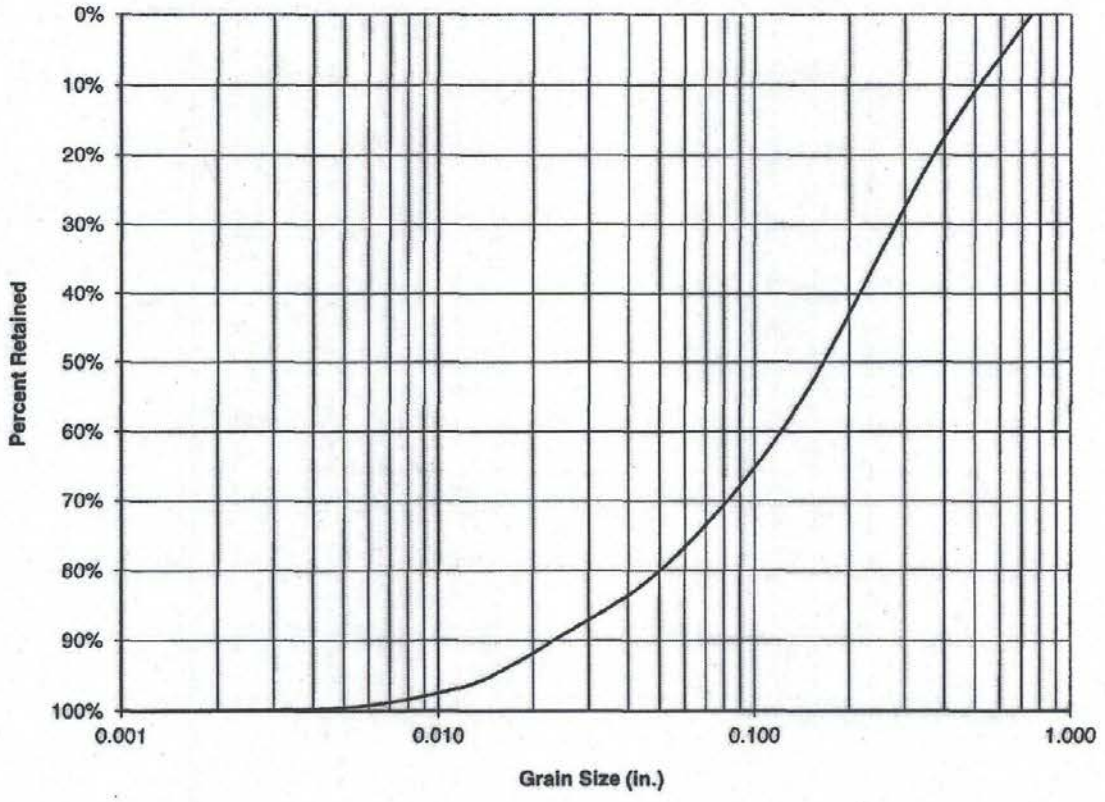
Job	Seattle Steam							
Job #	2719-001B							
Depth	333							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	21.6	8%		0	0	0	
	0.157	99.1	38%		0	0	0.148753	
	0.093	133.4	52%		0	0	0	
	0.047	176	68%		0	0.043118	0	
	0.023	207.9	80%		0	0	0	
	0.017	221.7	86%		0.013184	0	0	
	0.012	236.4	91%		0	0	0	
	0.006	252	97%		0	0	0	
	0.003	256.6	99%		0	0	0	
	0.001	258.8	100%		0	0	0	
			Depth	D10	D30	D60		
			333	0.013	0.043	0.149		



Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**335**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	84.7	19%		0	0	0.236456	
	0.157	224.9	52%		0	0	0	
	0.093	291.1	67%		0	0.083175	0	
	0.047	352.2	81%		0.023214	0	0	
	0.023	391.4	90%		0	0	0	
	0.017	406.5	94%		0	0	0	
	0.012	419.5	97%		0	0	0	
	0.006	430.8	99%		0	0	0	
	0.003	433.6	100%		0	0	0	
	0.001	434.5	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			335	0.023	0.083	0.236		

Grain Size Distribution

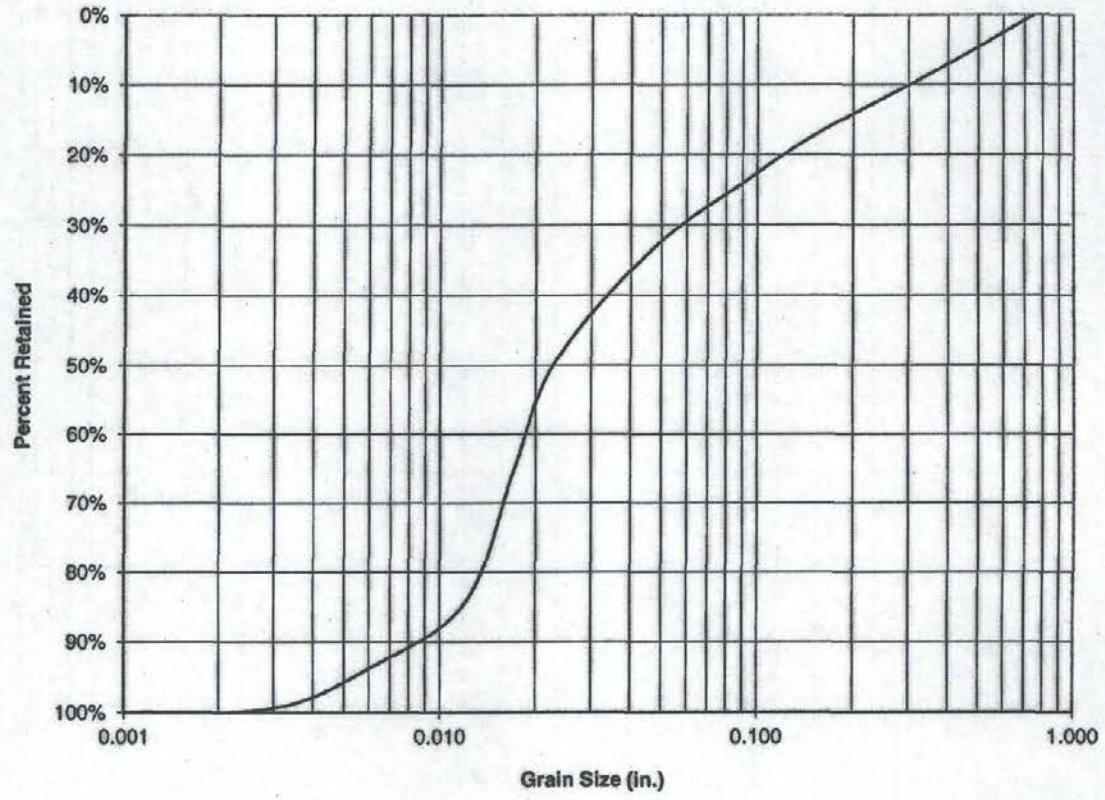


Robinson Noble, Inc.

Grain Size Calculations

Job	Seattle Steam							
Job #	2719-001B							
Depth	338							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	27.6	8%		0	0	0	
	0.157	59.7	17%		0	0	0	
	0.093	84.2	24%		0	0	0	
	0.047	118.9	33%		0	0	0.03711	
	0.023	176.9	50%		0	0	0	
	0.017	234	66%		0	0.01582	0	
	0.012	301.4	84%		0.008414	0	0	
	0.006	334.7	94%		0	0	0	
	0.003	354.8	99%		0	0	0	
	0.001	357	100%		0	0	0	
			Depth	D10	D30	D60		
			338	0.008	0.016	0.037		

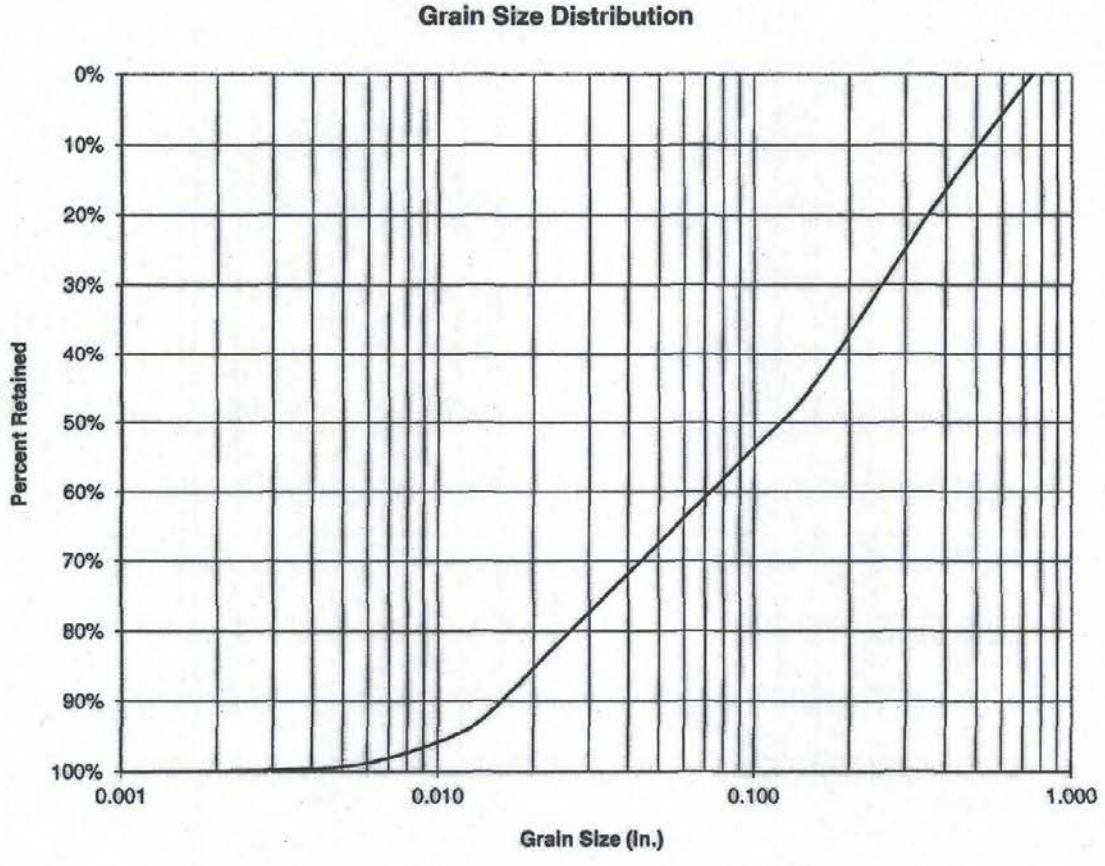
Grain Size Distribution



Robinson Noble, Inc.

Grain Size Calculations

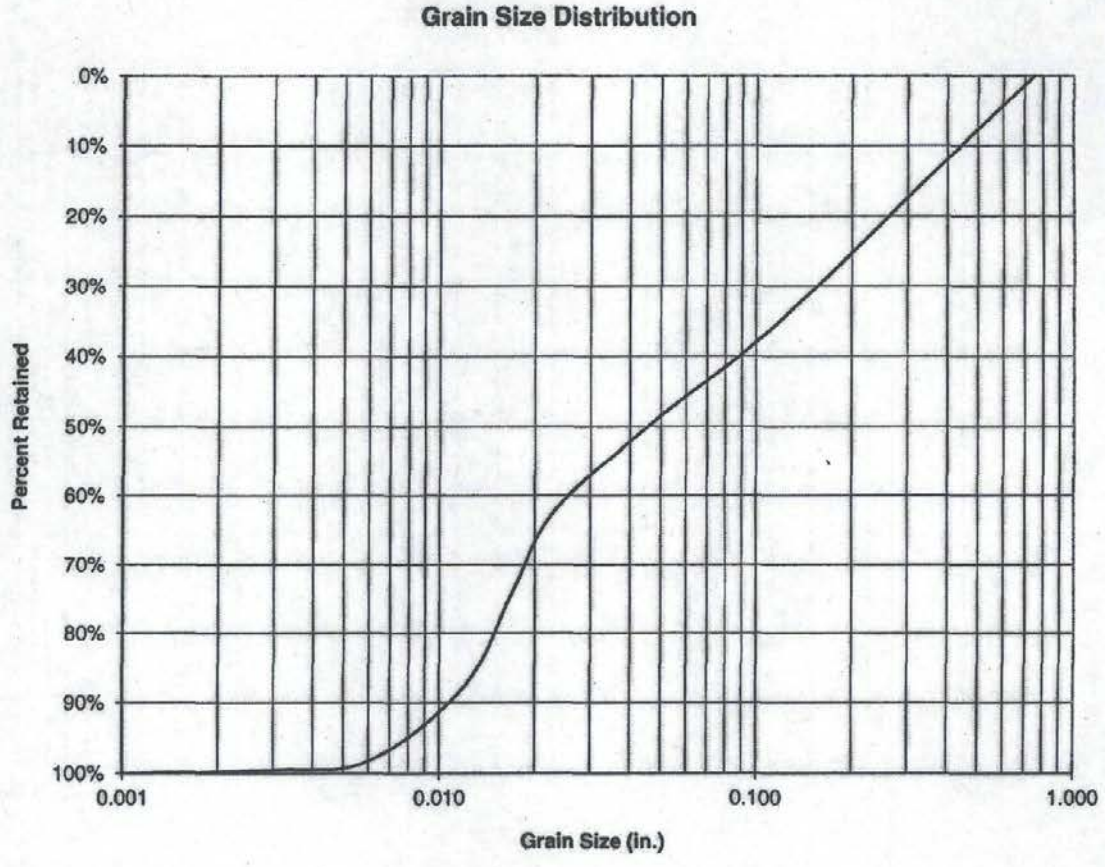
Job	Seattle Steam							
Job #	2719-001B							
Depth	341							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	83.6	18%		0	0	0.191306	
	0.157	203.7	44%		0	0	0	
	0.093	254.1	55%		0	0	0	
	0.047	317.4	69%		0	0.044729	0	
	0.023	380.8	82%		0	0	0	
	0.017	409.1	89%		0.015736	0	0	
	0.012	435.6	94%		0	0	0	
	0.006	456.2	99%		0	0	0	
	0.003	460.7	100%		0	0	0	
	0.001	462	100%		0	0	0	
			Depth	D10	D30	D60		
			341	0.016	0.045	0.191		



Robinson Noble, Inc.

Grain Size Calculations

Job	Seattle Steam							
Job #	2719-001B							
Depth	344							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	62.8	13%		0	0	0	
	0.157	143.1	30%		0	0	0	
	0.093	188.3	39%		0	0	0.089309	
	0.047	237.4	49%		0	0	0	
	0.023	299.5	62%		0	0.019044	0	
	0.017	355.5	74%		0	0	0	
	0.012	421.2	88%		0.010661	0	0	
	0.006	472	98%		0	0	0	
	0.003	478.1	99%		0	0	0	
	0.001	480.6	100%		0	0	0	
			Depth	D10	D30	D60		
			344	0.011	0.019	0.089		

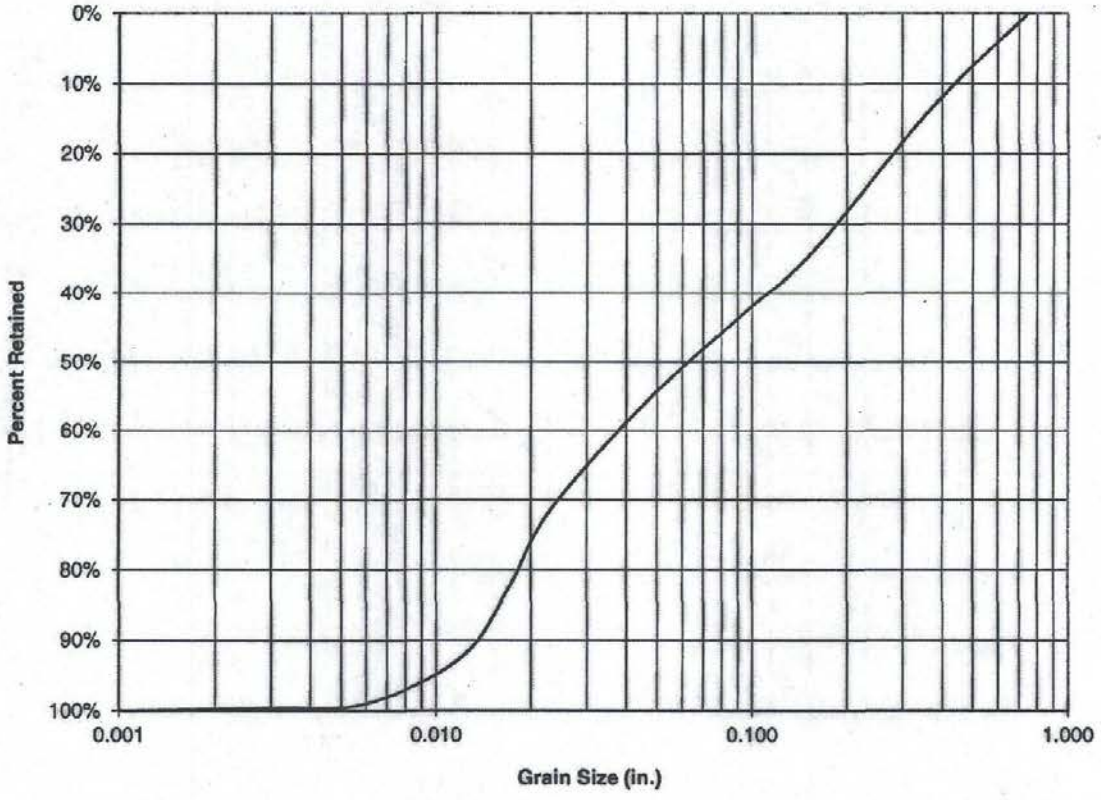


Robinson Noble, Inc.

Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**347**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	62.7	13%		0	0	0	
	0.157	159.9	34%		0	0	0.114285	
	0.093	204.4	43%		0	0	0	
	0.047	262.7	55%		0	0.025293	0	
	0.023	339.1	72%		0	0	0	
	0.017	391.5	83%		0.013258	0	0	
	0.012	438.4	92%		0	0	0	
	0.006	469	99%		0	0	0	
	0.003	472.2	100%		0	0	0	
	0.001	474	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			347	0.013	0.025	0.114		

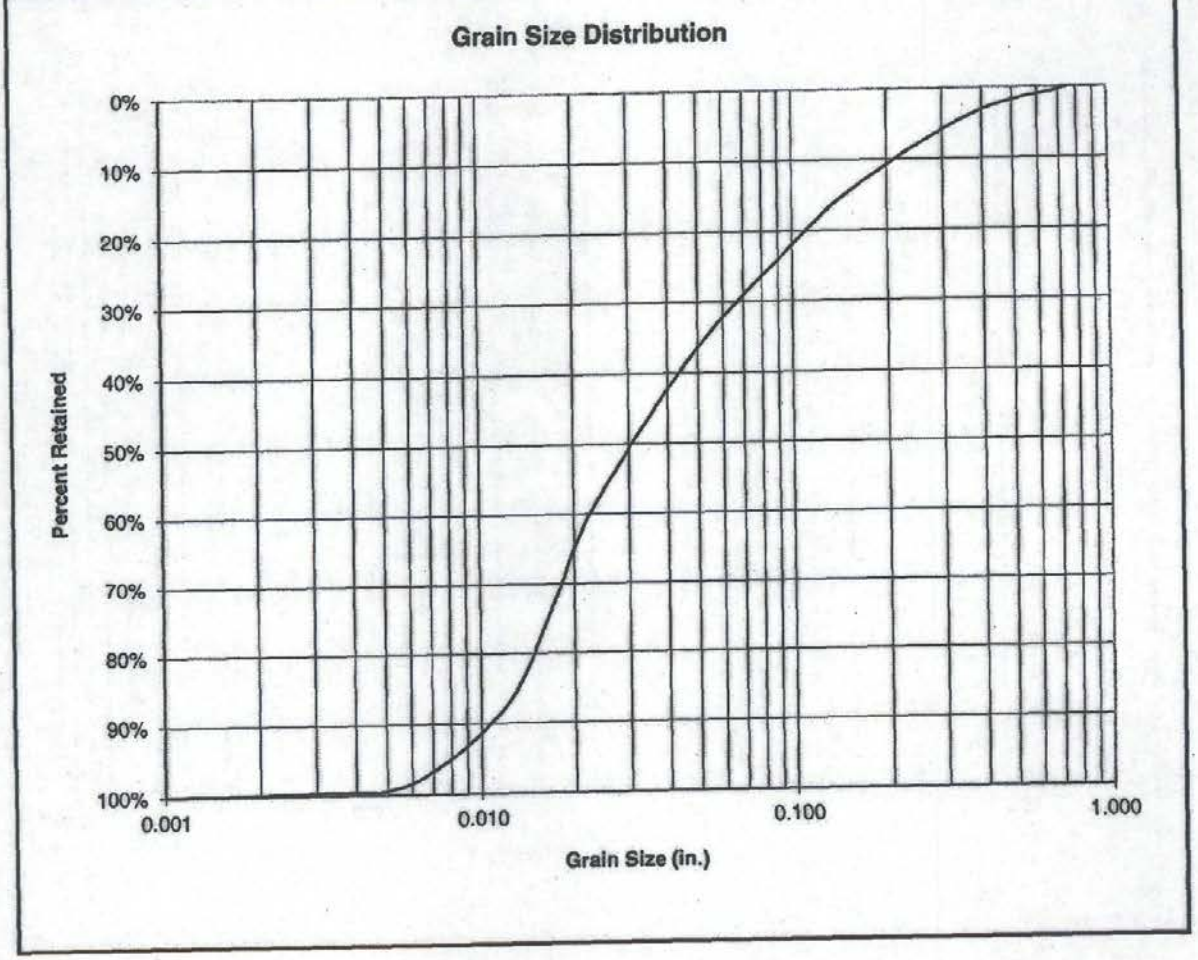
Grain Size Distribution



Robinson Noble, Inc.

Grain Size Calculations

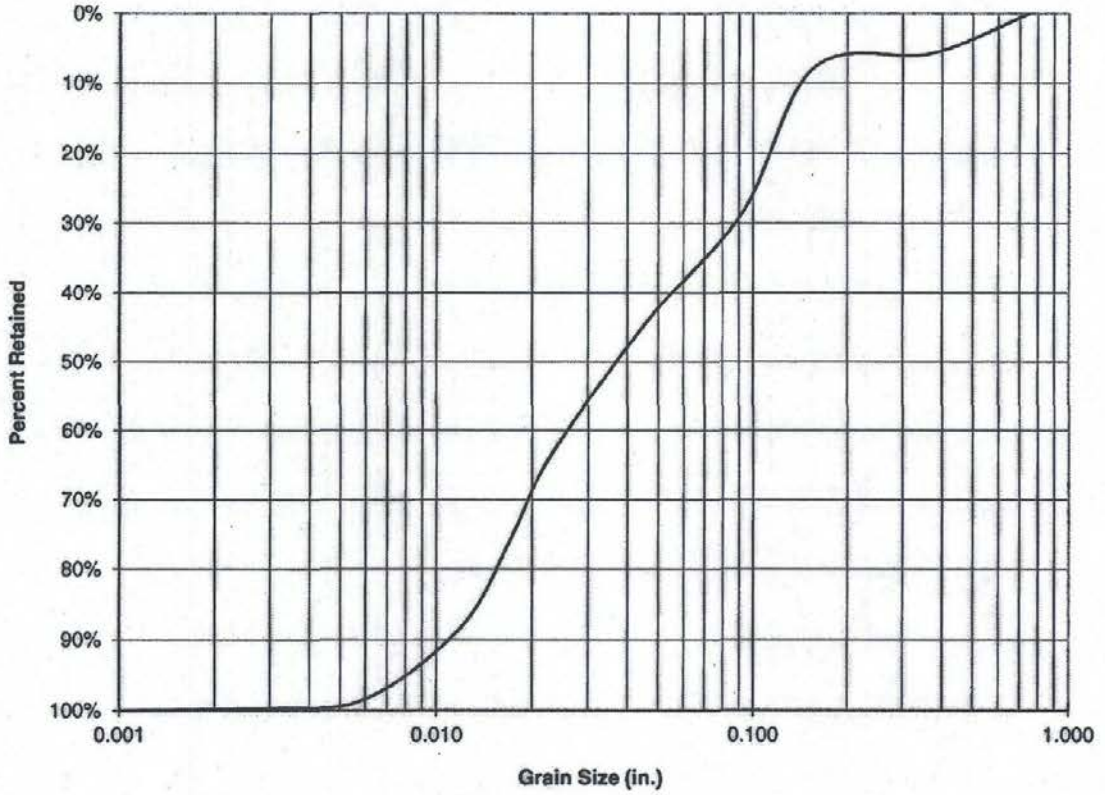
Job	Seattle Steam							
Job #	2719-001B							
Depth	350							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	16.7	4%		0	0	0	
	0.157	63.5	14%		0	0	0	
	0.093	106.7	23%		0	0	0	
	0.047	172.6	38%		0	0	0.04464	
	0.023	269.4	59%		0	0.018377	0	
	0.017	333.4	73%		0	0	0	
	0.012	398.5	88%		0.010626	0	0	
	0.006	447.7	98%		0	0	0	
	0.003	453.4	100%		0	0	0	
	0.001	455.3	100%		0	0	0	
			Depth	D10	D30	D60		
			350	0.011	0.018	0.045		



Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**353**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	25.2	6%		0	0	0	
	0.157	34.3	8%		0	0	0	
	0.093	126.1	28%		0	0	0.057879	
	0.047	194.6	44%		0	0	0	
	0.023	283.1	63%		0	0.019865	0	
	0.017	338.8	76%		0	0	0	
	0.012	392.9	88%		0.010886	0	0	
	0.006	438.7	98%		0	0	0	
	0.003	444.3	100%		0	0	0	
	0.001	446	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			353	0.011	0.020	0.058		

Grain Size Distribution

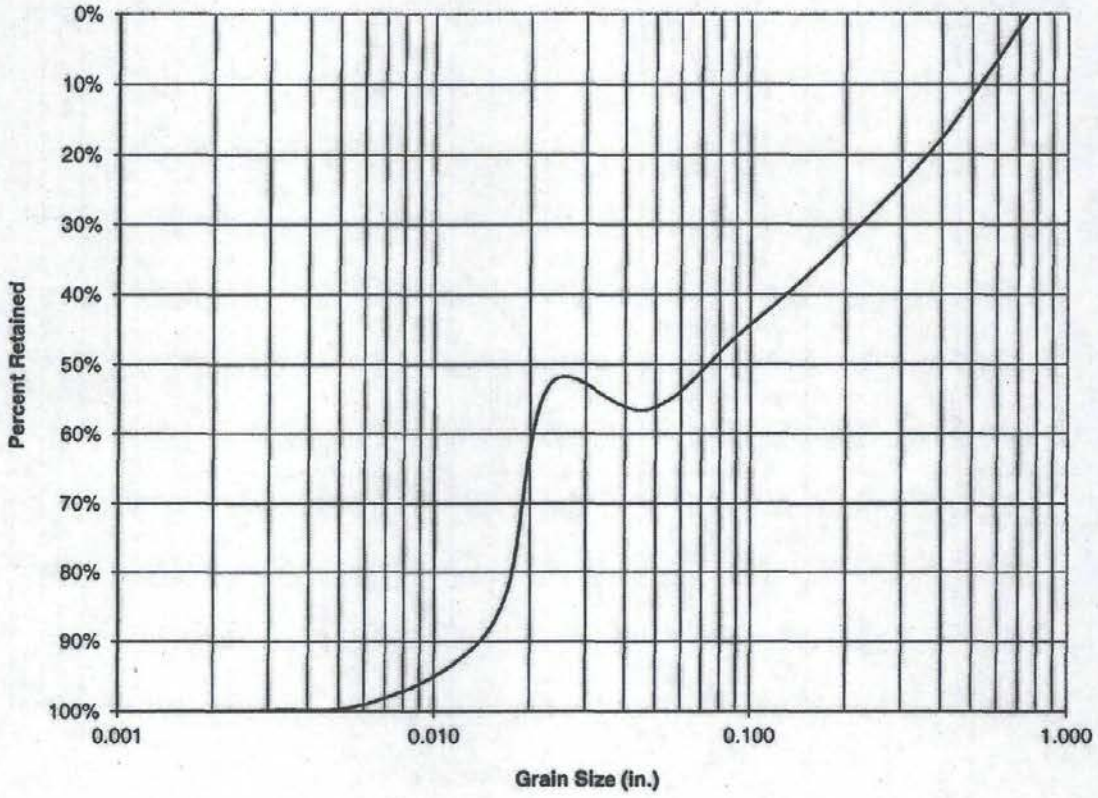


Robinson Noble, Inc.

Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**356**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	101.1	19%		0	0	0	
	0.157	193.2	37%		0	0	0.132212	
	0.093	240.5	45%		0	0	0	
	0.047	298.8	57%		0	0	0	
	0.023	279.5	53%		0	0.019533	0	
	0.017	436.4	83%		0.0133	0	0	
	0.012	489.8	93%		0	0	0	
	0.006	523.7	99%		0	0	0	
	0.003	527.7	100%		0	0	0	
	0.001	528.8	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			356	0.013	0.020	0.132		

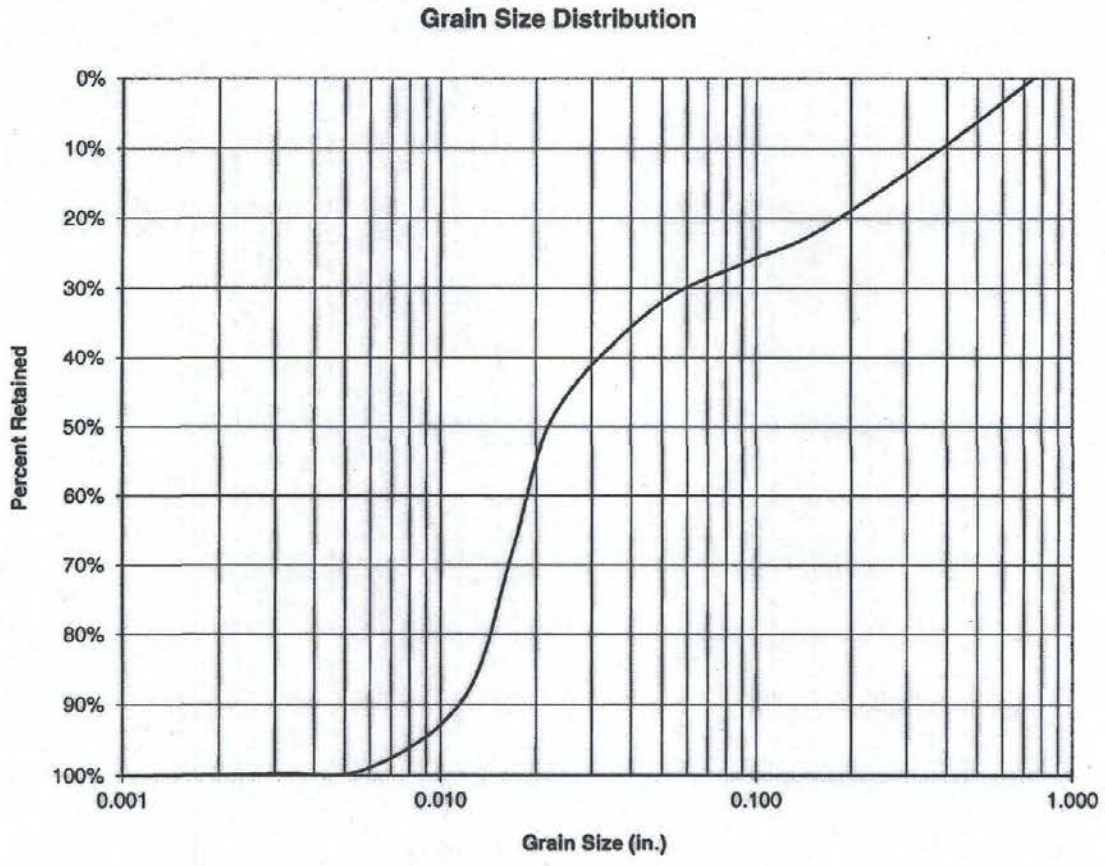
Grain Size Distribution



Robinson Noble, Inc.

Grain Size Calculations

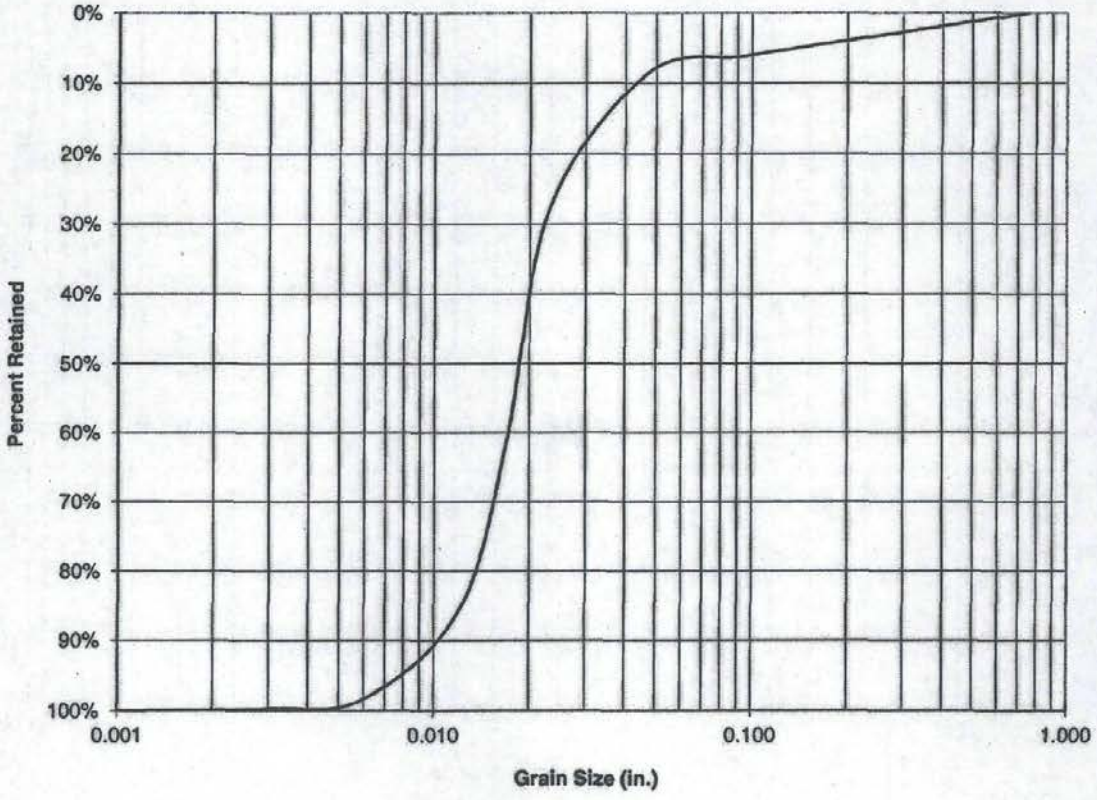
Job	Seattle Steam							
Job #	2719-001B							
Depth	359							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	47.7	10%		0	0	0	
	0.157	100.7	22%		0	0	0	
	0.093	121	26%		0	0	0	
	0.047	151.4	33%		0	0	0.035693	
	0.023	221.7	48%		0	0	0	
	0.017	310.3	67%		0	0.016361	0	
	0.012	409	89%		0.011214	0	0	
	0.006	456.1	99%		0	0	0	
	0.003	460.1	100%		0	0	0	
	0.001	461.3	100%		0	0	0	
			Depth	D10	D30	D60		
			359	0.011	0.016	0.036		



Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**362**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	8.8	2%		0	0	0	
	0.157	19.8	5%		0	0	0	
	0.093	26.6	6%		0	0	0	
	0.047	36.9	9%		0	0	0	
	0.023	120.5	28%		0	0	0.020816	
	0.017	263.1	61%		0	0.015183	0	
	0.012	369.3	86%		0.009945	0	0	
	0.006	423.6	98%		0	0	0	
	0.003	429.5	100%		0	0	0	
	0.001	431	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			362	0.010	0.015	0.021		

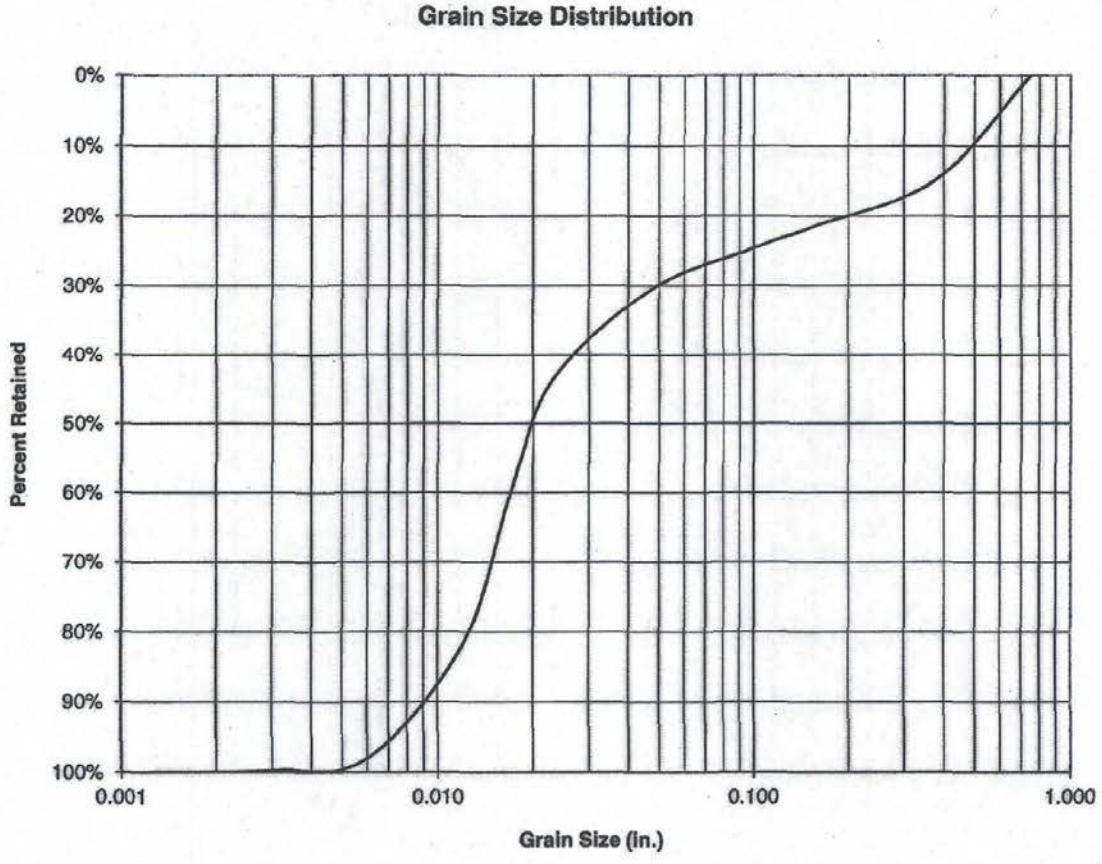
Grain Size Distribution



Robinson Noble, Inc.

Grain Size Calculations

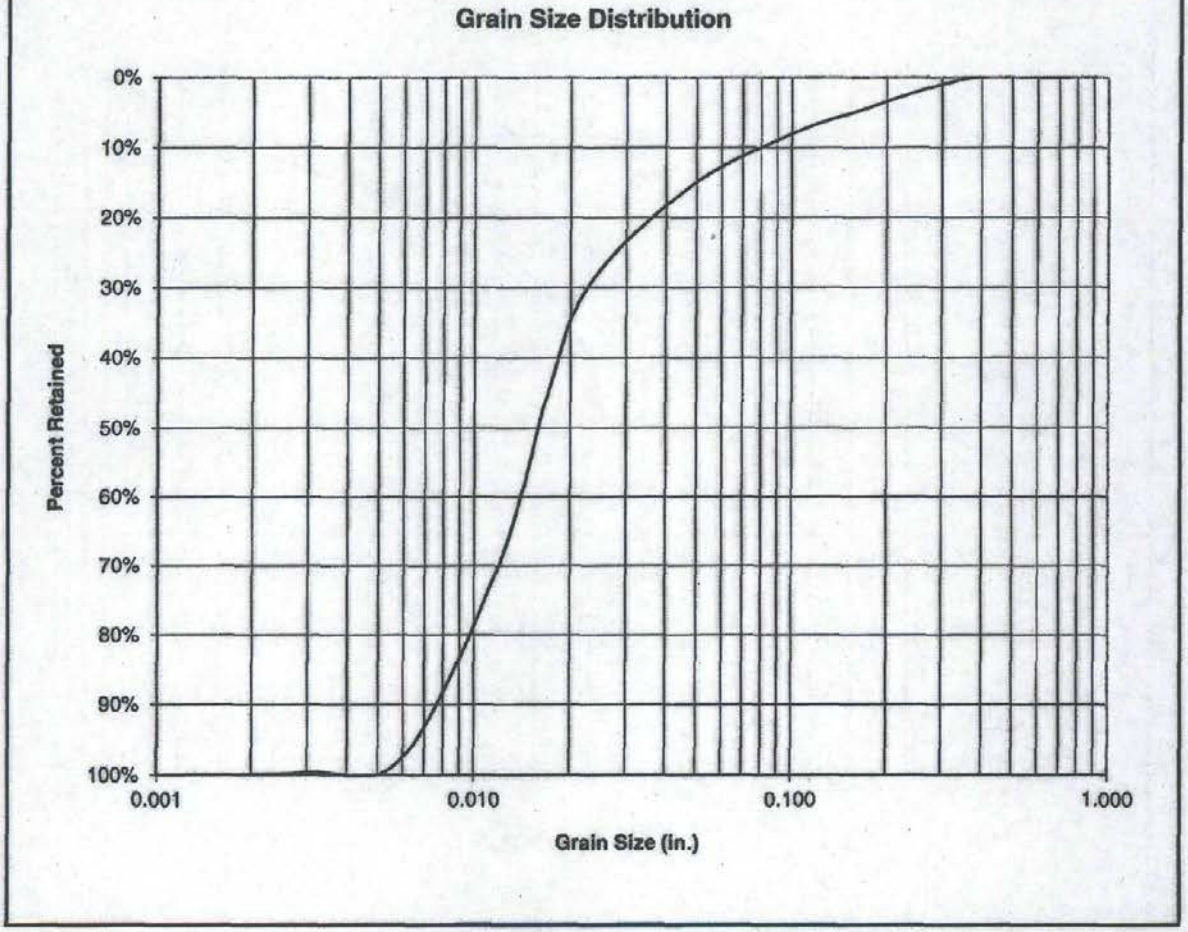
Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**365**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	69.3	15%		0	0	0	
	0.157	99.3	21%		0	0	0	
	0.093	116.5	25%		0	0	0	
	0.047	141.8	31%		0	0	0.029774	
	0.023	202.6	44%		0	0	0	
	0.017	278	60%		0	0.014697	0	
	0.012	379	82%		0.008949	0	0	
	0.006	454.2	98%		0	0	0	
	0.003	462.1	100%		0	0	0	
	0.001	463.6	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			365	0.009	0.015	0.030		



Robinson Noble, Inc.

Grain Size Calculations

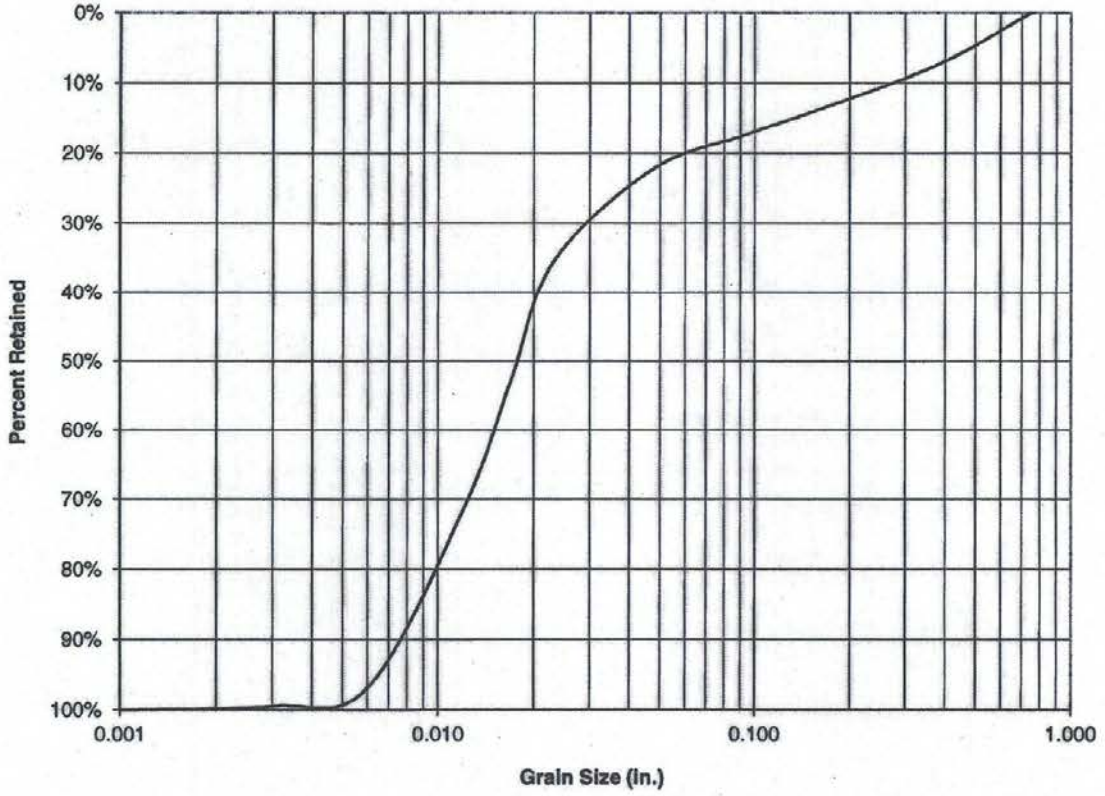
Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**368**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	0	0%		0	0	0	
	0.157	16.5	5%		0	0	0	
	0.093	28.7	9%		0	0	0	
	0.047	52.2	16%		0	0	0	
	0.023	97.4	29%		0	0	0.01892	
	0.017	148.7	45%		0	0	0	
	0.012	230.3	70%		0.007599	0.011922	0	
	0.006	322.1	97%		0	0	0	
	0.003	329.4	100%		0	0	0	
	0.001	330.7	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			368	0.008	0.012	0.019		



Grain Size Calculations

Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**371**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	26.9	8%		0	0	0	
	0.157	49.8	14%		0	0	0	
	0.093	62.4	17%		0	0	0	
	0.047	80.2	22%		0	0	0	
	0.023	127.6	36%		0	0	0.021445	
	0.017	188.7	53%		0	0.012411	0	
	0.012	256.6	72%		0.007625	0	0	
	0.006	347.3	97%		0	0	0	
	0.003	356.6	99%		0	0	0	
	0.001	358.6	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			371	0.008	0.012	0.021		

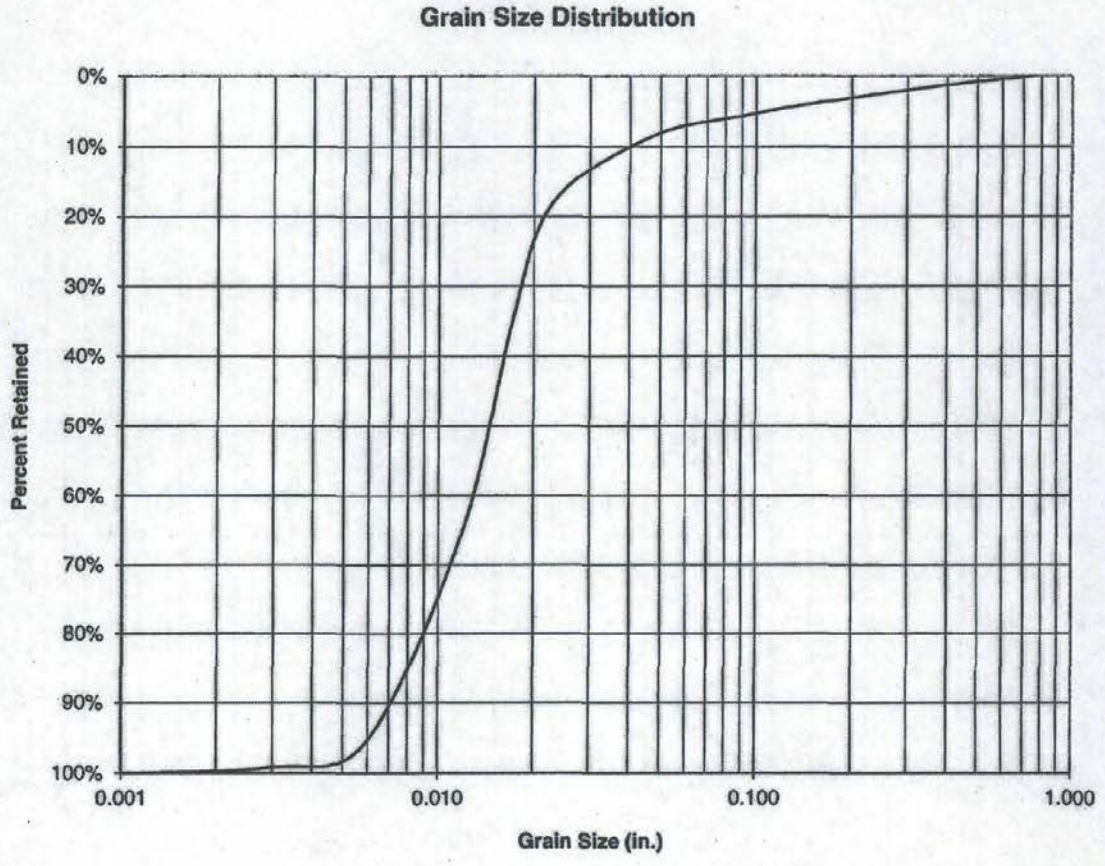
Grain Size Distribution



Robinson Noble, Inc.

Grain Size Calculations

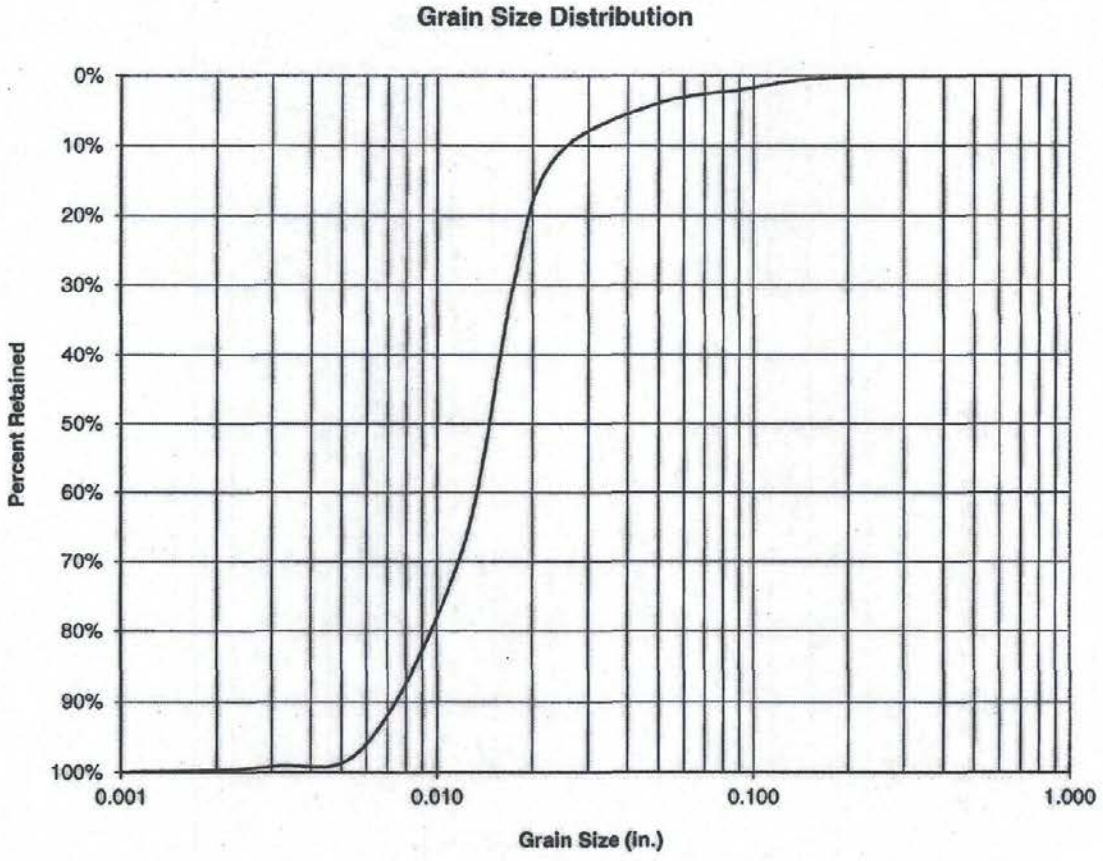
Job	**Seattle Steam**							
Job #	**2719-001B**							
Depth	**374**							
Well	**Seattle Steam Test Well**				**Calculations**			
		Weights	**Percentage**		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	4	1%		0	0	0	
	0.157	10.8	4%		0	0	0	
	0.093	16	6%		0	0	0	
	0.047	24.5	9%		0	0	0	
	0.023	51.5	18%		0	0	0	
	0.017	101.9	36%		0	0	0.016232	
	0.012	185.9	65%		0.007035	0.010971	0	
	0.006	273.4	95%		0	0	0	
	0.003	284.6	99%		0	0	0	
	0.001	287	100%		0	0	0	
			Depth	**D10**	**D30**	**D60**		
			374	0.007	0.011	0.016		



Robinson Noble, Inc.

Grain Size Calculations

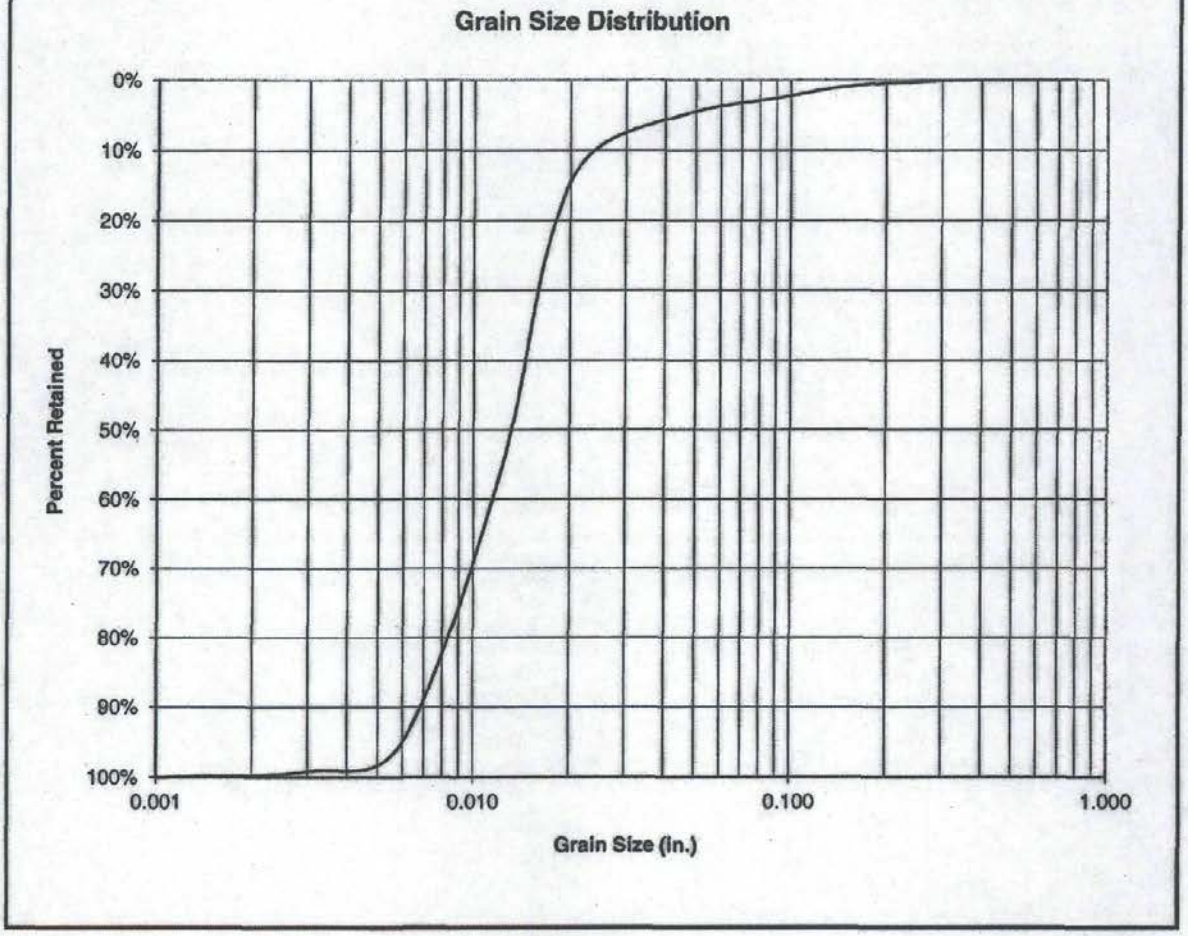
Job	Seattle Steam							
Job #	2719-001B							
Depth	377							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	0	0%		0	0	0	
	0.157	1.3	0%		0	0	0	
	0.093	6	2%		0	0	0	
	0.047	13.4	4%		0	0	0	
	0.023	38.2	12%		0	0	0	
	0.017	99.8	32%		0	0	0.015918	
	0.012	212.2	68%		0.007299	0.011649	0	
	0.006	297.8	96%		0	0	0	
	0.003	307.7	99%		0	0	0	
	0.001	310.3	100%		0	0	0	
			Depth	D10	D30	D60		
			377	0.007	0.012	0.016		



Robinson Noble, Inc.

Grain Size Calculations

Job	Seattle Steam							
Job #	2719-001B							
Depth	380							
Well	Seattle Steam Test Well				Calculations			
		Weights	Percentage		0.9	0.7	0.4	
Sieve Sizes (Assumes Max.Size of 3/4")	0.750	0	0%		0	0	0	
	0.375	0	0%		0	0	0	
	0.157	2.6	1%		0	0	0	
	0.093	7.7	2%		0	0	0	
	0.047	14.9	5%		0	0	0	
	0.023	32.8	11%		0	0	0	
	0.017	74.9	24%		0	0	0.014592	
	0.012	176.6	57%		0.00678	0.009946	0	
	0.006	294	95%		0	0	0	
	0.003	307.1	99%		0	0	0	
	0.001	309.7	100%		0	0	0	
			Depth	D10	D30	D60		
			380	0.007	0.010	0.015		



Water Well Report Form

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*

☒ Construction

☐ Decommission *ORIGINAL INSTALLATION*

Notice of Intent Number ____

PROPOSED USE: ☐ Domestic ☒ Industrial ☐ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other ____

TYPE OF WORK: Owner's number of well (if more than one) 1

☒ New well ☐ Reconditioned *Method:* ☐ Dug ☐ Bored ☐ Driven ☐ Deepened ☒ Cable ☐ Rotary ☐ Jetted

DIMENSIONS: Diameter of well 8 inches, drilled 385 ft. Depth of completed well 380ft.

CONSTRUCTION DETAILS

Casing Installed: ☒ Welded 16" Diam. from +1.2 ft. to 50 ft.

☐ Liner installed 12" Diam. from +1.7 ft. to 130 ft.

☐ Threaded 8" Diam. From +6.6 ft. to 335 ft.

Perforations: ☐ Yes ☒ No

Type of perforator used ____

SIZE of perfs ____ in. by ____ in. and no. of perfs ____ from ____ ft. to ____ ft.

Screens: ☒ Yes ☐ No ☐ K-Pac Location ____

Manufacturer's Name Johnson

Type PS Model No. SS304

Diam. 8 Slot size 0.050 from 335 ft. to 370 ft.

Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel/Filter packed: ☒ Yes ☐ No Size of gravel/sand CSS 8-12

Materials placed from 325 ft. to 380 ft.

Surface Seal: ☒ Yes ☐ No To what depth? 50ft.

Material used in seal cement

Did any strata contain unusable water? ☒ Yes ☐ No

Type of water? brackish Depth of strata 146

Method of sealing strata off Bentonite

PUMP: Manufacturer's Name ____

Type: ____ H.P. ____

WATER LEVELS: Land-surface elevation above mean sea level 15.65 ft.

Static level +2.77ft. below top of well Date 10/22/13

Artesian pressure ____ lbs. per square inch Date ____

Artesian water is controlled by cap,valve (cap, valve, etc.)

WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? RN

Yield: 416gal./min. with 35.2ft. drawdown after 25hrs.

Yield: ____gal./min. with ____ft. drawdown after ____hrs.

Yield: ____gal./min. with ____ft. drawdown after ____hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
1	18	6	15.6	30	14
2	17.41	16	15.1	45	13.22
5	16.47	26	14.3	60	12.63

Date of test Bailer test ____ gal./min. with ____ft. drawdown after ____hrs.

Airtest gal./min. with stem set at ____ft. for ____hrs.

Artesian flow ____g.p.m. Date ____

Temperature of water 53.5 Was a chemical analysis made? ☒ Yes ☐ No

CURRENT

Notice of Intent No. WE16531

Unique Ecology Well ID Tag No. BCS 872

Water Right Permit No. G1-28722A

Property Owner Name Seattle Steam Company

Well Street Address 1319 Western Avenue

City Seattle County King

Location NW1/4-1/4 SE1/4 Sec 31 Twn 25 R 04 EWM ☒ Or WWM ☐

Lat/Long (s, t, r Still REQUIRED) Lat Deg 47 Min 36 Sec 23.79 Long Deg 122 Min 20 Sec 25.11

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Asphalt	0	1.5
Brown sand and gravel fill	1.5	8
Dark brown wood waste fill	8	18
Gray silt clay and gravel	18	28
Gray brown silty clay, sand	28	39
Gray silty S&G Shells	39	42
Gray gravel silt clay compact	42	45
Gray silt clay compact	45	59
Gray clay trace gravel	59	63
Gray sand gravel silt layers	63	71
Gray clay trace gravel	71	146
Gray silt sand gravel water	146	158
Gray silt sand gravel	158	169
Gray silty sand gravel water	169	208
Gray sand gravel silt layers	208	210
Gray silty clay trace gravel	210	234
Gray clay gravel, till like	234	263
Gray F-C sand gravel	263	285.5
Brown-red silt clay gravel	285.5	292
Gray F-C sand gravel cobbles	292	301
Tan-orange clay sand gravel	301	307
Gray-green clay gravel tight	307	333
Gray gravel sand cobbles wate	333	360
Gray F-C sand occ gravel wate	360	385

Start Date 7/22/13 Completed Date 11/15/13

Tax Parcel No.7666202445

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee Driller or trainee License No. 1239

Name (Print Last, First) Carper, Robert B.

Driller/Engineer/Trainee Signature Robert B Carper

IF TRAINEE: Driller's License No:

Driller's Signature:

Drilling Company Hokkaido Drilling, Inc.

Address P.O. Box 100

City, State, Zip Graham, WA, 98338

Contractor's Registration No. HOKKADI017M8 Date 11/21/13

Water Level Measurements

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA
STEP TEST

Page: 1 of 2
Date: 10/21/13

Project: SEATTLE STEAM
Well: 1
Static Water Level: 1.44
Stick Up: 4.87
Reference Point: Top of 1" Tube
Measurement Device: Elec Tape

Project Number: 2719-001B
Weather Conditions:
Measured By: D. Dow
Contractor: Hokkaido
Pump Type: 40 hp Sub
Flow Meas. Method: Meter

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q	Comments
1800	0	1.44		16182750		Meter
	2	9.14				
	3	9.36			~200	Falling Tide
	4	9.49				Low Tide @ 1:18 pm
	5	9.57				
	6	9.68				
	7	9.74				
	8	9.82				
	9	9.88				
	10	9.95				
	12	10.06				
	14	10.18				
	16	10.29				
	18	10.37				
	20	10.42				Early T ~24,000
	25	10.63				
	35	10.92		11:37 16188750	~175	
1240	40	11.00	9.56		175	Q/s = 18.3
	41	16.80			~300	
	42	17.00				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

STEP TEST

Page: 2 of 2
Date: 10/21/13

Project: SEATTLE STEAM
Well: 1
Static Water Level: 1.44
Stick Up: 4.87
Reference Point: Top of 1" Tube
Measurement Device: Elec Tape

Project Number: 2719-001B
Weather Conditions:
Measured By: D. Dow
Contractor: Hokkaido
Pump Type: 40 hp. Sub
Flow Meas. Method: Meter

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q	Comments
1243	43	17.14			~300	
	44	17.19				
	45	17.25				
	50	17.60		67 16194300	Avg 277.5	
1300	60	18.05	16.61			Q/S = 16.70
	63	26.01				
	65	26.40		85 16197150	2400	
	72	27.05		75 16201600	Avg 345	
	86	27.88				Low Tide
1330	90	28.02		95 16210400	Avg 340	
	100	28.41	26.97			Q/S = 16.3
	105	34.15		107 16216200		
	110	34.64		117 16221600	Avg 340	Temp 53.5 F
1400	120	35.35	33.91			Q/S = 15.9
1402	122	Pump	off			Reset To 400
1403	1	9.30				
	2	8.76				
1405	3	8.27				
	4	7.86				
	5	7.56				
	8	6.93				
1417	15	6.15				

Robinson & Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

Date: 10-22-13

Project: Seattle STeam
Well: 1
Static Water Level: 2.10
Stick Up: 4.87 MPS
Reference Point: Top of I"
Measurement Device: Elec Tape

Project Number: 2719-001B
Weather Conditions: Overcast - Dry
Measured By: RN - DCD
Contractor: Hokkaido
Pump Type: Sub
Flow Meas. Method: Meter

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q (gpm)	Comments
1400	0	2.10		meter 16224250		
	1	21.66				
	2	22.33			~400	
	3	22.75				
	4	23.08				
	5	23.33				Low Tide
	6	23.55				
	7	23.75				
	8	23.90				
	9	24.08				
	10	24.18				
	12	24.43				
	14	24.66				
	16	24.85				
	18	25.00				
	20	25.14	(2)	16232700	402	Avg.
	25	25.53				
1430	30	25.81				WQ samples & 2 small jars
	35	26.10				
	40	26.32	(4)	16241550	442	Avg

Robinson Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

Date: 10/22/13

Project: SeaTTLe Steam
Well: 1
Static Water Level: 2.10
Stick Up: 4.87' AGS
Reference Point: Top of 1"
Measurement Device: Elec. Tape

Project Number: 2719-001B
Weather Conditions: Dry
Measured By: PD - DCD
Contractor: Hokkaido
Pump Type: Sub
Flow Meas. Method: Meter

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q ( )	Comments
1445	45	26.55				
	50	26.75				
	60	27.10	61	16250000	422	
	70	27.41				
	80	27.65	81	16258400	420	
1530	90	27.88				
1600	120	28.54				
1700	180	29.02				
1800	240	29.38				
1900	300	29.92				High Tide @ 1:04 PM
2000	360	30.61				
2100	420	31.63				
2200	480	32.91				
2300	540	34.38				
2400	600	35.60				
0100	660	36.79				
0200	720	37.24				Low Tide @ 1:52 AM.
0300	780	37.18				
0400	840	36.83				
0500	900	35.86				

Robinson Noble, Inc.
3011 South Huson Street, Suite A
Tacoma, WA 98409
253-475-7711

PUMPING TEST DATA

Date: 1-23-13

Project: Seattle Steam
Well: 1
Static Water Level: 2.10
Stick Up: 4.87 Ag2
Reference Point: Tac 1"
Measurement Device: Elec. Tape

Project Number: 2719-001 B
Weather Conditions: Dry
Measured By: RN · DCD
Contractor: Hokkaido
Pump Type: Sub
Flow Meas. Method: Meter

Time	Elapsed Time	Depth to Water	Drawdown	Flow Meas. Reading	Q ( )	Comments
0600	960	35.3				
0700	1020	34.4				
0800	1080	34.33				
0900	1140	34.32				High Tide @ 9:08 AM
1000	1200	34.63				
1100	1260	35.16				
1200	1320	35.82				
1300	1380	36.53		1390 16802750	416	Avg.
1400	1440	37.07		Sp. Cond. 200+		Low Tide @ 2:56 PM
1500	1500	37.32	35.22	16848300	416	Q/S = 11.8
	Recovery					
	1	18.0				Pump Surge
	2	17.41				
	3	17.00				
	4	16.73				
	5	16.47				
	6	15.60				
	16	15.10				
	20	14.70				
	26	14.30				
	30	14.00				High Tide @ 7:46 pm
	45	13.22				
1600	60	12.63				

Well Rating

Seattle Steam Company -predicted dd for late response scenarios for 1 year, 180 days and 90 day duration

Underlying parameter values for all scenarios

Aquifer transmissivity (T) =	13,500	gpd/ft		
Aquifer storage coefficient (S) =	0.001			
Projected pumping time (t) =	365	days	180 days	90 days
Specific capacity of well at 1-day from 416 gpm test =	11.89	gpm/ft		

Seattle Steam reported land surface elevation to be 15.65 ft above MLLW(?) (land surface elevation reported on 11-14-13)

Static water level at MLLW is approximately 2 feet above land surface (Elevation 17.5 ft above MLLW)

Predicted drawdown at well for 250 gpm after 90 days (using Q/s and "del s") =	30.6	ft
Predicted drawdown at well for 90 day pumping(using Theis only) =	44.8	ft
Percent difference in predicted dd *using specific capacity is*	31.7	% less dd

Predicted drawdowns at varied duration distance and pumping rates applying the correction for observed Q/s at 25 hours

Distance	elapsed t	predicted dd (ft)	Predicted elevation of PWL	Discharge rate (gpm)	Distance	elapsed t	predicted dd (ft)	Predicted elevation of PWL	Discharge rate (gpm)
500	365	7.6	8.2	150	500	365	12.6	3.2	250
1000	365	6.4	7.6	150	1000	365	10.6	3.4	250
2500	365	4.8	4.0	150	2500	365	7.9	0.8	250
500	180	6.9	8.8	150	500	180	11.6	4.2	250
1000	180	5.7	8.3	150	1000	180	9.6	4.4	250
2500	180	4.1	4.6	150	2500	180	6.9	1.8	250
500	90	6.3	9.4	150	500	90	10.6	5.2	250
1000	90	5.1	8.9	150	1000	90	8.6	5.4	250
2500	90	3.5	5.2	150	2500	90	5.9	2.9	250

The solution of the Theis distance drawdown equation using the aquifer transmissivity of the later test data overstates the drawdown. This is the case because the drawdown of the initial pumping is controled by the higher transmissivity of the aquifer near the well. This difficulty was addressed by comparing the observed response of the well during the 25-hour pumping test and comparing that observation to the predicted drawdown using the Theis equation and the later test transmissivity value. This indicates that the Theis solution overstates the drawdown by 31.7%. Standard Theis solutions were then calculated for the designated elapsed pumping times of 365, 180 and 90 days at distances of 500, 1,000 and 2500 feet from the well. These solutions were then adjusted using the 31.7% value to indicate the predicted drawdowns. drawdowns were then expressed as elevation by projecting the potentiometric gradient westward to define the static water level (swl) at the 500, 1,000, and 2,500 foot distances. The predicted drawdown was then subtracted from the presumed swl to provide a predicted elevation of the pumping water level at that point.