MEMO: GROUNDWATER MONITORING
IN CHUMSTICK CREEK SUBWATERSHED

Groundwater–Surface Water Interactions along
Chumstick Creek and Mission Creek in WRIA 45
Chelan County, Washington

Submitted to:
Chelan County Natural Resource Department,
Wenatchee, WA

Submitted by:
AMEC Geomatrix, Inc., Lynnwood, WA

June 2009

Project 12817.001

Funded by Ecology Grant No. G0800335

amec

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June 15, 2009
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This report was prepared by the staff of AMEC Geomatrix, Inc., under the supervision of the Engineer(s) and/or Geologist(s) whose seal(s) and signature(s) appear hereon.

The findings, recommendations, specifications, or professional opinions are presented within the limits described by the client, in accordance with generally accepted professional engineering and geologic practice. No warranty is expressed or implied.

David R Haddock

State of Washington
Hydrogeologist
1790
Licensed Geologist
DAVID R. HADDOCK

David R. Haddock, L.Hg
Principal Hydrogeologist

Memo

To: Lee Duncan,
Chelan County Natural Resource Department

Project: 12817.001

From: Dave Haddock and Steve Ellis,
AMEC Geomatrix, Inc.

Tel: (425) 921-4000

Fax: (425) 921-4040

Date: June 15, 2009

Subject: Groundwater Monitoring in Chumstick Creek Subwatershed
Groundwater–Surface Water Interactions along Chumstick Creek and Mission Creek in WRIA 45, Chelan County, Washington

1.0 INTRODUCTION

The Wenatchee Watershed (Water Resource Inventory Area [WRIA] 45) has been identified by the Washington State Department of Ecology (Ecology) as one of 16 watersheds in the state where water quantity is a probable limiting factor for anadromous fisheries resources. Increasing competition for hydrologic resources in the watershed in conjunction with seasonal low-flow conditions contribute to inadequate streamflows for fish, particularly during periods of late summer and early fall (Wenatchee Watershed Planning Unit [WWPU], 2006).

In an effort to address the condition of water resources within the Wenatchee Watershed, a final Wenatchee Watershed Management Plan (WWMP) was completed in April 2006. The WWMP identified insufficient streamflow, diminished water quality, and a lack of geologic and hydrologic data on which to evaluate water availability and management strategies within two Wenatchee subwatersheds (Chumstick Creek and Mission Creek). In 2007 existing data were utilized to prepare a water balance for the Chumstick Creek and Mission Creek subwatersheds and recommendations were provided to collect additional data that would reduce uncertainties associated with the water balance (Geomatrix, 2007a; 2007b). One of these recommendations was to install monitoring wells to determine groundwater levels within the aquifer along with water discharge measurements in Chumstick Creek during critical low-flow periods.

This memorandum provides groundwater level measurements, creek discharge measurements, and estimates of hydraulic conductivity measured during 2009.

2.0 STUDY DESIGN

The original study design for this project called for monitoring groundwater levels at six locations within the Chumstick Creek and Mission Creek subwatersheds (AMEC, 2008). The selection of well locations was made to allow for a general understanding of hydrologic conditions throughout each subwatershed. The locations were purposely biased to selecting locations within the lower subwatershed where groundwater flow may not be connected to the Chumstick or Mission creeks and instead flows toward the Wenatchee River. The emphasis on the lower watershed would reduce uncertainties associated with the water balance completed in 2007 (Geomatrix, 2007a; 2007a).

Subsequent discussions with Ecology staff and Chelan County Natural Resource Department (NRD) staff resulted in a new study design that was not focused on a water balance for the subwatersheds. The revised study design included the installation of two deep monitoring wells within the Chumstick Creek subwatershed (Figure 1) and no wells within the Mission Creek subwatershed. The primary study objectives were to: (1) evaluate whether more recent data supports Wildrick's (1979) conceptual model for the Chumstick Creek subwatershed, which proposed shallow, deep, and bedrock aquifers; (2) collect data that can be used to estimate hydraulic conductivity; and (3) begin a monitoring program to measure well water levels so that future data collection during low-flow conditions in Chumstick Creek can be used to better understand groundwater–surface water interactions during these periods.

3.0 CONCEPTUAL MODEL FOR CHUMSTICK CREEK SUBWATERSHED

The Wildrick (1979) conceptual model for aquifer characteristics within the Chumstick drainage basin was evaluated prior to selecting the locations where monitoring wells were installed. This model was further evaluated by measuring well water levels at different depths as the wells were installed.

3.1 Conceptual Model Review

Linton Wildrick's 1979 Open File Technical Report for Ecology (*Ground-Water Flow System of the Chumstick Drainage Basin*) discusses the geology and aquifer characteristics of the Chumstick drainage basin. Wildrick describes three distinctive layers of valley-fill deposits overlying the sedimentary sandstone and siltstone bedrock, in order of increasing depth: (1) an uppermost thin deposit (5 to 10 feet thick) of silty sand; (2) a series of clay and silt beds (fine-grained) with minor amounts of sand and gravel; and (3) coarse-grained sand and gravel. Wildrick surmised that three types of aquifers are used in the Chumstick drainage basin: (1) a shallow water table aquifer composed of the uppermost silty sand; (2) a deep aquifer in the lowermost sand and gravel above the bedrock; and (3) a bedrock aquifer within the sandstone bedrock. This conceptual model has important implications for water management with the Chumstick drainage basin as it suggests that water withdrawal from wells that are screened within the two deeper aquifers may have little connection to surface water flows in Chumstick Creek.

AMEC Geomatrix, Inc. (AMEC), completed a review of well log data for wells installed after Wildrick (1979) in the vicinity of Wildrick's cross section D-D' (east-west across the middle stretch of the Chumstick) (AMEC, 2008). Particular attention was paid to the nature and extent of the clay layer that Wildrick (1979) suggests acts as an aquitard. The more recent well log data indicates that the nature and extent of this clay layer is highly variable. Some of the lacustrine silt and clay deposits are interspersed with sandy or gravelly clay water-bearing deposits. It appears that many of the wells in the Chumstick Creek subwatershed are installed in these more gravelly horizons located within the “clay” layer, rather than being installed either below or above the clay layer as Wildrick concludes.

It seems that Wildrick’s model is oversimplified and the hydrostratigraphy is more complex than Wildrick originally thought 30 years ago. This complexity should not be a particular surprise. During the last large-scale glaciation over 10,000 years ago, the Chumstick Creek subwatershed was filled with a large valley glacier that extended eastward from the Cascade Crest. The glaciers deposited several different geological units, including lacustrine deposits (silts and clay deposited as lake bottom sediments behind glacial ice or moraine dams), outwash deposits (advancing and retreating glaciers deposit primarily sand and gravel sediments in front of the glacier from glacial melt water), and till (a very dense, poorly-sorted mixture of clay, silt, sand and gravel, deposited directly beneath glacial ice). These sequences of unconsolidated materials were deposited over thousands of years and included periods of damming and deposition of various types of glaciofluvial deposits, thereby creating a heterogeneous jumble of deposits.

3.2 Well Water Levels During Well Installation

Measuring water levels in nested wells screened at different depths is an established technique for determining the vertical component of hydraulic gradient (Yolcubal et al., 2004). If the clay layers mentioned by Wildrick (1979) were functioning as an aquitard, water levels in wells installed above and below these clay layers would differ. If there are no barriers to vertical water flow, water levels for wells installed at different depths would be the same, providing evidence that multiple aquifers are not present.

Ecology requested that water levels be measured at different depths as the two monitoring wells were being installed to evaluate the likelihood of shallow versus deeper aquifers. At the upper well site, a layer of clay was encountered at a depth of approximately 40 feet below ground surface (bgs). Water levels recorded above and below this clay layer were the same, about 10 feet bgs. At the lower well site, water levels were measured three times during the well installation at 56 feet bgs, 76 feet bgs, and 105 feet bgs. The water levels recorded were the same at all depths (47.2 feet bgs). These data show no evidence for a confined shallow aquifer at the locations where the wells were installed.

4.0 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity (K) defines the rate of movement of water through a porous medium such as a soil or aquifer. Hydraulic conductivity was estimated at each well location from an analysis of the grain size of material in the vicinity of the well screen depth range (Attachment A).

K values were calculated from grain size using the publicly-available program MVASKF. This program calculates K using 10 different empirical equations that have been developed to relate K to grain size (Vukovic and Soro, 1992). The average K value for the different empirical methods is 1.58 x 10^{-3} meters per second (m/s) for the upper well and 4.10 x 10^{-2} for the lower well (Table 1).

The upper well was screened in poorly-graded sand with gravel and the lower well was screened in well-graded sand with gravel. Both calculated K values from those screened intervals are within the range of standard values for saturated hydraulic conductivity for those kinds of lithologies (Freeze and Cherry, 1979). In addition, these K values are high enough to allow fairly rapid communication between aquifers or between groundwater and surface water.

5.0 MONITORING WELL DATA COLLECTION

5.1 Well Installation

The upper monitoring well was installed on December 9, 2008, by Tumwater Drilling. The total well depth is 120.5 feet bgs; the screen interval is 84 to 94 feet bgs. The log for this well is provided in Attachment B.

The lower monitoring well installation was begun on December 10, 2008, and completed the following day. The total well depth is 114.0 feet bgs; the screen interval is 64.5 to 74.5 feet bgs. The log for this well is provided in Attachment C.

5.2 Methods

NRD staff measured water levels in each well (distance from well casing to water surface) on seven dates from January 28, 2009, and to May 3, 2009 (Table 2). On most dates, the discharge in Chumstick Creek was also measured using a SonTek Acoustic Doppler Velocimeter.

On March 10, 2009, Onset® Hobo water level loggers were installed in each well to record water levels every 15 minutes. The distance from the well casing to the water level logger was 85.85 feet and 72.15 feet for the upper and lower wells, respectively. An additional water level logger was installed near each site to measure atmospheric pressure. The Hobo water level loggers measure water depth by recording absolute pressure (pounds per square inch [psi]), which includes pressure from the overlying water and the atmosphere. The atmospheric pressure was subtracted from the absolute pressure to provide a measure of the depth of water above the well water level loggers.

The monitoring of well water levels prior to installation of the Hobo water level loggers measured the distance from the top of the well casing to the water surface. The water level depth recorded by the Hobo loggers was subtracted from distance from the well casing to the logger to convert to common measurement of well water level.

5.3 Monitoring Results

The water levels in the two monitoring wells are shown in Table 2. The relationship between water level in the upper well and discharge in Chumstick Creek at Station CC8 is linear over the range of monitoring values (Figure 2). The coefficient of determination (R^2) is 0.93, which indicates that well water depth in this well provides a good prediction of Chumstick Creek discharge at monitoring Station CC8. Piezometer monitoring at CC8 measured a positive vertical hydraulic gradient (i.e., groundwater entering the creek) in September and November

2008 (AMEC, 2009a); therefore, it is not surprising that there is a good correlation between well water levels and creek discharge.

The relationship between water level in the lower well and discharge in Chumstick Creek at Gage 45C060, located approximately 1,500 feet upstream from the confluence with the Wenatchee River, is poor, with an R^2 value of 0.58 (Figure 2). The well water levels measured during the period of monitoring are below the creek bed, which suggests that groundwater was not entering this region of Chumstick Creek during the well monitoring period. Synoptic surveys of creek discharge and piezometer monitoring during late August to early October 2008 showed that the lower portions of Chumstick Creek are losing reaches, with negative vertical hydraulic gradients (AMEC, 2009a; 2009b).

The water level in the lower well calculated from water level logger data is shown on Figure 3. These data show that water levels in the well rose from mid-March to mid-April and then began to decline through the remainder of the monitoring period which ended in early June 2009. The predicted range of water depths agrees well with the manual measurements of water depth made by NRD staff (Table 2). The water level logger data for the upper well is not presented as the predicted water depth was about four times greater that the manual measurements made by NRD staff. No evidence of malfunction is evident from the Hobo battery voltage readings. NRD staff will be checking their data download procedures to try and determine the cause of this problem.

Sincerely yours,
AMEC Geomatrix, Inc.

Steven G. Ellis
Dave Haddock

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SGE
p:\chelan county\12817-001 wenatchee wtrshed hydro study\3000 reports\chumstick groundwater\chumstickgwmonitoringmemo061509.doc

Attachments:
Tables 1 to 2
Figures 1 to 3
Attachment A – Grain Size
Attachment B – Upper Well Monitoring Logs
Attachment C – Lower Well Monitoring Logs

6.0 REFERENCES

AMEC (AMEC Geomatrix, Inc.), 2008, Quality Assurance Project Plan – Groundwater–Surface Water Interactions along Chumstick Creek and Mission Creek in WRIA 45, Chelan County, Washington: Chelan County Natural Resource Department, Wenatchee, Washington.

AMEC, 2009a, Piezometer Monitoring in Chumstick and Mission Creeks – Groundwater–Surface Water Interactions along Chumstick Creek and Mission Creek in WRIA 45, Chelan County, Washington: Chelan County Natural Resource Department, Wenatchee, Washington.

AMEC, 2009b, Chumstick Creek Subwatershed Synoptic Survey of Creek Discharge – Groundwater–Surface Water Interactions along Chumstick Creek and Mission Creek in WRIA 45, Chelan County, Washington: Chelan County Natural Resource Department, Wenatchee, Washington.

Freeze, R. A., and Cherry, J.A., 1979, Groundwater: Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Geomatrix (Geomatrix Consultants, Inc.), 2007a, Current Water Use Characterization and Monitoring Needs, Chumstick Creek Subwatershed, Wenatchee Watershed Water Resource Technical Assistance, Chelan County, Washington: Chelan County Natural Resource Department, Wenatchee, Washington.

Geomatrix, 2007b, Current Water Use Characterization and Monitoring Needs, Mission Creek Subwatershed, Wenatchee Watershed Water Resource Technical Assistance, Chelan County, Washington: Chelan County Natural Resource Department, Wenatchee, Washington.

Vukovic, M., and Soro, A., 1992, Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition: Water Resource Publication, Highlands Ranch, Colorado.

Wildrick, L., 1979, Ground-Water Flow System of the Chumstick Drainage Basin: Washington State Department of Ecology, Water Resources Investigation Section, Open File Technical Report, Olympia.

WWPU (Wenatchee Watershed Planning Unit), 2006, Final Wenatchee Watershed Management Plan: Chelan County Natural Resource Department, Wenatchee, Washington.

Yolcubal, I., Brusseau, M.L., Artiola, J.F., Wierenga, P., and Wilson, L.G., 2004, Environmental Physical Properties and Processes, in Artiola, J.F., Pepper, I.L., and Brusseau, M.L. (eds.), Environmental Monitoring and Characterization: Elsevier Academic Press, London., p. 207-239.

TABLES

TABLE 1

HYDRAULIC CONDUCTIVITY (K) ESTIMATES FOR CHUMSTICK CREEK SUBWATERSHED MONITORING WELLS

Chumstick Creek Subwatershed
Wenatchee Watershed Water Resource Technical Assistance
Chelan County, Washington

MVASKF Empirical Equation	Upper Well in m/s	Lower Well in m/s
HAZEN	1.13E-03	5.12E-02
SLICHTER	2.25E-04	1.48E-02
TERZAGHI	3.28E-04	2.54E-02
BEYER	1.35E-03	4.49E-02
SAUERBREI	9.05E-04	8.28E-02
KRUEGERR	1.74E-03	8.36E-03
KOZENY	1.55E-03	1.42E-02
ZUNKER	1.20E-03	7.95E-03
ZAMARINU	1.47E-03	9.31E-03
USBR	5.88E-03	1.51E-01
Average	**1.58E-03**	**4.10E-02**

Note(s)

1. K values were calculated using the publicly-available program MVASKF, which calculates K from grain-size data using 10 different empirical equations (Vukovic and Soro, 1992).
   Vukovic, M., and Soro, A., 1992, Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition: Water Resource Publication, Highlands Ranch, Colorado.

Abbreviation(s)

m/s = meters per second

TABLE 2

WELL WATER LEVEL AND CHUMSTICK CREEK DISCHARGE MEASUREMENTS

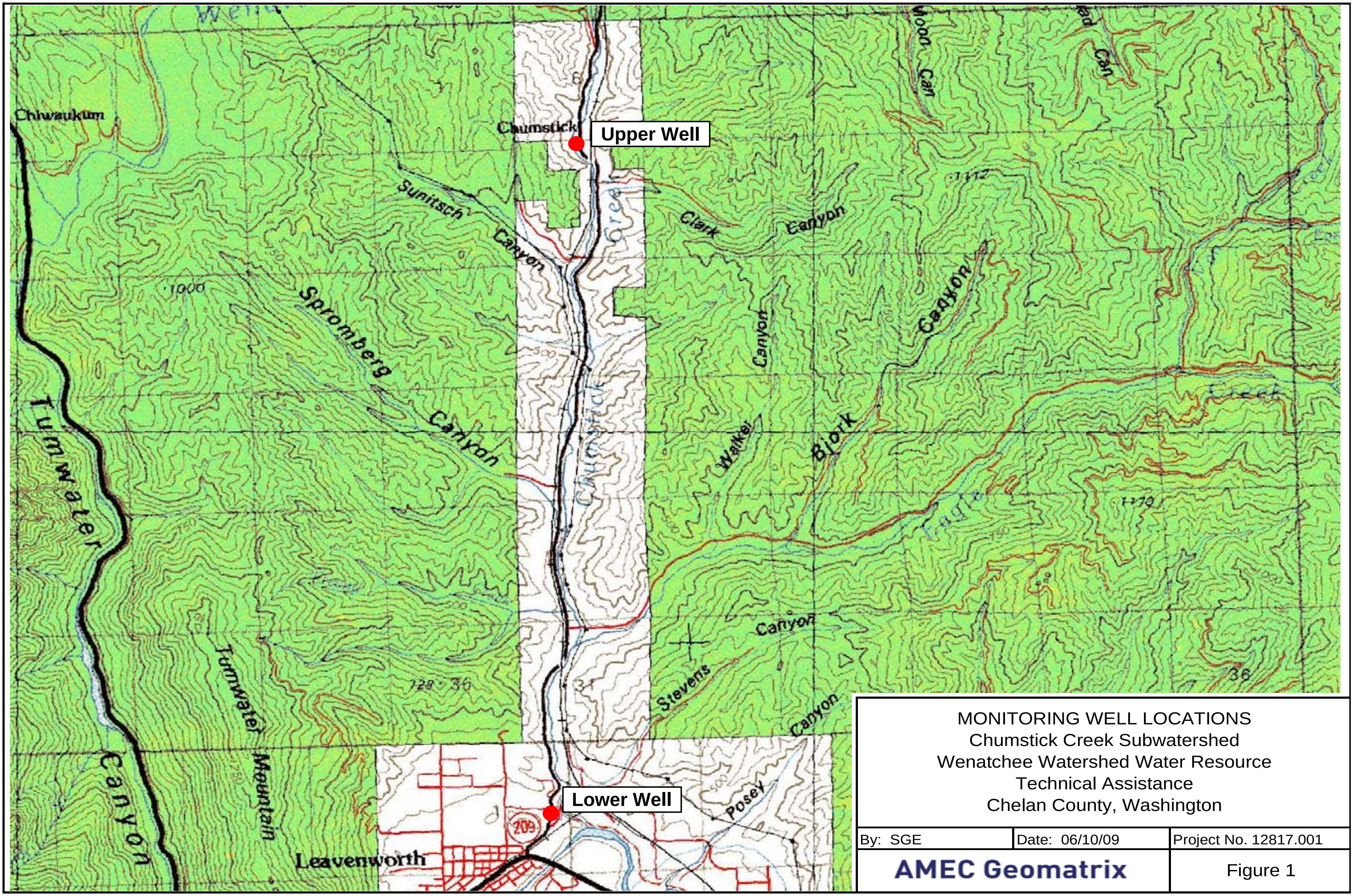
Chumstick Creek Subwatershed
Wenatchee Watershed Water Resource Technical Assistance
Chelan County, Washington

Date: Time	Upper Well Water Level (feet bgs)	Creek Discharge at Sta. CC8 (cfs)	Date: Time	Lower Well Water Level (feet bgs)	Creek Discharge at Gage 45C060 (cfs)
1/28/09/13:00	6.12	NA	1/28/09/13:30	45.68	19 - 20
2/19/09/11:12	6.52	7.08	2/19/09/ 11:30	46.14	13
3/10/09/14:45	5.70	10.90	3/10/09/15:25	45.55	33
3/20/09:/12:25	5.50	12.39	3/20/09:/14:00	45.09	33
3/27/09/12:48	5.00	16.80	3/27/09/13:02	44.75	44.75
4/24/09/11:25	3.26	21.90	4/24/09/11:35	44.40	43
5/3/09/14:20	1.50	NA	5/3/09/14:48	44.85	20.5

Abbreviation(s)

bgs = below ground surface
cfs = cubic feet per second
NA = not available

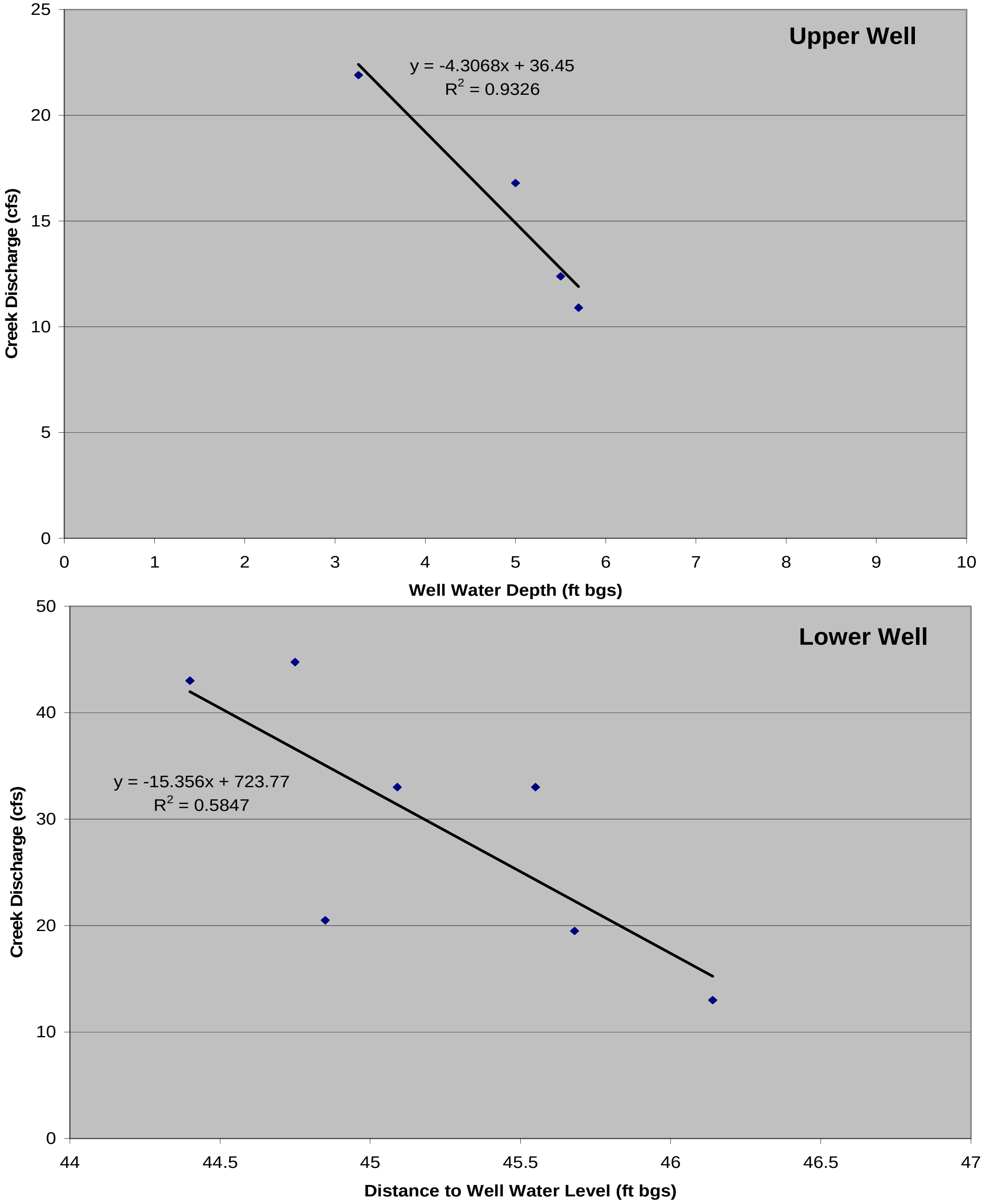
FIGURES



MONITORING WELL LOCATIONS
Chumstick Creek Subwatershed
Wenatchee Watershed Water Resource
Technical Assistance
Chelan County, Washington

By: SGE	Date: 06/10/09	Project No. 12817.001
AMEC Geomatrix		Figure 1

12817-001/Chumstick Groundwater/Figure 1.xls

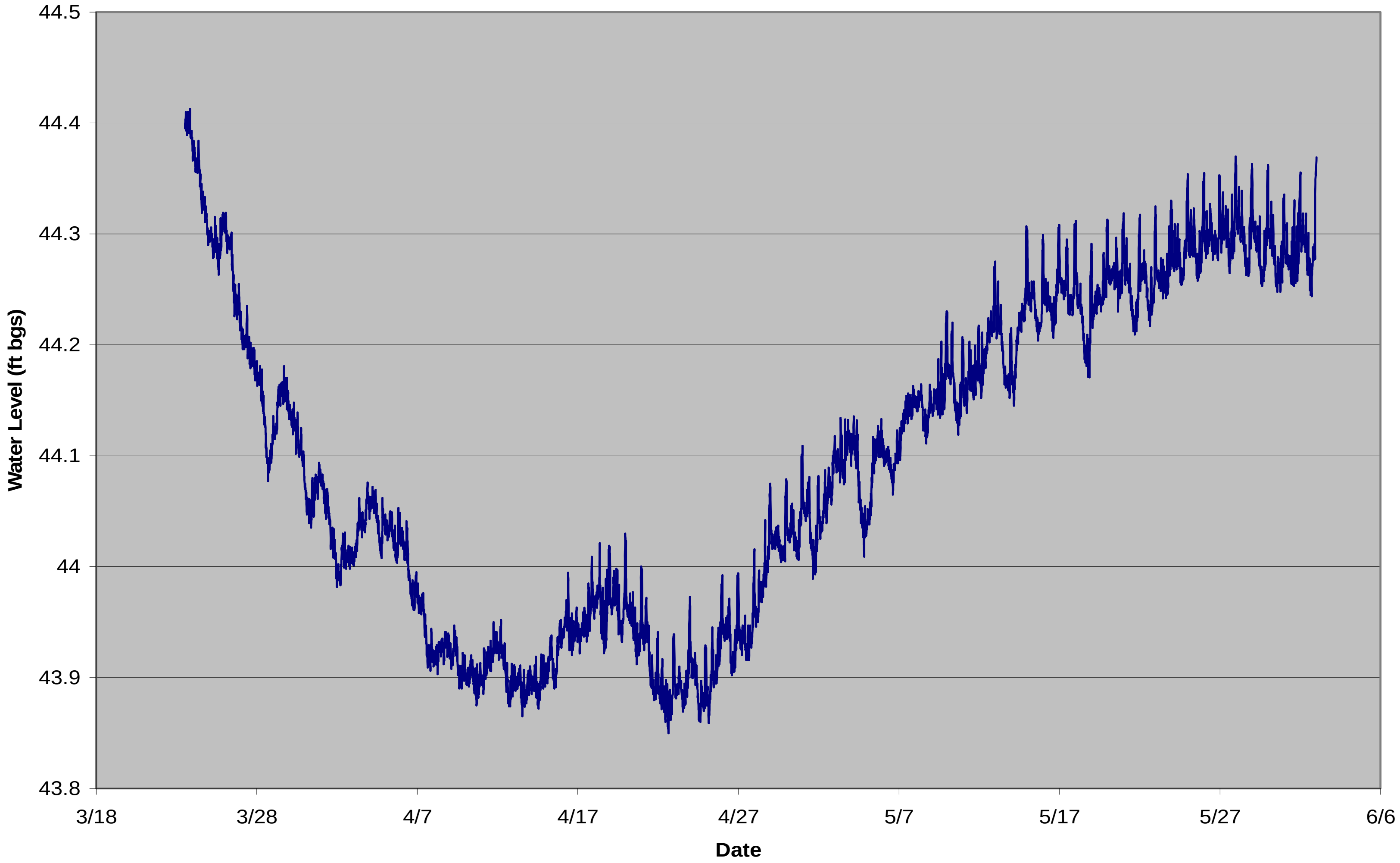


Abbreviation(s)
- bgs = below ground surface
- cfs = cubic feet per second
- ft = feet

RELATIONSHIP BETWEEN WELL WATER LEVEL
AND CHUMSTICK CREEK DISCHARGE
Chumstick Creek Subwatershed
Wenatchee Watershed Water Resource
Technical Assistance
Chelan County, Washington

By: sge	Date: 06/10/09	Project No. 12817.001
AMEC Geomatrix		Figure 2

12817-001\Chumstick Groundwater\Figure 2_waterlvl_vs_discharge.xls



Abbreviation(s)

bgs = below ground surface

ft = feet

LOWER WELL WATER LEVEL RECORDED BY
HOBO WATER LEVEL LOGGER
Chumstick Creek Subwatershed
Wenatchee Watershed Water Resource
Technical Assistance
Chelan County, Washington

By: sge	Date: 06/15/09	Project No. 12817.001
AMEC Geomatrix		Figure 3

ATTACHMENT A

Grain Size

Analytical Resources, Incorporated
Analytical Chemists and Consultants

19 March 2009

AMEC GEOMATRIX
Received
MAR 2 0 2009
SEATTLE

Nick Bacher
AMEC/Geomatrix
600 University, Suite 1020
Seattle, WA 98101

RE: Project No: Wenatchee Watershed Hydrogeologic Study
ARI Job No: OQ60

Dear Nick:

Please find enclosed the Chain-of-Custody (COC) record, sample receipt documentation, and the final results for the samples from the project referenced above. Two soil samples were received intact on March 13, 2009.

The samples were analyzed for grain size as requested.

A copy of these reports will remain on file with ARI. If you have any questions or require additional information, please contact me at your convenience.

Sincerely,

ANALYTICAL RESOURCES, INC.

Mark D. Harris
Project Manager
206/695-6210
markh@arilabs.com

Enclosures

cc: file OQ60

MDH/mdh

4611 South 134th Place, Suite 100 • Tukwila WA 98168 • **206-695-6200** • **206-695-6201** fax

CHAIN-OF-CUSTODY RECORD

OQ60

SEA 10440

PROJECT NAME: Wenatchee Watershed Hydrogeology Study

DATE: 3/13/09

PAGE 1 OF 1

PROJECT NUMBER: 12817

LABORATORY NAME: ARI

CLIENT INFORMATION: /

REPORTING REQUIREMENTS:

RESULTS TO: Nick Bacher

LABORATORY ADDRESS: Tukwila, WA

TURNAROUND TIME: Standard

SAMPLE SHIPMENT METHOD: hand delivered

LABORATORY CONTACT: Mark Harris

LABORATORY PHONE NUMBER:

GEOTRACKER REQUIRED YES NO

SITE SPECIFIC GLOBAL ID NO.

SAMPLERS (SIGNATURE): Nick Bacher

DATE	TIME	SAMPLE NUMBER	ANALYSES Sieve D421/422															CONTAINER TYPE AND SIZE	Soil (S), Water (W), Vapor (V), or Other (O)	Filtered	Preservative Type	Cooled	MS/MSD	No. of Containers	ADDITIONAL COMMENTS
12/9/08	1300	Upper-65	X															1-gal ziploc	S					1	
12/10/08	1230	Lower-66	X															1-gal ziploc	S					1	

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME
SIGNATURE: Nick Bacher PRINTED NAME: Nick Bacher COMPANY: AMEC GMX	3/13/09	1425	SIGNATURE: Sami Hayes PRINTED NAME: Sami Hayes COMPANY: ARI	3/13/09	1425
SIGNATURE: PRINTED NAME: COMPANY:			SIGNATURE: PRINTED NAME: COMPANY:		
SIGNATURE: PRINTED NAME: COMPANY:			SIGNATURE: PRINTED NAME: COMPANY:		

TOTAL NUMBER OF CONTAINERS:

SAMPLING COMMENTS:

Please retain all soil not used, hydrometer analysis might be run based on sieve data.

One Union Square, 600 University Street, Suite 1020
Seattle, Washington 98101-4107
Tel 206.342.1760 Fax 206.342.1761

Geomatrix

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Cooler Receipt Form

ARI Client: Geomatrix

COC No(s): 10440 NA

Assigned ARI Job No: OQ60

Project Name: Wenatchee Watershed Hydrogeologic Study

Delivered by: Fed-Ex UPS Courier [✓ Hand Delivered] Other: ______

Tracking No: ______ [✓ NA]

Preliminary Examination Phase:

Were intact, properly signed and dated custody seals attached to the outside of to cooler? YES [✓ NO]

Were custody papers included with the cooler? .... [✓ YES] NO

Were custody papers properly filled out (ink, signed, etc.) .... [✓ YES] NO

Temperature of Cooler(s) (°C) (recommended 2.0-6.0 °C for chemistry)........ AMB ____ ____ ____ ____

If cooler temperature is out of compliance fill out form 00070F

Temp Gun ID#: 101886

Cooler Accepted by: JH Date: 3/13/09 Time: 1625

Complete custody forms and attach all shipping documents

Log-In Phase:

Was a temperature blank included in the cooler? .... YES [✓ NO]

What kind of packing material was used? ... Bubble Wrap Wet Ice Gel Packs [✓ Baggies] Foam Block Paper Other: ______

Was sufficient ice used (if appropriate)? .... [✓ NA] YES NO

Were all bottles sealed in individual plastic bags? .... [✓ YES] NO

Did all bottles arrive in good condition (unbroken)? .... [✓ YES] NO

Were all bottle labels complete and legible? .... [✓ YES] NO

Did the number of containers listed on COC match with the number of containers received? .... [✓ YES] NO

Did all bottle labels and tags agree with custody papers? .... [✓ YES] NO

Were all bottles used correct for the requested analyses? .... [✓ YES] NO

Do any of the analyses (bottles) require preservation? (attach preservation sheet, excluding VOCs)... [✓ NA] YES NO

Were all VOC vials free of air bubbles? .... [✓ NA] YES NO

Was sufficient amount of sample sent in each bottle? .... [✓ YES] NO

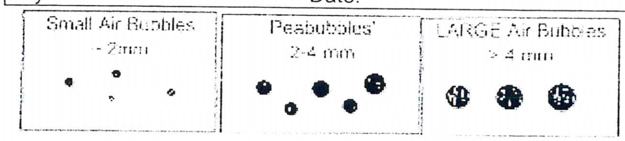
Samples Logged by: AV Date: 3/13/09 Time: 1545

***** Notify Project Manager of discrepancies or concerns *****

Sample ID on Bottle	Sample ID on COC	Sample ID on Bottle	Sample ID on COC

Additional Notes, Discrepancies, & Resolutions:

By: Date:



Small → "sm"
Peabubbles → "pb"
Large → "lg"
Headspace → "hs"

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Client: Geomatrix, Inc.	**ARI Project No.:** OQ60
Client Project: Wenatchee Watershed Hydrogeologic	**Client Project No.:** 12817

Case Narrative

1. Two samples were received on March 13, 2009, and were in good condition.
2. The samples were submitted for grain size distribution, according to ASTM D422.
3. The data is provided in summary tables and plots.
4. There were no noted anomalies in the samples or test method.

Approved by: ________________ Date: 3/19/09
Title: Geotechnical Division Manager

Geomatrix, Inc.
Wenatchee Watershed Hydrogeologic

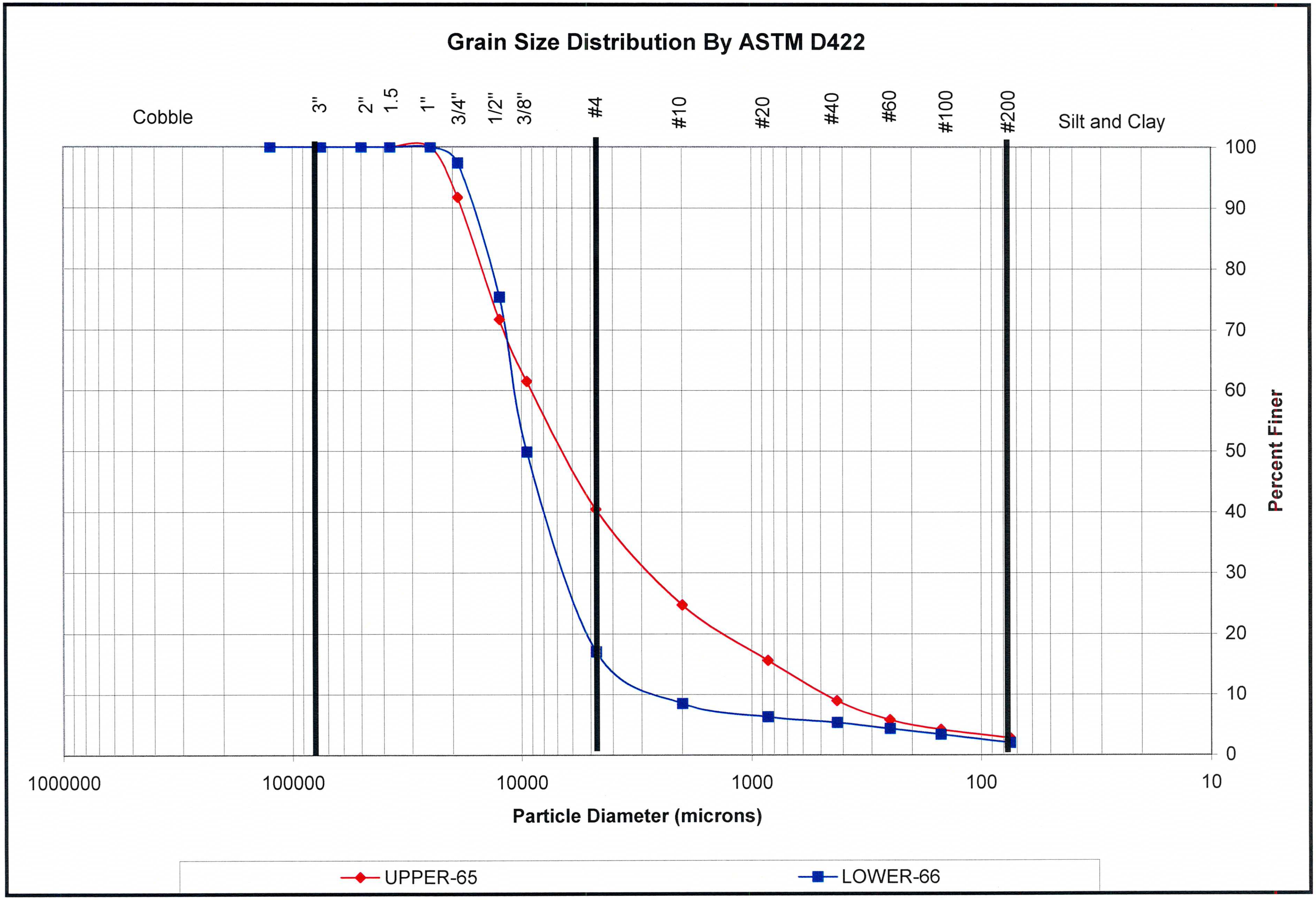
Percent Finer Than Indicated Size, By ASTM D422

Sample ID	Depth (ft)	Moisture Content (%)	5"	3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200
UPPER-65	A	4.60	100.00	100.0	100.0	100.0	100.0	91.7	71.7	61.4	40.4	24.7	15.6	8.9	5.8	4.2	2.8
LOWER-66	B	1.02	100.0	100.0	100.0	100.0	100.0	97.4	75.4	49.8	17.1	8.5	6.3	5.3	4.4	3.4	2.0

Geomatrix, Inc.
Wenatchee Watershed Hydrogeologic

Percent Retained in Each Size Fraction, By ASTM D422

Sieve Size (microns)	5"-3"	3-2"	2-1.5"	1.5-1"	1-3/4"	3/4-1/2"	1/2-3/8"	3/8-#4	4750-2000	2000-850	850-425	425-250	250-150	150-75	<75
UPPER-65	0.0	0.0	0.0	0.0	8.3	20.0	10.2	21.0	15.7	9.1	6.7	3.2	1.6	1.4	2.8
LOWER-66	0.0	0.0	0.0	0.0	2.6	22.0	25.5	32.8	8.6	2.2	1.0	1.0	1.0	1.4	2.0


Grain Size Distribution By ASTM D422
Cobble
3"
2"
1.5
1"
3/4"
1/2"
3/8"
#4
#10
#20
#40
#60
#100
#200
Silt and Clay
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
1000000
100000
10000
1000
100
10
Particle Diameter (microns)
UPPER-65
LOWER-66

ATTACHMENT B

Upper Well Monitoring Logs

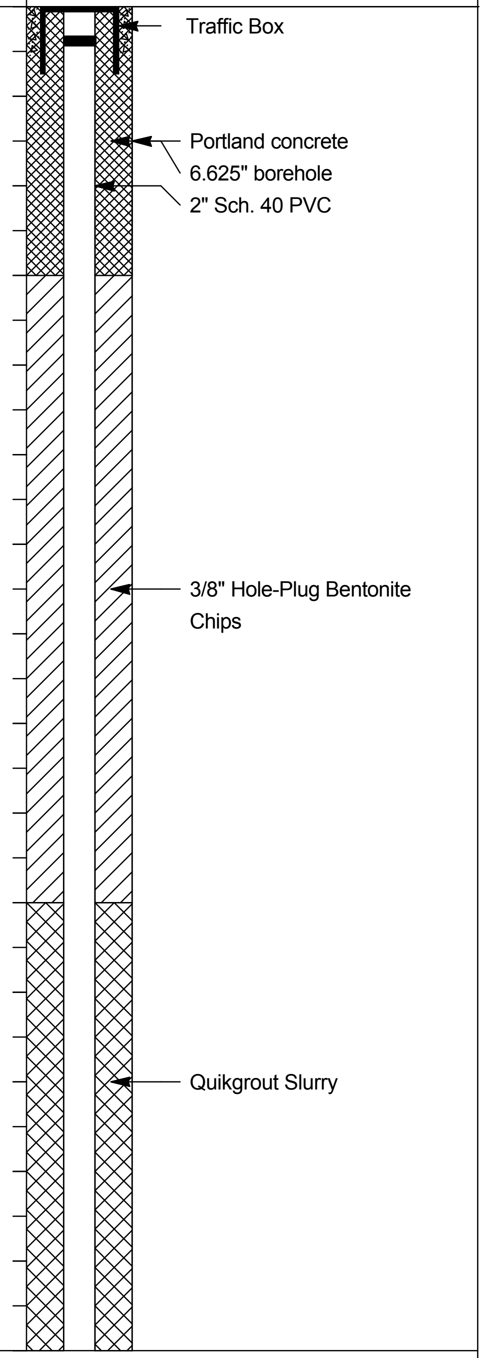
PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep

BORING LOCATION: Upper Watershed, Chumstick
GROUND SURFACE ELEVATION AND DATUM: Not Surveyed
DRILLING CONTRACTOR: Tumwater Drilling
DATE STARTED: 12/9/08
DATE FINISHED: 12/9/08
DRILLING METHOD: Air rotary
TOTAL DEPTH (ft.): 120.5
SCREEN INTERVAL (ft.): 84.0-94.0
DRILLING EQUIPMENT: Schramm T450 WS
DEPTH TO WATER: FIRST 10 COMPL. 9.7
CASING:
SAMPLING METHOD: Bulk sample collected from drill cuttings
LOGGED BY: N. Bacher
HAMMER WEIGHT: NA
DROP: NA
RESPONSIBLE PROFESSIONAL: N. Bacher
REG. NO. 2528

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:
0					WELL GRADED GRAVEL with SAND (GW): brown moist, 70% fine gravel, 30% fine to coarse sand, gravel is well rounded to 2", occasional gray boulder fragments
1					
2					
3					
4					
5					
6					
7					SANDY SILT (ML): brownish gray moist, 65% fines, 30% fine sand, 5% fine rounded gravel to 2"
8					
9					
10					
11					
12					
13					
14					gray, 70% fines, 30% fine sand,
15					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

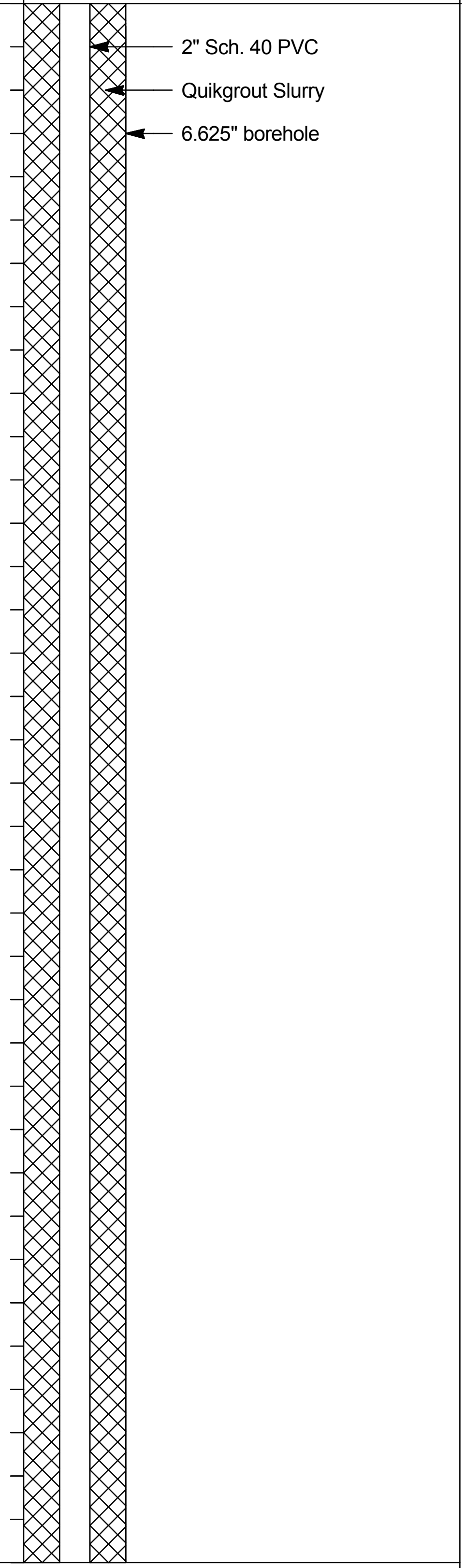


PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
15					(ML) cont.
16					water level measured: 11.0'
17					grayish brown
18					
19					WELL GRADED GRAVEL with SAND (GW): brown wet, 70% fine gravel, 30% fine to coarse sand, gravel is well rounded to 1.5"
20					
21					
22					
23					
24					SILTY SAND (SM): brown wet, 70% fine to medium sand, 30% low plasticity fines
25					
26					
27					
28					
29					
30					
31					
32					
33					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



OAKWELLV (REV. 9/2007)

AMEC Geomatrix

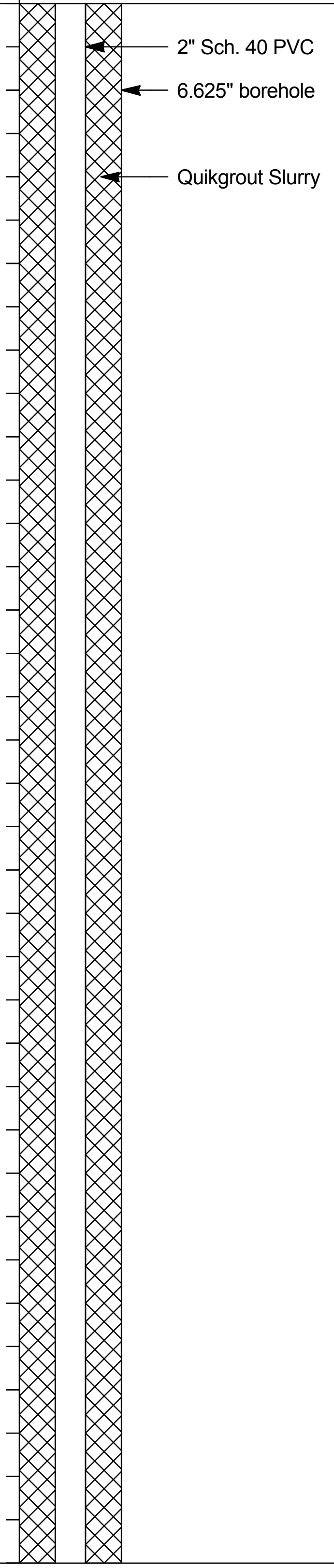
Project No. 12817.001

PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
33					(SM) cont.
34					
35					water level measured: 11.5'
36					
37					
38					
39					
40					LEAN CLAY (CL): gray moist, 90% fines, less than 10% fine sand, soft, medium plasticity
41					
42					
43					
44					
45					
46					
47					SILTY SAND (SM): gray wet, 80% fine to coarse sand, 20% fines, trace granitic pieces
48					
49					
50					
51					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

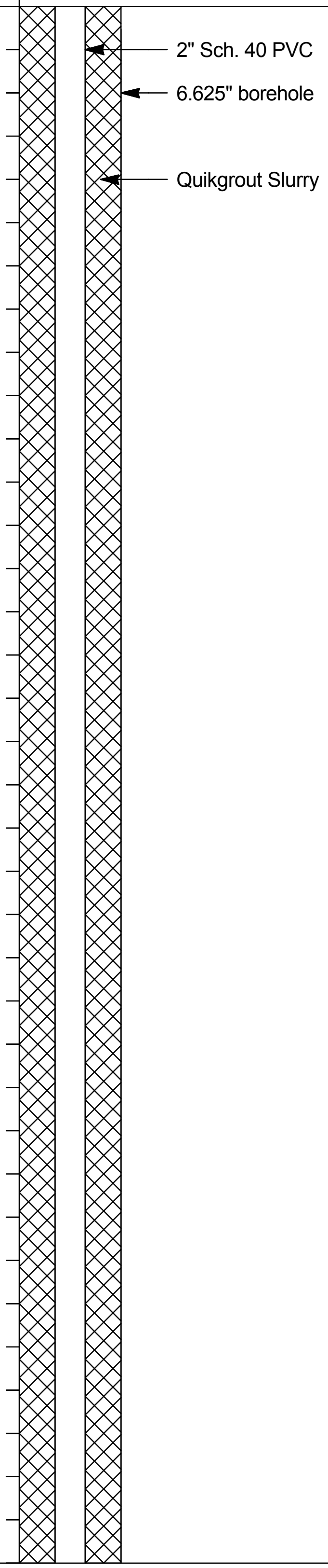


PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)

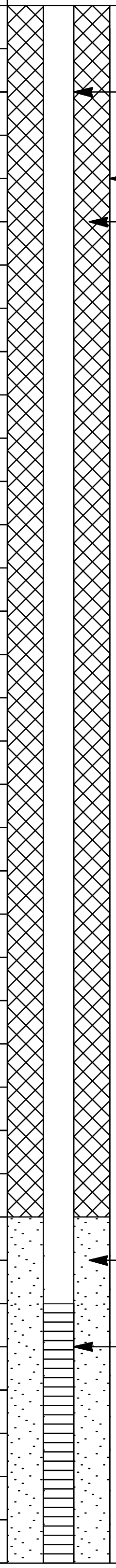
DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
51					(SM) cont.
52					
53					
54					
55					water level measured: 9.7'
56					
57					
58					
59					WELL GRADED GRAVEL with SAND (GW): gray wet, 65% fine gravel, 35% fine to coarse sand, gravel well rounded to 2"
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)



DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
69					(GW) cont.	
70					SILTY SAND (SM): gray 85% fine sand, 15% low plasticity fines, silt at various intervals	2" Sch. 40 PVC
71						6.625" borehole Quikgrout Slurry
72						
73						
74						
75						
76						
77						
78						
79						
80						
81						
82						
83						2/8 Colorado Silica Sand
84					POORLY GRADED SAND with GRAVEL (SP): gray wet, 90% fine to coarse sand, 10% fine well rounded gravel to 2"	2" Sch. 40 PVC 0.010 slot screen
85						
86						
87						

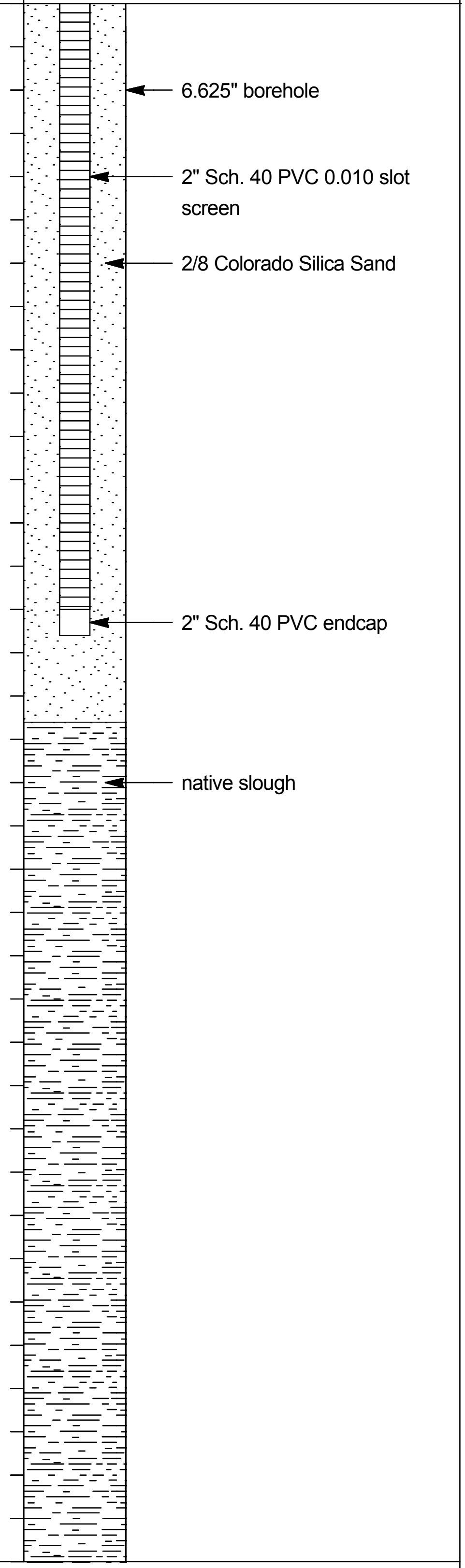
OAKWELLV (REV. 9/2007)

PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)

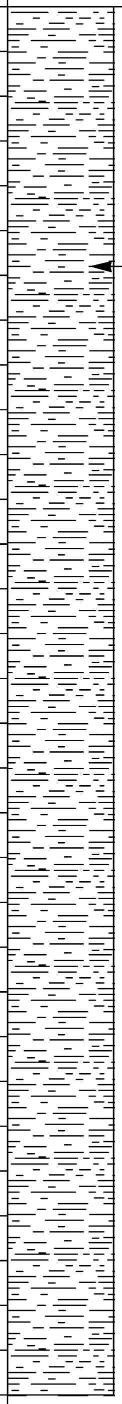
DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
87					(SP) cont.
88					
89					
90					
91					SILTY GRAVEL (GM): gray wet, 70% fine gravel, 20% low plasticity fines, 10% fine sand, trace wood.
92					
93					
94					
95					
96					
97					
98					
99					
100					⊤ mostly heave
101					
102					
103					
104					
105					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Upper Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
105					(GM) cont.	
106						
107						
108						native slough
109						
110						
111						
112						
113						
114						
115						
116						
117						
118						
119						
120					Bottom of boring at 120.5 feet.	
121						
122						
123						

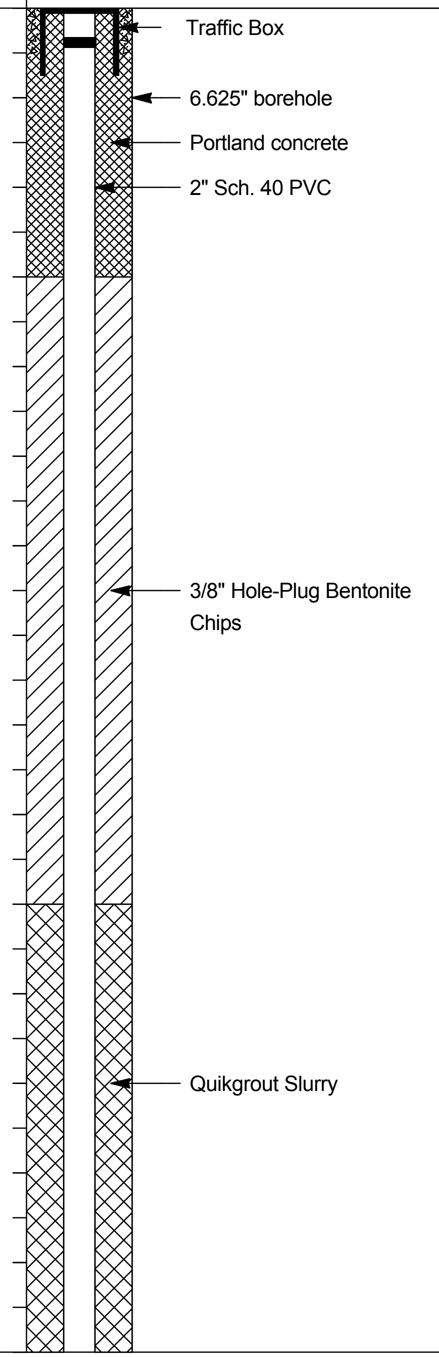
ATTACHMENT C

Lower Well Monitoring Logs

PROJECT: Wenatchee Watershed Hydrogeologic Study Chelan County, WA	**Log of Well No. Lower Deep**
BORING LOCATION: Lower Watershed, Chumstick	GROUND SURFACE ELEVATION AND DATUM: Not Surveyed
DRILLING CONTRACTOR: Tumwater Drilling	DATE STARTED: 12/10/08 / DATE FINISHED: 12/11/08
DRILLING METHOD: Air rotary	TOTAL DEPTH (ft.): 114.0 / SCREEN INTERVAL (ft.): 64.5-74.5
DRILLING EQUIPMENT: Schramm T450 WS	DEPTH TO WATER: FIRST 47 / COMPL. 47.2 / CASING:
SAMPLING METHOD: Bulk sample collected from drill cuttings	LOGGED BY: N. Bacher
HAMMER WEIGHT: NA / DROP: NA	RESPONSIBLE PROFESSIONAL: N. Bacher / REG. NO. 2528

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:
0					SILTY SAND (SM): brown dry, 80% medium sand, 15% low-plasticity fines, 5% trace well rounded gravel to 1.5"
1					
2					
3					
4					
5					
6					
7					
8					Solid rock
9					
10					
11					
12					moist
13					
14					
15					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



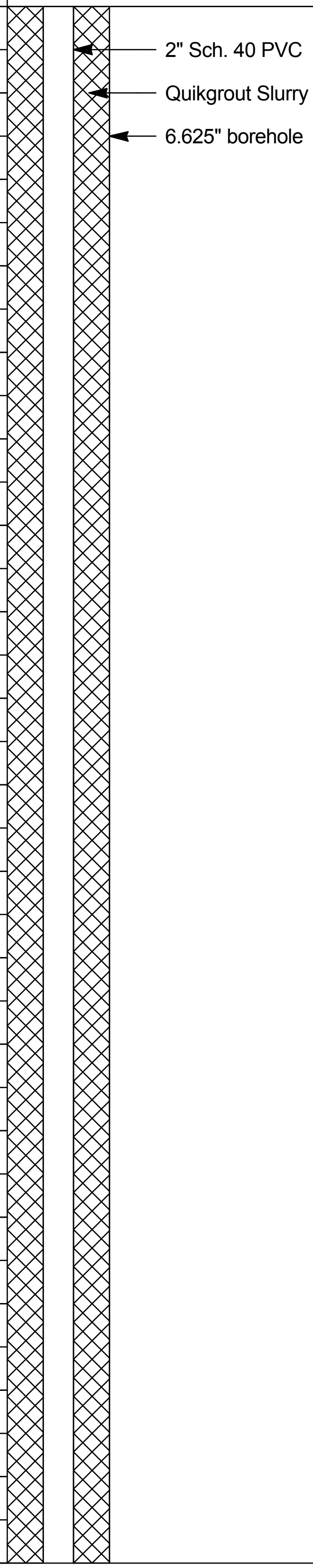
OAKWELLV (REV. 9/2007)

PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
15					(SM) cont.
16					
17					
18					boulders chunks of rock, very dusty
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					

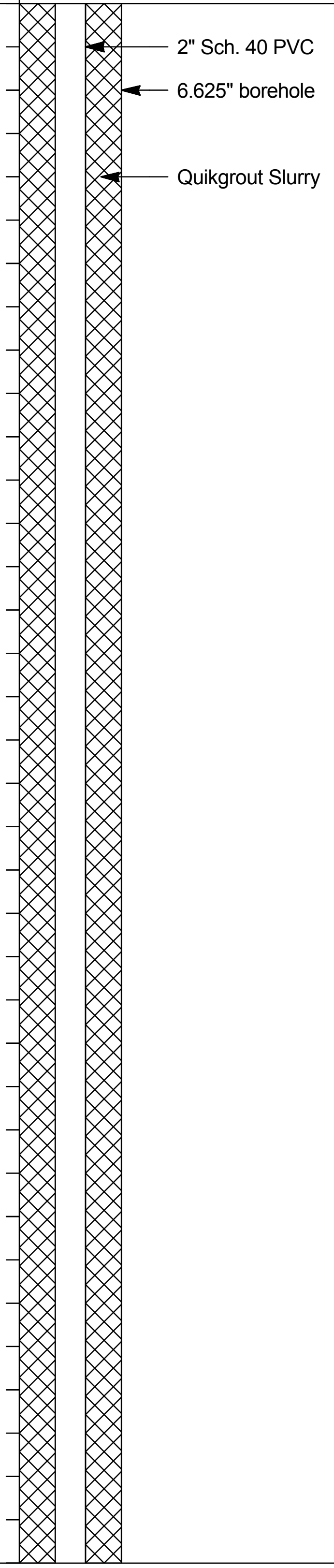
WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
33					boulders cont.
34					
35					
36					
37					
38					moist
39					
40					
41					
42					POORLY GRADED SAND (SP): light brown moist, 100% fine sand, metallic flecks
43					
44					
45					
46					
47					wet
48					
49					
50					
51					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

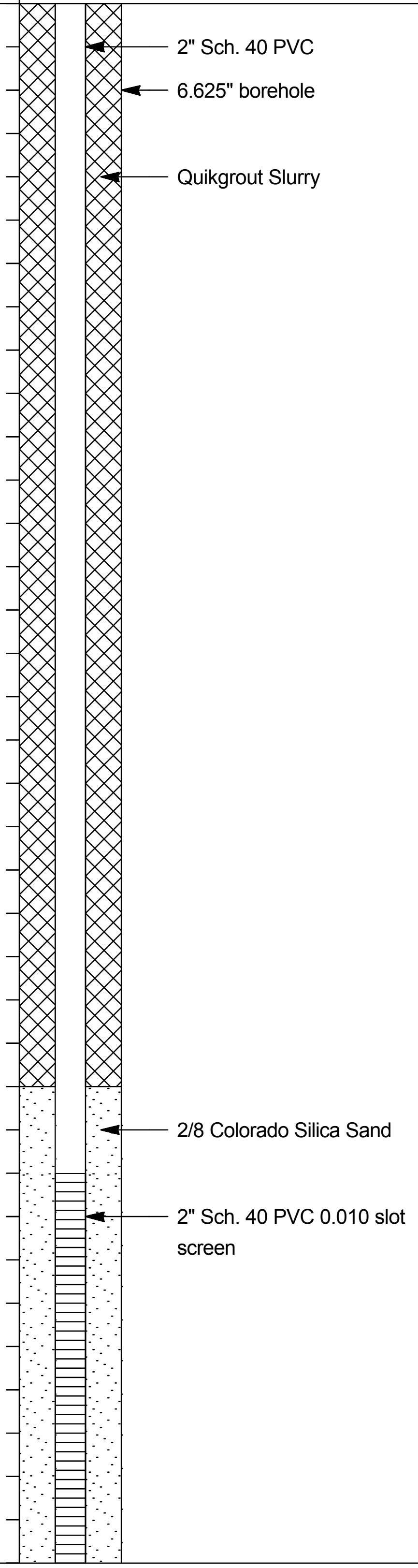


PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
51					(SP) cont.
52					
53					WELL GRADED GRAVEL with SAND (GW): brown wet, 75% fine gravel, 25% fine to medium sand, well rounded gravel to 1.5"
54					
55					90% fine gravel, 10% coarse to fine sand
56					
57					
58					
59					
60					
61					
62					
63					85% fine gravel, 15% coarse sand
64					
65					
66					
67					
68					
69					

WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS

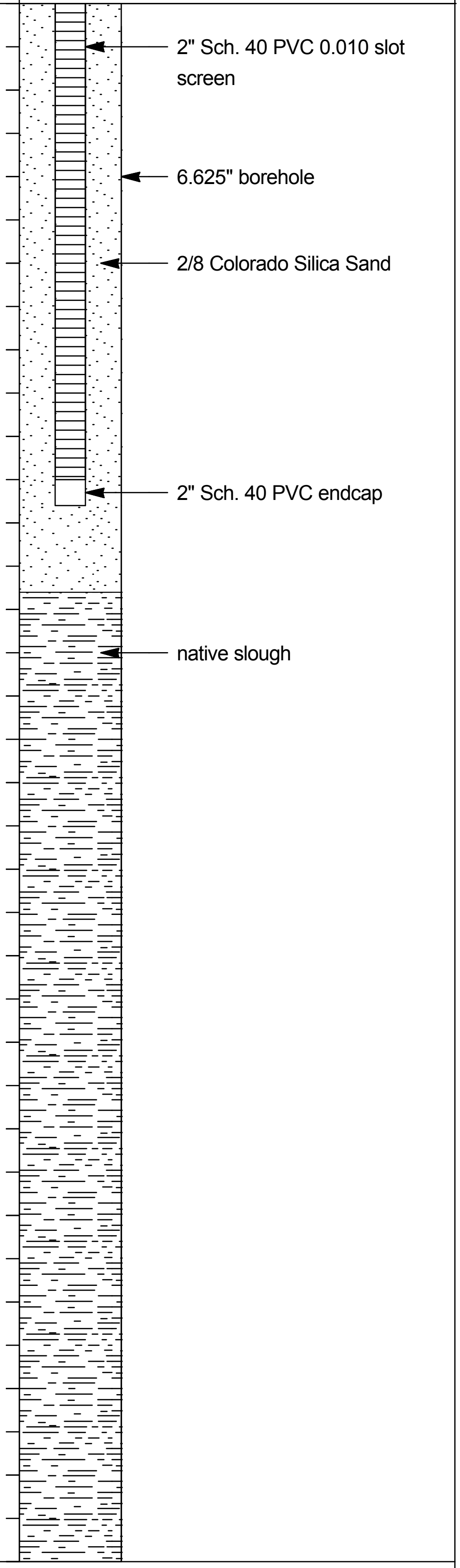


PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.
69					(GW) cont.
70					
71					
72					
73					
74					
75					
76					
77					
78					SILTY SAND (SM): brown wet, 85% fine to medium sand, 15% low-plasticity fines, grades from sand to slightly silty sand
79					
80					
81					
82					
83					
84					
85					
86					
87					

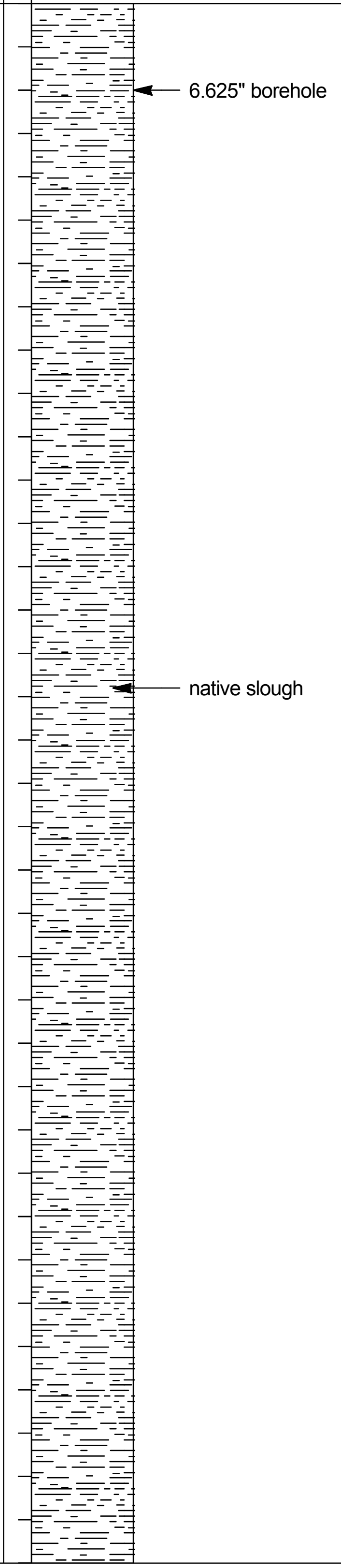
WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS



PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
87					(SM) cont.	
88						6.625" borehole
89						
90						
91						
92						
93						
94						
95						native slough
96						
97						
98						
99						
100						
101						
102						
103						
104						
105						



PROJECT: Wenatchee Watershed Hydrogeologic Study
Chelan County, WA

Log of Well No. Lower Deep (cont'd)

DEPTH (feet)	SAMPLES Sample No.	Sample	Blows/ Foot	OVM Reading	DESCRIPTION NAME (USCS): color, moist, % by wt., plast. density, structure, cementation, react. w/HCl, geo. inter.	WELL CONSTRUCTION DETAILS AND/OR DRILLING REMARKS
105					(SM) cont.	
106						
107						
108					SANDSTONE brown with conglomorated gravel	
109						
110						
111						
112						
113						
114					brown gray no gravel Bottom of boring at 114 feet.	
115						
116						
117						
118						
119						
120						
121						
122						
123