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Pacific Northwest
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300 Area VOC Program Slug Test Characterization Results for Selected Test/Depth Intervals for Wells 399-2-5, 399-3-22, and 399-4-14

D. R. Newcomer

March 2008

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99352

Executive Summary

Multiple, stress-level slug tests were performed at selected test/depth intervals within wells 399-2-5, 399-3-22, and 399-4-14 as part of the 300 Area volatile organic compound characterization program at the Hanford Site in Washington State. The temporary test screen lengths were characterized as the boreholes were advanced to their final drill depths and before their completion as monitor-well facilities. Following well completion, slug tests were performed in the final, completed well-screen sections. The objectives of the slug tests were to provide the vertical distribution of hydraulic conductivity with depth at these locations and to support selection of the final well screen-depth interval for each of these monitor-well facilities. This characterization information is important for predicting/simulating contaminant migration (i.e., numerical flow/transport modeling) and designing proper monitor-well strategies within this area.

Test-analysis results obtained from the multiple, stress-level slug tests provide vertical distribution of hydraulic conductivity for hydrogeologic units generally within the upper, middle, and lower sections of the unconfined aquifer. Individual test/depth intervals were sited to provide hydraulic-property information for the highly permeable Hanford formation (Unit 1) within the upper part of the unconfined aquifer and the underlying, less permeable Ringold Formation (Unit 5) within the middle and lower sections of the unconfined aquifer. Eight out of 10 discrete-depth intervals were tested successfully during borehole advancement, and one test/depth interval was tested after the wells were completed as monitor-well facilities. Two of the temporary test screen lengths could not be tested during borehole advancement because of sediment in-filling that occurred inside the temporary well-screen section.

No quantitative analysis for slug tests conducted within the three Hanford formation (Unit 1) test intervals was realized because of test-system limitations. Limiting qualitative analysis results, however, provide a lower, bounding hydraulic conductivity estimate range of ≥300 to ≥400 m/day for these Hanford formation tests. These hydraulic conductivity estimates were derived for test-interval sections that ranged from only 0.5 to 1.1 m in length. These lower bounding Hanford formation test values are comparable to the general range of lower bounding values (i.e., >100 to >2,000 m/day) for 300-Area test characterizations recently cited in Williams et al. (2007) and to the estimate of 568 m/day for one previous 300-Area volatile organic compound characterization test/depth interval (Spane 2007).

Analysis of the slug-tests conducted within six test/depth intervals within the Ringold Formation (Unit 5) indicates average hydraulic conductivity estimates ranging from ≤0.01 to 2.48 m/day. Hydraulic conductivity estimates for the Ringold Formation (Unit 5) were derived for test-interval sections that ranged from 0.6 to 2.9 m in length. These average hydraulic conductivity values are comparable to the lower range of 0.04 to 41.2 m/day, with a geometric mean of 2.38 m/day, for 16 other Ringold Formation test/depth intervals recently obtained for test-characterization boreholes in the 300 Area (Williams et al. 2007; Spane 2007).

Acknowledgments

Those acknowledged include field support provided by Rob Mackley of Pacific Northwest National Laboratory, Jake Horner of Gram, Inc., and field-testing personnel and test-equipment support provided by Blue Star Enterprises Northwest Drilling Company. Frank Spane provided technical peer review comments, Dave Lanigan provided graphics support, and Wayne Cosby provided editorial comments.

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1.0 Introduction

Pacific Northwest National Laboratory conducted multiple, stress-level slug tests at selected test/depth intervals within wells 399-2-5, 399-3-22, and 399-4-14 as part of the 300 Area volatile organic compound (VOC) characterization program at the Hanford Site in Washington State for the U.S. Department of Energy (Figure 1.1). The temporary test screen lengths were characterized as the borehole was advanced to its final drill depth and before its completion as a monitor-well facility. Where possible, the final well-screen sections were characterized following well completion. The primary objective of the slug tests was to provide information pertaining to the vertical distribution of hydraulic conductivity with depth at these locations and to select the final well screen-depth interval for each monitor-well facility. This type of characterization information is important for predicting/simulating contaminant migration (i.e., numerical flow/transport modeling) and designing proper monitor-well strategies within this area.

Section 2 describes the general hydrologic test system employed to perform the series of multiple, stress-level slug tests for each isolated test-interval section. Section 3 discusses slug-test response and analysis methods. Section 4 presents pertinent information describing slug-testing activities and analysis results for the test/depth zones that were hydrologically characterized at the 300 Area VOC wells. Slug-test results are described for each individual test zone within each of the three well locations. Section 5 presents the hydraulic conductivity depth profiles obtained at each of the three well sites. Conclusions and references are provided in Sections 6 and 7, respectively. Slug-test field notes are provided in Appendix A, and borehole lithologic logs are presented in Appendix B.

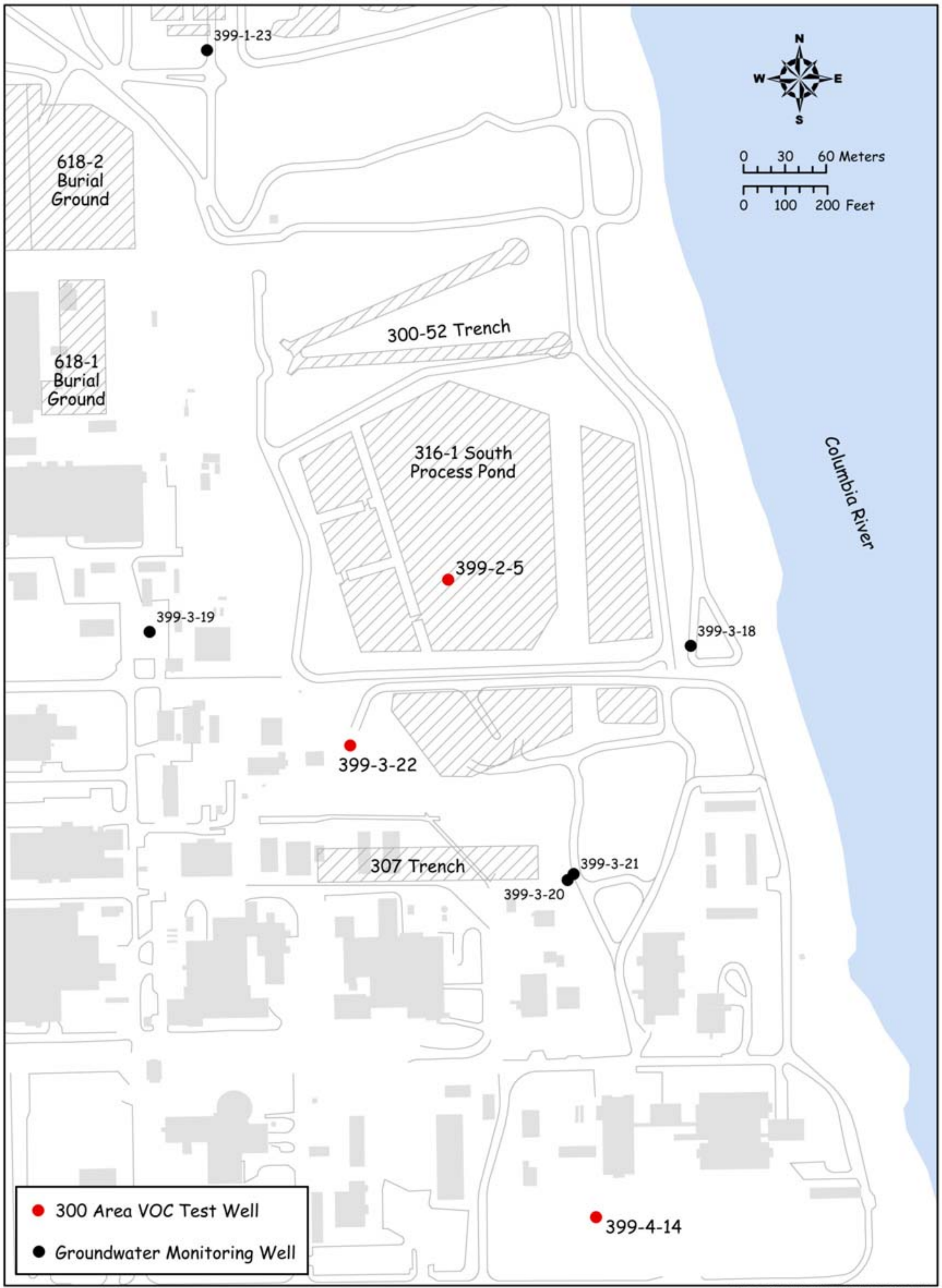

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Figure 1.1. Map Showing Locations of 300 Area VOC Well Sites

2.0 Hydrologic Test System Description

The following discussion of the general hydrologic test plan is taken primarily from similar slug-test characterization-program descriptions presented previously by Spane.[a] Hydrologic testing was implemented when the approximate targeted depth intervals within the unconfined aquifer were reached during drilling. To prepare the test zone for slug-test characterization, the packer/well-screen test assembly was lowered to the bottom of the borehole, and the drill casing was retracted, exposing an open borehole section of ~1 m or less within the Hanford formation and between 1 and 3.5 m within the Ringold Formation. The packer was then inflated to isolate the well-screened/test interval and the testing string from the inside of the drill casing. Following well completion, slug-test characterization was conducted in the final, completed well, well-screen section.

A series of multiple, stress-level slug tests were attempted for each isolated test-interval section. The reason for using a multi-stress-level approach was to determine whether the associated slug-test responses exhibited either a variable or stress-level dependence. As noted in Butler (1998) and Spane et al. (2003b), tests exhibiting either variable or stress-level dependence can provide valuable information pertaining to the presence of dynamic well skin or non-linear (i.e., turbulence) test-response conditions occurring within the test section. General slug-test stress levels applied during testing were designed to be within the range of ~0.3 to 0.7 m for lower stress tests and ~0.7 to 1.4 m for higher stress tests. The slug tests were initiated with two slugging rods of different, known displacement volumes. For most test zones, three or more multi-stress slug tests were conducted. Efforts were made to allow individual slug tests to approach full recovery before starting the next slug test within the characterization sequence. A wide range in recovery times was expected based on the anticipated range in permeability conditions. For example, Spane et al. (2001a, 2001b, 2002, 2003a) and Spane and Newcomer (2004) report recovery times as rapid as <15 sec for high-permeability test intervals (e.g., Hanford formation) to >10 min for lower permeability Ringold Formation test zones. A description of the hydrologic test system used during slug test characterization is provided in the following report section.

Figure 2.1 shows the general test-system configuration used for the slug tests conducted during the drilling and testing of 300 Area wells 399-2-5, 399-3-22, and 399-4-14. Slug tests were conducted with only slugging rods for all test zones (i.e., no pneumatic slug tests were performed). The test-system configuration includes a downhole inflatable packer/well-screen test assembly, a downhole pressure

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(a) FA Spane, Jr. 2003. *Slug Test Characterization Results for Multi- Test/Depth Intervals Conducted During the Drilling of WMA-C Well 299-E27-22 (C4124).* Letter report to Jane Borghese (Fluor Hanford, Inc.), October 8, 2003.

Spane FA, Jr. 2005a. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of WMA-BX-BY Well 299-E33-49.* Letter report to Jane Borghese (Fluor-Hanford, ORP), January 10, 2005.

Spane FA, Jr. 2005b. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit UP-1 Wells 299-W19-48, 699-30-66, and 699-36-70B.* Letter report to Mark Byrnes (Fluor-Hanford, ORP), September 13, 2005.

Spane FA, Jr. 2005c. *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16.* Letter report to Mark Byrnes (Fluor-Hanford, ORP), September 13, 2005.

transducer, a slugging rod lowered by a drill rig, and a surface data-logger system. The drill-casing string used for borehole advancement during the drilling of each well had inside diameter (I.D.) and outside diameter (O.D.) dimensions of 0.273 m (10 ¾ in.) and 0.298 m (11 ¾ in.), respectively. Except for slug tests conducted in Zone 1 near the water table, an inflatable packer was used to seal and isolate the temporary test screen length and test-casing string from the encompassing drill-casing area. The packer was not inflated during testing near the water table. While the packer was inflated, test-interval isolation was verified by adding ~20 L of water above the packer (i.e., in the annular area between the testing string and drill casing), both at the beginning and end of the testing sequence. A 3.05-m length of 0.152-m I.D., 30-slot (Schedule 20), well-screen section attached below the packer was used to maintain an open section for testing the formation after retracting the drill casing. A 0.1-m-long cap was attached to the bottom of the well-screen section. The inside diameter of the attached test-casing string above the well-screen section was 0.102 m. A Druck, Inc. pressure transducer strain-gauge, 0- to 69-kPa (0- to 10-psig) pressure transducer was installed below the fluid-column surface within the temporary test-casing string to monitor downhole test-interval response before and during slug testing. Pressure-transducer measurements were recorded with a Campbell Scientific, Inc. model CR-10X™ data logger.

Figure 2.2 shows the general slug-test configuration following well completion of each of the three wells. Slug tests were conducted in the final well-screen sections with the same slug rods as those used during testing within the temporary test-casing string. The test-system configuration within the final well-screen section includes a downhole pressure transducer, a slugging rod lowered by a drill rig, and a surface data-logger system. The final 10-slot (Schedule 10) well-screen section had a length of 3.0 m (10 ft) or 6.1 m (20 ft) and an I.D. dimension of 0.152 m (6 in.). A Druck, Inc. pressure transducer strain-gauge, 0- to 69-kPa (0- to 10-psig) pressure transducer was installed below the fluid-column surface within the well casing or well-screen section to monitor downhole test-interval response before and during slug testing. Pressure-transducer measurements were recorded with a Campbell Scientific, Inc. model CR-10X™ data logger.

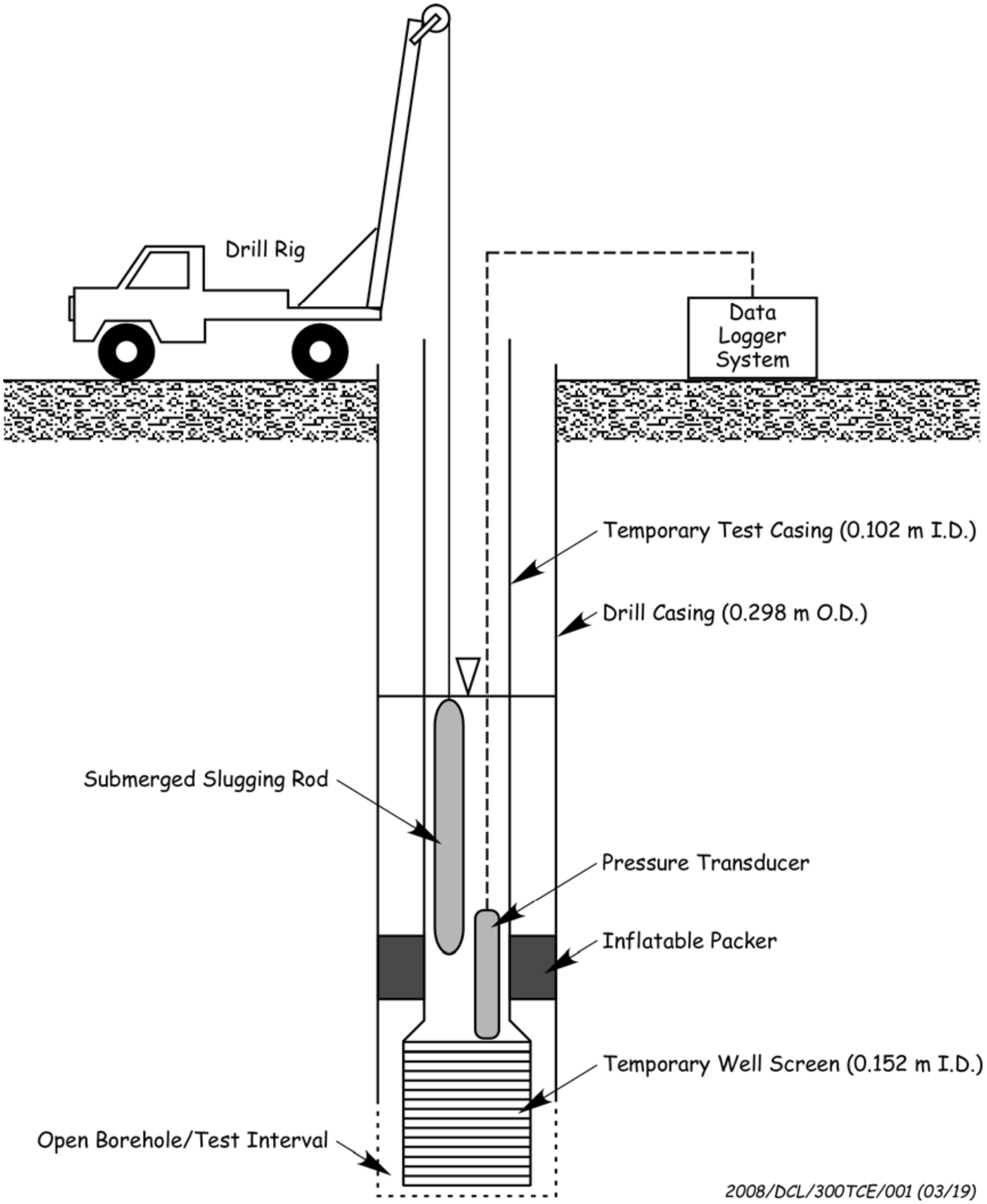


Figure 2.1. General Slug-Test Configuration within the Temporary Test-Casing String during the Drilling and Testing of Wells 399-2-5, 399-3-22, and 399-4-14

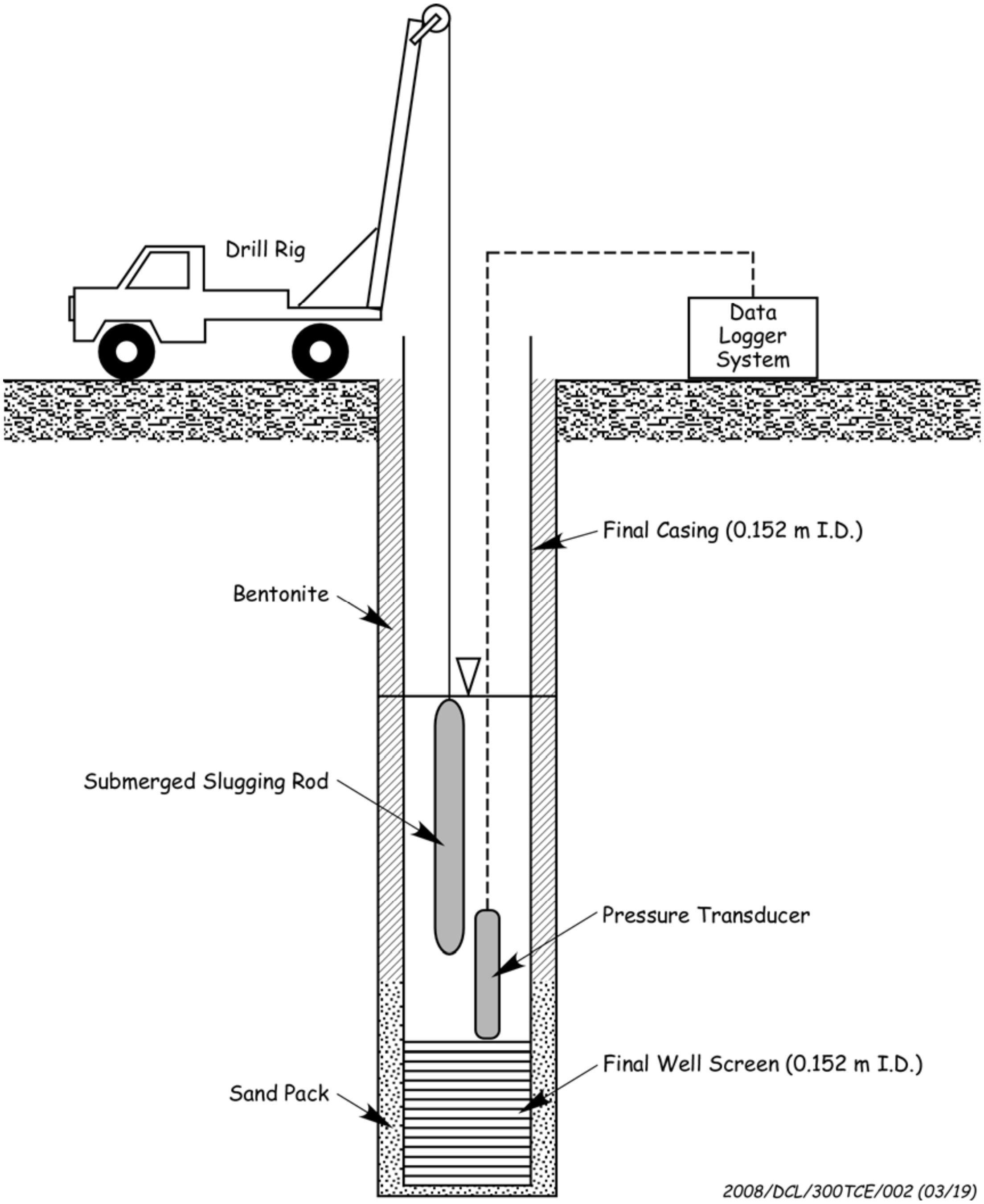


Figure 2.2. General Slug-Test Configuration within the Final Well-Screen Section

3.0 Slug Test Response and Analysis

The following discussion pertaining to slug-test response and analysis is taken primarily from Spane [see footnote 2.0 (a)]. As shown in Figure 3.1 and discussed in Butler (1998) and Spane et al. (2003b), water levels within a test well can respond in one of three ways to the instantaneously applied stress of a slug test. These response model patterns are 1) an over-damped response, where the water levels recover in an exponentially decreasing recovery pattern, 2) an under-damped response, where the slug-test response oscillates above and below the initial static, with decreasing peak amplitudes with time, and 3) a critically damped response, where the slug test behavior exhibits characteristics that are transitional to the over- and under-damped response patterns. Factors that control the type of slug-test response model that is exhibited within a well include a number of aquifer properties (hydraulic conductivity) and well-dimension characteristics (well-screen length, well-casing radius, well-radius, aquifer thickness, fluid-column length) and can be expressed by the response-damping parameter, C_D, which Butler (1998) reports for unconfined aquifer tests as:

$$C_D = \sqrt{\frac{g}{L_e}} * \frac{r_c^2 \ln\left[R_e / r_w\right]}{2KL} \tag{3.1}$$

where g = acceleration due to gravity
L_e = effective well water-column length
r_c = well casing radius; i.e., radius of well water-column that is active during testing
R_e = effective test radius parameter; as defined by Bouwer and Rice (1976)
r_w = well radius
K = hydraulic conductivity of test interval
L = well-screen length.

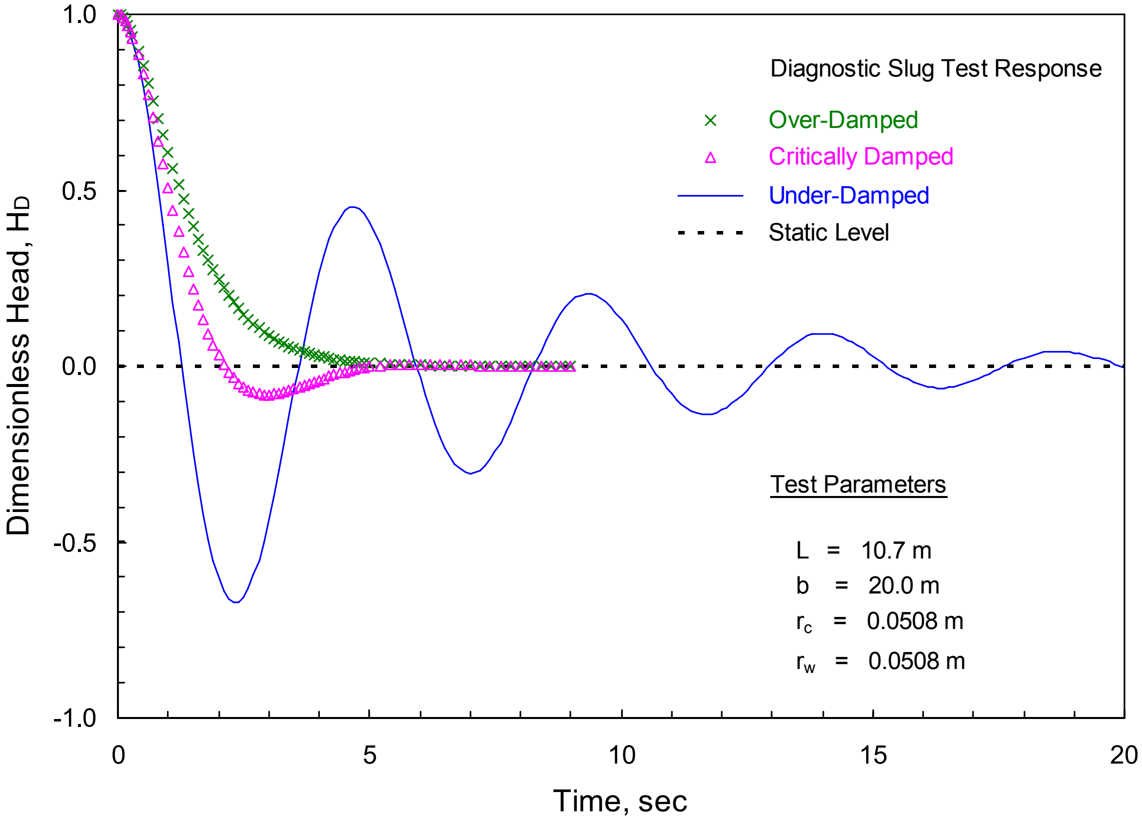


Figure 3.1. Diagnostic Slug Test Response (taken from Spane and Newcomer 2008)

Given the multitude of possible combinations of aquifer properties, well-casing dimensions, and test-interval lengths, no universal C_D value ranges can be provided that describe slug-test response conditions. However, for various combinations anticipated for testing at 300 Area VOC well sites during drilling, the following general guidelines on predicting slug-test responses are provided:

- C_D >3 = over-damped response
- C_D 1 - 3 = critically damped response
- C_D <1 = under-damped response.

An over-damped test response generally occurs within stress wells monitoring test formations of low to moderately high hydraulic conductivity (e.g., Ringold Formation) and are indicative of test conditions where frictional forces (i.e., resistance of groundwater flow from the test interval to the well) are predominant over test-system inertial forces. Figure 3.2 shows predicted slug-test recovery as a function of hydraulic conductivity (K range: 1.0 to 40 m/day; 1.0-m test interval) for test intervals exhibiting over-damped response characteristics and for general 300 Area VOC test well/interval conditions. The test predictions shown in the figure are based on responses occurring within a test system casing I.D. = 0.1016 m. As indicated in the figure, test intervals having hydraulic conductivity values of approximately 40 m/day or less should be readily resolved for tests exhibiting over-damped slug-test behavior. For over-damped slug tests, two different methods can be used for the slug-test analysis: the semi-empirical, straight-line analysis method described in Bouwer and Rice (1976) and Bouwer (1989) and the type-curve-matching method for unconfined aquifers presented in Butler (1998). For over-damped slug tests, hydraulic-conductivity estimates obtained with the Bouwer and Rice analytical method are generally less reliable than corresponding estimates obtained with the type-curve-matching method (Hyder and Butler 1995; Butler 1998). For this reason, only the type-curve-matching analytical method was used for estimating hydraulic conductivity for zones tested at the 300 Area VOC wells. A detailed description of over-damped, slug-test-analysis methods is presented in Spane and Newcomer (2004).

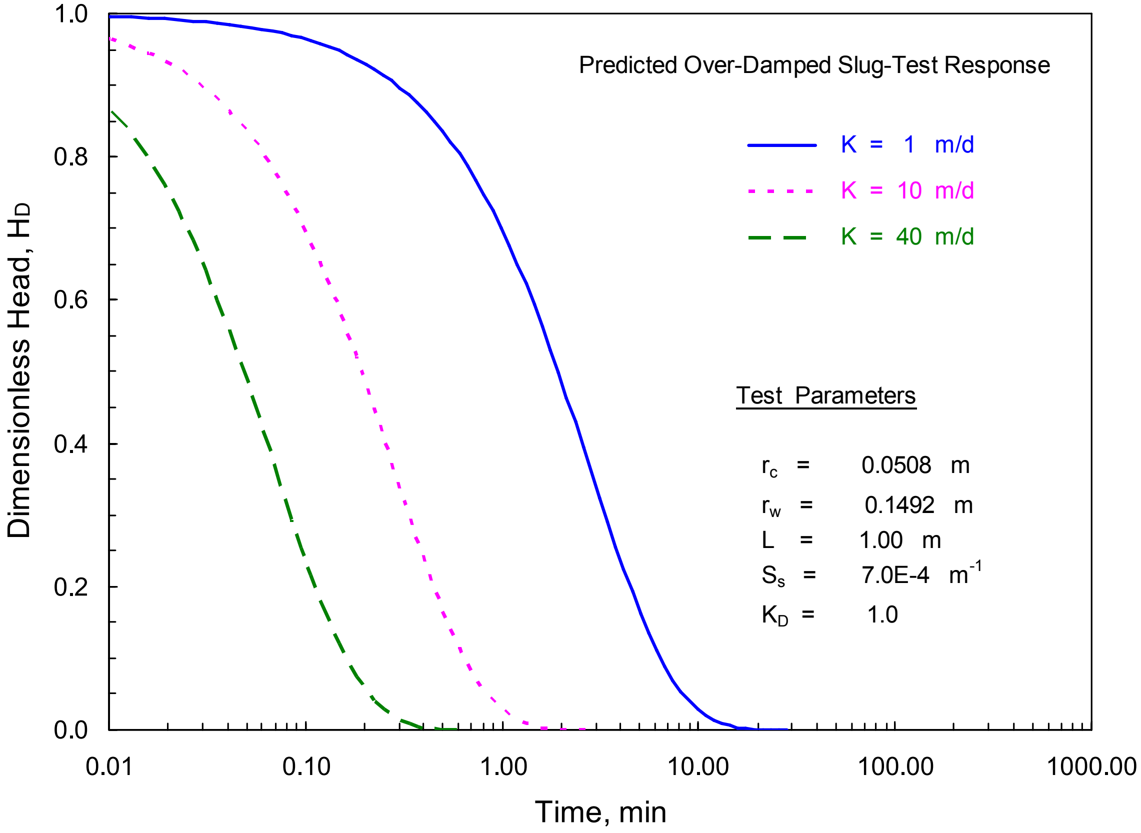


Figure 3.2. Over-Damped Slug-Test Response as a Function of Test-Interval Hydraulic Conductivity

The time-history matching method is used for lower permeability test intervals, where individual over-damped slug tests do not fully recover to pre-test conditions. This analysis method is based on the superposition principle that relies on super-imposing the predicted slug-test responses of subsequent tests that are conducted in a series. The predicted slug-test responses are calculated with the type-curve matching method described in Butler (1998), which are combined by super-imposing their individual responses for the respective times of test initiation to yield a predicted composite test response (i.e., time-history response). The analysis method is greatly facilitated by maintaining uniform slug-test recovery time periods and using equal slug-test volume displacements (e.g., alternating slug withdrawal and injection tests with a slugging rod, each phase for 30-minute periods). Strictly speaking, the super-position principle (and time-history matching) is only appropriate for linear-response aquifer systems (e.g., confined aquifers). However, Reilly et al. (1987) state that it is also appropriate for unconfined aquifers (non-linear response systems) if test stress levels are kept within 10% of the unconfined aquifer's thickness. This was the case for the time-history analysis of the testing sequence conducted for well 399-2-5, Zone 3.

Under-damped test-response patterns are exhibited within stress wells where inertial forces are predominant over formational frictional forces. This commonly occurs in wells with extremely long fluid columns (i.e., large water mass within the well column) and/or that penetrate highly permeable aquifers (e.g., Hanford formation). Tests exhibiting under-damped behavior should be conducted with very small stress-level applications. No 300 Area VOC well test intervals displayed formational test-response characteristics that were under damped.

As mentioned previously, critically damped test responses are indicated by stress well water-level responses that are transitional to the over- and under-damped test conditions, as shown in Figure 3.1. They typically occur in wells that monitor test formations exhibiting intermediate to high hydraulic conductivity. As noted in Butler (1998), distinguishing between slug-test responses that are over damped and critically damped may be difficult in some cases (i.e., due to test signal noise) when examined on arithmetic plots. Proper model identification may be enhanced when semi-log plots are used, i.e., log head versus time (e.g., Bouwer and Rice plot). Critically damped slug tests exhibit a diagnostic concave-downward pattern when plotted in this semi-log plot format. This is in contrast to over-damped response behavior, which displays either a linear or concave upward (elastic) pattern. Critically damped slug-test responses are influenced by processes (e.g., inertial) that are not accounted for in the previously discussed slug-test analytical methods (i.e., for over-damped tests). Because of this, slug tests exhibiting these response characteristics cannot be analyzed quantitatively with the Bouwer and Rice or standard type-curve methods. High-K analysis methods that can be employed for analyzing unconfined aquifer tests exhibiting response behavior that is either critically damped or under damped include those described in Springer and Gelhar (1991), Butler (1998), McElwee and Zenner (1998), McElwee (2001), Butler and Garnett (2000), and Zurbuchen et al. (2002). Because of the ease provided by a spreadsheet-based approach, the test-analysis method presented in Butler and Garnett (2000) is preferred for analyzing tests exhibiting critically damped behavior. A detailed discussion of this analytical procedure and method is presented in Spane and Newcomer (2004). No 300 Area VOC well test intervals displayed formational test-response characteristics that were critically damped.

4.0 Slug-Test Results

The following discussion presents pertinent information describing slug-testing activities and analysis results for the test/depth zones that were hydrologically characterized at the 300 Area VOC boreholes as they were advanced to their final drilling depths. Table 4.1 presents slug-test information for the respective test/depth intervals, while Table 4.2 summarizes the slug-test-analysis results. Selected borehole logs are presented in Appendix B, which can be referred to for a geologic description of the respective well test zone/depth intervals.

Table 4.1. Slug-Test Characteristics for Selected Test/Depth Intervals at 300 Area VOC Test Wells 399-2-5, 399-3-22, and 399-4-14

Test Well Number (Borehole ID)	**Test Zone**	**Test Parameters**				**Diagnostic Slug-Test Response Model**	**Hydrogeologic Unit Tested**[a]
		Test Date	**Number of Slug Tests**	**Depth to Water (m bgs)**	**Depth/Test Interval (m bgs)**		
399-2-5 (C5708)	Zone 1	9/7/07	4	9.72	10.1–10.9 (0.8)	Homogeneous Formation/ Exponential-Decay (over-damped)	Hanford formation (Unit 1)
	Zone 2	9/19/07	8	10.09	21.3–22.3 (1.0)	Heterogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 3	9/27/07	1	9.69	37.5–38.1 (0.6)	Homogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)
399-3-22 (C5706)	Zone 1	11/6/07	9	13.50	16.3–16.7 (0.4)	Homogeneous Formation/ Exponential-Decay (over-damped)	Hanford formation (Unit 1)
	Zone 2	11/8/07	3	13.55	23.6–24.3 (0.7)	Heterogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 3	11/15/07	0	13.93	39.0–41.0 (2.0)	NA	Ringold Formation (Unit 5)
	Zone 4[b]	12/3/07	6	13.29	38.2–41.1 (2.9)	Homogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)

Table 4.1. (Cont'd.)

Test Well Number (Borehole ID)	Test Zone	Test Parameters				Diagnostic Slug-Test Response Model	Hydrogeologic Unit Tested[(a)]
		Test Date	Number of Slug Tests	Depth to Water (m bgs)	Depth/Test Interval (m bgs)		
399-4-14 (C5707)	Zone 1	10/10/07	8	13.05	14.5–15.6 (1.1)	Homogeneous Formation/ Exponential-Decay (over-damped)	Hanford formation (Unit 1)
	Zone 2	10/15/07	0	13.03	24.5–25.4 (0.9)	NA	Ringold Formation (Unit 5)
	Zone 3	10/19/07	6	13.14	31.9–32.7 (0.8)	Homogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 4	10/23/07	6[(c)]	13.01	36.6–39.1 (2.5)	Homogeneous Formation/ Exponential-Decay (over-damped)	Ringold Formation (Unit 5)

NA = Not applicable.

Note: For all test wells, r_c ranged between 0.0508 and 0.0762 meter; r_w = 0.1492 meters. Hydrogeologic unit number in parentheses indicates the relevant groundwater-flow model layer, as described in Thorne et al. (1993).

(a) Assumed to be uniform within the well-screen test section.

(b) Final, completed well-screen section.

(c) No quantitative analysis was possible for one of the slug tests because the response of the exponential decay test was disturbed.

4.1 Well 399-2-5 (C5708)

The drilling of 300 Area VOC well 399-2-5 was initiated on September 4, 2007, and continued until reaching a final depth of 39.8 m bgs on September 28, 2007. The Lower Mud unit of the Ringold Formation was encountered at a depth of 38.1 m bgs, which represents the bottom boundary of the unconfined aquifer at this location. Three test-depth intervals were tested at the borehole location: Zone 1 = 10.1 to 10.9 m bgs; Zone 2 = 21.3 to 22.3 m bgs; and Zone 3 = 37.5 to 38.1 m bgs. Slug tests conducted within the final, completed well-screen section, with a test/depth interval of 9.9 to 12.5 m bgs, yielded test results similar to the Zone 1 test results (i.e., full recovery within ~3 seconds after test initiation). Because of these similar test results, the data analysis for tests conducted within the completed well-screen section was not included in this report. The slug-test field notes for this test/depth interval, however, are provided in Appendix A.

4.1.1 Zone 1 (Depth: 10.1 to 10.9 m)

After reaching a drill depth of 11.3 m bgs, the bottom 0.3 m of the borehole filled in with sediment slough. The well-screen assembly was lowered to the bottom of the borehole at a depth of 11.0 m bgs, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 0.9 m (i.e., from 11.0 to 10.1 m bgs), producing a test/depth interval for Zone 1 of 10.1 to 10.9 m bgs (bottom end-cap at 10.9 to 11.0 m bgs). The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a sandy gravel and gravel unit, composed of ~80% gravel, ~15% sand, and ~5% silt. At the time of testing, the well-screen test interval was located ~0.4 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Hanford formation (Unit 1).

Table 4.2. Slug Test Analysis Results for Wells 399-2-5, 399-3-22, and 399-4-14

Test Well Number (Borehole ID)	Test Zone	Type-Curve Analysis Method	
		Hydraulic Conductivity, $K_{h,}$[a] (m/day)	Specific Storage, S_s (m^{-1})
399-2-5 (C5708)	Zone 1	≥300	1.0E-5
	Zone 2 (outer zone formation)	1.17–1.73 (1.42)	1.0E-5
	Zone 2 (artificially-created inner zone)	6.05–9.50 (7.72)	1.0E-5
	Zone 3	≤0.01	1.0E-5
399-3-22 (C5706)	Zone 1	≥400	1.0E-5
	Zone 2 (outer zone formation)	0.32–0.61 (0.44)	1.0E-5
	Zone 2 (artificially-created inner zone)	1.56	1.0E-5
	Zone 3	NA	NA
	Zone 4[b]	1.04–1.51 (1.34)	1.0E-5
399-4-14 (C5707)	Zone 1	≥300	1.0E-5
	Zone 2	NA	NA
	Zone 3	2.20–2.85 (2.48)	7.0E-4–1.6E-3
	Zone 4	0.93–1.12 (1.04)	1.0E-4–2.0E-4

NA = Not applicable.
Note: Number in parentheses is the average value for all tests.
(a) Assumed to be uniform within the well-screen test section.
(b) Final, completed well-screen section.

A series of four slug withdrawal tests (one low-stress and three high-stress tests) were conducted between 0742 hours and 0810 hours (Pacific Standard Time [PST]), September 7, 2007. The slug tests were conducted with two different sized slugging rods that were partially submerged in the water column, one with a partially submerged volume of 0.0027 m^3 and a larger one with a partially submerged volume of 0.0059 m^3. These partially submerged slug-rod volumes imparted a theoretical applied stress level of 0.15 m for the low-stress test and 0.32 m for the high-stress tests within the 0.1524-m (6-in.) I.D. temporary screen. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~11-m bgs. The static depth-to-water for the test interval measured before testing was 9.72 m bgs.

All slug tests for Zone 1 exhibited full recovery within ~3 seconds after test initiation. A selected example of the pressure-test response for one of the slug-withdrawal tests is shown in Figure 4.1. Test responses of the formation dissipated within the initial seconds of the test because of very high-permeability test conditions within the Hanford formation. This rapid test response (i.e., 90% recovery within ~3 seconds) will be used for analyzing a minimum value for K.

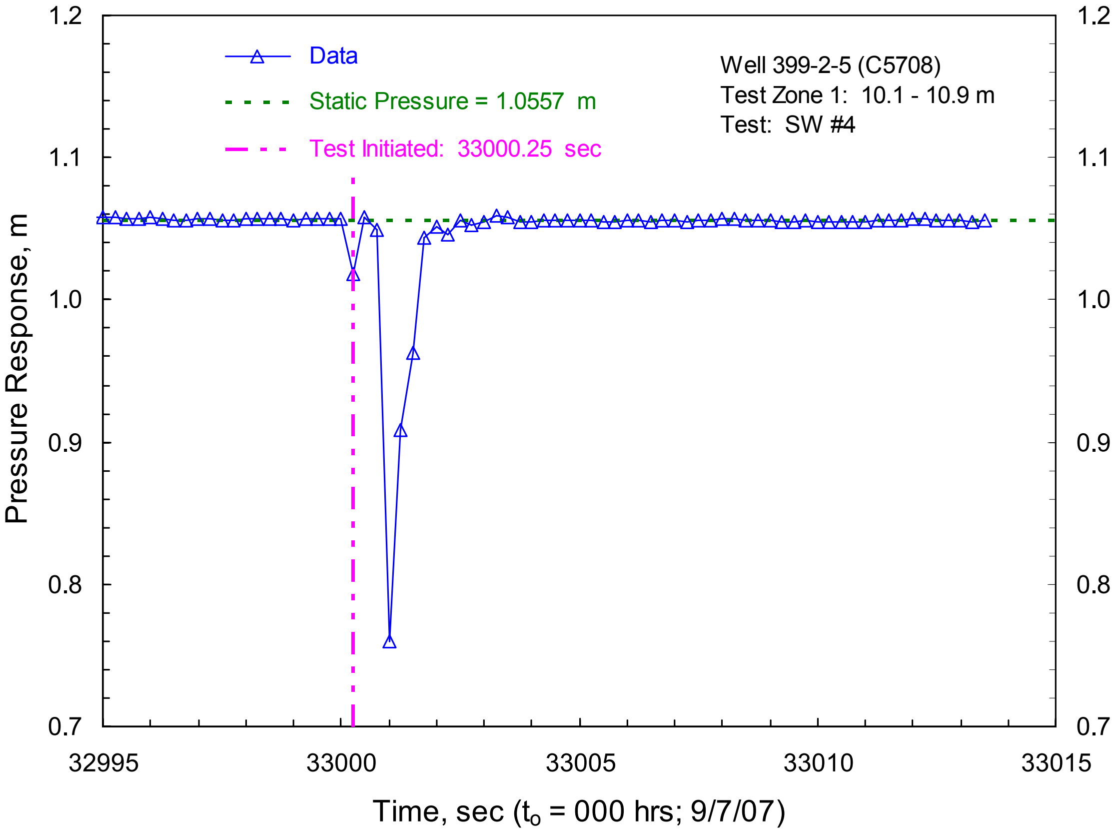


Figure 4.1. Example of Slug-Withdrawal Test Pressure Response for Zone 1, Well 399-2-5

To provide a bounding, greater-than K estimate for Zone 1 tests, a series of over-damped slug-test type curves were generated for various high K values with Zone 1 test parameters. Normalized plots of the type curves for K values ranging between 100 and 1000 m/day are shown in Figure 4.2. The plots in Figure 4.2 indicate a range of K ≥ 300 m/day (and assuming $S_s = 1.0E-05\ m^{-1}$) that correspond to rapid, formational test response recovery of 90% within ~3 seconds. This lower bounding limit value for K is the best estimate available for the Zone 1 test/depth interval.

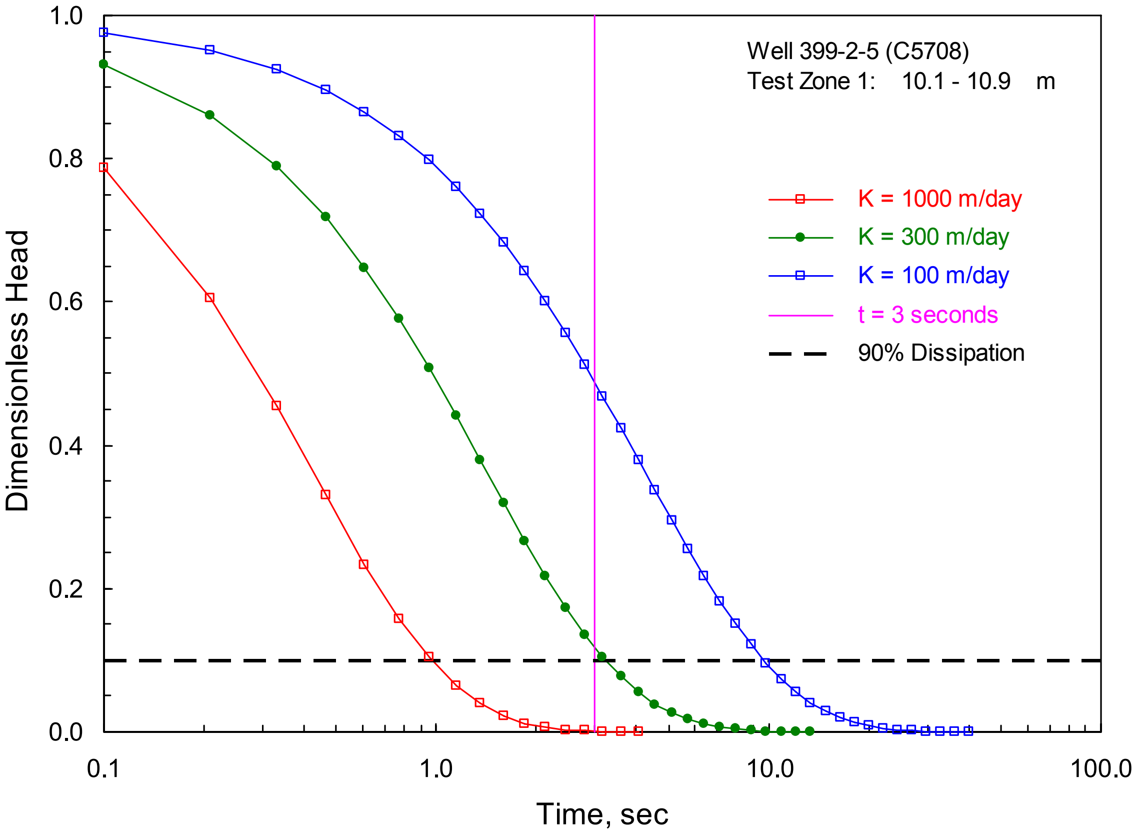


Figure 4.2. Over-Damped Slug-Test Type-Curve Plots for Various High K Values With Zone 1 Test Parameters, Well 399-2-5

4.1.2 Zone 2 (Depth: 21.3 to 22.3 m)

After reaching a drill depth of 22.9 m bgs, the bottom 0.5 m of the borehole filled in with sediment slough. The packer/well-screen assembly was lowered to the bottom of the borehole at a depth of 22.4 m bgs, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 1.1 m (i.e., from 22.4 to 21.3 m bgs), producing a test/depth interval for Zone 2 of 21.3 to 22.3 m bgs (bottom end-cap at 22.3 to 22.4 m bgs). The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a sandy gravel unit, composed of ~60% gravel and ~40% sand. At the time of testing, the well-screen test interval was located ~11.2 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5).

A series of four slug-injection tests and four slug-withdrawal tests (four low-stress and four high-stress tests) were conducted between 0931 hours and 1252 hours (PST), September 19, 2007. The slug tests were conducted with two different-sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.68 m for the low-stress tests and 1.36 m for the high-stress tests within the 0.1016-m (4-in.) I.D. temporary casing string. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~13-m bgs. The static depth-to-water for the test interval measured before testing was 10.09 m bgs.

A diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous formation response condition. This test pattern exhibits a high-permeability, inner-zone response during the initial fast-recovery portion of the test that slowly transitions to a lower permeability response for the surrounding outer-zone formation. The presence of an elastic, high-permeability inner-zone reflects an artificially induced condition that was likely attributed to collapse of unconsolidated formation sediments around the temporary well screen as the drill casing was retracted. An examination of the drilling log geologic description indicates sand heaving within this test interval during drilling.

As discussed in Spane (1993), slug tests exhibiting linear response characteristics for heterogeneous formation tests can be analyzed using the homogeneous formation analysis approaches described in Section 3.0. A comparison of the normalized, higher and lower stress, slug-test responses indicated identical behavior. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 1.17 and 1.73 m/day (average of 1.42 m/day) for the outer-zone formation and ranged between 6.05 and 9.50 m/day (average of 7.72 m/day) for the artificially created, higher permeability, inner-zone. Selected examples of the diagnostic and test-analysis plots for this test/depth interval are shown in Figure 4.3 and Figure 4.4(a, b), respectively.

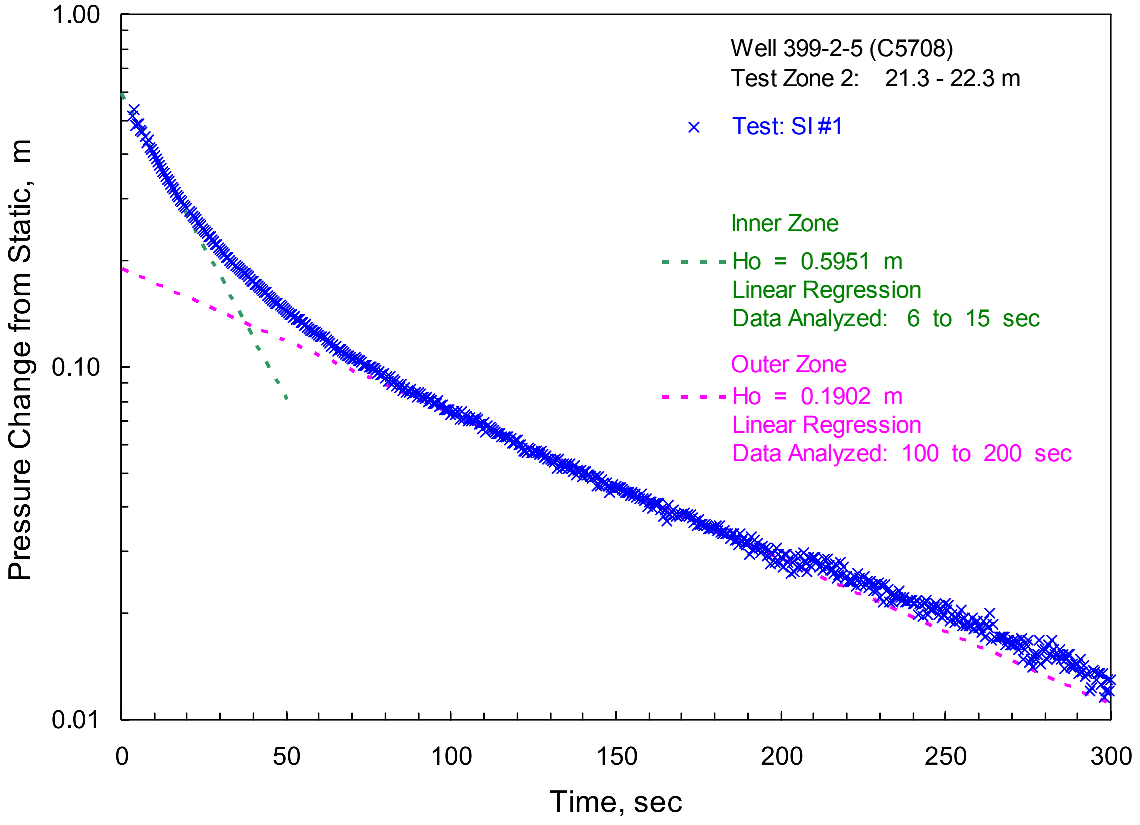


Figure 4.3. Selected Diagnostic Plot for Zone 2, Well 399-2-5

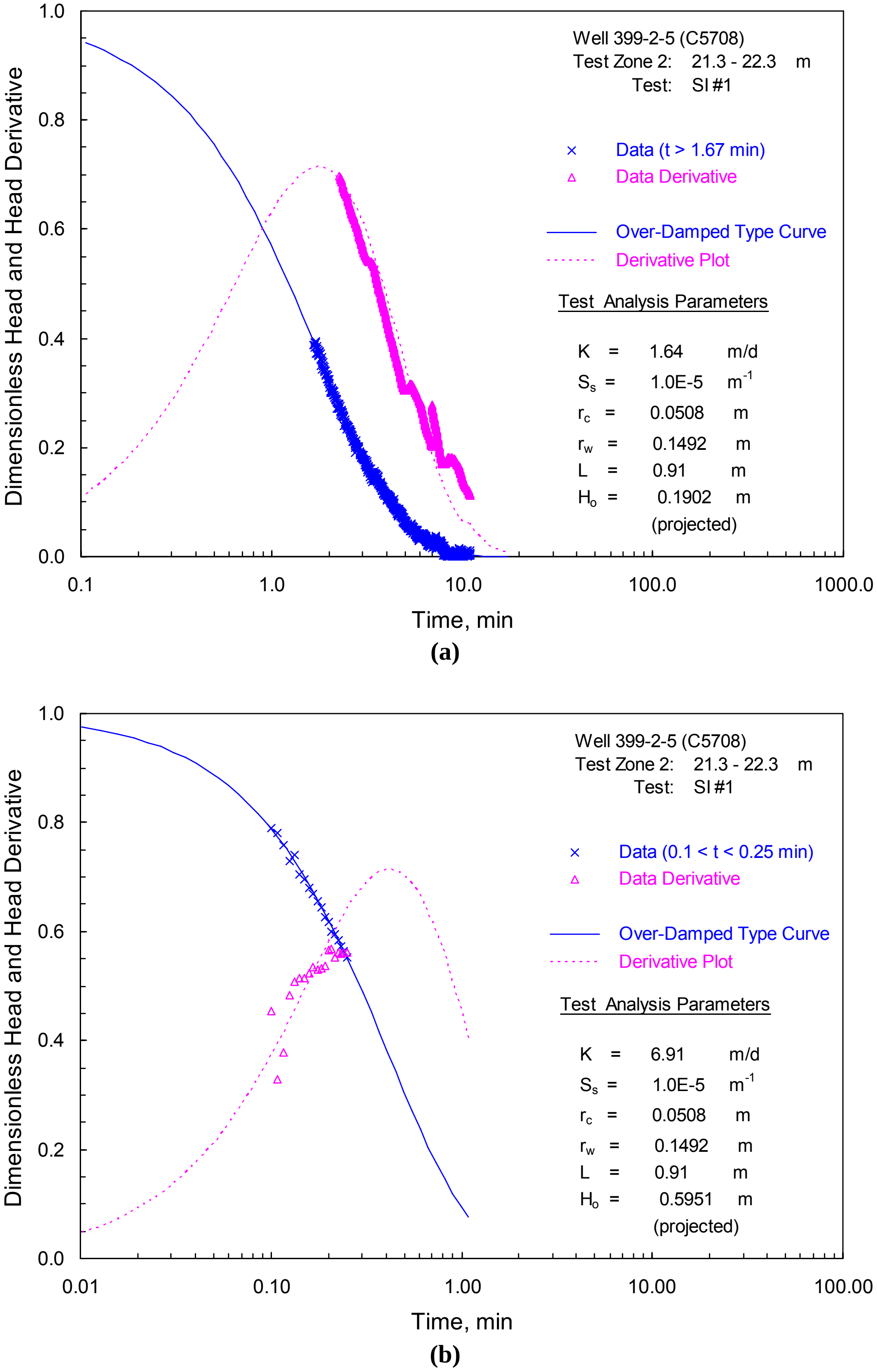


Figure 4.4. Selected Type-Curve Analysis Plots, Zone 2, Well 399-2-5, for (a) the Artificially Created, High-Permeability Inner-Zone and (b) the Lower Permeability Outer-Zone Formation

4.1.3 Zone 3 (Depth: 37.5 to 38.1 m)

After driving the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing to a depth of 37.5 m bgs and then drilling the open hole to a depth of 38.7 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole, exposing the temporary screen to the formation at a depth interval of 37.5 to 38.6 m bgs (bottom end-cap at 38.6 to 38.7 m bgs). The depth/test interval for Zone 3 was drilled ahead of the drill casing because, unlike the test/depth intervals for Zones 1 and 2 for this borehole, the formation sediments were consolidated, and the borehole remained open during drilling. While pumping during groundwater sampling before conducting the slug tests, the bottom 0.5 m of the well-screen section filled in with sediment slough (i.e., fine-grained sediments), effectively reducing the test/depth interval for Zone 3 to 37.5 to 38.1 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a silty sandy gravel unit, composed of 50 to 75% gravel, 25 to 50% sand, and <10% silt. At the time of testing, the well-screen test interval was located ~27.8 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5) just above the Ringold Lower Mud unit.

A series of three slug withdrawal and injection tests were conducted between 0843 hours and 0943 hours (PST), September 28, 2007. The tests were initiated by rapidly withdrawing a 0.0055-m^3 volume slugging rod (slug withdrawal test) from the fluid column within the 0.102-m (4-in.) I.D. testing-string casing used to set the packer/well screen assembly. After 30 minutes of recovery, the slugging rod was rapidly immersed into the fluid column initiating a slug-injection test. After another 30 minutes of recovery (from the slug-injection test), a third slug test (slug withdrawal test) was initiated by rapidly withdrawing the slugging rod from the fluid column. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~12 m bgs. The depth-to-water for the test interval measured before testing was 9.69 m bgs. This depth-to-water level is not representative of “static” conditions since a declining water-level trend of -0.0008104 m/min was observed for an extended period before and during slug testing.

The three slug tests indicated a recovery response behavior that was extremely slow and over-damped. Since the recovery times for the slug tests were slow, with <10% recovery of the applied stress, a test history match approach was used for analyzing the slug withdrawal and injection phases of the tests. Since a declining water-level trend (i.e., -0.0008104 m/min) was observed during the test phases, the predicted test responses were super-imposed on this trend to match the observed test responses.

Figure 4.5 shows the observed responses for each of the three slug-test phases and the predicted time history match for the testing sequence. As noted previously, a declining water-level trend of -0.0008104 m/min was observed over the test period. As indicated in Figure 4.5, a hydraulic conductivity K estimate of 0.01 m/day provides a good match to the observed test-response sequence.

To demonstrate the sensitivity of the analytical solution, Figure 4.6 shows the predicted test history match with K values of 0.01, 0.02, 0.05, and 0.1 m/day. As indicated, test-history matches depart significantly from the observed test responses with K values higher than 0.01 m/day. This suggests a K value of ≤0.01 m/day for the depth interval tested. Since slough filled in the lower 0.5 m of the well-screen section before slug testing, there is some uncertainty whether the relatively low hydraulic conductivity indicated for Zone 3 is representative of *in situ* formation conditions or is an artifact of borehole instability around the well screen. Pumping for groundwater samples from the test interval before slug testing may have contributed to this instability. However, the low-permeability condition is corroborated by the proximity of the test interval to the underlying Lower Mud unit of the Ringold Formation and by the observed slow static water-level recovery trend before and during the slug tests.

4.2 Well 399-3-22 (C5706)

The drilling of 300 Area VOC well 399-3-22 was initiated on October 31, 2007, and continued until reaching a final depth of 42.8 m bgs on November 13, 2007. The Lower Mud unit of the Ringold Formation was encountered at a depth of 41.1 m bgs, which represents the bottom boundary of the unconfined aquifer at this location. Three test-depth intervals were successfully tested at the borehole location: Zone 1 = 16.3 to 16.7 m bgs; Zone 2 = 23.6 to 24.3 m bgs; and Zone 4 = 38.2 to 41.1 m bgs. Zone 4 represents the final well-screen completion. One projected test-depth interval during drill advancement, Zone 3 = 39.0 to 41.0 m bgs, was not tested.

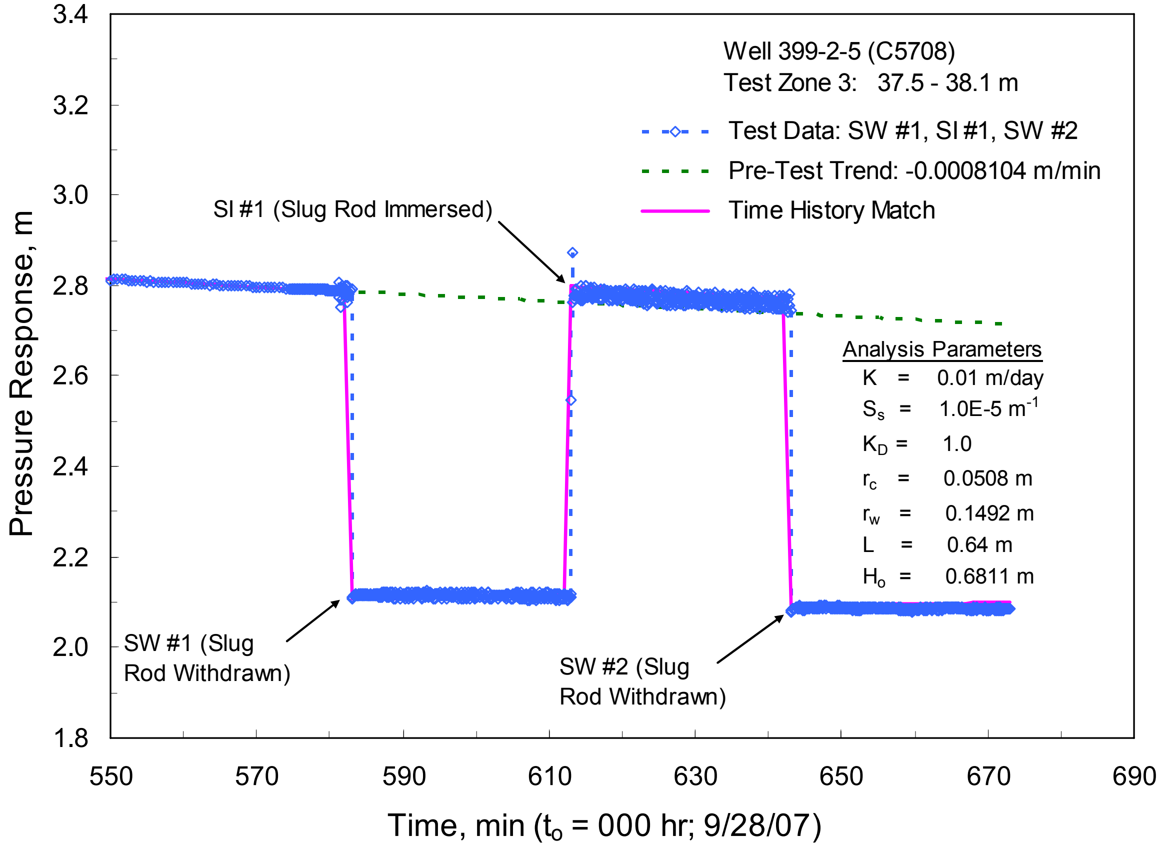


Figure 4.5. Slug Test Pressure Response and Time History Match for Zone 3, Well 399-2-5

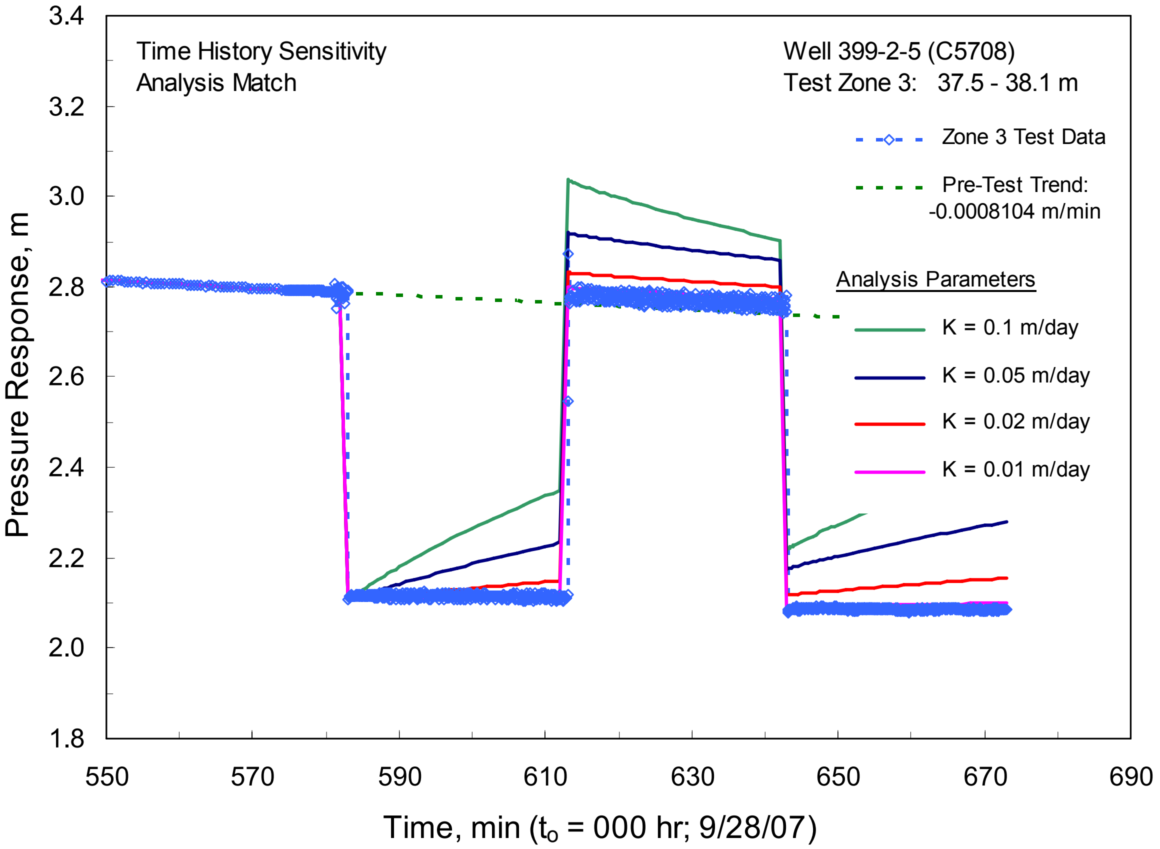


Figure 4.6. Slug Test Pressure Response for Zone 3, Well 399-2-5 and Time History Sensitivity Analysis Match for Varying K Values

4.2.1 Zone 1 (Depth: 16.3 to 16.7 m)

After reaching a drill depth of 16.8 m bgs, the well-screen assembly was lowered to the bottom of the borehole, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 0.5 m, producing a test/depth interval for Zone 1 of 16.3 to 16.7 m bgs (bottom end-cap at 16.7 to 16.8 m bgs). The borehole geology log (Appendix B; Figure B.2) indicates that the test-interval section generally consists of a sandy gravel unit, composed of >60% gravel, <40% sand, and <1% silt. At the time of testing, the well-screen test interval was located ~2.8 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Hanford formation (Unit 1).

A series of five slug-injection tests and four slug-withdrawal tests (five low-stress and four high-stress tests) were conducted between 0632 hours and 0743 hours (PST), November 6, 2007. The slug tests were conducted with two different-sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.30 m for the low-stress tests and 0.61 m for the high-stress tests within the 0.1524-m (6-in.) I.D. temporary well-screen. For the two high-stress slug-withdrawal tests, the pressure transducer cable was attached to the slugging rod to prevent the rod and transducer probe from becoming lodged inside the 0.1016-m (4-in.) I.D. casing above the screen during slug withdrawal. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16-m bgs for the first test and ~14-m bgs for the remaining slug tests. The static depth-to-water for the test interval measured before testing was 13.50 m bgs.

All slug tests for Zone 1 exhibited oscillations attributed to a test-configuration-induced condition. The oscillatory test pattern is believed to be primarily due to pressure imbalances between the water column inside the temporary well-screen and the water column in the annular space between the well-screen and drill casing. A selected example of these test-induced oscillations is shown in Figure 4.7. The oscillations in Figure 4.7 indicate a pressure change, ~0.04 m, immediately after test initiation that is significantly less than the theoretical H_o value of 0.30 m for this low-stress test (than would occur only within the well screen). This is an indication that the oscillations reflect the test configuration (i.e., pressure imbalance) and not an under-damped, oscillatory test response. The actual applied stress, H_o, to the formation is uncertain due to the time it takes (i.e., 1 to 2 seconds) to completely remove the slug rod and recover the associated rapid test response. Due to very high-permeability test conditions within the Hanford formation, formational test responses dissipated within the initial seconds (i.e., 90% recovery within ~3 seconds) of the test and are not discernable in the test-configuration-induced oscillatory pattern.

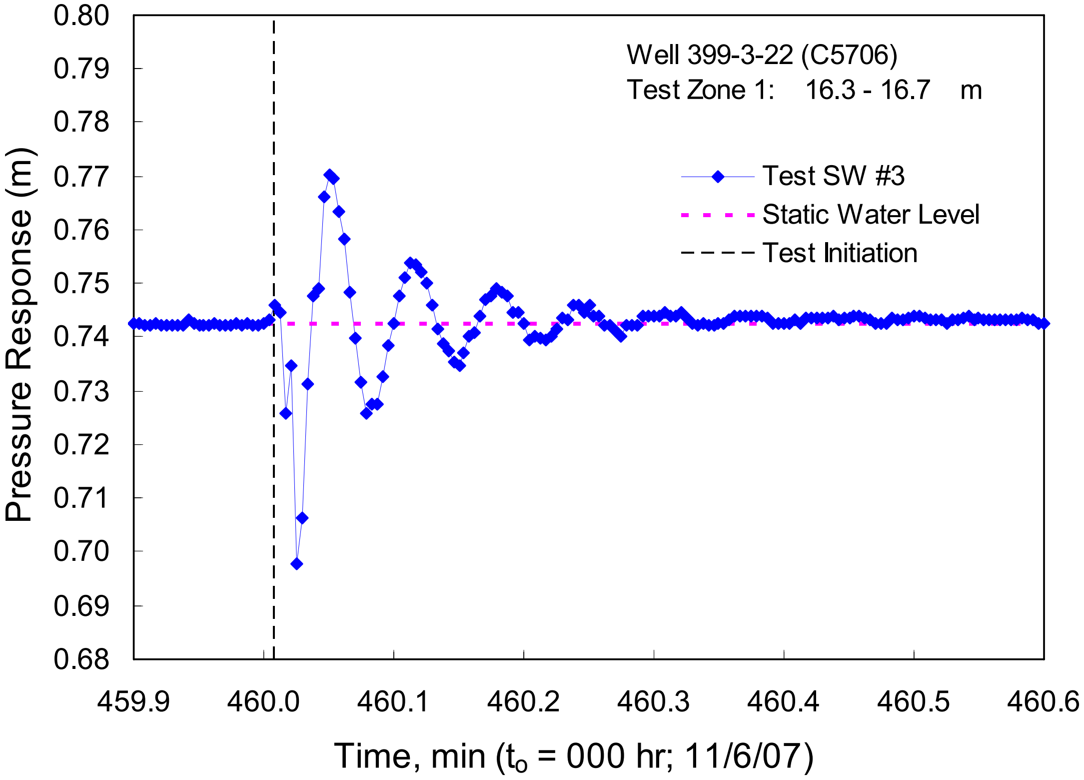


Figure 4.7. Example of Test-Configuration Induced Oscillatory Response for Zone 1, Well 399-3-22

To provide a bounding, greater-than K estimate for the Zone 1 tests, a series of over-damped slug-test type curves were generated for various high K values, using Zone 1 test parameters. Normalized plots of the type curves for K values ranging between 100 and 1000 m/day are shown in Figure 4.8. The plots in Figure 4.8 indicate a range of $K \geq 400$ m/day (and assuming $S_s = 1.0E\text{-}05\ m^{-1}$) that correspond to rapid, formational test-response recovery of 90% within ~3 seconds. This lower bounding limit value range for K is the best available estimate for the Zone 1 test/depth interval.

4.2.2 Zone 2 (Depth: 23.6 to 24.3 m)

After reaching a drill depth of 26.2 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 2.6 m, exposing the temporary screen to the formation at a depth interval of 23.6 to 26.1 m bgs (bottom end-cap at 26.1 to 26.2 m bgs). While pumping during groundwater sampling before conducting the slug tests, the bottom 1.8 m of the well-screen section filled in with sediment slough (i.e., fine-grained sediments), effectively reducing the test/depth interval for Zone 2 to 23.6 to 24.3 m bgs. A depth-to-bottom measurement after the second slug test indicated that this test/depth interval remained open during three of the four slug tests performed at this zone. The borehole geology log (Appendix B; Figure B.2) indicates that the test-interval section generally consists of a silty sand unit, composed of ~90% sand and ~10% silt. At the time of testing, the well-screen test interval was located ~10.1 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5).

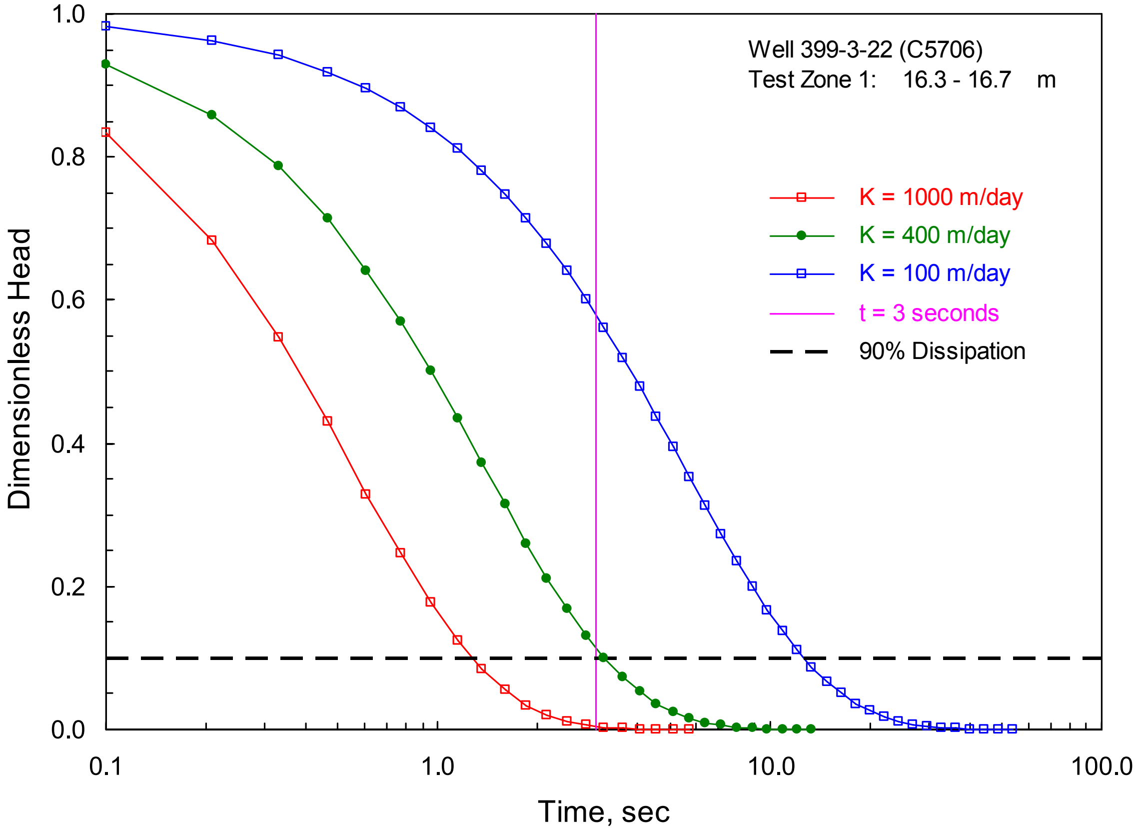


Figure 4.8. Over-Damped Slug-Test Type-Curve Plots for Various High K Values With Zone 1 Test Parameters, Well 399-3-22

A series of three slug tests (two low-stress and one high-stress test) were conducted between 1259 hours and 1439 hours (PST), November 8, 2007. A fourth slug test was conducted at 0637 hours, November 9, 2007, but was abandoned early in the test because of additional slough filling in the temporary test/screen interval. It is likely that deflating and re-inflating the packer contributed to the additional slough. The slug tests were conducted with two different sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.68 m for the low-stress tests and 1.36 m for the high-stress tests within the 0.1016-m (4-in.) I.D. temporary casing string. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16.6 m bgs for the first three tests. The static depth-to-water for the test interval measured before testing was 13.55 m bgs.

A diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous formation response condition. This test pattern exhibits a high-permeability, inner-zone response during the initial fast-recovery portion of the test that slowly transitions to a lower permeability response for the surrounding outer-zone formation. The presence of an elastic, high-permeability inner-zone reflects an artificially induced condition that was likely attributed to the collapse of unconsolidated formation sediments around the temporary well screen as the drill casing was retracted. An examination of the drilling log geologic description indicates sand heaving within this test interval during drilling.

As discussed in Spane (1993), slug tests exhibiting linear response characteristics for heterogeneous formation tests can be analyzed with the homogeneous formation analysis approaches described in Section 3.0. A comparison of the normalized, higher and lower stress, slug-test responses indicated stress dependence, with higher stress tests exhibiting a delayed test recovery. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 0.32 and 0.61 m/day (average of 0.44 m/day) for the outer-zone formation, and the estimate was 1.56 m/day for the artificially created, higher permeability, inner zone. Selected examples of the diagnostic and test-analysis plots for this test/depth interval are shown in Figure 4.9 and Figure 4.10(a, b), respectively.

4.2.3 Zone 3 (Depth: 39.0 to 41.1 m)

After reaching a drill depth of 41.1 m bgs and driving the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing to a depth of 39.0 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole, producing a test/depth interval for Zone 3 of 39.0 to 41.0 m bgs (bottom end-cap at 41.0 to 41.1 m bgs). The depth/test interval for Zone 3 was drilled ahead of the drill casing because, unlike the test/depth intervals for Zones 1 and 2 for this borehole, the formation sediments were consolidated, and the borehole remained open during drilling. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of silty sandy gravel, composed of 60 to 70% gravel, 15 to 30% sand, and 10 to 15% silt. The well-screen test interval was located ~25.1 m below the unconfined aquifer water-table surface, and the test/depth interval reflects sediments of the Ringold Formation (Unit 5) that were resting on the Ringold Lower Mud unit encountered at a depth of 41.1 m bgs.

While pumping during groundwater sampling (before conducting the projected slug tests on November 15, 2007), the entire well-screen test/depth interval filled in with fine-grained sediment. Slug tests were not performed at this test/depth interval for Zone 3 because the final, completed well-screen section was to be constructed over the bottom 2.9 m of the Ringold Formation (Unit 5). However, slug-test results for characterizing hydraulic properties are available for the final, completed well-screen section, which has a 0.9-m longer test/depth interval of 38.2 to 41.1 m bgs (see Section 4.2.4 below for Zone 4).

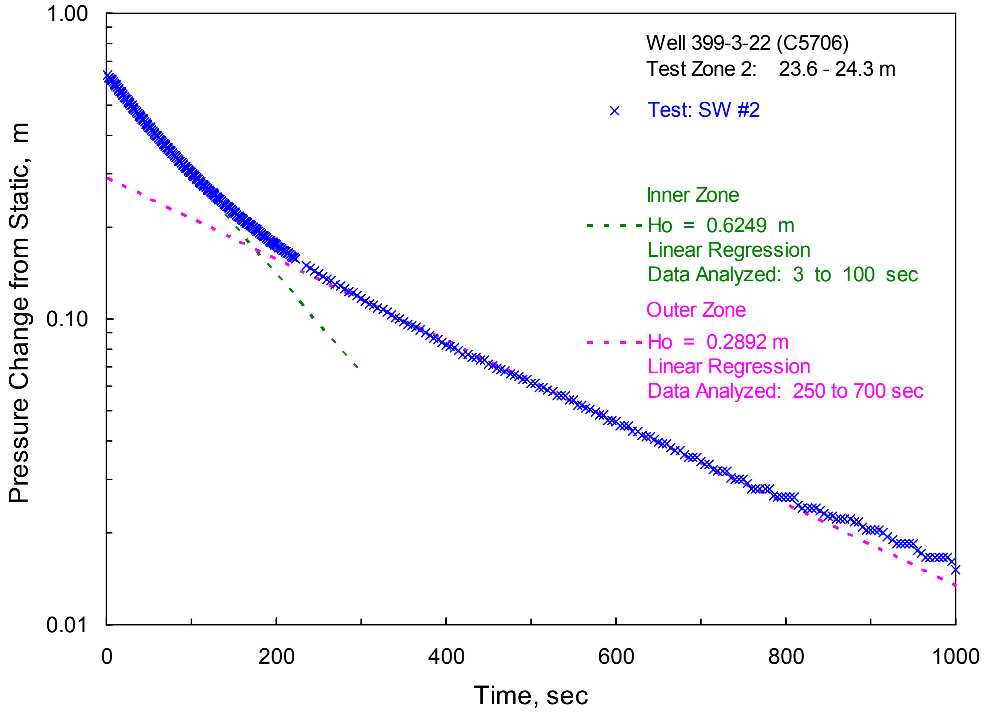
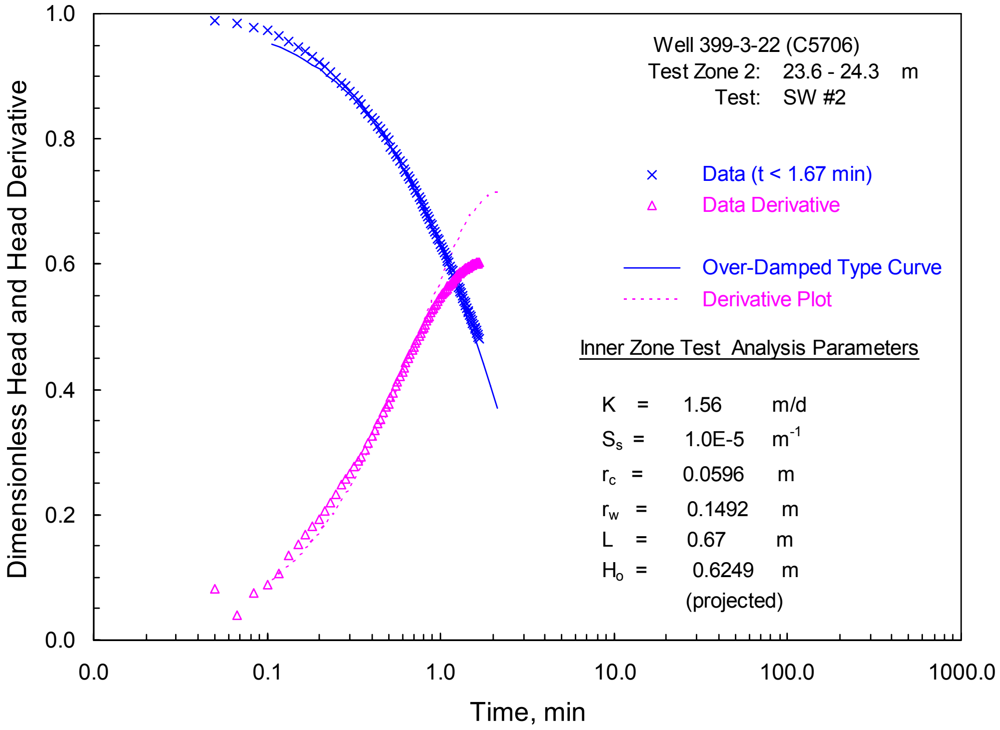
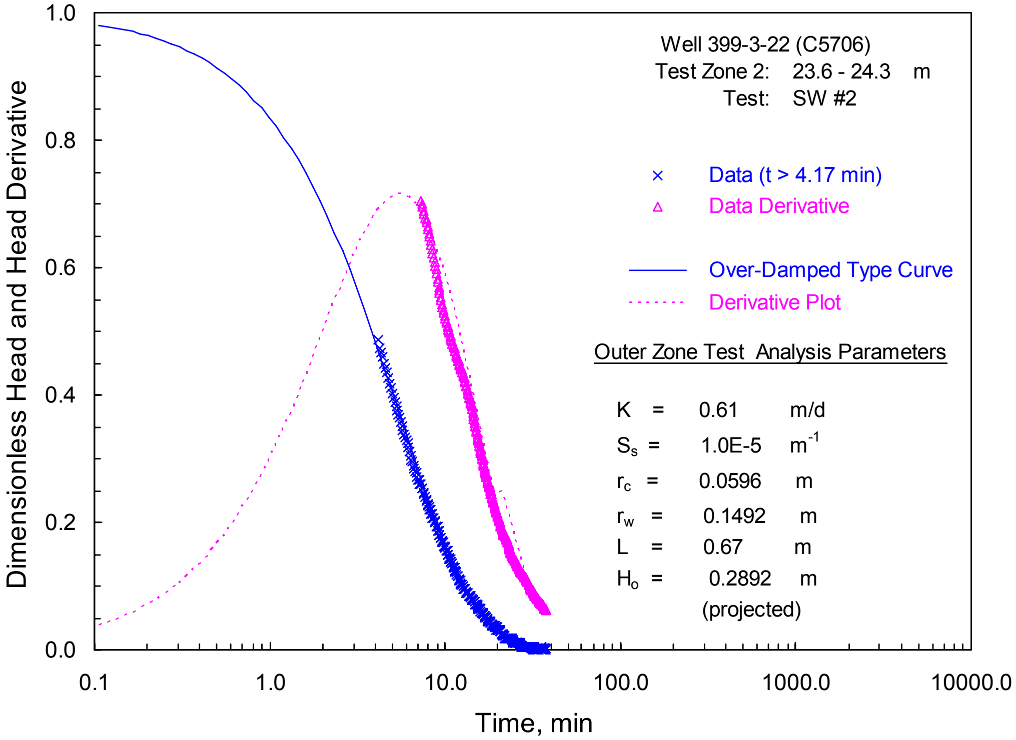


Figure 4.9. Selected Diagnostic Plot for Zone 2, Well 399-3-22



(a)

Figure 4.10. Selected Type-Curve Analysis Plots, Zone 2, Well 399-3-22, for (a) the Artificially Created, High-Permeability Inner-Zone and (b) the Lower Permeability Outer-Zone Formation



(b)

Figure 4.10. (contd)

4.2.4 Zone 4 (Final Well-Screen Section, Depth: 38.2 to 41.1 m)

A test/depth interval for Zone 4 of 38.2 to 41.1 m bgs represents the final well-screen section following well completion. The borehole geology log (Appendix B; Figure B.2) indicates that the final well-screen test-interval section generally consists of a silty sandy gravel unit, composed of 60 to 75% gravel, 15 to 30% sand, and 10 to 15% silt. At the time of testing, the well-screen test interval was located ~24.9 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5) just above the Ringold Lower Mud unit.

A series of three slug-injection tests and three slug-withdrawal tests (four low-stress and two high-stress tests) were conducted between 1355 hours and 1512 hours (PST), December 3, 2007. The slug tests were conducted with two different-sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.30 m for the low-stress tests and 0.61 m for the high-stress tests within the 0.1524-m (6-in.) I.D. well casing. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16 m bgs. The static depth-to-water for the test interval measured before testing was 13.29 m bgs.

All slug tests exhibited over-damped (exponential-decay response) homogeneous formation behavior, which is indicative of low to moderate permeability test zone conditions. A comparison of the normalized, higher and lower stress, slug-test responses indicated slight stress dependence, with higher stress tests exhibiting a slightly delayed test recovery. Slug tests exhibiting this type of response behavior can be analyzed quantitatively with homogeneous formation analysis approaches, as described in Butler

(1998). For the homogeneous formation analysis, the standard type-curve method provided estimates of K ranging between 1.04 to 1.51 m/day, averaging 1.34 m/day, and S_s of 1.0E-5 m^{-1}. A selected example of the test-analysis plots for this test/depth interval is shown in Figure 4.11.

4.3 Well 399-4-14 (C5707)

The drilling of 300 Area VOC well 399-4-14 was initiated on October 8, 2007, and continued until reaching a final depth of 41.5 m bgs on October 24, 2007. The Lower Mud unit of the Ringold Formation was encountered at a depth of 39.5 m bgs, which represents the bottom boundary of the unconfined aquifer at this location. Three test-depth intervals were tested successfully at the borehole location: Zone 1 = 14.5 to 15.6 m bgs; Zone 3 = 31.9 to 32.7 m bgs; and Zone 4 = 36.6 to 39.1 m bgs. One projected test-depth interval, Zone 2 = 24.5 to 25.4 m bgs, was not tested. Slug tests conducted within the final, completed well-screen section, with a test/depth interval of 13.0 to 17.7 m bgs, yielded test results similar to the Zone 1 test results (i.e., full recovery within ~3 seconds after test initiation). Because of these similar test results, the data analysis for tests conducted within the completed well-screen section was not included in this report. The slug-test field notes for this test/depth interval, however, are provided in Appendix A.

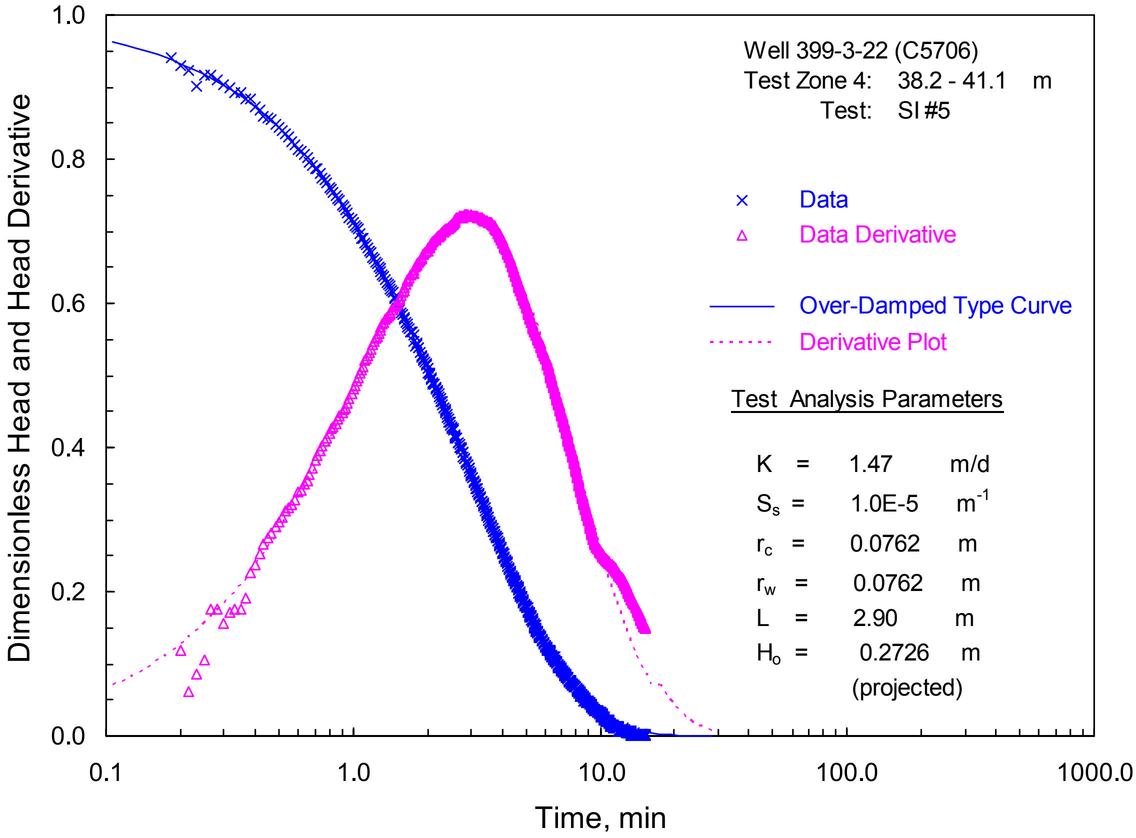


Figure 4.11. Selected Type-Curve Analysis Plot for Zone 4, Well 399-3-22

4.3.1 Zone 1 (Depth: 14.5 to 15.6 m)

After reaching a drill depth of 16.2 m bgs, the bottom 0.4 m of the borehole filled in with sediment slough. The well-screen assembly was lowered to the bottom of the borehole at a depth of 15.8 m bgs, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 1.7 m (i.e., from 16.2 to 14.5 m bgs). Following groundwater sampling from this well screen, the well-screen assembly was inadvertently raised 0.1 m during sample pump removal, producing a test/depth interval for Zone 1 of 14.5 to 15.6 m bgs (bottom end-cap at 15.6 to 15.7 m bgs). The borehole geology log (Appendix B; Figure B.1) indicates no sediment sample recovery from a depth of 13.1 to 17.4 m bgs after cleaning out the borehole. A split-spoon sample collected from a depth (i.e., 13.1 to 14.0 m bgs) above the test-interval section indicates a unit composed of gravels with a sand matrix. At the time of testing, the well-screen test interval was located ~1.5 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Hanford formation (Unit 1).

A series of four slug-injection tests and four slug-withdrawal tests (four low-stress and four high-stress tests) were conducted between 0933 hours and 1019 hours (PST), October 10, 2007. The slug tests were conducted with two different sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.30 m for the low-stress tests and 0.61 m for the high-stress tests within the 0.1524-m (6-in.) I.D. temporary screen. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16-m bgs for the first slug test and at a depth of ~14 m bgs for the remaining slug tests. The static depth-to-water for the test interval measured before testing was 13.05 m bgs.

All slug tests for Zone 1 exhibited oscillations attributed to a test-configuration-induced condition. The oscillatory test pattern is believed primarily attributable to pressure imbalances between the water column inside the temporary well-screen and the water column in the annular space between the well-screen and drill casing. A selected example of these test-induced oscillations is shown in Figure 4.12. The oscillations in Figure 4.12 indicate a pressure change, ~0.02 m, immediately after test initiation that is significantly less than the theoretical H_o value of 0.30 m for this low-stress test (than would occur only within the well screen). This is an indication that the oscillations reflect the test configuration (i.e., pressure imbalance) and not an under-damped, oscillatory test response. The actual applied stress, H_o, to the formation is uncertain due to the time required (i.e., 1 to 2 seconds) for complete slug-rod removal and the associated rapid-test-response recovery. Due to very high-permeability test conditions within the Hanford formation, formational test responses dissipated within the initial seconds (i.e., 90% recovery within ~3 seconds) of the test and are not discernable in the oscillatory pattern.

To provide a bounding, greater-than-K estimate for the Zone 1 tests, a series of over-damped slug-test type curves were generated for various high K values, using Zone 1 test parameters. Normalized plots of the type curves for K values ranging between 100 and 1000 m/day are shown in Figure 4.13. The plots in Figure 4.13 indicate a range of $K \geq 300$ m/day (and assuming $S_s = 1.0E\text{-}05\ m^{-1}$) that correspond to rapid, formational test response recovery of 90% within ~3 seconds. This value range for the lower bounding limit for K is the best available estimate for the Zone 1 test/depth interval.

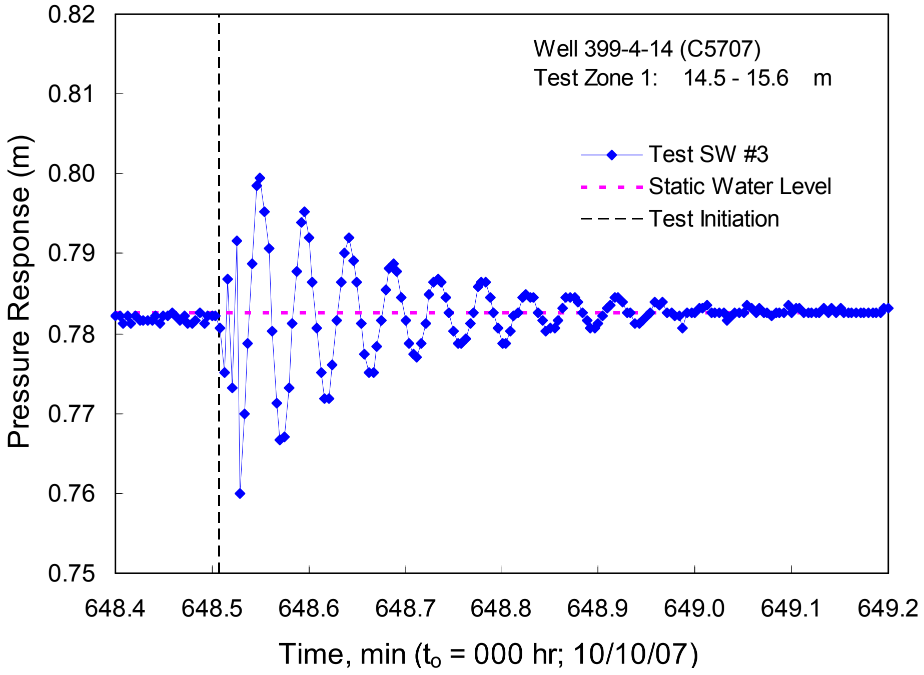


Figure 4.12. Example of Test-Configuration Induced Oscillatory Response for Zone 1, Well 399-4-14

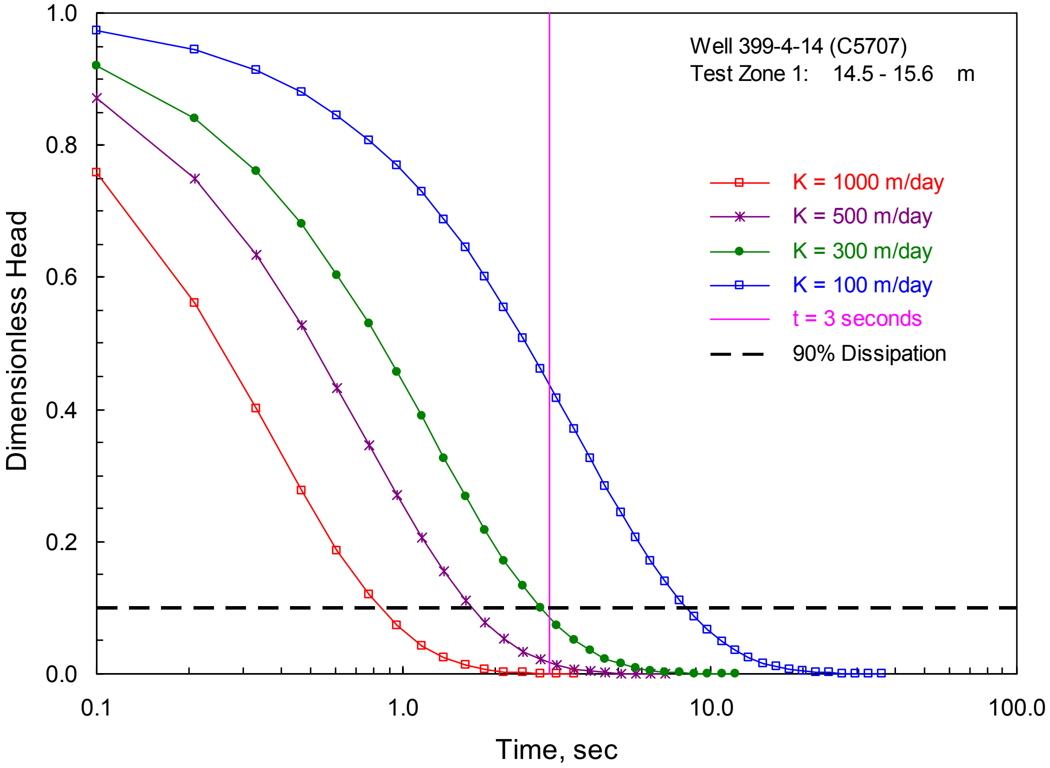


Figure 4.13. Over-Damped Slug-Test Type-Curve Plots for Various High K Values With Zone 1 Test Parameters, Well 399-4-14

4.3.2 Zone 2 (Depth: 24.5 to 25.4 m)

After reaching a drill depth of 26.2 m bgs, the packer/well-screen assembly was lowered to a depth of 25.5 m bgs, and the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing was retracted 0.8 m (i.e., from 25.3 to 24.5 m bgs), producing a test/depth interval for Zone 2 of 24.5 to 25.4 m bgs (bottom end-cap at 25.4 to 25.5 m bgs). The bottom of the open borehole between 25.5 and 26.2 m bgs collapsed after reaching the drill depth. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of sand, composed of >90% sand and <10% silt. The well-screen test interval was located ~11.5 m below the unconfined aquifer water-table surface, and the test/depth interval reflects sediments of the Ringold Formation (Unit 5).

While pumping during groundwater sampling (before conducting the projected slug tests on October 15, 2007), the entire well-screen section filled in with slough (sand) to a depth of 22.4 m bgs just above the top of the screen. Since “heaving” sand was an observed condition at this test/depth interval during drilling and borehole cleanout, slug tests were not performed and no slug-test results are available for characterizing hydraulic properties for Zone 2.

4.3.3 Zone 3 (Depth: 31.9 to 32.7 m)

After driving the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing to a depth of 31.9 m bgs and then reaching a drill depth of 35.1 m bgs, the bottom 1.1 m of the borehole filled in with sediment slough. The packer/well-screen assembly was lowered to the bottom of the borehole at a depth of 34.0 m bgs, exposing the temporary screen to the formation at a depth interval of 31.9 to 33.9 m bgs (bottom end-cap at 33.9 to 34.0 m bgs). While pumping during groundwater sampling before conducting the slug tests, the bottom 1.2 m of the well-screen section filled in with sediment slough (i.e., fine-grained sediments), effectively reducing the test/depth interval for Zone 3 to 31.9 to 32.7 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a silty sandy gravel unit, composed of 50 to 75% gravel, 30 to 40% sand, and 15 to 20% silt. At the time of testing, the well-screen test interval was located ~18.7 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5).

A series of three slug-injection tests and three slug-withdrawal tests (four low-stress and two high-stress tests) were conducted between 1322 hours and 1511 hours (PST), October 19, 2007. The slug tests were conducted with two different-sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.68 m for the low-stress tests and 1.36 m for the high-stress tests within the 0.1016-m (4-in.) I.D. temporary casing string. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16-m bgs. The static depth-to-water for the test interval measured before testing was 13.14 m bgs.

All slug tests exhibited over-damped (exponential-decay response) homogeneous formation behavior, which is indicative of low-to-moderate permeability test-zone conditions. A comparison of the normalized, higher and lower stress, slug-test responses indicated nearly identical behavior. Slug tests exhibiting this type of response behavior can be analyzed quantitatively with homogeneous formation analysis approaches, as described in Butler (1998). For the homogeneous formation analysis, the standard type-curve method provided estimates of K ranging between 2.20 to 2.85 m/day, averaging 2.48 m/day, and S_s ranging between 7.0E-4 and 1.6E-3 m^{-1}. A selected example of the test-analysis plots for this test/depth interval is shown in Figure 4.14.

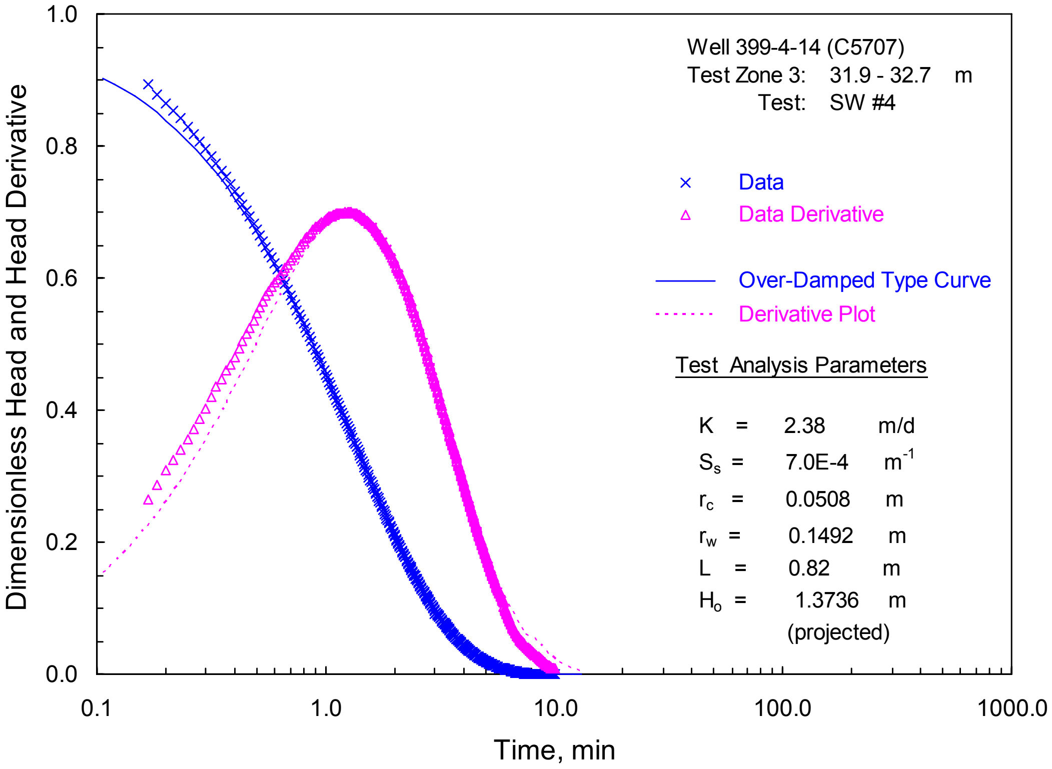


Figure 4.14. Selected Type-Curve Analysis Plot for Zone 3, Well 399-4-14

4.3.4 Zone 4 (Depth: 36.6 to 39.1 m)

After driving the 0.2985-m O.D. (11 ¾-in. O.D.) drill casing to a depth of 36.6 m bgs and then drilling an open hole to a depth of 40.1 m bgs, the bottom 0.5 m of the borehole filled in with sediment slough. The packer/well-screen assembly was lowered to the bottom of the borehole at a depth of 39.6 m bgs, exposing the temporary well-screen to the formation at a depth interval of 36.6 to 39.5 m bgs (bottom end-cap at 39.5 to 39.6 m bgs). While pumping during groundwater sampling before conducting the slug tests, the bottom 0.4 m of the well-screen section filled in with sediment slough (i.e., fine-grained sediments), producing a test/depth interval for Zone 4 of 36.6 to 39.1 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test-interval section generally consists of a silty sandy gravel unit similar to the unit for the Zone 3 test interval (i.e., composed of 50 to 70% gravel, 30 to 40% sand, and 15 to 20% silt). At the time of testing, the well-screen test interval was located ~23.6 m below the unconfined aquifer water-table surface, and test results reflect sediments of the Ringold Formation (Unit 5) just above the Ringold Lower Mud unit.

A series of three slug-injection tests and three slug-withdrawal tests (four low-stress and two high-stress tests) were conducted between 1250 hours and 1431 hours (PST), October 23, 2007. The slug tests were conducted with two different-sized slugging rods, one with a volume of 0.0055 m^3 and a larger one with a volume of 0.011 m^3. These slug-rod volumes imparted a theoretical applied stress level of 0.68 m for the low-stress tests and 1.36 m for the high-stress tests within the 0.1016-m (4-in.) I.D. temporary casing string. Downhole test-interval response pressures during testing were monitored with a 0- to 69-kPa (0- to 10-psig) pressure transducer set at a depth of ~16 m bgs. The static depth-to-water for the test interval measured before testing was 13.01 m bgs.

Five of the six slug tests exhibited elastic, over-damped (exponential-decay response) homogeneous formation behavior, which is indicative of low-to-moderate permeability test-zone conditions. Data for a sixth slug test (slug injection test #3) could not be analyzed because of a perturbation in the test response at an elapsed time of ~100 seconds. A comparison of the normalized, higher and lower stress, slug-test responses for the five analyzable tests indicated nearly identical behavior. Slug tests exhibiting this type of response behavior can be analyzed quantitatively with homogeneous formation analysis approaches, as described in Butler (1998). For the homogeneous formation analysis, the standard type-curve method provided estimates of K ranging between 0.93 to 1.12 m/day, averaging 1.04 m/day, and S_s ranging between 1.0E-4 and 2.0E-4 m^{-1}. A selected example of the test analysis plots for this test/depth interval is shown in Figure 4.15.

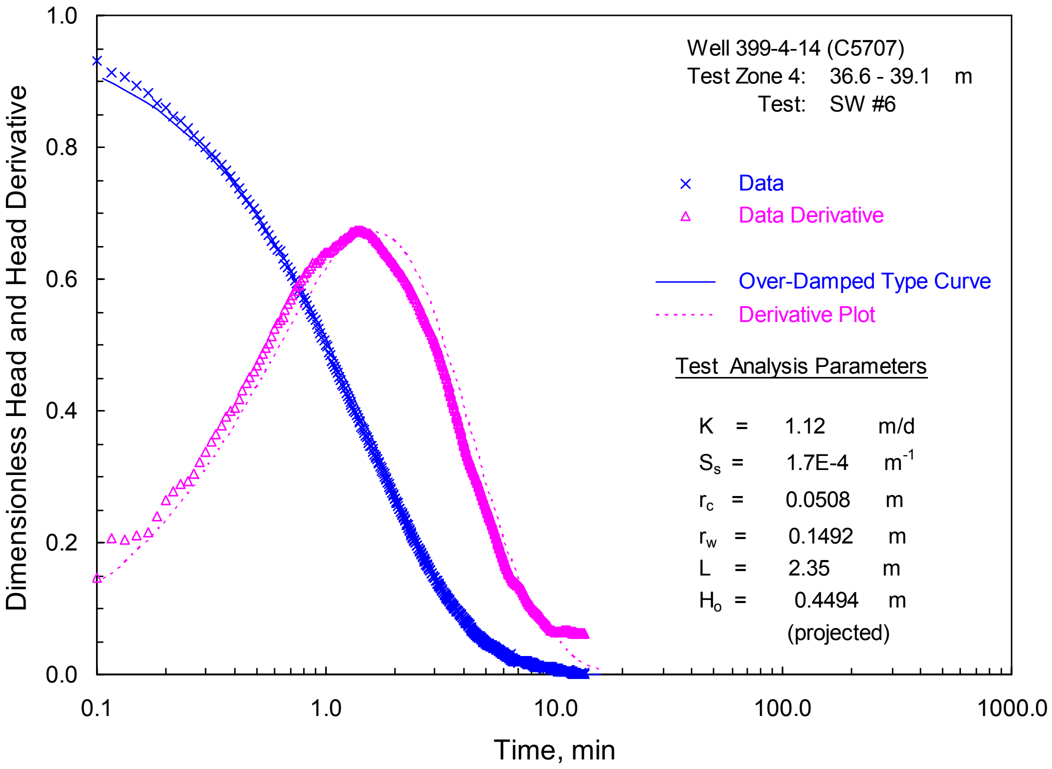


Figure 4.15. Selected Type-Curve Analysis Plot for Zone 4, Well 399-4-14

5.0 Hydraulic Conductivity Depth Profile

Figure 5.1 through Figure 5.3 show depth profiles of the vertical distribution of hydraulic conductivity values determined from slug tests conducted at the 300 Area VOC wells 399-2-5, 399-3-22, and 399-4-14, respectively. The distributions are based on test/depth slug-test characterization results summarized in Table 4.1 and Table 4.2. The unconfined aquifer (not shown) in Figure 5.1 to Figure 5.3 lies between the water table and the top of the Ringold Lower Mud unit. As indicated, the limited vertical profile information suggests a decrease in hydraulic conductivity with depth at two of the three well site locations, 399-2-5 and 399-4-14. For well 399-3-22, the vertical profile indicates the highest hydraulic conductivity within the Hanford unit and lowest hydraulic conductivity within the upper section of the Ringold Formation (i.e., fine-grained unit). The hydraulic conductivity depth profiles indicate that K values estimated for the Hanford unit are at least two orders of magnitude greater than K values estimated for the Ringold Formation. The vertical hydraulic conductivity profiles for these three wells are consistent with the hydraulic conductivity profile for 300 Area VOC well 399-3-21 provided in Spane (2007).

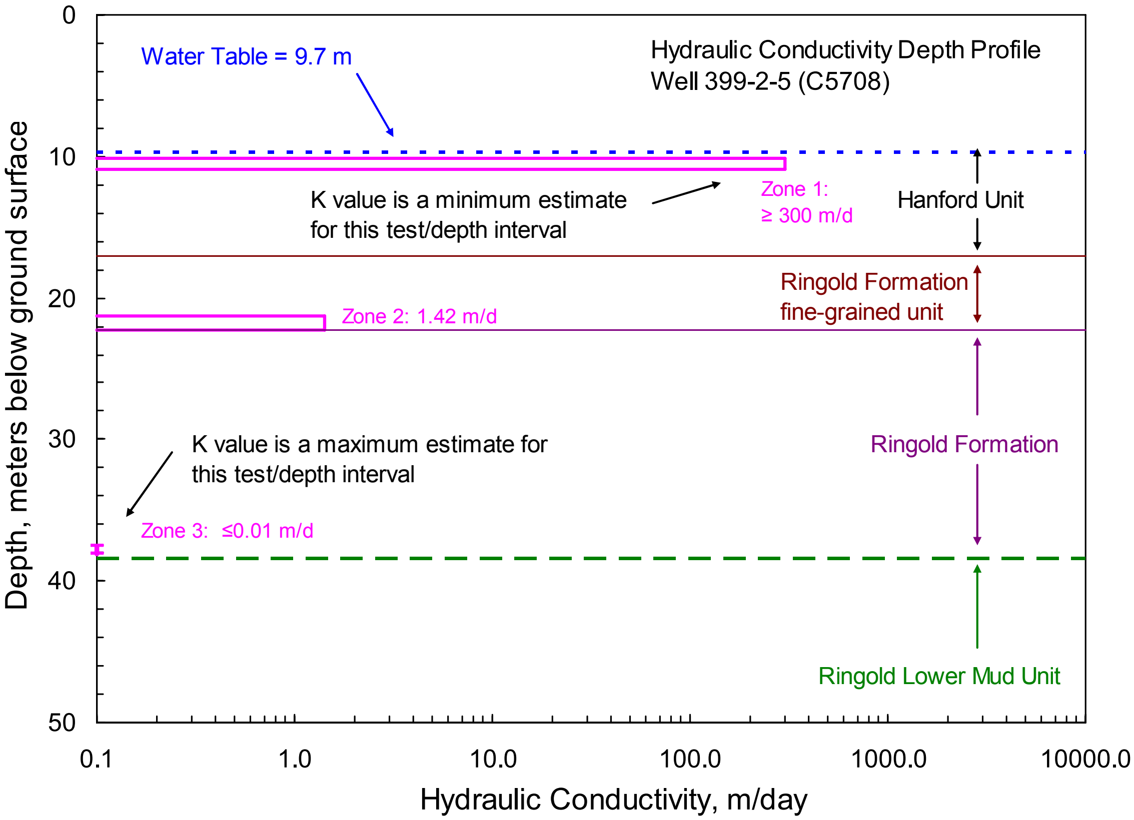


Figure 5.1. Hydraulic Conductivity Depth Profile for Well 399-2-5

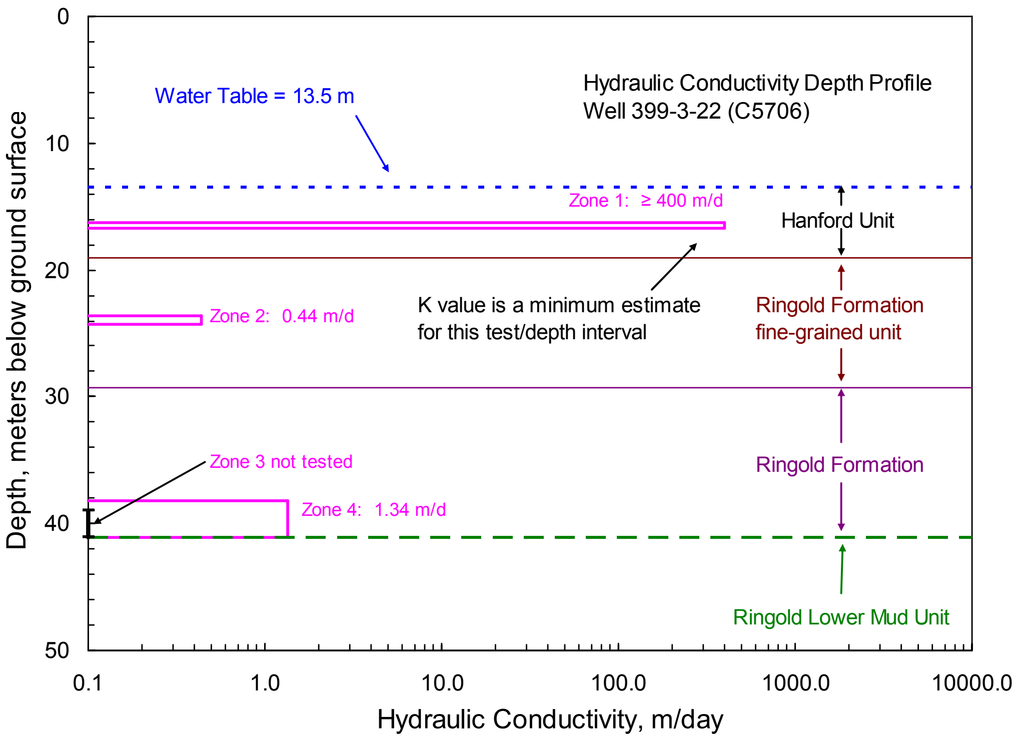


Figure 5.2. Hydraulic Conductivity Depth Profile for Well 399-3-22

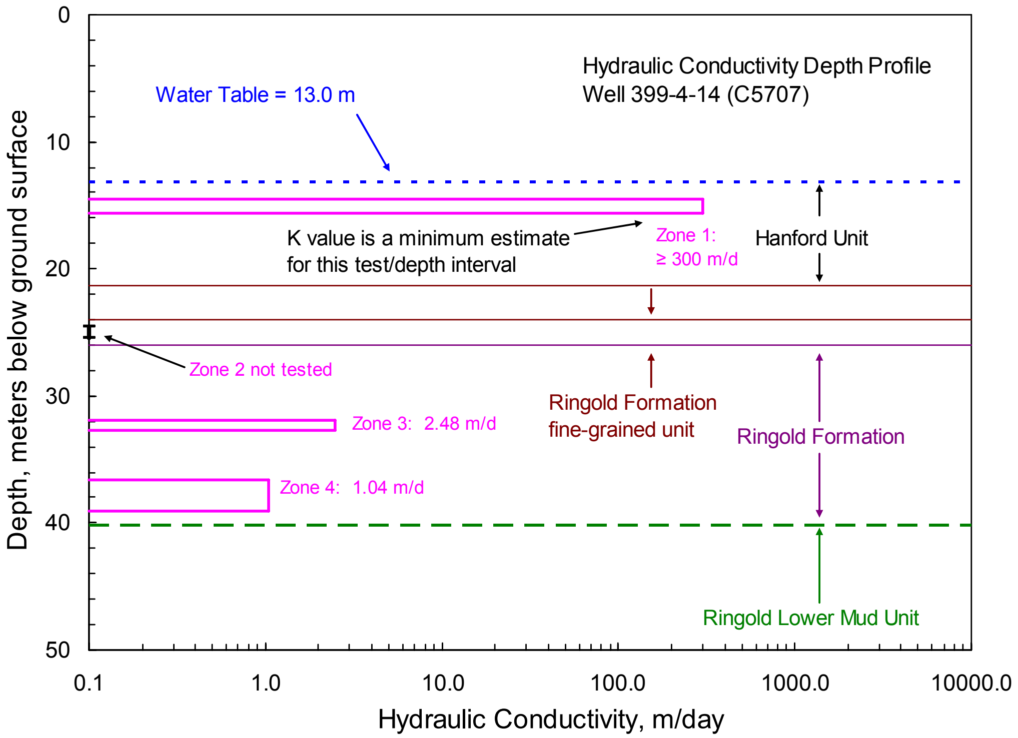


Figure 5.3. Hydraulic Conductivity Depth Profile for Well 399-4-14 (Note: Other Ringold Formation Fine-Grained Units Not Shown)

6.0 Conclusions

Slug-test analysis results were obtained for 8 of 10 planned test/depth intervals during the drilling and borehole advancement of three 300 Area VOC wells: 399-2-5, 399-3-22, and 399-4-14. Of the eight successful series of tests conducted, sediment filled in the bottom portion of the well-screen sections during pumping for groundwater samples before three of these series of tests, resulting in a smaller test/depth interval. Two of the test/depth intervals planned for slug-test characterization could not be tested because of sediment filling the entire temporary well-screen section. Following completion of each of these wells, slug-test results were obtained for one test/depth interval within the final well-screen section.

Results from the 300 Area well slug tests provide general vertical distribution of hydraulic characterization information, for the upper, middle, and lower sections of the unconfined aquifer. The upper section of the unconfined aquifer lies within the Hanford formation (Unit 1), and the middle and lower sections occur within the Ringold Formation (Unit 5).

For test-depth intervals within the Hanford formation (Unit 1), slug-test responses dissipated within the initial seconds of the tests, indicating very-high-permeability conditions. These high-permeability conditions were confirmed by analyzing for a rapid, exponential-decay (over-damped) test response recovery of 90% within ~3 seconds. Analyses indicate a range of $K \geq 300$ m/day for two of the well sites (399-2-5 and 399-4-14) and a range of $K \geq 400$ m/day for the third well site (399-3-22). These hydraulic conductivity ranges were derived for test-interval sections that ranged from 0.5 to 1.1 m in length. These lower bounding hydraulic conductivity values are comparable to the general range of lower bounding values of >100 to >2,000 m/day and to the estimate of 568 m/day for other Hanford formation test/depth intervals recently tested in 300-Area characterization boreholes.

All test/depth intervals within the Ringold Formation exhibit exponential-decay (over-damped) slug-test response behavior. This type of slug-test response pattern is indicative of test intervals with low to medium permeability. Analysis of slug-test data for these test intervals indicate an average, test-interval hydraulic conductivity ranging from ≤ 0.01 to 2.48 m/day for the Ringold Formation (Unit 5). The hydraulic-conductivity estimates were derived for test-interval sections that ranged from 0.6 to 2.9 m in length. These average hydraulic conductivity values are comparable to the lower range of 0.04 to 41.2 m/day for 16 other Ringold Formation test/depth intervals recently obtained for test characterization boreholes in the 300 Area.

The limited hydraulic conductivity depth profile information for the three 300 Area VOC wells suggests a general decrease in hydraulic conductivity with depth. An exception is a slightly lower hydraulic conductivity in the upper section than in the lower section of the Ringold Formation at one of the well-site locations.

7.0 References

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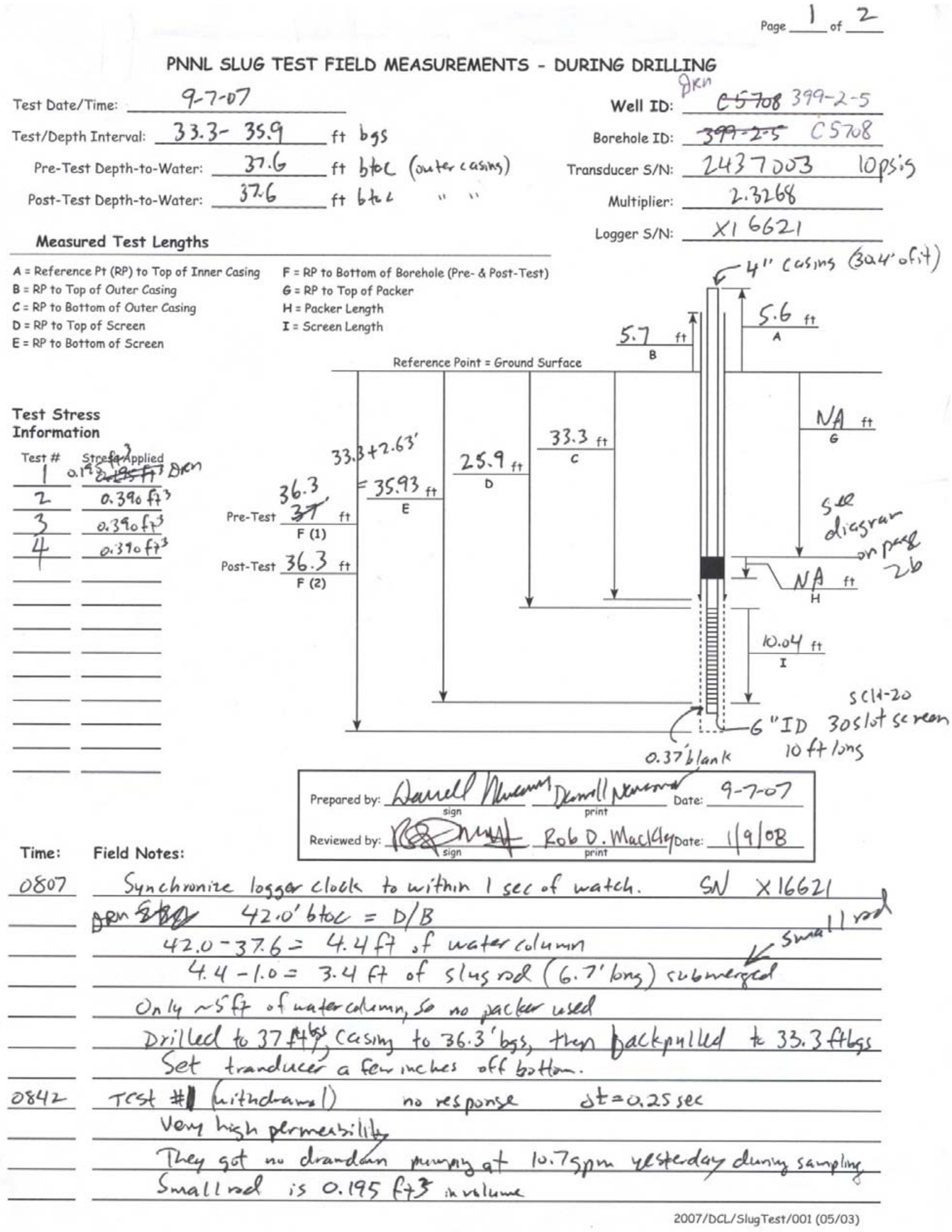
Appendix A

Slug Test Field Notes for Wells 399-2-5, 399-3-22, and 399-4-14

Well 399-2-5, Zone 1



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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 9-7-07

Test/Depth Interval: 33.3- 35.9 ft bgs

Pre-Test Depth-to-Water: 37.6 ft btoc (outer casing)

Post-Test Depth-to-Water: 37.6 ft btoc " "

Well ID: ~~C5708~~ 399-2-5 DRN

Borehole ID: ~~399-2-5~~ C5708

Transducer S/N: 2437003 10psig

Multiplier: 2.3268

Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Test Stress Information

Test #	Stress Applied
1	0.195 ~~2.195~~ ft^3 DRN
2	0.390 ft^3
3	0.390 ft^3
4	0.390 ft^3

Prepared by: Darrell Newcomer (sign) Darrell Newcomer (print) Date: 9-7-07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
0807	Synchronize logger clock to within 1 sec of watch. SN X16621
	DRN ~~[illegible]~~ 42.0' btoc = D/B
	42.0 - 37.6 = 4.4 ft of water column
	4.4 - 1.0 = 3.4 ft of slug rod (6.7' long) submerged ← small rod
	Only ~5 ft of water column, so no packer used
	Drilled to 37 ft bgs, casing to 36.3' bgs, then backpulled to 33.3 ftbgs
	Set tranducer a few inches off bottom.
0842	Test #1 (withdrawal) no response $\delta t = 0.25$ sec
	Very high permeability
	They got no drawdown pumping at 10.7 gpm yesterday during sampling
	Small rod is 0.195 ft^3 in volume

2007/DCL/SlugTest/001 (05/03)

Page 2 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 9-7-07

Well ID: C5708

Test/Depth Interval: 33.3 - 35.9 ft

Borehole ID: 399-2-5

Time:	**Field Notes:**
0850	Large slug rod lowered to 1.0' above bottom of well (set rod on bottom and then measure 1.0')
0855:30	Slug withdrawal test #2 (very little test response) Δt=0.25 sec
0857	Lower rod to partially submerged level.
0902:40	Slug withdrawal test #3 (large rod partially submerged)
	Very little response. ↖ 3.4' submerged
0906	Lower large rod back into water column. No sense in conducting slug
	test w/ small rod because of no response, so we'll conduct one more
	test using the large slug rod.
0910	Slug withdrawal test #4. Little response
	Large slug rod partially submerged for ~~tests #2, all tests~~ DRN; tests 2,3,4
	1' off bottom of well, i.e, 3.4' of rod submerged.
0913	logger off
0914	Downloaded data to file CR10X_X16621_C5708_33-36ft.dat
	Large slug rod has a stamp "0.390" ft3

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 9-7-07 Reviewed by: RDM (sign) Rob D. Mackley (print) Date: 1/9/08

2007/DCL/SlugTest/002 (04/04)

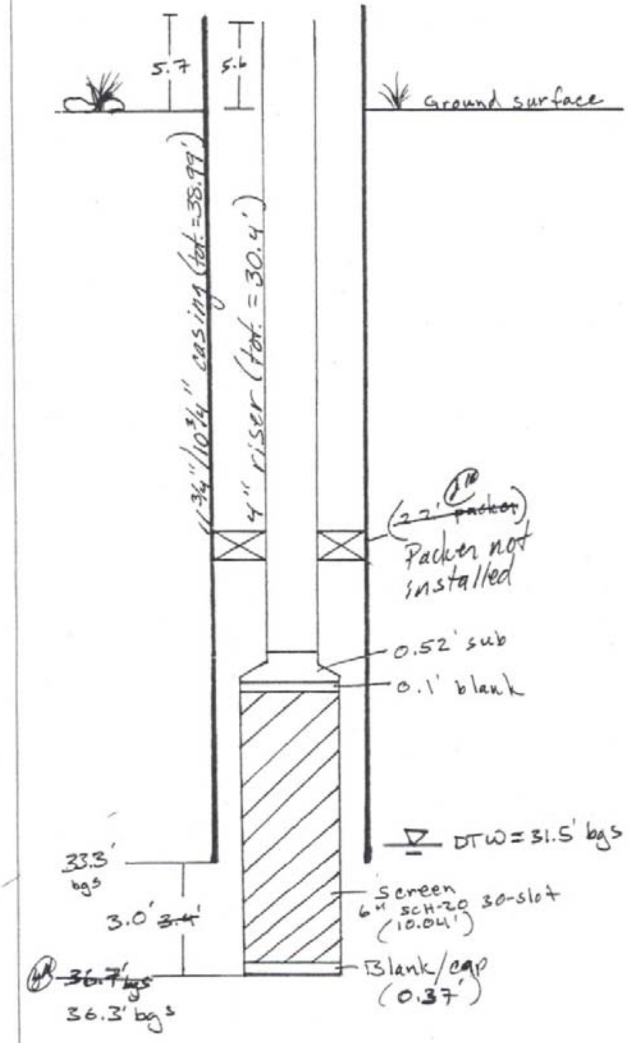
FIELD ACTIVITY REPORT
Drawing Continuation Page

Page 2 of 3
Date: 9-6-07

Well Name: 399-2-5
Well ID: C5708
Location: ~~399-~~ 300-FF-5 OU
Continuation of Report No.: 3

1st water sample/slug testing interval

1325 DTW = 37.4' btoc
(9/6) (31.7' bgs)



9/6/07

- Purged 23 min. @ ~10.7 gpm = ~246 gal.
- Pump failed prior to sampling, sample will be collected on 9/7.
- When removing the pump, the pump hitched up at the sub & pulled the screen up 0.4'. Bottom screen is @ 36.3' bgs

9/7/07

- Tripped pump in, too large to fit, decided to start slug testing & remove screen before sampling.
- Prior to collecting water sample, 4 withdrawal tests were performed, the screen was removed, the casing was advanced to 35.5' bgs & the bore hole cleaned out to 35.0' bgs (0.5' overlap).
- 1041-1045 (4 min.) @ 3 gpm = 12 gal.
  1045-1115 (30 min) @ ~10 gpm = 300 gal.
  12 + 300 = ~312 gallons

sample intv. I-13, B1PL94

Reported By: J. Horner
Title: Geologist
Date: 9-6-07
Signature: John Horner

Reviewed By:
Title:
Date:
Signature:

A-6003-711 (06/03)

Well 399-2-5, Zone 2

Page 1 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 9-19-07

Test/Depth Interval: 70-73 ft bgs

Pre-Test Depth-to-Water: 41.6 ft btoc (outer casing) @ 0953hr

Post-Test Depth-to-Water: 41.5 ft

Well ID: DRN ~~C5708~~ 399-2-5

Borehole ID: ~~399-2-5~~ C5708

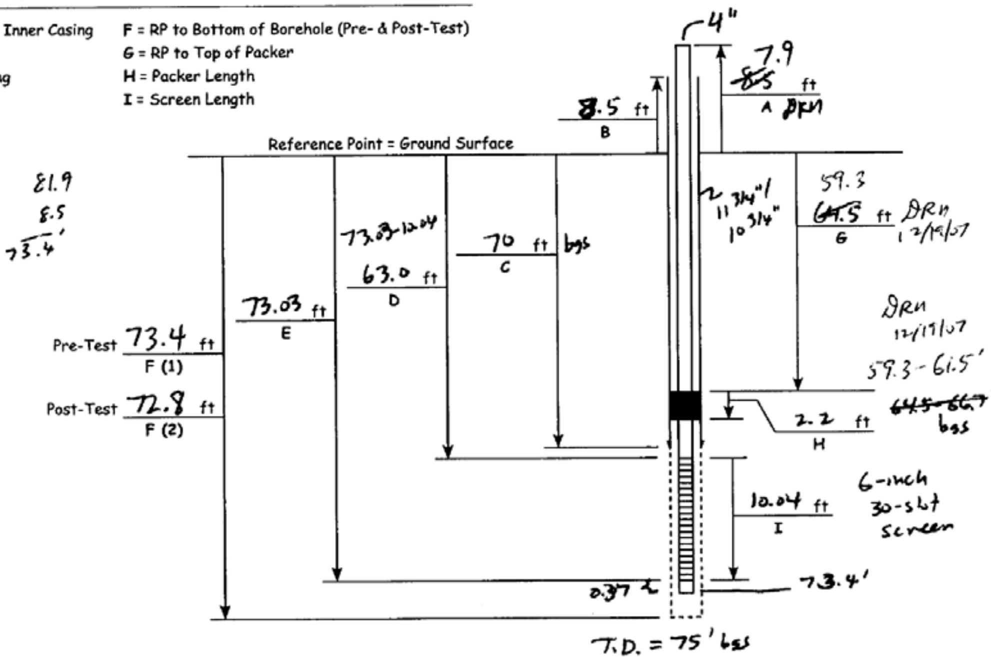
Transducer S/N: 2437003

Multiplier: 2.3268

Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Test Stress Information

Test #	Stress Applied
1	0.195 ft³
2	0.195 ft³
3	0.390 ft³
4	0.390 ft³
5	0.390 ft³
6	0.390 ft³
7	0.195 ft³
8	0.195 ft³

Prepared by: Darrell Newcomer (sign) Darrell Newcomer (print) Date: 9-19-07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
0858	Synchronize logger clock to within 1 sec of watch
0900	Pump turned off from sampling. Pump on for ~2 hr.
0914	Drillers are removing the sample pump from the 4" pipe
0940	Install transducer - reading is 9.63 ft and rising (psi, not feet) packer turned on (~75 psi)
0946	Transducer too deep
0947	Drillers working with compressor for inflatable packer
0950	Reset XD - now reading 9.08 ft on ch. 5; Ch. 1 is psi
0955	D/B. inside 4" = 81.9' btoc (outer casing) 81.3' btoc (4")
0959	Pour 5 gal of water down annular space to test packer
1013	Placed marks on cable after watching real-time plot - had to lower small 0.195 ft³ rod into water column
1019	Allow water levels to stabilize
1023	Compressor not holding pressure very well, must adjust it manually to keep pressure in the correct range.

Page 2 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

DRN

Test Date/Time: 9-19-07

Well ID: ~~G5708~~ 399-2-5

Test/Depth Interval: 70.0-73.0 ft bgs

Borehole ID: ~~399-2-5~~ C5708

Time:	Field Notes:
1031	Slug injection test #1 ; 2-3 sec to completely submerge 2"OD rod
	into water column. Δt=0.5sec
1049:36	Slug withdrawal test #2 ~1 sec to pull rod out of water column, much
	quicker than injecting the slug rod. Δt=0.5sec. 5-6 min to fully recover
1103	Remove 2"OD rod from well and replace it with a 3"OD rod.
1102	Change Δt to 1sec
1108:51	Lower slug rod into water column. Test #3. Drillers must go to lunch now and
	they won't be here to regulate packer pressure. Geologist will regulate packer pressure,
	so now test won't be disturbed.
1122	Turn compressor off
1127	Noticed that packer deflated - shows up on water-level plot.
1220	Inflate packer and allow water levels to stabilize
1234:30	Slug withdrawal test #4; 3"OD rod was fully submerged Δt=1sec
1259:30	Slug injection test #5 3"OD rod good test
1319	Slug withdrawal test #6 3" O.D rod was fully submerged
1334	Switch slug rods - back to smaller one (i.e., 2"OD)
1339	Slug injection test #7 ; 2"OD slug rod fully submerged
1352	Slug withdrawal test #8; 2"OD rod
1407	Turn logger off. Download data to file name CR10X_X16621_399-2-5_70-73ft.dat
1414	Packer test, pour 5gal between 4" and outer casing
1414:40	Turn pump off to pour 5gal
1420	D/W = 41.5' btoc (outer casing)
1421	D/B = 81.3' btoc (outer casing)
	Note: Jake Horner (geologist) has a nice diagram of packer/screen assembly

Prepared by: Darrell Newcomer (sign) Darrell Newcomer (print) Date: 9-19-07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

2007/DCL/SlugTest/002 (04/04)

FIELD ACTIVITY REPORT
Drawing Continuation Page

Page 2 of 3

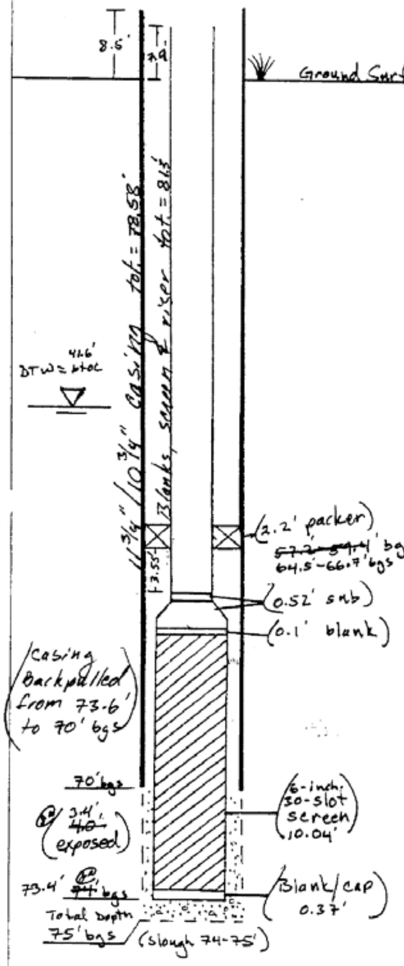
Date: 9-19-07

Well Name: 399-2-5

Well ID: C5708

Location: 300-FF-5 OU

Continuation of Report No.: 11



9-19-07 Pumped w.s./slug test intv.

Pump on: 0650⁰⁰ Intake @ ~57' bgs

① Sample time: 0800 (main bottle set)

② Sample time: 0845 (VOA samples)

Pump off: 0855³⁰

Purge ① 70 min. @ ~6 gpm = 420 gallons

Purge ② 115 min. @ ~6 gpm = 690 gallons

Max drawdown (packer not inflated) = 5.0'

Time	pH	Temp (°C)	Cond. (µs)	Turb. (NTU)
0725	6.49	15.9	285	> 1000
0735	6.745	15.7	269	> 1000
0740	6.868	16.2	265	> 1000
0750	7.201	15.8	261	> 1000
0800	7.531	16.1	261	> 1000

I-21 HEIS# B1PL97

Slug Testing:

- Packer inflated to 60-70 psi, passed 5-gal bucket integrity test.

#1) 1031 → Injection with 0.195 ft³ rod. (4:)

#2) 1049 → withdrawal " " "

#3) 1109 → Injection with 0.390 ft³ rod

#4) 1234 → withrawal " " "

#5) 1259 → Injection " " "

#6) 1319 → withdrawal " " "

#7) 1339 → Injection with 0.195 ft³ rod

#8) 1352 → withdrawal " " "

Reported By: J. Horner

Title: Geologist

Date: 9-19-07

Signature: John Horner

Reviewed By:

Title:

Date:

Signature:

A-6003-711 (06/03)

Well 399-2-5, Zone 3

Page 1 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 9-27-07

Test/Depth Interval: ~~123-125.1~~ ft 123'-125.1' bgs

Pre-Test Depth-to-Water: 37.2 ft btoc (outer casing)

Post-Test Depth-to-Water: 38.25 ft btoc (outer casing)

Well ID: DRn ~~C5708~~ 399-2-5

Borehole ID: ~~399-2-5~~ C5708

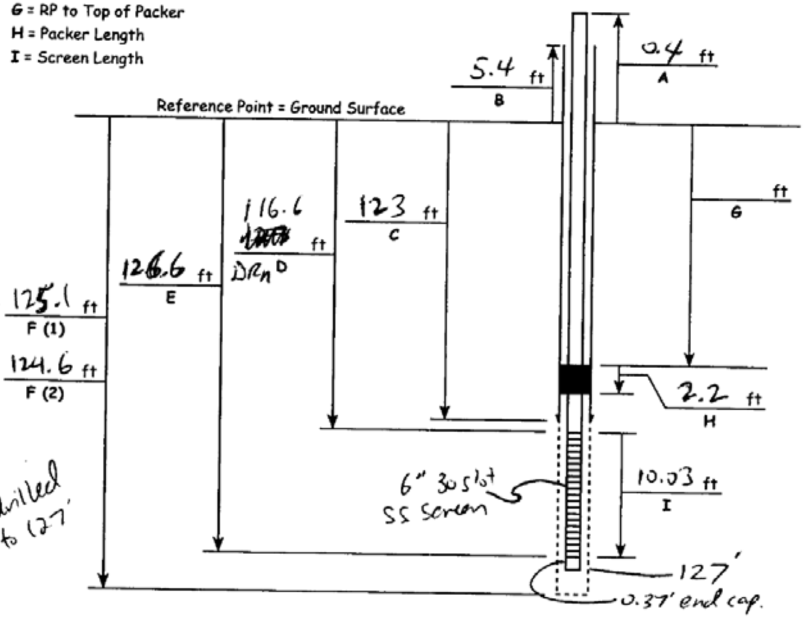
Transducer S/N: 2437003 (10psig)

Multiplier: 2.3268

Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Note: Borehole drilled open hole to 127' bgs.

Test Stress Information

Test #	Stress Applied
1	0195 ft³ (2" rod)

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 9-28-07

Reviewed by: Rob (sign) Rob Mackley (print) Date: 1/18/08

Time: PDT	Field Notes:
	Silted in up to 125.1' bgs, inside 4" ID casing where Ringold Mud contact lies
1458	Water level is still recovering from ground water sampling.
	Pumped at ~2gpm and 57' of drawdown during sampling.
1459	Still 4ft of recovery to go.
1506	D/W = 37.2' btoc (top of outer casing)
1510	Driller marking cable at 37.2' and 37.2 + 7' = 44.2' btoc
	2" OD rod was lowered into water column to get cable marked.
1514	Install XD to ~8' below water level and turn on logger.
1521	Packer integrity test - pour 5 gallons of water down annulus between
	inner and outer casing. - No response, packer is good.
	Don't ~~not~~ have a watch - will use clock on menu (logger clock on computer)

Use same packer/screen assembly as last series of slug tests ~~at~~ a depth of 70-73 ft bgs.

2007/DCL/SlugTest/001 (05/03)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 9-27-07 to 9-28-07

Well ID: ~~C5708~~ DRN 399-2-5

Test/Depth Interval: ~~116.6-12~~ DRN 123 - ~~126.6~~ 125.1 ft bgs

Borehole ID: ~~399-2-5~~ C5708

Time: Field Notes: ~~DRN~~

1527 PDT Initiate slug injection test #1, very slow ~~test~~ test response. Used small 2" slug rod.

Compressor must be turned off before everyone leaves today, so we'll conduct slug withdrawal test tomorrow morning.

Reset Δt from 1sec to 30sec and monitor overnight

0645 Driller and geologist provided breakfast! 9-28-07

0719 Download data

0735 Plot shows that water level is still recovering

0851 After consulting with Frank Spane, we will inflate the packer system

0853 Water level is rising in response to packer inflation.

0902 Water level beginning to stabilize at 9.22'

0930 Having trouble with datalogger - now got it to work - raining out. logger wet

0932 Change Δt from 30sec to 5sec.

Have no watch - lost it the other day, so we'll use the logger clock to initiate slug withdrawal and injection cyclical tests, 30min each. ½ cycle

0943 Withdrawal Slug rod. (2" rod)

1013 Inject Slug rod. (2" rod)

1016 Data shows some oscillations - Checked packer pressure and it is ok at 80 psi

Noisy data

1043 Slug withdrawal (2" rod)

1113 1½ cycles of slug testing finished.

1116 Driller's trash pump for pouring 5 gal of water doesn't work, so we can't conduct packer test

1117 Remove rod from well and get D/W + D/B

1118 D/W = 38.25' btoc (outer casing)

1120 D/B = 130.0' btoc, so 130.0' - 5.4' = 124.6' bgs. → tag line caught on transducer.

Turn packer off (deflate it)

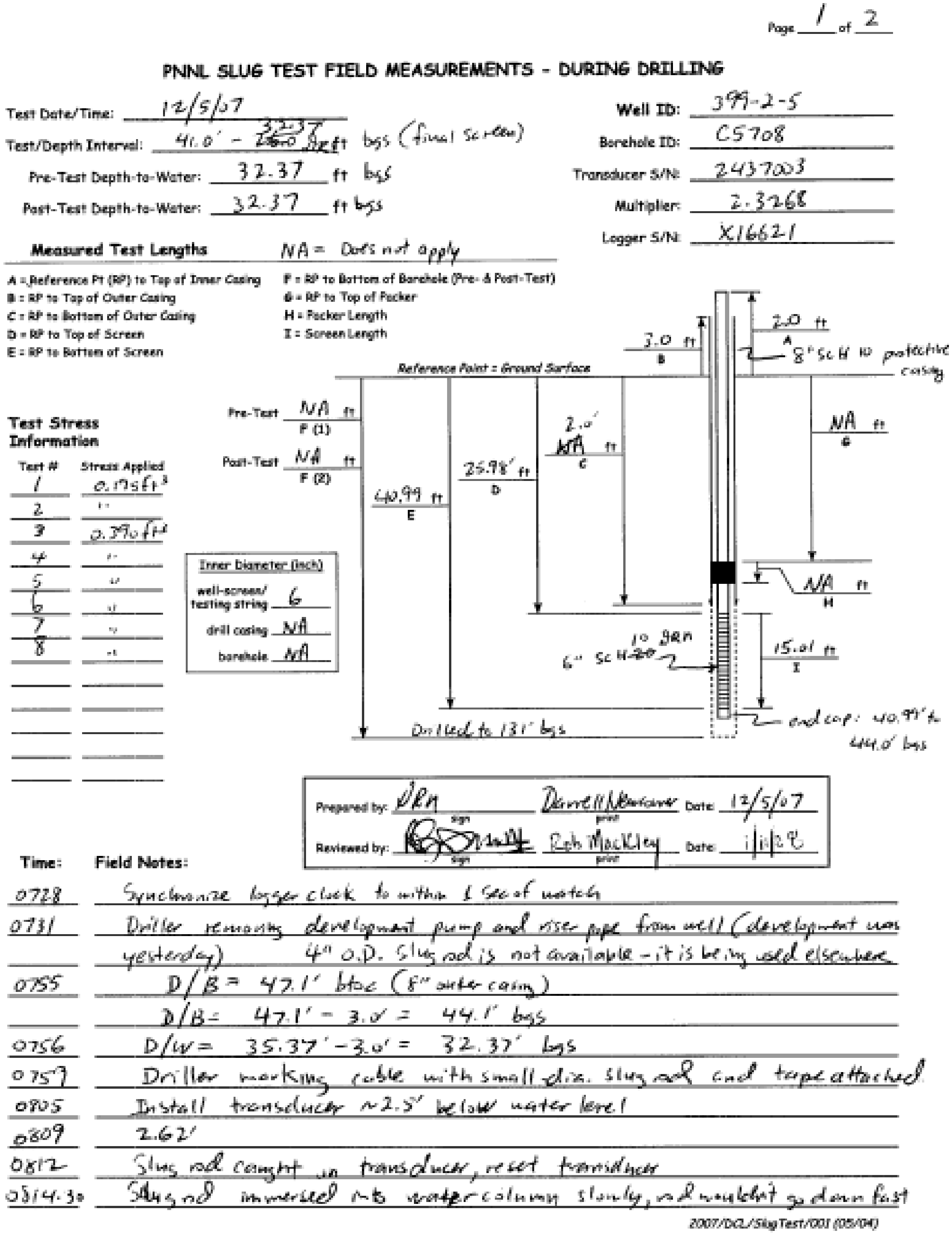
Download data to file CR10X_X16621_399-2-5_125ft.dat Not easy to tell where D/B is because of silt on bottom

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 9/28/07

Reviewed by: (sign) Rob Mackley (print) Date: 1/11/08

2007/DCL/SlugTest/002 (04/04)

Well 399-2-5, Final, Completed Well-Screen Section



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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 12/5/07

Test/Depth Interval: 41.0' – ~~28.0~~ 32.37 ft bgs (final screen)

Pre-Test Depth-to-Water: 32.37 ft bgs

Post-Test Depth-to-Water: 32.37 ft bgs

Well ID: 399-2-5

Borehole ID: C5708

Transducer S/N: 2437003

Multiplier: 2.3268

Logger S/N: X16621

Measured Test Lengths NA = Does not apply

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Reference Point = Ground Surface

A: 2.0 ft
B: 3.0 ft
C: ~~NA~~ 2.0' ft
D: 25.98' ft
E: 40.99 ft
Pre-Test F (1): NA ft
Post-Test F (2): NA ft
G: NA ft
H: NA ft
I: 15.01 ft

8" SCH 10 protective casing

6" SCH ~~20~~ 10 gRN

end cap: 40.99' to 44.0' bgs

Drilled to 131' bgs

Test Stress Information

Test #	Stress Applied
1	0.175ft³
2	"
3	0.390 ft³
4	"
5	"
6	"
7	"
8	"

Inner Diameter (inch)

well-screen/testing string: 6
drill casing: NA
borehole: NA

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 12/5/07

Reviewed by: (sign) Rob Mackley (print) Date: 1/11/08

Time:	Field Notes:
0728	Synchronize logger clock to within 1 sec of watch
0731	Driller removing development pump and riser pipe from well (development was yesterday) 4" O.D. slug rod is not available – it is being used elsewhere
0755	D/B = 47.1' btoc (8" outer casing)
	D/B = 47.1' – 3.0' = 44.1' bgs
0756	D/W = 35.37' – 3.0' = 32.37' bgs
0759	Driller marking cable with small dia. slug rod and tape attached
0805	Install transducer ~2.5' below water level
0809	2.62'
0812	Slug rod caught on transducer, reset transducer
0814.30	Slug rod immersed into water column slowly, rod wouldn't go down fast

2007/DCL/SlugTest/001 (05/04)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 12/5/07

Well ID: 399-2-5

Test/Depth Interval: 26.0' – 41.0' ft bgs (final screen)

32.37' [illegible]

Borehole ID: C5708

Time:	Field Notes:
0816:30	Slug withdrawal test #1; small rod - very little response
0818	Slug injection test #2, small rod - not much test response
	Change to larger slug rod
0822:30	Slug injection test #3, large rod
0824:30	Slug withdrawal test # 4, large rod
0826:30	Slug injection test #5 " " slow injection - bad test
0828	Slug withdrawal test #6 " "
0847:[illegible]	Slug injection test #7; large rod - let cable go slack and dropped rod very quickly.
0850:30	Slug injection test #8, large rod - let cable go slack and dropped large rod very quickly - nearly instantaneous slug displacement
	Download data and save it to file CR10X_x16621_399-2-5_28-41ft.dat

Prepared by: sign Darrell Newcomer print Date: 12/5/07

Reviewed by: sign Rob Mackley print Date: 1/11/08

2007/DOL/SlugTest/002 (04/04)

Well 399-3-22, Zone 1

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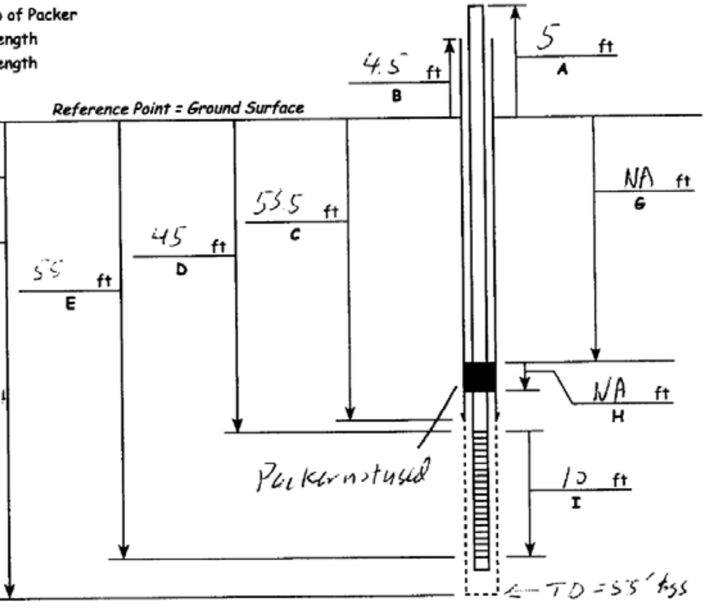
PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 11/6/07
Test/Depth Interval: 53.5 - 55 ft bgs
Pre-Test Depth-to-Water: 44.3 ft bgs
Post-Test Depth-to-Water: 44.3 ft bgs

Well ID: 399-3-22
Borehole ID: C 57086 DRN
Transducer S/N: 2437003
Multiplier: 2.3248
Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Pre-Test 55 ft F (1)
Post-Test 55 ft F (2)
A: 5 ft
B: 4.5 ft
C: 53.5 ft
D: 45 ft
E: 55 ft
G: NA ft
H: NA ft
I: 10 ft

Test Stress Information

Test #	Stress Applied
1	0.195 ft^3
2	"
3	"
4	0.390 ft^3
5	"
6	"
7	"
8	0.195 ft^3
9	"

Inner Diameter (inch)

well-screen/ testing string: 6 slot
drill casing: 10 3/4
borehole: 11 3/4

Prepared by: ARN (sign) Darrell Newcomer (print) Date: 11/6/07
Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
0710	Synchronized logger clock to within 1 sec of watch time
	7 gpm and no measurable drawdown during sampling
0720	Driller marked cable with tape attached to top of small slug rod.
0732	Slug injection test #1; small dia rod; not a good response
0733	Raise XD up to 2 3 ft into water column.
0736 30	Slug injection test #2, small dia. slug rod; small oscillatory response.
0740	Slug with. test #3 " " " " " "
0750	Change out slug rods - now use large slug rod (0.390 ft^3 volume)
0755	Slug injection test #4; large slug rod, oscillatory response
	Response dissipated within 20 to 30 sec.
	well 399-3-12 is located very close to well 399-3-22

2007/DCL/SlugTest/001 (05/04)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 11/6/07

Well ID: 399-3-22

Test/Depth Interval: 53.5-55 ft bgs

Borehole ID: C5708

Time:	Field Notes:
0812:30	Slug injection test # 5, large slug rod, oscillatory response
	Attached XD ~2.5' below large slug rod.
0818	Lowered large rod completely submerged in water column.
0821.30	Slug with test # 6; large slug rod with XD attached to rod.
[illegible]	DKN
0826	Lower rod into water column
[illegible]	DKN
0827.30	Slug with test # 7; large slug rod with XD attached to rod.
	Change back to small slug rod
0836	Lower XD to 1-2 ft into water column.
0841	Slug injection test # 8; small slug rod; oscillatory test response
0843.30	Slug with. test # 9; " " " " " "
0853	D/W = 49.3 - 5.0' = 44.3' bgs
0854	D/B = 60' btoc (4") = 60-5 = 55' bgs
	Data downloaded to file CR10X-X16621_399-3-22-53-55ft.dat

Prepared by: DKN (sign) Darrell Newcomer (print) Date: 11/6/07 Reviewed by: RDM (sign) Rob D. Mackley (print) Date: 1/9/08

2007/DCL/SlugTest/002 (04/04)

Well 399-3-22, Zone 2

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 11/8/07

Test/Depth Interval: 77.5 - ~~85.6~~ 79.7 DRN ft

Pre-Test Depth-to-Water: 44.45 ft bgs

Post-Test Depth-to-Water: 43.78 ft bgs

Well ID: 399-3-22

Borehole ID: C570~~8~~6 DRN

Transducer S/N: 2437003

Multiplier: 2.3268

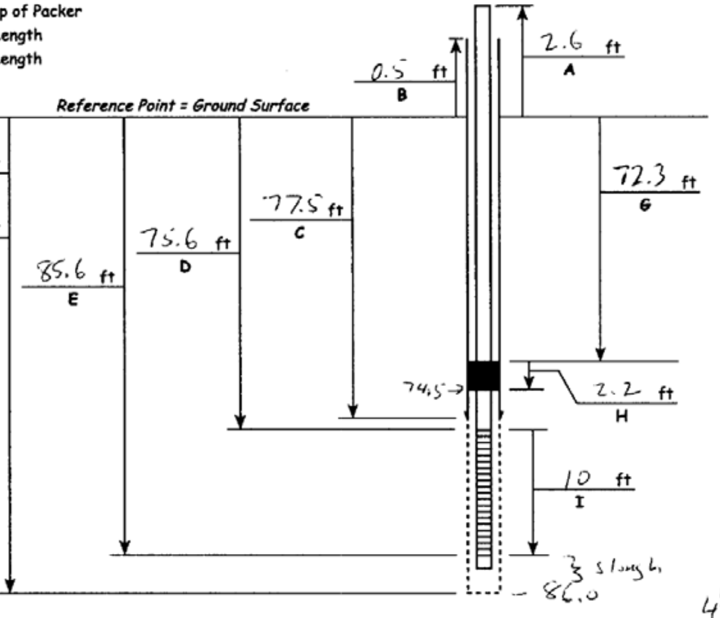
Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test 79.7 ft F (1)

Post-Test 77.3 ft F (2)



Test Stress Information

Test #	Stress Applied
1	0.190 ft^3
2	0.190 ft^3
3	0.395 ft^3
4	0.395 ft^3

Inner Diameter (inch)
well-screen/ testing string 6
drill casing 10 3/4
borehole 11 3/4
DRN

47.05
2.6
44.45

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 11-8-07

Reviewed by: RDM (sign) Rob D. Mackley (print) Date: 1/9/08

(pst) Time:	Field Notes:
1338	Synchronize logger clock to within 1 sec of watch
	Silted in from 79.7 to 85.6 bgs; so only 2.2' of screened exposed.
1347	D/W = 47.05' btoc (4")
1350.00	Packer integrity test - Began pouring 5 gal of water down annulus between
	inner and outer casing - Packer is already inflated
1350.15	End pouring - OK
1359.10	Slug injection test #1, small slug rod (0.190 ft^3) Slow exponential decay
	test response finer sediments on top; coarser sediments in lower part of
	screen. Δt = 1 sec Static level was 9.84'
1403	Change Δt to 5 sec
1437	Slug test curve beginning to flatten out - near pre-test level at 9.88'

2007/DCL/SlugTest/001 (05/04)

Page 2 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 11/8/07 - 11/9/07

Well ID: 399-3-22

Test/Depth Interval: ~~77.5-85.6~~ DRN ft bgs
77.5 - 79.7 ft bgs

Borehole ID: C5708

Time:	Field Notes:	
1453	9.88'	
1456	Slug withdrawal test #2; small slug rod (0.190 ft^3) Δt = 1sec	
1528	9.89'	82.2
1533	D/B = 82.2' btoc (4") = 79.6' bgs	2.6 79.6
1539	Slug injection test #3, large slug rod (0.395 ft^3)	
	Very slow test response	
1626	9.92'	
	Set Δt to 1min overnight	
	11/9/07 Friday	
0658	10.476' Downloaded data to laptop computer	46.38
0717	D/W = 46.38' btoc (4") = 46.38 - 2.6 = 43.78' bgs	2.6
	Try to lower transducer past slug rod	43.78
0730	Packer inflated	
0731	Set transducer at a deeper level. 18.09' Slug rod was pulled out	
	of water column to free transducer cable	
0737:10	Slug injection test #4; large slug rod	
	test Not responding correctly abandon test	
0744	D/B = 79.9' btoc (4") Silted to top of screen	
	CR10X-X1664-	
	Data downloaded to file 399-3-22-77-79ft.dat	

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 11/8/07 Reviewed by: (sign) Rob Mackley (print) Date: 1/9/08

Well 399-3-22, Zone 3

(no field notes—slug testing abandoned)

Well 399-3-22, Zone 4 (Final, Completed Well-Screen Section)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 12/3/07

Test/Depth Interval: 125.2' - 134.7 ft bgs (final screen)

Pre-Test Depth-to-Water: ~~44.5~~ 43.6 DRN ft bgs

Post-Test Depth-to-Water: ______ ft bgs

Well ID: 399-3-22

Borehole ID: C57086 DRN

Transducer S/N: 2437007

Multiplier: 2.3268

Logger S/N: X16621

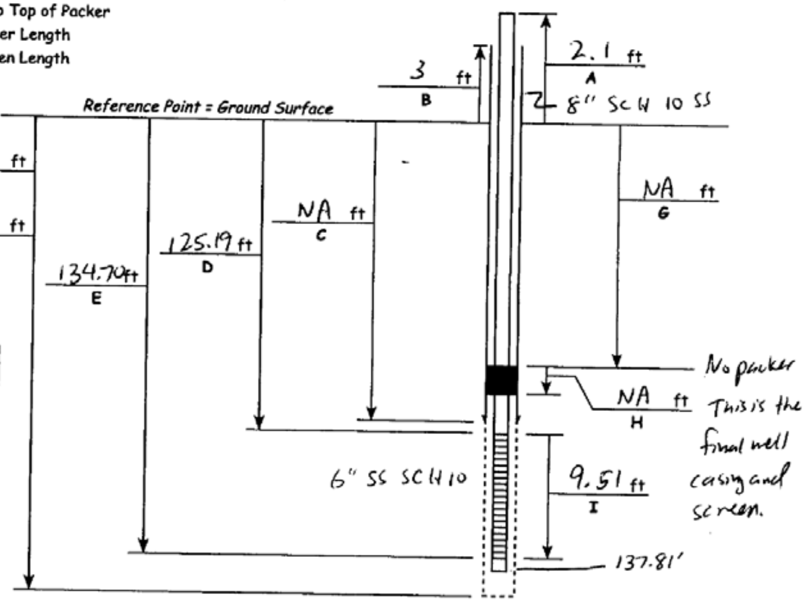
Measured Test Lengths NA = does not apply

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen

F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test NA ft F (1)

Post-Test NA ft F (2)



Test Stress Information

Test #	Stress Applied
1	0.195 ft³
2	"
3	0.390 ft³
4	"
5	0.195 ft³
6	"

Inner Diameter (inch)

well-screen/testing string 6"

drill casing NA

borehole NA

47.5
3.0
44.5

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 12/3/07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
1321 PST	Synchronized logger clock to within 1 sec of watch time
~~1339~~	~~D/W = 47.5' btoc (top of outer protective casing)~~ DRN
	Measured D/B was 141.2' btoc (outer casing) using driller tag line, which is off
	This would be 141.2' - 3.0' = 138.2' bgs, which is ~0.4' greater than 137.81',
	which is D/B based on casing lengths.
1345	D/W = 46.6' btoc = 43.6' bgs
	8" outer protective casing
1347	Install transducer to ~9' below water level.
1355	Initiate Slug injection test #1 using small-dia slugrod. Slow recovery response.
	Changed Δt from 0.125 sec to 1 sec. during early part of test.
	~10 min to fully recover

2007/DCL/SlugTest/001 (05/04)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 12/3/07

Test/Depth Interval: 125.2 - 134.7 ft bgs (final screen)

Well ID: 399-3-22

Borehole ID: C57086 DRN

Time:	Field Notes:
1407	9.0968'
1416	9.0882'
1419	Initiate slug withdrawal test #2 using small-dia rod
	Slow recovery, over-damped test response.
1444:30	Initiate slug injection test #3, large rod
	over-damped test response ~20 min to fully recover
1515	Initiate slug withdrawal test #4, large rod
1552:30	Initiate slug injection test #5, small slug rod
15:12	Initiate slug withdrawal test #6, small slug rod
1532	D/W = 46.62' btoc (outer protective casing top)
	Download data and save to file CR10X_X16621_399-3-22_125-135 ft.dat

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 12/3/07 Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

2007/DCL/SlugTest/002 (04/04)

Well 399-4-14, Zone 1

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 10/10/07 pm

Test/Depth Interval: 47.6-~~51.5~~ 51.1 ft bgs (3.5 ft test section)

Pre-Test Depth-to-Water: 47.9 ft btoc

Post-Test Depth-to-Water: 47.9 ft btoc

Well ID: 399-4-14

Borehole ID: C5707

Transducer S/N: 2437003

Multiplier: 2.3268

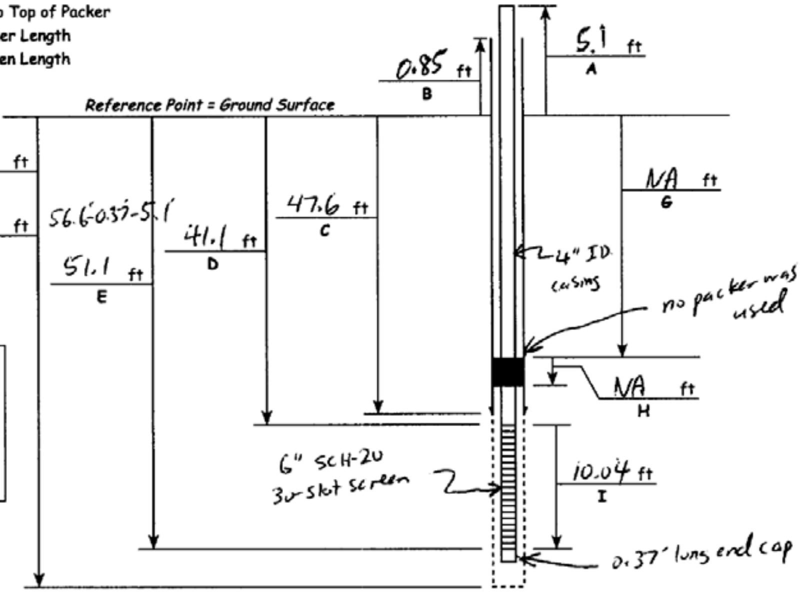
Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test 51.5 ft F (1)

Post-Test 51.5 ft F (2)



Test Stress Information

Test #	Stress Applied
1	0.195 ft^3
2	0.195 ft^3
3	0.195 ft^3
4	0.390 ft^3
5	0.390 ft^3
6	0.390 ft^3
7	0.390 ft^3
8	0.390 ft^3

Inner Diameter (inch)

well-screen/ testing string 6

drill casing 10 3/4

borehole 11 3/4

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 10/10/07

Reviewed by: RobDMack (sign) Rob D Mackley (print) Date: 1/9/08

Time:	Field Notes:
1000	Arrive at well site
	D/W = 47.9' btoc (4") D/B = 56.6' btoc (4")
	56.6 - 47.9 = 8.7 ft of water column.
1021	Synchronize logger clock to within 1 sec of watch.
1027	Lower transducer to a depth of ~57 btoc and we'll start with
	Small slug rod
103030	Inject slug rod (2-3 sec to lower rod); very little test response. Δt=0.25 sec
103330	Slug withdrawal test #1 (rod lifted out of water column in less than 1 sec)
1035	Raised XD so it is only in 2-3 ft of water column
1037	Lower slug rod slowly into water column
1039	Driller moved rod up a little

2007/DCL/SlugTest/001 (05/04)

Page 2 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 10/10/07

Well ID: 399-4-14

Test/Depth Interval: 47.6 ~~51.5~~ to 51.1 ft bgs DRN

Borehole ID: C5707

Time:	Field Notes:
1041	Rod moved up a little to get it off bottom of well.
1043	Slug with. test #2 using small rod; Small oscillatory response this time.
1045	Lower small slug rod to fully submerged level. (not a test).
1048:30	Slug with. test #3, small slug rod. (0.195 ft³)
1105	Remove small slug rod and attach large slug rod to cable
1106	Lower slug rod slowly into water column volume of rod is (0.390 ft³)
1108:30	Slug with. test #4; large rod raised very quickly (<1 sec)
1111:30	Slug injection test #5 (lowered rod in 1-2 sec)
1114	Slug withdrawal test #6 (rod raised in ~1 sec)
	Oscillatory responses look good on realtime plots for tests #3 - #6
1116:15	Slug injection test #7 (1-2 sec to lower rod all the way in water column)
	large slug rod
1119:30	Slug withdrawal test #8 (large slug rod) XD got caught inside
	4" casing with slug rod. Rod is jammed. Driller will try to tap
	on top of 4" casing to vibrate rod and transducer loose. Doesn't work.
1150	Driller got transducer unstuck by pulling with a third line. Transducer
	does not appear to be damaged. We will not conduct anymore slug tests
	in this well.
	D/W = 47.9' btoc D/B = 56.6' btoc
	Saved downloaded data to file CR10X_x16621_399-4-14_47-51ft.dat

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 10/10/07

Reviewed by: (sign) R.D. Mackley (print) Date: 1/9/08

Well 399-4-14, Zone 2

Page 1 of 1

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 10/15/07

Test/Depth Interval: 80.5 - 83.5 ft

Pre-Test Depth-to-Water: 42.75 ft bgs

Post-Test Depth-to-Water: 42.75 ft bgs

Well ID: 399-4-14

Borehole ID: C5707

Transducer S/N: 2437003 (10 psig)

Multiplier: 2.3268

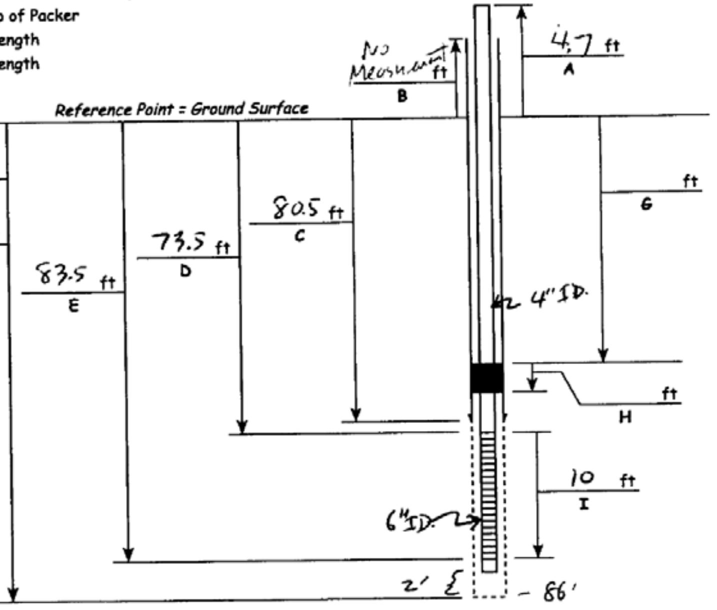
Logger S/N: X16271

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test 80.5 ft F (1)

Post-Test 73.4 ft F (2)



Test Stress Information

Test #	Stress Applied
NA	NA

Inner Diameter (inch)

well-screen/ testing string 6

drill casing 10 3/4

borehole 11 3/4

Prepared by: Darrell Newcomer (sign) Darrell Newcomer (print) Date: 10/15/07

Reviewed by: (sign) Rob Mackley (print) Date: 1/11/08

Time:	Field Notes:
1316	Synchronize logger clock to within 1 sec of watch.
1345	Screen is sanded in up to 73.4' bgs inside 4" inner casing and between
	4" inner casing and outer casing. It sanded in during groundwater sampling,
	when they pumped at a rate of 7.6gpm and 6' of drawdown.
1355	D/W = 47.45 btoc Stickup = 4.7 ft
	Slug testing will be abandoned at this test interval.

2007/DCL/SlugTest/001 (05/04)

Well 399-4-14, Zone 3

Page 1 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 10/19/07 RD Mackley

Test/Depth Interval: 104.5-107.2 ft

Pre-Test Depth-to-Water: 43.1 ft

Post-Test Depth-to-Water: 42.8 ft

Well ID: C5707 rdm

Borehole ID: 399-4-14

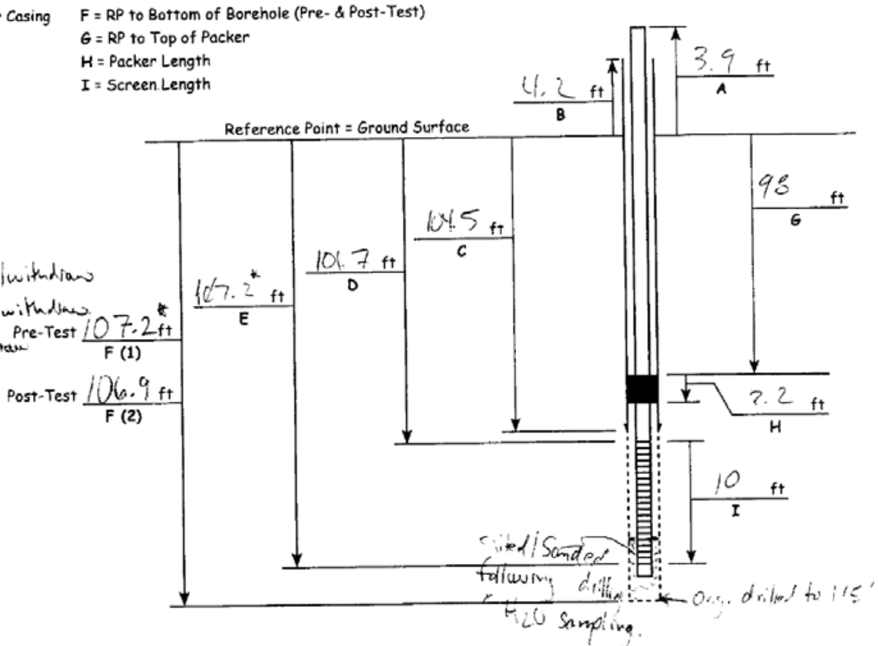
Transducer S/N: 2437003

Multiplier: 2.3268

Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length



Test Stress Information

Test #	Stress Applied
1	small rod inj/withdraw
2	large rod inj/withdraw
3	Small rod inj/withdraw

Prepared by: Rob D. Mackley (sign) Rob D. Mackley (print) Date: 11/15/07

Reviewed by: DRN (sign) Darrell Newcomer (print) Date: 1/8/08

Time:	Field Notes:
1315	Arrive @ well site
1345	Lowering transducer. *Orig. drilled to 115'; Sanded in to 111.7' before H_2O sample. Then filled in to 107.2' during H_2O sample.
	water sample, 107.2' after developing H_2O sample
1402	Small rod = 6.6' : Xducer to ~52.66' bgs (9.56' pressure)
1406	Rig turned off: collecting pre-test static pressure.
1413	Pressures bouncing up/down; probably due to windy conditions.
1420	Checked packer by dropping 5 gal down annulus. No response.
1422	Injection of small slug; ~2' response (H_0). Good curve.
1432	Pressure back to static. Collecting pre-withdrawal pressures. Slight
	positive trend in static pressures. (driller/geologist noted that water level
	prior to test was lower than static this morning).

2007/DCL/SlugTest/001 (05/03)

Page 2 of 2

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 10/19/07

Test/Depth Interval: 104.5-107.2' ft

Well ID: C5707

Borehole ID: 399-4-14 rdm

Time:	Field Notes:
1436	Rig turned back on - seeing interference
1438	Slug withdrawl. Good clean pull. Rig turned on right away. ~2' response
1440	fully recovered to static
1455	Raising small rod out of hole.
1458	Lowering larger rod down into hole. No twisting/rubbing of cable observed.
1505	Slug injection. (~4.3' responce [H0])
1520	fully recovered. Rig On.
1522	Withdrawl of large slug; rig off.
1529	fully recovered. (~4.8' responce).
1531	Rig On. Pulling up large slug rod. Some tangling but not too bad.
1539	DTB = 107.0' bgs; ~0.2' silted in to screen. Water level
	has risen about 0.25' since first got xducer in hole (now @ 9.81' of press)
1554	Slug injection w/ small rod. (~2.5' response). Clean push; no tangle.
1603	fully recovered. Collecting static press. Very stable.
1611	Slug withdrawl. ~2.14' response.
1619	fully recovered.
1631	Pulling small rod out of hole
1636	Poured 5 gal H2O down annulus: no response = packer not leaking
1637	W.L.=42.8 bgs; DTB = 106.9'. Total silting ~ =0.3' from start to end.
1645	Leaving site.
	Filename: C5707_SlugTestData_rdm_10_19-2007.xls

Prepared by: RD Mackley (sign) (print) Date: 11/15/07 Reviewed by: DRN (sign) Darrell Newcomer (print) Date: 1/8/08

Well 399-4-14, Zone 4

Page 1 of 3

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 10-23-07

Test/Depth Interval: 120-128.2 ft bgs

Pre-Test Depth-to-Water: 42.67 ft bgs

Post-Test Depth-to-Water: 42.9 ft bgs

Well ID: 399-4-14

Borehole ID: C5707

Transducer S/N: 2437003

Multiplier: 2.3268

Logger S/N: X16621

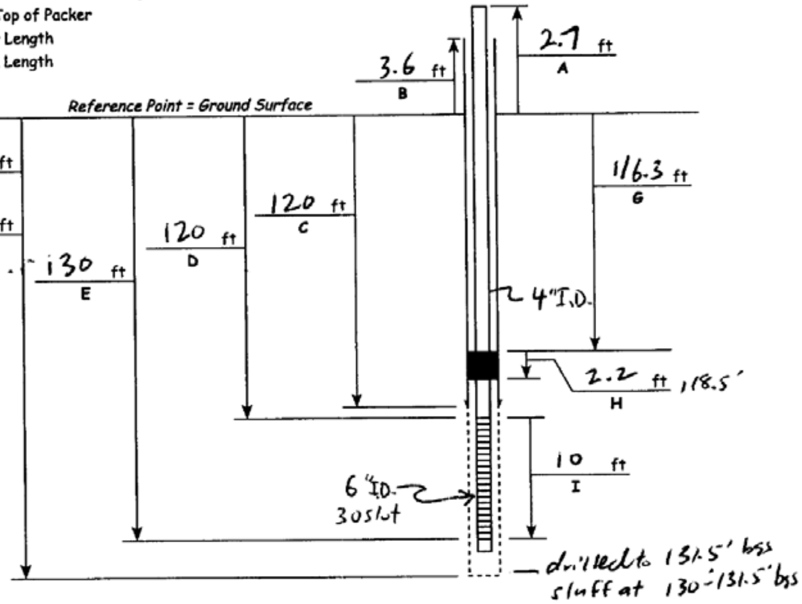
Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RR to Bottom of Screen

F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Pre-Test 128.2 ft F (1)

Post-Test 127.4 ft F (2)



Test Stress Information

Test #	Stress Applied
1	0.195 ft³ (small rod)
2	0.195 ft³ "
3	0.390 ft³ (large rod)
4	0.390 ft³
5	0.195 ft³
6	0.195 ft³

Inner Diameter (inch)

well-screen/testing string: 6
drill casing: 10 3/4
borehole: 11 3/4

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 10-23-07
Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
1255	Synchronize logger clock to within 1 sec of watch.
	After pumping for a sample, borehole silted in up to 128' bgs, according to geologist.
1310	Driller went to get gas for air compressor used to inflate packer.
	Driller said he drilled 6" into top of Ringold mud
1322	Driller back - packer inflated
1326	D/W = 44.7' btoc, but water level dropping in response to packer inflation
1330	Install transducer in ~10 ft of water column
1333	Water level is still dropping
1343	D/W = 46.27' btoc (outer casing)
1345	9.09 ft Δt = 1 sec

2007/DCL/SlugTest/001 (05/04)

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 10/23/07

Well ID: 399-4-14

Test/Depth Interval: 120-128.2 ft bss

Borehole ID: C5707

↑ NOTE: Test interval changed slightly after screen silted in.

Time:	Field Notes:
1349	Driller made marks uncable
1350	Slug injection test #1 using small slug rod ($0.195 ft^3$), fully submerged
	Slow recovery, ~10 min for full recovery good exponential decay curve.
1409:30	Slug withdrawal test #2, small rod fully submerged
	~10 min full recovery
1424	Remove small slug rod out of well. Disturbed XD.
1426	D/B = 131.3′ btoc outer casing
	D/B = 127.7′ bss, so screen silted in 0.5′ since slug tests started.
	We'll conduct one injection and one withdrawal test using large slug ($0.390 ft^3$)
	rod to minimize more silting in of 6″ I.D. screen.
1433:30	Slug injection test #3; large slug rod ($0.390 ft^3$) fully submerged
1435	Perturbation in slug test response at $t_e = 1.5$ min.; quicker recovery at $t > 1.5$ min
	Full recovery takes ~10 min. $H_0 \approx 4$ ft
	$r = 2''$
	$0.390 ft^3 = h \pi r^2 = h \pi \left(\frac{2}{12}\right)^2 = h(0.08722 ft^2)$ ~~3~~ DRN
	$h_{o_{calc.}} = \frac{0.390 ft^3}{0.08722 ft^2} = 4.47'$
1451	Slug withdrawal test #4; large slug rod fully submerged
	over-damped, exponential decay curve (no perturbation); good test
1507	Remove large slug rod out of well.
1512	D/B = 131.4′ btoc outer casing, so D/B = ~~FE8~~ DRN 127.8′ bss; 4″ hasn't
	silted in anymore since end of test #2.
1514	Slug injection test #5; small slug rod; good test, overdamped response.
	$H_{o_{calc}} = 2.24'$ inside 4″ I.D. casing and $0.195 ft^3$ volume.
1531	Slug withdrawal test #6; small slug rod fully submerged
	overdamped test responce; good test
1545:10	Packer integrity test - began pouring 5 gal down annulus between inner
	and outer casing
1545:45	End pouring No response - looks good.

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 10/23/07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 10/23/07

Well ID: 399-4-14

Test/Depth Interval: 120-128.2 ft bgs

Borehole ID: C5707

2 NOTE: Test interval changed after screen silted in

Time: **Field Notes:**

1548 Turn logger off

1550 D/B = 131.0' btoc (outer casing); so D/B = 131.0-3.6 = 127.4' bgs

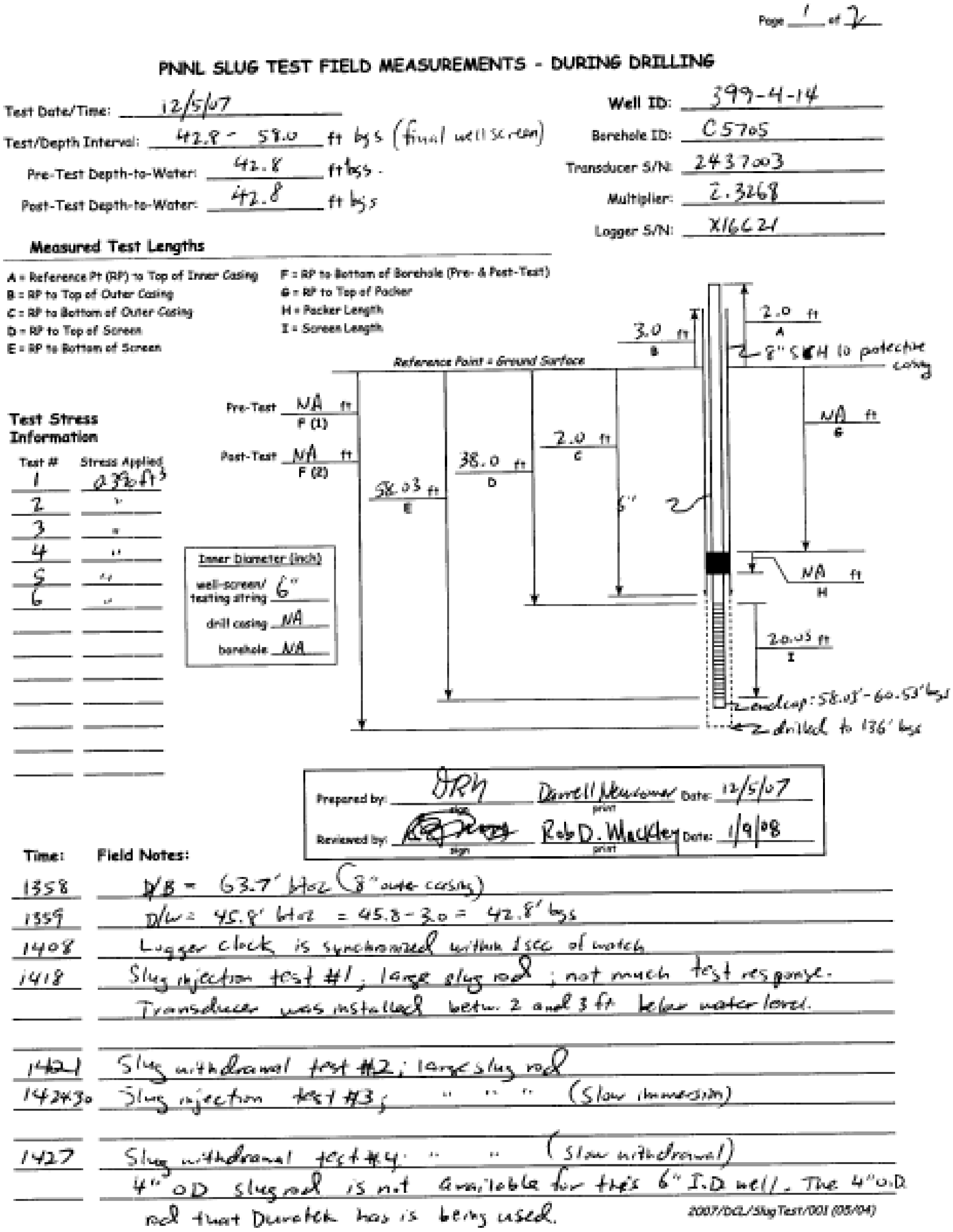
1552 D/W = 46.5' btoc " ", so D/W = 46.5'-3.6' = 42.9' bgs

Download data to file CR10X_X16621_399-4-14_120-128ft.dat

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 10/23/07

Reviewed by: (sign) Rob Mackley (print) Date: 1/9/08

Well 399-4-14, Final, Completed Well-Screen Section



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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 12/5/07
Test/Depth Interval: 42.8 - 58.0 ft bgs (final well screen)
Pre-Test Depth-to-Water: 42.8 ft bgs.
Post-Test Depth-to-Water: 42.8 ft bgs

Well ID: 399-4-14
Borehole ID: C5705
Transducer S/N: 2437003
Multiplier: 2.3268
Logger S/N: X16621

Measured Test Lengths

A = Reference Pt (RP) to Top of Inner Casing
B = RP to Top of Outer Casing
C = RP to Bottom of Outer Casing
D = RP to Top of Screen
E = RP to Bottom of Screen
F = RP to Bottom of Borehole (Pre- & Post-Test)
G = RP to Top of Packer
H = Packer Length
I = Screen Length

Test Stress Information

Test #	Stress Applied
1	0.320 ft^3
2	"
3	"
4	"
5	"
6	"

Inner Diameter (inch)
well-screen/testing string: 6"
drill casing: NA
borehole: NA

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 12/5/07
Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

Time:	Field Notes:
1358	D/B = 63.7' btoc (8" outer casing)
1359	D/W = 45.8' btoc = 45.8 - 3.0 = 42.8' bgs
1408	Logger clock is synchronized within 1 sec of watch
1418	Slug injection test #1; large slug rod; not much test response.
	Transducer was installed betw. 2 and 3 ft below water level.
1421	Slug withdrawal test #2; large slug rod
142430	Slug injection test #3; " " " (slow immersion)
1427	Slug withdrawal test #4. " " (slow withdrawal)
	4" OD slug rod is not available for this 6" I.D well. The 4" O.D rod that Duratek has is being used.

2007/DCL/SlugTest/001 (05/04)

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PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING (continuation sheet)

Test Date/Time: 12/5/07

Test/Depth Interval: 42.8'-58.0' ft bgs

Well ID: 399-4-14

Borehole ID: C5705

Time:	Field Notes:
143028	Slug injection test #5 ; large slug rod ; let line go slack and dropped rod very quickly.
1432	Slug withdrawal test #6 ; large slug rod not much test response.
	Download data and save to file CR10X_X16621_399-4-14-43-58ft.dat

Prepared by: DRN (sign) Darrell Newcomer (print) Date: 12/5/07

Reviewed by: (sign) Rob D. Mackley (print) Date: 1/9/08

2007/DCL/SlugTest/002 (04/04)

Appendix B

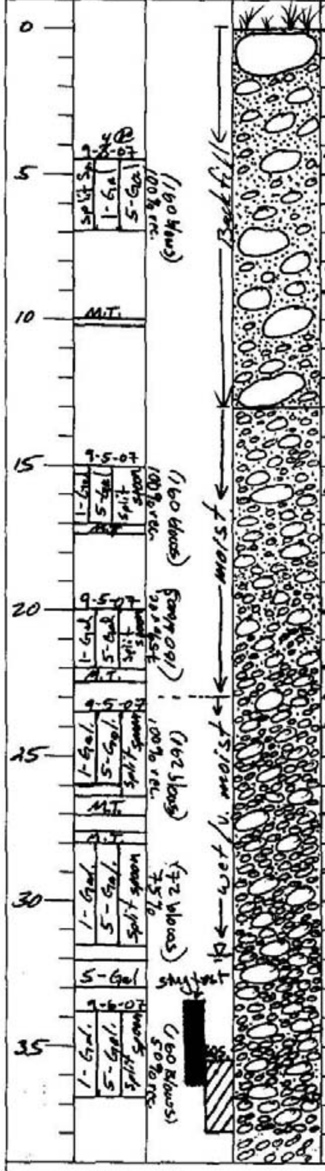
Borehole Logs for Wells 399-2-5, 399-3-22, and 399-4-14

BOREHOLE LOG

Page 1 of 4
Date: 9-3-07

Well ID: C5708
Well Name: 399-2-5
Location: 300-FF-5 Operable Unit
Project: 300 Area TCE Characterization
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level



Sample Description

0 - ~13': Sandy Gravel backfill
Poorly sorted with 60-70% f-vc angular felsic-dominated sand and 25-35% pebbles, cobbles and boulders (boulder present from ~0.1' to ~0.6' bgs). No rxn with HCl. ≤ 5% silt present (minor). Soil is olive brown (2.5Y, 4/4).

~13' - ~23': Sandy Gravel (sG)
Poorly sorted, sl. moist & v. dark grayish brown (2.5Y, ~~4/2~~ 3/2) with up to 80% sub-angular v. fine to v. coarse pebbles & cobbles (≥ 70% basalt). No rxn with HCl. < 20% m - vc sub-angular sand (basalt-dominated) with abundant zones of oxidation.
~20' m-f sand fraction increases m-f sand is generally oxidized & felsic-dominated.

~23 - 42 : sandy gravel / Gravel
Mod. sorted with > 80% basalt-dom. sub-ang. to sub-round pebbles & small cobbles ~ 15% m-vc ang. to sub-ang. sand (coarse sand is basalt-dom., med. & sparse fine sand is felsic-dom. [> 70% c-vc sand]) & ~ 5% pale olive (5Y, 6/4) silt is present (secondary clay). No rxn with HCl, max = 10-15 cm. Clast supported, very loose.
~30' matrix decreases, gravel below water table is washed clean with only a pebble matrix.

39' - coarse sand matrix, sG, heterolithic cobbles to 2.5", well-rounded.
- sand is very dark (mafic)

Comments

Cable tool drilling with drive barrel, advancing 11¾" casing.

Geologic archive samples at approx. 5' intv. (A.S.) (A.S. samples at: 5, 10, 15, 20'

Split spoon from 4.5' to 7.0' bgs (slough 4.5-5.0) HEIS # B1PL45 (160 blows). 1-Gal. & 5-Gal grab samples collected @ 4.5-7.0' bgs (post-S.S. cleanout).

Moisture tin sample @ 10' bgs (M.T.) # B1PL27

Split-Spoon @ 15-17' bgs HEIS # B1PL46
1-Gal. & 5-Gal. G.S. @ 15-17' bgs.
M.T. sample @ ~17' bgs (taken from S.S. shoe). HEIS # B1PL28

Split-spoon 20-22.5' bgs HEIS # = B1PL47
M.S. @ 22'-22.5' bgs (shoe of split-spoon) # B1PL29
1-Gal. & 5-Gal G.S. 20'-22' bgs

Split spoon 23.5-27' bgs HEIS # B1PL48
M.T., 1 & 5 gal. bucket samples 23.5-26' bgs M.T. # B1PL30

Split-spoon 28-31.5 (slough 28-30) # B1PL49
M.T. @ 30' bgs (b/f S.S.) # B1PL31.

5-gal. bucket sample @ 32-33'

DTW = 31.8' bgs (9-5-07)

Reported By: J Horner
Title: Geologist
Signature: John H
Date: 9/6/07

Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12-13-07

A-6003-642 (03/03)

BOREHOLE LOG

Page 2 of 4

Date: 9-6-07

Well ID: C5708

Well Name: 399-2-5

Location: 300-FF-5 OU

Project: TCE Characterization, 300 Area

Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
40				40-42: sandy gravel (sG), v. coarse	Split spoon 33.8'-36.8'
	5 gal grab 1 gal grab split spoon	160 blows 75% recovery		mafic sand matrix, well-rounded	160 Blows, 50% rec.
				heterolithic cobbles to 3", poorly	HEIS#BIPL50
				sorted	1-Gal. & 5-Gal grabs
				42-44.9' v. coarse sand (S), v. dark,	33.8-~36.8' bgs
45	5gal grab 1gal grab split spoon	160 blows		~ 40% mafic clasts, 60% qtz clasts,	
				sparse heterolithic cobbles to 2",	Water sample (pumped) from
		water sample		well rounded, well-sorted, salt	35.5' bgs to 37' bgs (slough
	5gal grab split spoon			& pepper texture	present 35'-37' bgs). No
				46.9-47.4': massive silt, tan-colored,	packer or screen used.
50	5 gal grab split spoon			dense, abundant clay, no cobbles	HEIS# BIPL94.
				47.4-53: very coarse salt & pepper sand	
				with sparse cobbles, ~40% mafic	split spoon 40.8'-43.8'
				clasts, 60% qtz, no HCl reaction,	160 blows, 75% recovery
	5 gal + 1 gal grabs			poorly well-sorted, cobbles to 3"	HEIS # BIPL51
55				53-56: sandy gravel (sG), v. coarse mafic	1 gal + 5 gal grabs
				sand (65%), heterolithic cobbles to	
				2.5" (35%), well-rounded, poorly	DTW = 33' (9-12-07)
				sorted.	
				56-60.5': massive silt unit (Ringold?),	split spoon 44.4-47.4'
60				medium tan, well-consolidated,	160 blows, 100% recovery,
				wkly plastic, no HCl reaction	HEIS # BIPL52
				60.5-66: massive silt unit as above,	
				color = dark green/grey	pumped water sample, 47-49'
				66-69: medium gray-green sand,	HEIS #s BIPL95, BIPL68,
65				well-sorted, no cobbles, mostly	BIPL71, no packer or screen
		W.S.		qtz, some micas	
				-71' dark gray (Gley 1, 4/N)	split spoon 49.5-52.5'
					160 blows, 75% recovery
				-72-73 fine pebbles present.	HEIS # BIPL53
70		W.S. S.T.			Pumped water sample from
				73'-103': Sandy Gravel (sG)	66-69' bgs (slough 67-69')
				Mod. sorted & v. dark gray (Gley, 3.5/N) with	HEIS# BIPL97
	9-18-07 Split Spoon BIPL54			~60% sub- to well-rounded vf-vc mafic-	1-Gal grab @ 73-75'; not
				dominated pebbles & ~40% m-c sub-ang.	enough recovery for 5-Gal.
75	100% rec 246 blows			felsic-dominated sand (?80% felsic,	grab sample.
				mostly qtz & <20% mafic). Sand matrix	Pumped w.s. from 70'-75'
				is the same as sand above, only	bgs (screened 70-73.4'; slough
				slightly more coarse. Some trouble	from 73.4'-75' bgs)
				with sand heaving near contact.	HEIS # BIPL97 (I-21).

Reported By: Michael E. Caron / J. Horner

Reviewed By: L.D. Walker

Title: Senior Geologist / Geologist

Title: Geologist

Signature: MEC / John Horner

Date: 9-20-07

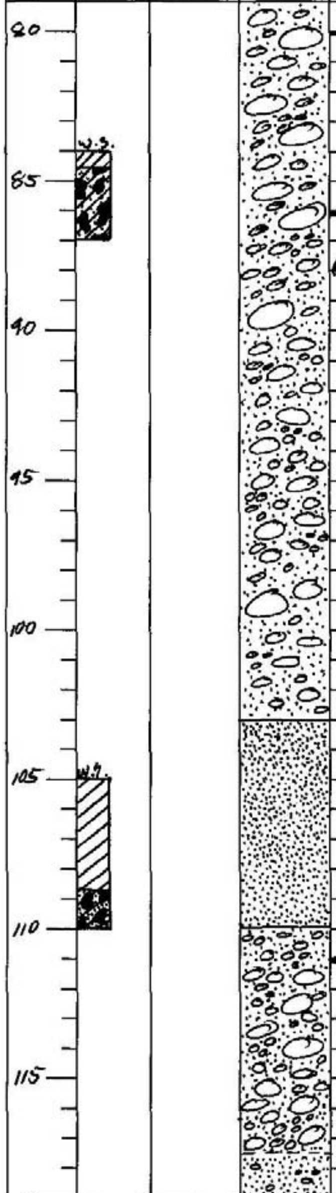
Signature:

Date: 12/13/07

BOREHOLE LOG

Page 3 of 4
Date: 9-20-07

Well ID: C5708
Well Name: 399-2-5
Location: 300-FF-5 OU
Project: 300 Area TCE Characterization
Reference Measuring Point: Ground Surface



Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
73' - 103': Sandy Gravel (SG)	split spoon 73-75'
-description on pg #2	246 blows, 100% rec.
JH 9-24-07	HEIS # B1PL54
- ~~100~~ heaving sand, started	
103' adding water	w.s. ~~85~~ JH 84'-87' bgs
	screen 84'-84.5', slough
103'-110': Sand (S)	84.5'-87' bgs. HEIS# B1PL99
well-sorted medium felsic-dom	Grab samples (G.S.).
(60-70% felsic) sub-ang sand.	G.S. @ 80', 85', 95',
	100', 105', 110' & 115' bgs. JH
	Pumped w.s. 105'-110'
	screen to 108.7', slough
	108.7' to 110'.
	HEIS # B1PLB0
110'-117': Sandy Gravel (SG)	
Mod. sort. with 50-75%	
pebbles & cobbles & 25-50%	
med.-coarse sand (~60% felsic)	
-117'-120' heaving m-c sand	
& pebbles (60-70% felsic)	

Reported By: J. Horner
Title: Geologist
Signature: John Horner
Date: 9-26-07

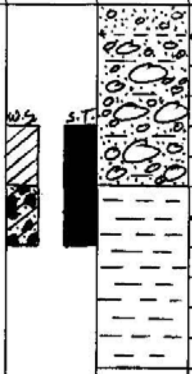
Reviewed By: L. D. Walker
Title: Geologist
Signature: L D Walker
Date: 12/13/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 4 of 4
Date: 9-26-07

Well ID: C5708
Well Name: 399-2-5
Location: 300-FF-5 OU
Project: 300 Area TCE Characterization
Reference Measuring Point: Ground Surface



Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
120				117'-120': Silty Sandy Gravel	Archive / Grab samples
				Same as gravel above, with	collected @ 120', ~~125~~,
				increased silt.	126-127, & 130' bgs
	W.S.	S.T.			Pumped w.s. 123-127'
					bgs, screen from
125					123-127, but tagged
				125'-131': Silt (M) RLM	top of sediment @
				Well-sorted & dark greenish gray	125' bgs after sampling
				Gley1 (4, 5G) clay	HEIS # B1PLB1
				-130' clay is very dark gray	
130				(2.5Y, 3.5/1)	Slug test with
					the same setup
					above for w.s.
					123-127, slough 125-127.
135					
140					
145					
150					
155					

Reported By: J. Horner
Title: Geologist
Signature: Tyler Horner
Date: 9-28-07

Reviewed By: L.D. Walker
Title: Geologist
Signature:
Date: 12/13/07

BOREHOLE LOG

Page 1 of 4
Date: 10-31-07

Well ID: C5706
Well Name: 399-3-22
Location: 300-FF-5 OU
Project: 300 Area TCE Investigation
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
0				0-0.5: Crushed gravel from	Cable tool drilling
				old road.	with 11¾" casing
				0.5-1.0: Silty sandy gravel (msG)	& drive barrel.
				Poorly sorted w/ 60% f-vc ang.	
				sand, 15-20% small to large	Archive grab samples @:
5				cobbles & 15-20% silt.	1', 5', 9.5', 15, 16-17, 20,
					23.5, 24.5, 25, 30, & 35' bgs.
				1.0-2.0: Silty Sand (mS)	Moisture Tin (M.T.)
				well-sorted, moderately consolidated	sample @ 9.5' bgs
	M.T.			& light ol. brown (2.5Y, 5/4) with	HEIS #B1PL33
10				~75% vf-m felsic-dom. sand & ~25%	
				silt. No rxn with HCl. sl. moist.	M.T. @ 15' bgs, B1PL34
		Dry			
				2.0-16': Silty Sandy Gravel (msG)	
				Poorly sorted & lt. yellowish brown (2.5Y, 6/4)	
15	M.T.			with 50-70% sub-ang. pebbles &	
		sl. moist		cobbles (>70% basalt), ~20-30% vf-	
				vc ang. sand (fine sand is felsic-dom,	
				m-vc sand is >60% basalt) with	M.T. @ 20' bgs, B1PL35
				>20% silt. No rxn with HCl. max.	
20	M.T.			cobble is ~25 cm. Unconsolidated.	*Boulder from 14'-16' bgs
				· ~6' color changes to gray (2.5Y, 5.5/1)	
				16-~~18'~~ 19': Silty Sandy Gravel (msG)	← 11-1-07
		sl. moist		Poorly sorted, well-consolidated with	
	M.T.			70-80% basalt-dom. pebbles/cobbles	M.T. @ 24' bgs, B1PL36
25				10-15% f-vc ang. basalt-dom.	
				sand & 10-15% lt. yellowish brown	
				(2.5Y, 6/4) sl. moist silt. Top of	
				unit (@ 16' bgs) has a strong rxn	
				with HCl, which decreases to	
30	M.T.			mod. to weak @ ~17' bgs	M.T. @ 30' bgs, B1PL37
				19'-23.5: Sandy Gravel (sG)	← 11-1-07
				Poorly sorted, unconsolidated & dk. gray	
				(2.5Y, 4/1) with ~60%-70% sub-ang.	M.T. @ 35' bgs, B1PL38
				to-ang basalt-dom. pebbles & small	
35	M.T.			cobbles (60% of gravel is 2-5mm &	Split-spoon 37' to 40' bgs
		v. moist		bulk is >80% basalt, max is ~15cm)	125 blows 65% rec. 11-1-07
	37'-40'			& 30-40% m-vc angular sand (>75%	HEIS # B1PL55
	Hand split spoon	125 bl. 65% rec.		basalt) & ≤10% vf-f sand & silt	Recovery from ~~37'-39'~~
				(>50% felsic) no rxn with HCl. Sl. moist.	11-15-07 37'-39'

Reported By: J. Horner
Title: Geologist
Signature: John Horner
Date: 11-1-07

Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/13/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 2 of 4
Date: 11-1-07

Well ID: C5706
Well Name: 399-3-22
Location: 300-FF-5 OU
Project: 300 Area TCE Investigation
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
40 45 50 55 60 65 70 75				**23.5 - 25.0: Silt / Sandy Silt** w/an well-consolidated lt. yellowish brown (2.5Y, 6/4) silt with irregular stringers & hardened nodules of oxidized yellowish brown (10YR, 5/6) silt. ~24' silt transitions to sM with the presence of v. fn. sand. No rxn with HCl. **25.0'-355': Sandy Gravel (sG)** Same as gravel above silt layer on page #1. **35.5'-43.0': Silty Sandy Gravel (msG)** Poorly sorted & unconsolidated. Same as gravel above, but with extensive weathering & secondary clay. Abundant ol. brown (2.5Y, 5/5) clay on pebble & cobble surfaces. **43.0-45.0: Silty Gravel (mG)** ~2' of well-consolidated silt/clay gravel above water table. Silt is light yellowish brown (2.5Y, 6/3) ~50% G, ~40% M, ~10% S **45.0'-63.5: Sandy Gravel (sG)** Poorly sorted & unconsolidated with minor heaving of small pebbles & coarse sand. >60% sub- to well-rounded pebbles & small cobbles (~60% heterolithic ~40% basalt) with <40% med-v. coarse ang. basalt-dom. sand. Trace fine & med. sand is felsic-dominated. <1% silt no rxn with HCl. **63.5-72.5: Sandy Silt (sM)** Well-consolidated lt. d. grayish brown (2.5Y, 5/2.5) with ~75% silt & ~25% v. fine felsic sand.	Split spoon 39.5'-42.5' 160 Blows, 75% rec. HEIS# B1PL56 1-Gal. G.S. ~41-43' DTW = 44.3' bgs (11-5-07) Split spoon 42.7-45.7' 310 blows, 100% rec. HEIS# B1PL57 1-Gal G.S. ~43-45' Archive samples @ 40, 45, 50, 55, 60, 63.5, 66, @ 70 & 75' bgs & Capillary fringe JH 11-5-07 Pumped w.s. 48-50' slough 48.5-50' bgs HEIS# B1PLB2 Pumped w.s. 53.5-55.0' HEIS# B1PLB3 Slug testing 53.5-55.0' Split Spoon 55.5'-58.5' 346 blows, 60% rec. HEIS# B1PL58 Pumped w.s. 62.5'-64' No open hole, slough from 62.0' to 64' bgs HEIS# B1PLB4, Split spoon 62.5-65' slough 62.5-64', bottom 1½" liner captured silt. HEIS# B1PL59 1-Gal grab sample of silt 62.5-65 (64'-65'). Split spoon 65.3'-67.8' HEIS# B1PL60

Reported By: J. Horner
Title: Geologist
Signature: John Horner
Date: 11-8-07

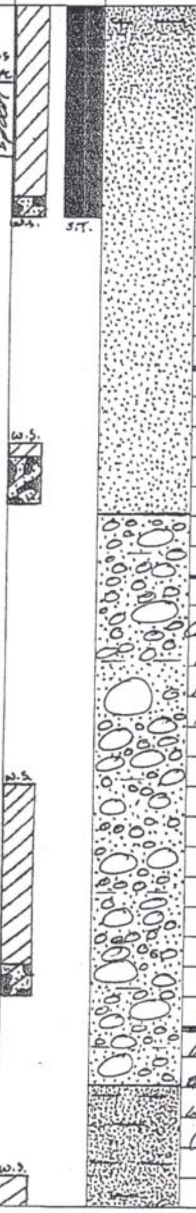
Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/13/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 3 of 4
Date: 11-8-07

Well ID: C5706
Well Name: 399-3-22
Location: 300-FF-5 OU
Project: 300-Area TCE Investigation
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
80	86 blows 100% rec			- @ 69.5' sediment is reduced	Split spoon @ 81.5-84.0'
				and is greenish gray (Gley 2, 4/5GB)	86' blows, 100% rec
	1-Gal.	Split spoon			HEIS # B1PL61
				72.5' - 80.0: Silty Sand (mS)	Soil VOA HEIS# B1R25
				well sorted & greenish gray (Gley 2, 4/5GB)	
85				& consolidated with ~90% felsic-	Pumped w.s. 72.5'-86.0'
				dominated (>90% felsic) sand &	screened 77.5-85.6' bgs
				~10% silt. Silt fraction gradually	slough 85.6 - 86.0' bgs
				decreases & sand grainsize	HEIS# B1PLB5 &
				gradually increases with depth.	Duplicate - B1PLC9
90					Archive grab samples
				80'-96': Sand (S)	@ 80, 89.5, 95, 100, 105,
				well-sorted, consolidated (wk) &	109, & 112-119' bgs
				greenish gray (Gley 2, 5/5GB) with	Slug test @ 77.5-86'
				100% ang. felsic sand (90% felsic)	screen filled in to 79.7'
95				Sand is medium, increasing to	prior to slug testing.
				med/coarse @ 95' bgs.	
					Pumped w.s. 93.5'-95.5'
				96'-115': Sandy Gravel (sG)	screened 93.5 - 94.0' &
				Poorly sorted with >75% basalt-	slough 94.0 - 95.5' bgs
100				dominated pebbles & cobbles, ~20%	HEIS# B1PLB6
				m-vc ang sand. medium sand	
				is felsic-dominated c-vc sand	Switched to hand tools
				is mafic-dominated with ≥5% M.	@ [illegible] 11-12-07 96' bgs.
				- minor heaving from 101'-103'	
105				- minor heaving from 106'-107'	Pumped w.s. 105'-112'
					w/ screen 105'-111' bgs
					& slough 111'-112' bgs
					HEIS # B1PLB7
110					
				115'-120': Sand (S)	
				well-sorted weakly consolidated	
115				& very dark greenish gray (Gley 1, 3/1)	
				with ≥90% very fine felsic sand	
				(~99% felsic) with ≤10% silt.	

Reported By: J. Horner
Title: Geologist
Signature: John Horner
Date: 11-13-07

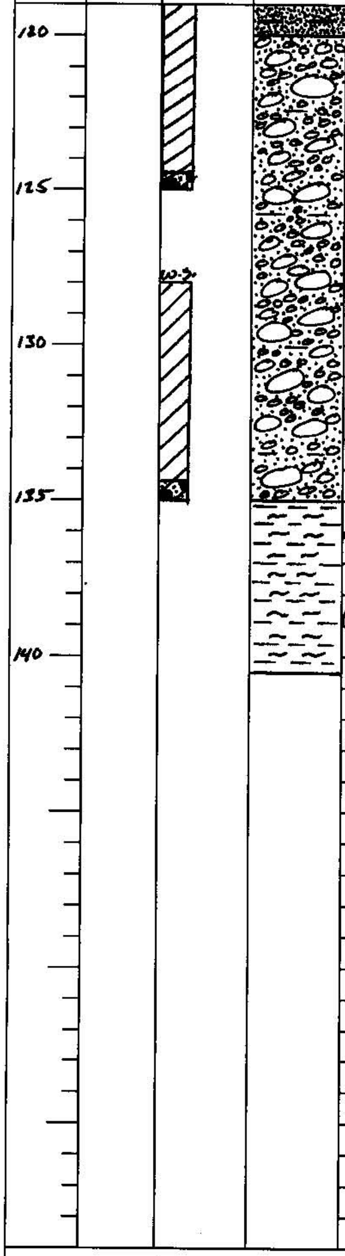
Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/13/07

BOREHOLE LOG

Page 4 of 4
Date: 11-13-07

Well ID: C5706
Well Name: 399-3-22
Location: 300-FF-5 OU
Project: 300 Area TCE Investigation
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample: Type No.	Sample: Blows Recovery	Graphic Log	Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level



120-135: Silty Sandy Gravel (msG) poorly sorted & consolidated with 60-75% angular to sub-rnd. pebbles & cobbles (basalt-dominated ~60% basalt), 15 to 30% m-vc ang. felsic-dominated sand & ~~[illegible]~~ @ 11-15-07 10-15% very dark gray silt (Gley 1, 3/N). No rxn with HCl.

135-140.5: Silt (M) RLM
Well-sorted, well-consolidated massive silt. Dark greenish gray (Gley 1, 5/5G) with medium plasticity. Trace of v. fine sand present. Hard tool bit is caked with large chunks of clay.

Total depth = 140.5' bgs

Pumped w.s. 118'-125'
Screened 118-124.5 w/ slough 124.5-125' bgs

Pumped w.s. 128'-135'
Screened 128-134.5' w/ slough 134.5'-135' bgs

Archive grab samples collected @ 125', 135, & 140' bgs

Reported By: J. Horner
Title: Geologist
Signature:
Date: 11-15-07

Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/13/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 1 of 4
Date: 10-8-07

Well ID: C5707
Well Name: 399-4-14
Location: 300-FF-5 OU
Project: 300 Area TCE Characterization
Reference Measuring Point: Ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
0				0-0.1': concrete parking lot	Cable tool drilling
					with drive barrel
				0.1'-3.5': Sandy Gravel (SG)	& 11¾" casing
				Mod. sort. & dark grayish brown with	
				50-60% sub-rounded pebbles & cobbles	Grab samples (archives).
5				& 40-50% m-c ang. sand (~70% iron-	collected @ 2', 4', 10',
				stained felsics, ~30% basalt). No rxn	15, 25, 27, 30, & 35' bgs
				with HCl (Extremely wk), max cobble	Moisture tin (M.T.)
				is ~25 cm, unconsolidated (2.5Y, 4/2)	sample @ 10' bgs
					HEIS # B1PL39
10	M.T.			3.5'-7.5': Sand (S)	
				~~Poorly~~ Mod. sorted olive brown (2.5Y, 4/4)	M.T. @ 15' # B1PL40
				sand (100%). sand is vf-vc with	
				>80% iron-stained felsics ~20%	M.T. @ 20' # B1PL41
				basalt. No rxn with HCl.	
15	M.T.			~5' some small pebbles present	
				~7' irregular stringers of very	Likely a paleosol @ the
				pale brown (10YR, 7/3) CaCO3	top of gravel deposit.
				clay, mainly present on pebble	
		moist		surfaces very strong rxn w/ HCl.	
20	M.T.			lt brown clays are also present.	
				7.5'-27': Sandy Gravel (SG)	M.T. @ 25' # B1PL42
				Poorly sorted with 80% vf-vc pebbles	
				cobbles & small boulders, sub-round	
				to sub ang. basalt-dominated with	
25	M.T.	v. moist		~20% m-vc ang. basalt-dom. sand	(>80% coarse/v. coarse)
				<5% silt present on pebble/cobble	
	M.T.			surfaces. CaCO3 rich clay mentioned	
				above continued into gravel to ~8.5'.	M.T. @ 27' # B1PL43
	1-Gal. Split-Spoon	90% 153 bl. wet		~15' silt fraction up to 5-10%	split spoon 28'-31' bgs
30				fine sand also increases, still	M.T. @ 31' bgs taken
	M.T.			~80% gravel.	from s.s. shoe.
	1-Gal. Split-Spoon	65% rec 128 bl.		~24' very moist, almost wet	S.S. # B1PL62
				with lt. brown silt hold-	M.T. # B1PL44
	M.T.			ing the moisture.	1-Gal G.S. 28-31 @ cleanout.
35	1-Gal. Split-Spoon	137 bl. 65% rec		~27'-43': Silty Sandy Gravel (msG)	← v. moist/almost wet
				Poorly sorted with 70-80% rounded	S.S. from 31'-34' bgs
	M.T.			pebbles & cobbles with ~10-15%	HEIS # B1PL63
				c-vc ang. basalt-dom. sand & 10-	M.T. @ 34' bgs # ~~B1PL45~~ B1R086
				15% lt. brown-ol. brown silts	1-Gal. G.S. 31-34' bgs.

Reported By: J. Horner
Title: Geologist
Signature: John H
Date: 10-9-07

Reviewed By: L. D. Walker
Title: Geologist
Date: 12-17-07

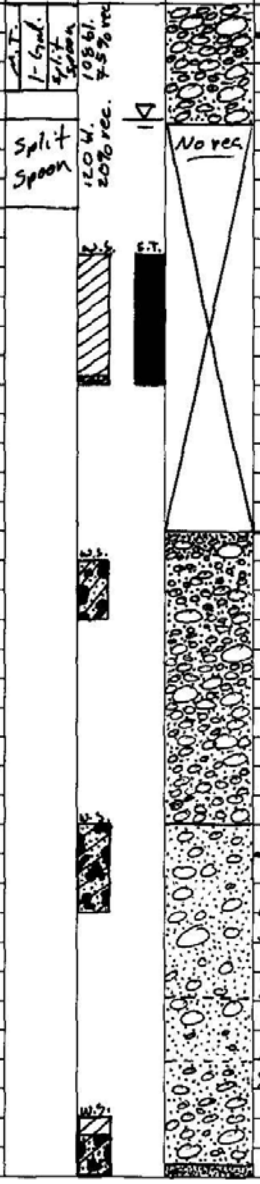
A-6003-642 (03/03)

BOREHOLE LOG

Page 2 of 4
Date: 10-9-07

Well ID: C5707
Well Name: 399-4-14
Location: 300-FF-5 OU
Project: 300 Area TCE Investigation (07)
Reference Measuring Point: Ground Surface

Sample: Type No. / Blows Recovery; Graphic Log



Depth (Ft.)	Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
40	27'-43': Silty Sandy Gravel (msG)	split spoon 34-37' bgs
	cont. from page #1. clast dom-	HEIS # B1PL64
	inated, unconsolidated. Combined	137 blows 65% rec.
	sand & silt fraction ranges from	M.T. @ 37' bgs #
	10-30% (G to msG).	1-Gal G.S. 34'-37' bgs
45	- below 27', sediment is	* DTW = 43.1' bgs (10-9-07)
	visibly wet, but not dripping.	Split spoon 39-42' bgs
	- split spoon from 43-46' bgs	HEIS # B1PL65
	contained washed pebbles &	75% rec. 108 blows
	cobbles with only ~20% rec.	M.T. 39'-42' # B1R088
50	- No recovery with cleanout	1-Gal G.S. 39-42' bgs
	from 43' bgs to 57' bgs. Based	
	on split spoon sediment within	Split spoon 43'-46'
	this interval likely consists of	HEIS # B1R089
	loose rounded pebbles & cobbles	120 blows ~20% rec.
55	with a coarse sand & pebble	~~1-Gal G.S. @~~ No recovery JH 10-10-07
	matrix.	
	57'-67': Sandy Gravel (sG)	Pumped w.s. 47.6'-52' bgs
	Poorly sorted with >70% pebbles	slough 51.7'-52.0' bgs
	& cobbles & <30% vf-vc sand.	screen 41.7'-51.7' bgs
60	c-vc sand is basalt-dominated	HEIS # B1PLC0 (I-10)
	& vf-m sand is felsic-dom.	Slug test 47.6 ~~51.7~~ bgs 51.5' bgs
	- 58'-60' bgs having trouble	
	with sand & fine pebbles heaving.	Pumped w.s. 58'-60' bgs
	f-m sand & trace silt seen	Drilled to 60', casing @
65	@ 57' not present in sediment rec-	56' bgs. tagged @ 57'.
	overed from 58-60' bgs.	HEIS # B1PLC1 (I-12)
	67'-73': Sandy Gravel (sG)	Pumped w.s. 67'-70'
	Poorly-sorted overall with a	Drilled to 70' casing
70	well-sorted sand matrix. ~60%	to 67' tagged @ 67' bgs.
	sub- to well-rounded hetrolithic	HEIS # B1PLC2 (I-13)
	pebbles & cobbles (>85% metamorphics	
	& igneous & <15% basalt). Matrix (40%)	Pumped w.s. 77'-79' bgs
	consists of well-sorted ang.- to sub-ang.	slough from 77.5-79' bgs.
75	med. felsic sand (>80% felsics, <20	HEIS # B1PLC3 (I-14)
	% mafics with very little basalt.	Archive samples @ 40, 43, 57,
	Color is gray (2.5Y, [illegible]/1).	58-60, 64.5, 67, 70, 75, & 76' bgs
	- 70' same as above, but weakly	solid core, but was
	consolidated (sample came out as	easily broke up by hand).

Reported By: J. Horner
Title: Geologist
Signature: Julie H
Date: 10-12-07

Reviewed By: L. D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/17/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 3 of 4

Date: 10-11-07

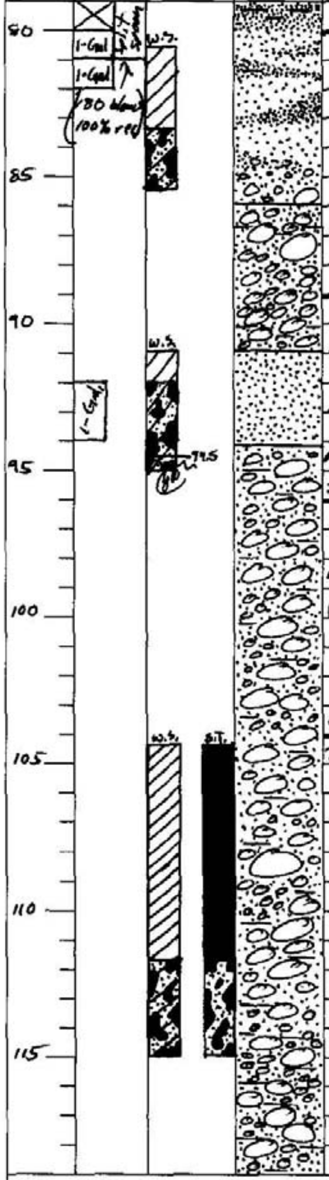
Well ID: C5707

Well Name: 399-4-14

Location: 300-FF-5 OU

Project: 300 Area TCE Investigation (07)

Reference Measuring Point: Ground Surface



Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
73'-75': Sand (S)	~~Slough~~ JH 10-11-07
well-sorted & gray (2.5Y, 5/1) with	
~98% ang- to sub-ang. med-coarse	Split spoon 78.5'-81'
felsic sand (>80% felsic, ≤20%	Looks like sand from
mafics with very little basalt).	above 78.5 heaved in
Sand is very similar to matrix	before sampling. 180 blows
sand from gravel above, both	100% could all be
have abundant micas (<5%). ~2%	slough, see FAR notes
f-m heterolithic pebbles.	for 10-12-07.
75'-78.5': Sandy Gravel (sG)	HEIS #B1PL66
Same as sG above sand layer.	1-Gallon bucket
Had some trouble with sand	samples @ 80'-81' bgs
heaving while drilling gravel. Could	and 81-82' bgs.
have been matrix separating from	Pumped w.s. 80.5-85.5' bgs
gravel (?).	~~slough~~ JH screen 80.5-83.5 &
10-12-07	slough 83.5'-85.5' bgs
78.5-85.5': Sand (~~100%~~ JH) (S)	
v. well sorted consolidated dark	Pumped w.s. 91'-94.5' bgs
greenish gray (Gley 1, 4/10GY) with	screen to 92' bgs slough
>90% angular vf-f felsic sand	92'-94.5' bgs. HEIS #
(98% felsic) with <10% silt.	B1PLC5.
~80' grain size increases to m-c.	*Switched to hard
Several lenses of f-vf sand	tools @ ~~105'~~ 95' bgs JH 10-19-07
still present.	Pumped w.s. 104.5-115' bgs
85.5'-91': Sandy Gravel (sG)	Exposed screen 104.5-111.7'
Mod-sorted with ~50-75% well	slough 111.7' to 115' bgs.
rounded heterolithic pebbles &	HEIS # B1PLC6
small cobbles, & 25%-50% f-vc	· Slug test of the
ang. felsic sand (>80% ~~[illegible]~~ JH m-c,	same intv.
>90% felsic & dark greenish gray,	
Gley 1, 4/5G). Thin gray silt	Archive samples @
lenses present @ ~86' bgs &	78.5-79', 80', 85', 89',
90' bgs.	91-92', 93', 100', 105', 110',
91'-94': Sand (S) 100% 10-18-07	& 115' bgs
v. well-sorted v. angular m-vc JH	
v. dark greenish gray felsic (>85%)	
sand.	
~92'- drastic color change from	
green to lt. greenish gray	
(Gley 1, 6/N).	

Reported By: J. Horner

Title: Geologist

Signature: John Horner

Date: 10-22-07

Reviewed By: L.D. Walker

Title: Geologist

Signature: LD Walker

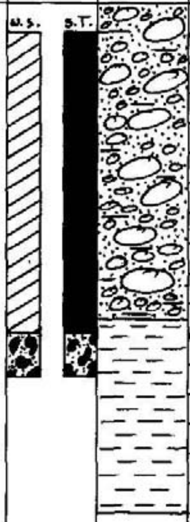
Date: 12/17/07

A-6003-642 (03/03)

BOREHOLE LOG

Page 4 of 4
Date: 10-22-07

Well ID: C5707
Well Name: 399-4-14
Location: 300-FF-5 OU
Project: 300 Area TCE Investigation, 2007
Reference Measuring Point: Ground Surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
120		w.s. s.T.		94'-129.5': Silty Sandy Gravel (msG)	Hard tool drilling
				Poorly sorted, very dark gray	(cable tool)
				(Gley 1, 3/N), & consolidated	Pumped w.s. 120'-131.5'
				with 50-70% ang. to well-	Exposed screen from
				rounded mafic-dom. pebbles &	120' to 130' bgs, slough
125				cobbles (>50% basalt), 30-40%	from 130' to 131.5' bgs.
				m-c, angular felsic-dom. sand	HEIS # B1PLC7 (I-19).
				(50-75% felsic) & 15-20% silt.	
				no rxn with HCl.	Slug test on 10-23-07
					with same setup
130				129.5'-136': Silt/clay (RLM)	as w.s. described above.
				Well-sorted massive silt.	
				Dark greenish gray (Gley 1, 5/5G)	Archive samples @ 120',
				medium plasticity. Trace of	125', 130', & 135' bgs
				v. fine sand is present.	
135				*note: sample taken from clay	
				on hard tool bit.	
				TD = 136' bgs	
140					
145					
150					
155					

Reported By: J. Horner
Title: Geologist
Signature: Julie Horner
Date: 10-24-07

Reviewed By: L.D. Walker
Title: Geologist
Signature: LD Walker
Date: 12/17/07

A-6003-642 (03/03)

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