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Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16

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To M.E. Byrnes

From F.A. Spane and D.R. Newcomer

Subject Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16

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The following draft letter report presents test descriptions and analysis results for multiple, stress-level slug tests that were performed at selected test/depth intervals within three Operable Unit (OU) ZP-1 wells: 299-W11-43 (C4694/Well H), 299-W15-50 (C4302/Well E), and 299-W18-16 (C4303/Well D). These wells are located within south-central region of the Hanford Site 200-West Area (Figure 1.1). The test intervals were characterized as the individual boreholes were advanced to their final drill depths. The primary objective of the hydrologic tests was to provide information pertaining to the areal variability and vertical distribution of hydraulic conductivity with depth at these locations within the OU ZP-1 area. This type of characterization information is important for predicting/simulating contaminant migration (i.e., numerical flow/transport modeling) and designing proper monitor well strategies for OU and Waste Management Area locations.

For ease in referencing results for the OU ZP-1 field testing program within the letter report, the following outline is provided:

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1. Executive Summary

Overall, the test results obtained from multiple, stress-level slug tests conducted during drilling and borehole advancement provide detailed information concerning the vertical distribution of hydraulic conductivity at three Hanford Site Operable Unit (OU) ZP-1 test well locations. The individual test/depth intervals were generally sited to provide hydraulic property information within the upper, middle, and lower sections of the unconfined aquifer (i.e., Ringold Formation, Unit 5). These characterization results complement previous and on-going drill-and-test characterization programs at surrounding 200-West and -East Area locations (e.g., Spane 2003, 2005).

Analysis of the slug test results indicate a relatively wide-range in the calculated average, test interval hydraulic conductivity (Table 5.2), with estimates ranging between 0.04 and 24.8 m/day. The ZP-1 well hydraulic conductivity estimates were derived for test interval sections that ranged from 2.29 to 3.05 m in length (Table 5.1). Overall, the highest hydraulic conductivity estimates were obtained for test zones within well 299-W11-43 (i.e., range: 16.0 to 24.8 m/day), which is the northernmost ZP-1 well tested. Most available surrounding well hydraulic characterization information is reflective of conditions within the upper 10-m of the unconfined aquifer. Only one ZP-1 test interval was located within this zone (i.e., well 299-W15-50, Zone 1; Table 5.2). The calculated hydraulic conductivity estimate of 3.07 m (type-curve analysis result) for this ZP-1 test interval is essentially identical to the reported 200-West Area geometric mean value (3.08 m/day) for recent slug tests conducted at thirty monitor well sites completed within the upper-part of the unconfined aquifer in the 200-West Area (Spane et al., 2001a, 2001b, 2002, 2003; Spane and Newcomer 2004).

The vertical hydraulic conductivity profiles for ZP-1 wells 299-W11-43 and 299-W15-50 (based on only two and three test/depth intervals at each site, respectively) do not suggest a consistent pattern for hydraulic conductivity with depth within the Ringold Formation at these two locations. As a point of comparison, a more extensive, on-going (unpublished) drill-and-test characterization program for a borehole site (well 299-W11-25) located within the WMA T area (located generally east to northeast of the ZP-1 test well sites), however, does exhibit a slightly increasing permeability with depth pattern, which may also be suggested at the well 299-W15-50 location.

2. General Hydrologic Test Plan Description

The following general hydrologic test plan discussion is taken primarily from a similar slug test characterization program description presented previously in Spane (2003, 2005). Hydrologic testing was implemented when the approximate targeted depth interval within the upper, middle and lower sections of 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 retracted exposing an approximate ≤3-m open borehole section (note: ~2.3 m for well 299-W18-16). The packer was then inflated to isolate the well-screened/test interval, and testing string from the inside of the drill casing.

A series of multiple, stress-level slug tests were performed for each isolated test-interval section. The reason for utilizing 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. (2003), 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 0.5 m for lower-stress tests and ~1.0 m for higher-stress tests. The slug tests were initiated utilizing several slugging rods of different, known displacement volumes (i.e., for test intervals at wells 299-W15-50 and –W18-16) or conducted pneumatically using compressed air/gas (i.e., for test intervals at well 299-W11-43).

For pneumatic tests, compressed air was used to depress the fluid-column levels within the test-casing/test interval system to the designed test stress levels. Actual stress levels applied for each test were determined by comparing pressure transducer readings below and above the borehole fluid-column surface. After the monitored fluid column stabilized for several minutes at the prescribed stress level, the slug test (slug withdrawal test) was initiated by rapidly releasing the compressed gas used to depress the borehole fluid-column level. The compressed gas was released from the borehole column by opening valves (e.g., ball valves) mounted on the surface wellhead used to seal the casing system. As noted in Spane et al. (1996), the gas release valves had a cross-sectional area that was greater (e.g. >1.5 times) than the cross-sectional area of the test system where fluid-level surface recovering took place during testing.

For most test zones, three or more multi-stress slug tests were conducted. Individual slug tests were fully recovered prior to depressing the fluid column for preparation of the next slug test within the characterization sequence. A wide-range in recovery times were expected based on anticipated range in permeability conditions. For example Spane et al., (2001a, 2001b, 2002, 2003) and Spane and Newcomer (2004) report recovery times as rapid as <15 sec for high permeability test intervals to

>5 min for lower permeability test zones for 200-West Area wells. A description of the hydrologic test system utilized during slug test characterization is provided in the following report section.

3. Hydrologic Test System Description

Figures 3.1 and 3.2 show the general test system configuration utilized for slug tests conducted during the drilling and testing of the ZP-1 wells using single- and dual-wall drill casing strings, respectively. Slug tests were conducted using only slugging rods for all test zones within single-wall drill casing wells 299-W15-50 and 299-W18-16; while pneumatic slug tests were performed solely for test zones within well 299-W11-43, which was drilled with dual-wall drilling casing. Salient features common to both test system configurations are: the downhole packer/well-screen test assembly and downhole pressure transducer and surface datalogger systems. The drill-casing strings used for borehole advancement during the drilling of the ZP-1 wells varied for the respective well sites and had the following I.D./O.D. dimensions: well 299-W11-43 (dual-wall casing: outer casing 0.216/0.229 m; inner casing 0.152/0.165 m); well 299-W15-50 (0.194/0.219 m); and well 299-W18-16 (0.222/0.244 m).

As shown in Figures 3.1 and 3.2, an inflatable packer was used to seal and isolate the test interval and testing string from the encompassing drill casing area. For tests conducted with dual-wall casing (i.e., well 299-W11-43), the annular zone between the drill casings was also connected (theoretically), to the isolated test interval during testing (note: this assumes that the drilling bit orifices at the bottom of the drill casings were not clogged with drill cutting debris, which could effectively seal the drill casing annular zone from contributing to associated test responses). A 20-slot, well-screen section was attached below the packer to maintain an open section for testing after retracting the drill casing. For testing at all ZP-1 well sites, one standard packer/well-screen assembly was utilized: 3-m well-screen (Figure 3.3). In most cases, a strain-gauge, 0 to 345 kPa (0 to 50 psig) pressure transducer was installed within the test-casing string to monitor downhole test interval response prior to and during slug testing. Selected pictures of the packer/well-screen test assembly are shown in Appendix A.

Pneumatic slug tests conducted at well 299-W11-43 required the use of a surface wellhead assembly for sealing the test-casing string, thereby isolating the test interval from the overlying inner, drill-casing section. The surface wellhead assembly encompassed not only the testing string, but also extended to the outer drill casing. This wellhead extension was necessary to permit equal application of compressed gas for depressing the fluid columns within the 0.102 m I.D. testing-string and annular zone between the dual-wall drill casing, which are both communicative with the underlying test interval. This wellhead isolation is required to contain the administered compressed air that is used to pneumatically depress the fluid columns to designed slug test stress levels, as discussed in Section 2. Salient features of the well-head assembly include:

- a sealed, pass-through connection allowing for passage of downhole pressure transducer and cable to be used to measure test interval pressure response within the test-casing string

- an outside pressure probe connection that allows direct measurement of the air/gas pressure within the test-casing below the surface seal
- a connection to allow compressed air to be introduced directly to the inside of the testing-string casing
- surface wellhead valves for the rapid release of the compressed air within the testing-string casing, which allows for the *immediate* initiation of slug test application.

The preceding discussion describes the test system as designed for use during pneumatic slug tests at well 299-W11-43. Slug tests conducted within test intervals at wells drilled with single-wall casing (i.e., wells 299-W15-50 and -W18-16) were performed using slugging rods to initiate the slug test response. The test system configuration utilized is shown schematically in Figure 3.1. The two slugging rods used for conducting the multiple, stress-level slug tests had O.D. dimensions of 0.038 and 0.051 m that theoretically produce a maximum initial displacement stress within the 0.102 m I.D. test casing of 0.255 and 0.458 m, respectively. Slug tests conducted with slugging rods are particularly well-suited for test/depth intervals exhibiting lower hydraulic property conditions (e.g., $K \leq 1$ m/day). This is because of the difficulty in establishing stability in downhole well pressures (i.e., prior to test initiated) when pneumatic methods are employed.

4. Slug Test Response/Analysis

The following discussion pertaining to slug test response and analysis is taken primarily from Spane (2003, 2005). As shown in Figure 4.1 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 underdamped response, where the slug test response oscillates above and below the initial static, with decreasing peak amplitudes with time; and 3) critically-damped, 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 will be 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:

$$C_D = (g/L_e)^{1/2}\, r_c^2 \ln (R_e/r_w)/(2\,K\,L) \qquad (1)$$

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.

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 ZP-1 well sites during drilling the following general guidelines on slug test response prediction are provided:

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

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. Most ZP-1 well test intervals exhibited over-damped response characteristics. Figure 4.2 shows predicted slug test recovery as a function of hydraulic conductivity (K range: 1 to 25 m/day; 3.05 m test interval) for test intervals exhibiting over-damped response characteristics, for general ZP-1 test well/interval conditions. The test predictions shown in the figure are based on responses occurring within a test system casing I.D. = 0.102 m. As indicated in the figure, test intervals having hydraulic conductivity values of approximately 25 m/day or less, should be readily resolved for tests exhibiting over-damped slug test behavior. For over-damped slug tests, two different methods were used for the slug-test analysis: the semiempirical, 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 (1997). A detailed description of over-damped slug-test analysis methods is presented in Spane and Newcomer (2004).

Under-damped test response patterns are exhibited within stress wells where inertial forces are predominant over formation 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 ZP-1 well test intervals displayed formational under-damped test response characteristics.

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 4.1. They typically occur in wells that monitor test formations exhibiting intermediate to high hydraulic conductivity. As noted in Butler (1998), distinguishing between over- and critically-damped slug test response 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 utilized, 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 using the Bouwer and Rice or standard type-curve methods. High-K analysis methods that can be employed for analyzing unconfined aquifer tests exhibiting either critically-damped or under-damped response behavior include those described in Springer and Gelhar (1991), Butler (1997), 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) was used for analyzing ZP-1 tests (i.e., at well 299-W11-43) exhibiting critically-damped behavior. A detailed discussion of this analytical procedure and method is presented in Spane and Newcomer (2004).

It should also be noted that slug test responses conducted within well 299-W11-43, which employed dual-wall drilling casing, were "complicated" by the presence of an annular zone between the dual-wall drill casing, which is potentially communicative with the underlying test interval (as shown in Figure 3.2). The presence of two connected test system areas (i.e., within the 0.102 m I.D. testing string and within the dual-wall drill casing annular area) to respond to the initiated slug test response can be visualized as a "u-tube" test system that is connected to the test formation (see Figure 4.3). As noted in Spane (1996), slug test response time, t, is directly related to the square of the radius of the area where the water-level response occurs, r_c^2, and can be expressed in the form of the relationship below:

$$t = (S\, r_c^2)/T \qquad (2)$$

where,

S = test interval storativity
T = test interval transmissivity

Slug test response recovery occurring in such a dual-area test system would be function not only of the hydraulic properties within the test interval, but also water-level (head) imbalances that occur between the two test system areas, and where the water-level responses are monitored. Water-level imbalances would be expected to be most pronounced during the early phases of test recovery and diminish with lowering recovery rates exhibited later during the tests. For the test system utilized as well 299-W11-43, early-time test responses would recover initially at a faster rate within the 0.102 I.D. test string and within the dual-wall drill casing annular area. Because the cross-sectional area within the dual-wall annulus is larger than within the test string (i.e., 0.015 m^2 vs. 0.008 m^2), recovery within this zone would noticeably lag behind that within the smaller testing string at the beginning of the slug test response period. This is shown diagrammatically in Figure 4.3, where t_i represents the equal fluid-column position at the initiation point of the test, and t_{i+1} shows the dissimilar fluid-column positions in the two areas at some early time in the slug test response (e.g., <5 sec). Since the test interval response pressure is only measured within the smaller testing string (r_c = 0.051 m), test recovery should initially be reflective of recovery solely within the testing string. At some point, the imbalance in water-level recovery (pressures) between the dual-wall area and the testing string would cause recovery to perceptively slow within the testing string and then oscillate against a common recovery trend back to static level conditions, which is controlled by the test interval hydraulic properties. Figure 4.4 illustrates this superimposed oscillatory recovery pattern for a test example observed at well 299-W11-43 (Zone 2; test SW #1), which was tested using dual-wall drill casing. As shown for the given test interval hydraulic conductivity, the initial oscillatory response behavior indicative of faster test recovery is directly bound by the predicted exponential-decay (over-damped) test response based on a test system radius, r_{in} that is the average of the smaller testing string radius, r_c, (0.051 m) and the average total test system, r_{avg} (0.069 m). Complimenting this response, the oscillatory behavior indicative of slower test recovery is directly bound by the predicted exponential-decay test response based on a test system radius, r_{out},, which equals the average of total test system equivalent radius, r_{eqv}, (0.086 m) and average test system radius, r_{avg}. Following the first oscillation cycle, the predicted exponential test recovery responses would be expected to encompass but not directly bound the oscillatory recovery back to static test interval conditions. For the testing string and dual-wall drilling casing used at ZP-1 well 299-W11-43, the following test system test radii analysis relationships apply:

r_c = radius of testing string; (0.051 m)

r_{an} = equivalent radius of the annular zone between the dual-wall drill casing; (0.070 m)

r_{eqv} = equivalent radius of the total test system: $(r_c^2 + r_{an}^2)^{1/2}$; (0.086 m)

r_{avg} = average test system radius: $(r_c + r_{eqv})/2$; (0.069 m)

r_{in} = radius of test system bounding faster oscillatory recovery: $(r_c + r_{avg})/2$; (0.060 m)

r_{out} = radius of test system bounding slower oscillatory recovery: $(r_{eqv} + r_{avg})/2$; (0.077 m)

The preceding discussion focuses primarily on influences and controlling factors of slug tests conducted in ZP-1 wells that utilize dual-wall drill casing. To analyze the results of tests exhibiting this type of oscillatory behavior superimposed on formational over-damped (exponential decay) or critically-damped (transitional) test response characteristics, a two-step analysis procedure was employed. First, to remove the effects of the artificially imposed test system oscillations, a polynomial (cubic) curve was applied to the observed test data. The calculated polynomial fit, which represents the test response reflective of the "average" test system, was then analyzed using the Butler and Garnett (2000) analysis method described previously for critically-damped tests. The well radius value (i.e., 0.069 m) used in test analysis represents the average radius, r_{avg}, for the two regions within the test system where the slug test response occurred (i.e. within the testing string and annular area between the dual-wall drill casing).

5. 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 ZP-1 boreholes, as they were advanced to their final drilling depths. Table 5.1 presents pertinent slug test information for the respective test/depth intervals, while Table 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.

5.1 Well 299-W11-43

Drilling of OU ZP-1 well 299-W11-43 was initiated on May 23, 2005 and continued until reaching a final depth of 136.55 m bgs on June 20, 2005. The Lower Mud unit of the Ringold Formation was not encountered during drilling, which represents the bottom boundary of the unconfined aquifer at this location. Based on projections from neighboring well sites, however, the Lower Mud unit contact would be expected at a depth of 60 to 65 m bgs. Three test depth intervals were tested at the borehole location; Zone 1 = 87.78 - 90.83 m bgs; Zone 2 = 106.28 - 109.33 m bgs; and Zone 3 = 133.50 - 136.55 m bgs.

5.1.1 Zone 1

After reaching a depth of 90.83 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.229 m O.D. dual-wall, drill casing retracted 3.05 m, producing a test/depth interval for Zone 1 of 87.78 to 90.83 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test interval section generally consists of a gravel unit, comprised of 85% gravel and 15% sand.

A series of four pneumatic slug withdrawal tests were conducted between 1008 hours and 1500 hours, (PDT) June 2, 2005. The pneumatic slug tests were conducted by pressurizing the 4-in testing-string casing (I.D. = 0.102 m) used to set the packer/well-screen assembly and the adjoining annular area between the dual-wall drilling casing. The pneumatic tests used applied stress (compressed air) pressures that produced fluid-column depressions ranging between 0.3 and 0.9 m for individual tests. After test zone pressure was stabilized, the slug tests were initiated by rapidly releasing the compressed air used to depress the test system fluid column by opening the wellhead surface valves. Downhole test interval response pressures during testing were monitored using a 0 - 50 psig (0 - 345 kPa) pressure transducer set at a depth of ~83.9 m bgs, while pneumatic gas injection pressure was recorded utilizing a 10 psig (0 - 69 kPa) pressure transducer installed on the surface wellhead assembly. The static depth-to-water for the test interval during testing was 81.56 m bgs.

Due to a field testing error, the data logger was not turned off at the termination of testing. This error caused the data logger to over-write the collected data, resulting in a loss of all test response information. Based on observations by the attending field hydrologist, however, the test responses exhibited relatively rapid recoveries (i.e., within 30 to 60 seconds, which appear similar to test responses for the underlying two test intervals. Based on this qualitative assessment, an intermediate to moderately high hydraulic conductivity is suggested for this test interval, within the range of 10 to 20 m/day.

5.1.2 Zone 2

After reaching a depth of 109.33 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.229 m O.D. dual-wall, drill casing retracted 3.05 m, producing a test/depth interval for Zone 2 of 106.28 to 109.33 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test interval section generally consists of a gravel unit, comprised of 80% gravel and 20% sand.

A series of three pneumatic slug withdrawal tests were conducted between 1206 hours and 1450 hours, (PDT) June 10, 2005. The pneumatic slug tests were conducted by pressurizing the 4-in testing-string casing (I.D. = 0.102 m) used to set the packer/well-screen assembly and the adjoining annular area between the dual-wall, drilling casing. The pneumatic tests used applied stress (compressed air) pressures that produced fluid-column depressions ranging between 0.5 and 0.9 m for individual tests. After the test zone pressure was stabilized, the slug tests were initiated by rapidly releasing the compressed air used to depress the test system fluid column by opening the wellhead surface valves. Downhole test interval response pressures during testing were monitored using a 0 - 50 psig (0 - 345 kPa) pressure transducer set at a depth of ~84.1 m bgs, while pneumatic gas injection pressure was recorded utilizing a 10 psig (0 - 69 kPa) pressure transducer installed on the surface wellhead assembly. The static depth-to-water for the test interval during testing was 81.53 m bgs.

Because of the utilization of dual-wall drill casing at this well, all slug tests exhibited oscillatory behavior superimposed on exponentially decay test response as illustrated in Figure 4.4. A comparison of the normalized, polynomial curve-fits of the observed test data shown in Figure 5.1, indicates a slight nonlinear (concave downward), critically-damped slug test response, which were fully recovered within ~30 sec of test initiation. The normalized test responses indicate a stress-dependence, with the highest stress test (SW #3) exhibiting more time lag in the observed recovery. This is common for critically-damped tests and is associated with increased turbulence effects imposed by higher stress levels. For this reason, hydraulic conductivity estimates for this test are based solely on the results of the two lower-stress slug tests (i.e., SW #1 and #2).

As noted previously, slug tests exhibiting this critically-damped response behavior cannot be analyzed quantitatively with the standard, linear, response-based analytical methods employed for over-damped tests (i.e., the Bouwer and Rice or type-curve methods). The High-K analysis method presented in Butler and Garnett (2000) was used to analyze the polynomial-curve fit slug test data for this test/depth interval. Because the critically-damped test responses for the two lower stress tests were very similar, results obtained from the High-K analysis method are quite comparable. Estimates for K ranged between 24.1 and 25.5 m/day, and averaged 24.8 m/day for the two tests, which is based on using the average test system radius (r_{avg} = 0.069 m). A selected example of an analysis plot for this test interval is shown in Figure 5.2.

For qualitative comparison, the type curve used in analyzing the polynomial-curve fit data in Figure 5.2 is shown superimposed with the observed test data response in Figure 5.3. The bounding type-curve solutions displayed previously in Figure 4.4 that are based on different test system radii are also included in the figure. As shown, the analysis type-curve matches the observed test data response, while the bounding type curves encompass the oscillatory test responses reasonably well indicating a corroboration of the more quantitative test analysis results.

It should also be noted that an additional slug test stress was applied solely within the annular zone of the dual-wall casing by rapidly adding ~5 gal of water between the two drill casings at land surface. This was not designed to be a quantitative test, but rather to assess the level of hydraulic communication between the annular zone and the test interval. The observed response indicated a very similar pattern (i.e., oscillatory response superimposed on exponential decay recovery) as exhibited for the lower stress pneumatic tests, indicating a highly communicative condition between this annular test area and the underlying test interval.

5.1.3 Zone 3

After reaching a depth of 136.55 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.229 m O.D. dual-wall, drill casing retracted 3.05 m, producing a test/depth interval for Zone 3 of 133.50 to 136.55 m bgs. The borehole geology log (Appendix B; Figure B.1) indicates that the test interval section generally consists of a sandy gravel unit, comprised of 40% gravel, 55% sand, and 5% silt.

A series of four pneumatic slug withdrawal tests were conducted between 1206 hours and 1450 hours, (PDT) June 22, 2005. The pneumatic slug tests were conducted by pressurizing the 4-in testing-string casing (I.D. = 0.102 m) used to set the packer/well-screen assembly and the adjoining annular area between the dual-wall, drilling casing. The pneumatic tests used applied stress (compressed air) pressures that produced fluid-column depressions ranging between 0.3 and 1.0 m for individual tests, which was then rapidly released using the wellhead surface valves. Downhole test interval response pressures during testing were monitored using a 0 - 50 psig (0 - 345 kPa) pressure transducer set at a depth of ~84.0 m bgs, while pneumatic gas injection pressure was recorded utilizing a 10 psig (0 - 69 kPa) pressure transducer installed on the surface wellhead assembly. The static depth-to-water for the test interval during testing was 81.53 m bgs.

Because of the utilization of dual-wall drill casing at this well, all slug tests exhibited oscillatory behavior superimposed on exponentially decay test response as previously illustrated in Figure 4.4. A comparison of the normalized, polynomial curve-fits of the observed test data shown in Figure 5.4, indicates a nonlinear (concave downward), critically-damped slug test response, which were fully recovered within ~45 sec of test initiation. The normalized test responses indicate a stress-dependence, with the highest stress test (SW #3) exhibiting more time lag in the observed recovery. This is common for critically-damped tests and is associated with increased turbulence effects imposed by higher stress levels. For this reason, hydraulic conductivity estimates for this test are based solely on the results of the two lower-stress slug tests (i.e., SW #1 and #4).

As noted previously, slug tests exhibiting this critically-damped response behavior cannot be analyzed quantitatively with the standard, linear, response-based analytical methods employed for over-damped tests (i.e., the Bouwer and Rice or type-curve methods). The High-K analysis method presented in Butler and Garnett (2000) was used to analyze the polynomial-curve fit slug test data for this test/depth interval. Because the critically-damped test responses for the two lowest stress tests were similar, results obtained from the High-K analysis method are quite comparable. Estimates for K ranged between 14.3 and 17.7 m/day, and averaged 16.0 m/day for the two low stress tests, which is based on using the average test system radius (r_{avg} = 0.069 m). A selected example of an analysis plot for this test interval is shown in Figure 5.5. As indicated, the High-K analysis solution matches the polynomial-curve fit slug test data for ~70% of the initial recovery curve. The reason for the faster test data recovery during the later stages of the test are not completely understood, but maybe attributed to minor leakage occurring around the packer used to isolate the test interval.

For qualitative comparison, the type curve used in analyzing the polynomial-curve fit data in Figure 5.5 is shown superimposed with the observed test data response in Figure 5.6. The bounding type-curve solutions that are based on different test system radii, are also included in the figure. As shown, the analysis type-curve matches the observed test data response over approximately 70% of the decay and the bounding type curves generally encompass the oscillatory test responses reasonably well. The oscillatory responses exhibited later in the test are attributed to equilibration effects due to minor pressure/recovery imbalances between the two test system fluid column areas.

It should also be noted that an additional slug test stress was applied solely within the annular zone of the dual-wall casing by rapidly adding ~5 gal of water between the two drill casings at land surface. This was not designed to be a quantitative test, but rather to assess the level of hydraulic communication between the annular zone and the test interval. The observed response indicated a very similar pattern (i.e., oscillatory response superimposed on exponential decay recovery) as exhibited for the lower stress pneumatic tests, indicating a highly communicative condition between this annular test area and the underlying test interval.

5.2 Well 299-W15-50

Drilling of OU ZP-1 well 299-W15-50 was initiated on January 4, 2005 and continued until reaching a final depth of 102.93 m bgs on February 9, 2005. The Lower Mud unit of the Ringold Formation was not encountered during drilling, which represents the bottom boundary of the unconfined aquifer at this location. Based on projections from neighboring well sites, however, the Lower Mud unit contact would be expected at a depth of 60 to 65 m bgs. Three test depth intervals were tested at the borehole location; Zone 1 = 71.02 - 74.04 m bgs; Zone 2 = 83.45 - 86.50 m bgs; and Zone 3 = 99.97 - 102.93 m bgs.

5.2.1 Zone 1

After reaching a depth of 74.04 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.219 m O.D. drill casing retracted 3.02 m, producing a test/depth interval for Zone 1 of 71.02 to 74.04 m bgs. The borehole geology log (Appendix B; Figure B.2) indicates that the test interval section encompassed several lithologic units: a silty sandy gravel between 71.02 and 72.54 m; a sandy gravel between 72.54 and 73.46 m; and a slightly silty sand between 73.46 and 74.04.

A series of five slug withdrawal tests (three low and two high stress tests) were conducted between 1223 hours and 1505 hours, (PST) January 26, 2005. The first slug withdrawal test (SW #1) was compromised by a deflated packer element recognized during monitoring the test response. The packer was subsequently re-inflated and the subsequent four slug withdrawal tests successfully conducted. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging rod volumes impart theoretical applied stress values of 0.255 m and 0.458 m for the low and high stress tests, respectively. Downhole test interval response pressures during testing were monitored using a 0 - 10 psig (0 - 69 kPa) pressure transducer set at a depth of ~69.7 m bgs. The static depth-to-water for the test interval during testing was 67.02 m bgs.

A comparison of the normalized, slug-test responses indicates a linear, inelastic (storage), over-damped slug test behavior (e.g. Figure 5.7). The slug tests exhibited homogeneous formation conditions over the entire test response. A comparison between normalized low and high stress tests indicates identical response behavior, suggesting that the well had been developed sufficiently to establish stable skin conditions.

Slug test results exhibiting homogeneous formation response behavior can be analyzed quantitatively using standard, linear-response based analytical methods (i.e., using either the Bouwer and Rice or standard type-curve methods) following procedures described in Spane and Newcomer (2003). A comparison of K estimates indicates that slightly lower results (~15% lower) were obtained for the Bouwer and Rice method. For the Bouwer and Rice method, a K estimate of 2.58 m/day was obtained, while the type-curve method provided a value of 3.07 m/day for all stress-level tests. (Note: results for the first test, SW #1, were not included for hydraulic property characterization due to packer deflation). A uniform specific storage estimate of 1.0E-5 was derived from all the type-curve analyses. This value is within the range commonly reported for slug tests conducted within alluvial formations (e.g., Butler 1998). Selected examples of analysis plots for this test interval are shown in Figure 5.7.

5.2.2 Zone 2

After reaching a depth of 86.50 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.219 m O.D. drill casing retracted 3.05 m, producing a test/depth interval for Zone 2 of 83.45 to 85.50 m bgs. The borehole geology log (Appendix B; Figure B.2) indicates that the test encompassing interval section of 83.02 to 86.87m generally consists of a gravel unit, comprised of 90% gravel, 5% sand, and 5% silt.

A series of four slug withdrawal tests (two low and two high stress tests) were conducted between 1254 hours and 1456 hours, (PST) February 2, 2005. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging rod volumes impart theoretical applied stress values of 0.255 m and 0.458 m for the low and high stress tests, respectively. Downhole test interval response pressures during testing were monitored using a 0 - 10 psig (0 - 69 kPa) pressure transducer set at a depth of ~69.7 m bgs. The static depth-to-water for the test interval during testing was 67.02 m bgs.

A comparison of the normalized, slug-test responses indicates a linear, inelastic (storage), over-damped slug test behavior (e.g. Figure 5.8). The slug tests exhibited homogeneous formation conditions over the entire test response. A comparison between normalized low and high stress tests indicates identical response behavior, suggesting that the well had been developed sufficiently to establish stable skin conditions.

Slug test results exhibiting homogeneous formation response behavior can be analyzed quantitatively using standard, linear-response based analytical methods (i.e., using either the Bouwer and Rice or standard type-curve methods) following procedures described in Spane and Newcomer (2003). A comparison of K estimates indicates that slightly lower results (~10% lower) were obtained for the Bouwer and Rice method. For the Bouwer and Rice method, a K estimate of 2.93 m/day was obtained, while the type-curve method provided a value of 3.20 m/day for all stress-level tests. A uniform specific storage estimate of 5.0E-5 was derived from all the type-curve analyses. This value is within the range commonly reported for slug tests conducted within alluvial formations (e.g., Butler 1998). Selected examples of analysis plots for this test interval are shown in Figure 5.8.

For characterization comparison purposes, two slug injection tests (one low and one high stress test) were also conducted. As anticipated, the slug injection tests exhibited identical recovery response plots as the slug withdrawal tests, indicating no stress direction dependence.

5.2.3 Zone 3

After reaching a depth of 102.93 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.219 m O.D. drill casing retracted 2.96 m, producing a test/depth interval for Zone 3 of 99.97 to 102.93 m bgs. The borehole geology log (Appendix B; Figure B.2) indicates that the test interval section generally consists of a sandy gravel unit, comprised of 70% gravel, 25% sand, and 5% silt.

A series of four slug withdrawal tests (two low and two high stress tests) were conducted between 0950 hours and 1225 hours, (PST) February 11, 2005. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging rod volumes impart theoretical applied stress values of 0.255 m and 0.458 m for the low and high stress tests, respectively. Downhole test interval response pressures during testing were monitored using a 0 -

10 psig (0 - 69 kPa) pressure transducer set at a depth of ~68.9 m bgs. The static depth-to-water for the test interval during testing was 66.30 m bgs.

A comparison of the normalized, slug-test responses indicates a linear, inelastic (storage), over-damped slug test behavior (e.g. Figure 5.9). The slug tests exhibited homogeneous formation conditions over the entire test response. A comparison between normalized low and high stress tests indicates a slight stress dependency, suggesting a near well dynamic skin condition. Slug test results exhibiting homogeneous formation response behavior can be analyzed quantitatively using standard, linear-response based analytical methods (i.e., using either the Bouwer and Rice or standard type-curve methods) following procedures described in Spane and Newcomer (2003). A comparison of K estimates indicates a close correspondence between results obtained for the Bouwer and Rice and type-curve analytical methods.

For the Bouwer and Rice method, estimates for K ranged between 8.07 and 9.63 m/day (average 8.77 m/day), while the type-curve method provided estimates between 8.06 and 9.50 m/day (average 8.66 m/day) for all stress-level tests. A uniform specific storage estimate of 1.0E-6 was derived from all the type-curve analyses. This value is within the range commonly reported for slug tests conducted within alluvial formations (e.g., Butler 1998). Selected examples of analysis plots for this test interval are shown in Figure 5.9.

For characterization comparison purposes, two slug injection tests (one low and one high stress test) were also conducted. As anticipated, the slug injection tests exhibited similar recovery response behavior and K estimates within the range cited above for the slug withdrawal tests. The close similarity in test responses indicates no stress direction dependence for the test results.

5.3 Well 299-W18-16

Drilling of OU ZP-1 well 299-W19-48 was initiated on October 20, 2004 and continued until reaching a final depth of 106.07 m bgs on December 13, 2004. The Lower Mud unit of the Ringold Formation was not encountered during drilling, which represents the bottom boundary of the unconfined aquifer at this location. Based on projections from neighboring well sites, however, the Lower Mud unit contact would be expected at a depth of 60 to 65 m bgs. Initially three test/depth intervals were planned to be tested at the borehole location; however, borehole instability conditions and end-of-year deadline requirements for completing the well restricted hydrologic testing to only one upper-unconfined aquifer test zone.

After reaching a depth of 97.99 m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole on December 7, 2004, and the 0.245 m O.D. drill casing retracted 2.29 m, producing a theoretical test/depth interval for Zone 3 of 95.70 to 97.99 m bgs. The borehole geology log (Appendix B; Figure B.3) indicates that the test interval section consists of a silty, sandy gravel unit, comprised of 50% gravel, 20% sand, and 30% silt.

Two slug withdrawal tests (one low and one high stress test) were conducted between 1228 hours and 1422 hours, (PST) December 7, 2004. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging rod volumes impart theoretical applied stress values of 0.255 m and 0.458 m for the low and high stress tests, respectively. Downhole test interval response pressures during testing were monitored using a 0 - 10 psig (0 - 69 kPa) pressure transducer set at a depth of ~74.8 m bgs. The pre-test depth-to-water for the test interval during testing was 71.69 m bgs. This value, however, is not considered to be representative of "static" conditions, since a declining water-level trend of -0.0008333 m/min was observed during testing.

Because of the extremely low recovery rate following initiation of the initial, low stress slug test (SW#1), the first slug test was aborted in favor of performing a high stress slug injection and withdrawal test sequence (SI #2 and SW #2). The two slug test sequence was initiated by rapidly submerging a 0.051 O.D. slugging rod (slug injection test) below the fluid column within the 4-in testing-string casing (I.D. = 0.102 m) used to set the packer/well-screen assembly. After approximately 40 minutes of recovery, the previously submerged slugging rod was removed from the fluid column initiating a slug withdrawal test.

Because the recovery times for these tests were extremely slow, the consecutive slug injection/withdrawal tests were combined and analyzed compositely using a test history match approach. This analysis approach is particularly useful when analysis of individual tests using standard techniques (e.g., Bouwer and Rice, type-curve methods) may be uncertain (i.e., due to only small recovery percentage; e.g. ≤10%). The test history match approach relies on superimposing the predicted test responses of subsequent testing activities, which can be used to match the entire composite test sequence (test history match). Figure 5.10 shows the observed well response for the composite slug injection/slug withdrawal tests using the 0.051 m O.D. slugging rod. Also shown in the figure, is the predicted test history match for the two tests, which was produced by superimposing the two individual slug tests at their appropriate time of test initiation. A declining water-level trend of -0.0008333 m/min was observed over the test period and included in the test history match. As indicated, a hydraulic conductivity, K, of 0.04 m/day provides a good match to the observed test response sequence.

To demonstrate the sensitivity of the analytical solution, Figure 5.11 shows the predicted history match using K values of 0.04, 0.2 and 1.0 m/day. As indicated, significant departures in the test history matches of the observed test responses are produced with higher K values. This suggests that the interval tested exhibits a K value of ~0.04 m/day, which is consistent with reported values for silts and silty fine-sand units (e.g., Freeze and Cherry, 1979). It is not completely certain whether the relatively low hydraulic conductivity indicated for this test interval is actually representative of in-situ formation conditions or an artifact of the drilling process or borehole instability (i.e., collapse of low permeability materials around the well screen during drill casing pullback/retraction to expose the depth interval for characterization. A number of observations, however, suggest that this test interval would likely exhibit low permeability conditions. These indications included:

- the high percentage of silt (i.e., 30%) as noted in the borehole geology log (Appendix B; Figure B.3), and

- previous low groundwater production and presence of abundant silt in the bailed water during the pre-test, interval development and hydrochemical sampling

6. Conclusions

Overall, test results were obtained for a total of seven test/depth intervals during the drilling and borehole advancement of three OU ZP-1 wells: 299-W11-43, 299-W15-50, and 299-W18-16. The results indicate that multiple, stress-level slug testing methods were successful in providing detailed information concerning the distribution of hydraulic conductivity at these Hanford Site locations. These characterization results are consistent with and complement previous and on-going drill-and-test characterization programs at surrounding 200-West and -East Area locations.

Results from the ZP-1 well slug tests provide hydraulic characterization information only for the Ringold Formation (Unit 5), for individual test/depth intervals generally sited within the upper, middle, and lower sections of the unconfined aquifer. All test/depth intervals exhibit either exponential-decay (over-damped) or critically-damped slug test response behavior. Over-damped type of slug test response patterns are indicative of test intervals having low to intermediate permeability conditions, while critically-damped test responses are reflective of test intervals having intermediate to high permeability characteristics. Analysis of the slug test results indicate a wide-range in the calculated average, test interval hydraulic conductivity (Table 5.2), with estimates ranging between 0.04 and 24.8 m/day. The ZP-1 well hydraulic conductivity estimates were derived for test interval sections that ranged from 2.29 to 3.05 m in length (Table 5.1). Overall, the highest hydraulic conductivity estimates were obtained for test zones within well 299-W11-43 (i.e., range: 16.0 to 24.8 m/day), which is the northernmost ZP-1 well tested.

For areal comparison purposes, Figure 6.1 shows a statistical summary for hydraulic conductivity based on recent slug test results (i.e., ≥FY1999) of the Ringold Formation, from thirty 200-West Area RCRA monitor wells (as reported in Spane et al. (2001a, 2001b, 2002, 2003) and Spane and Newcomer (2003)). As indicated in the figure, estimates of hydraulic conductivity for these 200-West Area Ringold Formation tests ranged between 0.07 to 28.1 m/day, with a geometric mean of 3.08 m/day and a standard deviation of ±7.70 m/day (note: based on type-curve slug test analysis results). It should be noted that these previously reported values are reflective of the upper 10 m of the unconfined aquifer (i.e., Ringold Formation). For a more representative comparison, only one ZP-1 well test zone was located within the upper 10 m of the unconfined aquifer (i.e., well 299-W15-50, Zone 1; Table 5.2). The calculated hydraulic conductivity estimate of 3.07 m (type-curve analysis result) is essentially identical to the reported 200-West Area geometric mean value (3.08 m/day).

The vertical hydraulic conductivity profiles for ZP-1 wells 299-W11-43 and 299-W15-50 are shown graphically in Figures 6.2 and 6.3, respectively. As indicated, the limited vertical profile information does not suggest a consistent pattern for hydraulic conductivity with depth within the Ringold Formation at these two well site locations. As a point of comparison, a more extensive, on-going (unpublished) drill-and-test characterization program for a borehole site (well 299-W11-25) located within the WMA T area (located generally east to northeast of the ZP-1 test well sites), however, does exhibit a slightly increasing permeability with depth pattern, which may also be suggested at the well 299-W15-50 location.

It should be noted that hydraulic property values reported in this letter report are determined from the slug test characterization that are believed to be representative of conditions in proximity to the individual well site locations. It is difficult to assess the representative scale or *radius of investigation* that the slug test characterization results represent. However based on theoretical relationships presented in Guyonnet et al. (1993), slug test results are likely more representative of formation conditions within ~3 m of test site. This scale-of-investigation estimate, however, is highly uncertain and provided only for qualitative discussion purposes. Previous Hanford Site hydraulic property comparisons of slug tests with larger scale-of-investigation pumping test results (reported in Spane et al. 2001a, 2001b, 2002, 2003) and Spane and Newcomer (2003) have indicated a fairly close agreement (i.e., within a factor of 2). This suggests that a larger scale may be representative for the slug test results.

7. References

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Table 1. Slug-Test Characteristics for Selected Test/Depth Intervals at Operable Unit ZP-1 Test Wells 299-W11-43, 299-W15-50, and 299-W18-16

Test Well	Test Zone	Test Parameters				Diagnostic Slug Test Response Model	Hydrogeologic Unit Tested [a]
		Test Date	Slug Tests #	Depth to Water, m bgs	Depth/Test Interval , m bgs		
299-W11-43	Zone 1	6/2/05	4	81.56	87.78 - 90.83 (3.05)	Critically-Damped[b]	Ringold Formation (Unit 5)
	Zone 2	6/10/05	3	81.53	106.28 - 109.33 (3.05)	Critically-Damped	Ringold Formation (Unit 5)
	Zone 3	6/22/05	4	81.53	133.50 - 136.55 (3.05)	Critically-Damped	Ringold Formation (Unit 5)
299-W15-50	Zone 1	1/26/05	5	67.02	71.02 - 74.04 (3.02)	Exponential Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 2	2/2/05	6	66.67	83.45 - 86.50 (3.05)	Exponential Decay (over-damped)	Ringold Formation (Unit 5)
	Zone 3	2/11/05	6	66.30	99.97 - 102.93 (2.96)	Exponential Decay (over-damped)	Ringold Formation (Unit 5)
299-W18-16	Zone 1	12/7/04	2	~71.69	95.70 - 97.99 (2.29)	Exponential Decay (over-damped)	Ringold Formation (Unit 5)

Note: For all test wells, r_c = 0.051 meter; r_w ranged between 0.111 and 0.149 meters. The ~ symbol used in combination with depth-to-water measurements indicates that the value is not considered to reflect static conditions at the time of testing

(a) Unit number in parentheses indicates the relevant groundwater-flow model layer, as described in Thorne, et al., 1993..

(b) Test data lost due to datalogger malfunction; assigned diagnostic response characteristics based on field test observations

Table 5.2 Slug-Test Analysis Results

Test Well	Test Zone	Bouwer and Rice Analysis Method	Standard or High-K[b]/ Type-Curve Analysis Method		Test History Matching Analysis Method[c]
		Horizontal Hydraulic Conductivity, K_h,[a] (m/day)	Horizontal Hydraulic Conductivity, K_h,[a] (m/day)	Specific Storage, S_s (m^{-1})	Horizontal Hydraulic Conductivity, K_h,[a] (m/day)
299-W11-43	Zone 1	NA	NA	NA	NA
	Zone 2	NA	24.1 - 25.5 (24.8)	NA	NA
	Zone 3	NA	14.3 - 17.7 (16.0)	NA	NA
299-W15-50	Zone 1	2.58	3.07	1.0E-5	NA
	Zone 2	2.93	3.20	5.0E-5	NA
	Zone 3	8.07 - 9.63 (8.77)	8.06 - 9.50 (8.66)	1.0E-6	NA
299-W18-16	Zone 1	NA	NA	NA	0.04

Number in parentheses is the average value for all tests.

NA = method is either not applicable or not applied

(a) Assumed to be uniform within the well-screen test section. For tests exhibiting a heterogeneous formation response, only outer zone analysis results are considered representative of in-situ formation conditions

(b) Standard analytical methods are not applicable for tests exhibiting critically-damped response characteristics. Results based on High-K analysis method presented in Butler and Garnett (2000)

(c) Because of test interval, low-permeability conditions, insufficient test response recovery (i.e., ≤10%) was collected for these tests to permit use of standard analytical methods. For these tests, a test history matching/type-curve analysis approach was applied

Figure 1.1. Location Map Showing OU ZP-1 Test Well Sites

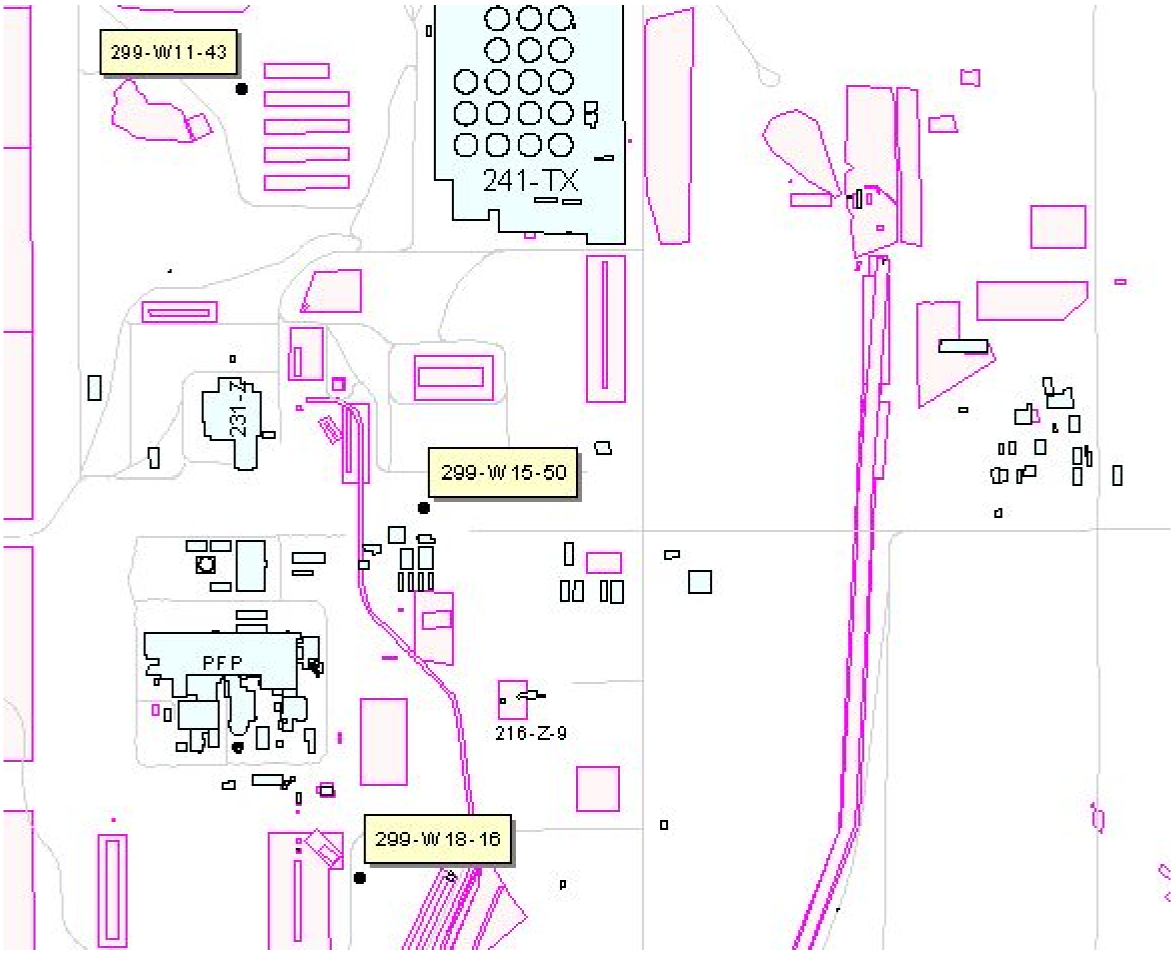


Figure 3.1. General Slug Test Configuration Using Slugging Rods

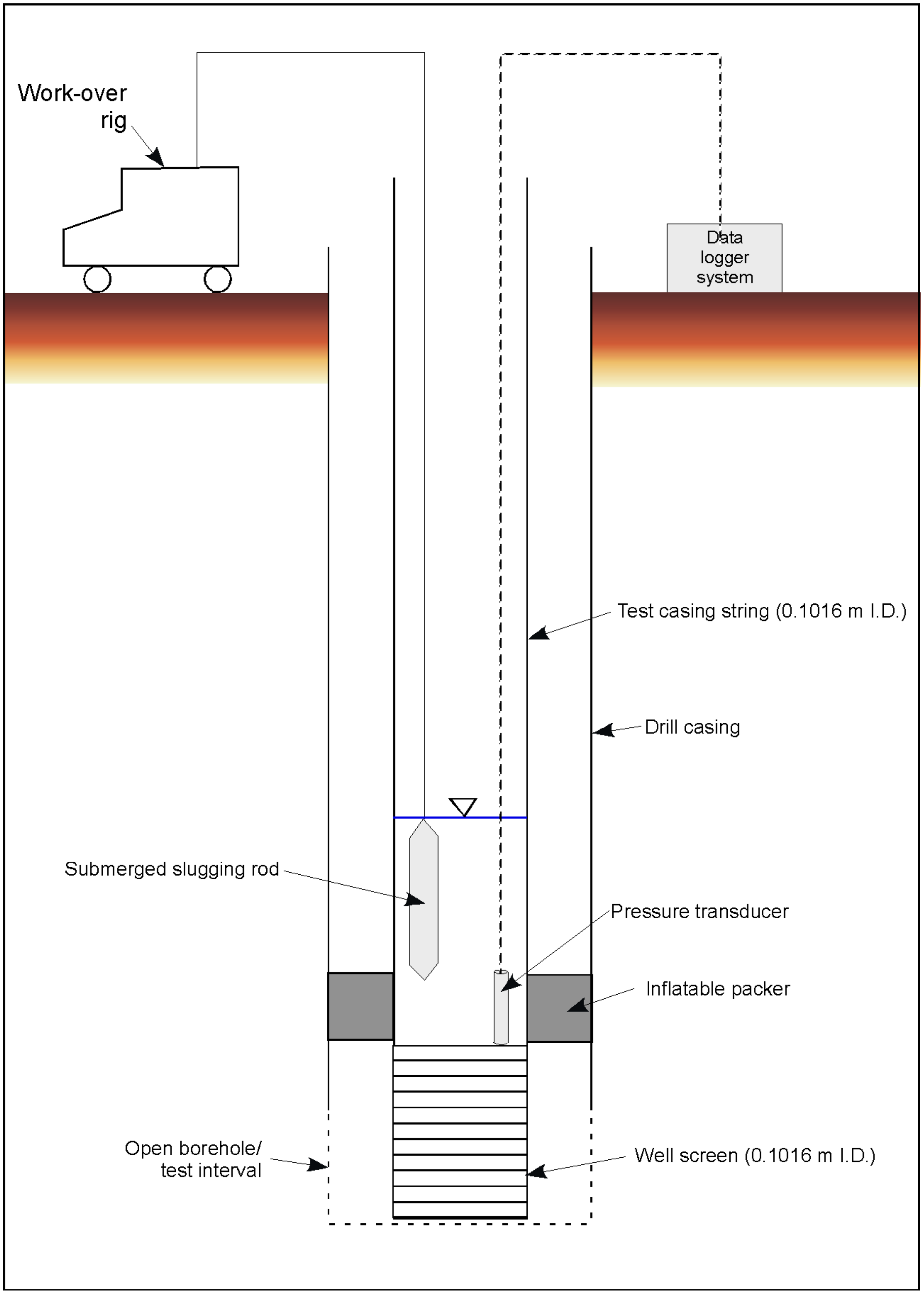


Figure 3.2. General Pneumatic Slug Test System Using Dual-Wall Drill Casing System

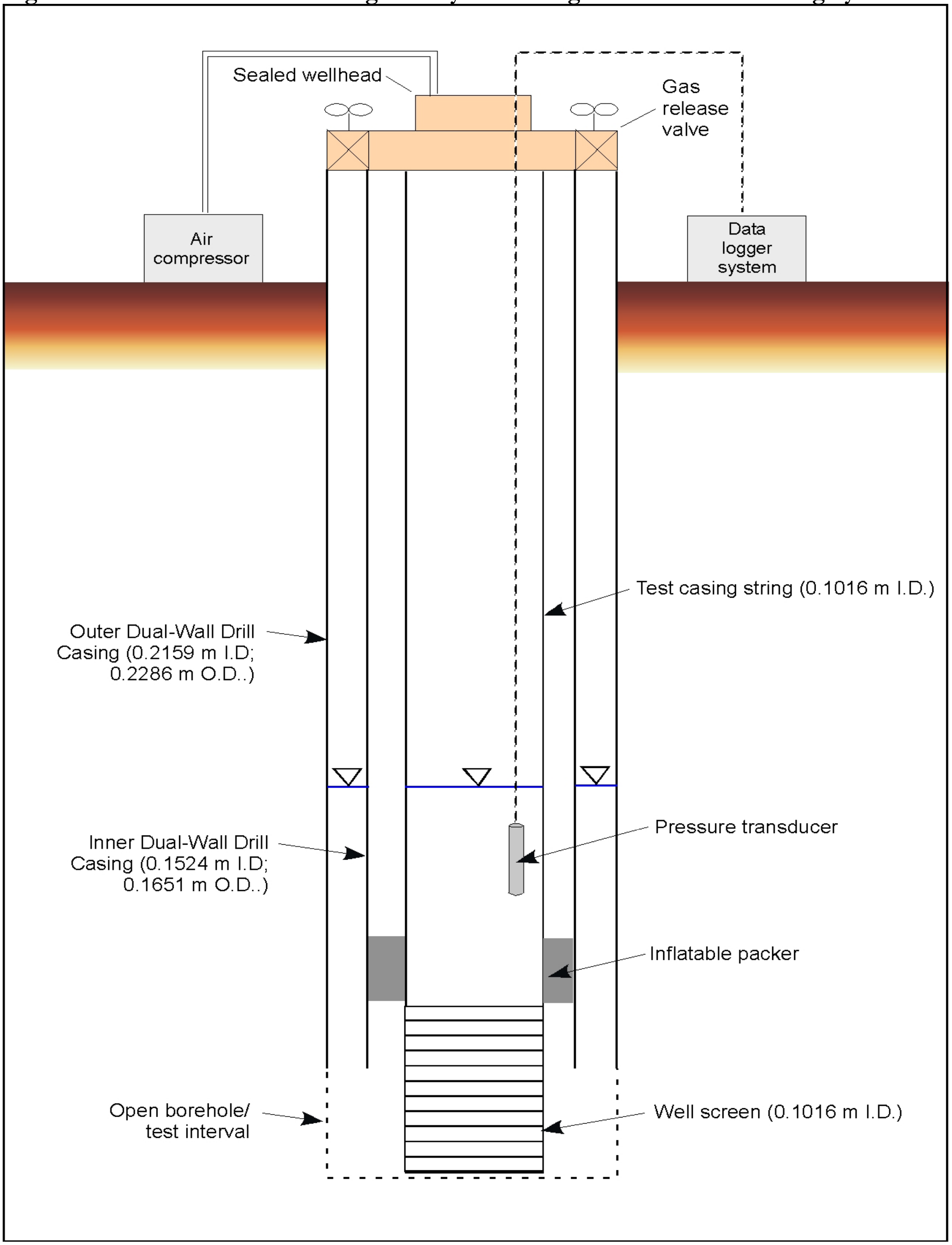


Figure 3.3. Packer/Well-Screen Assembly Dimensions

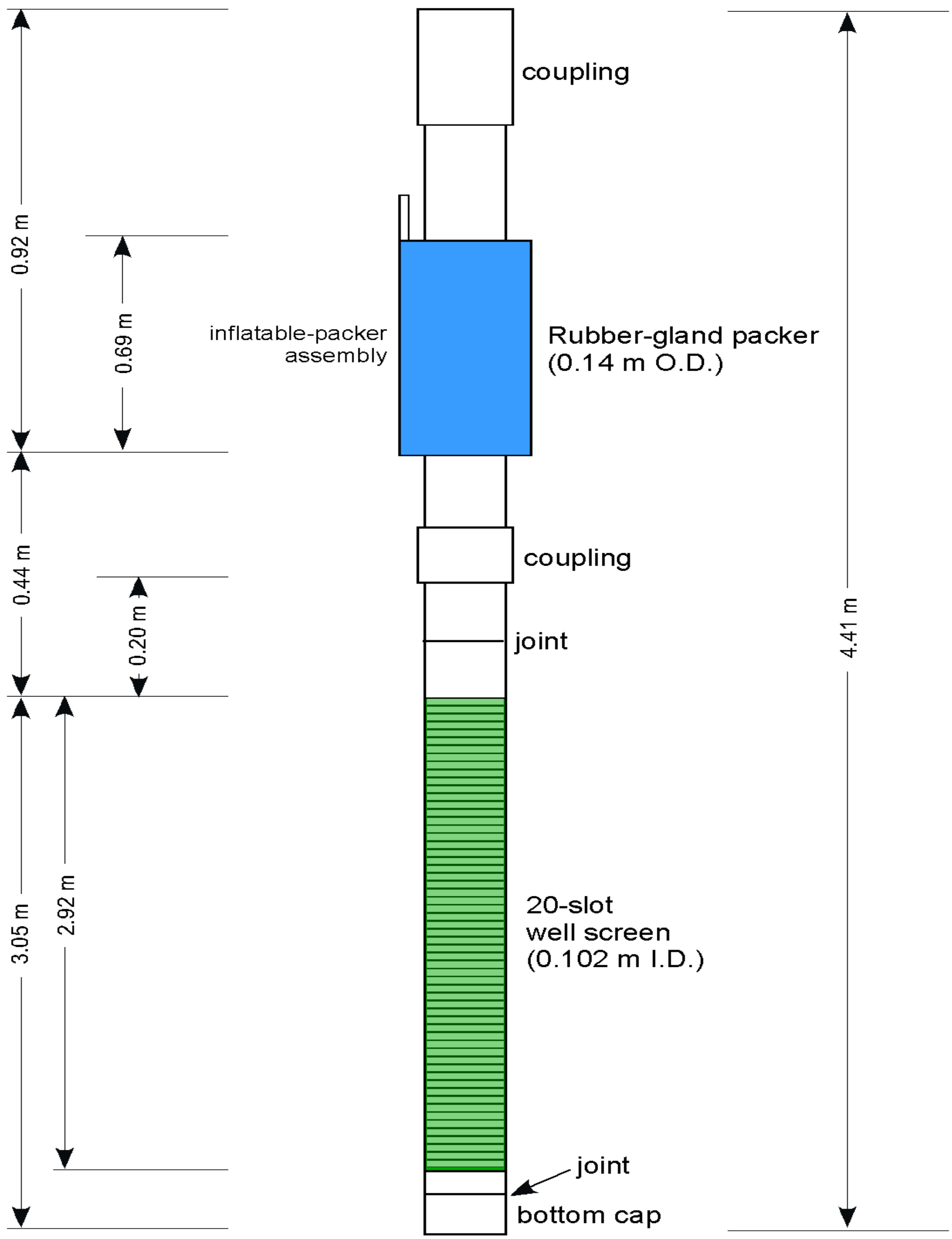


Figure 4.1. Diagnostic Slug Test Response (taken from Spane et al. (2003)

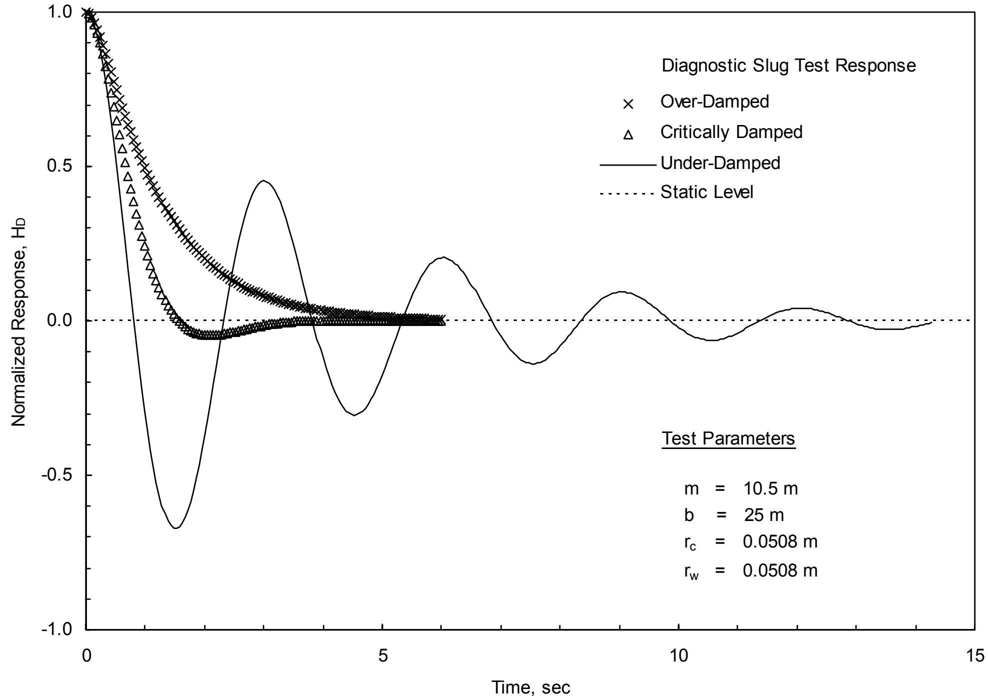


Figure 4.2 Over-Damped Slug Test Response as a Function of Test Interval Hydraulic Conductivity

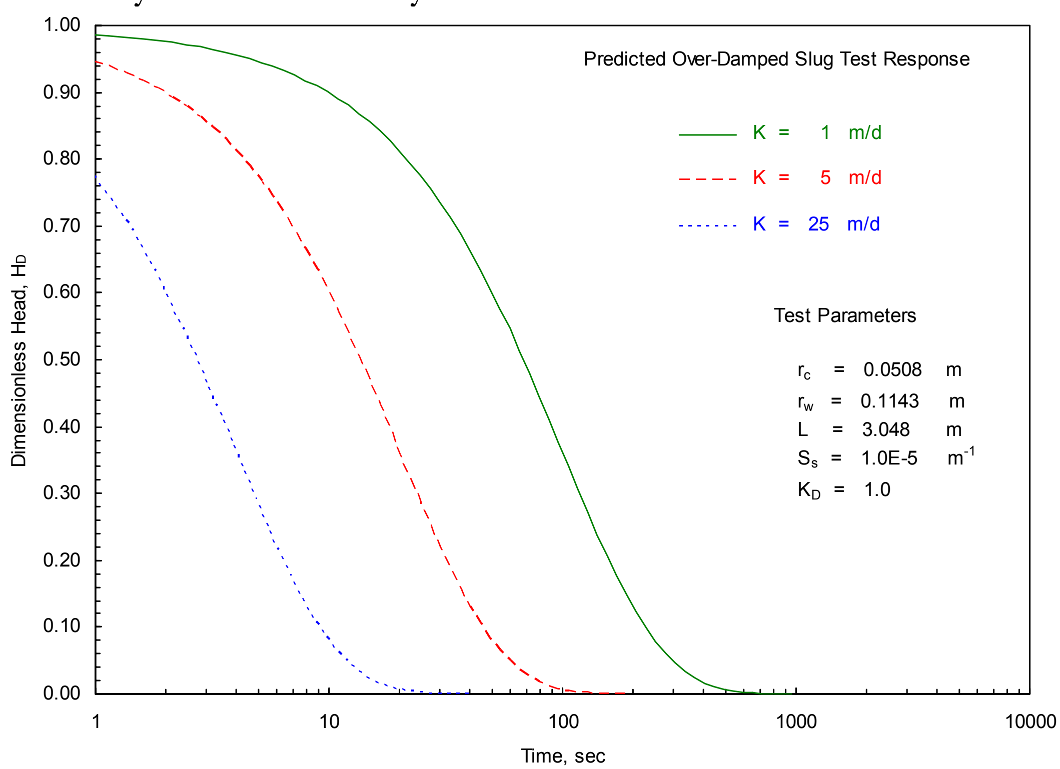


Figure 4.3. Diagnostic Slug Test Response

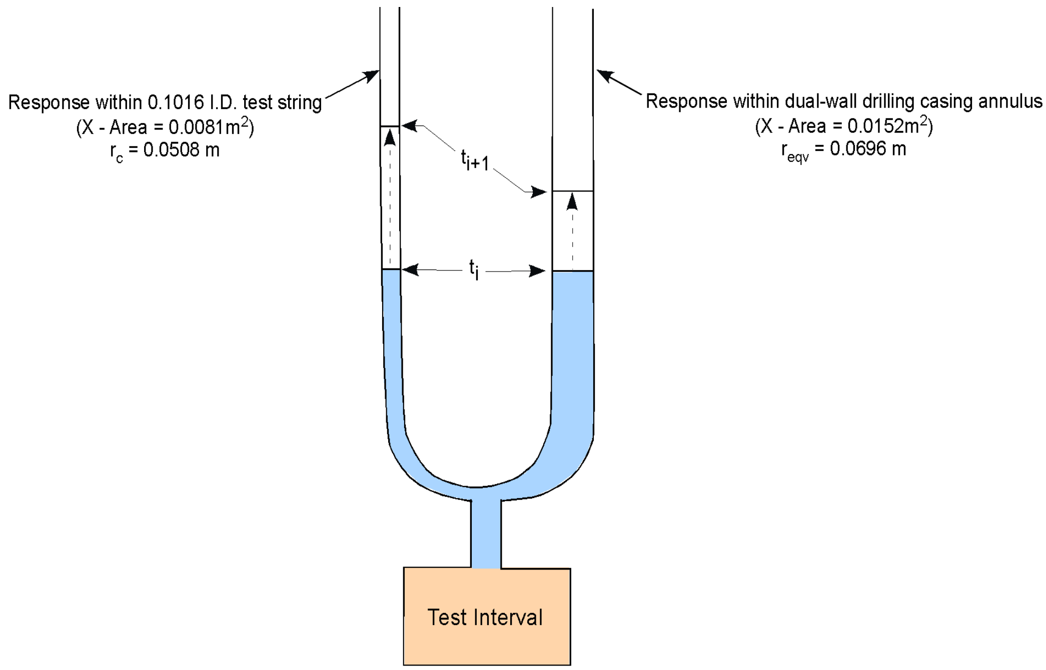


Figure 4.4. Example of Superimposed Oscillatory Response on Slug Test Recovery Conducted Within Test Intervals Using a Dual-Wall Casing System

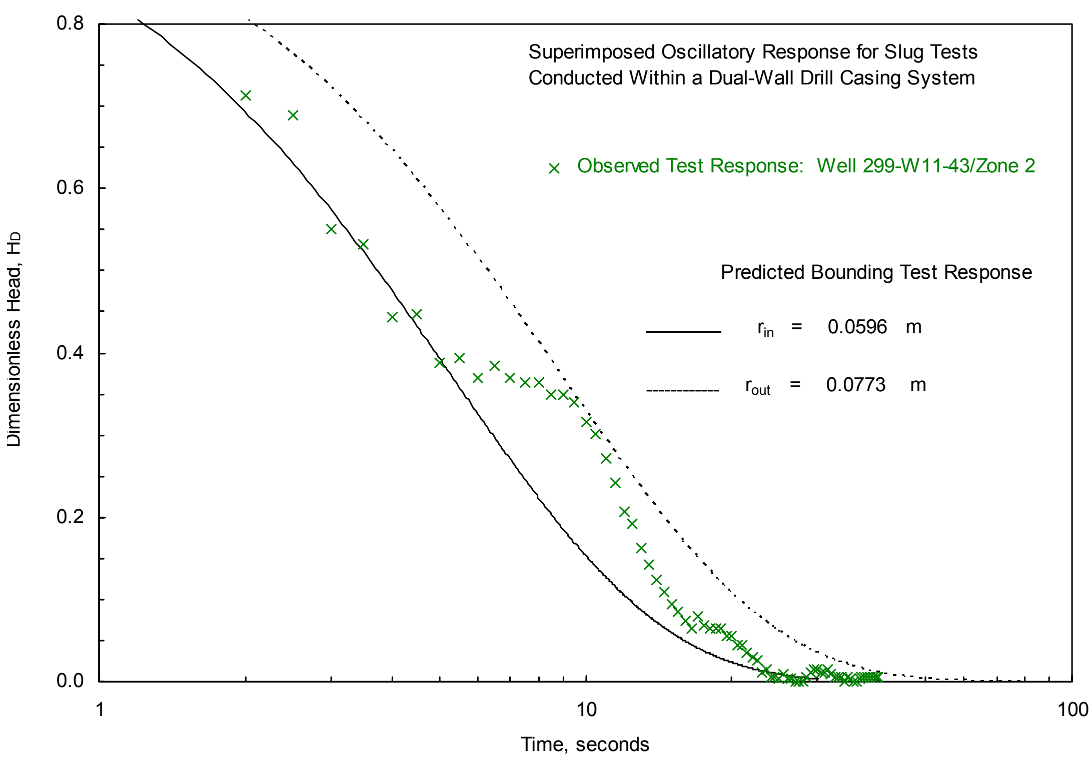


Figure 5.1 Diagnostic Analysis of Slug Test Responses Well 299-W11-43: Test Interval Zone 2

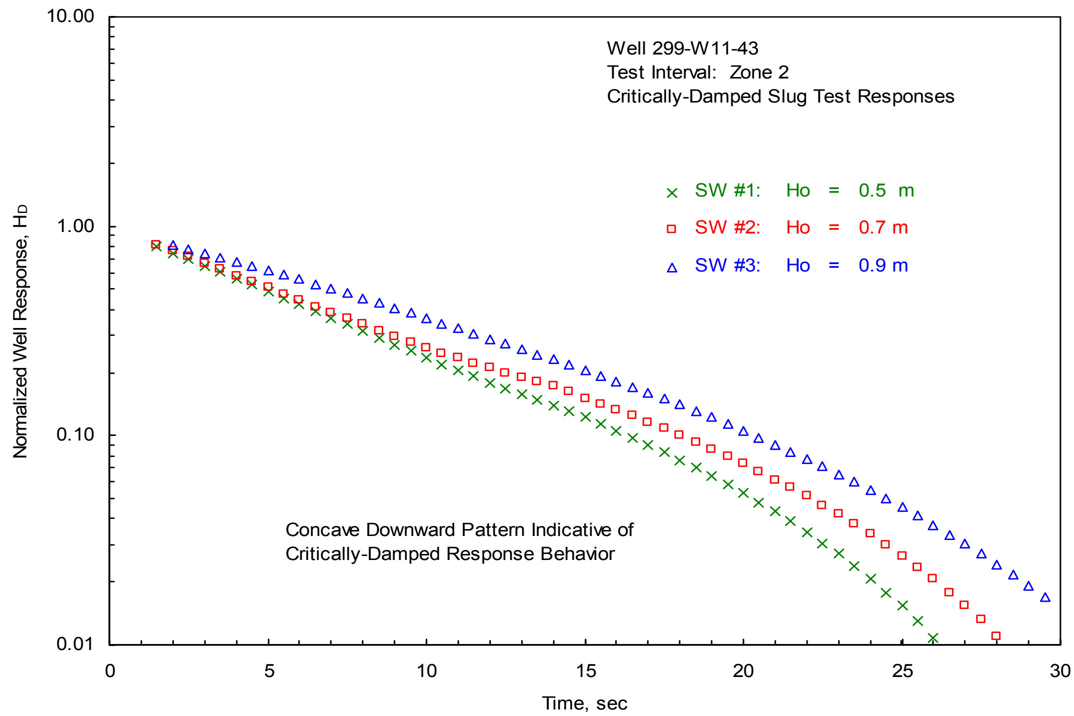


Figure 5.2 Selected High-K Test Analysis Plot for Well 299-W11-43: Test Interval Zone 2

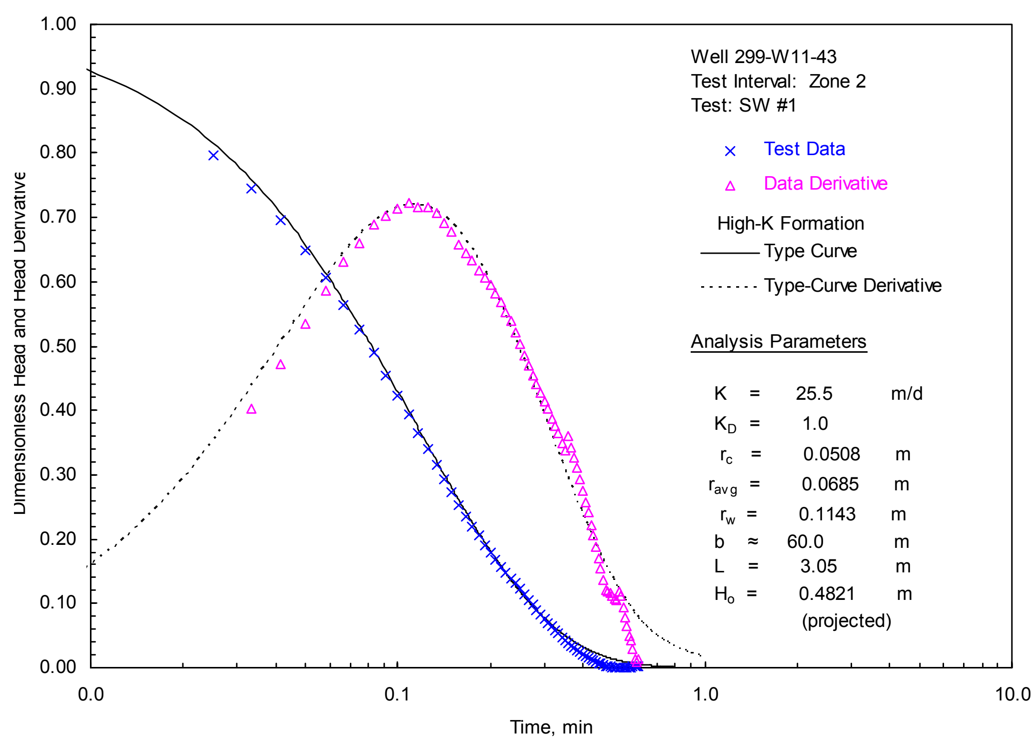


Figure 5.3 Qualitative Comparison of Analysis and Bounding Type Curves with Observed Test Response for Well 299-W11-43: Test Interval Zone 2

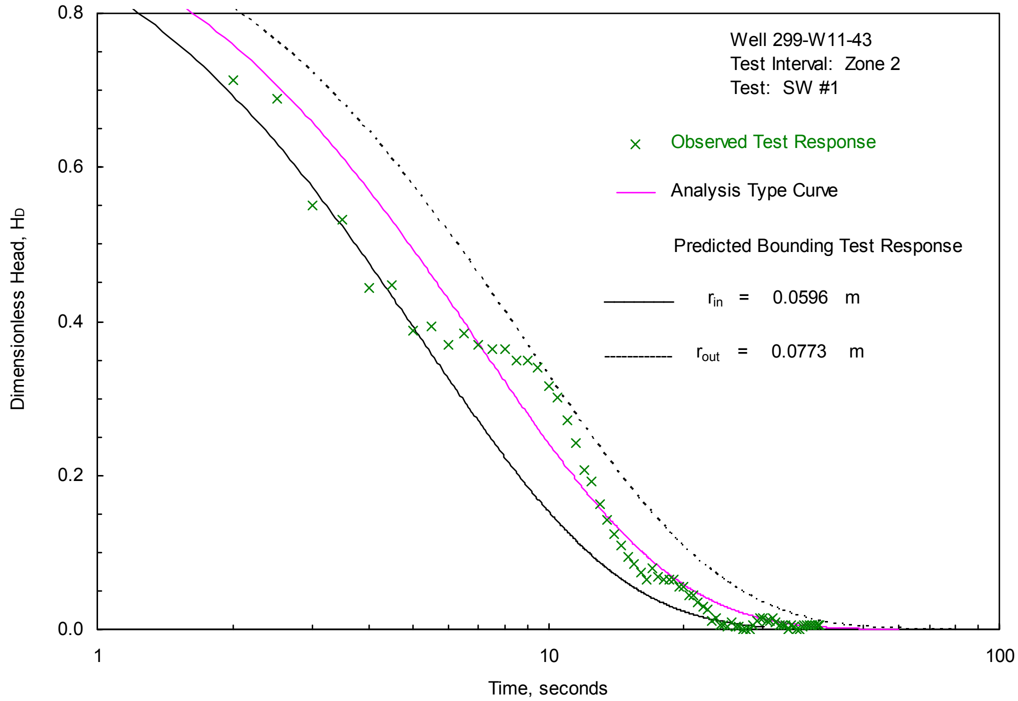


Figure 5.4 Diagnostic Analysis of Slug Test Responses Well 299-W11-43: Test Interval Zone 3

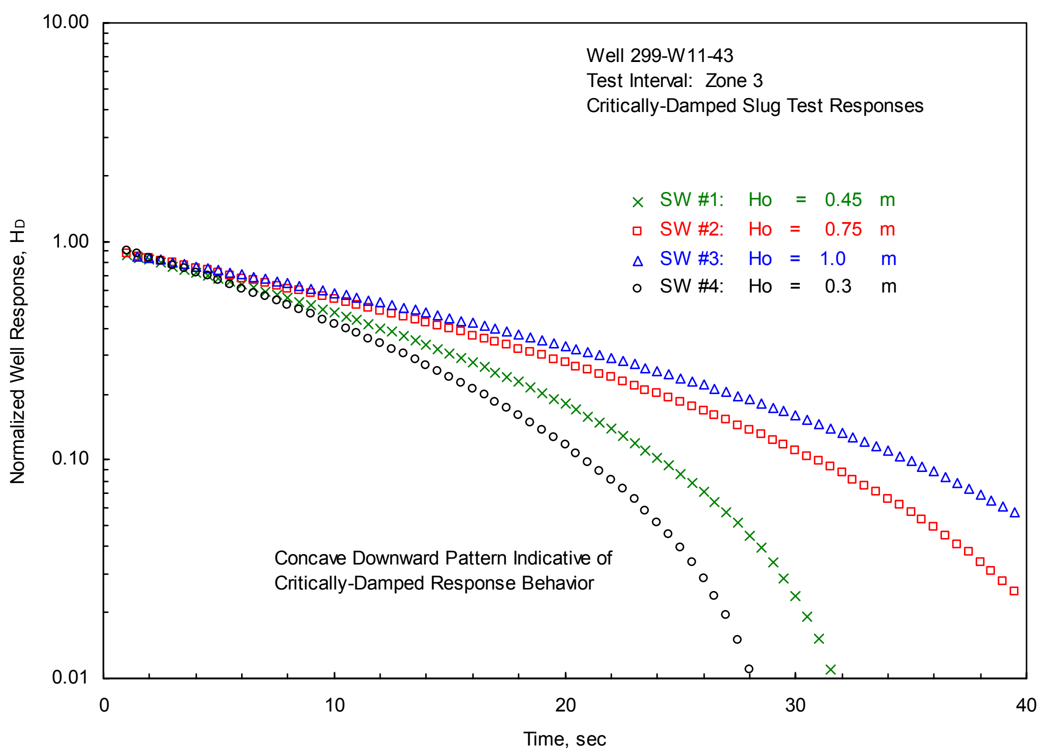


Figure 5.5 Selected High-K Test Analysis Plot for Well 299-W11-43: Test Interval Zone 3

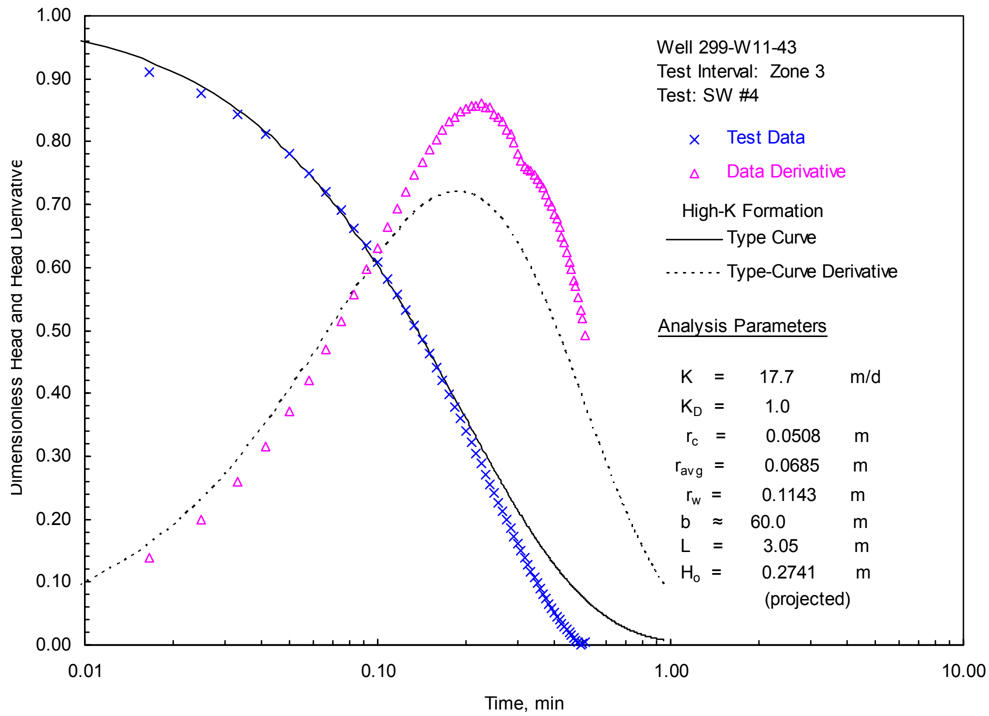


Figure 5.6 Qualitative Comparison of Analysis and Bounding Type Curves with Observed Test Response for Well 299-W11-43: Test Interval Zone 3

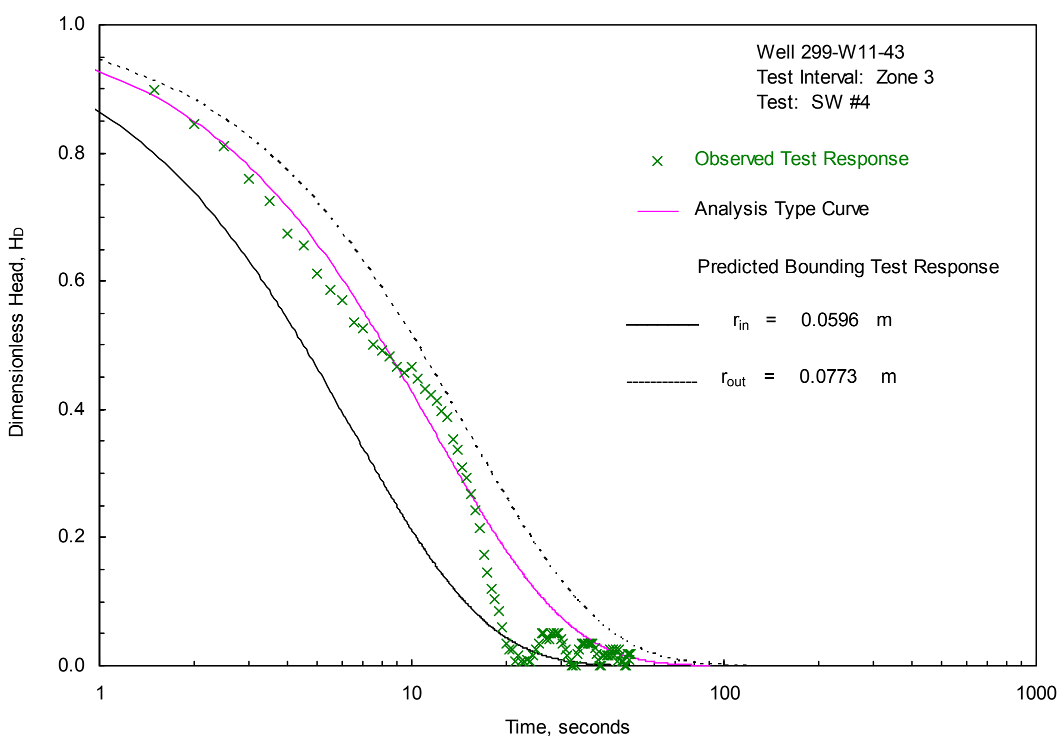
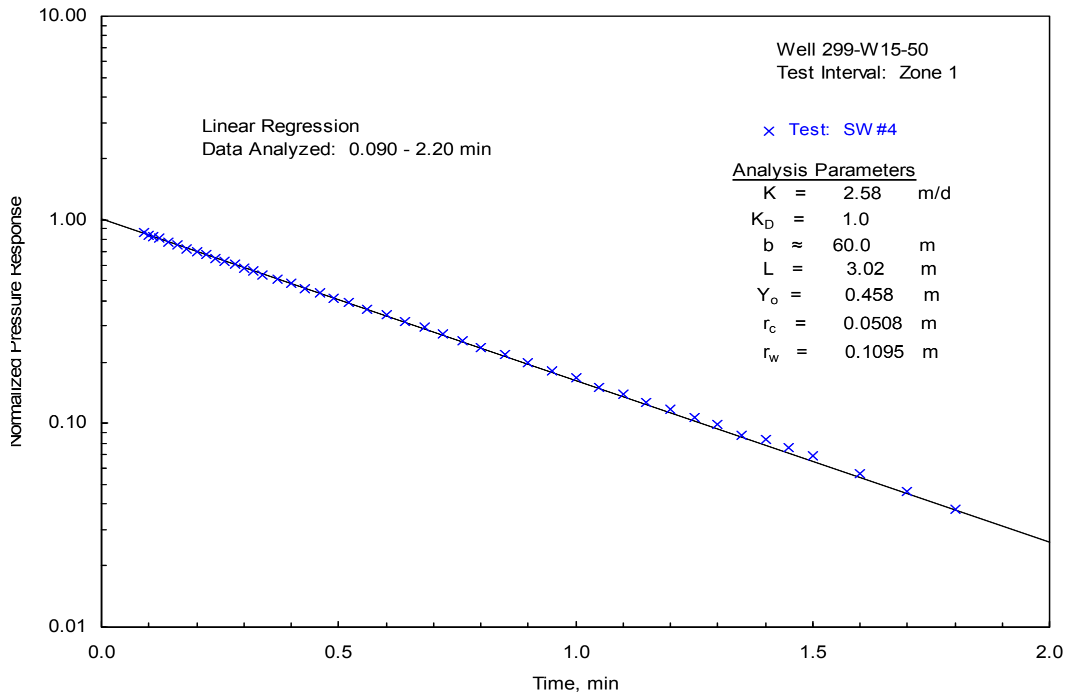


Figure 5.7 Selected Slug Test Analysis Plots for Well 299-W15-50: Test Interval Zone 1 (Bouwer and Rice Method [top} and Type-Curve Method {bottom})



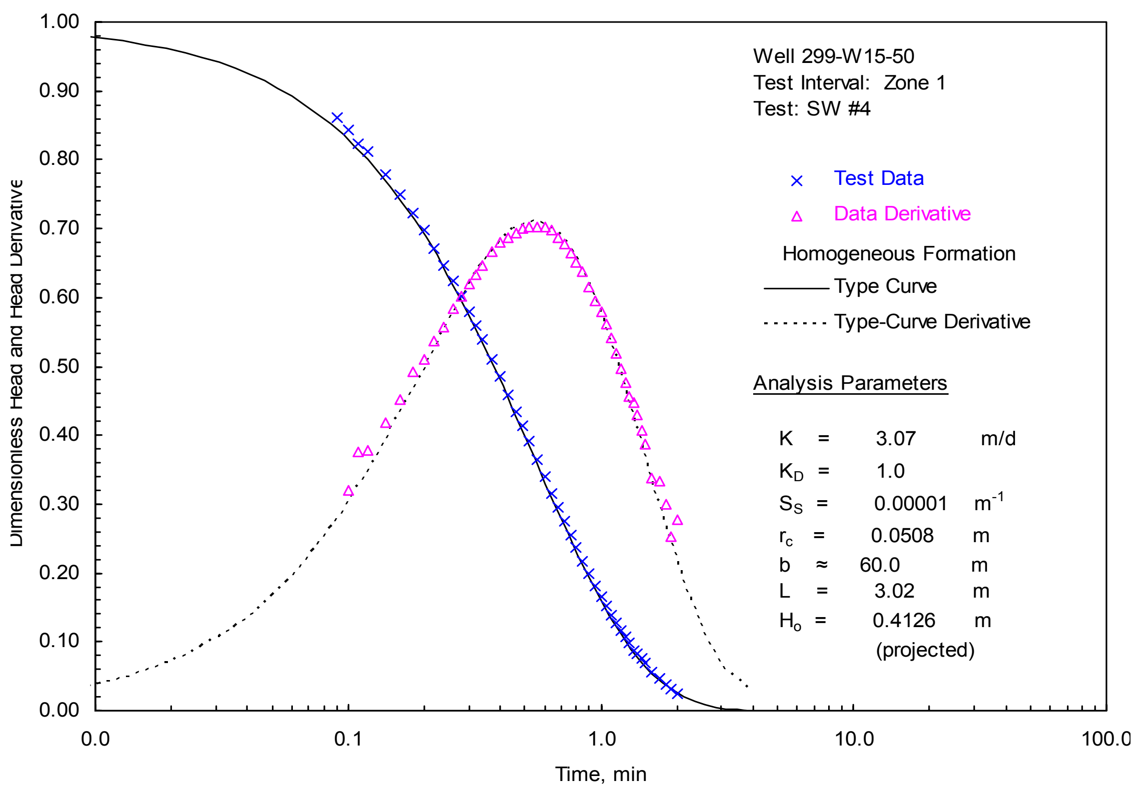
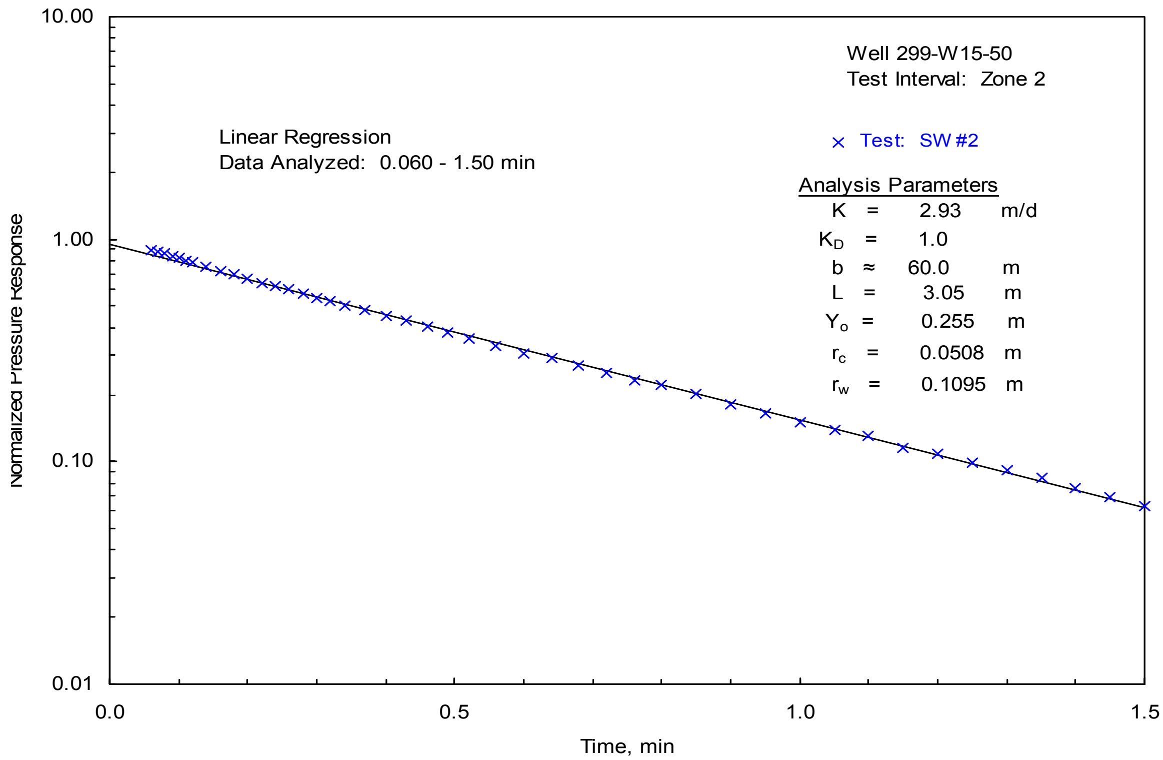


Figure 5.8 Selected Slug Test Analysis Plots for Well 299-W15-50: Test Interval Zone 2 (Bouwer and Rice Method [top} and Type-Curve Method {bottom})



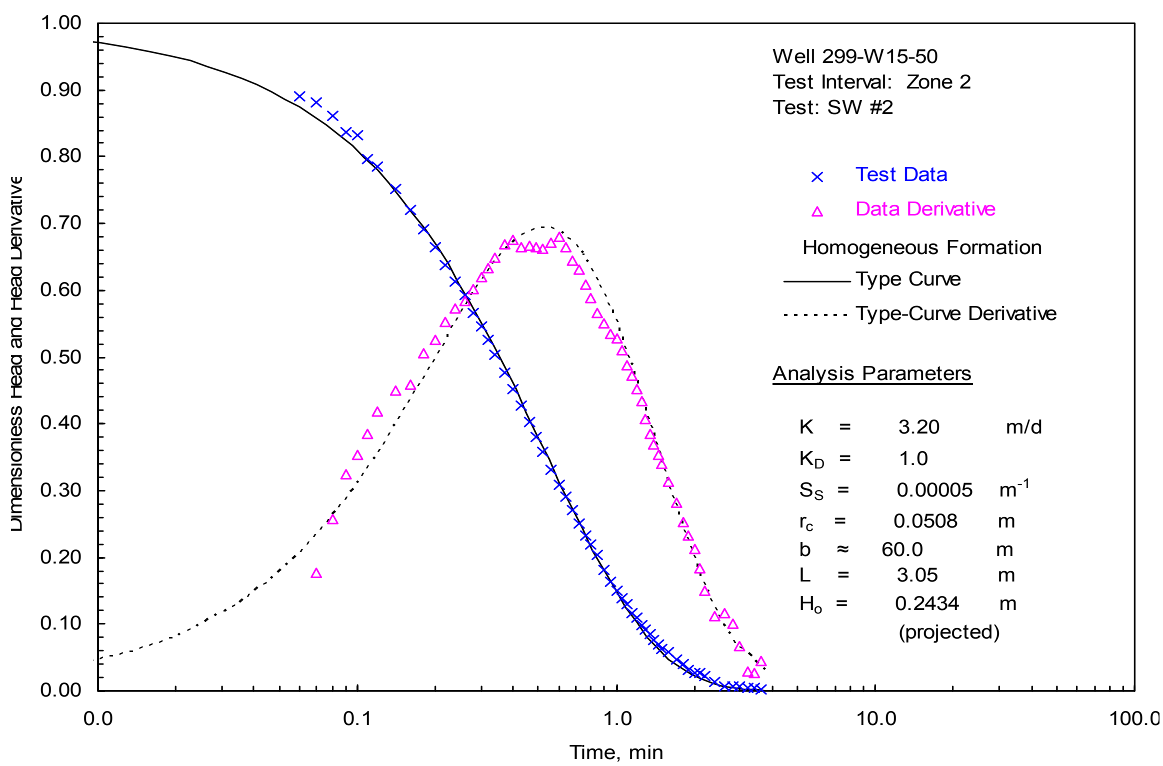
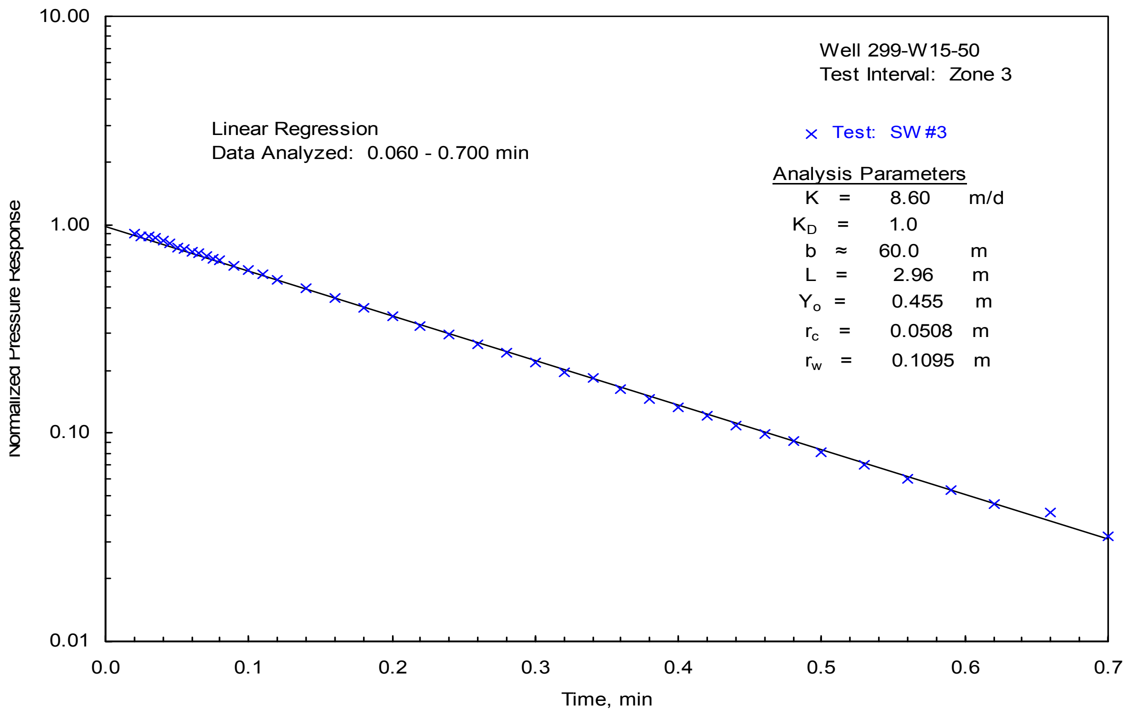


Figure 5.9 Selected Slug Test Analysis Plots for Well 299-W15-50: Test Interval Zone 3 (Bouwer and Rice Method [top} and Type-Curve Method {bottom})



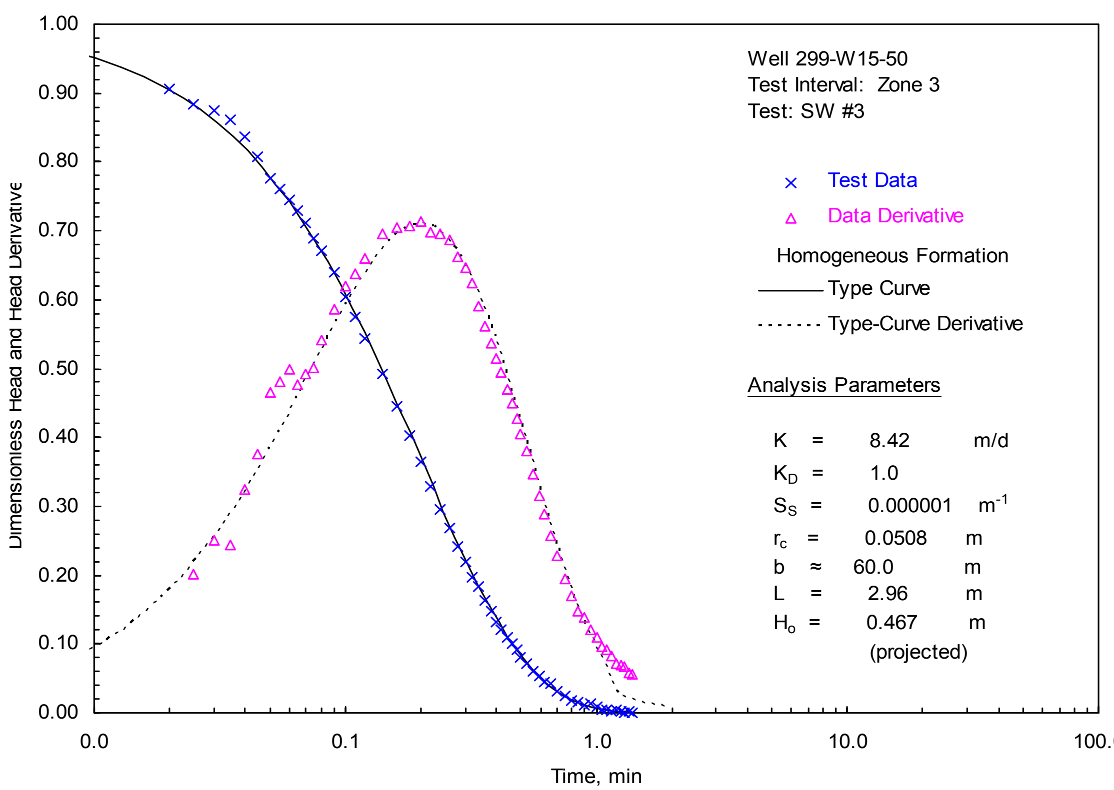


Figure 5.10 Slug Test SI #2 and SW #2 Response and Test History Match for Well 299-W18-16

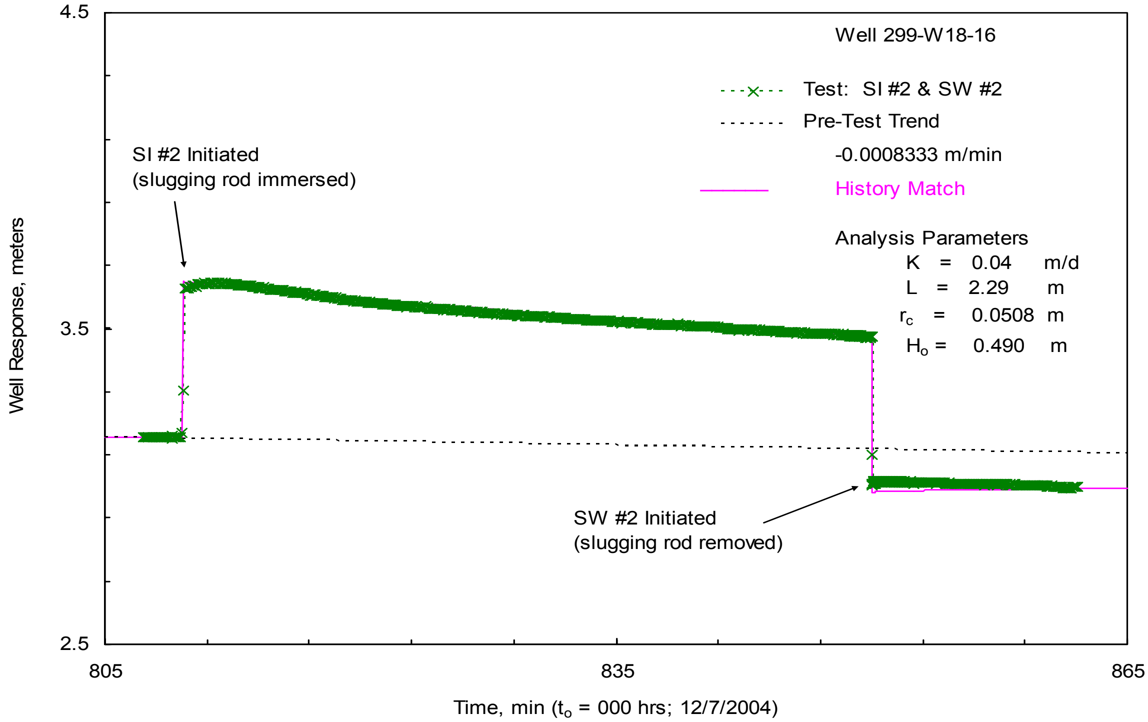


Figure 5.11 Slug Tests SI #1 and SW #1 Response and Test History Match for Well 299-W18-16: Sensitivity to Varying K Values (0.04, 0.2, 1.0 m/day)

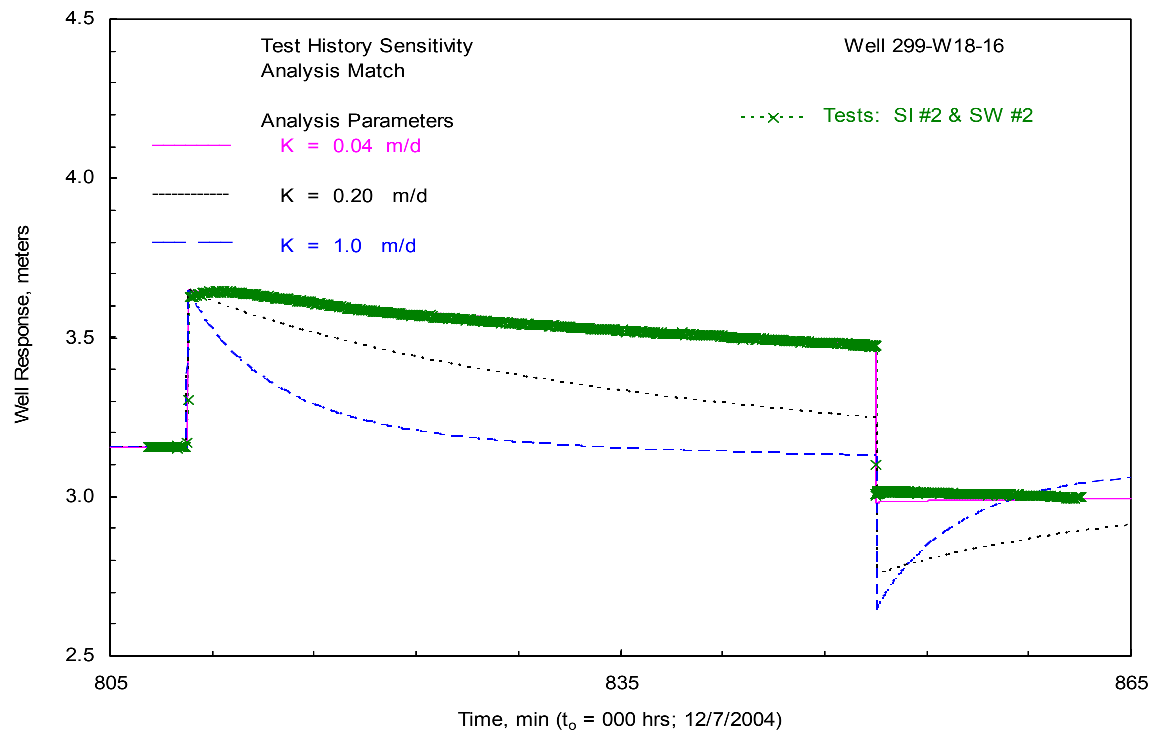


Figure 6.1 Hydraulic Conductivity Histogram for Recently Tested 200-West Area Wells

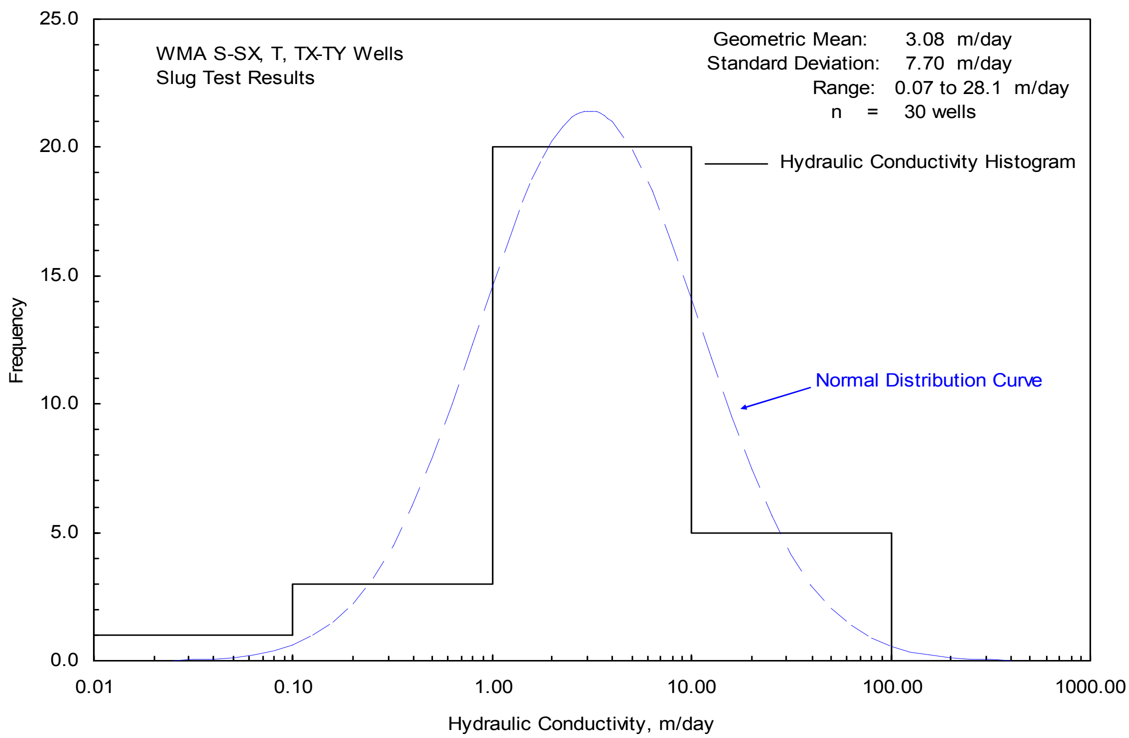


Figure 6.2 Hydraulic Conductivity Profile for ZP-1 Well 299-W11-43 Test/Depth Intervals

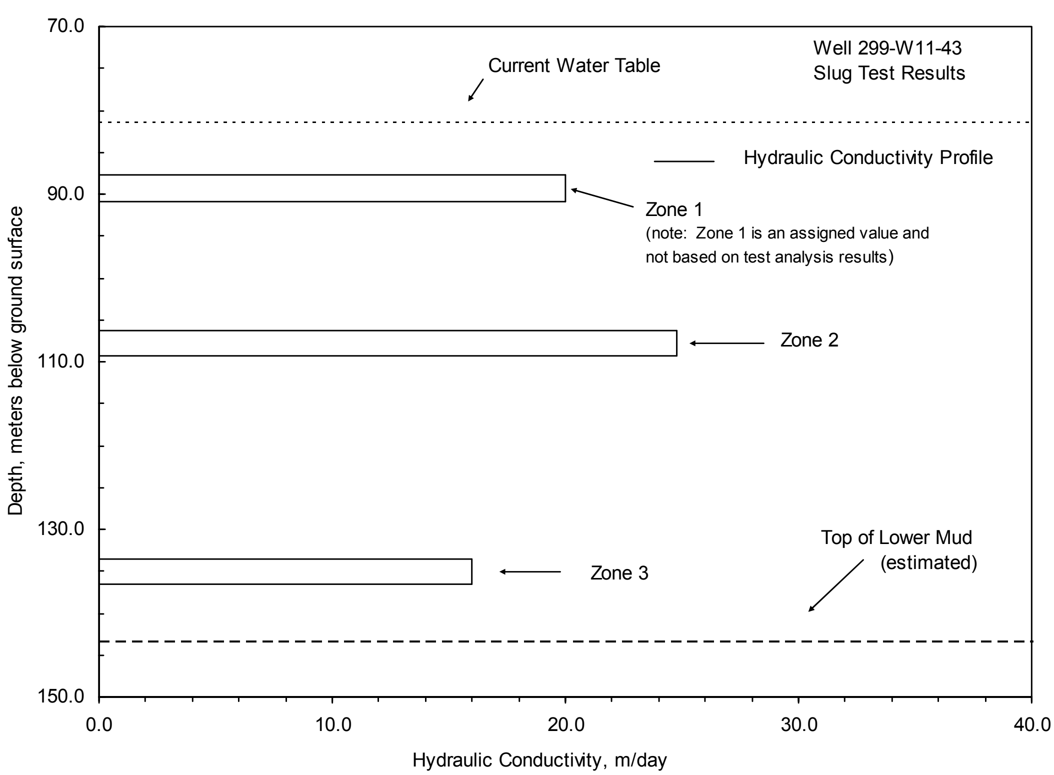
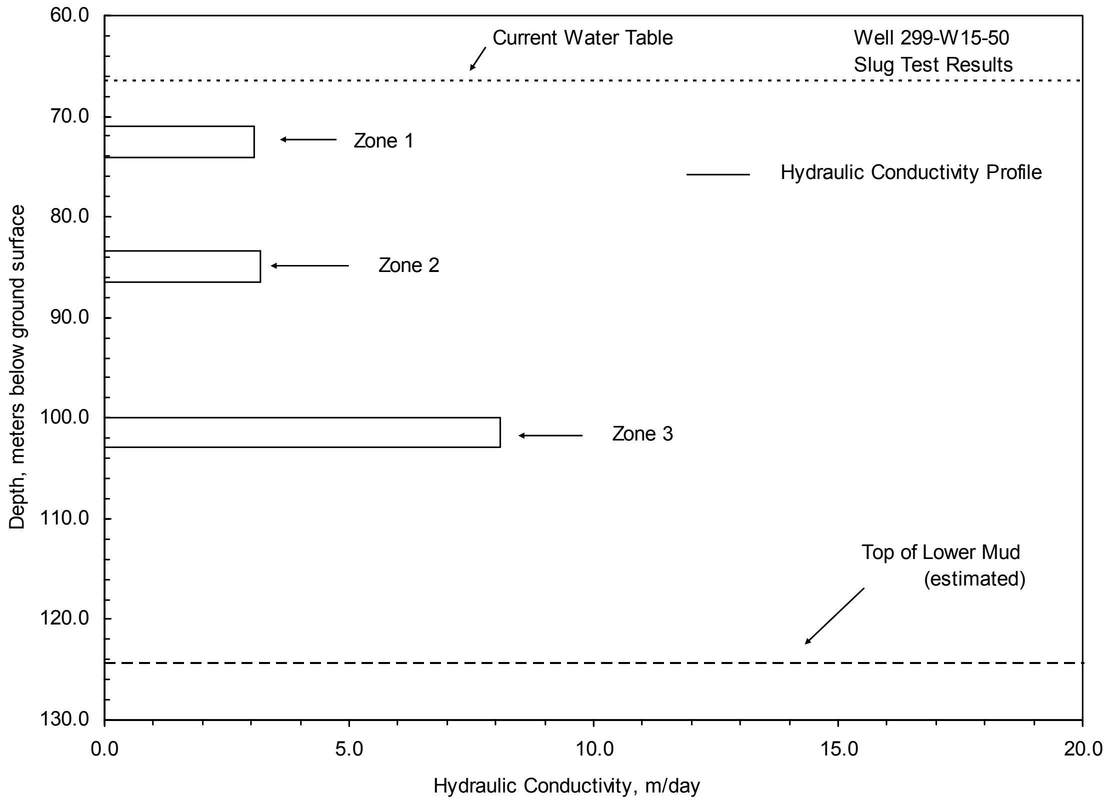


Figure 6.3. Hydraulic Conductivity Profile for ZP-1 Well 299-W15-50 Test/Depth Intervals



APPENDIX A. MISCELLANEOUS TEST EQUIPMENT PICTURES

Figure A.1 Inflatable Packer and Well-Screen Assembly Shown on Pipe Rack

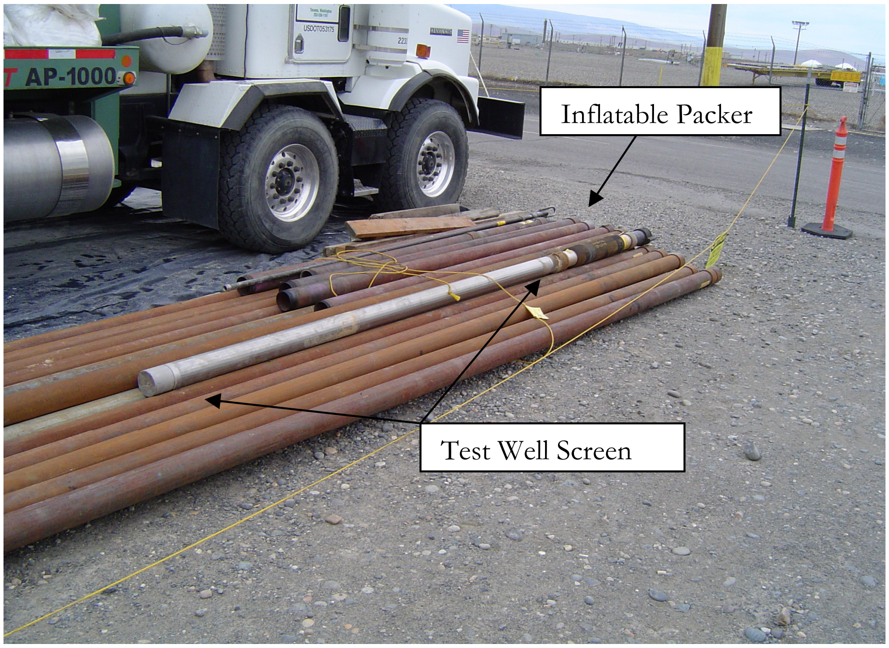
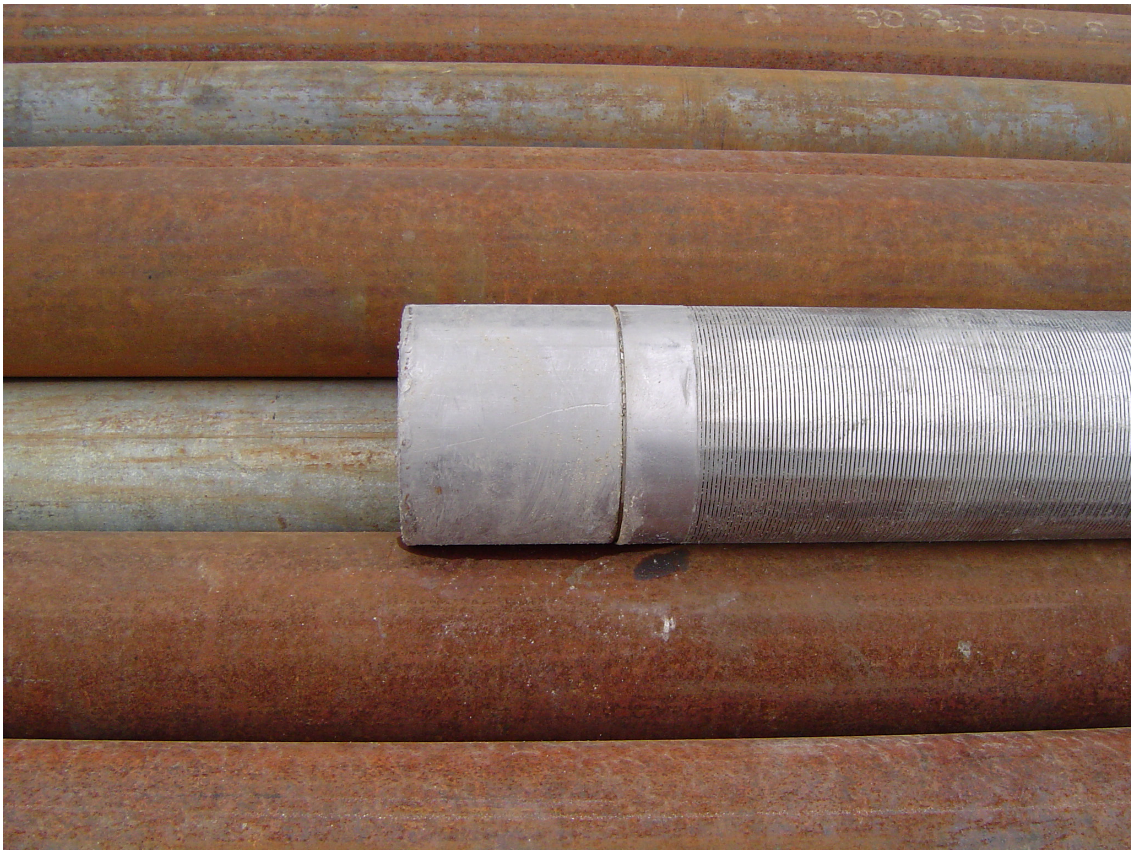


Figure A.2 Closer View of Packer/Well-Screen

Figure A.3 Close-up View of Test Well Screen and Bottom End-Cap



APPENDIX B. SELECTED BOREHOLE LOGS

Figure B.1 Well 299-W11-43

Figure B.2 Well 299-W15-50

Figure B.3 Well 299-W18-16

Figure B.1 Selected Borehole Log for Well 299-W11-43

BOREHOLE LOG — Page 7 of 12 — Date: 5/25/05

Well ID: C4694 | Well Name: 299-W11-43 | Location: W of T Plant

Project: CY05 CERCLA Monitoring Wells | 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)
240	GRAB B|H			240'-253' GRAVEL 85% gravel 15% sand; gravel, VC-m pebbles, SR-R, 20% basalt 80% Qtz/other; sand m-F, SA-SR, 10% basalt 90% Qtz/other; 5Y 6/2 L. Olive gray	Becker Hammer, 9 5/8" dual wall casing; Collect 240' archive
245	GRAB B|H				Collect 245' archive
250	GRAB B|H			253'-257' SANDY GRAVEL 75% gravel 25% sand; gravel VC-m pebbles, SR-R, 10% basalt 90% Qtz/other; sand, m-F, SA-SR, 10% basalt 90% Qtz/other trace mica; no rxn HCL, 5Y 6/2 L. Olive gray	Collect 250' archive; drill rate inc 253→257
255	GRAB B|H			257'-277' GRAVEL 90% gravel 10% sand; gravel, 25% >100mm, 50% C-m cobbles, 25% F-VF cobbles, A-R (angular pieces apear to have been crushed during drilling) 30% basalt 70% Qtz/other, sand, same as above; 5Y 5/3 Pale olive	Collect 255' archive; moisture at 257'
260	GRAB				Collect 260' archive
265	GRAB				Collect 265' archive; moisture at 267'; DTW 267.4 (5/31/05)
270	GRAB			270' sand inc to 15%, gravel 85%. 5Y 5/2 olive gray (wet)	Collect 270' archive
275	GRAB			275' gravel 90% sand 10%, same lithology as above	Collect 275' archive; increased water at 278'

Reported By: Jeffrey Weiss | Reviewed By: L.D. Walker

Title: Geologist | Title: Geologist

Signature: Jeffy Weiss | Date: 5/31/05 | Signature: L.D. Walker | Date: 7/20/05

Figure B.1 Selected Borehole Log for Well 299-W11-43, Cont.'

BOREHOLE LOG		Page 8 of 12
		Date: 5/31/05
Well ID: C4694	Well Name: 299-W11-43	Location: W of T Plant
Project: CY05 CERCLA Monitoring Wells		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
280				277'-287' SANDY GRAVEL sG, 75% gravel,	Becker Hammer 9"/6"
	GRAB			20% sand, 5% silt; gravel VC-m pebbles, SR-R	dual wall casing
	B H			10% basalt 90% Qtz/other; sand, m-F, SA-SR	Collect 280' archive
				10% basalt 90% Qtz/other; 5Y 4/2 olive gray	
				(wet)	
285	GRAB				Collect 285' archive
	B H				
		SS no recovery		287'-320' GRAVEL G, 85% gravel, 15% sand;	287' attempted split spoon
				gravel, VC-M, SR-R, 10% basalt, 90% Qtz/other;	no recovery
				sand m-F, SA-SR, 10% basalt 90% Qtz/other;	Water sample at 287' not
290	GRAB			5Y 4/1 olive gray (wet)	collected
	B H				Collect 290' archive
				293-295 sand inc to 20% same lithology	
				as above	
295	GRAB				Collect 295' archive
	B H	Pump sample			
		SS no recovery			297' pump sample HEIS #
				299' gravels are cemented together	B1D7K5
				strong rxn HCL, same as above	298' sieve sample taken from
300	GRAB			300' gravel inc to 95%, same lithology as	cuttings
	B H			above	Collect 300' archive
305	GRAB			305' sand inc to 15%, same lithology as	Collect 305' archive
	B H			above	
310	GRAB				Collect 310' archive
	B H				
315				315' gravel dec in size, 20% VC-m pebbles, 80%	Collect 315' archive
	GRAB			F-VF pebbles, same lithology as above	

Reported By: Jeffrey Weiss		Reviewed By: L.D. Walker	
Title: Geologist		Title: Geologist	
Signature: Jeffrey Weiss	Date: 6/6/05	Signature: L.D. Walker	Date: 7/20/05

Figure B.1 Selected Borehole Log for Well 299-W11-43, Cont.'

BOREHOLE LOG

Page 9 of 12
Date: 6/6/05

Well ID: C4694 | Well Name: 299-W11-43 | Location: W of T Plant
Project: CY05 CERCLA Monitoring Wells | 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
					Becker Hammer 9"/6"
320	GRAB BH ↓			320' GRAVEL, G, 80% gravel, 20% sand <5% silt; gravel, C-m pebbles, SR-R, 20% basalt 80% Qtz/other; sand, c-f, SA-SR, 20% basalt 80% Qtz/other; 5Y 5/2 Olive gray	dual wall casing Collect 320' archive
325	GRAB BH ↓	SS no recovery			Collect 325' archive 328 collect water sample B1D7K0, B1D7M2, B1D7Y5, B1D7N2
330	GRAB BH ↓				Collect 330' archive
335	GRAB BH			335'-345' SANDY GRAVEL, sG, 70% gravel, 30% sand; gravel, vc-m pebbles, SR-R, 20% basalt 80% Qtz/other; sand, m-f, SA-SR, 20% basalt 80% Qtz/other, 5Y 5/2 Olive gray	Collect 335' archive
340	GRAB BH ↓			340' gravel inc to 75% sand 25%, same lithology as above	Collect 340' archive
345	GRAB BH ↓			345'-363' GRAVEL, G, 80% gravel, 20% sand; gravel s. cobbles - c. pebbles <100mm, SR-R, 10% basalt, 90% Qtz/other; sand, vc-m, SA-SR, 10% basalt, 90% Qtz/other; 5Y 4/3 Olive	Collect 345' archive
350	GRAB BH ↓			350' GRAVEL, G, 90% gravel, 20% sand; gravel, vc-m pebbles, SR-R 20% basalt 80% Qtz/other; sand, c-m, SA-SR, 10% basalt 90% Qtz/other, no rxn HCL, 5Y 4/4 olive	Collect 350' archive 350' Δ color
355	GRAB				Collect 355' archive

Reported By: Jeffrey Weiss | Reviewed By: L.D. Walker
Title: Geologist | Title: Geologist
Signature: Jeffrey Weiss | Date: 6/8/05 | Signature: L.D. Walker | Date: 7/20/05

Figure B.1 Selected Borehole Log for Well 299-W11-43, Cont.'

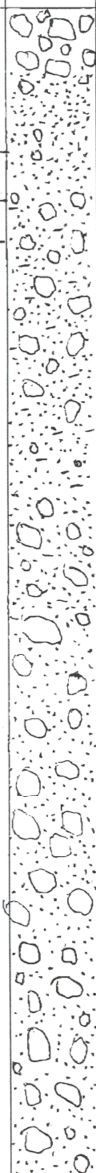
BOREHOLE LOG

Page 10 of 12
Date: 6/8/05

Well ID: C4694 | Well Name: 299-W11-43 | Location: W of T Plant

Project: CY05 CERCLA Monitoring Wells | Reference Measuring Point: Ground Surface

Graphic Log:



Depth (Ft.)	Sample Type No.	Sample Blows Recovery	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)
360	GRAB BH		360' GRAVEL G, 95% gravel 5% sand; gravel, m-F, SR-R, 20% basalt 80% Qtz/other; sand, c-F, SA-SR, 10% basalt 90% Qtz/other; 5Y 5/2 olive gray (sand), gravel color varies	Becker Hammer 9"/6" dual wall casing. Collect 360' archive. 362' water sample
		SS 100% recovery	363'-367' SAND, S, 5% gravel, 90% sand, 5% silt; gravel, c-m, SR-R, 20% basalt 80% Qtz/other;	364→365 SS split spoon sample. 365→366 split spoon sample
365	GRAB BH	SS 80% recovery	sand, m-f, SA-SR 90% Qtz/other <5% basalt <5% mica; no rxn HCl, 2.5Y 4/3 olive brown	Collect 365' archive
			367'-374' SILTY SANDY GRAVEL, msG, 55% gravel 30% sand, 15% silt; gravel, SR-R, vc-m pebbles, 40% basalt 60% Qtz/other; sand m-F, SA-SR,	
370	GRAB BH		10% basalt 90% Qtz/other; mica, 2.5Y 4/3 olive brown	Collect 370' archive
			374'-376' SAND, S, 80% sand, 10% gravel, 10% silt; gravel m-F pebbles, SR-R, 30% basalt 80% Qtz/other; sand, m-F, SA-SR, 90% Qtz/other, 10% basalt, trace	
375	GRAB BH		mica; 2.5Y 4/3 olive brown	Collect 375' archive
			376-412' SANDY GRAVEL, sG, 60% gravel, 35% sand, 5% silt; gravel, m-F pebbles, SR-R 15% basalt 85% Qtz/other; sand, c-m, SA-SR	Sand keeps coming in to borehole
380	GRAB BH		15% basalt 85% Qtz/other; 5Y 4/2 olive gray. 379' sand inc to 65%, same lithology as above	Collect 380' archive. Drilling becomes more difficult at 380'
385	GRAB BH		385' gravel inc to 60% same lithology as above. 387' - sand and gravel cemented together, mod rxn HCl, same lithology as above	Collect 385' archive
390	GRAB BH			Collect 390' archive
395	GRAB		396' - sand inc to 60% same lithology as above	Collect 395' archive

Reported By: Jeffrey Weiss | Reviewed By: L.D. Walker
Title: Geologist | Title: Geologist
Signature: [signature] Date: 6/15/05 | Signature: [signature] Date: 7/20/05

Figure B.1 Selected Borehole Log for Well 299-W11-43, Cont.'

BOREHOLE LOG

Page 11 of 12
Date: 6/15/05

Well ID: C4694 | Well Name: 299-W11-43 | Location: W of T Plant

Project: CY05 CERCLA Monitoring Wells | 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
400	GRAB BH			400' SANDY GRAVEL, sG, 60% gravel 40% sand; gravel 80% C-F pebbles, SR-R, 15% basalt 85% Qtz/other; sand VC-m, SA-SR, 15% basalt 85% Qtz/other; 5Y 4/2 olive gray	Becker Hammer 9"/6" dual wall casing. Collect 400' archive
405	GRAB BH			405' gravel clasts >150mm.	Collect 405' archive
410	GRAB BH			410' sand inc to 50%, same lithology as above	Collect 410' archive
				412-418' SILTY SANDY GRAVEL, msG, 60% gravel 30% sand 10% silt; gravel m-f pebbles, SR-R, 20% basalt 80% Qtz/other; sand C-F, SA-SR, 10% basalt 90% Qtz/other; 5Y 4/3 olive	412' cemented
415	GRAB BH			415' color change 5Y 4/2 olive gray same lithology as above	Collect 415' archive. Water sample at 418'
		SS no recovery		418-448' SANDY GRAVEL, sG, 40% gravel, 55% sand, 5% silt; gravel C-F pebbles, SA-SR, 20% basalt 80% Qtz/other; sand VC-F, SA-SR, 10% basalt 90% Qtz/other; 5Y 3/2 dark olive gray	420' cemented
420	GRAB BH				Collect 420' archive
425	GRAB BH			424' gravel inc to 50% same lithology as above	Collect 425' archive
430	GRAB BH			430' sand inc to 60% same lithology as above	Collect 430' archive
435	GRAB BH			435' gravel inc to 60%, same lithology as above	Collect 435' archive

Reported By: Jeffrey Weiss | Reviewed By: L. D. Walker

Title: Geologist | Title: Geologist

Signature: [signature] Date: 6/20/05 | Signature: [signature] Date: 7/20/05

Figure B.1 Selected Borehole Log for Well 299-W11-43, Cont.'

BOREHOLE LOG

Page 12 of 12

Date: 6/20/05

Well ID: C4694	Well Name: 299-W11-43	Location: W of T Plant
Project: CY05 CERCLA Monitoring Wells		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)
440					Becker Hammer 9"/6"
	GRAB B/H ↓			440' SANDY GRAVEL, sG, 60% gravel, 40% sand; gravel, 50% vc-m cobbles, 50% c-m pebbles, SR-R, 35% basalt 65% Qtz/other; sand c-m, SA-SR, 20% basalt 80% qtz/other; 5Y 4/2 olive gray	dual wall casing; Collect 440' archive
445	GRAB			445' gravel dec in size, c-m pebbles, same lithology as above	Collect 445' archive
		SS no rec		448' Total depth drilled	448' water sample; 448' Aquifer test
450					
455					
460					
465					
470					
475					

Reported By: Jeffrey Weiss		Reviewed By: L.D. Walker	
Title: Geologist		Title: Geologist	
Signature: Jeffrey Weiss	Date: 6/20/05	Signature: LD Walker	Date: 7/20/05

Figure B.2 Selected Borehole Log for Well 299-W15-50

BOREHOLE LOG		Page 6 of 9 Date: 1/14/05
Well ID: C4302	Well Name: 299-W15-50	Location: NE of PFP
Project: CERCLA Drilling		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
200	GRAB				Collect 200' Sample
				202-203 GRAVELY SILT, M 20% gravel	Cable Tool with
				10% sand 70% silt; gravel cobble-pebble	drive barrel
				SR-R P. sorted; silt med plasticity	
205	GRAB			no rxn HCL 5Y 6/3 olive	Collect 205' sample
				203-208' SILTY SANDY GRAVEL	Drilling becomes more difficult
				208-209' SAND	11 3/4" Casing set at 209'
					Continue with 8 5/8" OD casing
210	GRAB			210'-218' SILTY SANDY GRAVEL msG	Collect 210'
				60% GRAVEL, 25% SAND, 15% SILT	ORANGE/YELLOW COLOR, MOIST
				GRAVEL COBBLE-PEBBLE, SA-R, P. SORTED; SAND	
				70% QTZ/OTHER, 30% BASALT, M-F, SA-R; SILT	
				LOW PLASTICITY, 10YR 8/4, NO RXN HCL	COLLECT 215' ARCHIVE
215	GRAB				
				218'-225' SILTY GRAVEL mG	218.5' Final water depth 2/15
		▽		70% GRAVEL, 20% SILT, 10% SAND	
				GRAVEL SM COBBLE - VF PEBBLE, SR-R, P. SORTED;	
				SILT, LOW PLASTICITY, WEAK HCL RXN 10YR 6/3	
220	GRAB			TAN-BROWN, PALE BROWN	COLLECT 220' ARCHIVE
					223.5' WATER
	SIEVE SAMPLE	WATER ↓			223-224.5' SIEVE SAMPLE
				225'-229' SILTY GRAVEL mG	DRIVE BARREL W/ WIRE MESH
225	GRAB			SILT 50%, GRAVEL 30%, SAND 20%	COLLECT 225' ARCHIVE
				SILT MED PLASTICITY, WET, WEAK HCL RXN;	
				GRAVEL SM COBBLE - F PEBBLE, SA-R, P. SORTED	DIFFICULTY DRILLING
				SAND VF-M, 70% BASALTIC, SA-R	
				10YR 6/4 light yellowish brown	
230	GRAB				COLLECT 230' ARCHIVE
				229'-238' SILTY SANDY GRAVEL msG	
				50% GRAVEL 30% SAND 20% SILT	DRILLING EASIER / SANDS
				GRAVEL PEBBLE SA-R, P. SORTED, 70% QTZ	
235	GRAB			20% BASALT; SAND 60% QTZ/OTHER, 50% BASALT	
				SA-R, C-FN, SILT LOW PLASTICITY, 2.5Y 7/3	COLLECT 235' ARCHIVE
				PALE YELLOW	

Reported By: Jeffrey Weiss	Reviewed By: L. D. Walker
Title: Geologist	Title: Geologist
Signature: [signature] Date: 1/1/05	Signature: [signature] Date: 3/3/05

Figure B.2 Selected Borehole Log for Well 299-W15-50, Cont'.

BOREHOLE LOG

Page 7 of 9
Date: 1/21/05

Well ID: C4302 | Well Name: 299-W15-50 | Location: NE of PFP

Project: CERCLA | 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
				238'-241' SANDY GRAVEL (sG) -50% cobbles	
240	Grab			and pebbles, rounded, basalt (50%) + Qtz (50%)	Collect 240' Archive
	↓			max. size 70 mm, well developed iron oxide stain -	
				50% sand (med.-cs), well sorted, greenish-	242-245 heaving sand
				salt + pepper (50% qtz + 50% dark); Gley 1 6/1	245- H_2O sample + slug test
				241-246 SLIGHTLY SILTY SAND (m)S, greenish,	
245	Grab	H_2O + SWG TEST		med.-cs., sorted, salt and pepper (50% Qtz + 50%	Collect 245' Archive
	↓			dark); adheres in clumps; no acid Reaction; Gley 1 6/1	
				246-255 GRAVEL - 80% Pebbles (sm) and cobbles	
				(sm), 70% granite and Qtz + 30% basalt	
				15% SAND, salt + Pepper (m-cs) Gley 1 5/1	
250	Grab			5% SILT CLASTS, mottled brown + gray	Collect 250' Archive
	↓			(245-247 heaving sand)	
				(246-255 hard drilling gravels)	
	Sieve Sample				
255	Grab			255-265' SILTY SANDY GRAVEL (msG)	Collect 255' Archive
→ ↓	Start Hard Tooling			35% Gravel, coarse pebbles to v.f.; 50% Qtz + 50% basalt	Hit boulder at 256'
				40% Sand (f.-cs.), poorly sorted	
				25% Silt, mottled-green, violet, red-brown; plastic	
				Overall, poorly sorted, no acid reaction; 10YR 5/3	
260	Grab				Collect 260' Archive
	↓				
265	Grab			265-272 SANDY GRAVEL (sG)	Collect 265' Archive
	↓			70% Gravel (60% basalt + 40% Qtz); 25% Sand	
		H_2O Test		(vf-med.), well sorted; 5% silt 5Y 5/3	267.6' bgs Water Sample
				268-273 flowing sand zone	
270	Grab			270 sample 5Y 6/3	Collect 270' Archive
	↓				continued flowing sand in gravel -
					driller added water for head to
				273-278 GRAVEL (G) Gravel (rock chips	minimize sand inflow
				90% (65% basalt, 20% Qtz, 15 dk plagioclase); 5% Sand	
275	Grab			(v.c.-vf), poorly sorted, salt + pepper (70% Qtz + 30% dk)	Collect 275' Archive
	↓			5% silt; 5Y 6/3, no acid reaction	

Reported By: Scot C. Adams | Reviewed By: L.D. Walker

Title: Geologist | Title: Geologist

Signature: Scot C. Adams | Date: 2/1/05 | Signature: LD Walker | Date: 3/3/05

A-6003-642 (03/03)

Figure B.2 Selected Borehole Log for Well 299-W15-50, Cont'.

BOREHOLE LOG

Page 8 of 9
Date: 2/1/05

Well ID: C4302 | Well Name: 299-W15-50 | Location: NE of PFP

Project: CERCLA | 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)
				278-285'	
280	Grab			GRAVEL - 85% Gravel (rockchips) (65% basalt, 30% Qtz., 5% other varigated rock); 5% Sand (f to vf) greenish-gray; Silt 10%; no acid reaction 5Y 6/3	Collect 280' Archive driller reported easier drilling
285	Grab	H₂O + SLUG TEST		285-288' SANDY GRAVEL (sG) - 75% Gravel (rockchips), (30% basalt, 30% Qtz, 40% other mixed Rx; no acid reaction; 5Y 6/3	Collect 285' Archive 285.1' bgs - WATER + SLUG TEST SAMPLE # B1BJH8, B1BJK0, B1BJJ5
290	GRAB			290 - 293 SILTY SANDY GRAVEL (msG) 70% GRAVEL, 20% SAND, 10% SILT; GRAVEL 60% BASALTIC, 40% QTZ/FELD/OTHER, BROKEN PEBBLE SR-R, MOD SORTED; SAND 50% BASALT, 50% QTZ/OTHER vC-vf, SR-A, 5Y 6/3, NO RXN HCL	COLLECT 290' ARCHIVE
295	GRAB			293-318' SILTY SANDY GRAVEL (msG) GRAVEL 60%, SAND 25%, SILT 15%; GRAVEL 50% BASALTIC, 50% QTZ/FELDS, BROKEN + UNBROKEN COARSE PEBBLES, SR-R, POORLY SORTED; SAND 60% BASALTIC, 40% QTZ, m-vf, SA-R 2.5Y 6/2	COLLECT 295' ARCHIVE DRILLER NOTED DIFFICULTY IN DRILLING
300	GRAB				COLLECT 300' ARCHIVE
					304'-305' SANDY LENSE
305	GRAB			GRAVEL 50%, 30% SAND, 20% SILT ↓ INCREASING GRAVELS	COLLECT 305 ARCHIVE DIFFICULTY IN DRILLING
310	GRAB			GRAVEL 70%, 20% SAND, 20% SILT	COLLECT 310' ARCHIVE
					COLLECT 315' ARCHIVE
315	GRAB	H₂O SAMPLE		INCREASING SANDS ↓	318' WATER SAMPLE (B1BJH9, B1BJJ6, B1BJK1) HEAVING SANDS

Reported By: Scot C. Adams / Bjorn Helgeson | Reviewed By: L.D. Walker

Title: Geologist | Title: Geologist

Signature: | Date: 2/8/05 | Signature: | Date: 3/3/05

A-6003-642 (03/03)

Figure B.2 Selected Borehole Log for Well 299-W15-50, Cont'.

BOREHOLE LOG			Page 9 of 9
			Date: 2/8/05
Well ID: C4302	Well Name: 299-W15-50	Location: NE OF PFP	
Project: CERCLA		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
				320'-328' SANDY GRAVEL (SG)	319' SANDY LAYER
320	GRAB			GRAVEL 60%, SAND 35%, SILT 5%;	COLLECT 320' ARCHIVE
	↓			GRAVEL 70% BASALTIC, 30% QTZ/FELDS, BROKEN	
				M-VF PEBBLES, SA-R, MOD-SORT; SAND	EASIER DRILLING
				70% BASALT, 30% QTZ/OTHER, VC-FN, A-SR	
				WELL SORTED, 2.5Y 5/2 GRAYISH BROWN	
325	GRAB				COLLECT 325' ARCHIVE
	↓			328'-337' SANDY GRAVEL (SG) GRAVEL	
				70%, SAND 25%, SILT 5%; GRAVEL 70%	
				BASALTIC, BROKEN C-VF PEBBLES, A-SA,	
330	GRAB			WELL SORTED; SAND 60% BASALTIC, 40% QTZ/OTHER	COLLECT 330' ARCHIVE
	↓			VC-FN, A-SA, WELL SORTED, 2.5Y 6/2	
					DIFFICULT DRILLING
335	GRAB				COLLECT 335' ARCHIVE
				T.D. = 337.6' bgs	HEAVING SANDS
		H₂O + SLUG + GEOPHYSICAL TEST			
					337'. H_2O SAMPLE
340					#
					337' GEOPHYSICAL LOGGING
					337' SLUG TEST

Reported By: Bjorn Helgeson		Reviewed By: L.D. Walker	
Title: GEOLOGIST		Title: Geologist	
Signature: [signature]	Date: 2/9/05	Signature: [signature]	Date: 3/3/05

A-6003-642 (03/03)

Figure B.3 Selected Borehole Log for Well 299-W18-16

BOREHOLE LOG

Page 8 of 9
Date 11-24-04

Well ID C4303	Well Name 299-W18-16	Location 5E of PFP
Project CY04 RCRA/CERCLA Groundwater monitoring wells		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
280	GRAB HT			280' SILTY SANDY GRAVEL smG same as above	Collect 280' archive
285	GRAB HT			285' SILTY SANDY GRAVEL smG same as above	Collect 285' archive
290	GRAB HT			290' SILTY SANDY GRAVEL smG Gravel 60%, Sand 20%, Silt 20% Same as above	Collect 290' archive
295	GRAB HT			295' SILTY SANDY GRAVEL smG 60% Gravel 25% sand, 15% silt, gravel 50% basalt 50% qtz/ Sand coarse-F grained A-SA 50% basalt 50% qtz/other, no rxn HCL 2.5Y 4/2 Dark Grayish Brown	Collect 295' archive
300	GRAB HT			300' SILTY SANDY GRAVEL smG 60% GRAVEL 10% sand 30% silt, Same as above	Collect 300' archive
305	GRAB HT			305' SILTY SANDY GRAVEL smG Same as above, basalt inc to 60%.	Collect 305' archive
310	GRAB HT			310' SILTY SANDY GRAVEL smG 50% gravel 20% sand 30% silt, Gravel 50% basalt 50% Qtz/other, Sand Coarse-F grained 50% basalt 50% Qtz/other 5Y 5/3 Olive	Collect 310' archive
315	GRAB HT			315' SILTY SANDY GRAVEL smG same as above	Collect 315' archive

Reported By Jeffrey Weiss		Reviewed By L.D. Walker	
Title Geologist		Title Geologist	
Signature [signature]	Date 12-6-04	Signature [signature]	Date 1/4/05

Figure B.3 Selected Borehole Log for Well 299-W18-16Cont'.

BOREHOLE LOG

Page 9 of 9
Date 12-6-04

Well ID C4303 | Well Name 299-W18-16 | Location 8°W SE of PFP

Project Fy04 RCRA/CERCLA GW monitoring wells | 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)
320	GRAB HT			320' SILTY SANDY GRAVEL smG same as above	Collect 320' archive
325	GRAB HT			325' SILTY SANDY GRAVEL smG same as above	Collect 325' archive
330	GRAB HT			330' SILTY SANDY GRAVEL smG 30% gravel 50% sand 20% silt gravel crushed pebble-cobble SA-A, 30% basalt 70% Qtz/other sand C-F grained SA-A 30% basalt 70% Qtz/other 2.5Y 5/3 L Olive brown	Collect 330' archive
335	GRAB HT			335' SILTY SANDY GRAVEL smG 40% gravel 40% sand 20% silt gravel crushed pebble-cobble SA-VA 50% basalt 50% Qtz/other sand C-F grained SA-A 40% basalt 60% Qtz/other 2.5Y 5/3 L olive brown	Collect 335' archive
340	Grab HT			~~3~~ EJ 340' smG as above	340' Archive
345	Grab			345' smG as above	345' Archive
				TD 348'	Kavi's water sample 345'
350					
355					

Reported By Jeffrey Weiss/EJ Jensen | Reviewed By L. D. Walker

Title Geologist | Title Geologist

Signature Jeffrey Weiss | Date 12/6/04 | Signature LD Walker | Date 1/4/05