Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU ZP-1 Wells 299-W10-33 and 299-W11-48

D. R. Newcomer

September 2007

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Summary

Slug-test results obtained from single and multiple, stress-level slug tests conducted during drilling and borehole advancement provide detailed hydraulic conductivity information at two 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 ~10 m of the unconfined aquifer (i.e., Ringold Formations, Unit 5). These characterization results complement previous and ongoing drill-and-test characterization programs at surrounding 200-West and -East Area locations (see Figure S.1).\(^{(a)}\)

An analysis of the slug-test results indicates calculated average test-interval estimates of hydraulic conductivities ranging between 1.24 and 15.7 m/day. The ZP-1 well hydraulic-conductivity estimates were derived for test-interval sections that ranged from 1.0 to 1.6 m in length. The highest hydraulic-conductivity estimates were obtained for a single zone tested at well 299-W10-33 (i.e., range of 13.0 to 17.3 m/day), which is the southernmost ZP-1 well tested. These values bracket the reported 200-West Area geometric mean value (3.08 m/day) for recent slug tests conducted at 30 monitor-well sites completed within the upper part (i.e., upper 10 m) of the unconfined aquifer in the 200-West Area (Spane et al., 2001a, 2001b, 2002, 2003; Spane and Newcomer 2004).

References


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Figure S.1. Location Map Showing OU ZP-1 Test Well Sites
## Tables

4.1. Slug-Test Characteristics for Selected Test/Depth Intervals at Operable Unit ZP-1 Test  
Wells 299-W10-33 and 299-W11-48................................................................................................ 4.1

4.2. Slug-Test-Analysis Results............................................................................................................. 4.2
1.0 General Hydrologic Test Plan Description

The following discussion of the general hydrologic test plan is taken primarily from similar slug-test characterization-program descriptions presented previously in Spane.\(^\text{(a)}\) 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 retracted, exposing an approximate 1.5-m open borehole section. The packer was then inflated to isolate the well-screened/test interval and the testing string from the inside of the drill casing.

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 a 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 using two slugging rods of different, known displacement volumes. Unfortunately, only one of the three test zones (i.e., Zone 1 at well 299-W10-33) was tested successfully using slugging rods with different displacement volumes. The second of the three test zones (i.e., Zone 2 at well 299-W11-48) was tested successfully at a low stress, but not at a high stress, and the third zone (i.e., Zone 1 at well 299-W11-48) was tested successfully at a high stress, but not at a low stress.

For Zone 1, well 299-W10-33, three or more multi-stress slug tests were conducted successfully. Individual slug tests were fully recovered before depressing the fluid column to prepare the next slug test within the characterization sequence. A wide-range in recovery times was expected, based on an 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 to >5 min for lower permeability test zones for 200-West Area wells. A description of the hydrologic test system used during slug-test characterization is provided in the following report section.


2.0 Hydrologic-Test-System Description

Figure 2.1 shows the general test-system configuration used for slug tests conducted during the drilling and testing of the ZP-1 wells with single-wall drill-casing strings. Slug tests were conducted using slugging rods for all test zones within single-wall drill casing wells 299-W10-33 and 299-W11-48. Features common to this test-system configuration include a downhole packer/well-screen test assembly and a downhole pressure transducer and surface datalogger system. The drill-casing strings used for borehole advancement during the drilling of the ZP-1 wells varied slightly for the respective well sites and had the following I.D./O.D. dimensions: well 299-W10-33: 0.248/0.273 m; and well 299-W15-48: 0.248/0.260 m).

As shown in Figure 2.1, an inflatable packer was used to seal and isolate the test interval and testing string from the encompassing drill-casing area. 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 used: 3.05-m long, 0.1016-m I.D. well-screen (Figure 2.2). A strain-gauge pressure transducer was installed within the test-casing string to monitor downhole test-interval response before and during slug testing.
Figure 2.1. General Slug Test Configuration Using Slugging Rods
Figure 2.2. Packer/Well-Screen Assembly Dimensions
3.0 Slug Test Response/Analysis

The following discussion pertaining to slug-test response and analysis is taken primarily from Spane (see Footnote [a], p. 1.1). 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 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:

$$C_D = (g/L_e)^{1/2} r_c^2 \ln \left( \frac{R_e}{r_w} \right)/(2 K L)$$  (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.

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 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. All ZP-1 well test intervals exhibited over-damped response characteristics. Figure 3.2 shows predicted slug-test recovery as a function of hydraulic conductivity (K range: 2.5 to 40 m/day; 1.5-m test interval) for test intervals exhibiting over-damped response characteristics and 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. = 0.1016 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 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 (1998). For over-damped slug tests, hydraulic-conductivity estimates obtained using the Bouwer and Rice analytical method are generally less reliable than corresponding estimates obtained using 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 ZP-1 wells. 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 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 using 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

![Figure 3.2. Over-Damped Slug-Test Response as a Function of Test-Interval Hydraulic Conductivity](image)
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 ZP-1 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 ZP-1 boreholes as they were advanced to their final drilling depths. Table 4.1 presents pertinent 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>
<thead>
<tr>
<th>Test Well</th>
<th>Test Zone</th>
<th>Test Date</th>
<th>Number of Slug Tests</th>
<th>Depth to Water, m bgs</th>
<th>Depth/Test Interval, m bgs</th>
<th>Diagnostic Slug Test Response Model</th>
<th>Hydrogeologic Unit Tested (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>299-W10-33</td>
<td>Zone 1</td>
<td>7/6/07</td>
<td>5</td>
<td>69.98</td>
<td>73.2 - 74.2 (1.0)</td>
<td>Homogeneous Formation/ Exponential-Decay (over-damped)</td>
<td>Ringold Formation (Unit 5)</td>
</tr>
<tr>
<td></td>
<td>Zone 1</td>
<td>4/6/07</td>
<td>6(b)</td>
<td>73.64</td>
<td>76.8 - 78.4 (1.6)</td>
<td>Heterogeneous Formation/ Exponential Decay (over-damped)</td>
<td>Ringold Formation (Unit 5)</td>
</tr>
<tr>
<td>299-W11-48</td>
<td>Zone 2</td>
<td>4/12/07</td>
<td>4(b)</td>
<td>73.79</td>
<td>82.8 - 84.3 (1.5)</td>
<td>Heterogeneous Formation/ Exponential Decay (over-damped)</td>
<td>Ringold Formation (Unit 5)</td>
</tr>
</tbody>
</table>

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

Note: For all test wells, \( r_c = 0.0508 \) meter; \( r_w \) ranged between 0.1302 and 0.1365 meters.

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

(b) Only two of the slug tests provided analyzable results.
Table 4.2. Slug-Test-Analysis Results

<table>
<thead>
<tr>
<th>Test Well</th>
<th>Test Zone</th>
<th>Type-Curve Analysis Method</th>
<th>Horizontal Hydraulic Conductivity, $K_h^{(a)}$ (m/day)</th>
<th>Specific Storage, $S_s$ (m$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>299-W10-33</td>
<td>Zone 1</td>
<td></td>
<td>13.0 – 17.3 (15.7)</td>
<td>1.0E-5</td>
</tr>
<tr>
<td>299-W11-48</td>
<td>Zone 1</td>
<td></td>
<td>1.17 - 1.30 (1.24)</td>
<td>5.0E-5 - 1.0E-4</td>
</tr>
<tr>
<td></td>
<td>Zone 2</td>
<td></td>
<td>5.62 - 6.91 (6.27)</td>
<td>1.0E-5</td>
</tr>
</tbody>
</table>

Number in parentheses is the average value for all tests.
(a) Assumed to be uniform within the well-screen test section.

4.1 Well 299-W11-48 (C5243)

The drilling of OU ZP-1 well 299-W11-48 was initiated on November 29, 2006, and continued until reaching a final depth of 124.7-m bgs on June 4, 2007. 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 130 to 140-m bgs. Two test-depth intervals were tested at the borehole location: Zone 1 = 76.8 to 78.4 m bgs; and Zone 2 = 82.8 to 84.3 m bgs.

4.1.1 Zone 1

After reaching a depth of 78.4-m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole and the 0.2731-m O.D. (10-3/4 inch O.D.) dual-wall, and the drill casing retracted 1.6 m, producing a test/depth interval for Zone 1 of 76.8 to 78.4-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 60 to 70% gravel, 30 to 35% sand, and 10 to 20% silt.

A series of three slug injection tests (two low and one high stress test) and a series of three slug withdrawal (two low and one high stress test) were conducted between 1349 hours and 1609 hours (PST), April 6, 2007. The low-stress slug-injection and withdrawal tests were unsuccessful and yielded test data that could not be analyzed. The high-stress slug injection (SI #3) and withdrawal (SW #3) tests were marginally successful using a slugging rod with a volume of 0.011 m$^3$. This slug-rod volume imparted a theoretical applied stress value of 1.36 m for the high-stress tests. Downhole test-interval response pressures during testing were monitored using a 0 to 20 psig (0 to 138 kPa) pressure transducer set at a depth of ~76.7-m bgs. The static depth-to-water for the test interval during testing was 73.64-m bgs.

A diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous formation/composite response condition. This composite pattern exhibits a high-permeability, fast-initial-
recovery, inner-zone response, which transitions to a lower permeability response for the surrounding outer-zone formation. The presence of a high-permeability inner-zone is believed to be reflective of an artificially created condition. This artificially created high-permeability condition may be attributed to the setting of a smaller diameter packer/well-screen assembly and the retraction of the much larger diameter drill casing to expose the test/depth interval. The creation of an artificial high-permeability inner-zone (surrounding the temporary well screen) is believed to be the result of dislodged gravel and cobbles collapsing around the temporary well screen as the drill casing was retracted. An examination of the drilling log geologic description indicates the presence of a high percentage of silty, sandy gravel for this particular test/depth interval.

As discussed in Spane (see Footnote [a], p. 1.1), slug tests exhibiting linear response characteristics for heterogeneous formation tests can be analyzed quantitatively using the homogeneous-formation-analysis approaches described in Section 4. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 1.17 and 1.30 m/day (average 1.24 m/day) for the various high-stress-level tests for the formational outer-zone. Selected examples of the diagnostic and test analysis plots for this test/depth interval are shown in Figure 4.1a and b, respectively.

### 4.1.2 Zone 2

After reaching a depth of 84.3-m bgs, the packer/well-screen assembly was lowered to the bottom of the borehole, and the 0.2731-m O.D. (10-3/4-inch O.D.) dual-wall, drill casing retracted 1.5 m, producing a test/depth interval for Zone 2 of 82.8 to 84.3-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 Zone 1, composed of 60 to 70% gravel, 30 to 35% sand, and 10 to 20% silt.

A series of four slug withdrawal tests (all low stress tests) were conducted between 1029 hours and 1130 hours (PST), April 12, 2007. High-stress tests could not be performed because the larger slugging rod (i.e., volume of 0.011 m$^3$) would not go past the first pipe joint near the surface. Only two of the four low-stress slug tests (i.e., SW #1 and SW #3) were performed successfully, but yielded noisy data, using a slugging rod with a volume of 0.006 m$^3$. This slug-rod volume imparted a theoretical applied stress value of 0.68 m for the low-stress tests. It is not known what contributed to the noise in the data, but it is suspected to be vibrations associated with the drill-rig engine used to power the raising of the slugging rod. Downhole test-interval response pressures during testing were monitored using a 0 to 5 psig (0 to 35 kPa) pressure transducer set at a depth of ~76.6-m bgs. The static depth-to-water for the test interval during testing was 73.79-m bgs.

As for tests conducted for overlying Zone 1, a diagnostic analysis of slug tests conducted for this test/depth interval indicates a heterogeneous-formation/composite-response condition. This composite pattern exhibits a high permeability, fast initial recovery, and inner-zone response, which transitions to a lower permeability surrounding the outer-zone-formation response. The presence of a high permeability inner-zone is believed to be reflective of an artificially created condition. This artificially created high permeability condition may be attributed to the setting of a smaller diameter packer/well-screen assembly and retraction of the much larger diameter drill casing to expose the test/depth interval. The creation of an artificial high-permeability inner-zone (surrounding the temporary well screen) is believed to be the result of dislodged gravel and cobbles collapsing around the temporary well screen while the drill casing
Figure 4.1. Selected Slug Test Analysis Plot for Well 299-W11-48: (a) Diagnostic (top) and (b) Type-Curve Analysis Method (bottom)
is being retracted. An examination of the drilling-log geologic description indicates the presence of a high percentage of silty, sandy gravel for this particular test/depth interval.

As discussed in Spane (see Footnote [a], p. 1.1), slug tests exhibiting linear, heterogeneous-formation, test-response characteristics can be analyzed quantitatively using the homogeneous-formation-analysis approaches described in Section 4. For the homogeneous-formation analysis, the type-curve method estimates for K ranged between 5.62 and 6.91 m/day (average 6.27 m/day) for the various low-stress-level tests for the formational outer-zone. It should be noted that the K estimates for this test interval have a higher degree of uncertainty, due to the high dissipation of low-stress slug tests by 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 4.2a and b, respectively.

4.2 Well 299-W10-33 (C5855)

During drilling of OU ZP-1 well 299-W10-33, the Lower Mud unit of the Ringold Formation was not encountered, 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 130 to 140-m bgs. One test-depth interval was tested at the borehole location; Zone 1 = 73.2- to 74.2-m bgs.

4.2.1 Zone 1

After reaching a depth of 74.9-m bgs, the packer/well-screen assembly was lowered to a depth of 74.2-m bgs, and the 0.2604-m O.D. (10-1/4 inch O.D.) dual-wall drill casing retracted 1.0 m, producing a test/depth interval for Zone 1 of 73.2- to 74.2-m bgs. The borehole geology log for well 299-W10-33 was not available for this report.

A series of five slug withdrawal tests (two low-stress and three high-stress tests) were conducted between 1203 hours and 1444 hours (PST), July 6, 2007. The slug tests were initiated using slugging rods having two different displacement volumes. The calculated slugging-rod volumes impart theoretical applied stress values of 0.68 and 1.16 m for the low and high stress tests, respectively. Downhole test-interval response pressures during testing were monitored using a 0 to 5 psig (0 to 35 kPa) pressure transducer set at a depth of ~72.5-m bgs. The static depth-to-water for the test interval during testing was 69.98-m bgs.

The low-stress, slug-test responses indicate a linear, inelastic (storage), over-damped, slug-test behavior (e.g. Figure 4.3). The low-stress slug tests exhibited homogeneous-formation conditions over the entire test response. For the high-stress slug tests, a comparison of the normalized slug-test responses indicates a linear, inelastic (storage), over-damped, slug-test behavior during the early part of the test. There is some indication that test responses yield to a slightly critically damped condition during the latter part of the tests, as shown by the slightly curvi-linear semi-log plot (Figure 4.4). A comparison between normalized low and high stress tests indicates slight differences in response behavior, suggesting that the well had not been developed sufficiently to establish stable skin conditions.
Figure 4.2. Selected Slug-Test-Analysis Plot for Well 299-W11-48: (a) Diagnostic (top) and (b) Type-Curve Analysis Method (bottom)
Slug-test results exhibiting homogeneous-formation response behavior can be analyzed quantitatively using standard, linear-response-based analytical methods (i.e., using standard type-curve methods) following procedures described in Spane and Newcomer (2004). Estimates for $K$ using the type-curve method ranged between 13.0 and 17.3 m/day, with an average of 15.7 m/day for the five slug-withdrawal tests. Figure 4.3 shows a selected example of the analysis plots for this test interval.

Figure 4.3. Selected Slug Test Analysis Plot for Well 299-W10-33: Test Interval Zone 1 (Type-Curve Method)
Figure 4.4. A High-Stress Slug Test Showing Slightly Critically Damped Behavior on a Semi-Log Plot for Test Interval Zone 1, Well 299-W10-33
5.0 Conclusions

Slug-test results were obtained for a total of three test/depth intervals during the drilling and borehole advancement of two OU ZP-1 wells: 299-W10-33 and 299-W11-48. The results indicate that multiple, stress-level, slug-testing methods were successful at well 299-W10-33 in providing detailed hydraulic conductivity information for two test zones. For well 299-W11-48, the slug-test results were marginally successful, and only one stress-level test for each of the two zones tested was achieved.

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 ~10 m of the unconfined aquifer. All test/depth intervals exhibit exponential-decay (over-damped) slug-test response behavior. However, the high-stress slug tests performed at well 299-W10-33 indicate slightly critically damped response behavior during the latter part the tests. Over-damped, 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. An analysis of the slug-test results indicates calculated average test-interval estimates of hydraulic conductivities ranging between 1.24 and 15.7 m/day (Table 4.2). The ZP-1 well hydraulic-conductivity estimates were derived for test-interval sections that ranged from 1.0 to 1.6 m in length (Table 4.1).
6.0 References


Appendix A

Slug Test Field Notes
## Appendix A: Slug Test Field Notes

### FIELD ACTIVITY REPORT - DAILY DRILLING

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td>0630</td>
<td>1615</td>
<td>9:45</td>
</tr>
<tr>
<td>Hole Depth/Casing</td>
<td>285.5 1,250.0</td>
<td>Hole Depth/Casing</td>
</tr>
</tbody>
</table>

**Reference Measuring Point:**
- Casing String No. 0673 4
- Rod Size: 0.1274"
- See Report No. 1

### Time/Depth

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Description of Activities/Operations with Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0630</td>
<td>0715</td>
<td>PDC meeting: Pump sample &amp; Slug test.</td>
</tr>
<tr>
<td>0715</td>
<td>0735</td>
<td>Test pump time (R.B. vol.) = (3)(1/2)(1/4) x 15.48 = 180 gal.</td>
</tr>
<tr>
<td>0735</td>
<td>0815</td>
<td>Test pump time (R.B. vol.) = (3)(1/2)(1/4) x 15.48 = 180 gal.</td>
</tr>
<tr>
<td>0815</td>
<td>0830</td>
<td>Trip in pump with 1&quot; riser pipe. Tank set at 250 lbs.</td>
</tr>
<tr>
<td>0830</td>
<td>0900</td>
<td>Connect hose &amp; wire. Tag water @ 250 lbs. 241.43</td>
</tr>
<tr>
<td>0900</td>
<td>0933</td>
<td>Start pumping. DWR = 445.3 toe (open hole skin 282 257.3')</td>
</tr>
<tr>
<td>0933</td>
<td>0935</td>
<td>First water.</td>
</tr>
<tr>
<td>0935</td>
<td>0940</td>
<td>Stabilized @ 247.5 75C (60%) pumping @ 4 gpm.</td>
</tr>
<tr>
<td>1005</td>
<td>1030</td>
<td>Flow check @ 5 gpm: DWR = 247.5 75C (60%)</td>
</tr>
<tr>
<td>1030</td>
<td>1050</td>
<td>Collecting samples: BL146, BL154, BL152 1/4, BL140 &amp; BL156.</td>
</tr>
<tr>
<td>1100</td>
<td>1105</td>
<td>Stop pumping. Total high vol. est: 82 gpm x 90 min = 73.5 gal.</td>
</tr>
<tr>
<td>1105</td>
<td>1145</td>
<td>Relaxing for RCT to recharact pump/flush. (Full time coverage)</td>
</tr>
<tr>
<td>1145</td>
<td>1230</td>
<td>RCT to test trip out pump (all reading &lt;200)</td>
</tr>
<tr>
<td>1230</td>
<td>1240</td>
<td>DWR = 247.3 75C (4&quot;). 241.43 lbs. 257.3' 4 gpm (no kill)</td>
</tr>
<tr>
<td>1240</td>
<td>1300</td>
<td>Measuring in slug rod &amp; setting transmitter 700' east.</td>
</tr>
<tr>
<td>1300</td>
<td>1308</td>
<td>Waiting for water to stablize.</td>
</tr>
<tr>
<td>1308</td>
<td>1328</td>
<td>Running test #1 &quot;Slug baseline&quot; linear test.</td>
</tr>
<tr>
<td>1328</td>
<td>1330</td>
<td>Testing packer (set 2500'). Added 3 gal water to annulus, no response in 4&quot; indicated on log.</td>
</tr>
<tr>
<td>1330</td>
<td>1335</td>
<td>Test 2 injection with 0.195 lb rod. Removed rod too soon.</td>
</tr>
</tbody>
</table>

### Miscommunication with drillers. Decided to scrub tests.

---

**Reported By:** J. Homer  
**Reviewed By:**

**Title:** Geologist  
**Date:** 06.07

**Signature:** J. Homer  
**Signature:**
<table>
<thead>
<tr>
<th>Time/Depth</th>
<th>Description of Activities/Operations with Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 1353</td>
<td>To 1416. Set rod in place above water &amp; wait for stabilization.</td>
</tr>
<tr>
<td>From 1416</td>
<td>To 1438. Test #4 (skipped #3); injection with 0.195 ft³ red &quot;lag a&quot;.</td>
</tr>
<tr>
<td></td>
<td>Start reading @ 10.72 bit End @ 13.67 bit.</td>
</tr>
<tr>
<td>From 1438</td>
<td>To 1457. Test #5; withdrawal 10.2 ft. remove 0.195 ft³ red &quot;lag rod&quot;.</td>
</tr>
<tr>
<td></td>
<td>Start reading @ 10.72 bit End @ 16.00 bit.</td>
</tr>
<tr>
<td>From 1457</td>
<td>To 1505. Decided to make up for test #3, inject rod &amp; wait for rod.</td>
</tr>
<tr>
<td>From 1505</td>
<td>To 1520. Test #5; withdrawal 10.2 ft. remove 0.195 ft³ red &quot;lag rod&quot;.</td>
</tr>
<tr>
<td></td>
<td>Start reading @ 9.90 bit End @ 15.15 bit.</td>
</tr>
<tr>
<td>Note: Data logger start time on test #5 was 1/444 h, test 5.8 should be perfect timing.</td>
<td></td>
</tr>
<tr>
<td>From 1520</td>
<td>To 1535. Decided to try larger slug rod (not much room for cable).</td>
</tr>
<tr>
<td>From 1535</td>
<td>To 1634. Driller changing to 0.390 ft³ red &quot;lag rod&quot;. Same length, 7.4 ft.</td>
</tr>
<tr>
<td>From 1634</td>
<td>To 1654. Injection with 0.390 ft³ red &quot;lag rod&quot;.</td>
</tr>
<tr>
<td></td>
<td>Start reading @ 9.90 bit End @ 16.15 bit.</td>
</tr>
<tr>
<td>From 1654</td>
<td>To 1609. Test #10; withdrawal test &quot;Spring Force 10&quot; 0.390 ft³ red.</td>
</tr>
<tr>
<td></td>
<td>Start @ 9.29 End @ 9.15 bit.</td>
</tr>
<tr>
<td>1609</td>
<td>Drillers remove H.T. bit to take to town for hard facing.</td>
</tr>
<tr>
<td>1615</td>
<td>Geologist leaves SVE.</td>
</tr>
</tbody>
</table>

*Note: Final pipes on tests #9 & #10 were removed to:
- 3F #10D inject on #5
- Spring Force #10 withdrawal #5

<table>
<thead>
<tr>
<th>Reported By:</th>
<th>Reviewed By:</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. Horner</td>
<td></td>
</tr>
</tbody>
</table>

Signature: [Signature]

Title: Geologist

Date: 4-6-07
PNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 4-12-07
Test/Depth Interval: 215.5 - 279.5 ft bgs
Pre-Test Depth-to-Water: 249.7 ft bgs
Post-Test Depth-to-Water: 249.6 ft bgs

Well ID: C5243
Borehole ID: 980577
Transducer S/N: 2.162697 (Spoo)
Multiplier: 1.042 ft (VU)
Logger S/N: 56 x 40733

Measured Test Lengths
A = Measurement Pt (MP) to Ground Surface
B = MP to Bottom of Outer Casing
C = MP to Top of Screen
D = MP to Bottom of Screen
E = MP to Bottom of Bonshole (Pre- & Post-Test)
F = MP to Top of Packer
G = MP to Top of Outer Casing
H = Packer Length
I = Screen Length

Pre-Test
Post-Test

<table>
<thead>
<tr>
<th>Test #</th>
<th>Stress Applied</th>
<th>Stress Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stress applied = 0.451 ft

2.217

Prepared by NPL
Reviewed by:

See notebook pages 70-72

Slug test dimensions for 2" rod:

\[ \pi \cdot 0.041^2 \cdot 4 \]

\[ \frac{\pi}{2} \cdot 0.041^2 \cdot 4 \cdot \frac{0.1774}{2} \]

\[ = 0.0788 \text{ in} \]

81.2 - 6.2 = 7.96 = 0.1974 ft

\[ = 0.9135 \text{ ft} \]

\[ h_0 = \frac{7.61}{0.1975} = 39.1 \text{ in} \]

\[ h_0 = 2.217 \text{ ft} \]

A.3
Slug Testing at T Tank Farm well 4-12-77
(North of T Tank Farm) 291-611-48 (C5243)

D/W = 2,421.1 ft lbs (measured by Geo lovely)

2"/ft Screen = 249.7', avg 1' bng. Stickup = 7.6 ft

D/W Bottom Screen = 2765' lbs
Bottom of packer = 266.5' lbs

10 ft Screen, 5 ft Screen, Expanded Screen

0900 Attached stage to top of small die. Slug rod and run it down inside 4" ID casing. Driller ran slug rod past transducer point. When rod was raised up, it got stuck in hole at -42 m below. They are running a camera down hole now.

0945 Transducer rod & E-type was removed, but they are destroyed.

Lowered 2" rod to bottom of well at 2841' below.

Raising rod up 42' so it is out of water column. Make mark on cable. Now lower rod 71' (submerged level) and make another mark on cable. End of rod is 35' off bottom.

Now use SW 2161639 Druck Transducer (5 psi) set to 259' bgl.

1019 Packer inflated to 70 psi

1020 Reading is 9,6695'
Well 299-W11-48 (C5243) 4-12-07

1029 initiate test #1, but little or no response.

1035 Large slug rod will not go past 1st joint at 5' below, because 4" ID casing is not straight. We'll repeat tests with small slug rod.

During sampling, it was 11:59pm and there was no measurable drawdown according to geologist. They got very little test response on last set of slug tests 10ft higher, 2000ft rad.

1106 Initiate slug withdrawal test #2, 1-2 sec to completely withdraw slug rod. At 0.5 sec.

1108 Transducer readings changed abruptly for no apparent reason.

1111 Lower rod into water column

1120 Change at to 0.25 sec

1120:30 Test #3 (slug withdrawal test with 2" OD rod)

1122:40 Lower rod back down into water column

1130 Test #4; Slug withdrawal with 2" OD rod

There is a much slower test response now.

1136 Packer pressure still at 720 psi

1138:40 Conduct packer integrity test - pump 5 gpd of clean water down annulus between 4" OD inner casing and outer casing.

1139:40 Finished pouring 5 gpd. Appears to be no response, so packer is holding fine.
Save data to file well14851-4.dat and back it up on
a jump drive.

1150 D/Bottom = 2848.0' b.g. (4")
1153 O/yr = 249.6' b.g. (4")

[Signature]

Davell Venable  
4/12/07
PNNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: 7/4/07 1100
Test/Depth Interval: 233.5 - 243.5 ft
Pre-Test Depth-to-Water: 242.6 ft
gave by driller
Post-Test Depth-to-Water: 242.95 ft

Well ID: TS Borehole
Borehole ID: 65855
Transducer S/N: 2162689 Dekk 585G
Multiplier: 2.34 ft/mv/v
Logger S/N: X14115.8

Measured Test Lengths
A = Reference Point (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 red
2   | Small red
3   | Large red
4   | Large red
5   | Large red
6   | Large red
7   | Large red
8   | Large red
9   | Large red

Reference Point = Ground Surface

Pre-Test
F (D) 242.6 ft
Post-Test
F (D) 242.95 ft

Inner Diameter (inch)
well-screen/testing string
9.75
drill casing
10.25

Prepared by: Rob D. MacKey
Date: 7/4/07

Reviewed by: sign

Field Notes:
1120 Geologist (Jesse Hawkins) has marked string DIW ( BAS) of 229.6' P 0721 7/4/07.
        Small slurry red is 2 3/4 OD x 81' long w/ layers at both ends 0.145 shop.
        Large slurry red is 3' OD x 81' long w/ layers at both ends. No shop.
1125 DI/W = 245.4 ft BAS DIW = 229.59'
1130 Made marks on cable-tie via cable of chalk at submerged and un-submerged depths.
        Rod submerged ~1' below water table, Rod suspended 1' above water table.
1137 Varyer set at 238' BAS (~8.38' pressure).
1145 Pour 5 gallon clean H2O down manifold to verify packer seal passed - NO pressure response.
1151 Lowered small slug rod into water (1.74' increase initially-then stabilized)

2007/DCL/SlugTest/001 (05/04)
PNINL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: ________________

Test/Depth Interval: ________________ ft

Pre-Test Depth-to-Water: ________________ ft

Post-Test Depth-to-Water: ________________ ft

Well ID: __________________________

Borehole ID: ________________________

Transducer S/N: ________________

Multiplier: ________________

Logger S/N: ________________________

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

Reference Point = Ground Surface

Test Stress Information

Test # Stress Applied

Pre-Test ________________

Post-Test ________________

Inner Diameter (inch)

Well Screen Testing String

Drill Casing

Borehole

Field Notes:

12:03 Test #1 - Slugging w/ small red w/ withdrawal. Test 192. Stress w/ exp. decay (wave recovery) over-damped.

12:12 Good recovery back to stable pressure at 0.02' lower pressure.

12:16 Lowered small slug into water for next withdrawal.

12:23 Starting cable tool rig. Small increase in background noise in signal.

12:30 Test #2 - Slugging w/ small rod w/ withdrawal test. 212 stress with exp. decay (over-damped) response.

12:41 Trippery on X-driver to clear gap for removal of slug rod.

13:01 Test in X-driver. Re-installed C 238' B.D.

13:08 Stable pressure. Fixed short in cable in Campbell Box.

13:30 Stable pressure but 0.1' offset from previous install - I think.

Prepared by: ________________________

Reviewed by: ________________________

Date: ________________________

Print: ________________________

Page 2 of 4

2007/01/SlugTest/001 (05/04)
A.9
PNL SLUG TEST FIELD MEASUREMENTS - DURING DRILLING

Test Date/Time: ____________________________
Test/Depth Interval: __________ ft
Pre-Test Depth-to-Water: __________ ft
Post-Test Depth-to-Water: __________ ft

Well ID: ____________________________
Borehole ID: ____________________________
Transducer S/N: ____________________________
Multiplier: ____________________________
Logger S/N: ____________________________

Measured Test Lengths

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

Test Stress Information

Test # | Stress Applied
-------|------------------

Pre-Test | F (1)
Post-Test | F (2)

Inner Diameter (inch)
well screen/ test string
drill casing
borehole

Time: ____________________________
Field Notes:

1428  Tripping out longer slug rod - finished using longer rod.
1428  Tripping M (mud) smaller slug rod; left Y-ducer installed 2.40' BAS.
1444  Test #5 - slugging with smaller slugger rod with withdrawal test 2.15'
       stress with overexpanded response.
1451  Tripping out long rod; re-checked packer for leaks using 5 gals
       of mix H.O down annulus. No change in pressure - looks like
       a good seal still. Had driller take D/W; D/B again.
1510  D/W = 229.65' BAS  D/B = 245.65'.
       Leaving Site; HPT cleaned equipment.

Prepared by ____________________________
Reviewed by ____________________________

Date: ____________________________

2007/02/SLUG Test/001 (05/04)
Appendix B

Selected Borehole Logs
Appendix B: Selected Borehole Logs

Figure B.1    Well 299-W11-48

Borehole Log for Well 299-W10-33 not available.
<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Type</th>
<th>Blows</th>
<th>Graphic Log</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Grap</td>
<td>6</td>
<td></td>
<td>0-0.5: gravel and (crushed rock) CDFX drilling with 12% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Grap</td>
<td>7</td>
<td></td>
<td>0.5-1.0: Silty Sand, (m.), S, carbon steel casing, 11% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Grap</td>
<td>3</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Grap</td>
<td>5</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Grap</td>
<td>3</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Grap</td>
<td>3</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Grap</td>
<td>3</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Split-Spoon</td>
<td>3</td>
<td></td>
<td>0-2.2: Silty Sand, gravel , approximately 14% (50%) HCl.</td>
<td></td>
</tr>
</tbody>
</table>

**Group Name:** Gravel Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reactivity to HCl.

**Comments:**

- 0-0.5: gravel and (crushed rock) CDFX drilling with 12% (50%) HCl.
- 0.5-1.0: Silty Sand, carbon steel casing, 11% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.
- 0-2.2: Silty Sand, gravel approximately 14% (50%) HCl.

**Reviewed by:** L. O. Walker

**Title:** Geologist

**Signature:** [Signature]

**Date:** 11/19/04

**Title:** Geologist

**Signature:** [Signature]

**Date:** 11/19/04
<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Sample Type</th>
<th>Blows</th>
<th>Graphic Log</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Gravel</td>
<td></td>
<td></td>
<td>Gray sand with 25% gravel angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>45</td>
<td>Gravel</td>
<td></td>
<td></td>
<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>50</td>
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<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>55</td>
<td>Gravel</td>
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<td></td>
<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>60</td>
<td>Gravel</td>
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<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
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<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>70</td>
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<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
</tr>
<tr>
<td>75</td>
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<td>Gray sandstone angular 6.5% porosity 18.5% sandstone 20% limestone 5% sandstone 40% limestone</td>
<td>Depth of casing, Drilling Method, Method of Driving, Sampling Tool, Borehole Size, Water Level</td>
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Reported By: J. Harper
Reviewed By: L. D. Wallace
Title: Geologist
Signature: [Signature]
Date: 12-5-86

A-6003-542 (03/03)
<table>
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<th>Blows</th>
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<th>Graphic Log</th>
<th>Sample Description</th>
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<td>100</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**
- 0 ft: Gravel, Gravels.
- 5 ft: Sandy Silt (Silt).
- 10 ft: Sand, Gravel.
- 15 ft: Sand, Gravel.
- 20 ft: Sand, Gravel.
- 25 ft: Sand, Gravel.
- 30 ft: Sand, Gravel.
- 35 ft: Sand, Gravel.
- 40 ft: Sand, Gravel.
- 45 ft: Sand, Gravel.
- 50 ft: Sand, Gravel.
- 55 ft: Sand, Gravel.
- 60 ft: Sand, Gravel.
- 65 ft: Sand, Gravel.
- 70 ft: Sand, Gravel.
- 75 ft: Sand, Gravel.
- 80 ft: Sand, Gravel.
- 85 ft: Sand, Gravel.
- 90 ft: Sand, Gravel.
- 95 ft: Sand, Gravel.
- 100 ft: Sand, Gravel.

**Sample Description:**
- 0 ft: Gravel, Gravels.
- 5 ft: Sandy Silt (Silt).
- 10 ft: Sand, Gravel.
- 15 ft: Sand, Gravel.
- 20 ft: Sand, Gravel.
- 25 ft: Sand, Gravel.
- 30 ft: Sand, Gravel.
- 35 ft: Sand, Gravel.
- 40 ft: Sand, Gravel.
- 45 ft: Sand, Gravel.
- 50 ft: Sand, Gravel.
- 55 ft: Sand, Gravel.
- 60 ft: Sand, Gravel.
- 65 ft: Sand, Gravel.
- 70 ft: Sand, Gravel.
- 75 ft: Sand, Gravel.
- 80 ft: Sand, Gravel.
- 85 ft: Sand, Gravel.
- 90 ft: Sand, Gravel.
- 95 ft: Sand, Gravel.
- 100 ft: Sand, Gravel.
## BOREHOLE LOG

**Well ID:** C5243  
**Well Name:**  
**Location:** North of T-Farm, 2006  
**Date:** 12-11-06  
**Project:**  
**Reference Measuring Point:** Ground Surface  
**Sample Description:**

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Sample</th>
<th>Graphic Log</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 65</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>65 - 120</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>120 - 185</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>185 - 250</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>250 - 300</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>300 - 350</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>350 - 400</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>400 - 450</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>450 - 500</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>500 - 550</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>550 - 600</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>600 - 650</td>
<td>Grab</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Mass Particle Size, Reaction to HCl:**

- 115' - 128': Silty Sand, gravel (16)  
- 128' - 185': Gravel, with > 25% sub-angular,  
- 185' - 250': Silt, some small rocks,  
- 250' - 300': Silt, some small rocks,  
- 300' - 350': Silt, some small rocks,  
- 350' - 400': Silt, some small rocks,  
- 400' - 450': Silt, some small rocks,  
- 450' - 500': Silt, some small rocks,  
- 500' - 550': Silt, some small rocks,  
- 550' - 600': Silt, some small rocks,  
- 600' - 650': Silt, some small rocks,  

**Depth of Core, Drilling Method, Method of Drilling Sampling Tool, Sampler Size, Water Level:**

- 0' - 65'  
- 65' - 120'  
- 120' - 185'  
- 185' - 250'  
- 250' - 300'  
- 300' - 350'  
- 350' - 400'  
- 400' - 450'  
- 450' - 500'  
- 500' - 550'  
- 550' - 600'  
- 600' - 650'

**Reported By:** J. Vorex  
**Reviewed By:** L.S. Wolfe  
**Title:** Geologist  
**Signature:**  
**Date:** 12-11-06  
**Signature:**  
**Date:** 1/3/07

A-6003-642 (03/03)

B.5
# Borehole Log

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Sample No.</th>
<th>Blows Type</th>
<th>Log Graphic</th>
<th>Sample Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>120-125</td>
<td>GB</td>
<td>23</td>
<td></td>
<td>Sandy Gravel, continuous from 120-125 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandy gravel (45%)</td>
</tr>
<tr>
<td>125-130</td>
<td>GB</td>
<td>62</td>
<td></td>
<td>Sandy gravel (55%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silt (5%) mixed with gravel (45%)</td>
</tr>
<tr>
<td>130-135</td>
<td>GB</td>
<td>120</td>
<td></td>
<td>Sandy gravel (60%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silt (20%) mixed with gravel (20%)</td>
</tr>
<tr>
<td>135-140</td>
<td>GB</td>
<td>158</td>
<td></td>
<td>Sandy gravel (60%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silt (20%) mixed with gravel (20%)</td>
</tr>
<tr>
<td>140-145</td>
<td>GB</td>
<td>102</td>
<td></td>
<td>Sandy gravel (60%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silt (20%) mixed with gravel (20%)</td>
</tr>
<tr>
<td>145-150</td>
<td>GB</td>
<td>85</td>
<td></td>
<td>Sandy gravel (60%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silt (20%) mixed with gravel (20%)</td>
</tr>
</tbody>
</table>

**Comments:**
- Silt and gravel mixed with sand and clay in the 125-130 ft depth range.
- Sandy gravel is continuous from 120-125 ft.
- Silt content increases in the 125-130 ft range.
- Drilling difficulties encountered in the 130-135 ft range due to hard rock conditions.

**Depth of Casing:**
- GB (Gravel)
- 120 ft to 145 ft

**Drilling Method:**
- Cable tool drilling

**Sample Name:**
- GB

**Recommended:**
- Drill more carefully in the 125-130 ft range.
- Use heavy duty equipment in the 130-135 ft range.

**Reviewed By:**
- L.D. Walker

**Date:**
- 7/3/03

---

**Reported By:**
- J. Horner

**Title:**
- Geologist

**Signature:**
- [Signature]

**Date:**
- 7/3/03

---

**Reviewed By:**
- L.D. Walker

**Title:**
- Geologist

**Date:**
- 7/3/03

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**A-0003-042 (03/03)**

---

**B.6**
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Sample No.</th>
<th>Blows Log Recovery</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>3</td>
<td></td>
<td>silky sandy gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>well-sorted, wet,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>consolidated, dry</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>drill hole</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>4</td>
<td></td>
<td>small to medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>gravel, sand (0.05 to 2&quot;)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>slightly spread,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>clayey, sandy,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>slightly</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>5</td>
<td></td>
<td>soft, red clay,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>well-consolidated,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>clayey,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>slightly</td>
<td></td>
</tr>
<tr>
<td>215</td>
<td>6</td>
<td></td>
<td>dark brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>silt,</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>7</td>
<td></td>
<td>yellowish, brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>silt,</td>
<td></td>
</tr>
<tr>
<td>225</td>
<td>8</td>
<td></td>
<td>gray,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>silt,</td>
<td></td>
</tr>
</tbody>
</table>

Depth of casing, Diameter method, Diameter, Diameter method, Diameter, Diameter method.

Reported By: J. Horner
Reviewed By: J. N. Walker
Title: Geologist

Signature: [Signature]
Date: 7/14/03
**BOREHOLE LOG**

**Well ID:** C5143  
**Well Name:** 199-01  
**Location:** North of W1-47, 200 W

**Project:** T-4 Measuring Well  
**Reference Measuring Point:** Ground Surface

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Sample Type</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>66.5</td>
<td>233'-235' Silty Sand Gravel</td>
<td>Slightly hard but with an increase on silts/loams. Drilling at 234' L.</td>
</tr>
<tr>
<td>365</td>
<td>46.5</td>
<td>255' Mixed sand (AT) caliche</td>
<td>Drilling at 254' L.</td>
</tr>
<tr>
<td>420</td>
<td>66.5</td>
<td>270' Ramped and spread</td>
<td>Ramped at 270' L.</td>
</tr>
<tr>
<td>500</td>
<td>66.5</td>
<td>290' Drilling mud, pack, thinner</td>
<td>Pack 290' L.</td>
</tr>
<tr>
<td>575</td>
<td>66.5</td>
<td>315' Drilling mud, pack, thicker</td>
<td>Pack 315' L.</td>
</tr>
<tr>
<td>625</td>
<td>66.5</td>
<td>375' Same desc. as above</td>
<td>Same desc. as above</td>
</tr>
</tbody>
</table>

**Reported By:** T. Hoare  
**Reviewed By:** L. D. Walker

**Title:** Geologist  
**Title:** Geologist

**Signature:**  
**Date:** 7/9/97  
**Signature:**  
**Date:** 7/9/97

---

B.8
<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Sample Type</th>
<th>Description</th>
<th>Graphic Log</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>297-300: Silty Sandy Gravel, poor sorting</td>
<td>Core sample, 297.0</td>
<td>Silty sandy gravel, poor sorting</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Silty to Fine Gravel</td>
<td>Core sample, 290.0</td>
<td>Silty to fine gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Subangular Gravel</td>
<td>Core sample, 290.0</td>
<td>Subangular gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Sand (S)</td>
<td>Core sample, 290.0</td>
<td>Sand (S)</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Subangular Gravel</td>
<td>Core sample, 290.0</td>
<td>Subangular gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Gravel (G)</td>
<td>Core sample, 290.0</td>
<td>Gravel (G)</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Subangular Gravel</td>
<td>Core sample, 290.0</td>
<td>Subangular gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Gravel (G)</td>
<td>Core sample, 290.0</td>
<td>Gravel (G)</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Subangular Gravel</td>
<td>Core sample, 290.0</td>
<td>Subangular gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Gravel (G)</td>
<td>Core sample, 290.0</td>
<td>Gravel (G)</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Subangular Gravel</td>
<td>Core sample, 290.0</td>
<td>Subangular gravel</td>
</tr>
<tr>
<td>60.5</td>
<td>Core Sample</td>
<td>290-295: Gravel (G)</td>
<td>Core sample, 290.0</td>
<td>Gravel (G)</td>
</tr>
</tbody>
</table>

**Reported By:** J. Miller  
**Reviewed By:** L. D. Walker  
**Signature:** Date: 4-6-07  
**Signature:** Date: 7-6-07
## BOREHOLE LOG

<table>
<thead>
<tr>
<th>Depth (FT.)</th>
<th>Sample Collector</th>
<th>Graphic Log</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>320'</td>
<td>Gravel size 1/2&quot;</td>
<td></td>
<td>Same description as above</td>
<td>Cable Tool Drilling</td>
</tr>
<tr>
<td>325'</td>
<td>Gravel size 1/2&quot;</td>
<td></td>
<td>Same description as above</td>
<td>Cable Tool Drilling</td>
</tr>
<tr>
<td>330'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 330</td>
</tr>
<tr>
<td>335'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 335</td>
</tr>
<tr>
<td>340'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 340</td>
</tr>
<tr>
<td>345'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 345</td>
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<tr>
<td>350'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 350</td>
</tr>
<tr>
<td>355'</td>
<td>Ring Tool Sherry</td>
<td></td>
<td>Hand tool Sherry same description</td>
<td>Sample Taken @ 355</td>
</tr>
</tbody>
</table>

---

**Reported By:** J. Meiner  
**Reviewed By:** L. A. Walker

**Title:** Soil Scientist  
**Title:** Geologist

**Signature:**  
**Date:** 7/4/64
## BOREHOLE LOG

<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Sample Type</th>
<th>Sample Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>350</td>
<td>Pump Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
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<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
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<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
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<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
<td>350</td>
<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
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<tr>
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<td>Sample</td>
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</tr>
<tr>
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<td>Sample</td>
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<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
<td>360' Hard Tool Slurry</td>
<td>Sample taken.</td>
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<tr>
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<td>Sample</td>
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</tr>
<tr>
<td>350</td>
<td>Sample</td>
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<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
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<td>Sample taken.</td>
</tr>
<tr>
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<td>Sample</td>
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</tr>
<tr>
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<td>Sample</td>
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<tr>
<td>350</td>
<td>Sample</td>
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<td>Sample taken.</td>
</tr>
</tbody>
</table>

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**Reported By:** [Signature]

**Reviewed By:** [Signature]

**Date:** 5/25/07

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**Location:** North of T Farm, 7000W

**Date:** 5/25/07
<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Sample</th>
<th>Graphic Log</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>Top</td>
<td>Sample 1</td>
</tr>
<tr>
<td>3980</td>
<td></td>
<td>Sample 2</td>
</tr>
<tr>
<td>3960</td>
<td></td>
<td>Sample 3</td>
</tr>
<tr>
<td>3940</td>
<td></td>
<td>Sample 4</td>
</tr>
</tbody>
</table>

**Sample Description**

- **Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Minerals:**
  - **(29.5)** clay, largest fragment 63.5 @ 400 ft.
  - *3" clay fragment w/ Mica*
  - 10" sample collected 400 ft.

**Comments**

- **Core Type:** Drilling
- **Core Description:**
  - Abundant clay fragments
  - *silt* 1" diameter
  - Split sample collected from 400 ft.
  - *40" core* 1" diameter
  - Sample collected from 400 ft.
  - *40" core* 1" diameter
  - Sample collected from 400 ft.

**Reported By:** J. Warner
**Reviewed By:** L.D. Walker
**Title:** Geologist
**Date:** 6-5-02

---

B.12
# Distribution

## ONSITE - Pacific Northwest National Laboratory
- P. E. Dresel
- J. S. Fruchter
- F. A. Spane

## ONSITE - Fluor Hanford, Inc.
- J. V. Borghese
- M. E. Byrnes
- D. B. Erb
- D. G. Horton
- S. P. Luttrell
- V. J. Rohay
- C. Sutton
- L. C. Swanson
- B. A. Williams
- C. S. Wright

## ONSITE - CH2M Hill Hanford Group, Inc.
- F. J. Anderson
- M. Connelly
- W. J. McMahon

## ONSITE - U.S. Department of Energy-Richland Operations
- J. G. Morse
- A. C. Tortoso

## ONSITE - Vista Engineering
- W. Bratton