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Mortandad Canyon Groundwater Monitoring Well Network Evaluation

Los Alamos
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CONTENTS

Figures

Appendixes

1.0 INTRODUCTION

This monitoring well network evaluation is being conducted pursuant to a requirement set forth by the New Mexico Environment Department's (NMED's) "Approval with Direction, Mortandad Canyon Investigation Report" (NMED 2007, 095109)Additional details of the elements of this well network evaluation are provided in NMED's letter on "Well Evaluations for Intermediate and Regional Wells," dated April 5, 2007 (NMED 2007, 095999). The evaluation contained in this report for Mortandad Canyon also addresses the requirement of the April 5, 2007, letter for a network evaluation for Technical Area (TA) 50.

Two significant investigations for Mortandad Canyon have been completed to date: the Mortandad Canyon investigation and the Middle Mortandad/Ten Site aggregate investigation. An additional investigation is underway at Material Disposal Area (MDA) C. Investigation results for MDA C and for Mortandad Canyon indicate the need for corrective measures evaluations (CMEs). The CMEs and reports for each of the two areas are pending.

This evaluation is being conducted at a stage in the regulatory process that will bridge to the monitoring recommendations that will be specifically tied to the evaluation and selection of remedial alternatives presented in the CME reports for Mortandad Canyon and MDA C. The CME reports for these two sites will be submitted to NMED in 2008 and 2010, respectively. Therefore, the network recommendations that derive from this evaluation are intended to capture the monitoring requirements for the 3- to 5-yr time frame prior to selection and implementation of the final remedies.

The group of intermediate and regional groundwater monitoring wells evaluated in this report was predominantly installed during implementation of the "Hydrogeologic Workplan" (LANL 1998, 059599; NMED 2007, 095999). One additional well, Test Well-8, was installed as a monitoring well in 1960. The Hydrogeologic Workplan wells were installed as part of a project to collect fundamental hydrologic, geologic, geophysical, and geochemical data across the Los Alamos National Laboratory (LANL or Laboratory) site. Although the Hydrogeologic Workplan wells were installed primarily as characterization wells, the Laboratory had a "next-phase" objective to evaluate the utility of each well in the context of area-specific objectives, such as corrective measures evaluations and implementation and overall network objectives. This evaluation is intended to accomplish that goal. Some wells located in canyons north and south of the Mortandad watershed are included because they are possibly located along the regional groundwater flow paths that might originate from recharge areas beneath Mortandad Canyon.

The approach used to evaluate the monitoring network involves examination of well and network performance in three main categories—physical, hydrologic, and geochemical—and are all considered in the context of the monitoring objectives and conceptual models of contaminant pathways as they relate to groundwater systems. The physical and hydrologic criteria include the effectiveness of sampling systems to provide representative groundwater data; well construction; isolation of sampling zones; and a review of factors such as well locations, screen positions, and screen lengths evaluated in the context of the conceptual model and monitoring objectives. Geochemical criteria include an assessment of whether there are conditions present in the aquifer that cause sample data to not meet monitoring objectives. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy policy.

2.0 CONCEPTUAL MODEL

2.1 Mortandad Canyon

The investigations conducted to date in Mortandad Canyon have led to an understanding of nature and extent of contamination, and they support a conceptual model for fate and transport of contaminants. This information is used in this report to guide an evaluation of the intermediate and regional groundwater monitoring network. The conceptual model summary provided below is derived from information presented in detail in the "Mortandad Canyon Investigation Report" (MCIR) (LANL 2006, 094161).

The dominant source of dispersed contaminants distributed within and beneath the Mortandad watershed was derived from the Radioactive Liquid Wastewater Treatment Facility (RLWTF). Contamination from the RLWTF was dispersed through effluent releases at the TA-50 RLWTF outfall (Figure 2-1) from 1963 to present and subsequent transport processes. Over the decades, treatment processes were improved, and the improvements are manifested in subsequent lowering of contaminant concentrations in channel sediments, surface-water base flow, and alluvial groundwater. Investigations presented in the MCIR indicate an area of focused recharge from alluvial groundwater into the vadose zone. This recharge area from the alluvium is indicated in Figure 2-2, and the resultant breakthrough location at the regional aquifer is indicated in Figure 2-1.

Moderately and strongly sorbing contaminants (e.g., strontium-90 and plutonium-239, respectively) are found dispersed at shallow depths associated with predominantly very young sediments associated with post-release flood deposits and, to a lesser extent, in older, underlying alluvial deposits. Residual concentrations of contaminants with sorbing behavior are steady, indicating their tendency to not migrate along with infiltrating alluvial groundwater. The more mobile contaminants have migrated into the vadose zone and are also found in perched intermediate and regional groundwater beneath the watershed.

In order to identify the specific contaminants to be addressed by this network evaluation, a data screen presented in the May 2007 version of the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) was used. The screen was conducted on the two most recent years of data using half of the lowest applicable standard for metals, radionuclides, and general inorganic compounds and detection for organic compounds. The contaminants that exceeded the screening threshold include ammonia, nitrate, perchlorate, antimony, chromium, iron, lead, manganese, nickel, bis(2-ethylhexyl)phthalate, and 1,4-dioxane. Additional contaminants that fell below the screening threshold are also included because their presence indicates that a pathway may exist for other potentially important groundwater contaminants. These include alkalinity, calcium, chloride, fluoride, molybdenum, sulfate, tritium, and uranium. Trichloroethene (TCE) and tetrachloroethene (PCE) are primary contaminants in the vadose zone beneath MDA C, so they are also included as potentially important contaminants.

A mass balance was determined for perchlorate and nitrate, which in addition to tritium, are the most important contaminants found at depth beneath the canyon. The results of the mass balance indicate that the vast majority of the mass of perchlorate and nitrate is located within pore water approximately 150–250 ft beneath the watershed in vadose-zone pore water. For example, an estimated 94.6% of the perchlorate mass is contained within that zone. However, some small portion of the perchlorate mass has also entered the perched intermediate and regional groundwater beneath the watershed. Concentrations in those groundwater zones are generally either steady or are increasing slightly, potentially indicating an ongoing downward flux of some portion of the mass.

The perched intermediate groundwater is considered to be of limited volume and lateral extent and likely represents temporary perching of percolating vadose-zone pore water. Contaminants that have migrated into the regional groundwater are transported and dispersed along the groundwater flow path. Natural or supply-well pumping-induced gradients are observed in regional groundwater monitoring wells across the Pajarito Plateau. Recent unpublished observations of molybdenum concentrations in samples collected from R-35 boreholes show vertical dispersion of molybdenum at concentrations well above background to depths of 350 ft below the water table. This finding indicates that appreciable vertical dispersion does occur with the regional groundwater and that discrete-horizon contaminant transport over long distances is unlikely.

2.2 MDA C

MDA C (Figure 2-1) at TA-50 is a mesa-top disposal facility with wastes buried in pits and shafts; radioactive wastes, metals, and some containerized liquids are present. The conceptual model for this site is based on data presented in the MDA C investigation report (LANL 2006, 094688, Appendix L) and on observations from similar disposal sites at TA-54, particularly MDA G and MDA L.

Vapor-phase transport of contaminants in the upper unsaturated zone occurs at MDA C. Most notably, tritium and the volatile organic chemicals (VOCs) TCE and PCE measured in pore gas over the entire length of several boreholes to depths of 150 to 300 ft below the mesa top. In one 600-ft borehole, however, pore-gas concentrations drop by 2 orders of magnitude throughout the Otowi Member. This drop in concentration with depth (especially in the Otowi Member) is consistent with observations at MDA L, where much larger volumes of VOCs were disposed, and some were not containerized. Vapor transport is largely controlled by vapor diffusion, and higher moisture content in the Otowi Member effectively inhibits downward diffusion of the vapor plume at MDA L (Stauffer et al. 2005, 090537). This same phenomenon is likely occurring at MDA C. Deeper pore-gas monitoring boreholes will be installed into the Otowi Member to further determine nature and extent at MDA C.

Over the next few years, contaminant migration from MDA C is expected to be of limited extent and to not reach the regional aquifer. No intermediate perched water was encountered beneath the site (to approximately 600 ft).

3.0 MONITORING OBJECTIVES

The monitoring objectives for Mortandad Canyon and MDA C are based on the regulatory status described in Section 1 and on the conceptual model described in Section 2. The objectives of the monitoring network are described below. The recommendations provided in Section 5 are made in the context of these objectives.

1. Demonstrate that wells in the existing network provide an understanding of nature and extent of contamination sufficient to support pending corrective measures evaluations

   This objective is focused on an evaluation of the network from the perspective of whether there is some unknown aspect of nature and extent related to the physical, geochemical, or hydrologic status of wells that is sufficient to change or affect the general path forward on the CME. This objective is partly addressed by NMED's approval of the "Mortandad Canyon Investigation Report" (NMED 2007, 095109; NMED 2007, 096394).

2. Collect data to verify the vadose-zone model for use in the CME decision process

   This objective reflects the need to continue to evaluate temporal trends in contaminant concentrations in the perched intermediate and regional groundwater in the wells within the predominant infiltration pathway through the vadose zone, as presented in the conceptual model. The perched intermediate and regional groundwater beneath Mortandad Canyon shows the presence of contaminants whose mass is primarily stored in unsaturated rocks above those groundwater zones. The future vadose-zone model will predict a flux through the vadose zone that should be manifested and measurable within wells in each of the groundwater zones.

3. Evaluate the configuration of the monitoring network to confidently protect water-supply wells and detect contaminants that might migrate off-site

   This objective ensures that contaminants do not go undetected prior to reaching water-supply wells or the Laboratory boundary. The objective is met using a groundwater-transport model that traces the path of hypothetical mobile contaminants from locations where infiltration is thought to enter the regional groundwater system. The model is used to assess the ability of the current well network to detect at least 95% of potential plumes from a source in the Mortandad watershed before they arrive at a production well or leave Laboratory boundary. This assessment considers network performance for the period leading up to the CME report that will make recommendations about long-term monitoring needs as part of the remedy selection.

4.0 MONITORING NETWORK ASSESSMENT

The following table summarizes the results of the evaluation of the physical and geochemical performance of the group of wells considered for Mortandad Canyon and TA-50 (MDA C) in the context of the monitoring objectives described in Section 3. The physical and hydrologic criteria include the effectiveness of sampling systems to provide representative groundwater data, well construction, isolation of sampling zones, a review of factors such as screen positions, and screen length evaluated in the context of the conceptual model and monitoring objectives. Geochemical criteria include the consideration of conditions within the aquifer related to drilling operations that may result in sample data that do not meet monitoring objective #1.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-1	Meets objectives	Meets objectives
R-10a	Meets objectives	Meets objectives
R-10 screen 1	Meets objectives	Meets objectives
R-10 screen 2	Meets objectives	Meets objectives
R-11	Meets objectives	Meets objectives
R-12 screen 1	Meets objectives	Conditionally meets objectives. Samples collected during rehabilitation activities conducted in fall 2006 showed significant improvement in conditions related to residual drilling effects. Good prognosis for meeting objectives.
R-12 screen 2	Meets objectives	Conditionally meets objectives. Samples collected during rehabilitation activities conducted in fall 2006 showed significant improvement in conditions related to residual drilling effects. Good prognosis for meeting objectives.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-12 screen 3	Screen 3 flooded by 623,000 gal. of contaminated perched zone water from screens 1 and 2 during well rehabilitation. Screen may also be affected by cement used to retrieve tools out of borehole prior to well installation. Screen 3 located in Miocene basalt may be poorly connected to upgradient contaminant pathways.	Does not meet objectives. Samples collected as part of rehabilitation are inconclusive with respect to changes in geochemistry because of the introduction of perched-zone groundwater into this interval when the Westbay sampling system was removed. Uncertain prognosis for meeting objectives.
R-13	Meets objectives	Meets objectives
R-14 screen 1	Meets objectives	Conditionally meets objectives. Slightly reducing but improving. Good prognosis for meeting objectives.
R-14 screen 2	Meets objectives	Does not meet objectives. Strongly and persistently iron-reducing conditions, presence of residual inorganic drilling constituents as indicated by elevated phosphate concentrations, carbonate-mineral disequilibria. Poor prognosis for meeting objectives within useful time frame.
R-15	Meets objectives	Meets objectives
R-16 screen 1	Screen 1 is isolated from aquifer by drill casing that could not be retracted during well construction. Nonfunctional screen. Replaced by R-16r.	Nonfunctional screen. Replaced by R-16r.
R-16 screen 2	Meets objectives	Conditionally meets objectives. Continued presence of slightly reducing conditions immediately following rehabilitation but at significantly improved levels relative to those prior to rehabilitation. Good prognosis for meeting objectives.
R-16 screen 3	Meets objectives	Conditionally meets objectives. Rehabilitation activities successful in restoring oxidizing conditions and removing residual drilling constituents but carbonate-mineral system still reequilibrating. Good prognosis for meeting objectives.
R-16 screen 4	Meets objectives	Does not meet objectives. Persistent reducing conditions and residual organic drilling constituents present, although visibly improved following rehabilitation. Poor prognosis for meeting objectives within useful time frame.
R-16r	Meets objectives	Meets objectives
R-17 screen 1	Meets objectives	Conditionally meets objectives. No drilling effects are apparent. Overall geochemical trends are favorable. Limited sample data are available for well; need to confirm well equilibration with additional sampling.
R-17 screen 2	Meets objectives	Conditionally meets objectives. No drilling effects are apparent. Overall geochemical trends are favorable. Limited sample data are available for well; need to confirm well equilibration with additional sampling.
R-28	Meets objectives	Meets objectives

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-33 screen 1	Barcad sampling system is operationally complex and has had problems maintaining packer isolation between the two screens.	Conditionally meets objectives. Overall geochemical conditions are favorable for most chemicals of potential concern (COPCs). Redox indicators are still equilibrating. These conditions may improve after installation of a sampling system that can be purged.
R-33 screen 2	Barcad sampling system is operationally complex and has had problems maintaining packer isolation between the two screens.	Conditionally meets objectives. Overall geochemical conditions are favorable for most COPCs. Redox indicators are still equilibrating. These conditions may improve after installation of a sampling system that can be purged.
R-34	Meets objectives	Meets objectives
TW-8	Annular seal is inadequate, possible leakage of surface water to regional groundwater along well casing.	Meets objectives
MCOBT-4.4	Possible breach of confining layer by leakage of perched groundwater around filter pack	Meets objectives
MCOI-4	Meets objectives	Meets objectives
MCOI-5	Meets objectives	Meets objectives
MCOI-6	Meets objectives	Meets objectives
MCOI-8	Water in well confined to sump; well screen is not producing water.	Does not meet objectives. Persistent iron-reducing conditions. Water in well confined to sump; well screen is not producing water.

Appendix C presents an assessment of the overall monitoring well network to determine the efficiency of the existing regional well locations for intercepting potential plumes prior to their arrival at production wells or Laboratory boundary. The results are presented in detail in Appendix C, and the implications on recommendations are discussed in Section 5.

5.0 RECOMMENDATIONS

The table below presents the recommended actions and rationale for each of the group of wells evaluated as part of the Mortandad Canyon and TA-50 (MDA C) evaluation. These recommendations are based on the physical, geochemical, and hydrologic factors that may affect the contribution of each well to the monitoring objectives. The ability of these wells to meet the monitoring objectives is evaluated for the time frame leading to the CMEs for Mortandad Canyon and MDA C.

Well Name	Recommended Action	Rationale
R-1	Monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665)	Well meets monitoring network objectives.
R-10a	Monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665)	Well meets monitoring network objectives.

Well Name	Recommended Action	Rationale
R-10 screen 1	Monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665)	Well meets monitoring network objectives.
R-10 screen 2	Monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665)	Well meets monitoring network objectives.
R-11	Monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665)	Well meets monitoring network objectives.
R-12 screen 1	Replace Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The Baski sampling system allows two well screens to be isolated and for each screen to be purged prior to sampling. This will allow water to be drawn into the well screen from areas outside the influence of possible residual drilling fluids during groundwater sampling. Preliminary data of developed water from the R-12 rehabilitation indicate that the water quality from screen 1 is much improved. Because there is currently no sampling system in R-12, screen 1 has not been sampled since a screening sample was collected (29-Sep-06) at the end of well rehabilitation. Once the Baski sampling system is installed, screen 1 groundwater data should be evaluated by quarterly sampling for a year to determine if water produced from the screen is sufficiently representative of groundwater conditions to meet monitoring network objectives.
R-12 screen 2	Replace Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the “Interim Facility-wide Groundwater Monitoring Plan” (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The Baski sampling system allows two well screens to be isolated and for each screen to be purged prior to sampling. This will allow water to be drawn into the well screen from areas outside the influence of possible residual drilling fluids during groundwater sampling. Preliminary data of developed water from the R-12 rehabilitation indicate that the water quality from screen 2 is much improved. Because there is currently no sampling system in R-12, screen 2 has not been sampled since a screening sample was collected (1-Oct-06) at the end of well rehabilitation. Once the Baski sampling system is installed, screen 2 groundwater data should be evaluated by quarterly sampling for a year to determine if water produced from the screen is sufficiently representative of groundwater conditions to meet monitoring network objectives.

Well Name	Recommended Action	Rationale
R-12 screen 3	Plug and abandon screen 3 Install new regional well (R-36) to replace screen 3 in R-12	After rehabilitation, the water quality of screen 3 shows improvement, although it continues to be impacted by residual drilling fluids. About 623,000 gal. of perched zone water was introduced into screen 3 during well rehabilitation. An attempt to remove this much introduced water would face two major problems. 1. Developed water would have to be containerized and stored on-site until analyses can be performed for the notice of intent to discharge groundwater. Approximately one million gallons of water would have to be pumped from screen 3 to ensure the introduced water is removed. Storage of such large volumes of water is impractical. 2. A sustained pump rate of 10 gal./min would require 70 d to remove one million gal. of water. Sustained pumping for this length of time is impractical. NMED has directed the Laboratory to abandon this screen and install a replacement well.
R-13	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-14 screen 1	Replace Westbay sampling system with a submersible pump Redevelop the well Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well redevelopment	Although screen 1 does not presently meet geochemical monitoring objectives, it shows an improving trend. The prognosis for complete recovery from drilling effects looks good, based on steadily improving trends for the key redox indicators and the absence of residual organic drilling fluids. Nitrate and possibly perchlorate appear to be the only COPCs that currently cannot be reliably detected, but this condition is expected to be resolved as the interval continues to improve. Additional development could accelerate the recovery of this screen and enable it to produce water that is sufficiently representative of groundwater conditions to meet monitoring network objectives.
R-14 screen 2	Plug and abandon screen 2	Screen 2 does not presently meet geochemical monitoring objectives, and although it shows a slowly improving trend, iron-reducing conditions persist in this screen, rendering it incapable of providing representative and reliable data for a majority of the COPCs in Mortandad Canyon. Recovery to predrilling conditions is highly unlikely within the next few years in the absence of rehabilitation efforts. Rehabilitation efforts may not be cost-effective for this well screen. Loss of screen 2 should not significantly impact groundwater monitoring at this location because screens 1 and 2 are separated by only 50 ft, and their water levels are within 0.5 ft of one another. Screen 1 is sufficiently representative of groundwater conditions at the top of the regional groundwater system at this location (and could improve with redevelopment), and it meets other monitoring network objectives.

Well Name	Recommended Action	Rationale
R-15	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-16 screen 1	No further action is necessary.	After it became apparent that screen 1 could not be saved during well construction, it was isolated from the regional aquifer by placing bentonite above and below the screen inside the abandoned drill casing. A surface seal for the drill casing was created by injecting cement between the drill casing and the borehole wall from the surface to 130 ft depth. The role of screen 1 for monitoring water levels and water quality at the top of the regional aquifer at this location is satisfied by the installation of replacement well R-16r.
R-16 screen 2	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Although screen 2 does not presently meet geochemical monitoring objectives, it shows an improving trend. The prognosis for complete recovery from drilling effects looks good, based on steadily improving trends for the key redox indicators and the absence of residual organic drilling fluids. Nitrate and possibly perchlorate appear to be the only COPCs that currently cannot be reliably detected, but this condition is expected to improve over time. Groundwater modeling indicates that the R-16 location is not needed to detect contaminant plumes from the Mortandad watershed in the 3- to 5-yr time frame leading up to CME decisions.
R-16 screen 3	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-16 screen 4	Use primarily to monitor pressure responses in the regional aquifer due to pumping from Buckman Pajarito municipal well fields. Monitor groundwater for tritium	The primary purpose for R-16 is to determine the extent of pumping effects in the regional aquifer from municipal well production. Pressure data from screen 4 contribute to this objective and should continue to be monitored. After rehabilitation, the water quality of screen 4 shows improvement, but it continues to be significantly impacted by residual drilling fluids. Groundwater modeling indicates that the R-16 location is not needed to detect contaminant plumes from Mortandad Canyon in the 3- to 5-yr time frame leading up to CME decisions. Tritium is not affected by residual drilling fluids and is a good indicator of Laboratory releases. Tritium is the only constituent that should be monitored in screen 4 in the unlikely event that Mortandad Canyon releases reach the vicinity of R-16.
R-16r	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.

Well Name	Recommended Action	Rationale
R-17 screen 1	Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the stability of water quality parameters over a longer period of record	Well currently appears to meet monitoring network objectives. However, given the limited period of record, the well will continue to be evaluated to determine if it meets monitoring network objectives as new groundwater data are collected.
R-17 screen 2	Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the stability of water-quality parameters over a longer period of record	Well currently appears to meet monitoring network objectives. However, given the limited period of record, the well will continue to be evaluated to determine if it meets monitoring network objectives as new groundwater data are collected.
R-28	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-33 screen 1	Replace Barcad sampling system with a purgeable Baski sampling system and monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	The Baski sampling system allows two well screens to be isolated from one another and for each screen to be individually purged prior to sampling. This will allow groundwater to be drawn into the well screen from the formation away from any near-field geochemical conditions attributable to residual drilling fluids. With the Baski system, screen 1 is expected to be fully capable of producing water that is sufficiently representative of groundwater conditions to meet monitoring network objectives.
R-33 screen 2	Replace Barcad sampling system with a purgeable Baski sampling system and monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	The Baski sampling system allows two well screens to be isolated from one another and for each screen to be individually purged prior to sampling. This will allow groundwater to be drawn into the well screen from the formation away from any near-field geochemical conditions attributable to residual drilling fluids. With the Baski system, screen 1 is expected to be fully capable of producing water that is sufficiently representative of groundwater conditions to meet monitoring network objectives.
R-34	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-35a	After well construction and development is completed, monitor in accordance with the "Interim Groundwater Monitoring Plan" (LANL 2007, 096665)	Well will be evaluated to determine if it meets monitoring network objectives as new groundwater data are collected.
R-35b	After well construction and development is completed, monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well will be evaluated to determine if it meets monitoring network objectives as new groundwater data are collected.
TW-8	Plug and abandon well	R-1 was installed as a replacement well for TW-8 and meets monitoring objectives for regional groundwater in that reach of Mortandad Canyon. TW-8 should be plugged and abandoned because the annulus of the well is a potential pathway for alluvial and intermediate groundwater to reach regional groundwater.

Well Name	Recommended Action	Rationale
MCOBT-4.4	Plug and abandon well	MCOI-4 was installed as a replacement well for MCOBT-4.4 and meets monitoring objectives for perched groundwater in that part of Mortandad Canyon. MCOBT-4.4 should be plugged and abandoned because the sand pack may provide a pathway for perched intermediate groundwater to enter deeper parts of the Cerros del Rio basalt. Additionally, the groundwater sample yield has declined over the past several years and has been insufficient in the past 2 yr to obtain samples.
MCOI-4	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
MCOI-5	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
MCOI-6	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
MCOI-8	Maintain well for water-level measurements	Very limited water is present and is only in the sump. MCOI-8 will not continue to be sampled because the data it provides are not representative. The well will continue to be monitored for water levels; if the water level increases, the well will be sampled.

The regional network assessment presented in Appendix C supports the recommendations presented in Section 5. Several regional wells were identified as not currently meeting the physical/hydrologic and geochemical monitoring objectives (R-14, R-16, and TW-8). The assessment indicates that contamination from the Mortandad watershed is not likely to arrive at R-16 prior to the CMEs for Mortandad Canyon and MDA C; thus, it is not needed to meet the goals of this network assessment. R-14 was shown to be an important monitoring well with respect to detecting potential plumes from MDA C, and the proposed effort to rehabilitate it as a single screen well is consistent with goals for the monitoring network. Further evaluation of groundwater monitoring needs for MDA C will be addressed during the CME process. The network analysis shows that the overall network efficiency would not be significantly reduced if TW-8 were plugged and abandoned because R-1 intercepts essentially all of the plumes that are intercepted by TW-8.

The modeling results presented in Appendix C also conclude that the configuration of the monitoring well network is sufficient to detect contaminants as described in monitoring objective #3 without the need to add wells to the network prior to the CMEs for Mortandad Canyon and MDA C.

6.0 SCHEDULE

Upon NMED's approval of the recommendations contained in this report, the Laboratory will submit work plan(s) for implementation of the actions within 30 calendar days. The work plan will contain specifics for each of the actions and propose a schedule for implementation.

7.0 REFERENCES

The following list includes all documents cited in the main text of this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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NMED (New Mexico Environment Department), April 5, 2007. "Well Evaluations for Intermediate and Regional Wells," New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 095999)

NMED (New Mexico Environment Department), May 29, 2007. "Approval of Response to Approval with Direction, Mortandad Canyon Investigation Report," New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 096394)

Stauffer, P.H., K.H. Birdsell, M.S. Withowski, and J.K. Hopkins, 2005. "Vadose Zone Transport of 1,1,1-Trichloroethane: Conceptual Model Validation through Numerical Simulation," *Vadose Zone Journal,* Vol. 4, pp. 760-773. (Stauffer et al. 2005, 090537)

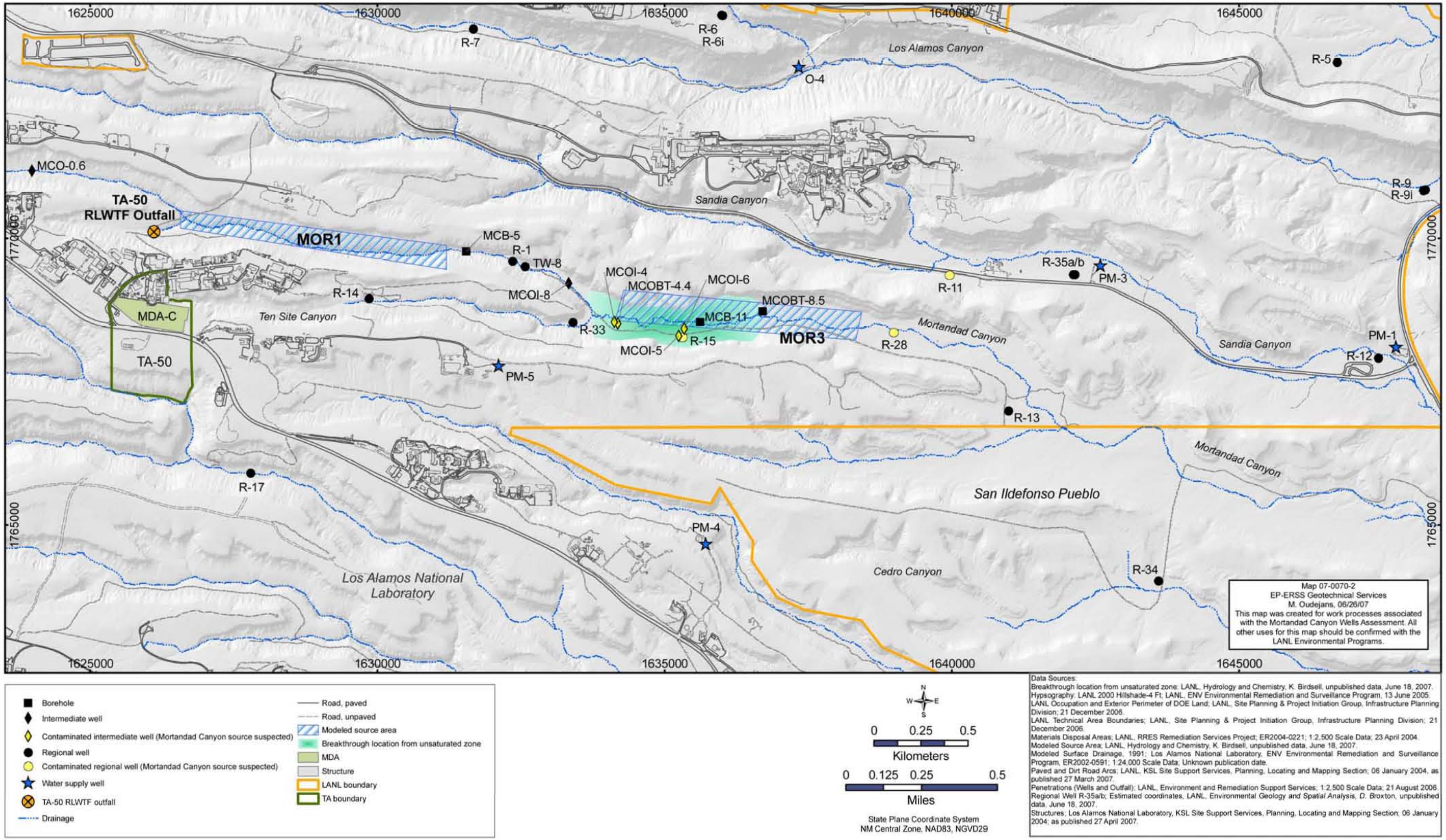
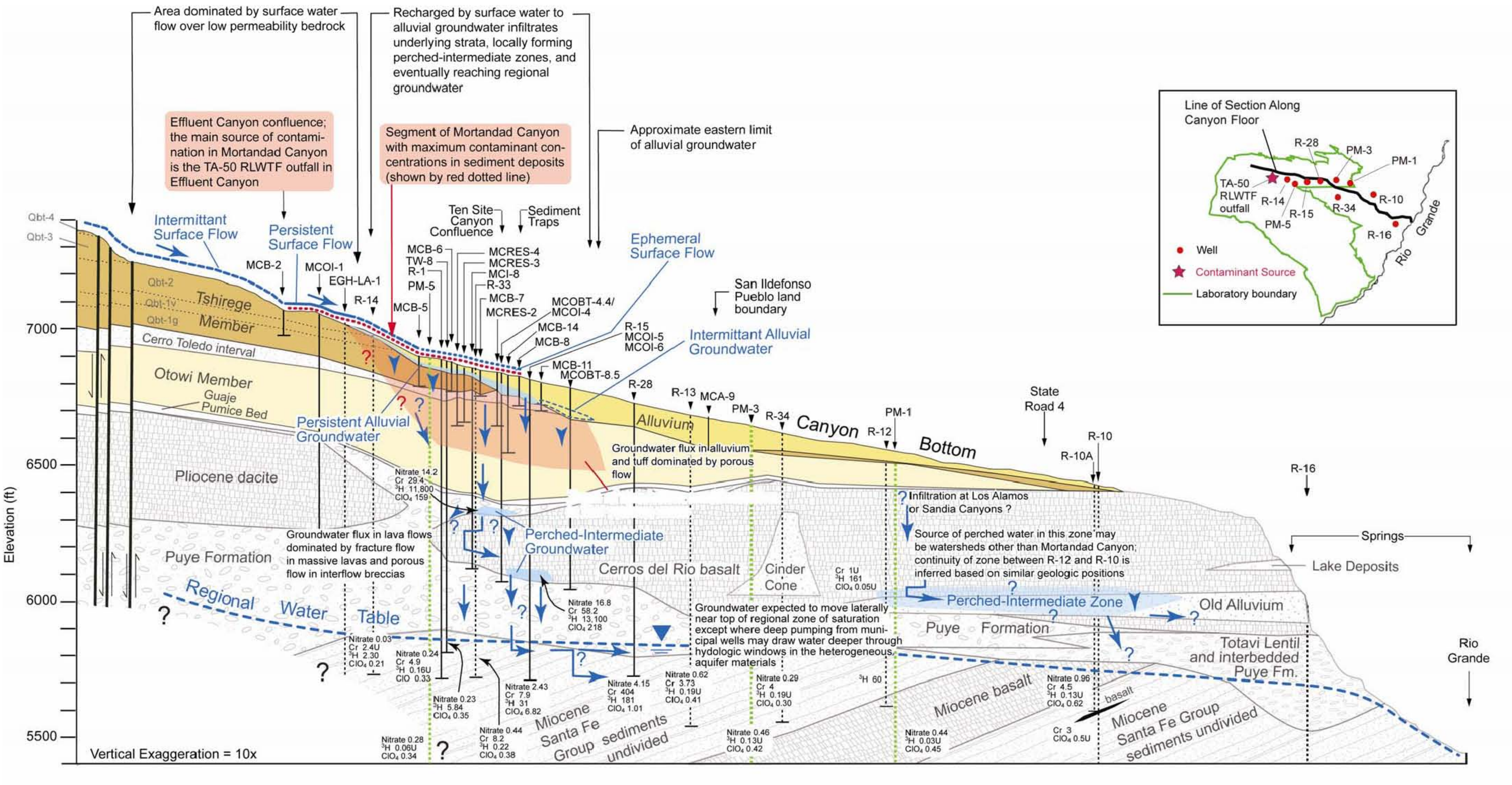


Figure 2-1 Location of Mortandad Canyon and MDA C showing the TA-50 RLWTF outfall, selected boreholes, intermediate wells, regional wells, water-supply wells, and the approximate breakthrough location of mobile contaminants that have migrated through the unsaturated zone in Mortandad Canyon to the regional water table



Note: The line of section follows the Mortandad Canyon stream channel. Wells in Mortandad Canyon along the line of section are shown by solid lines. Nearby test wells projected into the line of section are shown as dashed black lines. Nearby water supply wells projected into the line of section are shown as dashed green lines. Groundwater concentration data for nitrate, chromium, tritium, and perchlorate are the most recent data available through 2005. In cases where regional wells have more than one well screen (e.g., R-10, R-14, R-33), the highest measured concentration for the constituents is shown. In cases where multiple wells penetrate a perched water body (e.g., MCOI-5, MCOI-6), the highest measured concentration for the constituents is shown.

Figure 2-2 Conceptual hydrogeologic cross section showing potential contaminant transport pathways

Appendix A

Physical and Hydrologic Attributes of Network Wells

The acronyms and abbreviations defined below are used throughout this appendix.

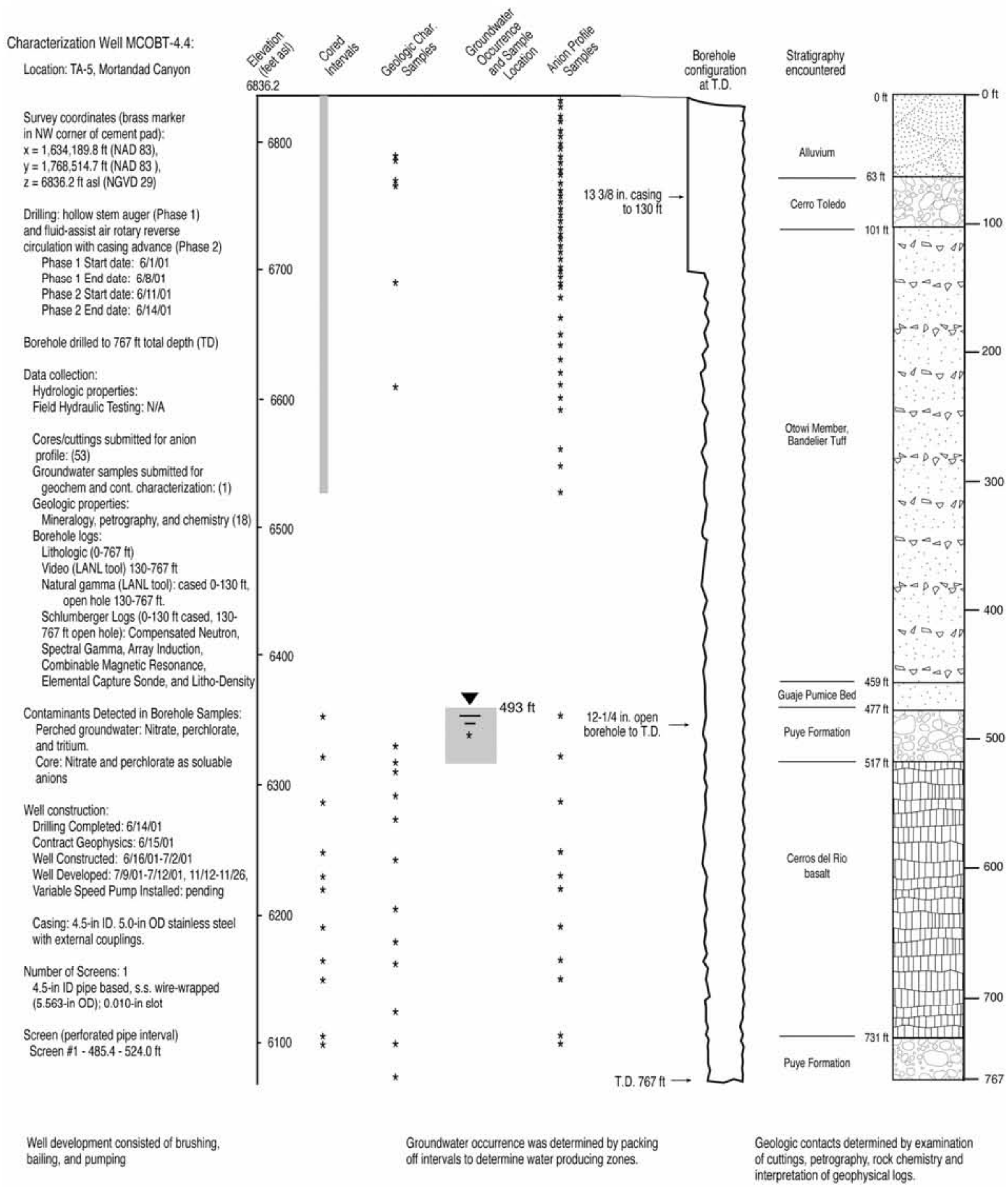
AE	acid enhancer
AIT	Array Induction Tool
API	American Petroleum Institute
bgs	below ground surface
CMR	Combinable Magnetic Resonance
CNT	Compensated Neutron Tool
ECS	elemental capture spectroscopy
ELAN	Elemental Log Analysis
FMI	Formation MicroImager
GPIT	General-Purpose Inclinometry Tool
HSA	hollow-stem auger
HQ	hazard quotient
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MCOBT	Mortandad Canyon Observation Bandelier Tuff (well)
MCOI	Mortandad Canyon Observation Intermediate (depth)
MGA	modified granular acid
n/a	not applicable
NGS	natural gamma spectrometry
NMED	New Mexico Environment Department
NTU	nephelometric turbity unit
O.D.	outside diameter
PFD	phosphate-free dispersant
PVC	polyvinyl chloride
TD	total depth
TLD	triple lithodensity

MCOBT-4.4 Well

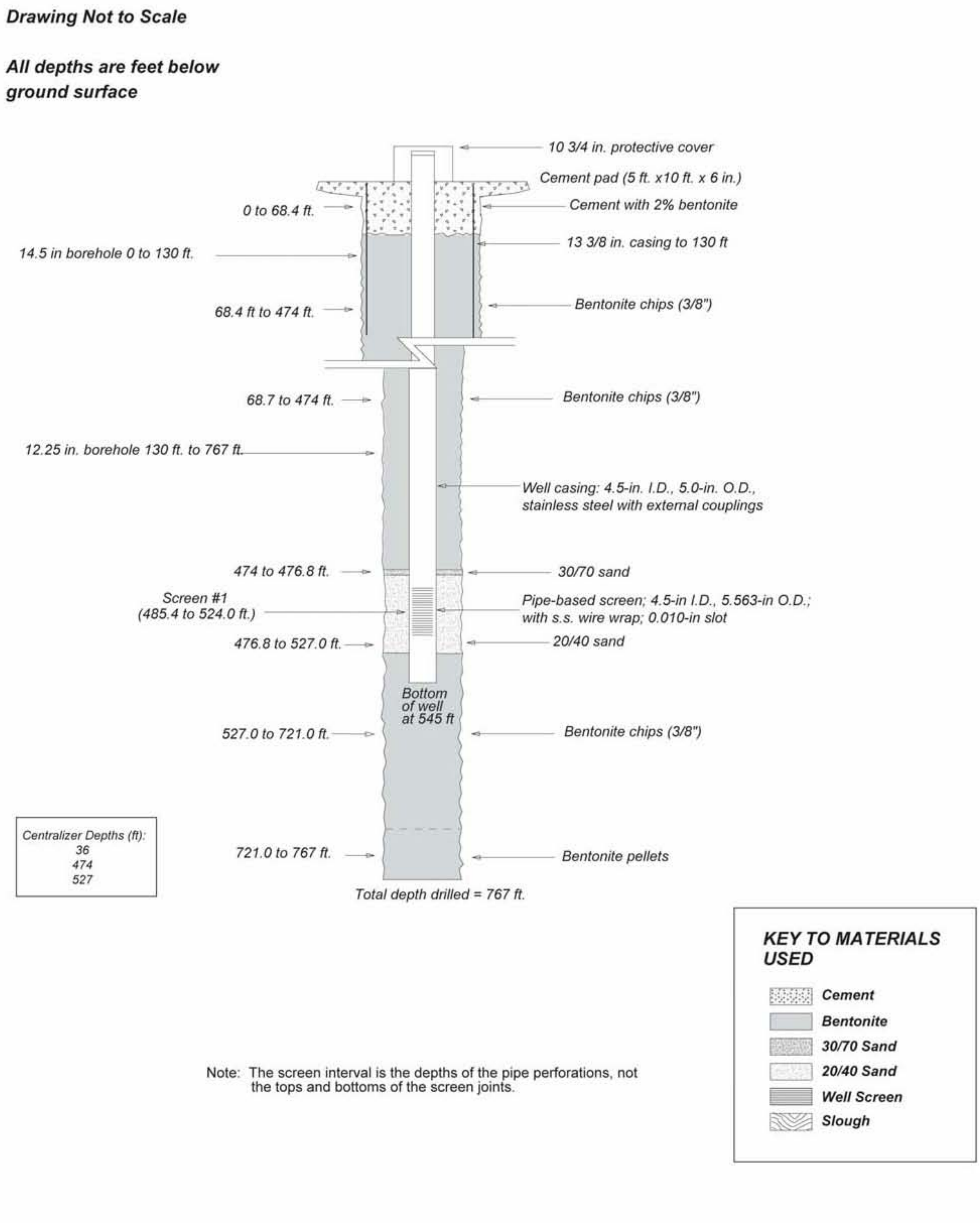
MCOBT-4.4 Well		
	Description	Evaluation
Drilling Method	MCOBT-4.4 was drilled using fluid-assisted air-rotary casing advance methods.	MCOBT-4.4 was drilled by reverse-circulation fluid-assisted air-rotary methods using casing advance to 130 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 767 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM and EZ-MUD. Drilling additives can adversely affect the ability to collect representative water samples. Normally this effect is minimized in single completion wells because they have sufficient flow to facilitate development and purging. However, the water flow at MCOBT-4.4 is limited, impacting development and purging.
General Well Characteristics	MCOBT-4.4 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.-I.D./ 5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two well screens were damaged during installation of R-25 well. A drawback to pipe-based screens is that water surged into the filter pack, and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also the wire wrap on the MCOBT-4.4 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. The perched zone that is sampled by MCOBT-4.4 is thin and does not produce sufficient water to generate extensive flow during development.
Screen Length and Placement	The well screen extends from 485.4 to 524 ft and has a length of 38.6 ft. Water levels have been steadily declining since MCOBT-4.4 was installed, and the current water level is about 523 ft bgs.	MCOBT-4.4 was installed to monitor a thin, perched groundwater zone located in the Puye Formation atop the Cerros del Rio basalt. The saturated thickness of this interval currently ranges between 2 and 4 ft. The MCOBT-4.4 well was constructed with a screened interval of 482.1 to 524 ft bgs and a sand pack interval of 474.0 to 527 ft bgs. The well design was based on the following information: (1) a static water level was measured at 493 ft bgs above an inflatable packer (524.5 to 531.5 ft bgs) in the open borehole; (2) a likely water-producing zone from 516 to 524 ft bgs was identified by the geophysical logs; and (3) the massive basalt from 522.5 to 535 ft bgs was considered a possible perching layer. Initial water levels measured inside the newly completed well seemed to validate the well design.

MCOBT-4.4 Well (continued)		
	Description	Evaluation
		Following well development, there was an unexplained decline in the static water level in MCOBT-4.4. A borehole video was run in the well casing on January 30, 2002, prior to installation of the submersible pump. The borehole video camera showed that the static water level had dropped from 493 to 519 ft bgs and that water was entering the screen at a depth of 497 ft bgs. After discussions with NMED, it was decided that the perching layer might be breached by the well's filter pack, causing the water to drain. A decision was made to replace MCOBT-4.4, and MCOI-4 well was installed 70 ft to the northwest in autumn 2004. Water levels from MCOI-4 are about 4 ft higher than those for MCOBT-4.4, generally confirming the breach of the filter pack as the cause of lower water levels observed in MCOBT-4.4 following well development. Currently, the water level in MCOBT-4.4 is about a foot above the bottom of the well screen.
Filter Pack Materials and Placement	The primary filter pack extends from 476.8 to 527 ft and is made up of 20/40 sand. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 474 to 476.8 ft.	The primary filter pack extends from 8.6 ft above to 3 ft below the well screen. The filter pack above the well screen is slightly longer than optimum but has no effect on samples collected because it is above the static water level in the perched zone. The filter pack below the well screen was made only thick enough to ensure the well screen was not impacted by bentonite in the annulus below.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers. The low-flow conditions in MCOI-4 offset some the advantages that are normally associated use a submersible pump in a single completion well.
Other Issues That Could Affect the Performance of the Well	None	n/a

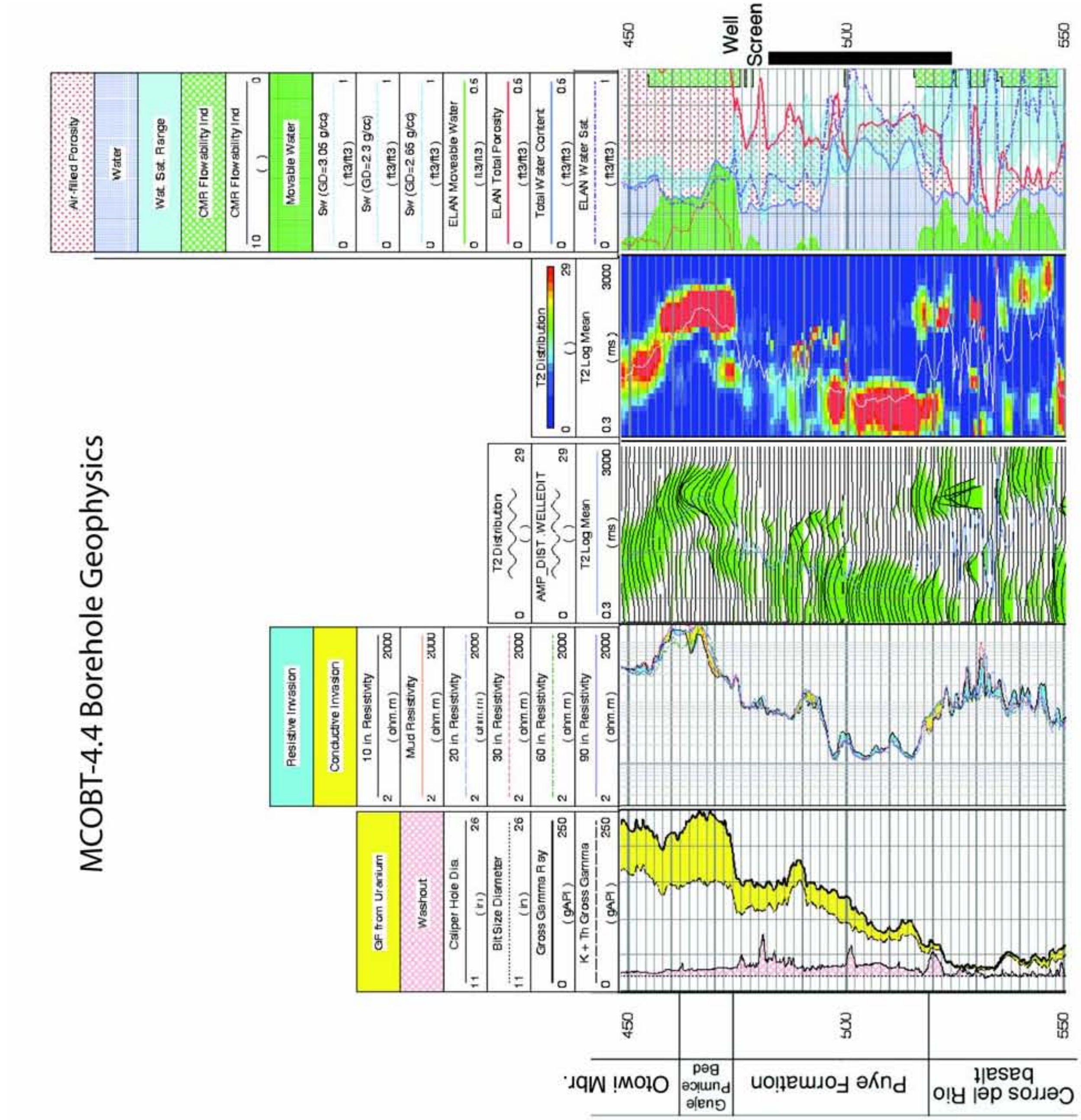
MCOBT-4.4 Well (continued)		
	Description	Evaluation
Additives used		Municipal water QUIK-FOAM EZ-MUD Fluids recovered during development—1895 gal. (1825 gal. bailed, 75 gal. pumped).
Annular fill other than filter and transition sands		Benseal high-solids multipurpose bentonite grout (1.66 bags) Holeplug 3/8-in. diameter bentonite chips (637.4 bags) Pelplug bentonite (0.25 in. by 0.375 in. refined elliptical pellets (62 buckets) Surface seal of cement slurry (44 bags)



Drilling, stratigraphic, and hydrologic information for characterization well MCOBT-4.4 rev 0a (1/31/02).



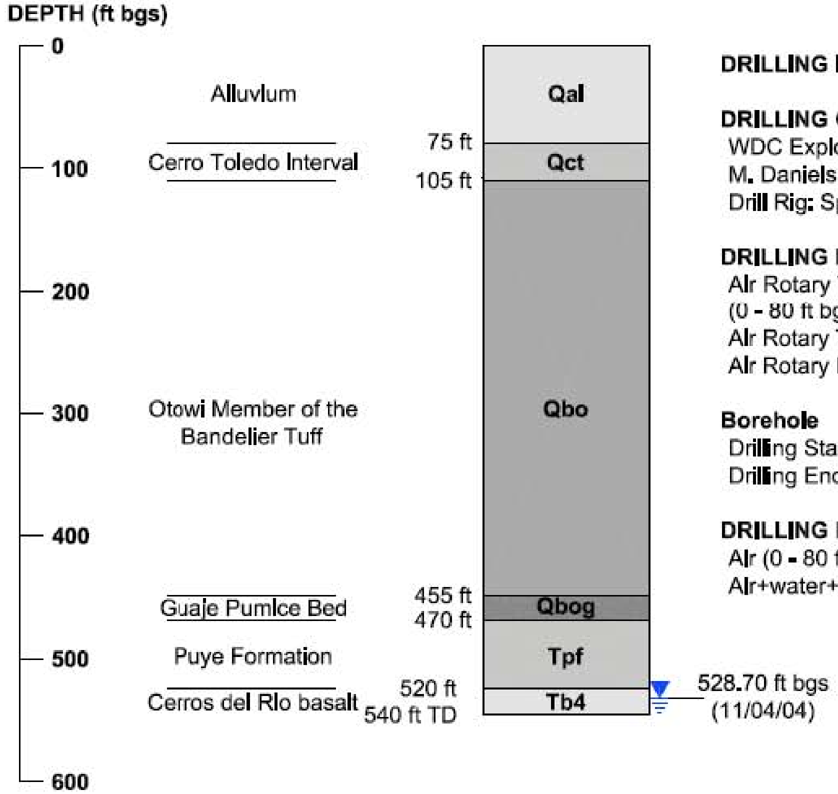
As-built well completion diagram of Well MCOBT-4.4 rev.0a (1/31/02).


MCOBT-4.4 Borehole Geophysics
Otowi Mbr.
Guaje Pumice Bed
Puye Formation
Cerros del Rio basalt
450
500
550
Well Screen
GR from Uranium
Washout
Caliper Hole Dia.
Bit Size Diameter
Gross Gamma Ray
K + Th Gross Gamma
Resistive Invasion
Conductive Invasion
10 in. Resistivity
Mud Resistivity
20 in. Resistivity
30 in. Resistivity
60 in. Resistivity
90 in. Resistivity
T2 Distribution
AMP_DIST_WELLEDIT
T2 Log Mean
Air-filled Porosity
Water
Wat. Sat. Range
CMR Flowability Ind
Movable Water
ELAN Moveable Water
ELAN Total Porosity
Total Water Content
ELAN Water Sat

MCOI-4 Well

MCOI-4 Well		
	Description	Evaluation
Drilling Method	MCOI-4 was drilled using fluid-assisted air-rotary methods.	MCOI-4 was drilled by normal-circulation fluid-assisted air-rotary methods to TD at 540 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM. Drilling additives can adversely affect the ability to collect representative water samples. Normally this effect is minimized in single completion wells because they have sufficient flow to facilitate development and purging. However, the water flow at MCOI-4 is limited, impacting development and sampling.
General Well Characteristics	MCOI-4 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The MCOI-4 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling. The perched zone that is sampled by MCOI-4 is thin and does not produce sufficient water to generate extensive flow during sampling.
Screen Length and Placement	The well screen extends from 499 to 522 ft and has a length of 23 ft. The screen straddles the water level, which is currently at a depth of about 520 ft bgs.	MCOI-4 is a replacement well for well MCOBT-4.4, located about 70 ft to the southeast. MCOI-4 was installed to monitor a thin, perched groundwater zone located in Puye Formation atop the Cerros del Rio basalt. The saturated thickness of this interval currently ranges between 2 and 4 ft. MCOBT-4.4 is installed in the same perched zone and initially had a water level of 493–494.5 ft bgs prior to well development. Following well development, there was an unexplained decline in the static water level in MCOBT-4.4. A borehole video was run in the MCOBT-4.4 well casing prior to installation of the submersible pump, and it showed that the static water level had dropped from 493 to 519 ft bgs and that water was entering the screen at a depth of 497 ft bgs. After discussions with NMED, it was decided that the perching layer might be breached by the well's filter pack, causing the water to drain. A decision was made to replace MCOBT-4.4, and well MCOI-4 was installed for this reason in autumn 2004. Water levels from MCOI-4 are about 4 ft higher than those for MCOBT-4.4, generally confirming the breach of the filter pack as the cause of lower water levels observed in MCOBT-4.4 following well development. Currently, the water level in MCOI-4 is about 3 ft above the bottom of the well screen. MCOBT-4.4 and MCOI-4 provide redundant monitoring of the perched intermediate groundwater in this part of Mortandad canyon.

MCOI-4 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement	The primary filter pack extends from 494 to 523.5 ft and is made up of 10/20 sand. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 492 to 494 ft.	The primary filter pack extends 5 ft above and 1.5 ft below the well screen. The filter pack above the well screen has no effect on samples collected because it is above the static water level in the perched zone. The filter pack below the well screen was made only thick enough to ensure the well screen was not impacted by bentonite in the annulus below.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers. The low-flow conditions in MCOI-4 offset some the advantages that are normally associated use a submersible pump in a single completion well.
Other Issues That Could Affect the Performance of the Well	n/a	
Additives used		Municipal water—1266 gal. QUIK-FOAM—35 gal. Fluids recovered during drilling and well development—1820 gal. (~1700 during drilling and ~120 during well development).
Annular fill other than filter and transition sands		Lower bentonite: Sand seal (4 ft^3:1.3 ft^3) Bentonite chips (301.5 ft^3) Surface seal of cement slurry (67.5 ft^3)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL
WDC Exploration
M. Daniels, C. Matthews, C. Bufkin, R. Price
Drill Rig: Speedstar 90k

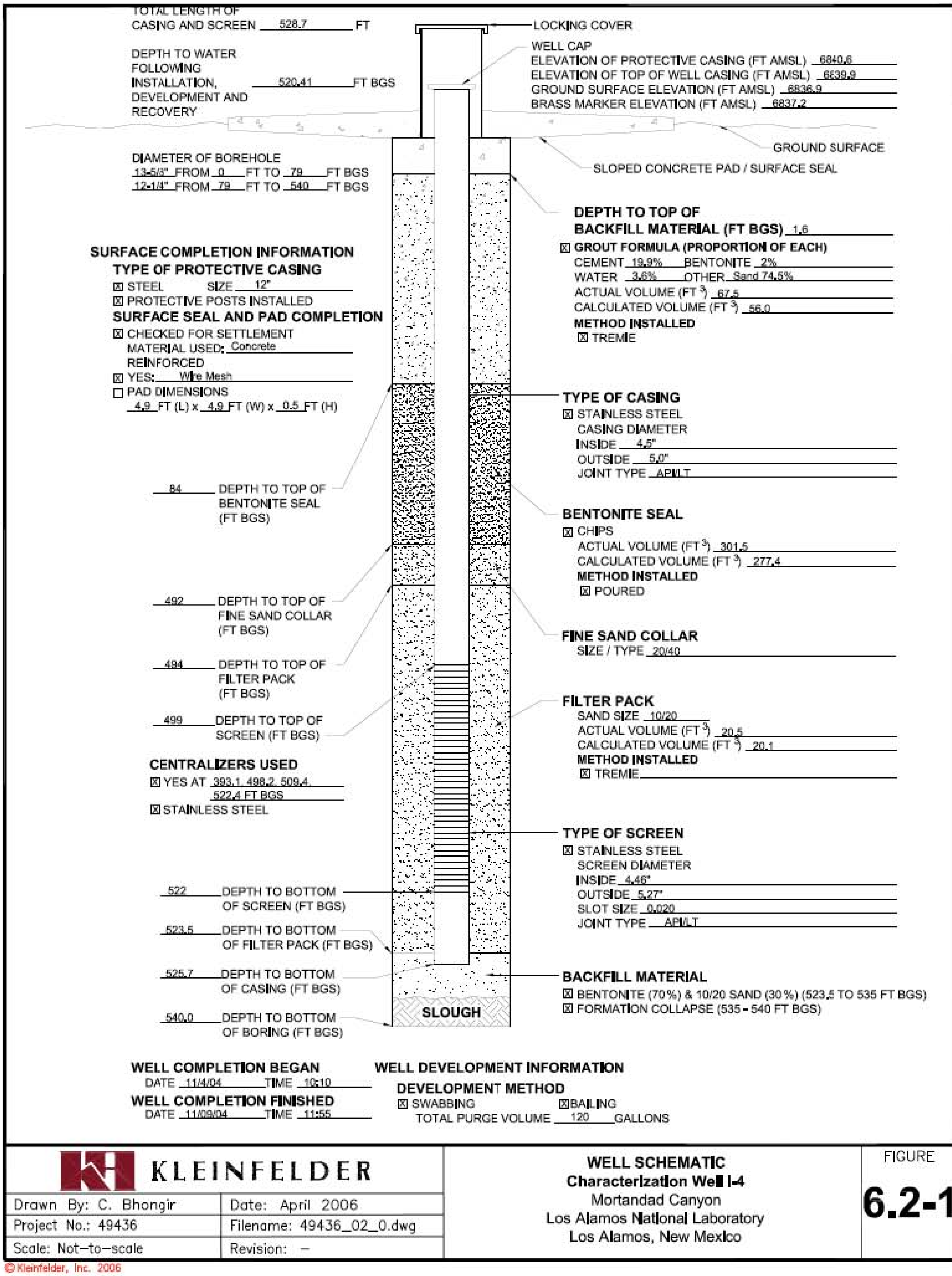
DRILLING METHOD
Air Rotary Tri-cone bit with casing hammer
(0 - 80 ft bgs)
Air Rotary Tri-cone bit (80 - 519 ft bgs)
Air Rotary Downhole hammer (519 - 540 ft bgs)

Borehole
Drilling Start Date: 10/24/04 Time: 16:50
Drilling End Date: 11/02/04 Time: 17:30

DRILLING FLUID TYPE
Air (0 - 80 ft bgs)
Air+water+QUIK-FOAM® (80 - 540 ft bgs)

Notes:
1. Geologic contacts are preliminary and subject to change.
2. Perched water at 59 ft bgs. Zone sealed off by surface casing.
3. Video survey indicated borehole wall moist below 504 ft bgs.
4. Groundwater level at 528.70 ft bgs in open hole after reaching TD of 540 ft bgs

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET I-4 Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE **5.1-1**
Drawn By: C. Bhongir	Date: April 2006		
Project No.: 49436	Filename: 49436_01_0.dwg		
Scale: not - to - scale	Revision: -		


TOTAL LENGTH OF CASING AND SCREEN 528.7 FT
DEPTH TO WATER FOLLOWING INSTALLATION, DEVELOPMENT AND RECOVERY 520.41 FT BGS
LOCKING COVER
WELL CAP
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6840.6
ELEVATION OF TOP OF WELL CASING (FT AMSL) 6839.9
GROUND SURFACE ELEVATION (FT AMSL) 6836.9
BRASS MARKER ELEVATION (FT AMSL) 6837.2
GROUND SURFACE
SLOPED CONCRETE PAD / SURFACE SEAL
DIAMETER OF BOREHOLE
13-5/8" FROM 0 FT TO 79 FT BGS
12-1/4" FROM 79 FT TO 540 FT BGS
DEPTH TO TOP OF BACKFILL MATERIAL (FT BGS) 1.6
GROUT FORMULA (PROPORTION OF EACH)
CEMENT 19.9% BENTONITE 2%
WATER 3.6% OTHER Sand 74.5%
ACTUAL VOLUME (FT³) 67.5
CALCULATED VOLUME (FT³) 56.0
METHOD INSTALLED
TREMIE
SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
STEEL SIZE 12"
PROTECTIVE POSTS INSTALLED
SURFACE SEAL AND PAD COMPLETION
CHECKED FOR SETTLEMENT
MATERIAL USED: Concrete
REINFORCED
YES: Wire Mesh
PAD DIMENSIONS
4.9 FT (L) x 4.9 FT (W) x 0.5 FT (H)
TYPE OF CASING
STAINLESS STEEL
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"
JOINT TYPE API/LT
84 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)
BENTONITE SEAL
CHIPS
ACTUAL VOLUME (FT³) 301.5
CALCULATED VOLUME (FT³) 277.4
METHOD INSTALLED
POURED
492 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)
FINE SAND COLLAR
SIZE / TYPE 20/40
494 DEPTH TO TOP OF FILTER PACK (FT BGS)
499 DEPTH TO TOP OF SCREEN (FT BGS)
FILTER PACK
SAND SIZE 10/20
ACTUAL VOLUME (FT³) 20.5
CALCULATED VOLUME (FT³) 20.1
METHOD INSTALLED
TREMIE
CENTRALIZERS USED
YES AT 393.1, 498.2, 509.4, 522.4 FT BGS
STAINLESS STEEL
TYPE OF SCREEN
STAINLESS STEEL
SCREEN DIAMETER
INSIDE 4.46"
OUTSIDE 5.27"
SLOT SIZE 0.020
JOINT TYPE API/LT
522 DEPTH TO BOTTOM OF SCREEN (FT BGS)
523.5 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)
525.7 DEPTH TO BOTTOM OF CASING (FT BGS)
540.0 DEPTH TO BOTTOM OF BORING (FT BGS)
BACKFILL MATERIAL
BENTONITE (70%) & 10/20 SAND (30%) (523.5 TO 535 FT BGS)
FORMATION COLLAPSE (535 - 540 FT BGS)
SLOUGH
WELL COMPLETION BEGAN
DATE 11/4/04 TIME 10:10
WELL COMPLETION FINISHED
DATE 11/09/04 TIME 11:55
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
SWABBING BAILING
TOTAL PURGE VOLUME 120 GALLONS
KLEINFELDER
Drawn By: C. Bhongir
Date: April 2006
Project No.: 49436
Filename: 49436_02_0.dwg
Scale: Not-to-scale
Revision: –
WELL SCHEMATIC
Characterization Well I-4
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
6.2-1

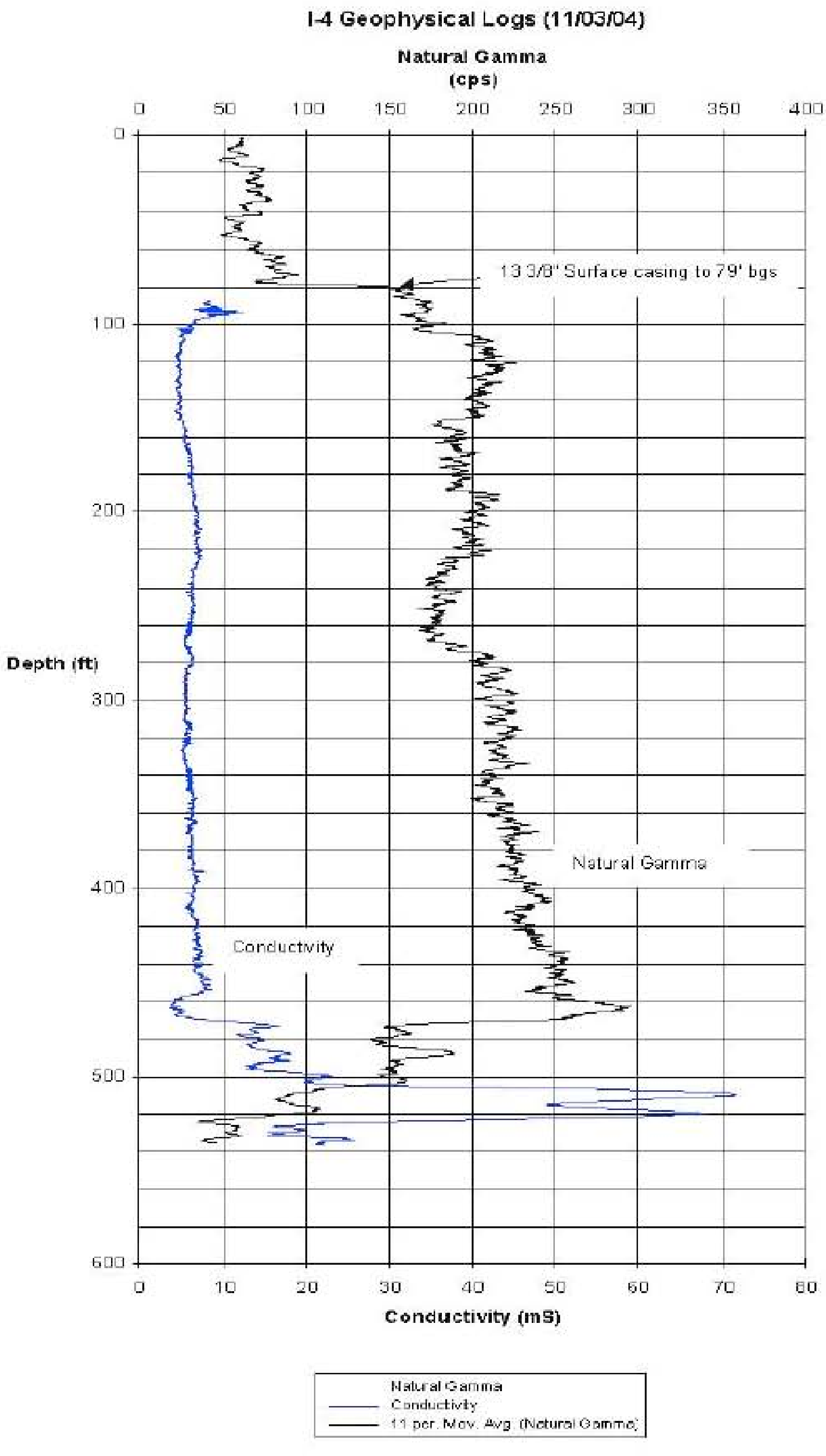
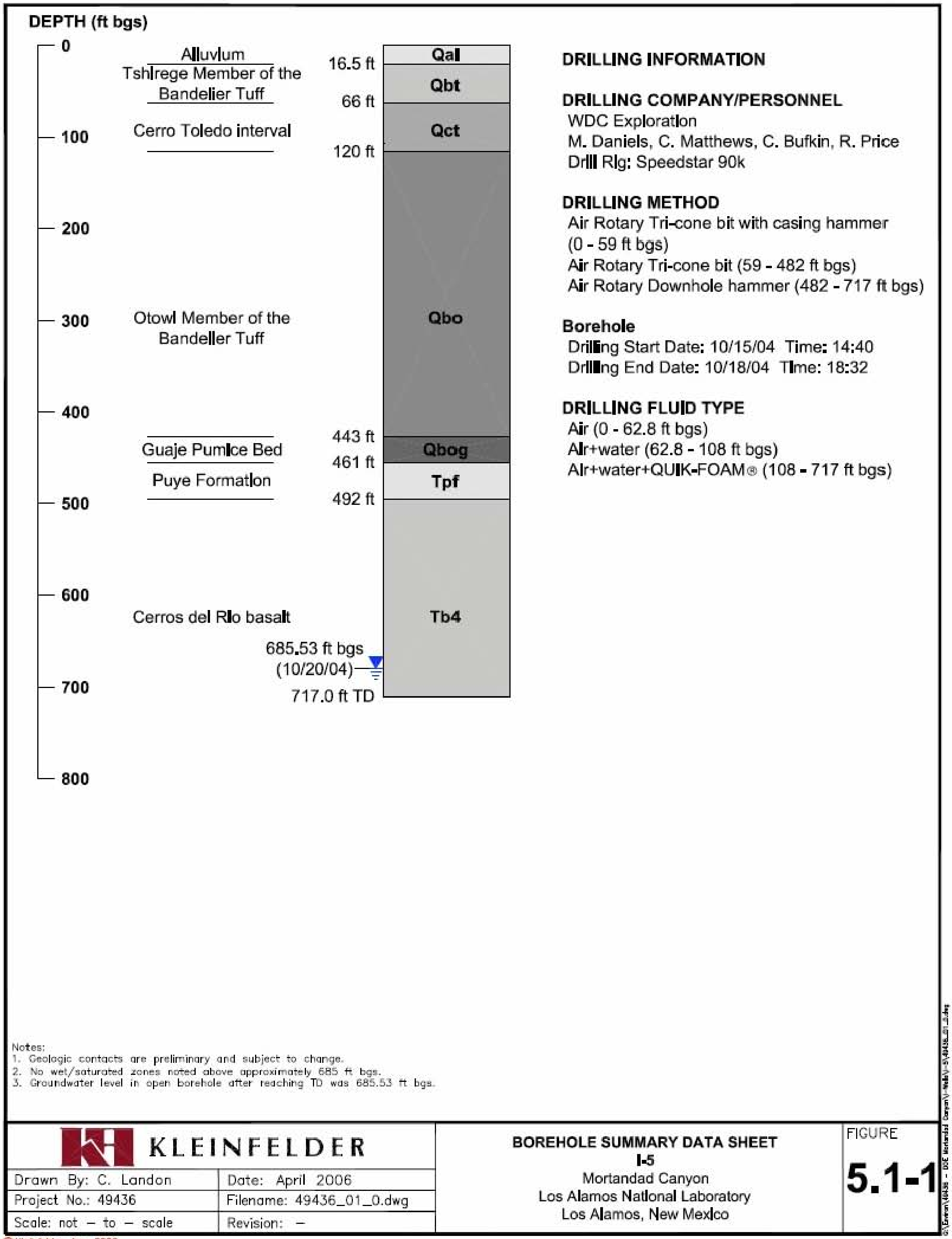


Figure 4.2-1 Natural Gamma and Induction Array Geophysical Logs

MCOI-5 Well

MCOI-5 Well		
	Description	Evaluation
Drilling Method	MCOI-5 was drilled using fluid-assisted air-rotary methods.	MCOI-5 was drilled by normal-circulation fluid-assisted air-rotary methods to TD at 717 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized at MCOI-5 because it is a single completion well, which is easier to develop and can be purged before sampling.
General Well Characteristics	MCOI-5 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The MCOI-5 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well with the need to promote the free flow of water during well development and sampling. The perched intermediate zone that is sampled by MCOI-5 does not produce sufficient water to generate extensive flow during sampling.
Screen Length and Placement	The well screen extends from 689 to 699 ft and has a length of 10 ft. The screen is beneath the perched intermediate water level, measured at 685.5 ft bgs on 10/20/2004.	MCOI-5 is located to sample a perched zone in the lower Cerros del Rio lavas that was noted in drilling R-15, which is ~66 ft to the east. The saturated thickness of this perched zone is believed to be ~60 ft (data from R-15 indicate base of Cerros del Rio lavas at ~745 ft depth, where flow-base clays may induce perching). ***Relevant stratigraphy:*** Cerros del Rio lavas from 492 ft depth to TD at 717 ft. ***<u>Geophysical logs:</u>*** Kleinfelder gamma and induction logs were run from 65 to 480 ft depth. An Alpha Southwest video log was collected from 65 to 704 ft depth, noting standing water at 686 ft depth when borehole depth was at 717 ft. Schlumberger logs were run from 59 to 715 ft and included CMR, CNT, TLD, AIT, NGS, ECS, and caliper. Schlumberger results were consistent with a water level at 684–685 ft depth and indicated a porous zone at 691–699-ft depth that may correspond with interflow rubble. The screen at MCOI-5 was placed to include the porous rubble zone and to provide a modest amount of submersion for well development, while being long enough to allow for temporal variation of the perched zone thickness.

MCOI-5 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement	The primary filter pack extends from 680 to 706.5 ft and is made up of 10/20 sand. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 677.5 to 680 ft.	The primary filter pack extends 9 ft above and 7.5 ft below the well screen. The filter pack above ~685 ft depth has no effect on samples collected because it is above the static water level in the perched zone.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers. The low-flow conditions in MCOI-5 offset some the advantages that are normally associated use a submersible pump in a single completion well.
Other Issues That Could Affect the Performance of the Well		Pumping rates are limited and may affect development and sampling.
Additives used		Municipal—2900 gal. QUIK-FOAM—55 gal. Fluids recovered during drilling, well development, and hydrologic testing—2170 gal. (~1440 during drilling, 35 by bailing and swabbing, 615 by development pumping, and 80 during hydrologic testing)
Annular fill other than filter and transition sands		Bentonite chips (440.2 ft^3) Surface seal of cement slurry (67.5 ft^3)


DEPTH (ft bgs)
0
100
200
300
400
500
600
700
800
Alluvium
Tshirege Member of the Bandelier Tuff
Cerro Toledo interval
Otowi Member of the Bandelier Tuff
Guaje Pumice Bed
Puye Formation
Cerros del Rio basalt
16.5 ft
66 ft
120 ft
443 ft
461 ft
492 ft
685.53 ft bgs (10/20/04)
717.0 ft TD
Qal
Qbt
Qct
Qbo
Qbog
Tpf
Tb4
DRILLING INFORMATION
DRILLING COMPANY/PERSONNEL
WDC Exploration
M. Daniels, C. Matthews, C. Bufkin, R. Price
Drill Rig: Speedstar 90k
DRILLING METHOD
Air Rotary Tri-cone bit with casing hammer (0 - 59 ft bgs)
Air Rotary Tri-cone bit (59 - 482 ft bgs)
Air Rotary Downhole hammer (482 - 717 ft bgs)
Borehole
Drilling Start Date: 10/15/04 Time: 14:40
Drilling End Date: 10/18/04 Time: 18:32
DRILLING FLUID TYPE
Air (0 - 62.8 ft bgs)
Air+water (62.8 - 108 ft bgs)
Air+water+QUIK-FOAM® (108 - 717 ft bgs)
Notes:
1. Geologic contacts are preliminary and subject to change.
2. No wet/saturated zones noted above approximately 685 ft bgs.
3. Groundwater level in open borehole after reaching TD was 685.53 ft bgs.
KLEINFELDER
Drawn By: C. Landon
Date: April 2006
Project No.: 49436
Filename: 49436_01_0.dwg
Scale: not - to - scale
Revision: -
BOREHOLE SUMMARY DATA SHEET
I-5
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
5.1-1
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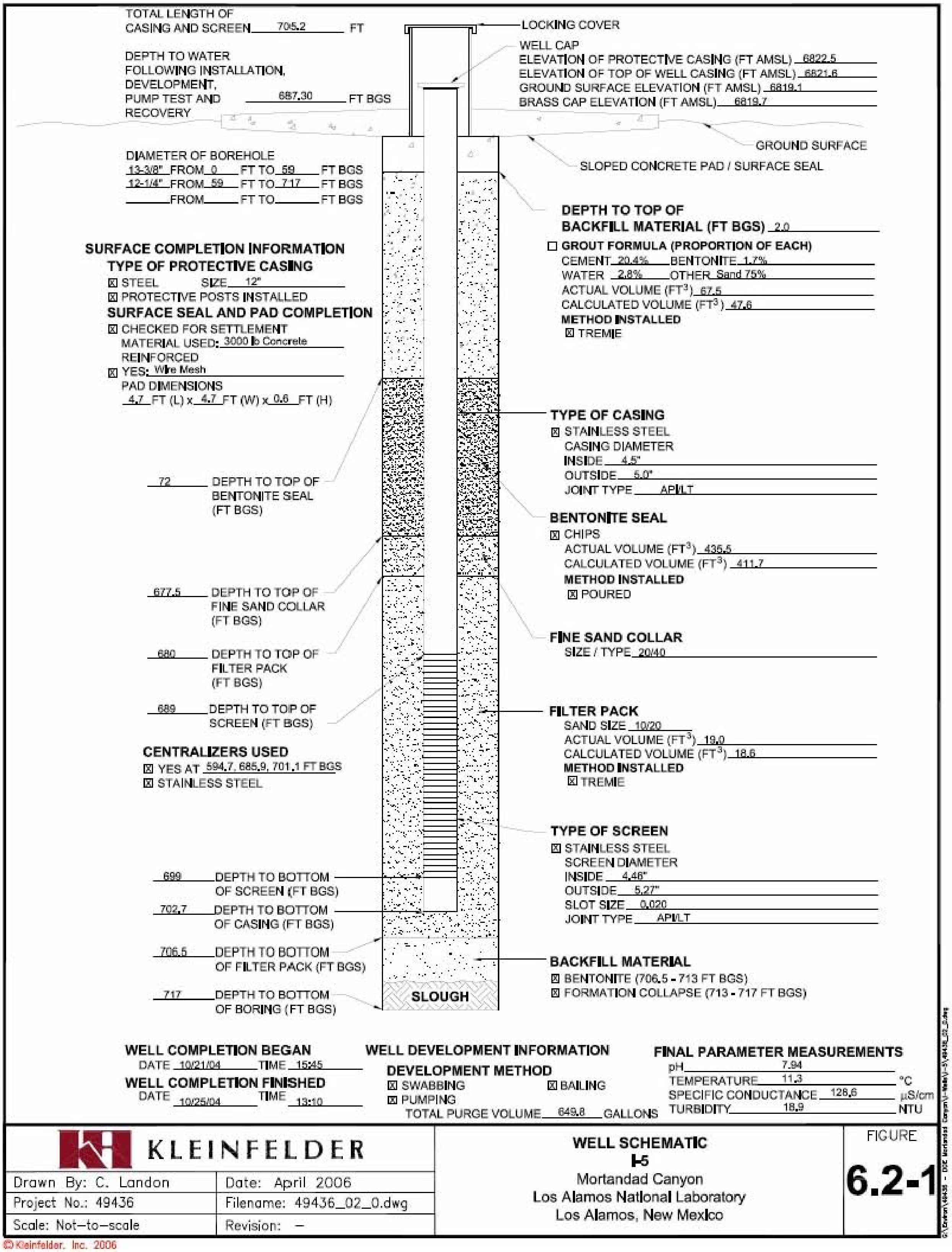

TOTAL LENGTH OF CASING AND SCREEN 705.2 FT
DEPTH TO WATER FOLLOWING INSTALLATION, DEVELOPMENT, PUMP TEST AND RECOVERY 687.30 FT BGS
LOCKING COVER
WELL CAP
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6822.5
ELEVATION OF TOP OF WELL CASING (FT AMSL) 6821.6
GROUND SURFACE ELEVATION (FT AMSL) 6819.1
BRASS CAP ELEVATION (FT AMSL) 6819.7
GROUND SURFACE
SLOPED CONCRETE PAD / SURFACE SEAL
DIAMETER OF BOREHOLE
13-3/8" FROM 0 FT TO 59 FT BGS
12-1/4" FROM 59 FT TO 717 FT BGS
FROM FT TO FT BGS
DEPTH TO TOP OF BACKFILL MATERIAL (FT BGS) 2.0
GROUT FORMULA (PROPORTION OF EACH)
CEMENT 20.4% BENTONITE 1.7%
WATER 2.8% OTHER Sand 75%
ACTUAL VOLUME (FT3) 67.5
CALCULATED VOLUME (FT3) 47.6
METHOD INSTALLED
TREMIE
SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
STEEL SIZE 12"
PROTECTIVE POSTS INSTALLED
SURFACE SEAL AND PAD COMPLETION
CHECKED FOR SETTLEMENT
MATERIAL USED: 3000 lb Concrete
REINFORCED
YES: Wire Mesh
PAD DIMENSIONS
4.7 FT (L) x 4.7 FT (W) x 0.6 FT (H)
TYPE OF CASING
STAINLESS STEEL
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"
JOINT TYPE API/LT
72 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)
BENTONITE SEAL
CHIPS
ACTUAL VOLUME (FT3) 435.5
CALCULATED VOLUME (FT3) 411.7
METHOD INSTALLED
POURED
677.5 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)
FINE SAND COLLAR
SIZE / TYPE 20/40
680 DEPTH TO TOP OF FILTER PACK (FT BGS)
689 DEPTH TO TOP OF SCREEN (FT BGS)
FILTER PACK
SAND SIZE 10/20
ACTUAL VOLUME (FT3) 19.0
CALCULATED VOLUME (FT3) 18.6
METHOD INSTALLED
TREMIE
CENTRALIZERS USED
YES AT 594.7, 685.9, 701.1 FT BGS
STAINLESS STEEL
TYPE OF SCREEN
STAINLESS STEEL
SCREEN DIAMETER
INSIDE 4.46"
OUTSIDE 5.27"
SLOT SIZE 0.020
JOINT TYPE API/LT
699 DEPTH TO BOTTOM OF SCREEN (FT BGS)
702.7 DEPTH TO BOTTOM OF CASING (FT BGS)
706.5 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)
717 DEPTH TO BOTTOM OF BORING (FT BGS)
BACKFILL MATERIAL
BENTONITE (706.5 - 713 FT BGS)
FORMATION COLLAPSE (713 - 717 FT BGS)
SLOUGH
WELL COMPLETION BEGAN
DATE 10/21/04 TIME 15:45
WELL COMPLETION FINISHED
DATE 10/25/04 TIME 13:10
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
SWABBING
BAILING
PUMPING
TOTAL PURGE VOLUME 649.8 GALLONS
FINAL PARAMETER MEASUREMENTS
pH 7.94
TEMPERATURE 11.3 °C
SPECIFIC CONDUCTANCE 128.6 µS/cm
TURBIDITY 18.9 NTU
KLEINFELDER
Drawn By: C. Landon
Date: April 2006
Project No.: 49436
Filename: 49436_02_0.dwg
Scale: Not-to-scale
Revision: -
WELL SCHEMATIC
I-5
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
6.2-1
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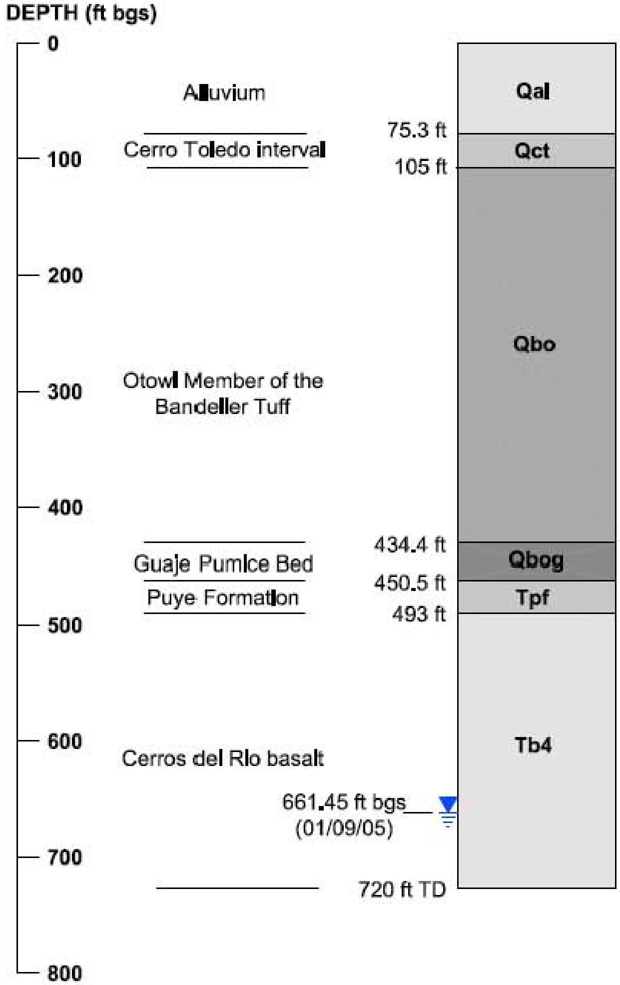
MCOI-6 Well

MCOI-6 Well		
	Description	Evaluation
Drilling Method	MCOI-6 was drilled using air rotary and fluid-assisted air-rotary methods.	MCOI-6 was drilled by normal-circulation air rotary and fluid-assisted air-rotary methods to TD at 720 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized at MCOI-6 because it is a single completion well, which is easier to develop and can be purged before sampling.
General Well Characteristics	MCOI-6 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The MCOI-6 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 686 to 709 ft and has a length of 23 ft. The top of the screen is 23.4 ft below the water table that is currently at a depth of about 662.6 ft bgs.	MCOI-6 is one of three wells (including R-15 and MCOI-5) that encountered perched water within the lower part of the Cerros del Rio basalt east of the sediment traps in Mortandad Canyon. The perched zone is ≥ 74 ft thick at MCOI-6, and saturation appears to be associated with fractured lava flows and interflow breccias. The perched zone at MCOI-6 was probably not fully penetrated during drilling, and the perching horizon is uncertain. The top of basalt at MCOI-6 is at 495 ft, and the borehole was terminated at 720 ft while still in basalt. The target depth was based on the perched water occurrence in nearby well MCOI-5 and a desire to avoid draining the perched zone by penetrating the confining unit. Because of relatively low rates of water production and the use of municipal water with foam, the driller could not determine when he entered saturated conditions while drilling. Saturation was determined by resting the hole overnight and measuring water levels in the morning. Confirmation of perched groundwater was made when analyses of bailed samples indicated the presence of Laboratory contaminants, indicating that this was native groundwater rather than accumulated drilling fluids. The water level in the open borehole was about 662 ft bgs. The field contractor conducted video, induction, and gamma logging of the borehole to assess geologic and hydrologic conditions prior to well installation. The Cerros del Rio basalt is generally resistive to a depth of about 645 ft and conductive below. There is a zone of elevated conductivity between 605 and 617 ft, but no flowing water was observed in this interval by the borehole video camera. Also, the 605 to 617 ft zone coincides with a prominent gamma peak; gamma peaks in basalt are frequently associated with clay-filled interflow breccias that are generally impermeable.

MCOI-6 Well (continued)		
	Description	Evaluation
		The rocks below 645 ft are most conductive at depths of 675, 682, 695, and 717 ft. These conductive zones are separated by relatively resistive rocks, particularly between 686- and 692-ft depth and between 700 and 715 ft. The resistive zones probably represent massive, low-porosity, basalt flow interiors, whereas the high conductivity peaks are centered on high-porosity interflow breccias. The well design incorporated the information about the rock lithology from drill cuttings, geophysical and video logs, and water-level measurements. Based on these data, the well was constructed so that the screen was centered at the 695-ft conductivity peak. The primary filter pack was extended uphole to ensure that most of the high-conductivity zone would be captured by the well.
Filter Pack Materials and Placement	The primary filter pack extends from 669 to 714 ft and is made up of 10/20 sand. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 667to 669 ft.	The primary filter pack extends 17 ft above and 5 ft below the well screen. The filter pack above the well screen was extended uphole to ensure that water from the upper part of the perched system could be captured by the well.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	n/a	
Additives used		Municipal water—7500 gal. QUIK-FOAM—90 gal. Fluids recovered during drilling and well development—9704 gal.
Annular fill other than filter and transition sands		Lower bentonite seal—pellets (1.3 ft^3) Upper bentonite seal—pellets and chips (481.1 ft^3) Surface seal of cement slurry (108 ft^3)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL
WDC Exploration
M. Daniels, C. Matthews, R. Price
Drill Rig: Gefco 50k
Spectrum Exploration
S. Jager
Drill Rig: DB-540

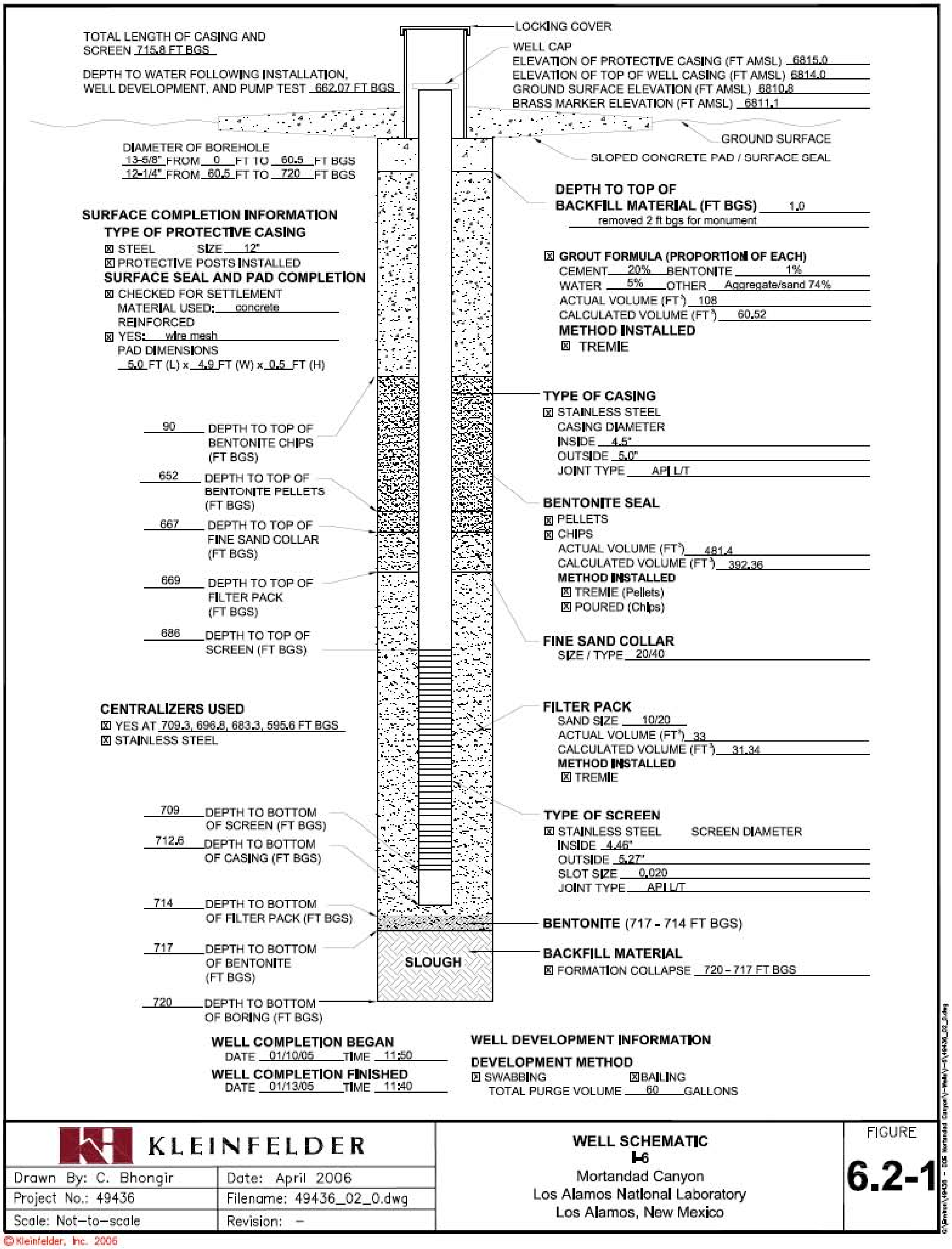
DRILLING METHOD
Corehole
0 - 498.2 ft bgs
Borehole
Air Rotary Tri-cone bit with casing hammer (0 - 60.5 ft bgs)
Air Rotary Tri-cone bit (60.5 - 495 ft bgs)
Air Rotary Downhole hammer (495 - 720 ft bgs)

Corehole
Drilling Start Date: 10/21/04 Time: 15:40
Drilling End Date: 10/28/04 Time: 18:09
Borehole
Drilling Start Date: 01/03/05 Time: 18:05
Drilling End Date: 01/06/05 Time: 17:28

DRILLING FLUID TYPE
Corehole: Air (0 - 498.2 ft bgs)
Borehole: Air, water, QUIK-FOAM®
Air (0-60.5 ft bgs)
Air+water+QUIK-FOAM® (60.5 - 720 ft bgs)

Notes:
1. Geologic contacts are preliminary and subject to change.
2. Wet/saturated zone in Alluvium at approximately 57.5 ft bgs in corehole.
3. Groundwater level in open borehole after reaching TD was 661.45 ft bgs.

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET I-6 Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 5.1-1
Drawn By: C. Landon	Date: April 2006		
Project No.: 49436	Filename: 49436_01_0.dwg		
Scale: not – to – scale	Revision: –		



TOTAL LENGTH OF CASING AND SCREEN 715.8 FT BGS
DEPTH TO WATER FOLLOWING INSTALLATION, WELL DEVELOPMENT, AND PUMP TEST 662.07 FT BGS
LOCKING COVER
WELL CAP
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6815.0
ELEVATION OF TOP OF WELL CASING (FT AMSL) 6814.0
GROUND SURFACE ELEVATION (FT AMSL) 6810.8
BRASS MARKER ELEVATION (FT AMSL) 6811.1
GROUND SURFACE
SLOPED CONCRETE PAD / SURFACE SEAL
DIAMETER OF BOREHOLE
13-5/8" FROM 0 FT TO 60.5 FT BGS
12-1/4" FROM 60.5 FT TO 720 FT BGS
DEPTH TO TOP OF BACKFILL MATERIAL (FT BGS) 1.0
removed 2 ft bgs for monument
SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 12"
☒ PROTECTIVE POSTS INSTALLED
SURFACE SEAL AND PAD COMPLETION
☒ CHECKED FOR SETTLEMENT
MATERIAL USED: concrete
REINFORCED
☒ YES: wire mesh
PAD DIMENSIONS
5.0 FT (L) x 4.9 FT (W) x 0.5 FT (H)
☒ GROUT FORMULA (PROPORTION OF EACH)
CEMENT 20% BENTONITE 1%
WATER 5% OTHER Aggregate/sand 74%
ACTUAL VOLUME (FT³) 108
CALCULATED VOLUME (FT³) 60.52
METHOD INSTALLED
☒ TREMIE
TYPE OF CASING
☒ STAINLESS STEEL
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"
JOINT TYPE API L/T
90 DEPTH TO TOP OF BENTONITE CHIPS (FT BGS)
652 DEPTH TO TOP OF BENTONITE PELLETS (FT BGS)
667 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)
669 DEPTH TO TOP OF FILTER PACK (FT BGS)
686 DEPTH TO TOP OF SCREEN (FT BGS)
BENTONITE SEAL
☒ PELLETS
☒ CHIPS
ACTUAL VOLUME (FT³) 481.4
CALCULATED VOLUME (FT³) 392.36
METHOD INSTALLED
☒ TREMIE (Pellets)
☒ POURED (Chips)
FINE SAND COLLAR
SIZE / TYPE 20/40
CENTRALIZERS USED
☒ YES AT 709.3, 696.8, 683.3, 595.6 FT BGS
☒ STAINLESS STEEL
FILTER PACK
SAND SIZE 10/20
ACTUAL VOLUME (FT³) 33
CALCULATED VOLUME (FT³) 31.34
METHOD INSTALLED
☒ TREMIE
709 DEPTH TO BOTTOM OF SCREEN (FT BGS)
712.6 DEPTH TO BOTTOM OF CASING (FT BGS)
TYPE OF SCREEN
☒ STAINLESS STEEL SCREEN DIAMETER
INSIDE 4.46"
OUTSIDE 5.27"
SLOT SIZE 0.020
JOINT TYPE API L/T
714 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)
BENTONITE (717 - 714 FT BGS)
717 DEPTH TO BOTTOM OF BENTONITE (FT BGS)
SLOUGH
BACKFILL MATERIAL
☒ FORMATION COLLAPSE 720 - 717 FT BGS
720 DEPTH TO BOTTOM OF BORING (FT BGS)
WELL COMPLETION BEGAN
DATE 01/10/05 TIME 11:50
WELL COMPLETION FINISHED
DATE 01/13/05 TIME 11:40
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
TOTAL PURGE VOLUME 60 GALLONS
KLEINFELDER
Drawn By: C. Bhongir
Date: April 2006
Project No.: 49436
Filename: 49436_02_0.dwg
Scale: Not-to-scale
Revision: –
WELL SCHEMATIC
I-6
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
6.2-1
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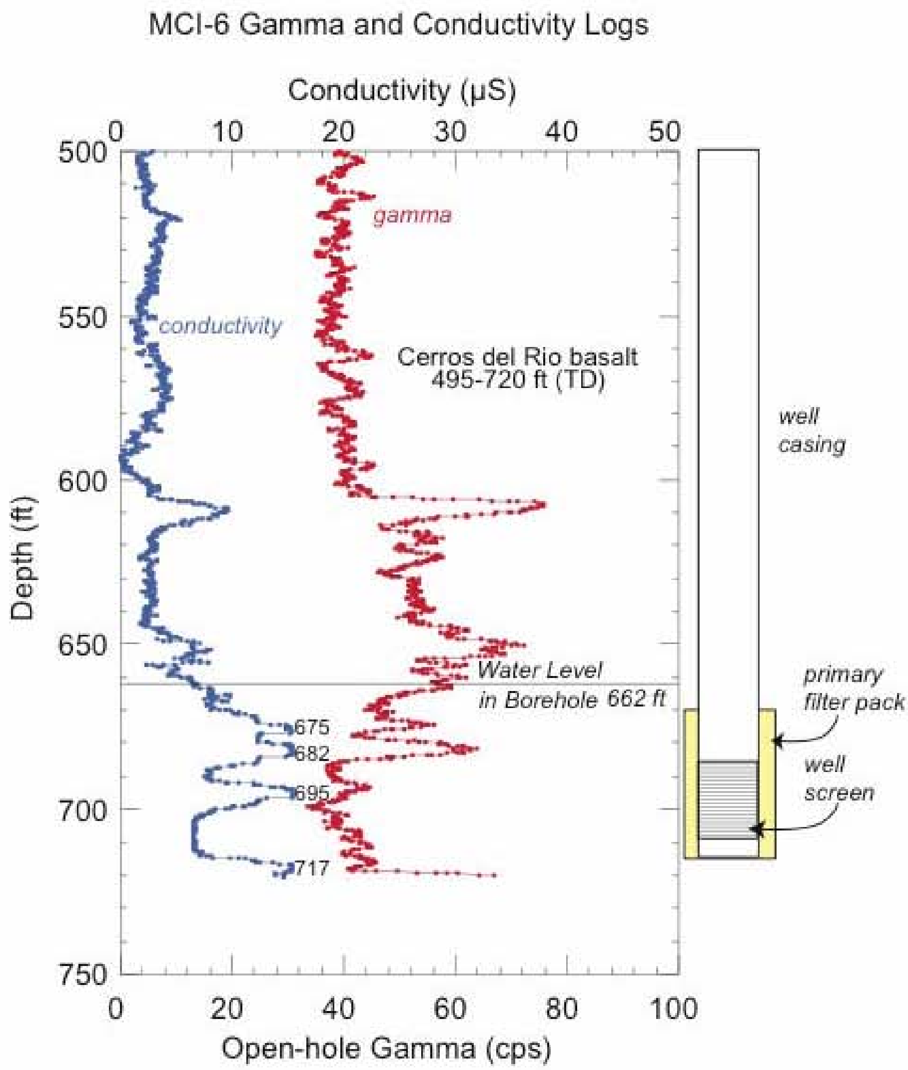
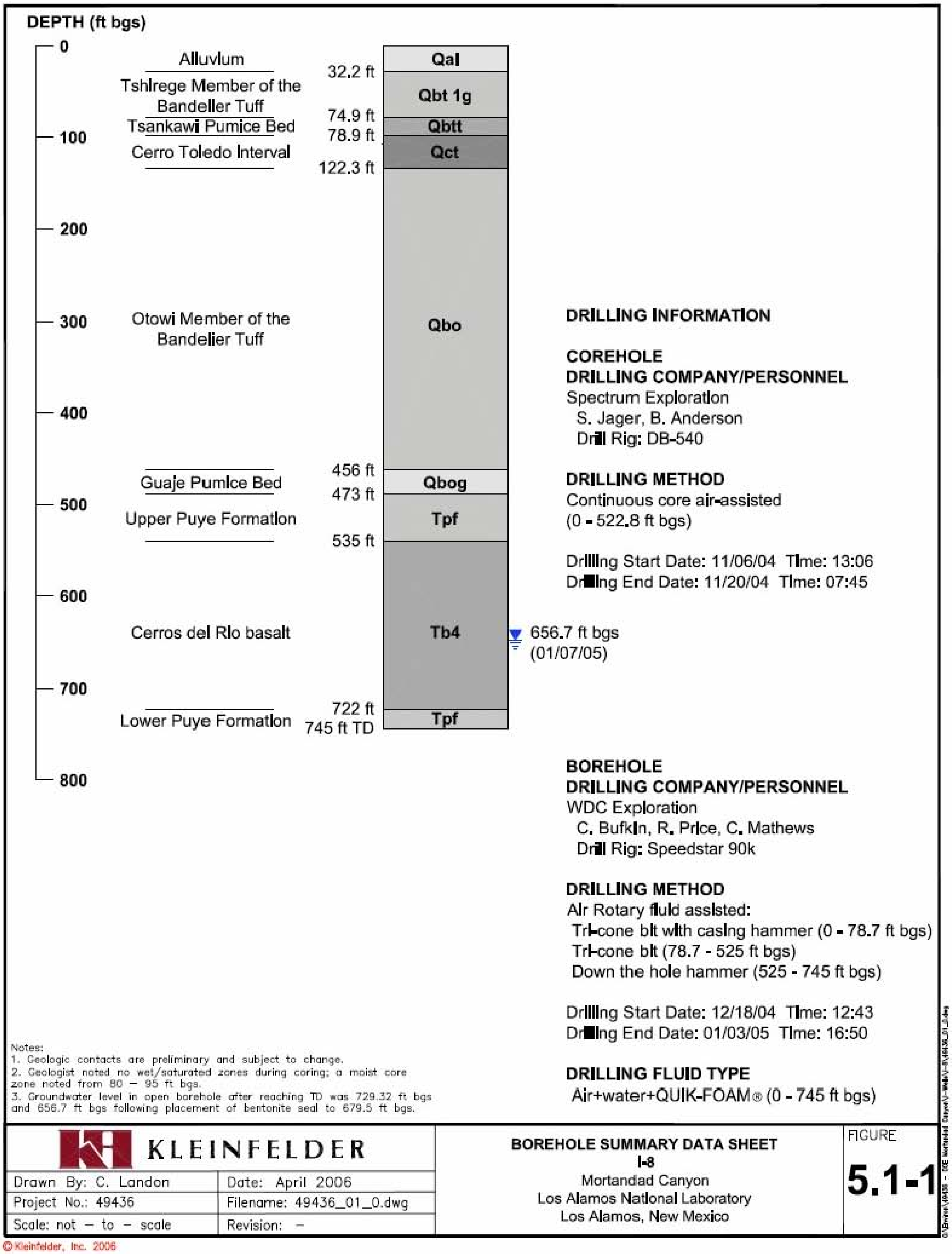

MCI-6 Gamma and Conductivity Logs
Conductivity (µS)
0
10
20
30
40
50
500
550
600
650
700
750
Depth (ft)
gamma
conductivity
Cerros del Rio basalt
495-720 ft (TD)
Water Level
in Borehole 662 ft
675
682
695
717
0
20
40
60
80
100
Open-hole Gamma (cps)
well
casing
primary
filter pack
well
screen

MCOI-8 Well

MCOI-8 Well		
	Description	Evaluation
Drilling Method	MCOI-8 was drilled using coring and fluid-assisted air-rotary methods.	MCOI-8 was drilled in two phases. In phase 1, core was collected from surface to 522.8 ft depth. In phase 2 a separate borehole was drilled to 745 ft depth by normal-circulation fluid-assisted air-rotary methods. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM. Drilling additives can adversely affect the ability to collect representative water samples, but this effect can be minimized in single-completion wells, which are easier to develop and can be purged before sampling. However, water in the well at MCOI-8 has dropped to the level of the sump, thus development of the well and collection of sufficient volumes of water for analysis are limited.
General Well Characteristics	MCOI-8 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The MCOI-8 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well with the need to promote the free flow of water during well development and sampling. However, the perched zone that is sampled by MCOI-8 has produced little water.
Screen Length and Placement	The well screen extends from 665 to 675 ft and has a length of 10 ft. The screen is beneath a water level measured at 656.7 ft bgs on 1/7/2005.	MCOI-8 is located to sample a perched zone within the Cerros del Rio lavas. The saturated thickness of this perched zone is unknown. ***Relevant stratigraphy:*** Cerros del Rio lavas from 525 to 722 ft depth; Puye Formation fanglomerates from 722 ft to TD at 745 ft. ***Geophysical logs:*** Kleinfelder gamma and induction logs were run from 100 to 514 ft depth and from 0- to 125-ft depth with the casing pulled back. A second gamma log was collected from 0- to 745-ft depth. A video log was collected from 0- to 741-ft depth with TD at 745 ft, noting standing water at 741-ft depth and water entering the hole at 669-ft depth. The screen at MCOI-8 was placed to include the zone at 669-ft depth where water was seen entering the borehole and to be below the depth of 656.7 ft where standing water was measured in the open borehole prior to well construction.

MCOI-8 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement	The primary filter pack extends from 650 to 678.5 ft and is made up of 10/20 sand. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 648 to 650 ft.	The primary filter pack extends 15 ft above and 3.5 ft below the well screen. The long upper filter pack was intended to capture possible flow entry points between the top of the screen and the zone of depth to static water measured prior to well construction.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers. The lack of water in the well screen at MCOI-8 offsets the advantages that are normally associated use a submersible pump in a single completion well.
Other Issues That Could Affect the Performance of the Well		Pumping is not practical at MCOI-8 because water is typically in the sump below the screened interval.
Additives used		Municipal—2450 gal. QUIK-FOAM—55 gal. Fluids recovered during drilling, well development, and hydrologic testing—1838 gal. (~1800 during drilling, 35 by bailing and swabbing, and 2.5 during hydrologic testing)
Annular fill other than filter and transition sands		Bentonite pellets below screen sands (43.6 ft^3) Bentonite chips above screen sands (482.3 ft^3) Surface seal of cement slurry (54 ft^3)


DEPTH (ft bgs)
0
100
200
300
400
500
600
700
800
Alluvium
Tshirege Member of the Bandelier Tuff
Tsankawi Pumice Bed
Cerro Toledo Interval
Otowi Member of the Bandelier Tuff
Guaje Pumice Bed
Upper Puye Formation
Cerros del Rio basalt
Lower Puye Formation
32.2 ft
74.9 ft
78.9 ft
122.3 ft
456 ft
473 ft
535 ft
722 ft
745 ft TD
Qal
Qbt 1g
Qbtt
Qct
Qbo
Qbog
Tpf
Tb4
Tpf
656.7 ft bgs (01/07/05)
DRILLING INFORMATION
COREHOLE
DRILLING COMPANY/PERSONNEL
Spectrum Exploration
S. Jager, B. Anderson
Drill Rig: DB-540
DRILLING METHOD
Continuous core air-assisted (0 - 522.8 ft bgs)
Drilling Start Date: 11/06/04 Time: 13:06
Drilling End Date: 11/20/04 Time: 07:45
BOREHOLE
DRILLING COMPANY/PERSONNEL
WDC Exploration
C. Bufkin, R. Price, C. Mathews
Drill Rig: Speedstar 90k
DRILLING METHOD
Air Rotary fluid assisted:
Tri-cone bit with casing hammer (0 - 78.7 ft bgs)
Tri-cone bit (78.7 - 525 ft bgs)
Down the hole hammer (525 - 745 ft bgs)
Drilling Start Date: 12/18/04 Time: 12:43
Drilling End Date: 01/03/05 Time: 16:50
DRILLING FLUID TYPE
Air+water+QUIK-FOAM® (0 - 745 ft bgs)
Notes:
1. Geologic contacts are preliminary and subject to change.
2. Geologist noted no wet/saturated zones during coring; a moist core zone noted from 80 – 95 ft bgs.
3. Groundwater level in open borehole after reaching TD was 729.32 ft bgs and 656.7 ft bgs following placement of bentonite seal to 679.5 ft bgs.
KLEINFELDER
Drawn By: C. Landon
Date: April 2006
Project No.: 49436
Filename: 49436_01_0.dwg
Scale: not – to – scale
Revision: –
BOREHOLE SUMMARY DATA SHEET
I-8
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
5.1-1
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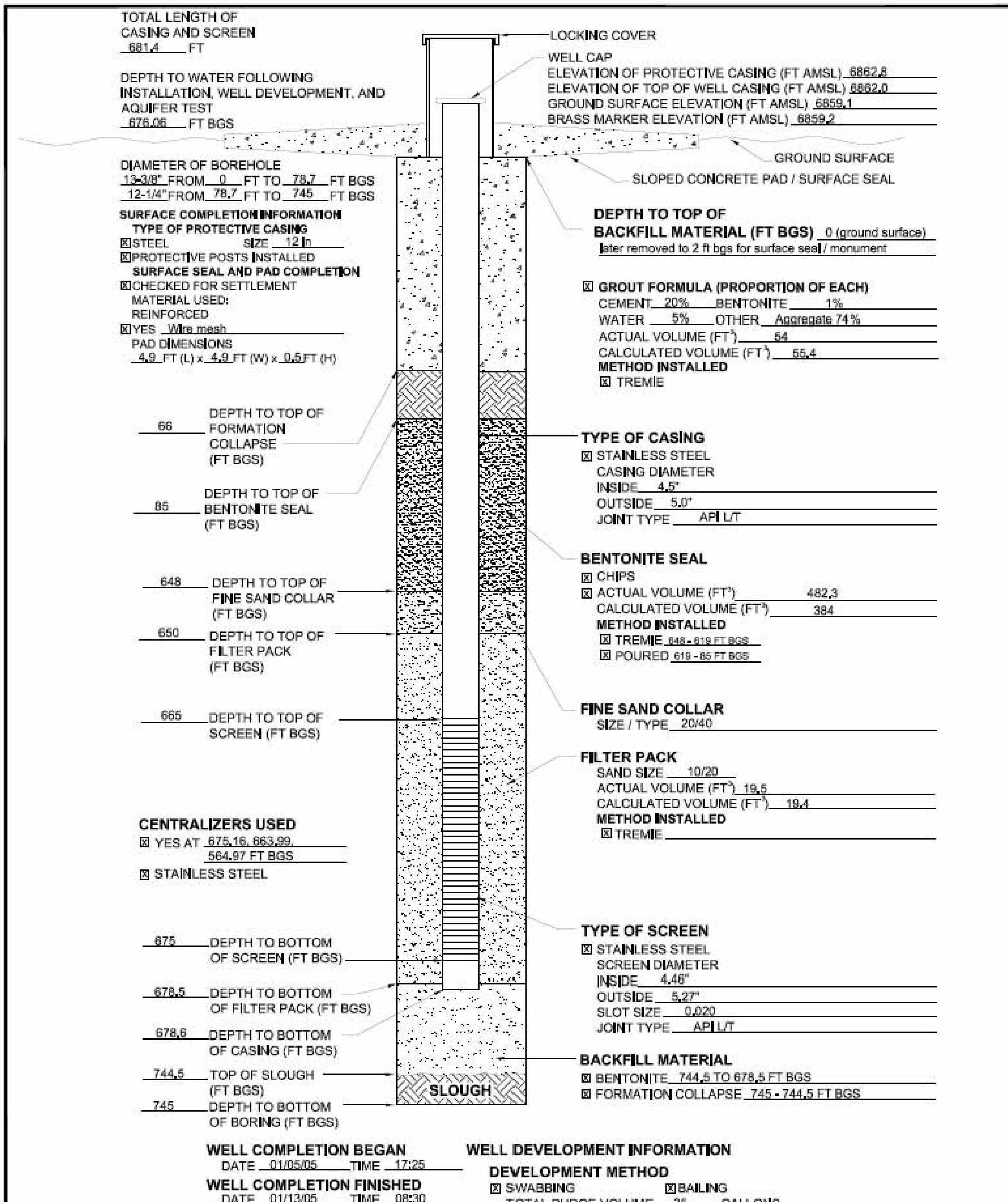


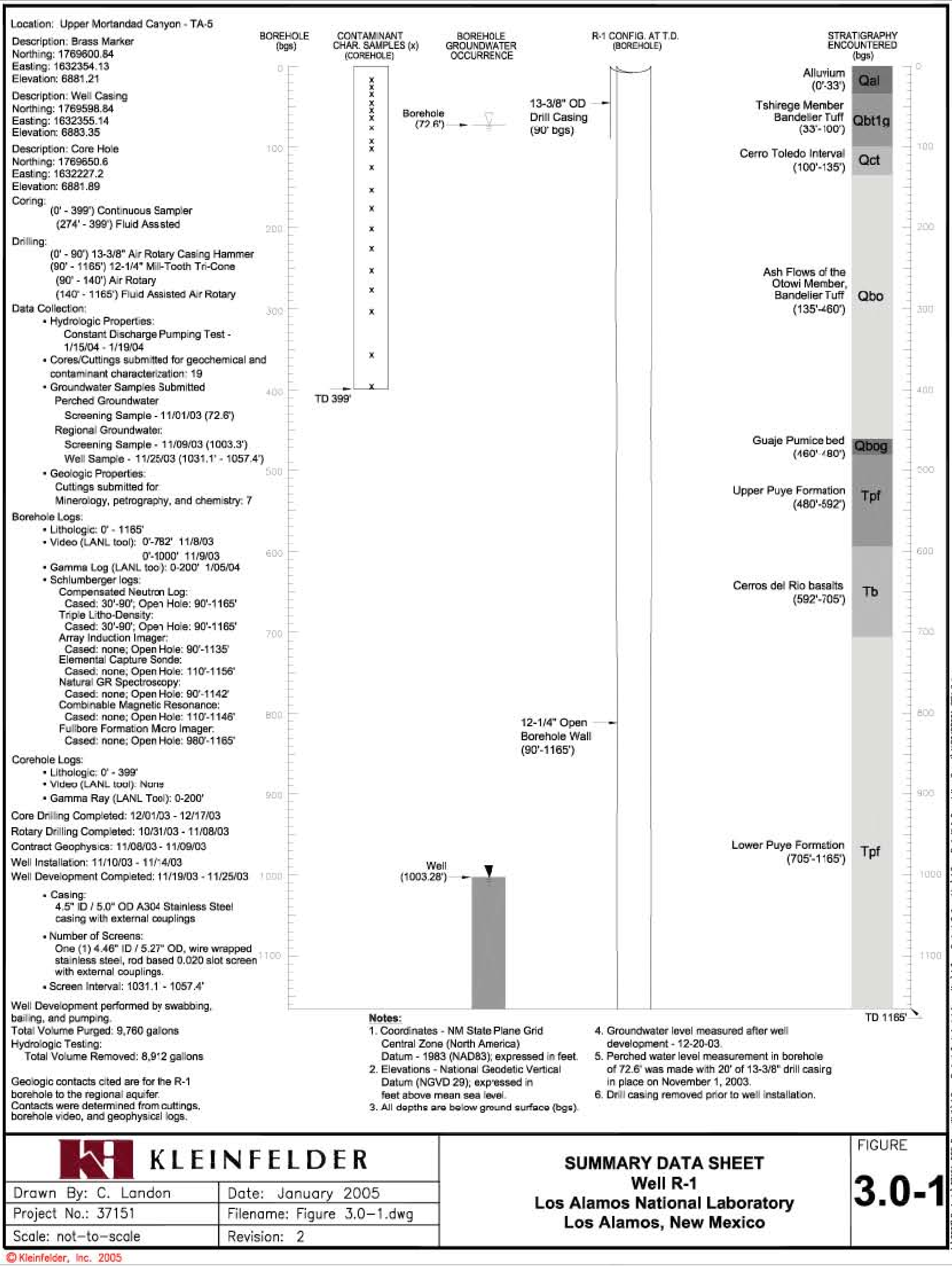
KLEINFELDER		WELL SCHEMATIC I-8 Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE **6.2-1**
Drawn By: C. Bhongir	Date: April 2006		
Project No.: 49436	Filename: 49436_02_0.dwg		
Scale: Not-to-scale	Revision: –		

R-1 Well

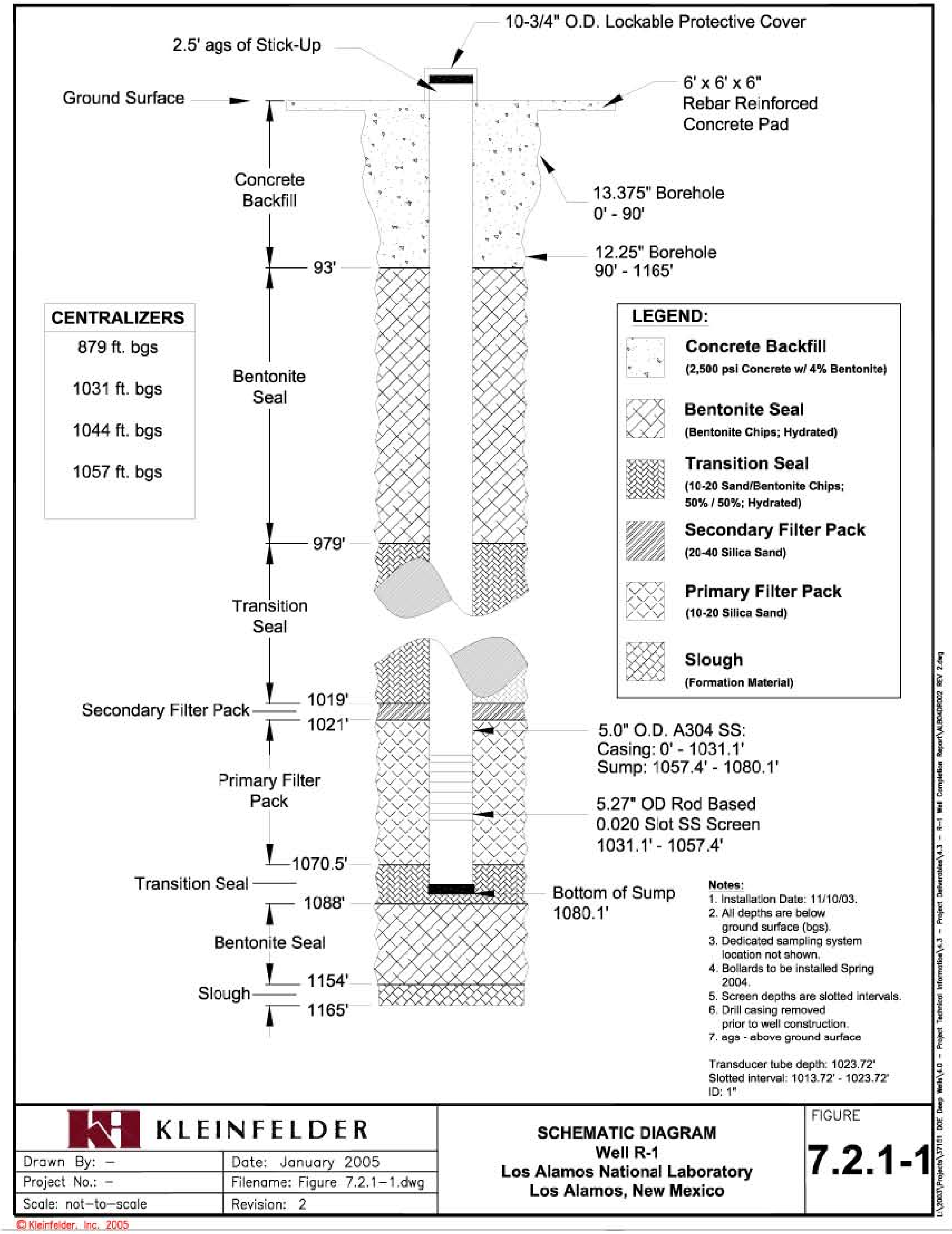
R-1 Well		
	Description	Evaluation
Drilling Method	R-1 was drilled using fluid-assisted air-rotary methods.	R-1 was drilled using a combination of conventional-circulation fluid-assisted air-rotary methods with casing advance to 90 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1165 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-1 because it is a single completion well; this type of well is intrinsically easier to develop, and it can be purged before sampling.
General Well Characteristics	R-1 is a single-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D.-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in. I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-1 well screen construction (0.020-wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 1031.1 to 1057.4 ft and has a length of 26.3 ft. The top of the screen is 28 ft below the water table (currently 1002.7 ft below the surface).	R-1 is designed to replace TW-8, and its screen length and placement were selected with the following goals in mind: Provide a monitoring point for the regional aquifer below the floor of Mortandad canyon where contaminants could be entering the regional aquifer Screen across a long-enough stratigraphic interval so that contaminants, if present, could be detected among several possible but unknown shallow flow paths Submerge the screen fully to facilitate well development. Install a well with a 50-yr service life in an area where municipal well drawdown is about 0.4 ft/yr (20 ft over 50 yr) The geology below the water table at R-1 is similar to the lower part of the stratigraphic sequence encountered in wells such as R-13, R-15, and R-28. At R-1; the regional aquifer from 1002.3 to 1165 ft is composed of well-stratified sands and gravels with significant amounts of crystal-poor pumice. FMI logs indicate that individual beds within the regional aquifer are mostly a few inches to 2 ft thick. Beds dip predominately to the southwest and dip angles are mostly less than 10°.

R-1 Well (continued)		
	Description	Evaluation
		The Schlumberger log interpretation indicates that all of the rocks beneath the water table are relatively porous. The well screen interval from 1031.1 to 1057.4 ft is characterized by total porosities of 20%–40% and effective porosities of 10%–20%. Below 1052- ft depth, total porosities are consistently 30%–40%. The zone between 1074 and 1104 ft has the highest porosities (up to 40%) and highest effective porosity (15%–30%). This deeper zone was considered too deep for well-screen placement because it did not meet the goal of monitoring groundwater near the water table. At R-1, the placement of a 26.3-ft well screen 28 ft beneath the water table in highly stratified and porous rocks satisfied all four of the design goals described above.
Filter Pack Materials and Placement	The primary filter pack is made up of 10/20 sand from 1021 to 1070.5 ft. A secondary filter packs of 20/40 sand was placed above the primary filter pack from 1019 to 1021 ft.	The primary filter pack extends 9.9 ft above and 13.1 ft below the well screen. The primary filter pack is slightly longer than the nominal well design of 5 ft above and below the well screen but does not adversely impact the ability of the well to detect contaminants entering the regional aquifer beneath the canyon floor. The longer filter pack above the well screen allows groundwater to be drawn from strata more proximal to the water table.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives used		Municipal water during drilling—10,800 gal. Municipal water during well construction—6650 gal. EZ-MUD—5.5 gal. QUIK-FOAM— 42 gal. Fluids recovered—31,352 gal.

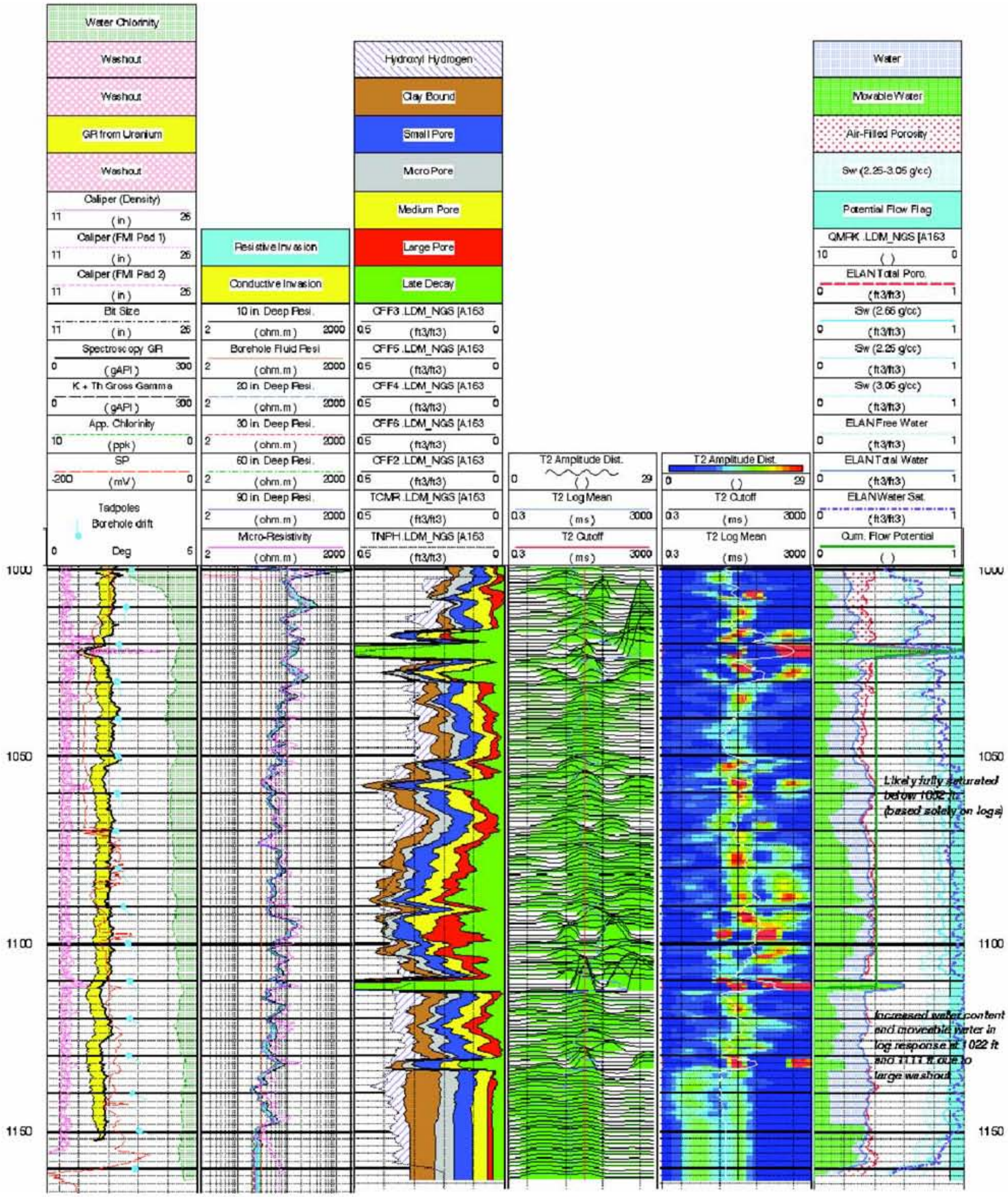
R-1 Well (continued)		
	Description	Evaluation
Annular fill other than filter and transition sands		Backfill—10 bags of sand and 1 supersack (3000 lb) of bentonite Bentonite— 3/8-in chips (15 supersacks) Transition seal of 10/20 sand and bentonite (50 bags of sand and 38 bags of bentonite) Surface seal of cement slurry (3 yd^3)



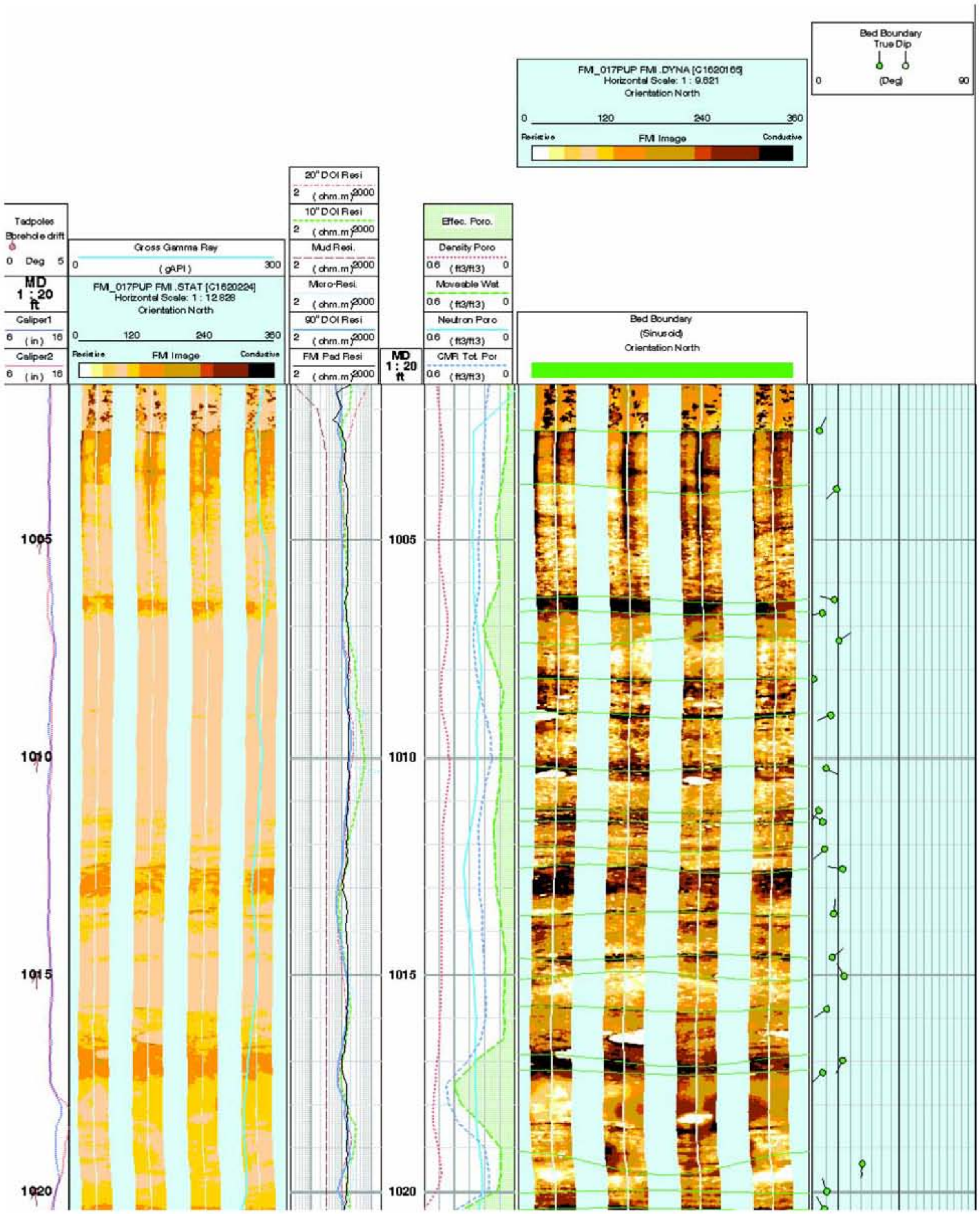
R-1 Well Fact Sheet



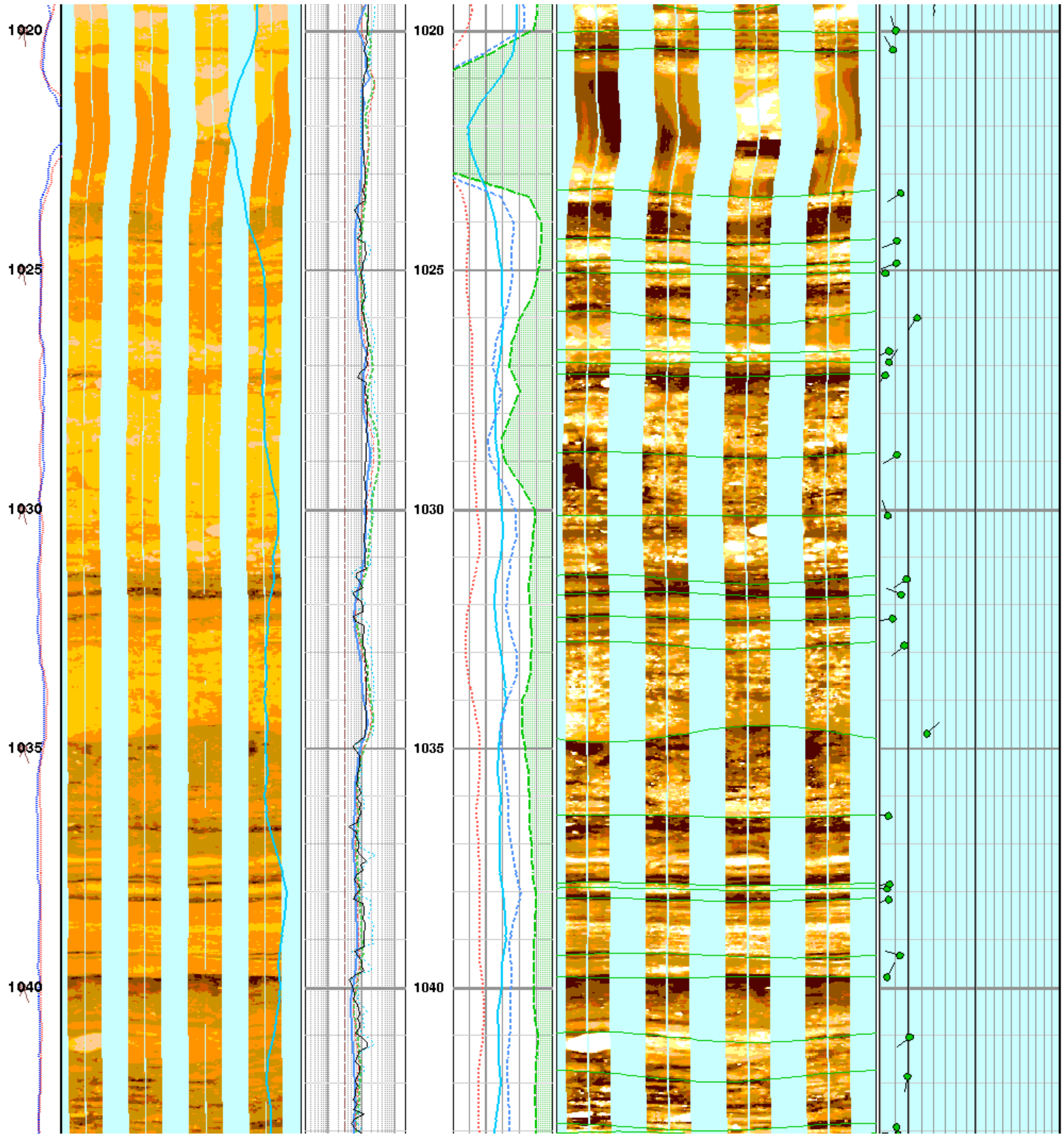
R-1 Well Construction Diagram



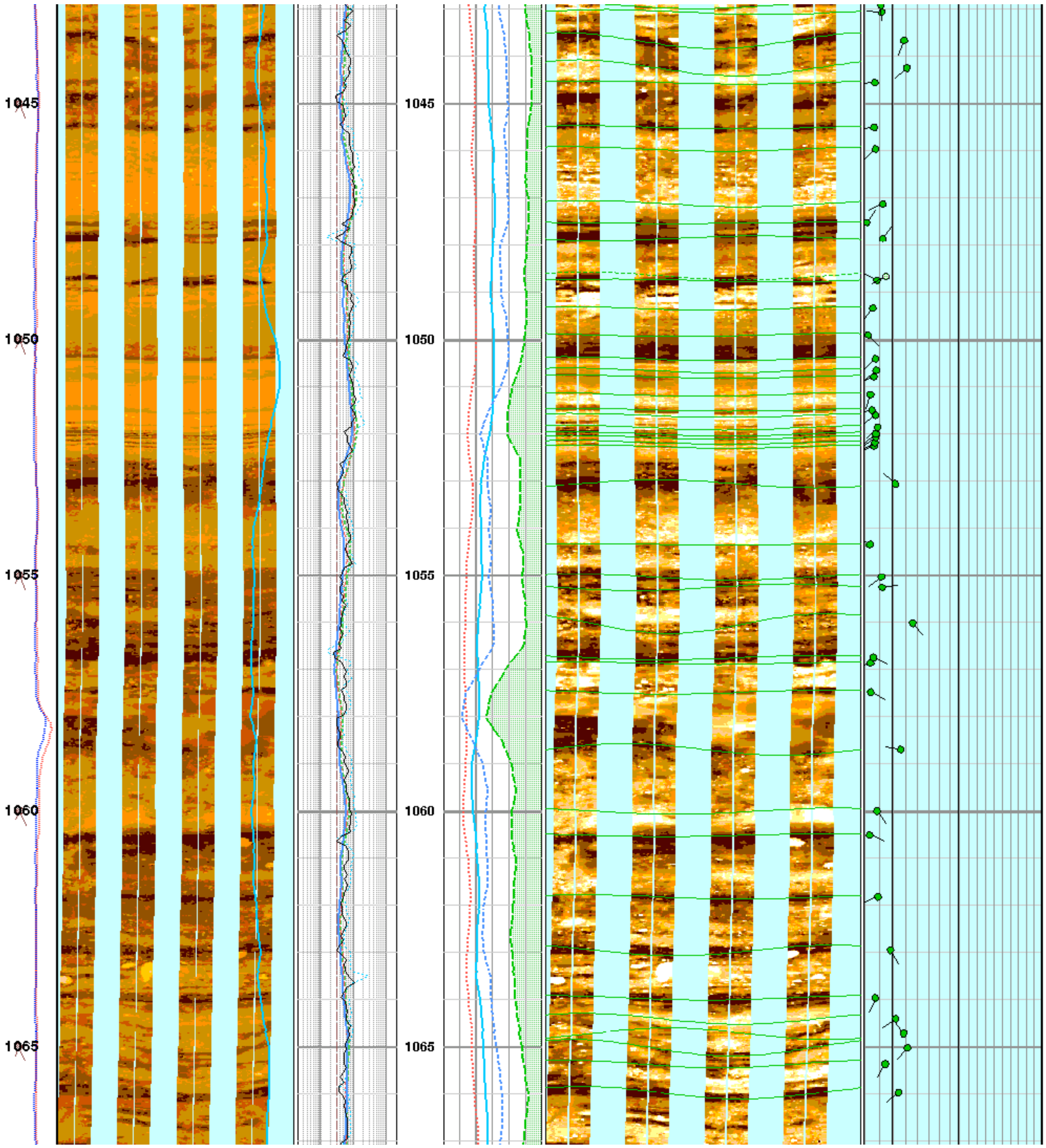
Summary of R-1 Borehole Geophysical Logs for the Regional Aquifer



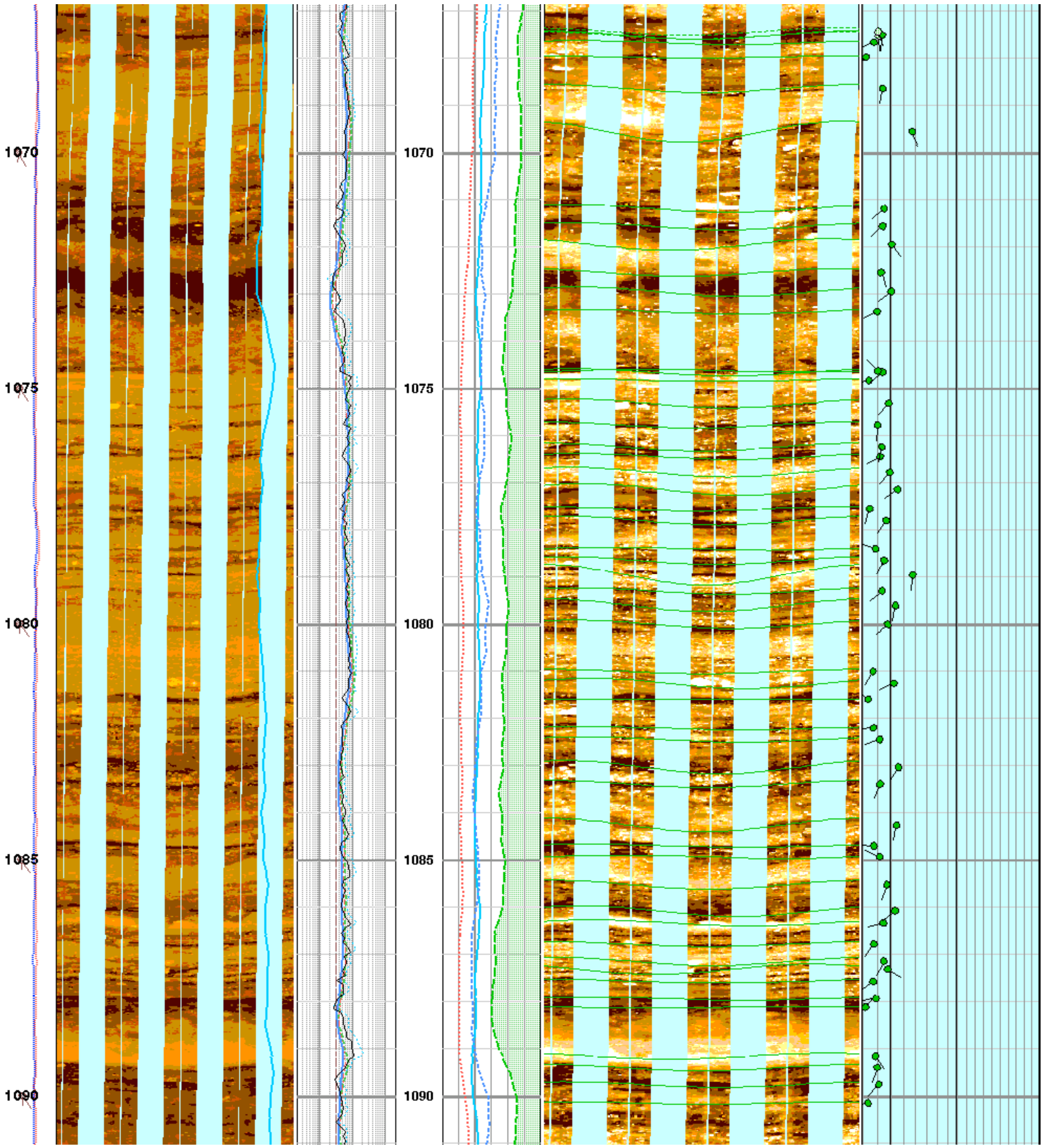
Formation Microimager Log for R-1



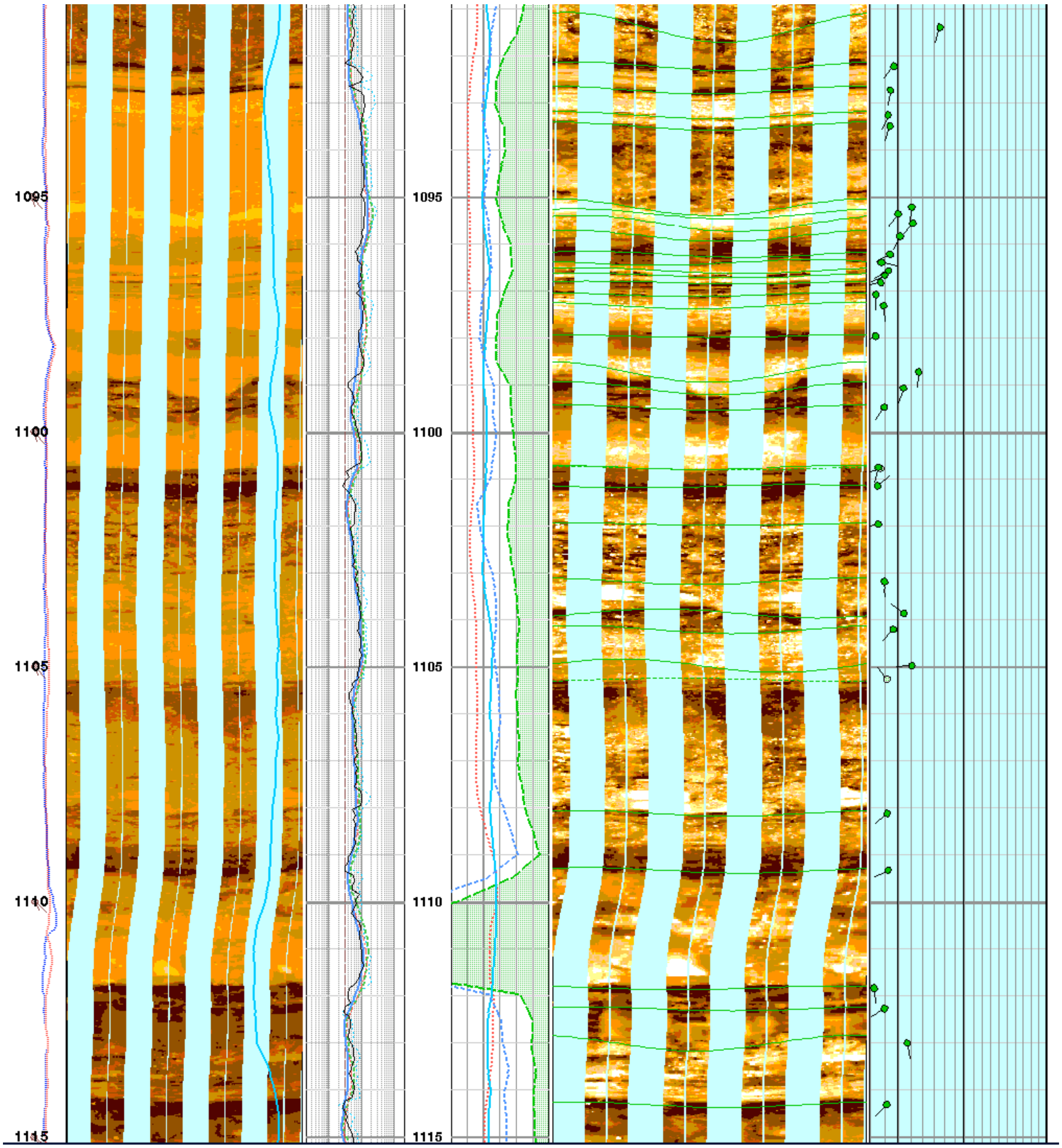
Formation Microimager Log for R-1 (continued)



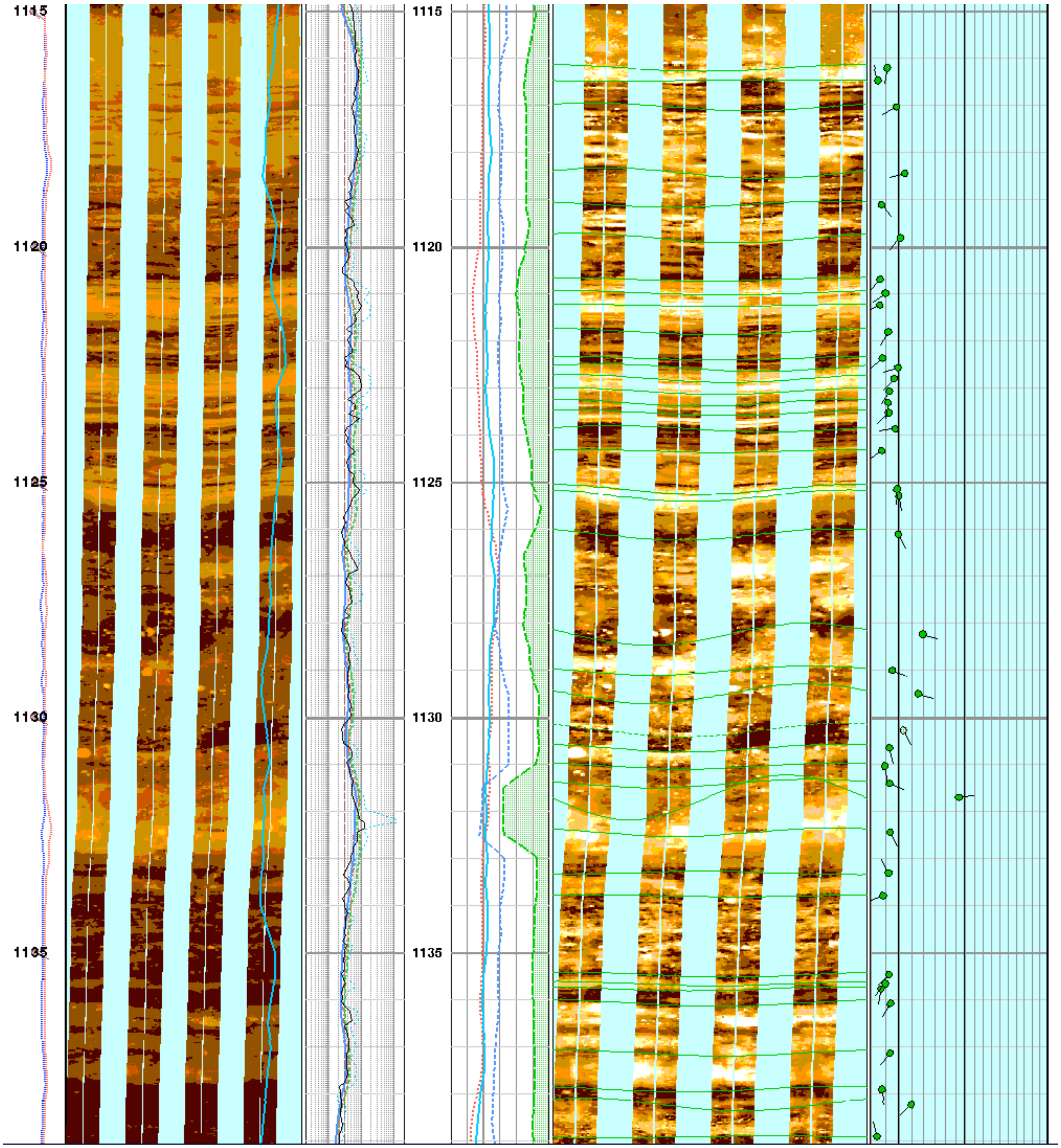
Formation Microimager Log for R-1 (continued)



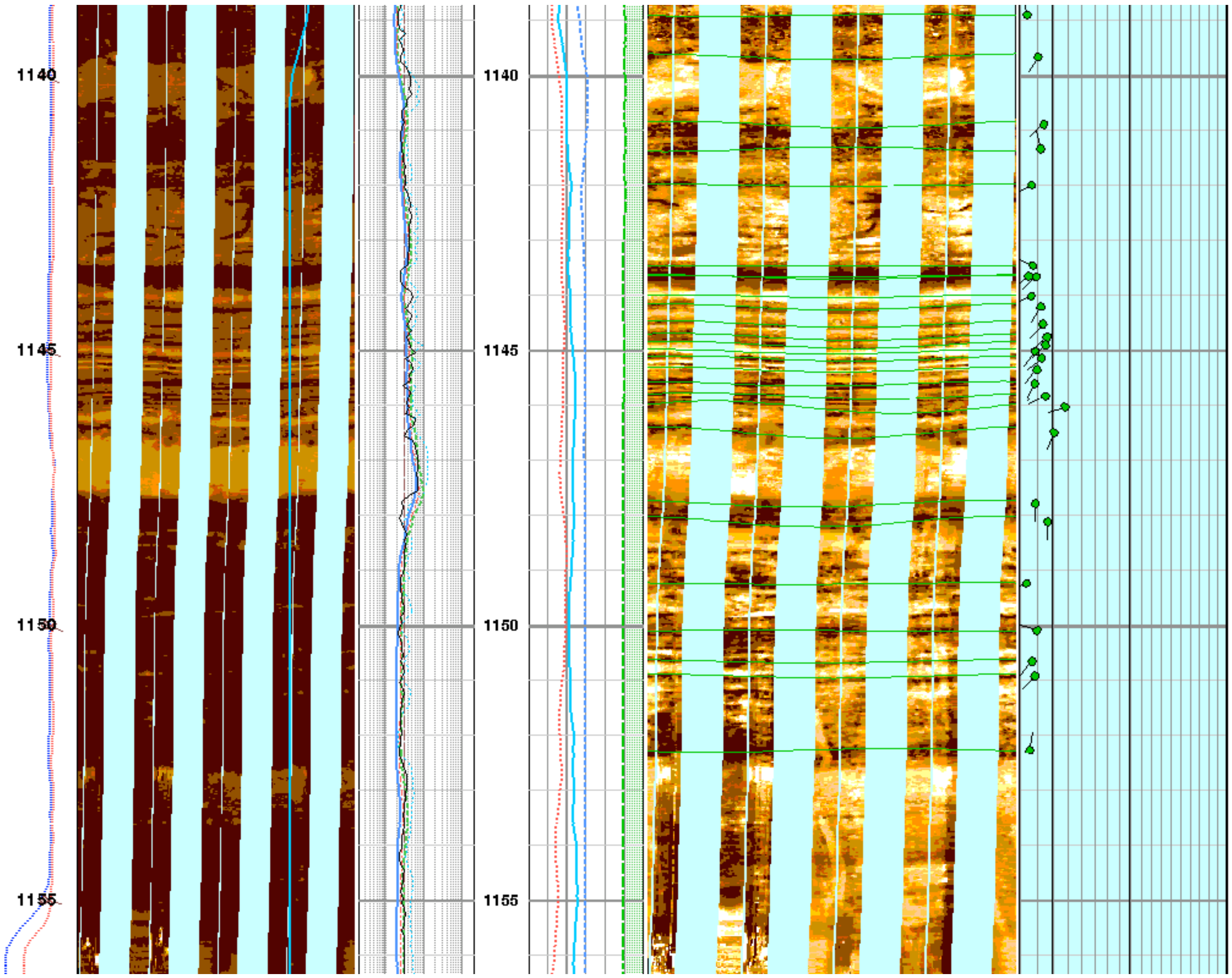
Formation Microimager Log for R-1 (continued)



Formation Microimager Log for R-1 (continued)



Formation Microimager Log for R-1 (continued)



Formation Microimager Log for R-1 (continued)

R-10a and R-10 Wells

R-10 and R-10a Wells		
	Description	Evaluation
Drilling Method	R-10a was drilled to 765-ft depth using air-rotary and fluid-assisted air rotary methods. Both tricone bits and down-the-hole-hammers were used. R-10 was drilled using both air-rotary and mud-rotary methods to 1165 ft depth. Both tricone bits and down-the-hole-hammers were used.	No core was collected at either R-10a or R-10. ***R-10a:*** Air rotary with a 14.75 in. tricone, 12.25 in. tricone and down-the-hole hammer bits, and a 5.5 in. tricone bit. Fluid additives were used and casing was used to stabilize the drill hole. R-10a was designed as a single-screen well. ***R-10:*** Air rotary to 528 ft using 15 in. and 12.25 in. hammers and a 10 5/8 in. tricone. Mud-rotary methods were used from 528- to 1165-ft depth with the 10 5/8 in. tricone. R-10 was designed as a two-screen well. The screens are separated by a packer and can be pumped separately. A Baski sampling system has been installed.
General Well Characteristics	R-10a is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel-casing. R-10 is a two-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction ***R-10a:*** (690–700) ***R-10:*** (874–897 and 1042–1065)	The rod-based wire-wrapped screens are constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-10/R-10a screens allow greater water movement during development than 0.010-in. screen openings. The ability of 0.020-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. The screen at R-10a and both screens at R-10 were developed successfully using bailing, swabbing, and pumping.
Screen Lengths and Placement	The screen at R-10a is 10 ft long, placed from 690- to 700-ft depth. The top of this screen is 18.5 ft below the water table (671.5-ft depth on 7/29/2005, when total depth had been reached and prior to well installation).	***Relevant stratigraphy:*** Miocene basalt from 586- to 675-ft depth; Santa Fe Group sediments from 675-ft depth to TD (1165 ft) with a thin Miocene basalt flow at 757.4- to 762-ft depth. ***Relevant geophysical log results:*** ***R-10a:*** Two video logs were run by LANL in open hole to 302 ft and 342 ft, noting a bridge and water dripping into the hole at 340–342 ft. Two video logs were run by Kleinfelder in open hole to 345 ft and 356 ft, noting water on the borehole wall at 348–350 ft. In addition, gamma and caliper logs were run by JetWest to 675 ft with casing in the hole to 588 ft; standing water was at 621 ft at that time.

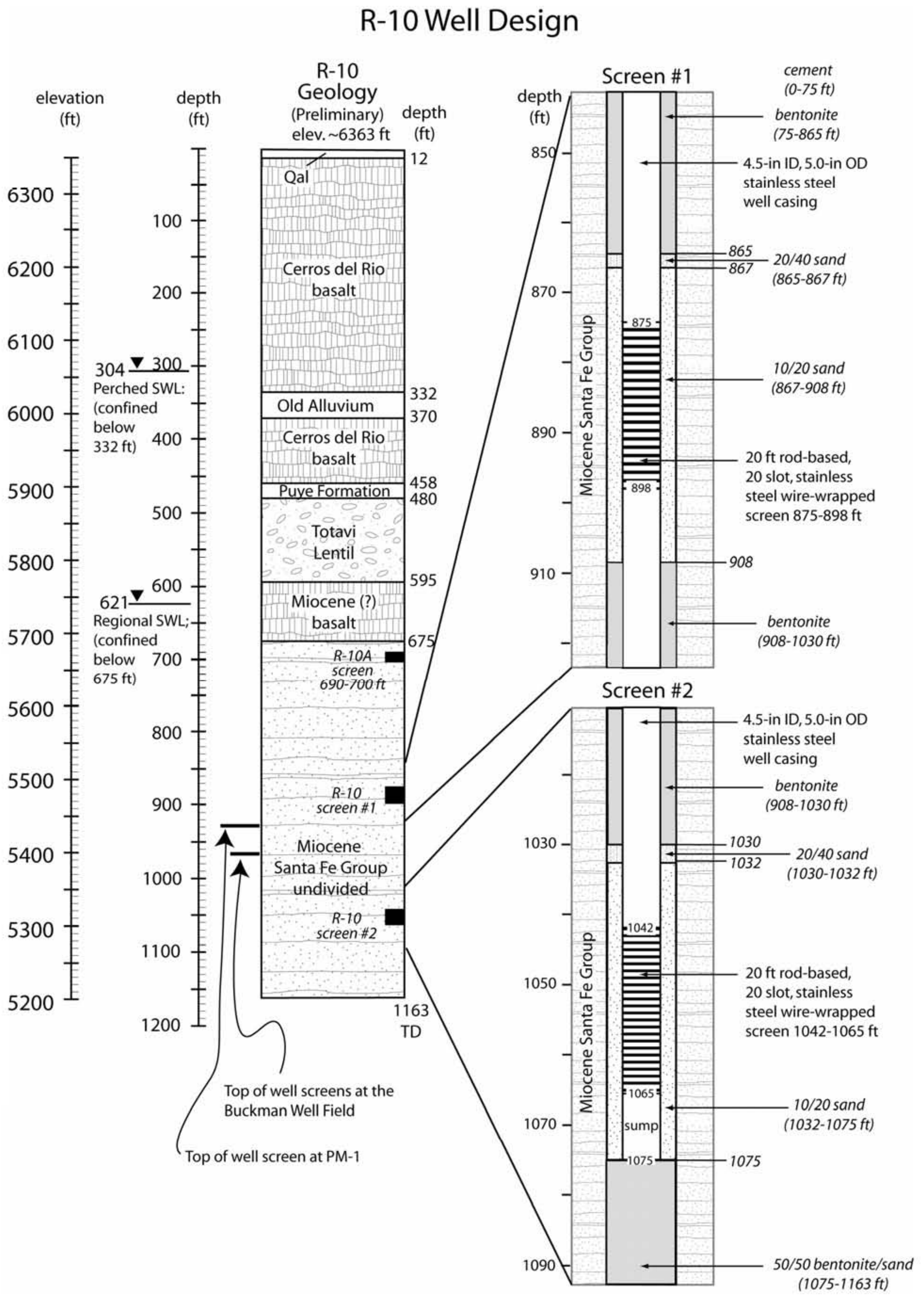
R-10 and R-10a Wells (continued)		
	Description	Evaluation
Screen Lengths and Placement (continued)	The upper screen at R-10 is 23 ft long, placed from 874- to 897 ft depth. The top of the upper screen is 222.6 ft below the water table (651.4-ft depth on 11/1/2005, measured at the upper screen during hydrologic testing with a packer installed between the two screens). The lower screen at R-10 is also 23 ft long, placed from 1042- to 1065-ft depth. The top of the lower screen is 376.5 ft below the water table (665.5-ft depth on 11/1/2005, measured at the lower screen during hydrologic testing with a packer installed between the two screens).	Based on depth-to-water observations during drilling, there is a confined perched system within the Older Alluvium at 330–370-ft depth, sandwiched between flows of Cerros del Rio lavas and with head extending up to 302 ft depth. ***R-10:*** One video log was run by Kleinfelder when the hole was at 543-ft depth with casing to 410 ft; standing water was observed at 490.5 ft. Schlumberger logging tools were run to 1162-ft depth with casing to 414 ft. The tools used were CMR, CNT, TLD. AIT, FMI, GPIT, NGS, ECS, and Digital Sonic Log. ELAN was performed by Schlumberger using the log results. The ELAN analysis initially indicated regional saturation below 586-ft depth, although the borehole was full of drilling mud during logging and this estimate is therefore suspect and was shown to be in error after well emplacement. The ELAN analysis indicated productive intervals to be at 600–604, 618–620, 641–646, and 651–670 (all above the top of regional saturation noted at R-10a); below the top of regional saturation, productive intervals were noted at 680–698, 730–756, 842–870, 920–968, 974–988, 1040–1054, and 1068–1074. ***R-10a screen placement:*** The screen at R-10a is located to be close to the top of regional saturation yet submerged deep enough for aggressive development. This screen is within the upper section of Santa Fe Group sediments and 18 ft beneath a thick section of Miocene basalt. The upper screen length and placement were selected with the following goals in mind: 1 Provide a monitoring point for the uppermost part of the regional aquifer in lower Sandia Canyon east of the Laboratory boundary 2. Submerge the screen fully to facilitate well development 3. Capture much of the uppermost productive zone of the regional aquifer (680–698-ft depth) identified in the Schlumberger ELAN analysis 4. Provide a location to evaluate cross-river effects of pumping at the Buckman well field, near the top of the regional aquifer ***R-10 upper screen placement:*** The upper screen at R-10 was placed to 1. provide a monitoring point at intermediate depth within the regional aquifer in lower Sandia Canyon, east of the Laboratory boundary; 2. provide an intermediate-depth location to evaluate cross-river effects of pumping at the Buckman well field, ~200 ft beneath the top of the regional aquifer; and 3. provide head data to define flow paths from the Laboratory toward the White Rock Canyon springs, the Rio Grande, or the Buckman well field.

R-10 and R-10a Wells (continued)		
	Description	Evaluation
		R-10 lower screen placement: The lower screen was placed to 1. provide a monitoring point at greater depth within the regional aquifer in lower Sandia Canyon, east of the Laboratory boundary; 2. provide a deep location to evaluate cross-river effects of pumping at the Buckman well field, ~400 ft beneath the top of the regional aquifer; and 3. provide head data to define flow paths from the Laboratory toward the Buckman well field.
Filter Pack Materials and Placement ***R-10a:*** (primary 682–711 ft; no secondary sand, filter pack bounded above by slough and below by fill of bentonite plus 10/20 sand) ***R-10 upper screen:*** (primary 868–907 ft; upper secondary sand 866–868 ft; bentonite below primary) ***R-10 Lower screen:*** (primary 1030.5–1077 ft; upper secondary sand 1028–1030.5 ft; fill of bentonite plus 10/20 sand below primary)	The primary filter packs are made up of 10/20 sand. At R-10, upper collars of 20/40 secondary sand were emplaced.	***R-10a:*** Primary filter pack extends 8 ft above the screen openings and 11 ft below. ***R-10 upper screen:*** Primary filter pack extends 6 ft above the screen openings and 10 ft below. ***R-10 lower screen:*** Primary filter pack extends 11.5 ft above the screen openings and 12 ft below.

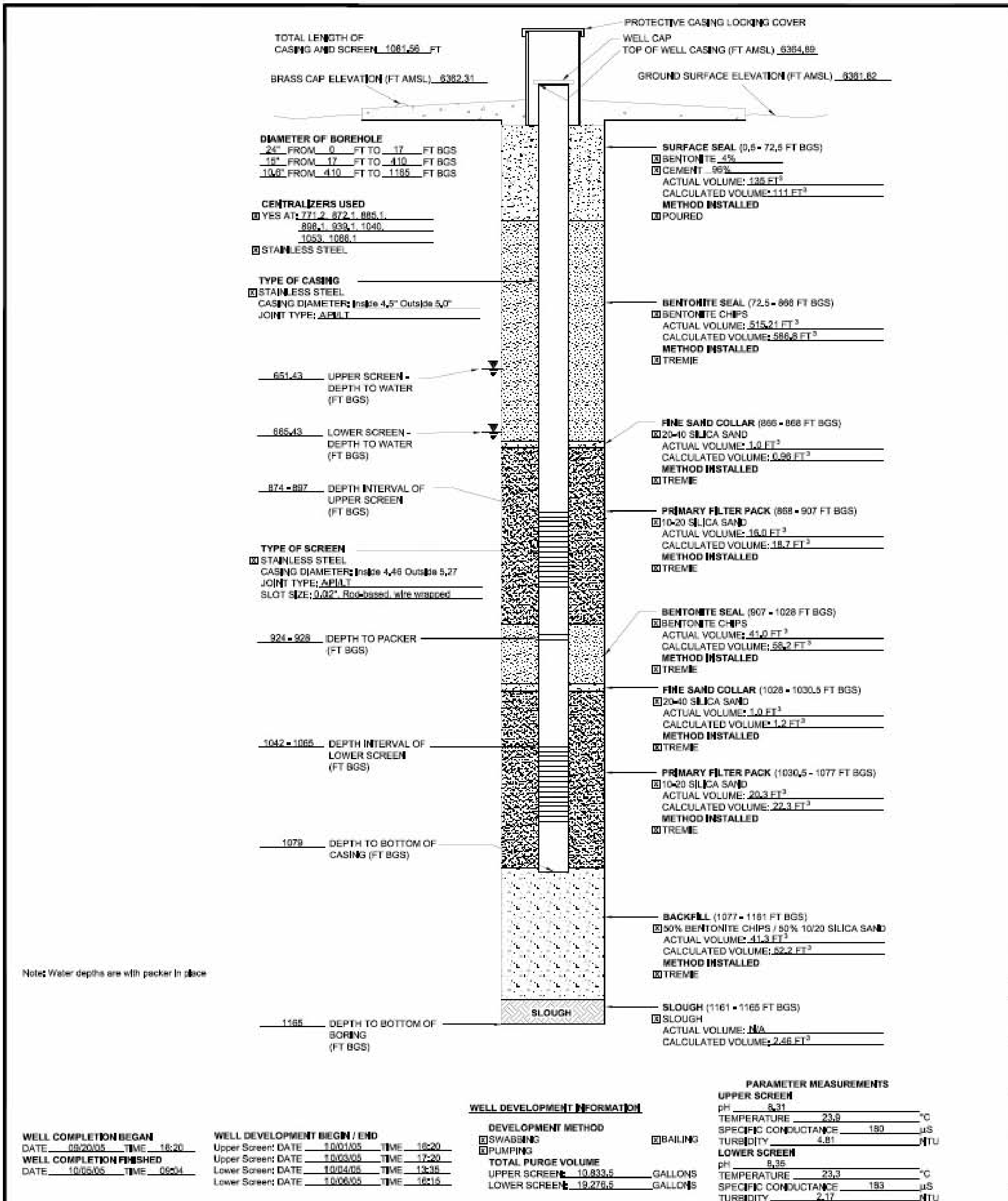
R-10 and R-10a Wells (continued)		
	Description	Evaluation
R-10a: Sampling System	***R-10a:*** Baski packer with dual valve system and single pump	***R-10a:*** Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
R-10: Sampling System	***R-10:*** Baski packer with dual valve system and single pump	***R-10:*** The Baski system is a conventional-flow sampling system that allows groundwater to be sampled from two well screens within a single well installation. Well screens are isolated by packers and sampled individually. Pressure-activated valves are situated at each screen and connected by 1-in. diameter pipe to the pump. The pump is located above the packer and is shrouded to isolate the pump to obtain water from whichever valve is open. The pump is capable of 12 gal./m, which provides quick conventional purging and sampling of each zone in the well. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. The Baski packer system incorporates separate gage tubes that provide access to each screen zone using conventional transducer equipment and manual measurement methods. A design flaw at R-10 using small diameter tubing through the pump shroud is probably responsible for plugging of the access tube and unreliable water-level measurements. However, this flaw does not affect the quality of water samples collected for analysis.

R-10 and R-10a Wells (continued)		
	Description	Evaluation
Other Issues That Could Affect the Performance of the Well		**R-10a**: No issues evident based on analysis of produced water. **R-10**: Use of mud-rotary methods required aggressive development to remove bentonite introduced during drilling; 28,532 gal. of mud and additives introduced vs. 81,592 gal. of water removed during development and testing. The geochemical evaluation in Appendix B indicates development was successful.
Additives used		**R-10a:** Air-rotary drilling was assisted by municipal water mixed with limited amounts of QUIK-FOAM and EZ-MUD, followed by defoamer. The drilling report (Kleinfelder Project 49436) provides the following information on additive use: Municipal water—44,377 gal. QUIK-FOAM—287 gal. EZ-MUD—5.5 gal. Defoamer—6 gal. **R-10:** Mud-rotary drilling used QUICK-GEL as the mud medium with lesser amounts of Drispac and QUIK-FOAM along with municipal water. The drilling report (Kleinfelder Project 49436) provides the following information on additive use: Municipal water—19,205 gal. QUIK-GEL—26,851 gal.* Drispac—1,365 gal.* QUIK-FOAM—316 gal. *2,000 gal. of QUIK-GEL plus Drispac was removed from the borehole before well construction, plus an additional 19,130 gal. airlifted from the screens during construction.
Annular fill other than filter and transition sands		**R-10a:** Bentonite chips—144.1 ft^3 Bentonite mixed with 10/20 sand—354.8 ft^3 Cement slurry surface seal—188 ft^3 **R-10:** Bentonite chips—566.2 ft^3 Bentonite mixed with 10/20 sand—41.3 ft^3 Cement slurry surface seal—135 ft^3

R-10 and R-10a Wells (continued)		
	Description	Evaluation
Water produced on development and testing		**R-10a:** 1,180 gal. bailed and swabbed, 36,643 gal. pumped, and 3,516 gal. removed during aquifer testing (total 41,339 gal.) **R-10 upper screen:** 189 gal. bailed and swabbed, 10,644.5 gal. pumped, and 32,489.5 gal. removed during aquifer testing (total 43,323 gal.) **R-10 lower screen:** 19,276.5 gal. pumped and 18,992.2 gal. removed during aquifer testing (total 38,268.7 gal.)



R-10 Well Design
elevation (ft)
depth (ft)
R-10 Geology (Preliminary) elev. ~6363 ft
depth (ft)
Qal
Cerros del Rio basalt
Old Alluvium
Cerros del Rio basalt
Puye Formation
Totavi Lentil
Miocene (?) basalt
R-10A screen 690-700 ft
R-10 screen #1
Miocene Santa Fe Group undivided
R-10 screen #2
12
332
370
458
480
595
675
1163 TD
304
Perched SWL: (confined below 332 ft)
621
Regional SWL; (confined below 675 ft)
Top of well screens at the Buckman Well Field
Top of well screen at PM-1
Screen #1
cement (0-75 ft)
bentonite (75-865 ft)
4.5-in ID, 5.0-in OD stainless steel well casing
865
867
20/40 sand (865-867 ft)
875
10/20 sand (867-908 ft)
20 ft rod-based, 20 slot, stainless steel wire-wrapped screen 875-898 ft
898
908
bentonite (908-1030 ft)
Miocene Santa Fe Group
Screen #2
4.5-in ID, 5.0-in OD stainless steel well casing
bentonite (908-1030 ft)
1030
1032
20/40 sand (1030-1032 ft)
1042
20 ft rod-based, 20 slot, stainless steel wire-wrapped screen 1042-1065 ft
1065
sump
10/20 sand (1032-1075 ft)
1075
50/50 bentonite/sand (1075-1163 ft)

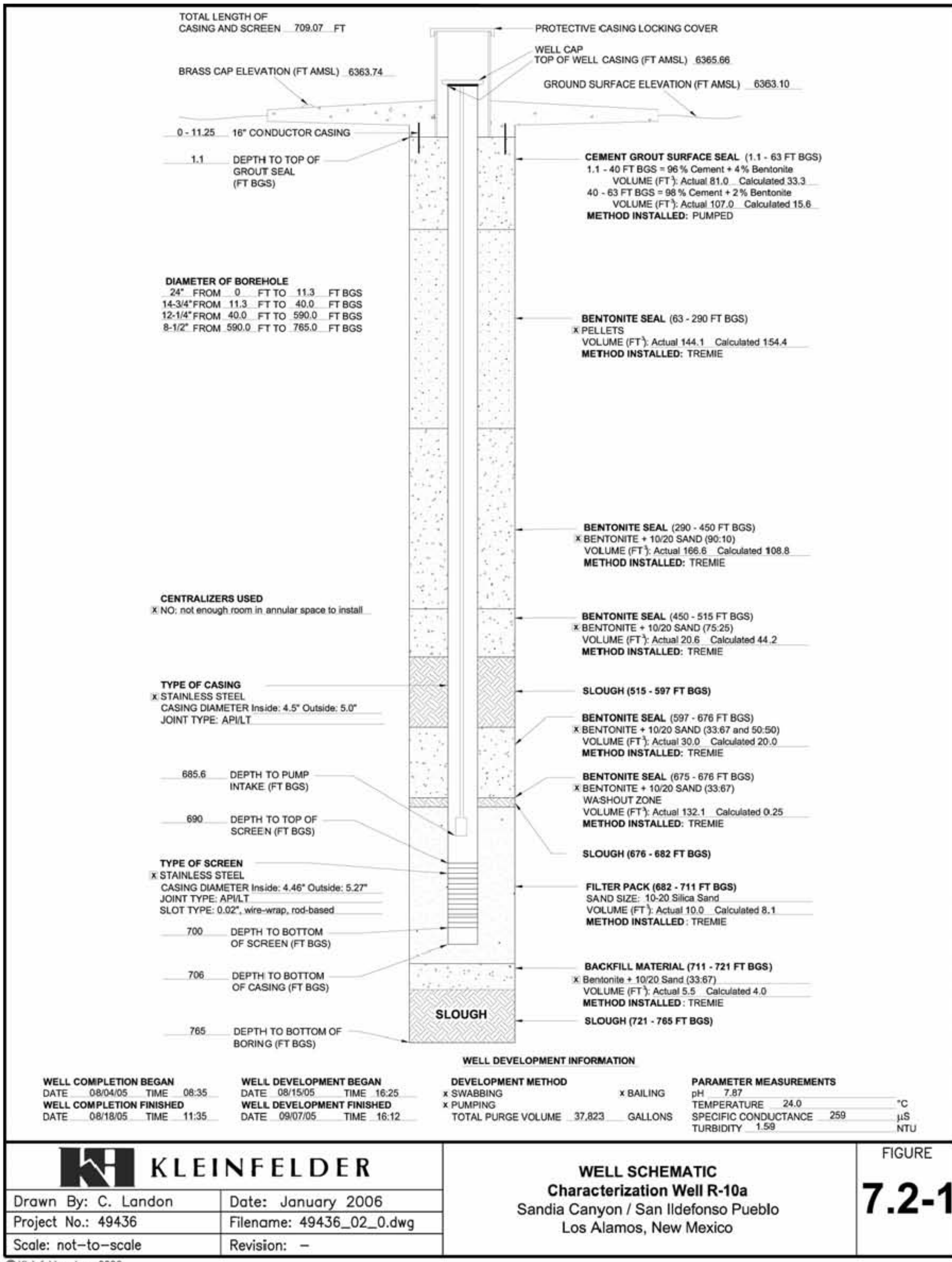


KLEINFELDER

Drawn By: C. Landon	Date: January 2006
Project No.: 49436	Filename: 49436_02_0.dwg
Scale: not-to-scale	Revision: –

WELL SCHEMATIC
Characterization Well R-10
Sandia Canyon / San Ildefonso Pueblo
Los Alamos, New Mexico

FIGURE **10.5-1**

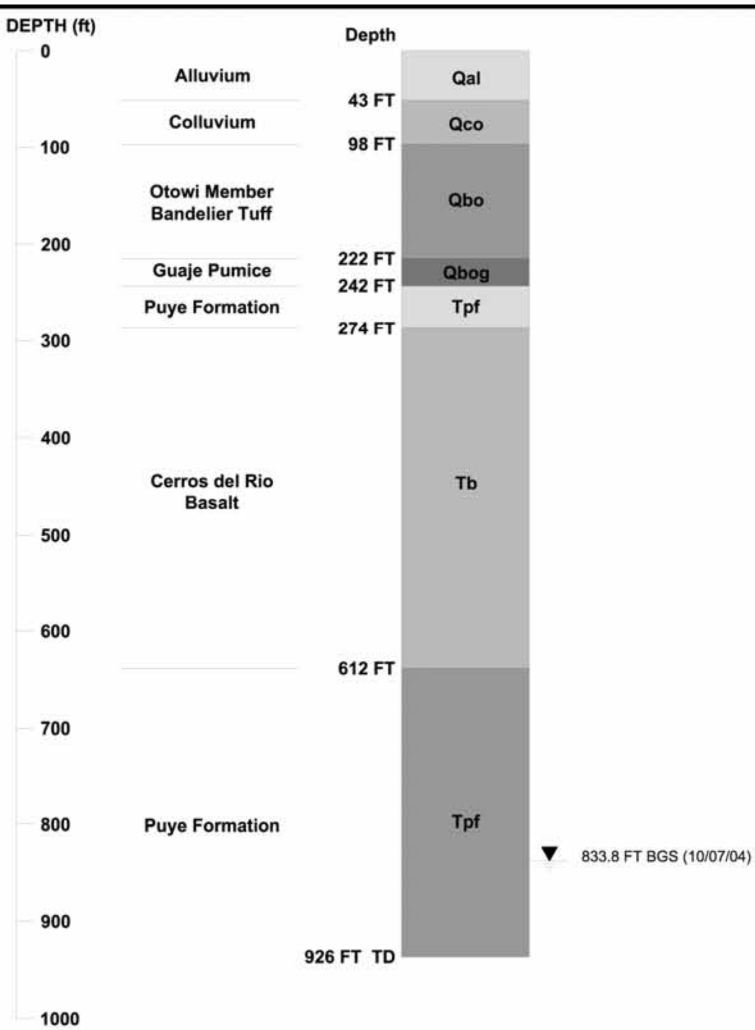

TOTAL LENGTH OF CASING AND SCREEN 709.07 FT
PROTECTIVE CASING LOCKING COVER
WELL CAP
TOP OF WELL CASING (FT AMSL) 6365.66
BRASS CAP ELEVATION (FT AMSL) 6363.74
GROUND SURFACE ELEVATION (FT AMSL) 6363.10
0 - 11.25 16" CONDUCTOR CASING
1.1 DEPTH TO TOP OF GROUT SEAL (FT BGS)
CEMENT GROUT SURFACE SEAL (1.1 - 63 FT BGS)
1.1 - 40 FT BGS = 96 % Cement + 4 % Bentonite
VOLUME (FT³): Actual 81.0 Calculated 33.3
40 - 63 FT BGS = 98 % Cement + 2 % Bentonite
VOLUME (FT³): Actual 107.0 Calculated 15.6
METHOD INSTALLED: PUMPED
DIAMETER OF BOREHOLE
24" FROM 0 FT TO 11.3 FT BGS
14-3/4" FROM 11.3 FT TO 40.0 FT BGS
12-1/4" FROM 40.0 FT TO 590.0 FT BGS
8-1/2" FROM 590.0 FT TO 765.0 FT BGS
BENTONITE SEAL (63 - 290 FT BGS)
X PELLETS
VOLUME (FT³): Actual 144.1 Calculated 154.4
METHOD INSTALLED: TREMIE
BENTONITE SEAL (290 - 450 FT BGS)
X BENTONITE + 10/20 SAND (90:10)
VOLUME (FT³): Actual 166.6 Calculated 108.8
METHOD INSTALLED: TREMIE
CENTRALIZERS USED
X NO: not enough room in annular space to install
BENTONITE SEAL (450 - 515 FT BGS)
X BENTONITE + 10/20 SAND (75:25)
VOLUME (FT³): Actual 20.6 Calculated 44.2
METHOD INSTALLED: TREMIE
TYPE OF CASING
X STAINLESS STEEL
CASING DIAMETER Inside: 4.5" Outside: 5.0"
JOINT TYPE: API/LT
SLOUGH (515 - 597 FT BGS)
BENTONITE SEAL (597 - 676 FT BGS)
X BENTONITE + 10/20 SAND (33:67 and 50:50)
VOLUME (FT³): Actual 30.0 Calculated 20.0
METHOD INSTALLED: TREMIE
685.6 DEPTH TO PUMP INTAKE (FT BGS)
BENTONITE SEAL (675 - 676 FT BGS)
X BENTONITE + 10/20 SAND (33:67)
WASHOUT ZONE
VOLUME (FT³): Actual 132.1 Calculated 0.25
METHOD INSTALLED: TREMIE
690 DEPTH TO TOP OF SCREEN (FT BGS)
SLOUGH (676 - 682 FT BGS)
TYPE OF SCREEN
X STAINLESS STEEL
CASING DIAMETER Inside: 4.46" Outside: 5.27"
JOINT TYPE: API/LT
SLOT TYPE: 0.02", wire-wrap, rod-based
FILTER PACK (682 - 711 FT BGS)
SAND SIZE: 10-20 Silica Sand
VOLUME (FT³): Actual 10.0 Calculated 8.1
METHOD INSTALLED: TREMIE
700 DEPTH TO BOTTOM OF SCREEN (FT BGS)
706 DEPTH TO BOTTOM OF CASING (FT BGS)
BACKFILL MATERIAL (711 - 721 FT BGS)
X Bentonite + 10/20 Sand (33:67)
VOLUME (FT³): Actual 5.5 Calculated 4.0
METHOD INSTALLED: TREMIE
SLOUGH
SLOUGH (721 - 765 FT BGS)
765 DEPTH TO BOTTOM OF BORING (FT BGS)
WELL DEVELOPMENT INFORMATION
WELL COMPLETION BEGAN
DATE 08/04/05 TIME 08:35
WELL COMPLETION FINISHED
DATE 08/18/05 TIME 11:35
WELL DEVELOPMENT BEGAN
DATE 08/15/05 TIME 16:25
WELL DEVELOPMENT FINISHED
DATE 09/07/05 TIME 16:12
DEVELOPMENT METHOD
x SWABBING
x BAILING
x PUMPING
TOTAL PURGE VOLUME 37,823 GALLONS
PARAMETER MEASUREMENTS
pH 7.87
TEMPERATURE 24.0 °C
SPECIFIC CONDUCTANCE 259 µS
TURBIDITY 1.59 NTU
KLEINFELDER
Drawn By: C. Landon
Date: January 2006
Project No.: 49436
Filename: 49436_02_0.dwg
Scale: not-to-scale
Revision: –
WELL SCHEMATIC
Characterization Well R-10a
Sandia Canyon / San Ildefonso Pueblo
Los Alamos, New Mexico
FIGURE
7.2-1

R-11 Well

R-11 Well		
	Description	Evaluation
Drilling Method	R-11 was drilled in two phases. Phase I involved coring to 296.5 ft. Phase II used air-rotary methods with foam to 926.5-ft depth.	Phase I: Core was collected with 8-in. O.D. HSAs to 180-ft depth, followed by HQ air-rotary coring or split spoon sampling to 296.5 ft with periodic advance of the HSA system over the HQ system to free the drill stem. Phase II: Open-hole air rotary with a combination of 12.25 in. tricone bit and 12.25 in. rotary hammer from 59 to 926.5 ft depth. R-11 was designed as a single-screen well.
General Well Characteristics	R-11 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction (856.3-878.5)	The rod-based screen is constructed of 4.5-in.-I.D./5.0-in.-O.D. wire-wrapped screens with 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-11 screen allow greater water movement during development than 0.010-in. screen openings. The ability of 0.020-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. The screen at R-11 was developed successfully using bailing, swabbing, and pumping. The screen at R-11 is rated as very good in the Well Screen Analysis Report (2005, 091121).
Screen Length and Placement	The screen is 22.2 ft long, placed from 856.3 to 878.5- ft depth. The top of the screen is 20.8 ft below the water table (835.5- ft depth prior to well development).	***Relevant stratigraphy:*** Puye Fm (Tpf) from 612- to 834-ft depth; pumiceous deposits of the upper Santa Fe Group from 834- ft depth to TD (926.5 ft) Relevant geophysical log results: Most of the Schlumberger logging tools were run open hole from near surface (below or within permanent casing, which extends to 59 ft) to 916–928-ft depth (depending on the tool being run). Exceptions are the FMI and GPIT tools, which were run only at over an Interval of 93 ft near the bottom of the hole (830–923 ft). The tools used were CMR, CNT, TLD, AIT, FMI, GPIT, NGS, and ECS. An ELAN was performed by Schlumberger using the log results. The ELAN analysis indicated likely top of regional saturation at ~842-ft depth (below the measured depth to water of 833 ft). The ELAN analysis indicated the most productive interval to be below 842-ft depth. The screen at R-11 is within this zone. The Schlumberger analysis noted no perched saturation The LANL video tool was run twice, from surface to 885 ft and to 926.5- ft depth.

R-11 Well (continued)		
	Description	Evaluation
		Screen placement: The screen was located to be close to the top of regional saturation yet submerged deep enough for aggressive development. The screen is within pumiceous deposits of the upper Santa Fe Group. Screen length and placement were selected with the following goals in mind: 1. Provide a monitoring point for the uppermost part of the regional aquifer downgradient of contaminant sources in Sandia Canyon 2. Submerge the screen fully to facilitate well development, 3. Capture the upper portion of the productive zone (below 842- ft depth) identified in the Schlumberger ELAN analysis
Filter Pack Materials and Placement (Primary sand 851–884 ft; upper collar of secondary sand 847–851 ft; no lower secondary sand)	The primary filter pack is made up of 10/20 sand, with an upper collar of secondary 20/40 sand.	Primary filter pack extends 5.3 ft above the screen openings and 5.5 ft below.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a

R-11 Well (continued)		
	Description	Evaluation
Additives used		In Phase I drilling, no additives were used. In Phase II drilling, air-rotary drilling to 926.5 ft depth was assisted by municipal water mixed with limited amounts of QUIK-FOAM and EZ-MUD. The drilling report (Kleinfelder Project 37151) provides the following information on additive use: Municipal water—26,690 gal. QUIK-FOAM—95 gal. EZ-MUD—4.25 gal.
Annular fill other than filter and transition sands		Bentonite chips—810.8 ft^3 Cement grout surface seal—64 ft^3
Water produced on development and testing		40 gal. was removed from the screen by bailing and swabbing; 18,660 gal. was removed by pumping; and 27,648 gal. was removed during hydrologic testing (total of 85,976 gal.).



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL
WDC Exploration & Wells
Steve Odom, S. Ward, H. Endito, M. Daniels

DRILL RIG Speedstar

DRILLING METHOD
☐ HOLLOW-STEM AUGER
x AIR ROTARY
☐ MUD/WATER ROTARY
x Water, QUIK-FOAM®, and EZ-MUD®

DRILLING
START 09/26/04 END 10/02/04

DRILLING FLUID TYPE
☐ BENTONITE x WATER
x POLYMER x Air

Notes:
1. Geologic contacts are preliminary and subject to change.
2. All depths are below ground surface.

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET Characterization Well R-11 Sandia Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 3.0-1
Drawn By: C. Landon Project No.: 37151	Date: February 2005 Filename: Figure 3.0-1.dwg		

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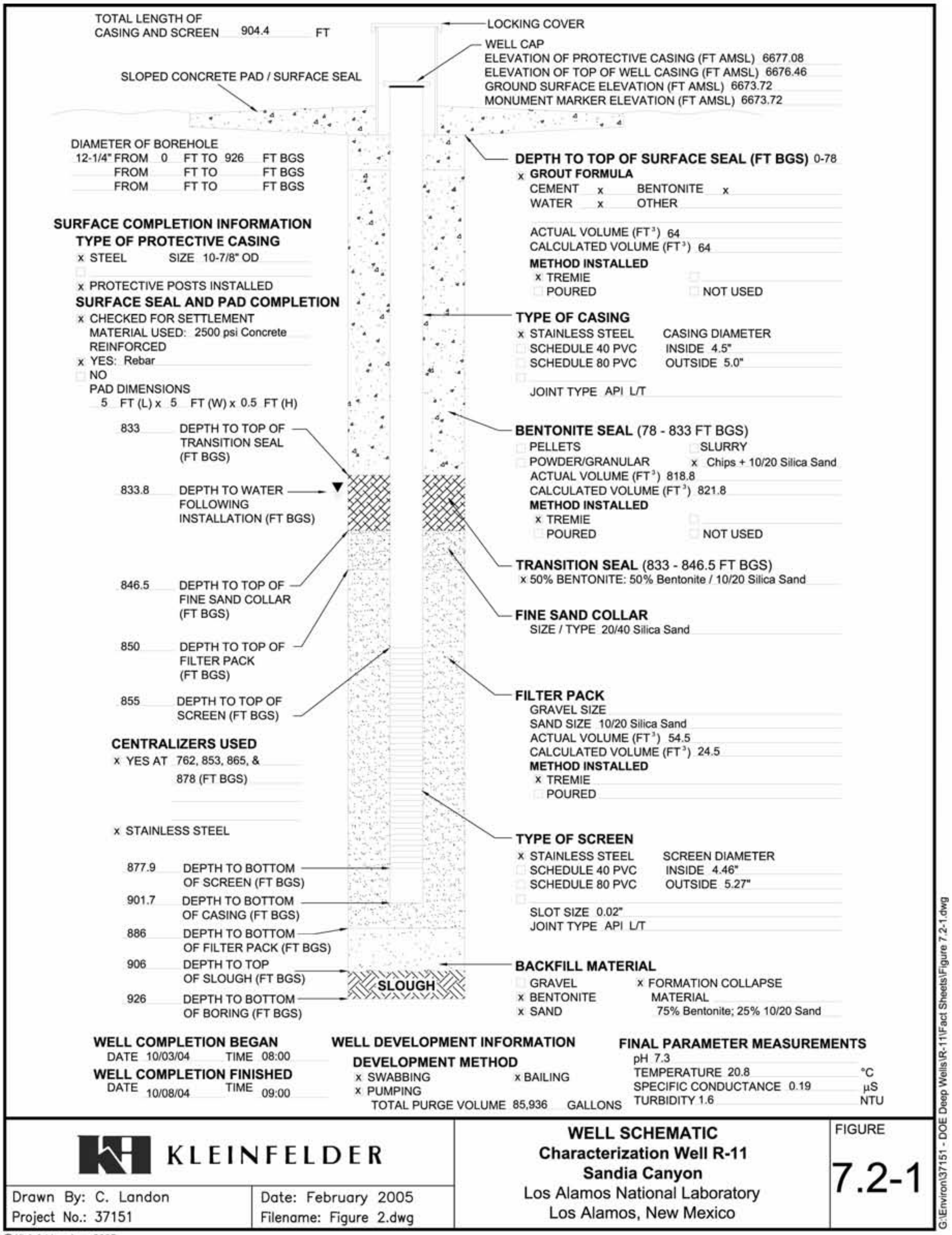
TOTAL LENGTH OF CASING AND SCREEN 904.4 FT
LOCKING COVER
WELL CAP
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6677.08
ELEVATION OF TOP OF WELL CASING (FT AMSL) 6676.46
GROUND SURFACE ELEVATION (FT AMSL) 6673.72
MONUMENT MARKER ELEVATION (FT AMSL) 6673.72
SLOPED CONCRETE PAD / SURFACE SEAL
DIAMETER OF BOREHOLE
12-1/4" FROM 0 FT TO 926 FT BGS
FROM FT TO FT BGS
FROM FT TO FT BGS
DEPTH TO TOP OF SURFACE SEAL (FT BGS) 0-78
x GROUT FORMULA
CEMENT x BENTONITE x
WATER x OTHER
ACTUAL VOLUME (FT³) 64
CALCULATED VOLUME (FT³) 64
METHOD INSTALLED
x TREMIE
POURED
NOT USED
SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
x STEEL SIZE 10-7/8" OD
x PROTECTIVE POSTS INSTALLED
SURFACE SEAL AND PAD COMPLETION
x CHECKED FOR SETTLEMENT
MATERIAL USED: 2500 psi Concrete
REINFORCED
x YES: Rebar
NO
PAD DIMENSIONS
5 FT (L) x 5 FT (W) x 0.5 FT (H)
TYPE OF CASING
x STAINLESS STEEL
SCHEDULE 40 PVC
SCHEDULE 80 PVC
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"
JOINT TYPE API L/T
833 DEPTH TO TOP OF TRANSITION SEAL (FT BGS)
833.8 DEPTH TO WATER FOLLOWING INSTALLATION (FT BGS)
BENTONITE SEAL (78 - 833 FT BGS)
PELLETS
SLURRY
POWDER/GRANULAR
x Chips + 10/20 Silica Sand
ACTUAL VOLUME (FT³) 818.8
CALCULATED VOLUME (FT³) 821.8
METHOD INSTALLED
x TREMIE
POURED
NOT USED
TRANSITION SEAL (833 - 846.5 FT BGS)
x 50% BENTONITE: 50% Bentonite / 10/20 Silica Sand
846.5 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)
FINE SAND COLLAR
SIZE / TYPE 20/40 Silica Sand
850 DEPTH TO TOP OF FILTER PACK (FT BGS)
855 DEPTH TO TOP OF SCREEN (FT BGS)
FILTER PACK
GRAVEL SIZE
SAND SIZE 10/20 Silica Sand
ACTUAL VOLUME (FT³) 54.5
CALCULATED VOLUME (FT³) 24.5
METHOD INSTALLED
x TREMIE
POURED
CENTRALIZERS USED
x YES AT 762, 853, 865, &
878 (FT BGS)
x STAINLESS STEEL
TYPE OF SCREEN
x STAINLESS STEEL
SCHEDULE 40 PVC
SCHEDULE 80 PVC
SCREEN DIAMETER
INSIDE 4.46"
OUTSIDE 5.27"
SLOT SIZE 0.02"
JOINT TYPE API L/T
877.9 DEPTH TO BOTTOM OF SCREEN (FT BGS)
901.7 DEPTH TO BOTTOM OF CASING (FT BGS)
886 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)
906 DEPTH TO TOP OF SLOUGH (FT BGS)
926 DEPTH TO BOTTOM OF BORING (FT BGS)
SLOUGH
BACKFILL MATERIAL
GRAVEL
x BENTONITE
x SAND
x FORMATION COLLAPSE
MATERIAL
75% Bentonite; 25% 10/20 Sand
WELL COMPLETION BEGAN
DATE 10/03/04 TIME 08:00
WELL COMPLETION FINISHED
DATE 10/08/04 TIME 09:00
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
x SWABBING
x PUMPING
x BAILING
TOTAL PURGE VOLUME 85,936 GALLONS
FINAL PARAMETER MEASUREMENTS
pH 7.3
TEMPERATURE 20.8 °C
SPECIFIC CONDUCTANCE 0.19 µS
TURBIDITY 1.6 NTU
KLEINFELDER
Drawn By: C. Landon
Project No.: 37151
Date: February 2005
Filename: Figure 2.dwg
WELL SCHEMATIC
Characterization Well R-11
Sandia Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
7.2-1
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R-12 Well

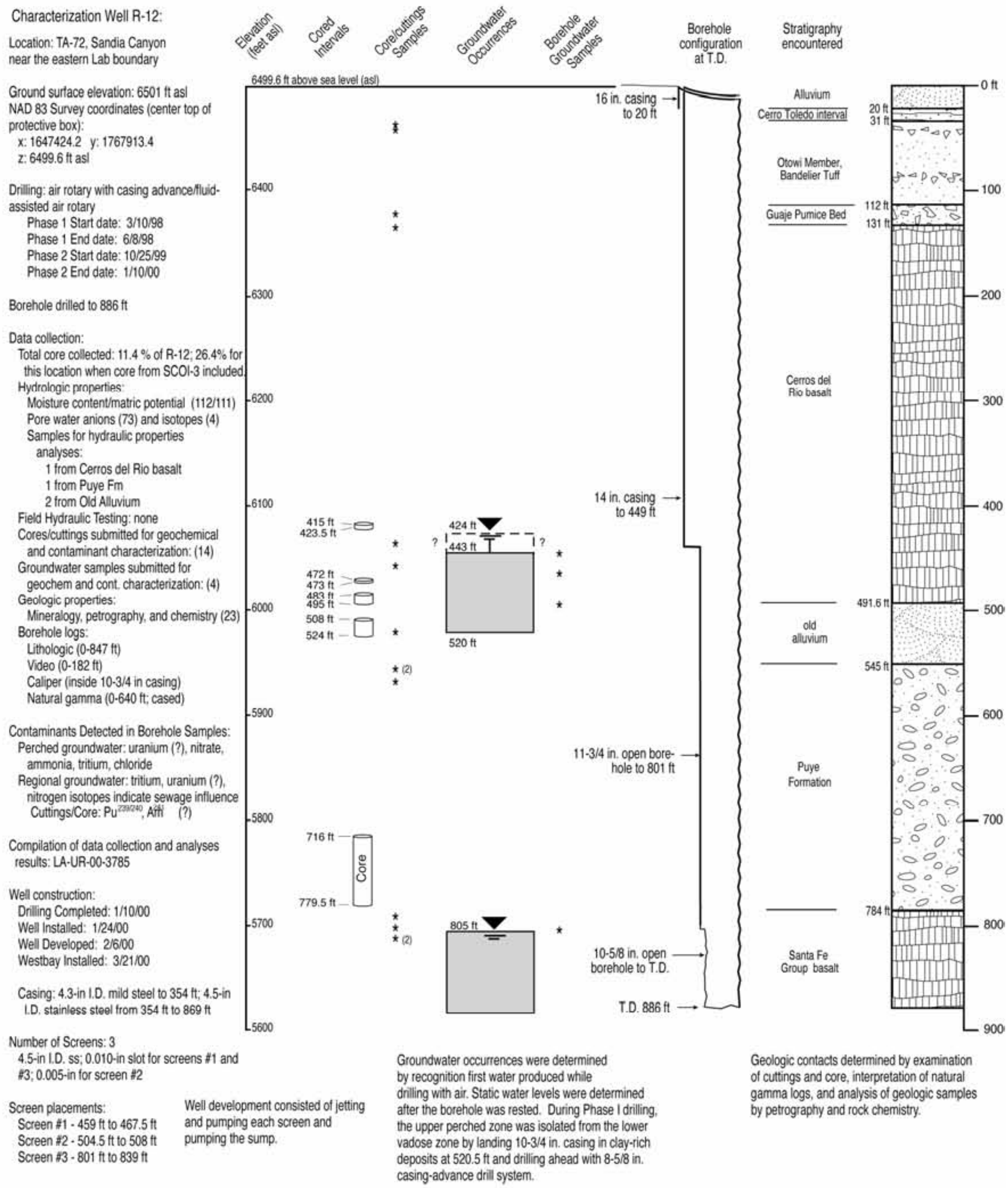
R-12 Well		
	Description	Evaluation
Drilling Method	R-12 was drilled using a combination of reverse-circulation air-rotary methods in open hole and with casing advance to 847 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 886 ft.	R-12 was drilled in two stages. During stage 1 from March 10, 1998, to June 8, 1998, the initial borehole was drilled to a depth of 847 ft using reverse-circulation air-rotary methods in open hole and with casing advance. A perched groundwater system was encountered from depths of 443 to 519 ft in the lower part of the Cerros del Rio basalt and in the underlying old alluvium. The saturated thickness of this groundwater body is approximately 75 ft, making it one of the thickest intermediate-depth perched groundwater bodies identified on the eastern part of the Pajarito Plateau. Three drill-casing strings (14 in., 10 in., and 8 in.) were used to isolate the perched groundwater and to advance the borehole to the top of the regional groundwater system that was encountered at a depth of 805 ft. A temporary PVC well was installed inside the three drill casings to better understand water-level data and to evaluate contaminants in the regional groundwater system prior to installation of a permanent well. After a period of data acquisition, a decision was made to install a well with two screens in the perched zone and one screen in the regional aquifer. A Westbay sampling system was selected to isolate the three screens and to collect water samples. Because of the proximity of R-12 to supply well PM-1, the borehole was deepened slightly so that a well with a 30-ft well screen and 20-ft sump could be installed in the regional zone of saturation. When drilling activities began October 25, 1999 to deepen the well (stage 2), problems were encountered retrieving the PVC well casing and advancing the borehole with the 8-in. drill system. Because of the clay-rich nature of the lower Puye Formation at this site, both the PVC casing and the 8-in. drill casing were effectively rock-locked by shifting ground and could not be easily moved. After considerable effort, all but the lower 50 ft of the PVC well were removed, which was subsequently drilled out. A more serious problem developed during efforts to advance the 8-in. drill casing. While attempting to advance the casing, the shoe on which the down-hole-hammer strikes became detached from the bottom of the 8-in.-casing string. Cement was introduced to the bottom of the hole so that the 8-in. drill shoe could be retrieved with the 8-in.-drill casing. Eventually, the borehole was deepened to 886 ft, and the well was installed by January, 21, 2000. Drilling from 847- to 886-ft depth was accomplished by reverse-circulation fluid-assisted air-rotary drilling methods. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives. After the borehole was deepened, a well with two screens in perched zones and one screen in the regional aquifer was installed. During well installation, drill casing was extracted as the filter pack and annular fill were installed around the well. The 14-in.-drill casing could not be retracted from its original landed depth of 450 ft, and it was grouted in place. The use of cement used to assist retrieval of the 8-in. drill shoe and the use of drilling additives during stage 2 drilling are possibly important considerations when evaluating groundwater data collected from screen 3 at R-12, particularly in light that a low-flow Westbay sampling system was deployed in this well.

R-12 Well (continued)		
	Description	Evaluation
General Well Characteristics	R-12 is a three-screen well constructed of 4.3-in.-I.D./5-in.-O.D. low-carbon steel casing from the surface to 354-ft depth and 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing from 354 ft to 869 ft.	The low-carbon steel casing was used in the vadose zone above the perched groundwater zones and thus does not affect groundwater chemistry of the three well screens. Use of stainless-steel casing in the region of perched groundwater and in the regional groundwater system prevents corrosion of well materials in the vicinity of well screens.
Well Screen Construction	The well screen is constructed of 4.5-in.-I.D./5.1-in.-O.D. 304 stainless-steel wire wrap with 0.010-in. slots in the upper and lower screens and 0.005-in. slots in the middle screen.	Wire-wrap screen is considered the optimum design for promoting the free flow of water during well development and sampling. The wire wrap on the R-12 well screen contains 0.010-in. slots in the upper and lower screen and 0.005-in. slots in the middle screen, primarily to minimize the intake of fine-grained aquifer material into the well during sampling. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The quality of groundwater data from screens 1 and 2 following well rehabilitation in September and October 2006 is much improved; this suggests that the 0.005-in. and 0.010-in. slot screens can be properly developed and yield representative water samples. The 0.010-in. slots in the regional aquifer screen probably do not inhibit proper development, but other factors, discussed below, compromise groundwater data collected from this well screen.
Screen Length and Placement	Screen 1 is submerged in perched water within CdR basalt and extends from 459 to 467.5 ft (length of 8.5 ft). Screen 2 is submerged in perched water within old alluvium and extends from 504.5 to 508 ft (length of 3.5 ft). The current water level in screens 1 and 2 is about 427 bgs. Screen 3 straddles the regional water table within Miocene basalt and extends from 801 to 839 ft (length of 30 ft). The water level in screen 1 is currently 804.4 ft.	This screen lengths and their placement were selected with the following goals in mind: Provide a monitoring point straddling the regional aquifer at the Laboratory boundary Install a sentry well upgradient of municipal supply well PM-1 Install a well screen in the upper part of the perched system within a permeable part of the Cerros del Rio basalt Install a well screen in the lower part of the perched system within permeable sediments of the old alluvium Install a well with a 50-yr service life near municipal well PM-1 where drawdown is expected to be high

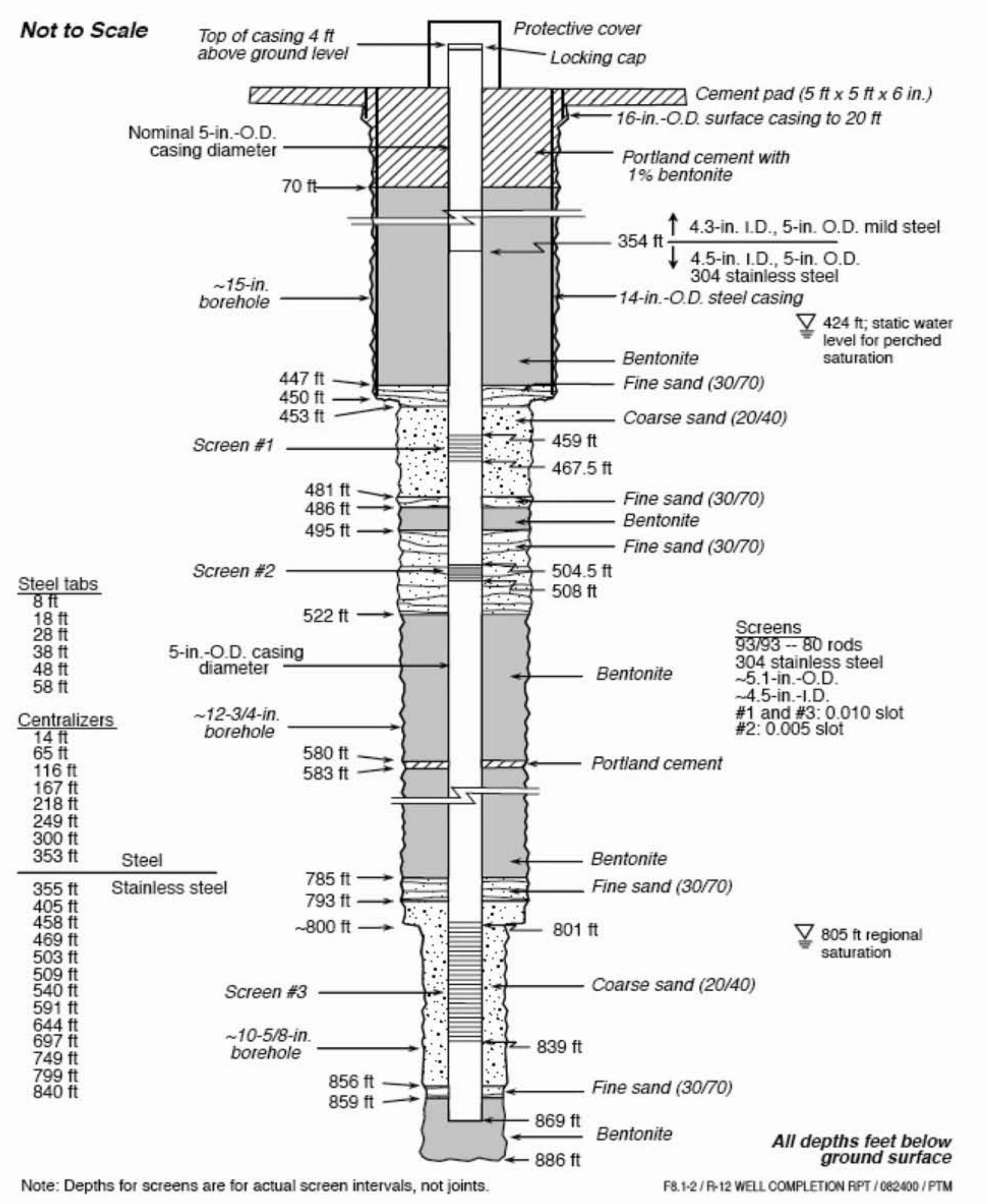
R-12 Well (continued)		
	Description	Evaluation
		The upper screen was placed in perched groundwater within Cerros del Rio basalt at a depth below where groundwater was first noted in the borehole (443-ft depth) and where cuttings sampled indicated the basalt was fractured. Perched zone water quickly rose to 424 ft when it was first encountered, indicating either that it was confined or that suitable interconnected fractures did not extend into the upper part of the perched zone at this location. For either hydrologic interpretation, it was necessary to place the well screen in fractured basalts that would yield groundwater. Screen 2 targeted the lower part of the perched zone within the old alluvium that contained sandy axial river gravels made up of well-rounded quartzite, granite, gneiss, and intermediate volcanics. These deposits are poorly cemented and were selected for their high permeability. Screen 3 was designed to straddle the regional water table at the Laboratory boundary. As a result, screen 3 was placed near the top of a thick stack of west-dipping Miocene basalt at this location. Because R-12 is located only about 340 ft from PM-1, a 30-ft well screen was installed to ensure that at least part of well screen remained submerged for its designed service life. Screen 3 at R-12 is probably not ideally located to serve as a sentry well for PM-1. The top of the louvers at PM-1 are 93 ft deeper than the bottom of screen 3. More importantly, the altered nature of the Miocene basalt, including deposition of clay minerals in fractures, may result in lower hydraulic conductivity than in overlying and underlying Miocene sedimentary rocks. The louvers in PM-1 lie mostly below the Miocene basalt encountered at R-12 and are largely within Miocene sands and silts with thin intercalated basalts. Because of the west dip of Miocene basalt and the easterly regional groundwater flow, a sentry well located to the west of R-12 could target sedimentary rocks above the Miocene basalt. These sedimentary rocks may represent areas with faster pathways for potential contaminants approaching PM-1. The paired shallow and deep regional aquifer wells R-35a and R-35b located near PM-3 may also adequately monitor groundwater approaching PM-1 because they lie along the same or related flow paths.
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the three well screens in the column to the right.	The primary filter pack for screen 1 is made up of 20/40 sand from 453 to 481 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 447 to 453 ft and 481 to 486 ft, respectively. The primary filter pack extends 6 ft above and 13.5 ft below the well screen. This filter pack length allows groundwater to be drawn from a larger volume of the basalt where the distribution of water-producing fractures is poorly known. The primary filter pack for screen 2 is made up of 30/70 sand from 495 to 522 ft. A secondary filter pack was not used in screen 2. The primary filter pack extends 9.5 ft above and 14 ft below the well screen. The combination of this filter pack with a relatively short well screen allows groundwater to be drawn from throughout the interval, representing the permeable portion of the old alluvium from the base of the Cerros del Rio basalt to the top of the confining layer of silt and clay.

R-12 Well (continued)		
	Description	Evaluation
		The primary filter pack for screen 3 is made up of 20/40 sand from 793 to 856 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 785 to 793 ft and 856 to 859 ft, respectively. The primary filter pack extends 8 ft above and 17 ft below the well screen. This upper part of the filter pack length is above the water table and does not affect well performance. The lower part of the filter pack extends farther below the well screen than current well designs (of about 5 ft below the well screen). However, because the Miocene basalt is altered and the distribution of water-producing fractures is poorly known, a long filter pack allows groundwater to be drawn from a larger volume in rocks where the amount and location of water production are uncertain.
Sampling System	Westbay Multiple Port (MP) sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids is critical prior to installation of Westbay wells because groundwater is collected in close proximity to the well due to low-flow sampling and the inability to purge the well prior to sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	Well Development	After R-12 was installed, development took place in the open well casing without the use of packers to isolate each of the well screens. Consequently, jetting with municipal water and the free flow of water from the perched zone were the only effective development that occurred in the upper two well screens. The limited success of this development approach is reflected by the high TOC concentrations measured in the first characterization samples collected after February 2000. The upper two well screens were redeveloped as part of a well rehabilitation program in September and October 2006. This rehabilitation effort resulted in a more thorough development of screens 1 and 2, but over 623,000 gal. of perched zone water flowed out of screens 1 and 2 and accumulated in screen 3 before it was isolated by installation of a packer. This large amount of water cannot be easily removed from screen 3 through normal pumping development (typically at a rate of 10 gal./min) and it is uncertain how long it will take for the water to disperse downgradient under ambient flow in the regional system.

R-12 Well (continued)		
	Description	Evaluation
Additives used		Municipal water during drilling and well construction EZ-MUD QUIK-FOAM TORKEASE
Annular fill other than filter and transition sands		Bentonite was placed above and below the filter packs to isolate the well screens and to seal off the perched zones from the regional aquifer as well as unsaturated portions of the vadose zone. The upper 70 ft of the well was cemented in place to provide a surface seal, and cement was placed between 580 and 583 ft to provide a stable platform for annular materials above.



Construction, stratigraphic, and hydrologic information for Hydrogeologic Workplan characterization well R-12.


Not to Scale
Top of casing 4 ft above ground level
Protective cover
Locking cap
Cement pad (5 ft x 5 ft x 6 in.)
16-in.-O.D. surface casing to 20 ft
Nominal 5-in.-O.D. casing diameter
Portland cement with 1% bentonite
70 ft
354 ft
4.3-in. I.D., 5-in. O.D. mild steel
4.5-in. I.D., 5-in. O.D. 304 stainless steel
~15-in. borehole
14-in.-O.D. steel casing
424 ft; static water level for perched saturation
Bentonite
447 ft
450 ft
453 ft
Fine sand (30/70)
Coarse sand (20/40)
Screen #1
459 ft
467.5 ft
481 ft
486 ft
495 ft
Fine sand (30/70)
Bentonite
Fine sand (30/70)
Screen #2
504.5 ft
508 ft
Steel tabs
8 ft
18 ft
28 ft
38 ft
48 ft
58 ft
522 ft
5-in.-O.D. casing diameter
Bentonite
Screens
93/93 -- 80 rods
304 stainless steel
~5.1-in.-O.D.
~4.5-in.-I.D.
#1 and #3: 0.010 slot
#2: 0.005 slot
Centralizers
14 ft
65 ft
116 ft
167 ft
218 ft
249 ft
300 ft
353 ft
Steel
Stainless steel
355 ft
405 ft
458 ft
469 ft
503 ft
509 ft
540 ft
591 ft
644 ft
697 ft
749 ft
799 ft
840 ft
~12-3/4-in. borehole
580 ft
583 ft
Portland cement
Bentonite
785 ft
793 ft
Fine sand (30/70)
~800 ft
801 ft
805 ft regional saturation
Screen #3
Coarse sand (20/40)
~10-5/8-in. borehole
839 ft
856 ft
859 ft
Fine sand (30/70)
869 ft
Bentonite
886 ft
All depths feet below ground surface
Note: Depths for screens are for actual screen intervals, not joints.
F8.1-2 / R-12 WELL COMPLETION RPT / 082400 / PTM

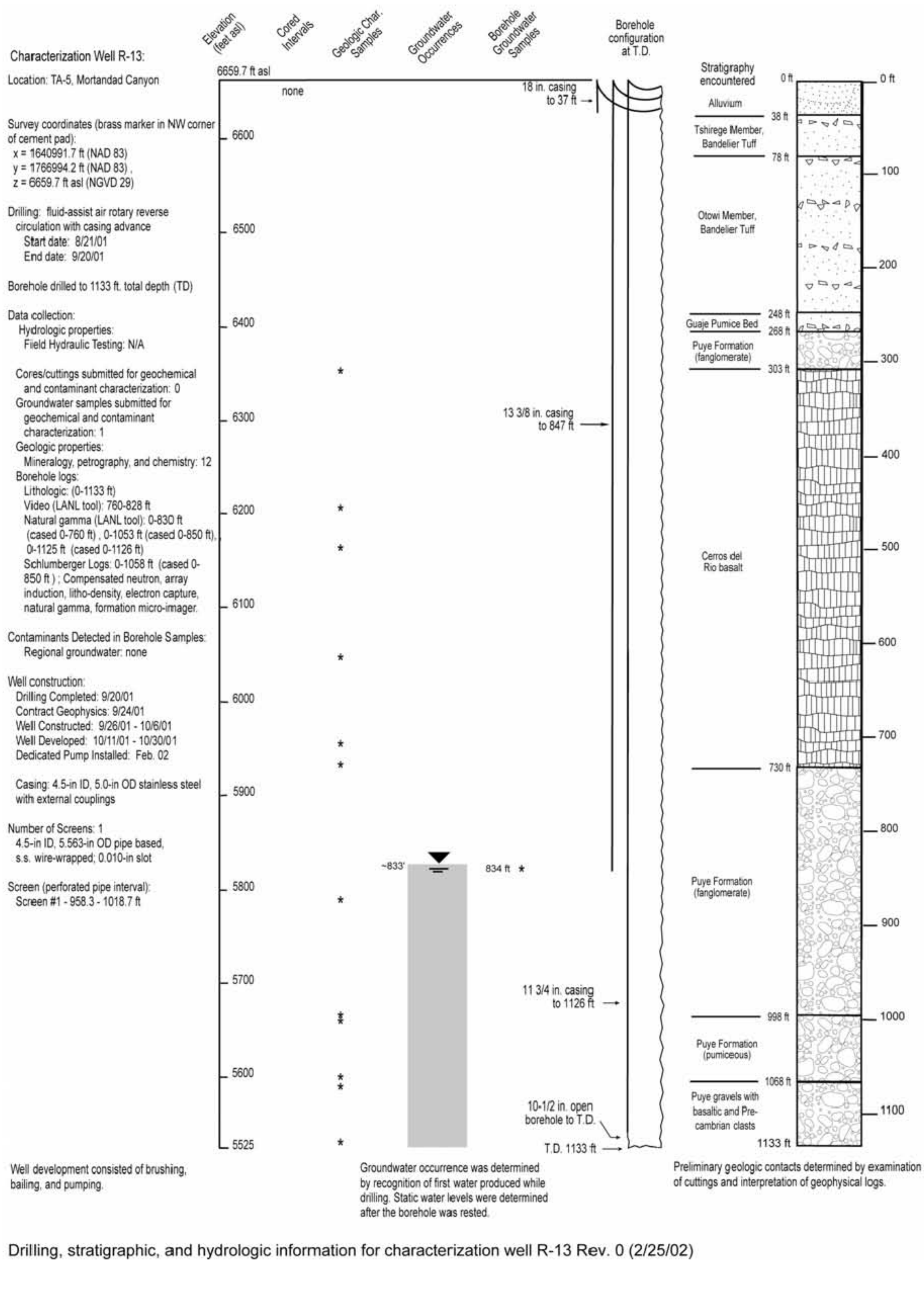
R-13 Well

R-13 Well		
	Description	Evaluation
Drilling Method	R-13 was drilled using fluid-assisted air-rotary casing advance methods.	R-13 was drilled using a combination of reverse-circulation, fluid-assisted air-rotary methods in open hole and with casing advance to TD at 1133 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives including QUIK-FOAM and EZ-MUD. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-13 because there is limited contact between drilling fluids and the borehole wall because drilling and casing advance takes place concurrently. Also, R-13 is a single completion well; these types of wells are intrinsically easier to develop and they can be purged before sampling.
General Well Characteristics	R-13 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.-I.D./ 5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was used after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also the wire wrap on the R-13 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-13 consistently yields water samples considered representative of groundwater conditions in the regional aquifer at this location (see Appendix B). Field parameters, including turbidity, are consistently within acceptable limits. These data indicate that the well is properly designed, installed, and developed.
Screen Length and Placement	The well screen extends from 958.3 to 1018.7 ft and has a length of 60.4 ft. The top of the screen is 121 ft below the water table.	This screen length and its placement were selected with the following goals in mind: Provide a monitoring point in the regional aquifer at the Laboratory boundary Place a screen in upper part of the regional aquifer along potential lateral groundwater flow paths approximately 5000 ft downgradient of where contaminants are believed to be entering the regional aquifer Submerge the screen fully to facilitate well development

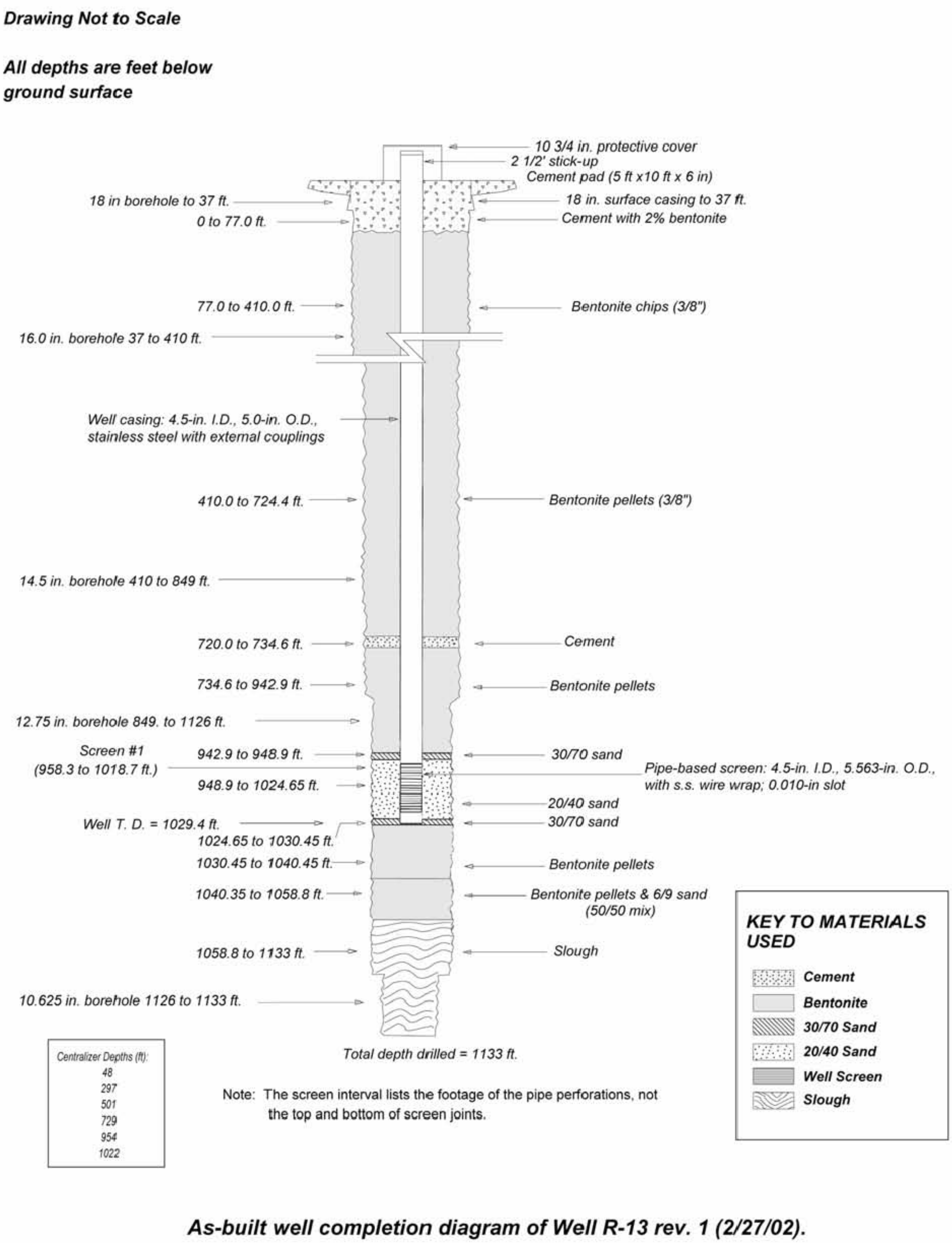
R-13 Well (continued)		
	Description	Evaluation
		Screen across a long-enough stratigraphic interval so that contaminants, if present, could be detected among several possible but unknown flow paths Install a well with a 50-yr service life in an area where municipal well drawdown is about 0.6 ft/yr (30 ft over 50 yr). The upper part of the regional aquifer at R-13 is composed of Pliocene and Miocene continental sedimentary deposits. These deposits are composed of poorly cemented volcaniclastic detritus that forms well-stratified, poorly sorted beds of silts, sands, gravels, and cobbles. Individual beds within the regional aquifer sequence range from a few inches up to 3 ft thick, based on FMI imaging. The interval from 998 to 1068 ft contains pumiceous deposits that have proved to be highly transmissive at other wells (e.g., R-11 and R-28). The borehole was terminated at a depth of 1133 ft due to unstable borehole conditions that developed when axial river deposits were penetrated below a depth of 1068 ft. Drill casing was landed at 847 ft at the time the geophysical logs were collected. According to the Schlumberger log evaluation, the upper regional aquifer has the following characteristics: *Note: Water table occurs at a depth of 837 ft.* 835–860-ft interval—Has high water-filled porosity, reaching 40% at 842 ft, but this increase may be due to washouts behind the casing. *(Note: The borehole was overreamed to advance the 13.375-in. drill casing to 847-ft depth. The zone of high water-filled porosity corresponds to a pronounced decrease in gamma counts, suggesting the tools are responding to water behind the casing in an overreamed part of the borehole.)* 850–927-ft interval—Appears to contain significant amounts of clay and clay-rich rocks, especially in the zones 873–881 ft and 858–865 ft, which contain as much as 50% and 20% clay volume fraction, respectively. The zone 875–910 ft is characterized by an increase in effective porosity (moveable water) and hydraulic conductivity, reaching 10% and 1×10^{-5} cm/s, respectively, at 890 ft. 910–980-ft interval—Zone of very low effective porosity (near 0%) and low hydraulic conductivity (estimated 5×10^{-8} cm/s), although there are a number of thin intervals of higher effective porosity across this interval. Effective porosity and hydraulic conductivity increase downward. 980–1022-ft interval—Contains the highest effective porosity and estimated hydraulic conductivity, reaching 30% and 0.001 cm/s, respectively, at 1004 ft. These measurements indicate a high groundwater flow capacity. 1050-ft interval—Contains the highest water-filled porosities measured in the open borehole, averaging 40% at 1050 ft. Porosities decline steadily uphole, decreasing to 25% at 860 ft.

R-13 Well (continued)		
	Description	Evaluation
		The placement of the well screen across the 958.3- to 1018.7-ft-depth interval meets the goals for monitoring well at this location. The well screen is located in the uppermost permeable zone, which is well documented by geophysical logs and represents the most likely contaminant fast pathway. Clay-rich rocks (850 to 927 ft) above this zone are unsuitable for monitoring fast pathways. The thin zone from 837 to 850 ft is poorly characterized because it is covered by well casing, and it is not known whether the rocks in this interval are suitable for monitoring purposes. Additionally, R-13 is located in an area of declining water levels due to extraction of water by surrounding water-supply wells; a short screen near the water table could dry up within an unacceptably short period of time. R-13 is located at the Laboratory boundary more than 5000 ft downgradient of where contaminants are believed to be entering the regional aquifer. Given the highly stratified nature of the sedimentary deposits, there might be a concern that water entering the aquifer is trapped above clay-rich rocks such as those occurring from 850 to 927 ft. This might be the case where sediments dip eastward parallel to the groundwater flow direction. However, measured dips from the FMI log suggest that the directions of dips are highly variable in the upper part of the aquifer and that eastward dips are relatively uncommon in this area. Additionally, individual rock layers are relatively thin (inches to a few feet thick), and they probably have limited lateral continuity either because they were deposited over limited areas or because they were partly eroded before being buried by younger deposits. Thus, while groundwater generally flows eastward across the area, the path that water takes through these heterogeneous sediments is likely to be complex with preferential flow occurring in the more permeable units and with local diversions where less permeable dipping strata are encountered. Consequently, contaminants are probably more dispersed than they would be if the groundwater flowed through homogeneous media. Given these complexities, relatively long well screens across multiple permeable horizons in the upper part of the groundwater system are probably the best strategy for detection monitoring at the Laboratory boundary.
Filter Pack Materials and Placement	The primary filter pack extends from 948.9 to 1024.7 ft and is made up of 20/40 sand. Secondary filter packs of 30/70 sand were placed above and below the primary filter pack at 942.9–948.9 ft and 1024.7–1030.5 ft, respectively.	The primary filter pack extends 9.4 ft above and 6 ft below the well screen. The filter pack above the well screen is slightly longer than optimum but has relatively little effect on samples collected because the most productive water–bearing zones are located toward the bottom of the screen interval.

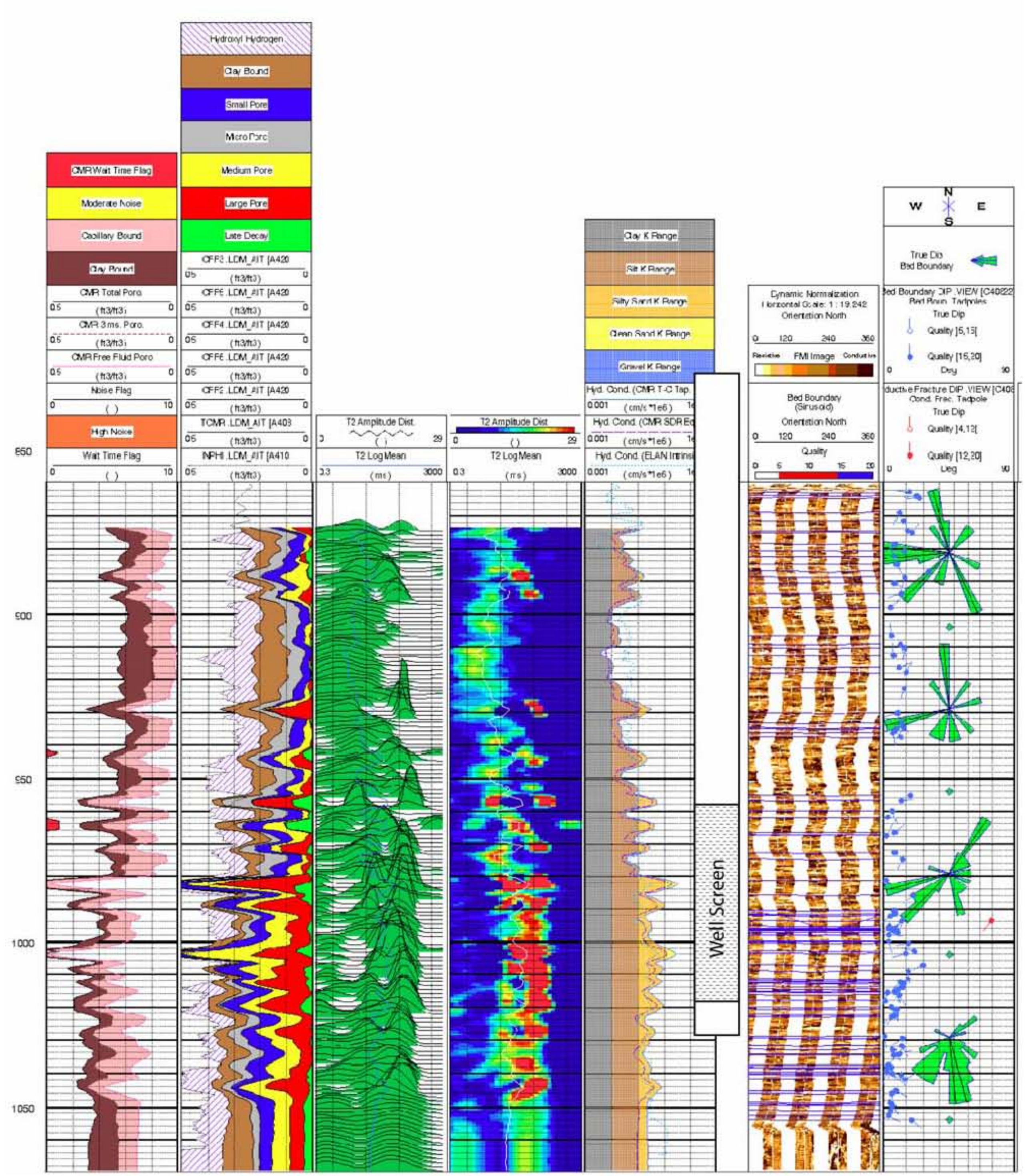
R-13 Well (continued)		
	Description	Evaluation
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	During drilling, hydraulic fluid was noted in the cuttings in the rocks just above the water table at 827–832 ft. After shutdown, the leak was traced to a mixing tank pump; about 165 gal. of hydraulic fluid was lost.	The uncased portion of the borehole from 760 to 832 ft was flushed with 500 gal. of municipal water mixed with 1 cup of QUIK-FOAM. Subsequently, 300 gal. of water was purged from the borehole. Analyses of the purged water indicated the borehole was free of hydraulic fluid. To further ensure potential hydraulic fluid was isolated from the well-screen target depth, casing was advanced to 850-ft depth. Subsequent analyses of groundwater samples from the completed well do not show any indication of hydraulic fluid contamination, which would have manifested itself by elevated TOC and perhaps alkalinity as a result of biodegradation (see Appendix B).
Additives used		Municipal water QUIK-FOAM EZ-MUD Fluids recovered during development—24,710 gal.
Annular fill other than filter and transition sands		Benseal high-solids multipurpose bentonite grout (5.5 bags) Pelplug bentonite (0.25 in. by 0.375. in. refined elliptical pellets (899 buckets) Surface seal of cement slurry (159 bags)



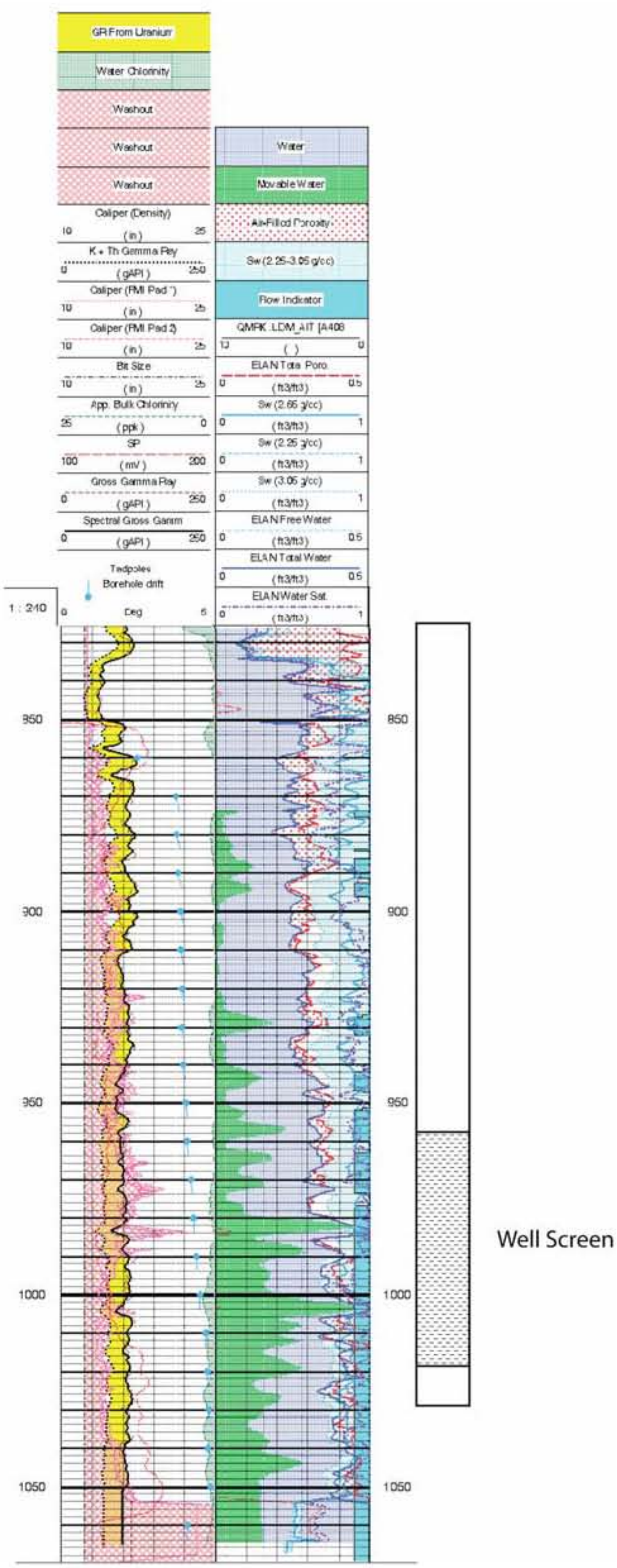
Drilling, stratigraphic, and hydrologic information for characterization well R-13 Rev. 0 (2/25/02)



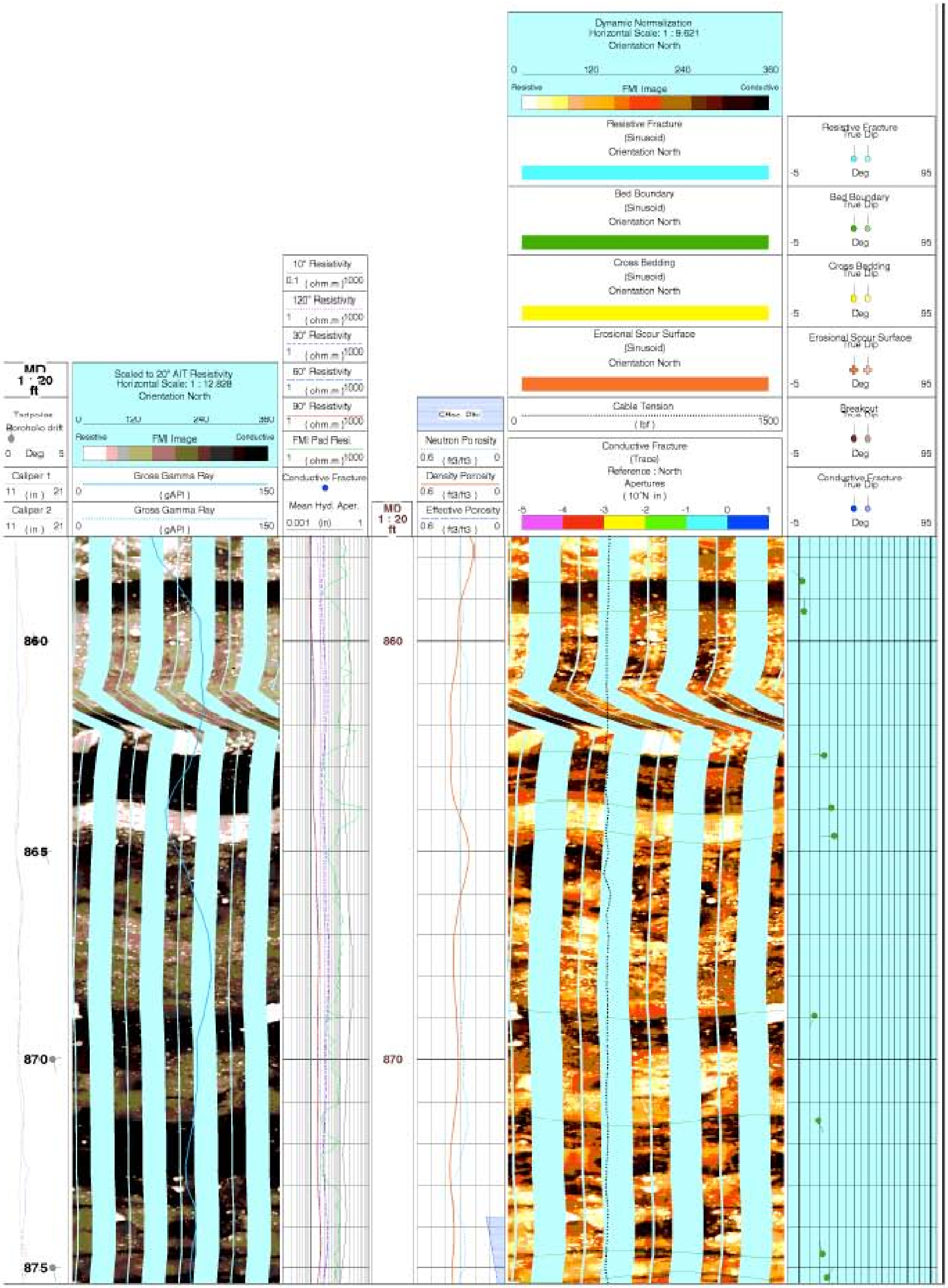
As-built well completion diagram of Well R-13 rev. 1 (2/27/02).



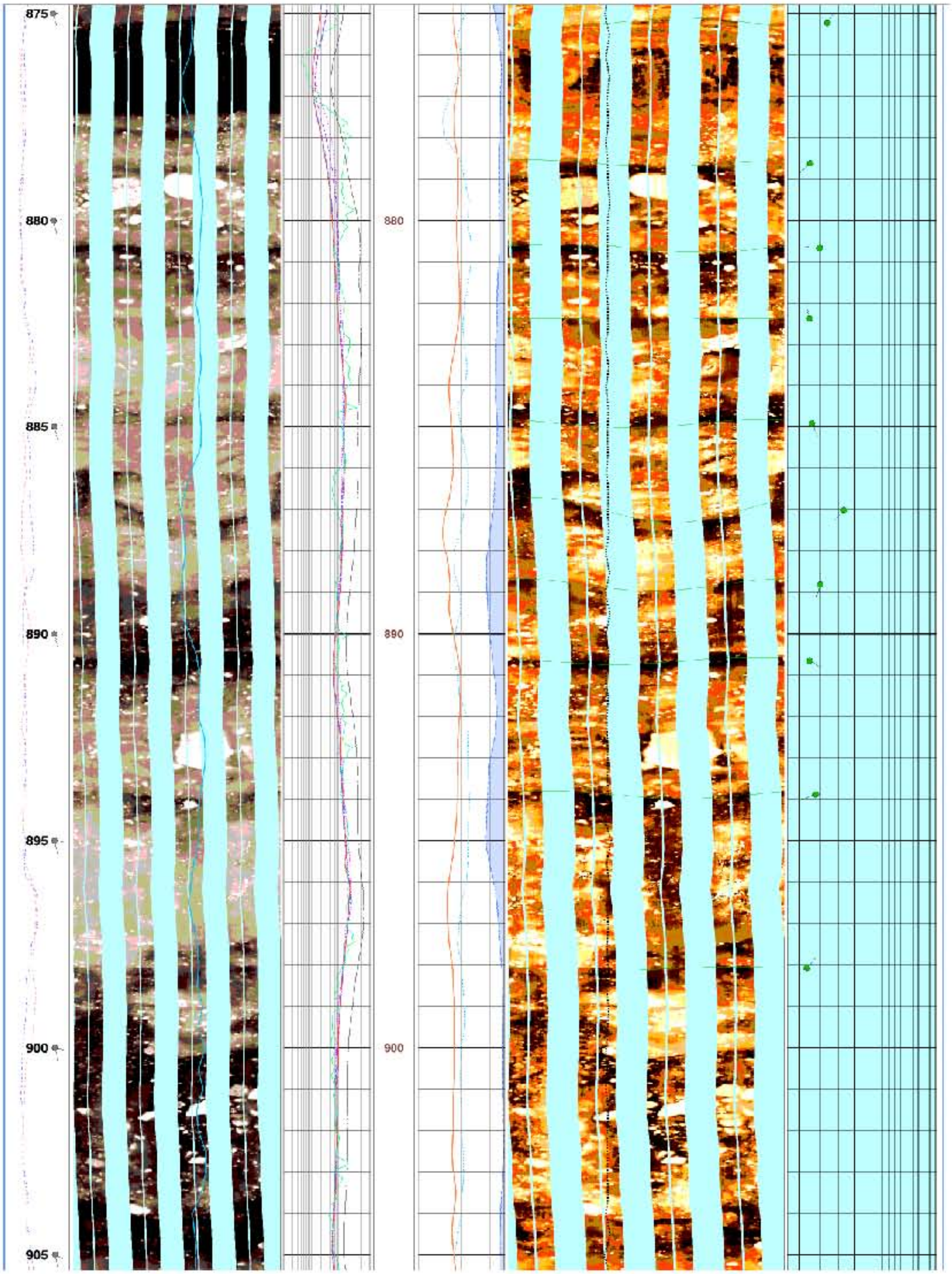
Summary of R-13 Borehole Geophysical Logs for the Regional Aquifer



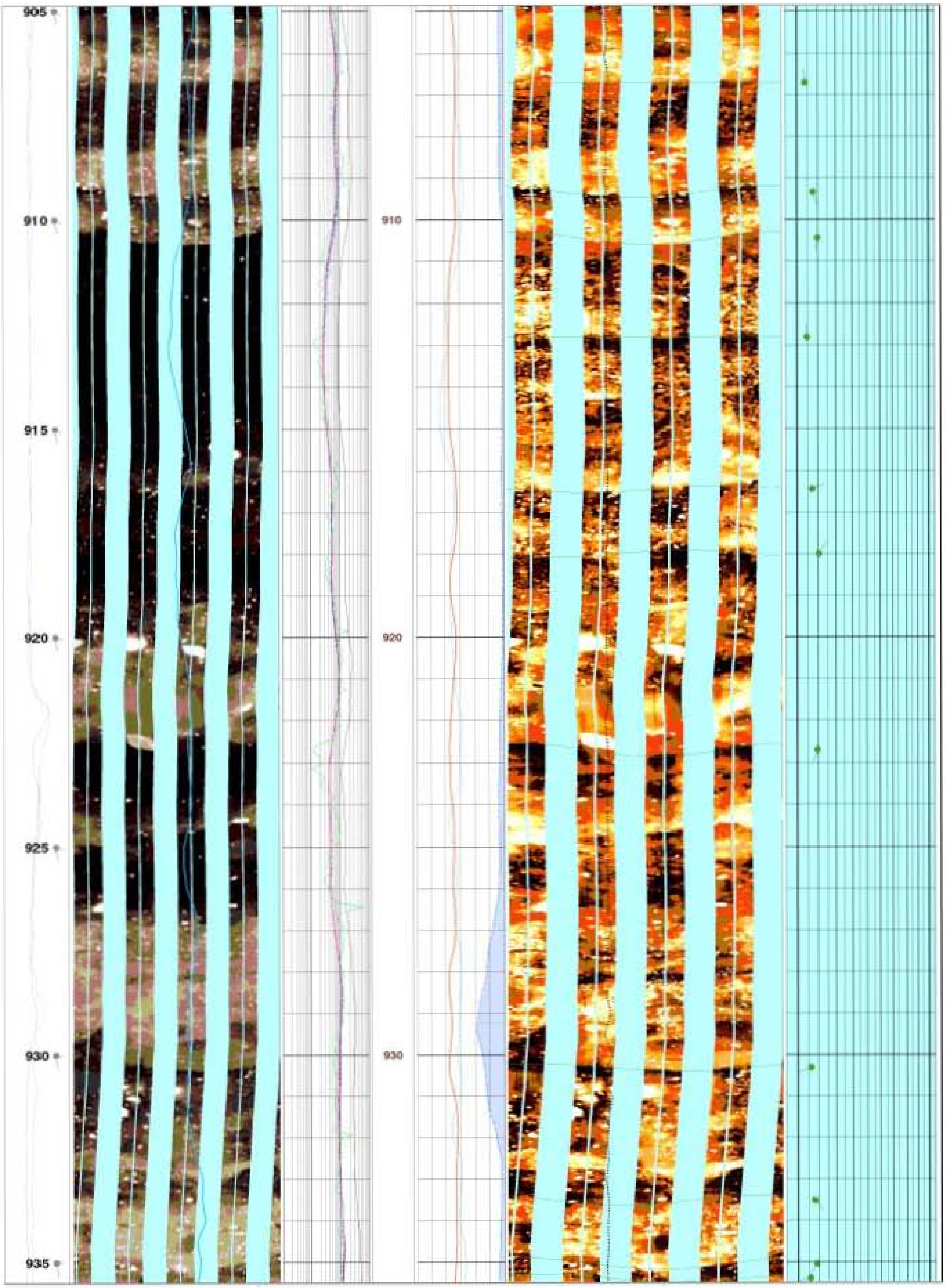
Summary of R-13 Borehole Geophysical Logs for the Regional Aquifer (continued)



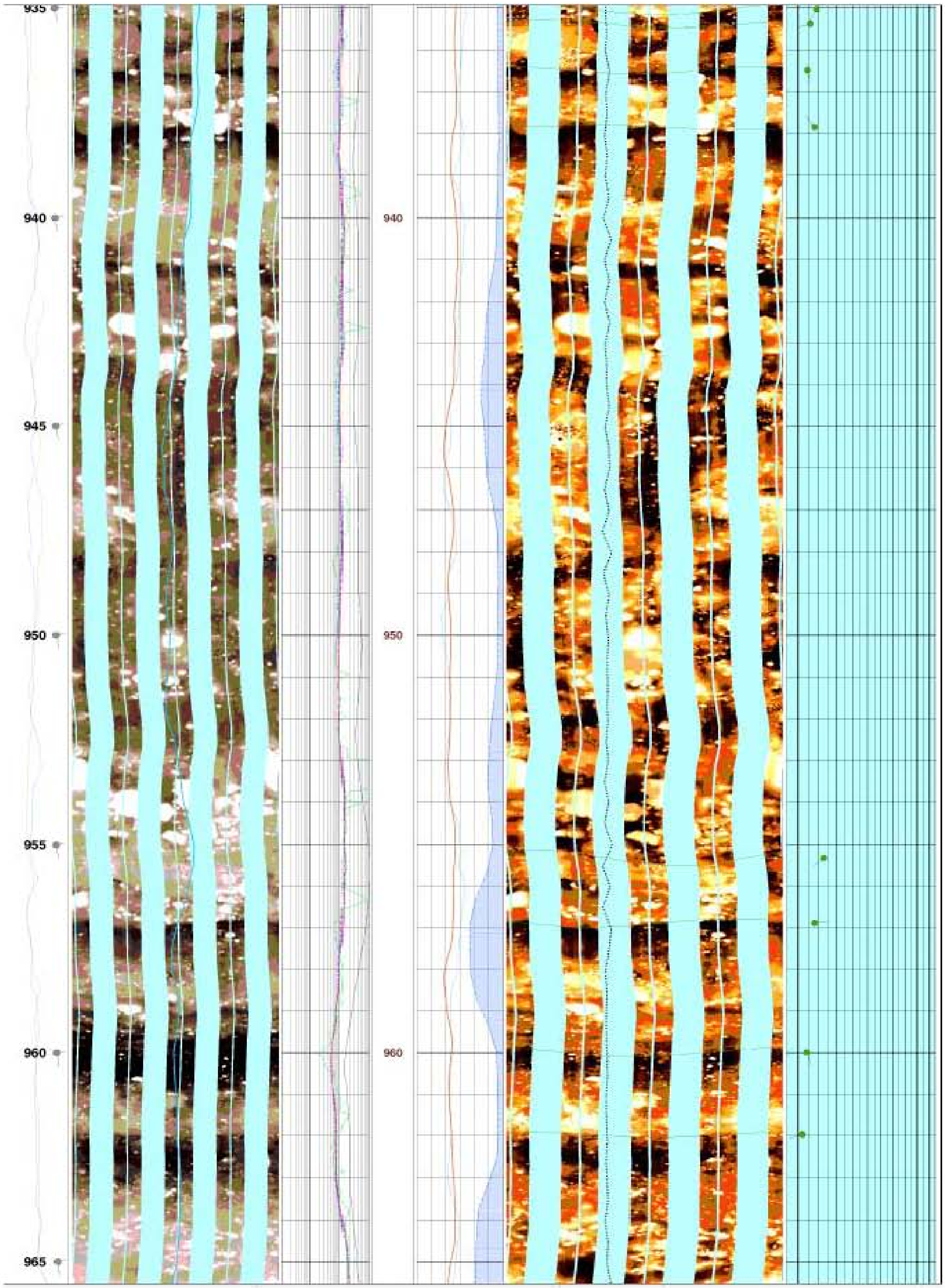
Formation Microimager Log for R-13



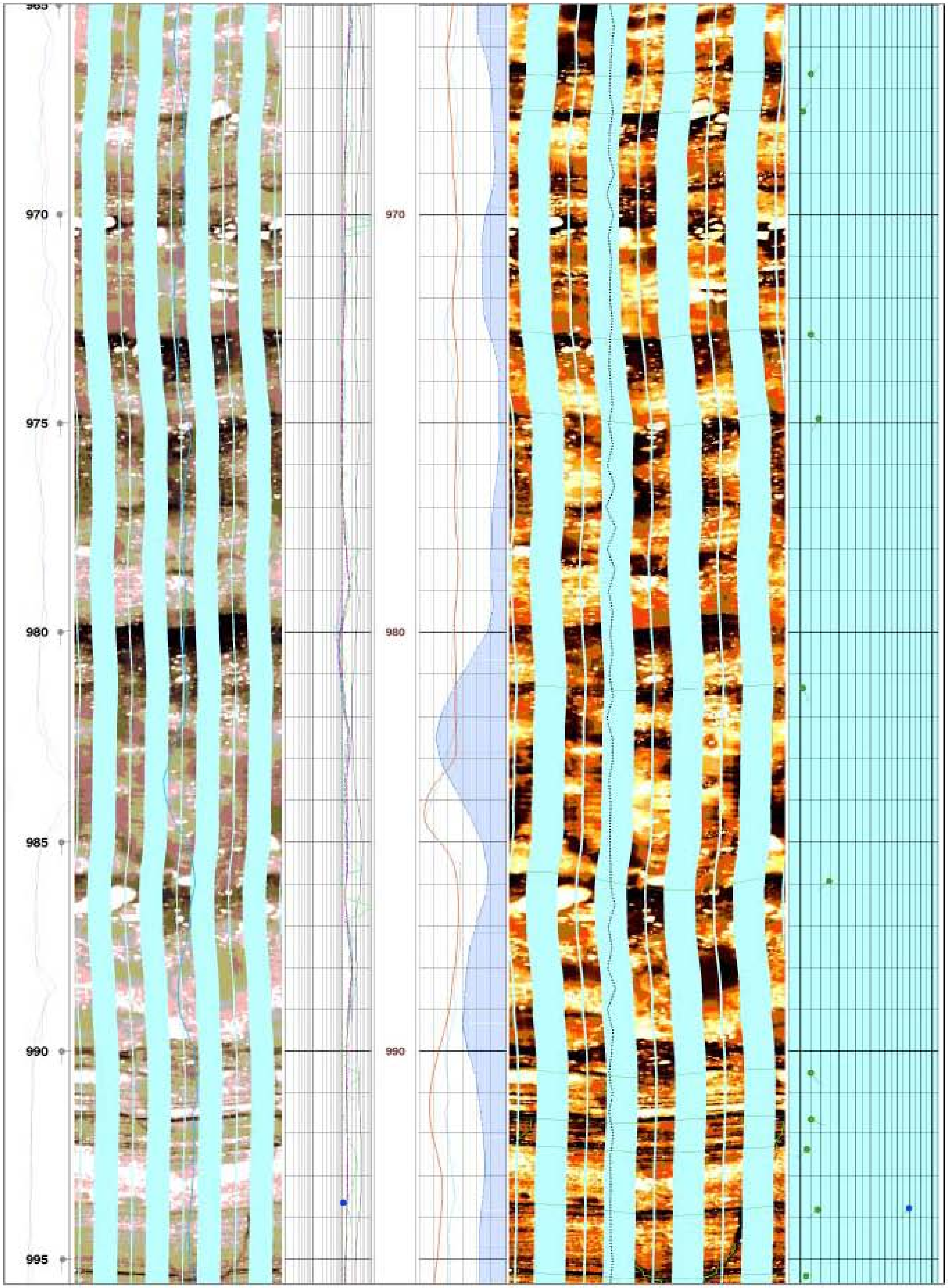
Formation Microimager Log for R-13 (continued)



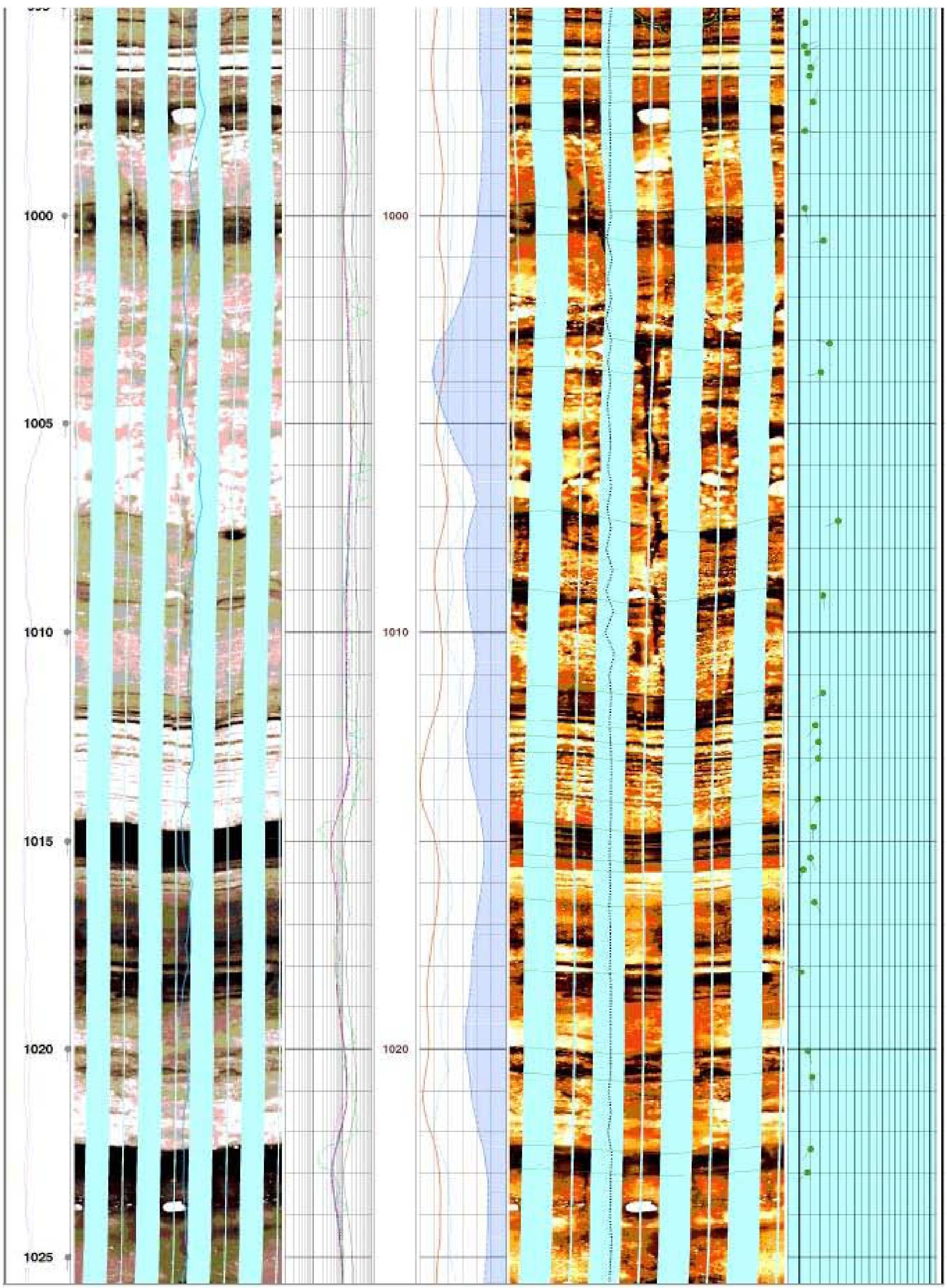
Formation Microimager Log for R-13 (continued)



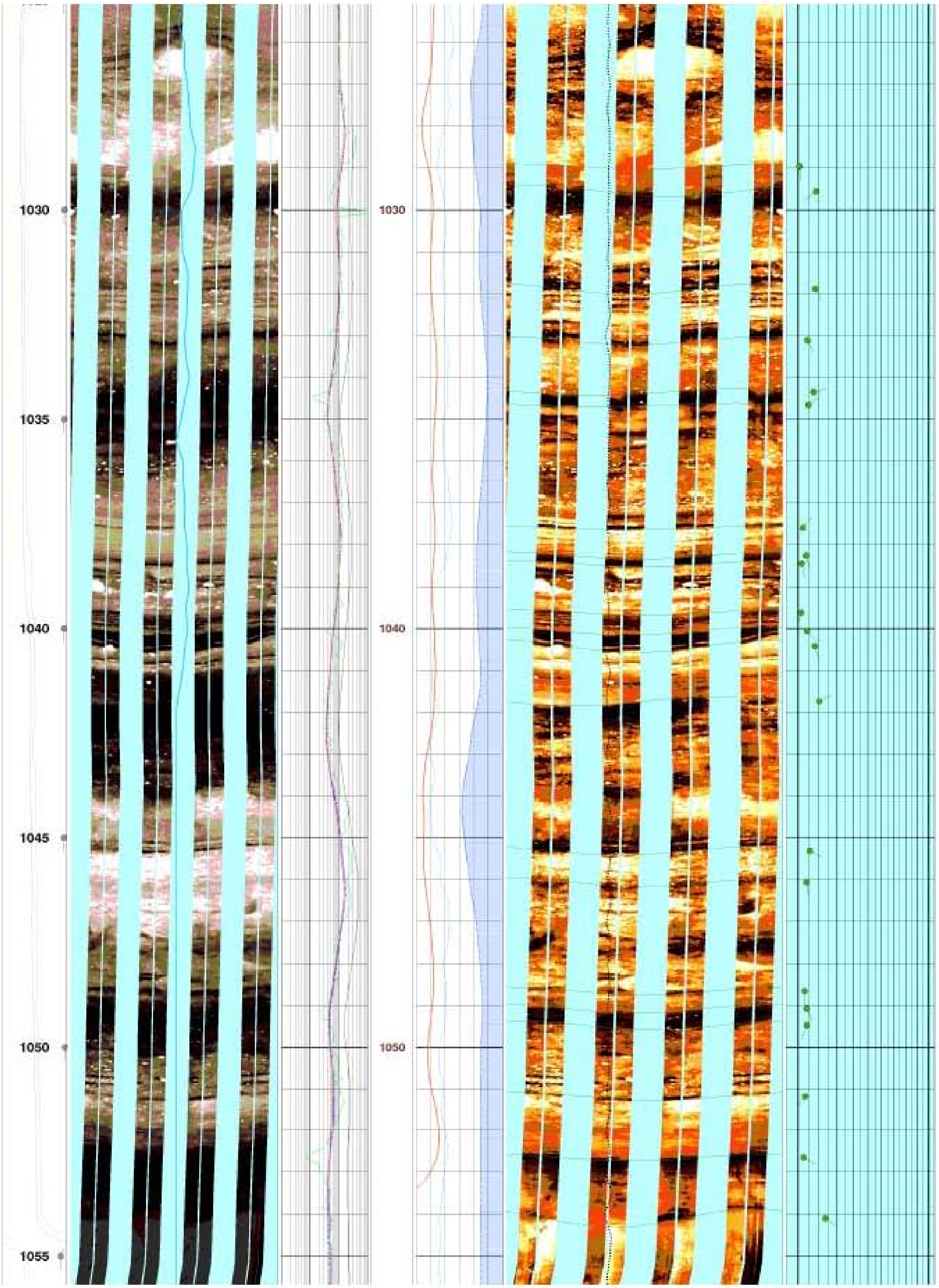
Formation Microimager Log for R-13 (continued)



Formation Microimager Log for R-13 (continued)



Formation Microimager Log for R-13 (continued)



Formation Microimager Log for R-13 (continued)

R-14 Well

R-14 Well		
	Description	Evaluation
Drilling Method	R-14 was drilled in two phases. Phase I involved coring to 306 ft. Phase II used air-rotary methods with foam to the water table; beneath the water table (from 1225 ft depth), conventional mud rotary methods were used.	Wireline core retrieval was used to 306- ft depth. Open-hole air rotary with 16 in. tricone from 306- to 1068-ft depth, where 13.375 in. casing was pressure grouted in place. Open-hole air rotary with 12.25 in. tricone from 1068- to 1225-ft depth. Conventional mud rotary with 12.25 in. tricone from 1225- to1285-ft depth, where lost circulation prompted drilling with 11.75 in. casing and down-the-hole under-reaming bit to TD at 1327 ft. An installed Westbay sampling system limits purge volumes during sampling.
General Well Characteristics	R-14 is a two-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction (1200.6–1233.2 and 1286.5–1293.1)	The pipe-based screen is constructed of 4.5-in.-.I.D./5.5-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-14 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. Development of the two screens at R-14 included bailing, surging, and brushing; integral pumping; and separate pumping at each screen with a packer emplaced. Acids and dispersants were used during development to remove lost-circulation materials introduced by drilling. At the end of development, the upper screen was capable of producing water with NTUs < 1, whereas the lower screen would be initially cloudy (NTUs ~83) before dropping to values < 1. Although the upper screen at R-14 does not yet yield water samples that are fully representative of groundwater conditions in the upper part of the regional aquifer, it shows an improving trend, and the prognosis is good for meeting goals in the future (see Appendix B). However, water produced from the lower screen at R-14 shows persistent iron-reducing conditions and possible residual organic drilling fluids; the prognosis for screen 2 to improve in the future is not as good (see Appendix B).

<table>
<tr><th colspan="3">R-14 Well (continued)</th></tr>
<tr><th></th><th>Description</th><th>Evaluation</th></tr>
<tr><td>Screen Lengths and Placement</td><td>The upper screen is 32.6 ft long, placed from 1200.6- to 1233.2-ft depth. The top of the upper screen is 18.6 ft below the water table (1182-ft depth on 6/26/2002, when drilled depth was 1225 ft and before switching over to mud-rotary drilling).

The lower screen is 6.6 ft long, placed from 1286.5- to 1293.1-ft depth. The top of the lower screen is 104.5 ft below the water table (1182- ft depth on 6/26/2002).</td><td>Relevant stratigraphy:

Puye Fm (Tpf) from 768- to 1210-ft depth; pumiceous deposits of the upper Santa Fe Group from 1210-ft depth to TD (1327 ft).

Relevant geophysical log results:

Schlumberger logging tools were run from 12.2-ft depth (below conductor casing) to 1068-ft (depth of drilling at the time Schlumberger logs were acquired on 6/19 to 6/20/2002); the Schlumberger data are thus limited to the vadose zone, 14 ft above the top of regional saturation. The Schlumberger tools were run open hole and indicated no perched zones in the logged interval. The LANL natural gamma, induction, and video tools were also run to 1068-ft depth, right after the Schlumberger logging; again there was no indication of perched zones.

The LANL gamma tool was run to 1325.4-ft depth on 7/3/2002 when the hole was at TD (1327 ft). The gamma log indicates a sharp drop in signal at 1182–1184-ft depth, coincident with the top of regional saturation tagged on 6/26/2002 when the drilled depth was 1225 ft. The gamma signal also rises in passing from the Puye Formation into the pumiceous Santa Fe, from ~35 to 40 API units in the Puye to ~50–60 API units in the pumiceous sequence.

Upper screen placement:

The upper screen was located so as to be close to the top of regional saturation yet submerged deep enough for aggressive development. This screen spans the contact between Puye Formation fanglomerates and the underlying pumiceous unit of the upper Santa Fe Group. The upper screen length and placement were selected with the following goals in mind:
1. Provide a monitoring point for the uppermost part of the regional aquifer beneath the collection ponds in the upper part of Ten Site Canyon
2. Submerge the screen fully to facilitate well development
3. Screen a long-enough stratigraphic interval so that contaminants, if present, could be detected among several possible but unknown flow paths, some of which may be related to the stratigraphic transition from Puye Formation fanglomerates to the Santa Fe Group vitric, pumiceous sediments</td></tr>
<tr><td></td><td></td><td>Lower screen placement:

The lower screen was placed to
1. monitor a deeper zone of the regional aquifer in the pumiceous sequence, and
2. provide greatest possible vertical distance from the upper screen so as to obtain vertical head gradient data relevant to the regional aquifer beneath upper Ten Site canyon.</td></tr>
</table>

R-14 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement *Upper screen:* (primary 1196.8–1240.2 ft, with a small amount of slough at 1211.6–1211.9 ft; secondary 1190.7–1196.8 ft; no lower secondary sand) *Lower screen:* (primary 1281.0–1299.0; secondary 1276.3–1281.0 ft; no lower secondary sand)	The primary filter pack is made up of 20/40 sand. Secondary filter packs of 30/70 sand were placed above and below the primary filter pack.	***Upper screen:*** Primary filter pack extends 3.8 ft above the screen openings and 7 ft below, with 0.3 ft of slough against the screen at 1211.6 to 1211.9- ft depth (just below the top of the pumiceous unit at 1210-to ft depth). ***Lower screen:*** Primary filter pack extends 5.5 ft above the screen openings and 5.9 ft below.
Sampling System	Westbay Multiple Port (MP) sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids is critical prior to installation of Westbay wells because groundwater is collected in close proximity to the well due to low-flow sampling and the inability to purge the well prior to sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	Severe lost-circulation conditions were encountered from 1285-ft depth to TD, requiring use of an extensive suite of stabilizing materials in addition to bentonite mud.	During drilling below 1285-ft depth, severe lost circulation required addition of sealants to the bentonite mud used to stabilize the borehole (see below: additives used). It is likely that disturbance to the formation and washouts resulted from drilling in this interval, although geophysical logs are not available beneath the water table to assess the extent of disturbance. Nevertheless, during well construction slough was limited to thin intervals: • TD (1327 ft) to 1324.1 ft (2.9 ft of slough) • 1276.3–1271.0 ft (5.3 ft of slough) • 1241.2–1240.2 ft (1.0 ft of slough) • 1211.9–1211.6 ft (0.3 ft of slough) • 1190.7–1186.8 ft (3.9 ft of slough)

R-14 Well (continued)		
	Description	Evaluation
Additives used		In Phase I drilling, no additives were used. In Phase II drilling, air-rotary drilling to 1225-ft depth was assisted by municipal water mixed with soda ash, QUIK-GEL, LIQUI-TROL, and QUIK-FOAM. Below 1225 ft bentonite-based mud was used along with QUIK-GEL and LIQUI-TROL. As lost circulation problems became more severe below 1285- ft depth, additional materials were added to retain circulation: Pac-L, N-seal, and Magma Fiber. The well completion report provides the following information on additive use: • 0–848 ft depth: • Municipal water—22,200 gal. • QUIK-GEL bentonite—7.3 lb • LIQUI-TROL—4.25 lb • QUIK-FOAM—201 gal. • Soda ash—18 lb • 848–1315-ft depth: • Municipal water—104,300 gal. • Bentonite—28,250 lb • LIQUI-TROL—22 gal. • QUIK-FOAM—175 gal. • Pac-L—700 lb • N-seal—1830 lb • Magma fiber—2160 lb
Annular fill other than filter and transition sands		Pelplug bentonite pellets below the water table—403 buckets QUIK-GROUT powdered bentonite—132 bags Benseal granular bentonite—2 bags Portland cement—57 bags mixed with 5 gal. municipal water per bag.
Water produced and chemicals added on development and testing		11,550 gal. was removed from both screens (no packer present) through bailing, brushing, surging, and pumping over six episodes. ***Upper screen:*** 5,610 gal. pumped with packer in place 310 gal. of chemical treatment added: AQUA-CLEAR MGA and AQUA-CLEAR AE with AQUA-CLEAR PFD dispersant

R-14 Well (continued)		
	Description	Evaluation
		Lower screen: 173,760 gal. pumped with packer in place 9200 gal. pumped without packer but with pump at the screen 90 gal. of chemical treatment added: AQUA-CLEAR MGA and AQUA-CLEAR AE with PFD dispersant

Location: In Ten Site Canyon, east of the former radioactive liquid waste and septic treatment facilities at TA-35.

Survey coordinates (brass marker in NW corner of R-14 cement pad):
x: 1629855 E y: 1768953 N (NAD 83)
z: 7062.1 ft asl (NGVD 29)

Drilling: air rotary core w/ wireline retrieval, conventional mud drilling, casing advance.
R-14 Start date: 06/02/02.
R-14 End date: 07/02/02.

Borehole R-14 drilled to 1327 ft bgs (TD).

Data collection:
Hydrologic properties: Field hydraulic test: Constant Rate Injection Test on screen #2
Cores/cuttings submitted for geochemical and contaminant characterization: (24)
Groundwater samples submitted for geochem and contaminant characterization: (2)
Geologic properties: (11)
Mineralogy, petrography, and chemistry.

Borehole logs from R-14:
Lithologic: 0-1327 ft
Video (LANL tool): 0-923 ft. and 0-975 ft
Natural gamma (LANL tool): 0-1068 ft and 1046-1325 ft bgs
Schlumberger Logs: 0-12.2 ft (cased), 12.2-1068 ft (open hole): Litho density, Spectral Gamma, Elemental Capture, Thermal/Epithermal Neutron, Combinable Magnetic Resonance, and Natural Gamma.

Contaminants Detected in R-14 Water Samples: none

Well construction:
Drilling Completed: 07/02/02
Contract Geophysics: 06/19/02 - 06/20/02
Well Constructed: 07/04/02 - 07/11/02
Well Developed: 07/19/02 - 11/18/02
Westbay Installed: 11/19/02 - 11/25/02

Casing: 4.5-in I.D. stainless steel with external couplings.

Number of Screens: 2
4.5-in. I D pipe based, s.s. wire-wrapped with 0.010-in. slots.

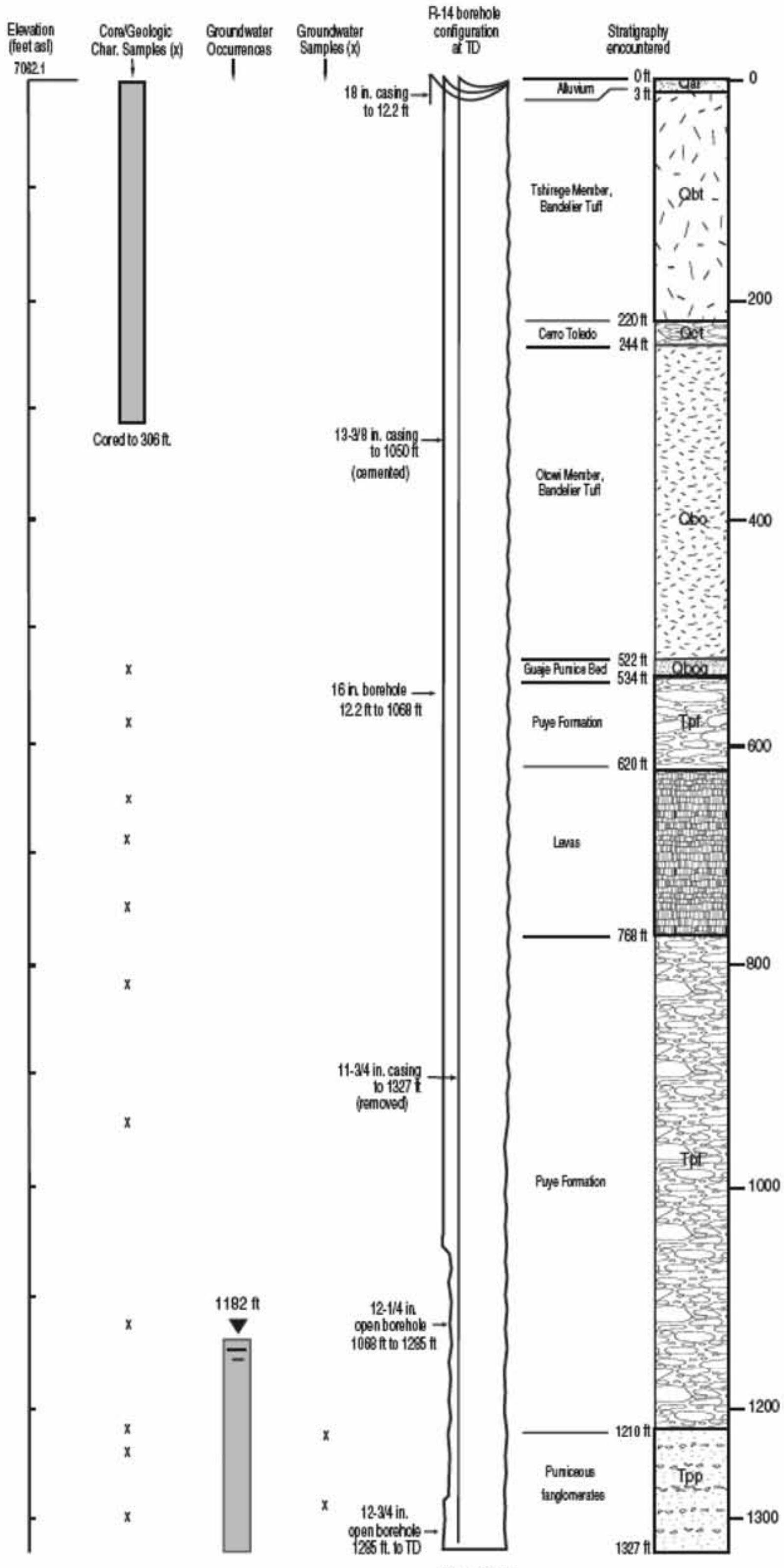
Screen (perforated pipe interval):
Screen #1 - 1200.6-1233.2 ft. bgs.
Screen #2 - 1286.5-1293.1 ft. bgs.

Well development consisted of wire brushing, bailing, chemical treatments, surging, and pumping.

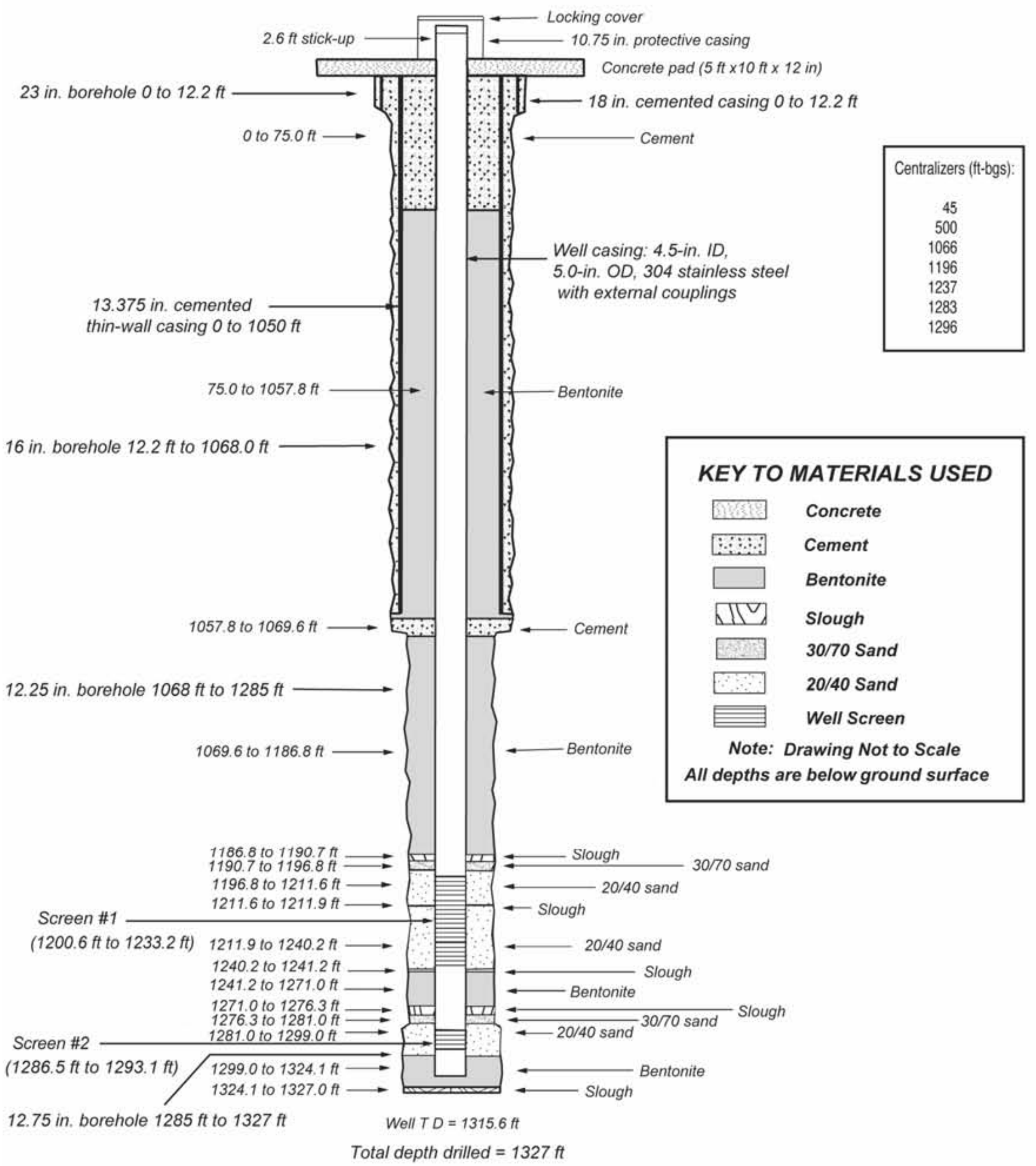
Groundwater occurrence was determined for R-14 by recognition of first water produced while drilling, by borehole geophysics, and by borehole video. Static water levels were determined after the R-14 borehole was rested.

Groundwater samples collected from packed off screen intervals after well development.

Geologic contacts for R-14 were determined by examination of cuttings and interpretation of borehole video and geophysical logs. Contacts and stratigraphy may be refined by petrographic, geochemical, or mineralogic analysis of geologic samples.



Well Summary Data Sheet for Well R-14



Note: 1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.

2. The intervals of slough consist of sands and gravel of the Puye Formation.

3. Westbay multiport sampling system (MP-55) casing not shown.

4. Pipe-based screen: 4.5-in. ID, 5.563-in. OD,304 stainless steel with s.s. wire wrap; 0.010-in. slot.

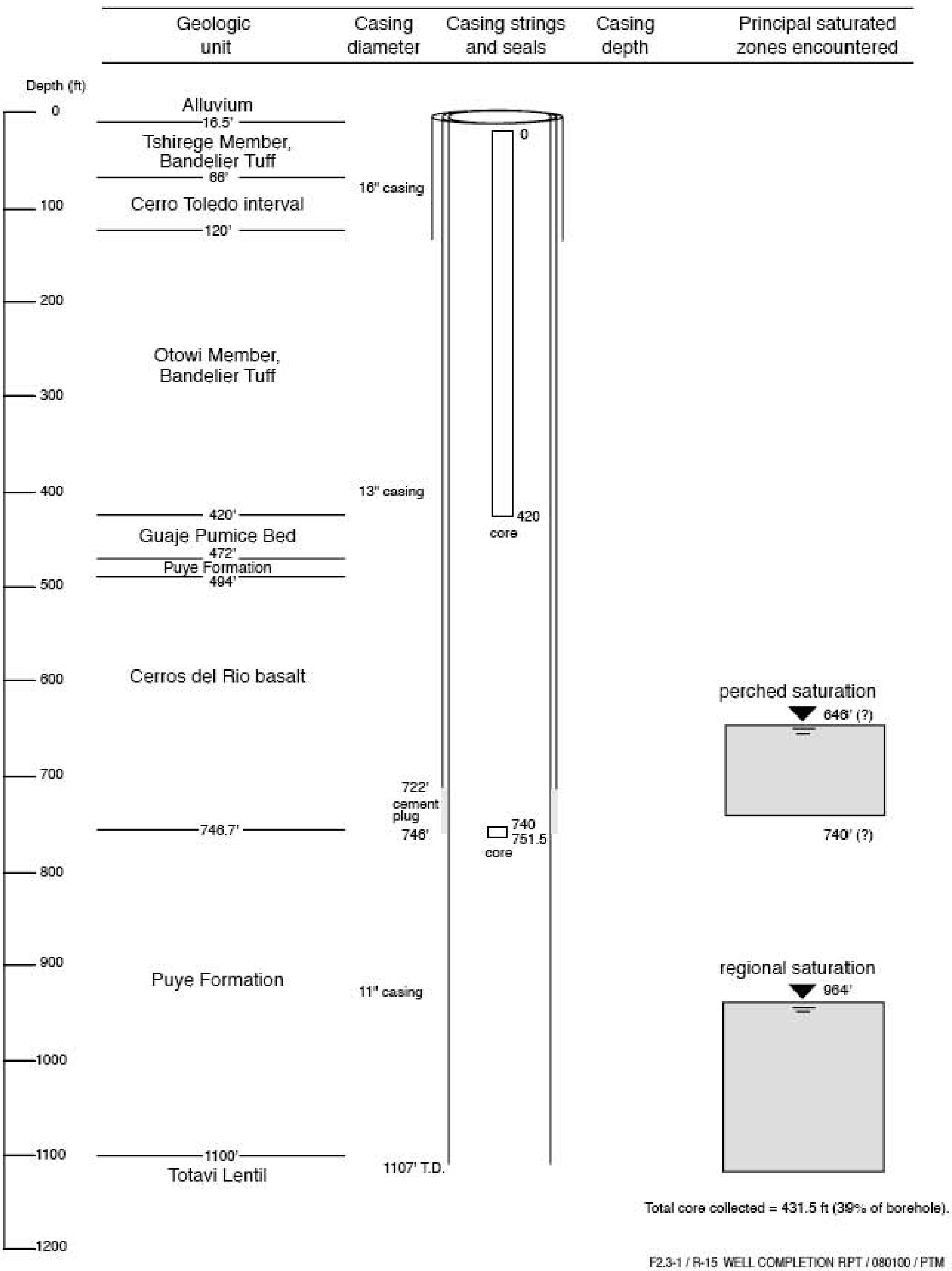
5. Well sump interval: 1293.1 to 1315.6 ft

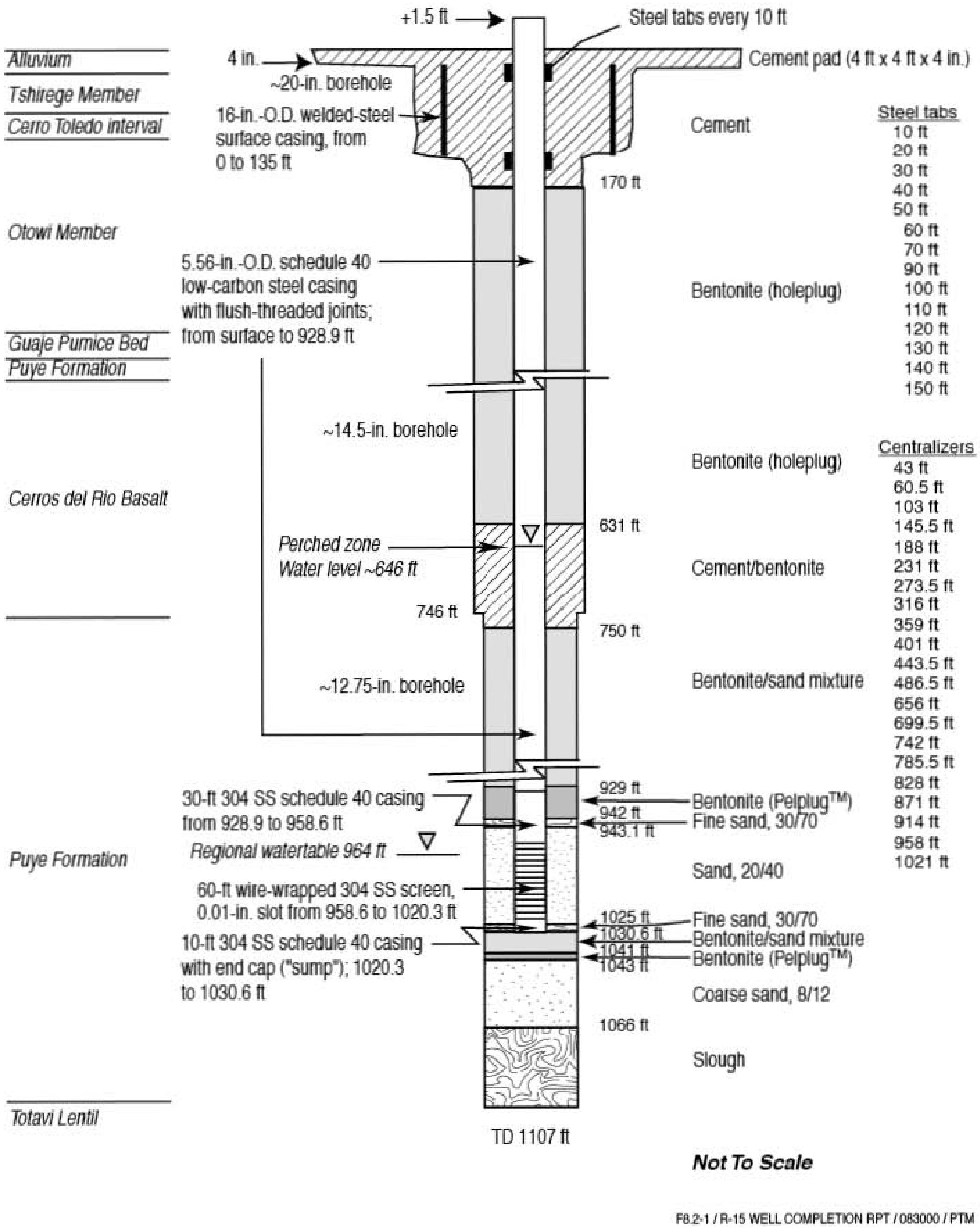
R-15 Well

R-15 Well		
	Description	Evaluation
Drilling Method	R-15 was drilled using fluid-assisted air-rotary casing advance methods.	R-15 was drilled using a combination of reverse-circulation, fluid-assisted air-rotary methods in open hole and with casing advance to TD at 1107 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives (EZ-MUD and TORKEASE). Drilling additives can adversely affect the ability to collect representative water samples, but this effect was minimized in R-15 because drilling and casing advance took place concurrently, thus limiting contact between drilling fluids and the borehole wall. In addition, R-15 is a single completion well; these types of wells are intrinsically easier to develop, and they can be purged before sampling.
General Well Characteristics	R-15 is a single-screen well constructed of 5.56-in.-O.D. schedule 40 low-carbon steel casing from the surface to 928.9-ft depth and 4.5-in.-I.D./ 5-in.-O.D. 304 stainless-steel casing from 928.9 to 1030.6 ft.	The low-carbon steel casing was used in the vadose zone and thus does not affect chemistry of the regional groundwater samples collected. Use of stainless-steel casing in the regional groundwater system prevents corrosion of well materials in the vicinity of the well screen.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.010-in. slots.	Wire-wrap screen is considered the optimum design for promoting the free flow of water during well development and sampling. The wire wrap on the R-15 well screen contains 0.010-in. slots, primarily to minimize the intake of fine-grained aquifer material into the well during development and sampling. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-15 consistently yields water samples considered representative of groundwater conditions in the regional aquifer at this location (see Appendix B). Field parameters, including turbidity, are consistently within acceptable limits. These data indicate that the well screen is properly designed, installed, and developed.
Screen Length and Placement	The well screen extends from 958.6 to 1020.3 ft and has a length of 61.7 ft. It straddles the water table (currently 969 ft below the surface). The amount of submerged screen is 51.3 ft.	This screen length and its placement were selected with the following goals in mind: Provide a monitoring point straddling the regional aquifer below the area where contaminants are believed to be entering the regional aquifer Screen across a long-enough stratigraphic intervals so that contaminants, if present, could be detected among several possible but unknown shallow flow paths Install a well with a 50-yr service life in an area where municipal well drawdown is about 0.8 ft/yr (40 ft over 50 yr)

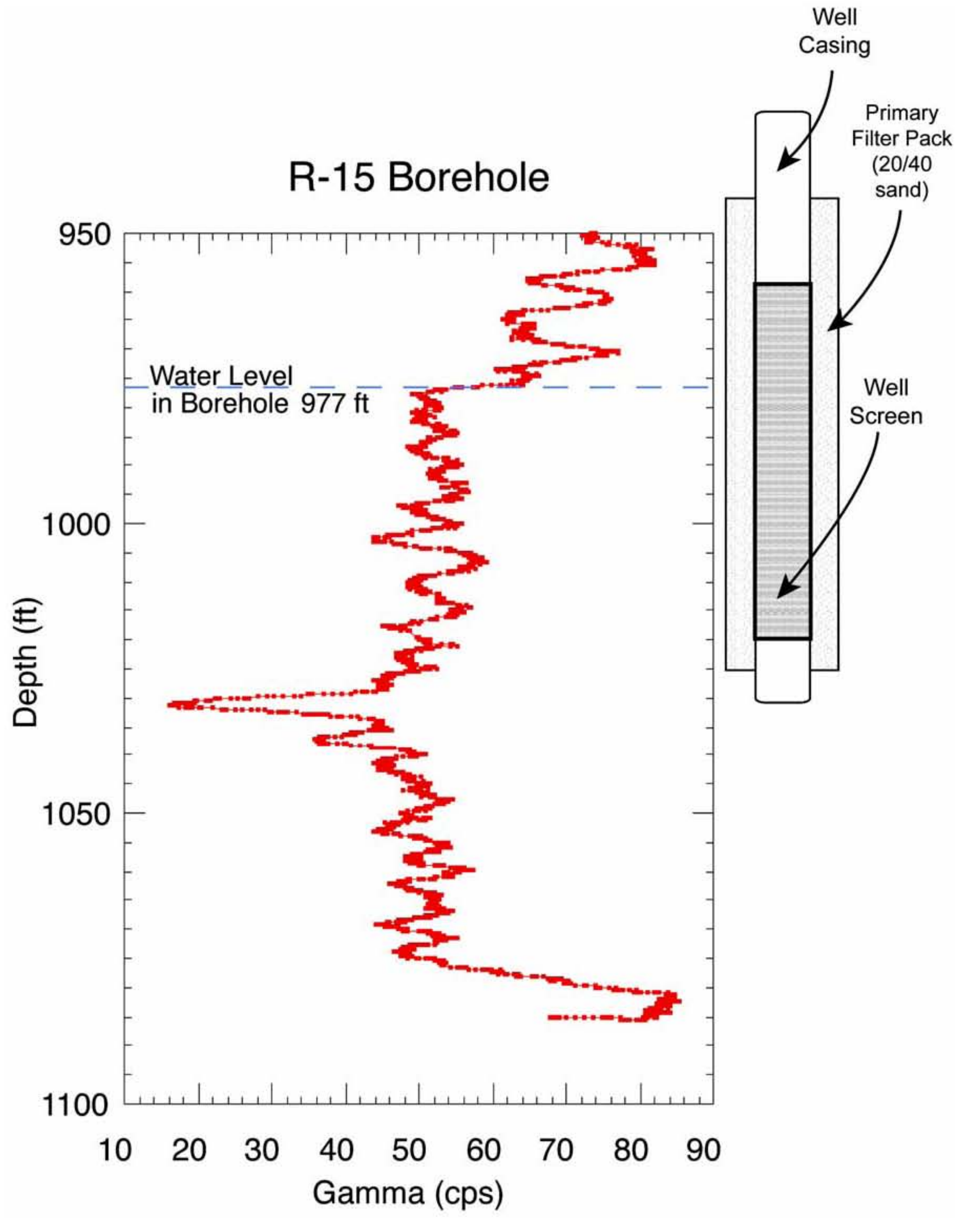
R-15 Well (continued)		
	Description	Evaluation
		The geology below the water table at R-15 is similar to that at nearby wells R-13 and R-28. The upper part of the regional aquifer from 964 to 973 ft is composed of poorly cemented volcaniclastic detritus that forms well-stratified, poorly sorted beds of silts, sands, gravels, and cobbles. From 973 to 1100 ft, the rocks consist of well-stratified sands and gravels with varying amounts of crystal-poor pumice. River gravels were encountered from 1100 to 1107 ft before the borehole was terminated due to unstable borehole conditions. FMI logs from nearby wells such as R-28 and R-33 indicate that individual beds within the regional aquifer range in thickness from a few inches to 5 ft. R-15 was installed prior to extensive use of Schlumberger borehole geophysics for site characterization. In the regional aquifer, a gamma log was collected inside 11 7/8-in. casing using LANL tools. The gamma log shows the usual sharp decline in gamma signal at the water table. Below the water table, the well-screen interval is characterized by a fairly narrow range of gamma values. Below the well-screen interval, there is a pronounced gamma low between 1030- and 1040-ft depth; the very low gamma counts in this zone suggest it may represent a water-filled washout behind the drill casing. Below 1040 ft, gamma counts return to levels observed in the well-screen interval until a depth of 1080 ft where gamma counts sharply increase as the probe approached the open bottom of the borehole. At R-13 and R-28, where more extensive Schlumberger geophysical logs were collected, the lower pumice-rich part of the stratigraphic sequence has higher overall porosity than the pumice-poor rocks at the water table. These higher-porosity pumice-rich rocks are believed to represent hydraulic fast pathways. The placement of the well screen straddling the water table satisfies all three of the three design goals described above. The detection of soluble contaminants and documentation of their temporal variations indicates R-15 is a properly functioning monitoring well (see Appendix B).
Filter Pack Materials and Placement	The primary filter pack is made up of 20/40 sand from 943.1 to 1025 ft. Secondary filter packs of 30/70 sand were placed above the primary filter pack from 942 to 943.1 ft and from 1025 to 1030.6 ft.	The primary filter pack extends 15.5 ft above and 4.7 ft below the well screen. The primary filter pack above the well screen is relatively long, but this part of the well is above the water table, and the longer filter pack does not affect groundwater samples. The 4.7 ft of primary filter pack below the well screen is within normal design criteria.

R-15 Well (continued)		
	Description	Evaluation
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives used		Municipal water EZ-MUD TORKEASE Fluids recovered during development—41,130 gal.
Annular fill other than filter and transition sands		Pelplug Bentonite chips Transition seal of sand and bentonite Surface seal of cement from 0 to 170 ft and cement bridge from 631 to 750 ft.


Geologic unit
Casing diameter
Casing strings and seals
Casing depth
Principal saturated zones encountered
Depth (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Alluvium
16.5'
Tshirege Member, Bandelier Tuff
66'
Cerro Toledo interval
120'
Otowi Member, Bandelier Tuff
420'
Guaje Pumice Bed
472'
Puye Formation
494'
Cerros del Rio basalt
746.7'
Puye Formation
1100'
Totavi Lentil
16" casing
13" casing
722'
cement plug
746'
11" casing
1107' T.D.
0
420
core
740
751.5
core
perched saturation
646' (?)
740' (?)
regional saturation
964'
Total core collected = 431.5 ft (39% of borehole).
F2.3-1 / R-15 WELL COMPLETION RPT / 080100 / PTM



+1.5 ft
Steel tabs every 10 ft
Alluvium
Tshirege Member
Cerro Toledo interval
Otowi Member
Guaje Pumice Bed
Puye Formation
Cerros del Rio Basalt
Puye Formation
Totavi Lentil
4 in.
~20-in. borehole
16-in.-O.D. welded-steel surface casing, from 0 to 135 ft
Cement pad (4 ft x 4 ft x 4 in.)
Cement
170 ft
5.56-in.-O.D. schedule 40 low-carbon steel casing with flush-threaded joints; from surface to 928.9 ft
Bentonite (holeplug)
~14.5-in. borehole
Bentonite (holeplug)
631 ft
Perched zone
Water level ~646 ft
Cement/bentonite
746 ft
750 ft
~12.75-in. borehole
Bentonite/sand mixture
30-ft 304 SS schedule 40 casing from 928.9 to 958.6 ft
929 ft
942 ft
943.1 ft
Bentonite (Pelplug™)
Fine sand, 30/70
Regional watertable 964 ft
Sand, 20/40
60-ft wire-wrapped 304 SS screen, 0.01-in. slot from 958.6 to 1020.3 ft
10-ft 304 SS schedule 40 casing with end cap ("sump"); 1020.3 to 1030.6 ft
1025 ft
1030.6 ft
1041 ft
1043 ft
Fine sand, 30/70
Bentonite/sand mixture
Bentonite (Pelplug™)
Coarse sand, 8/12
1066 ft
Slough
TD 1107 ft
Steel tabs
10 ft
20 ft
30 ft
40 ft
50 ft
60 ft
70 ft
90 ft
100 ft
110 ft
120 ft
130 ft
140 ft
150 ft
Centralizers
43 ft
60.5 ft
103 ft
145.5 ft
188 ft
231 ft
273.5 ft
316 ft
359 ft
401 ft
443.5 ft
486.5 ft
656 ft
699.5 ft
742 ft
785.5 ft
828 ft
871 ft
914 ft
958 ft
1021 ft
Not To Scale
F8.2-1 / R-15 WELL COMPLETION RPT / 083000 / PTM


R-15 Borehole
950
1000
1050
1100
Depth (ft)
10 20 30 40 50 60 70 80 90
Gamma (cps)
Water Level
in Borehole 977 ft
Well
Casing
Primary
Filter Pack
(20/40
sand)
Well
Screen

R-16 Well

R-16 Well		
	Description	Evaluation
Drilling Method	R-16 was drilled using a combination of fluid-assisted air-rotary methods with casing advance and mud-rotary drilling.	R-16 was drilled by reverse-circulation fluid-assisted air-rotary methods in open hole in combination with casing advance to 729 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to 867 ft. The borehole was completed using conventional-circulation mud-rotary methods from 867 to 1287 ft (TD). Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives above 867 ft and by bentonite mud 867 ft to 1287 ft. The borehole was drilled using the drilling additives EZ-MUD and QUIK-FOAM from the surface to a depth of 867 ft. After the change over to mud-rotary drilling, the borehole was held open by bentonite mud as the borehole advanced from 867 ft to 1287 ft. Drilling fluids can adversely affect the ability to collect representative water samples, and aggressive development is critical for their removal. These concerns are particularly important in wells such as R-16 that uses the Westbay sampling system. Westbay is a low-flow sampling system that lacks the ability to purge the well prior to sample collection; consequently, groundwater samples represent waters in proximity to the well screen where residual drilling effects are most pronounced.
General Well Characteristics	R-16 is a four-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.-I.D./ 5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screens were used at R-16 after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective at developing the well in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-16 well screen contains 0.010-in. slots. More recent wells in coarser deposits to the west of R-16 contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The use of the 0.010-in. slot size is appropriate at R-16 to prevent silting of the well, particularly in the lower three screens that are located within generally fine-grained Miocene sedimentary deposits in the deeper part of the aquifer. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. Prior to rehabilitation actvities, none of the well screens produced water that could be considered representative of the regional aquifer at that location (see Appendix B). Screens 2 and 4 in particular had persistent reducing conditions, anomalously high pH values, and residual inorganic drilling constituents.

R-16 Well (continued)		
	Description	Evaluation
Screen Length and Placement	Screen 1 extends from 641 to 648.6 ft (length of 7.6 ft). Based on R-16r, the regional water table is at a depth of 564 ft bgs. Screen 2 extends from 863.4 to 870.9 ft (length of 7.5 ft). The current water level in screen 2 is about 616.9 ft bgs. Screen 3 extends from 1014.8 to 1022.4 ft (length of 7.6 ft). The water level in screen 3 is currently 696.9 ft. Screen 4 extends from 1237 to 1244.8 ft (length of 7.8 ft). The water level in screen 4 is currently 711.9 ft.	The R-16 well screen length and placement were selected with the following goals in mind: Determine the position of the regional water table in the vicinity of the Rio Grande and compare it with the elevation of springs in White Rock Canyon Determine the magnitude and direction of vertical pressure gradients in the vicinity of the Rio Grande Monitor water levels at multiple depths to determine if pressure responses due municipal well pumping in Buckman Well Field extend to the east side of the Pajarito Plateau Characterize the range of hydraulic properties within the Miocene Santa Fe Group sedimentary rocks Provide an off-site monitoring point for mobile constituents in groundwater in the vicinity of the Rio Grande and the Buckman Well Field The geology below the water table at R-16 is composed of, in descending order, (1) interfingering porous axial-river sands and well-rounded gravels of the Totavi Lentil and distal fanglomerate deposits of the Puye Formation (both Pliocene) and (2) interfingering sedimentary deposits of the Miocene Santa Fe Group. The Santa Fe Group rocks are fluvial sediments consisting of sands and gravels deposited in channels intercalated with clay, silt, fine sands, and silty sands deposited on floodplains. Based on the FMI log, the Miocene rocks are generally thin bedded and dip 7°–14° to the west. Schlumberger borehole geophysical logs were collected at R-16; these logs were collected through 11.75-in. drill casing to a depth of 729 ft and in an open hole below. The R-16 logs were of limited use for evaluating screen placement in the cased portion of the borehole because logs show unreasonably high porosities (> 50%), suggesting there are large water-filled washouts behind the casing. The upper part of the open borehole from 729 to 804 ft also has large washouts that impacted the quality of the geophysical logs. The quality of the logs is good for the rest of the borehole. Screen 1 targeted the uppermost part of the regional aquifer in intercalated Totavi and Puye rocks near the water table. During well construction, the 11.75-in. drill casing enclosing screen 1 could not be retracted when it came time to install the annular fill and filter pack around the upper part of the well. The 11.75- in. drill casing remained stuck in place from ground surface to 729 ft bgs, resulting in screen 1 losing its functionality. When it became apparent screen 1 could not be saved, bentonite seals were placed above and below the screen to isolate it from the other screens, and the annulus of the 11.75-in. casing was cemented in place from 130 ft bgs to the surface. R-16 screen 1 was eventually replaced by installation of R-16r, a single-screen well on the same well pad that was completed at the top of the regional aquifer.

R-16 Well (continued)		
	Description	Evaluation
		Screens 2, 3, and 4 are distributed through the Miocene rocks in the middle and lower parts of the regional aquifer. Total porosity of the Miocene rocks typically ranges between 20% and 40%, with clay beds as high as 50% in parts of the borehole unaffected by washouts. Total porosity in screen 2 ranges between 30% and 45%, somewhat greater than the average Miocene rock. Screens 3 and 4 have porosities of 30%–35% that are more typical of the Miocene sediments. The distribution of the screens in rocks with good porosity through the regional aquifer in R-16 and R-16r satisfy the five goals described above. The combination of R-16 and R-16r is particularly well suited to address the hydrologic issues listed in goals 1 through 4. Goal 5 may be impacted to varying degrees by the use of drilling additives and should be evaluated based on sampling results from the individual screens.
Filter Pack Materials and Placement	**Screen 1** (Nonfunctional) **Screen 2** The primary filter pack extends from 852.1 to 877.5 ft and is made up of 20/40 sand. Secondary filter packs of 30/70 sand were placed above and below the primary filter pack at 851.4–852.1 ft and 877.5–882.5 ft, respectively. **Screen 3** The primary filter pack extends from 1006.7 to 1028.5 ft and is made up of 20/40 sand. A secondary filter pack of 30/70 sand was placed above the primary filter pack at 1005–1006.7 ft.	The nominal well design calls for the primary filter pack to extend 5 ft above and below the well screen. The primary filter packs for screens 2 and 3 are very close to the nominal well design. The screen 2 primary filter pack extends 11.3 ft above and 6.6 ft below the well screen. The screen 3 primary filter pack extends 8.1 ft above and 6.1 ft below the well screen. These filter packs are appropriate for the intended use of the well. Slough of formation materials largely covered screen 4 before the primary filter pack could be installed. The filter pack covers 0.7 ft of the well screen and extends 25.3 ft above the well screen. The primary function of this deep screen is to provide water-level data deep within the aquifer. Turbidity values less than 1.9 NTU were achieved during development of screen 4, indicating that fine-grain material was adequately removed from the natural filter pack around the well screen, thereby allowing water to enter the well screen unimpeded.

R-16 Well (continued)		
	Description	Evaluation
	Screen 4 The primary filter pack extends from 1211.7 to 1237.7 ft and is made up of 20/40 sand. A secondary filter pack of 30/70 sand was placed above the primary filter pack at 1203.7–1211.7 ft.	
Sampling System	Westbay Multiple Port (MP) sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids is critical prior to installation of Westbay wells because groundwater is collected in close proximity to the well due to low-flow sampling and the inability to purge the well prior to sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	Well Development	Because of concerns about the removal of drilling additives, the development of R-16 was particularly aggressive. After the well casing was installed, but before the annular fill material was placed, municipal water was pumped into the well annulus at a rate of 20 gal./min to reduce the viscosity of the drilling mud and to facilitate placement of backfill material. A jetting tool was used to help remove drill mud cake from the borehole wall. After jetting, approximately 5 gal of AQUA-CLEAR PFD mixed with 2000 gal. of municipal water was injected at 900 ft bgs. An additional 2 gal. of AQUA-CLEAR PFD mixed with 1000 gal. of municipal water was injected while the tremie pipe was raised and lowered through the screen 2 interval (863 to 871 ft bgs). Water from the borehole annulus then was airlifted from the borehole, and additional water was introduced to ensure the viscosity of the borehole fluid was low enough to begin annular fill placement. Well development at R-16 consisted of wire-brushing the well interior, swabbing and surging the screen intervals to draw fine sediment from the constructed filter pack, and bailing to remove solid materials from the well. Chemical treatment procedures (AQUA-CLEAR MGA, AQUA-CLEAR AE, and AQUA-CLEAR-PFD) were applied to individual well screens to break up and disperse borehole-wall filter cake and particulate buildup in the screen and formation, which were consequences of mud-rotary drilling. To pump each screen level, a submersible pump was lowered to screens 2, 3, and 4, and each isolated water-bearing zone was pumped to remove remaining fines from the filter packs and adjacent formation. At the end of development, screens 2, 3, and 4

R-16 Well (continued)		
	Description	Evaluation
		water-quality parameters were stable, and turbidity was less than the target goal of 5 NTUs; nonetheless, water-quality data from the well screens continued to show effects of residual drilling fluids during subsequent routine sampling. As a result, R-16 was selected for redevelopment in the summer 2006. Extensive redevelopment efforts resulted in much improved water-quality data for screens 2, 3, and 4 (see Appendix B).
Additives used		Interval from 0 to 729 ft: Municipal water—35,800 gal. Liqui-Trol—100 gal. QUIK-GEL—20,000 lb Foam—650 gal. Soda ash—400 lb Interval from 729 to 1287 ft: Municipal water—38,350 gal. EZ-MUD—25.5 gal. Liqui-Trol—5 gal. QUIK-GEL—31,100 lb Magma Fiber—800 lb Pac-L—50 lb N-Seal—800 lb Soda ash— 100 lb Water recovered during development – 76,850 gal.
Annular fill other than filter and transition sands		Pelplug—coated bentonite pellets (39,500 lb) Benseal—grout (100 lb) Surface seal of cement slurry in upper 100 ft of borehole (6580 lb)

Location: West of the waste treatment ponds, north of Overlook Road in White Rock, N.M.

Survey coordinates (brass marker in NW corner of R-16 cement pad):
x: 1659284 E y: 1756711 N (NAD 83)
z: 6256.9 ft asl (NGVD 29)

Drilling: Conventional mud drilling, casing advance.
R-16 Start date: 08/16/02.
R-16 End date: 08/29/02.

Borehole R-16 drilled to 1287 ft bgs. (T.D.).

Data collection:
- Hydrologic properties: Field hydraulic test: Constant Rate Injection Test on screen #2, screen #3, and screen #4
- Cores/cuttings submitted for geochemical and contaminant characterization: (0)
- Groundwater samples submitted for geochem and contaminant characterization: (3)
- Geologic properties: (16) Mineralogy, petrography, and chemistry
- Borehole logs from R-16: Lithologic: 0-867 ft and 1047 ft-1287 ft. Natural gamma (LANL tool): 0-729 ft (cased), 729-1287 ft (open hole). Schlumberger Logs: 0-729 ft (cased), 729-1287 ft (open hole): Array Induction, Combinable Magnetic Resonance, Micro Imager, Sonic Caliper, Litho density, Spectral Gamma, Elemental Capture, Thermal/Epithermal Neutron, Natural Gamma.

Contaminants Detected in R-16 Water Samples: none.

Well construction:
- Drilling Completed: 08/29/02
- Contract Geophysics: 08/30/02 - 08/31/02
- Well Constructed: 08/31/02 - 09/07/02
- Well Developed: 09/14/02 - 12/04/02
- Westbay Installed: 12/6/02 - 12/10/02

Casing: 4.5-in I.D. stainless steel with external couplings.

Number of Screens: 4
4.5-in I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

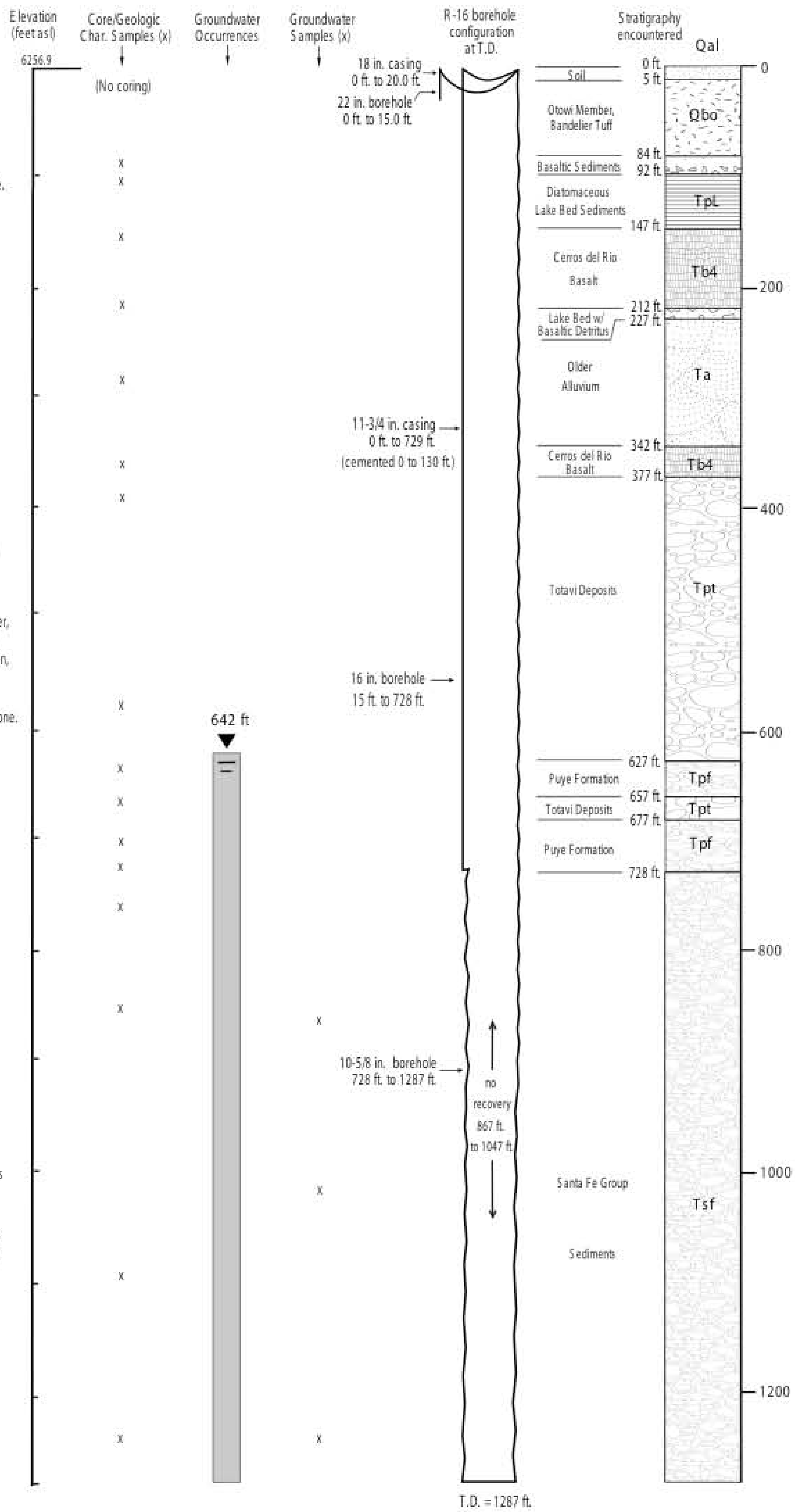
Screen (perforated pipe interval):
- Screen #1 - 641.0 - 648.6 ft bgs. (isolated behind stuck casing)
- Screen #2 - 863.4 - 870.9 ft bgs.
- Screen #3 - 1014.8 - 1022.4 ft bgs.
- Screen #4 - 1237.0 - 1244.6 ft bgs.

Well development consisted of wire brushing, bailing, chemical treatments, surging, simultaneous jetting and pumping, and pumping.

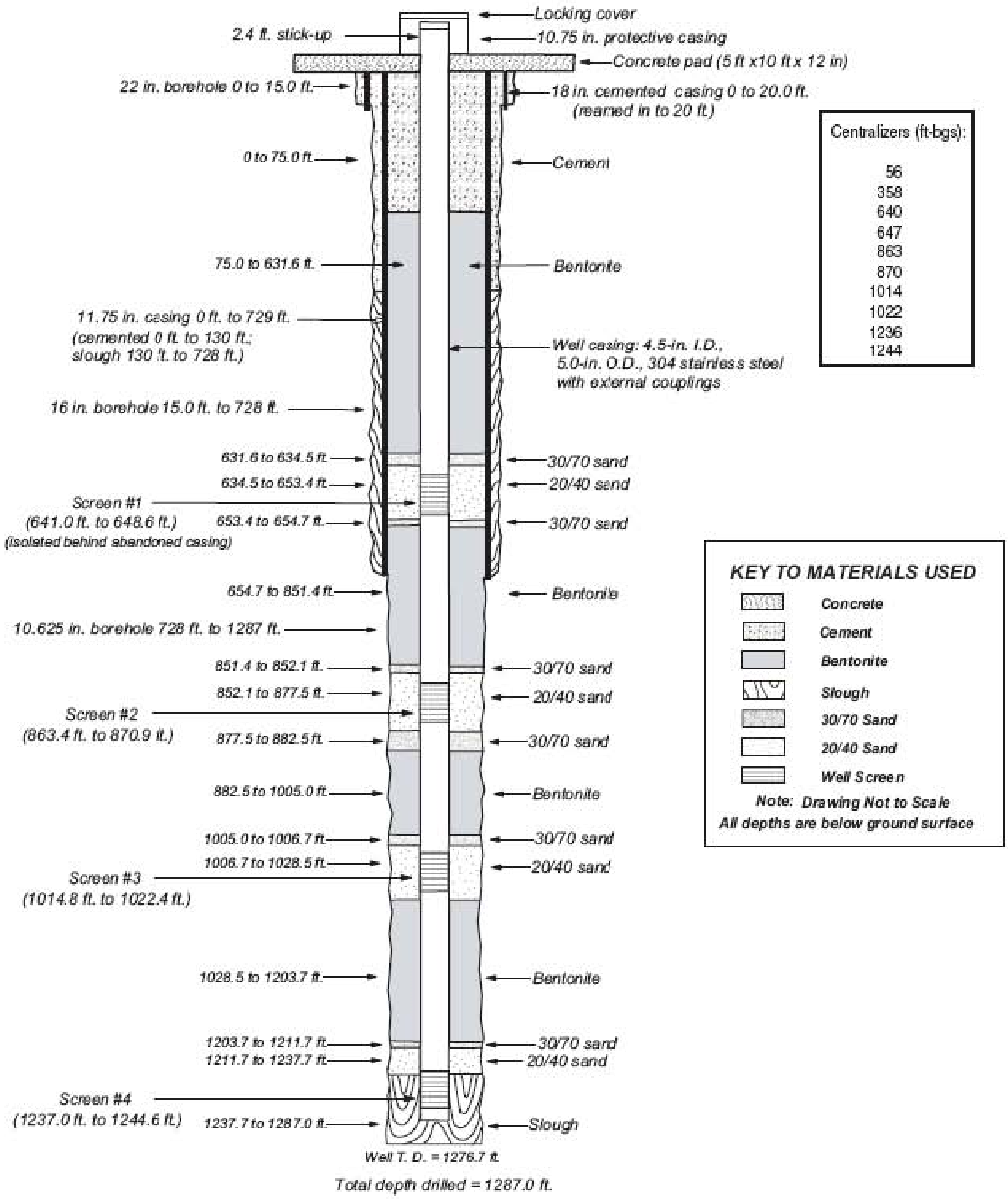
Groundwater occurrence was determined for R-16 by recognition of first water produced while drilling, by borehole geophysics, and by borehole video. Static water levels were determined after the R-16 borehole was rested.

Groundwater samples collected from packed off screen intervals after well development.

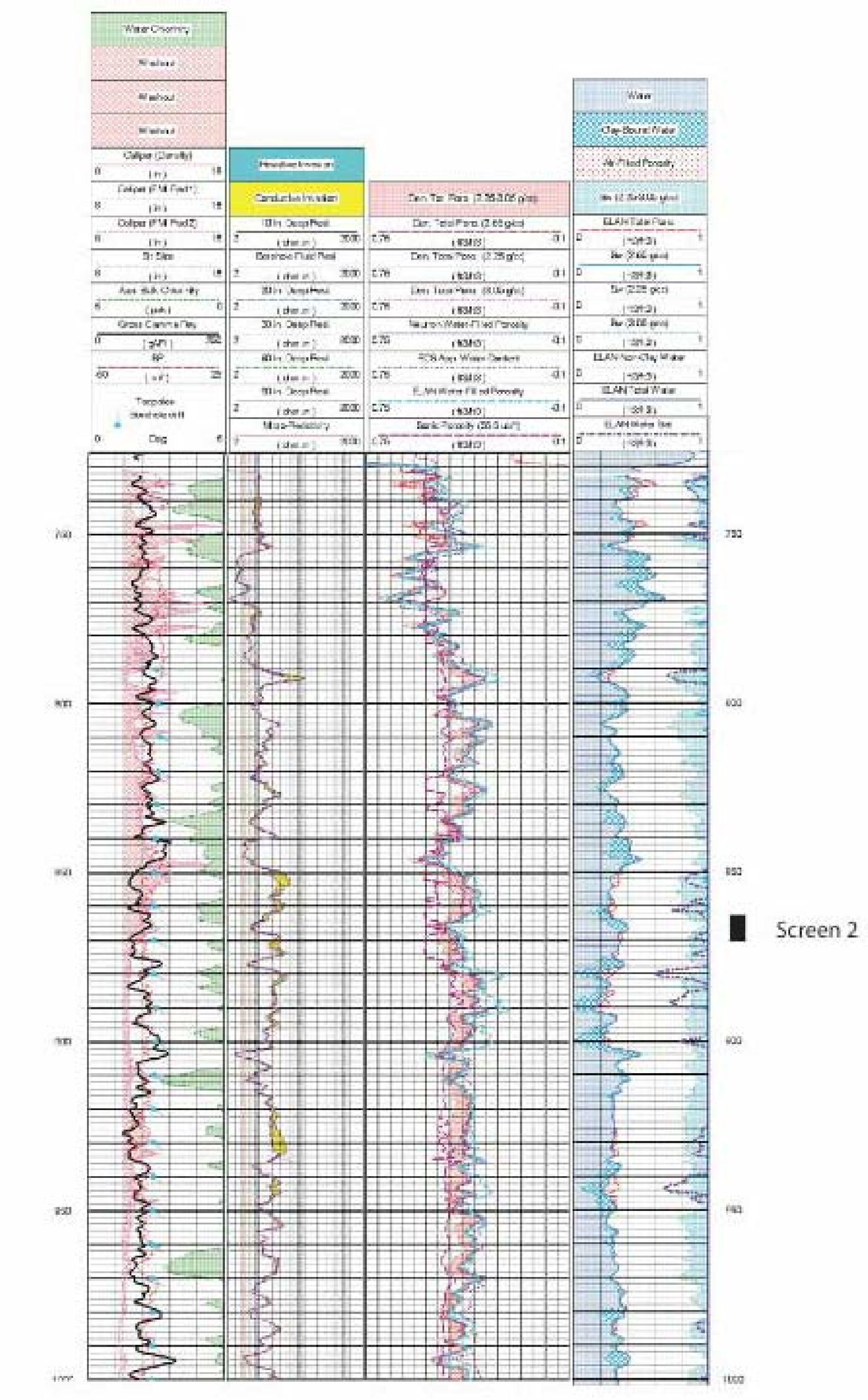
Geologic contacts for R-16 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrographic, geochemical, or mineralogic analysis of geologic samples.



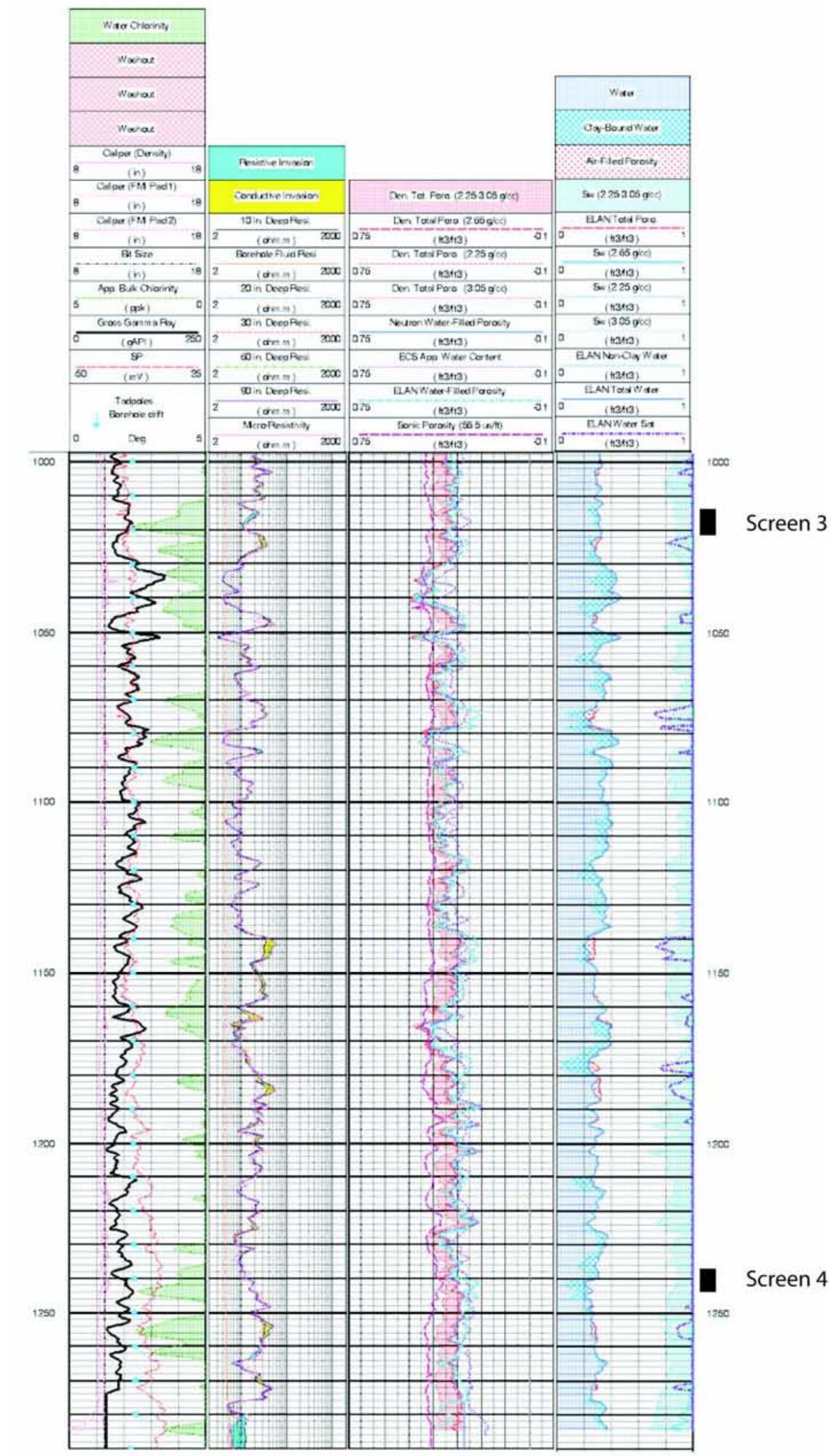
R-16 Well Fact Sheet



Note:
1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. All screens are pipe-based 304 stainless steel, 4.5 in. I.D., 5.563 in. O.D., with s.s. 0.010 in. wire wrap slots.
3. The interval of slough consists of sands and gravel of the Santa Fe Group Sediments.
4. Westbay multiport sampling system (MP-55) casing not shown.
5. 11.75 in. casing abandoned in borehole rendered screen #1 non-functional.
6. Well sump interval: 1244.6 to 1276.4 ft.



Summary of R-16 Open Borehole Geophysical Logs for the Regional Aquifer



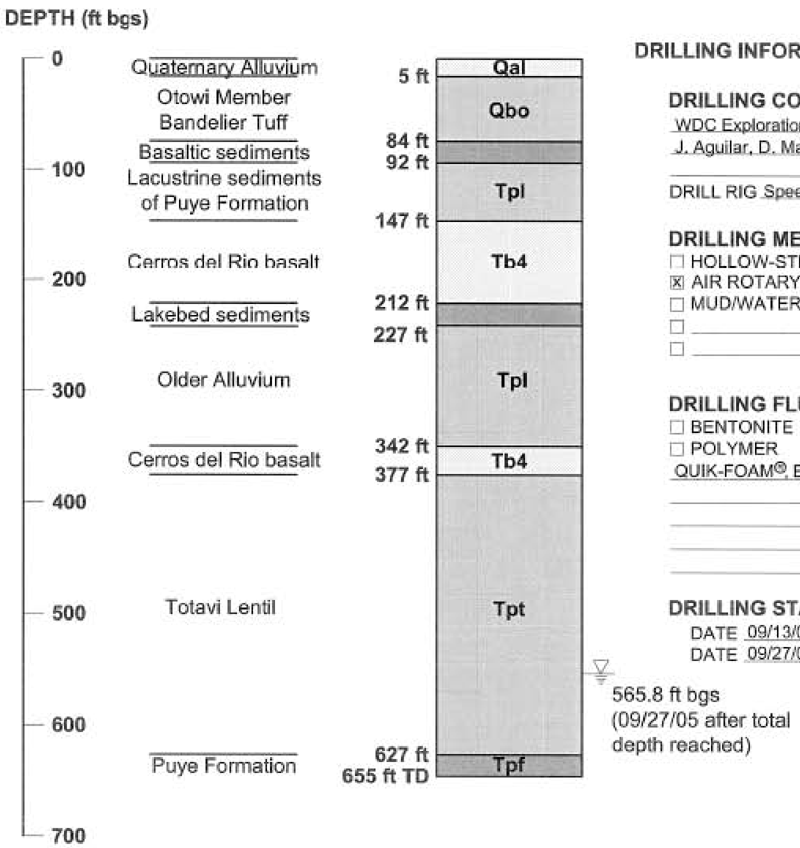
Summary of R-16 Open Borehole Geophysical Logs for the Regional Aquifer (con't)

R-16r Well

R-16r Well		
	Description	Evaluation
Drilling Method	R-16r was drilled using a combination of air-rotary and fluid-assisted air-rotary methods with casing advance.	R-16r was drilled by conventional-circulation fluid-assisted air-rotary methods with casing advance to TD at 640 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives (QUIK-FOAM and EZ-MUD). Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-16r because the regional aquifer was drilled by casing advance methods, resulting in minimal contact of fluids with the borehole wall during drilling. Also, R-16r is a single completion well; these types of wells are intrinsically easier to develop, and they can be purged before sampling.
General Well Characteristics	R-16r is a single-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D.-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.- I.D./ 5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation may be less effective at developing the well in those areas that are not adjacent to the holes in the well casing. Also, the wire wrap on the R-16r well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-16r consistently yields water samples considered representative of groundwater conditions in the regional aquifer at this location (see Appendix B). Field parameters, including turbidity, are consistently within acceptable limits. These data indicate that the well is properly designed, installed, and developed.
Screen Length and Placement	The well screen extends from 600 to 617.6 ft and has a length of 17.6 ft. The top of the screen is 36 ft below the water table (currently 564 ft below the surface).	The R-16r well screen length and placement were selected with the following goals in mind: Replace R-16, screen 1 that is covered by drill casing and is unusable Provide an off-site monitoring point for groundwater quality near the regional water table in the vicinity of the Rio Grande and the Buckman Well Field Place the screen in strata with good hydraulic characteristics Submerge the screen fully to facilitate well development

R-16r Well (continued)		
	Description	Evaluation
		The geology below the water table at R-16r is made up of porous axial-river sands and well-rounded gravels of the Totavi Lentil. Schlumberger borehole geophysical logs were collected at R-16; these logs were collected through 11.75-in. drill casing to a depth of 729 ft and in an open hole below. The R-16 logs were of limited use in placing the R-16r well screen because the interval of interest was logged through drill casing. The cased-hole logs show unreasonably high porosities (> 50%) throughout the Totavi Lentil, suggesting there are large water-filled washouts behind the casing. Lack of useful logs did not significantly hinder the well design because the goal of placing a fully submerged screen near the regional water table constrained the vertical position of the well screen. Also, the screen was placed within the Totavi Lentil, a very conductive unit. The placement of a 17.6-ft well screen 36 ft beneath the water table in permeable rocks satisfied the four design goals described above.
Filter Pack Materials and Placement	The primary filter pack is made up of 10/20 sand from 567 to 640 ft.	The primary filter pack extends 33 ft above and 22.4 ft below the well screen. The primary filter pack is longer than the nominal well design of 5 ft above and below the well screen because the field team had difficulty accurately tagging the top of the filter pack during installation. After emplacement, drillers used a swabbing tool to settle the filter pack along the screened interval. A transition filter pack of 20/40 was not placed above the primary filter pack because the primary filter pack extended so far above the well screen. The extended filter pack should not adversely affect the ability of the well to detect contaminants near the water table. The top of the primary filter pack is 3 ft below the water table, allowing water to be drawn from the uppermost part of the regional aquifer. The bottom of the filter pack from 627 to 640 ft is within Puye Formation strata that are interbbeded with the lower part of the Totavi Lentil. The Puye Formation is generally less conductive than the Totavi Lentil; thus, groundwater samples are probably drawn primarily from the Totavi Lentil.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a

R-16r Well (continued)		
	Description	Evaluation
Additives used		Municipal water during drilling and well construction—5879 gal. EZ-MUD—14 gal. QUIK-FOAM—25 gal. Fluids recovered—21,411 gal.
Annular fill other than filter and transition sands		Bentonite—(468.5 ft^3) Surface seal of cement slurry (81 ft^3)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL
WDC Exploration & Wells
J. Aguilar, D. Mathews, Q. Stevens

DRILL RIG Speedstar 50k

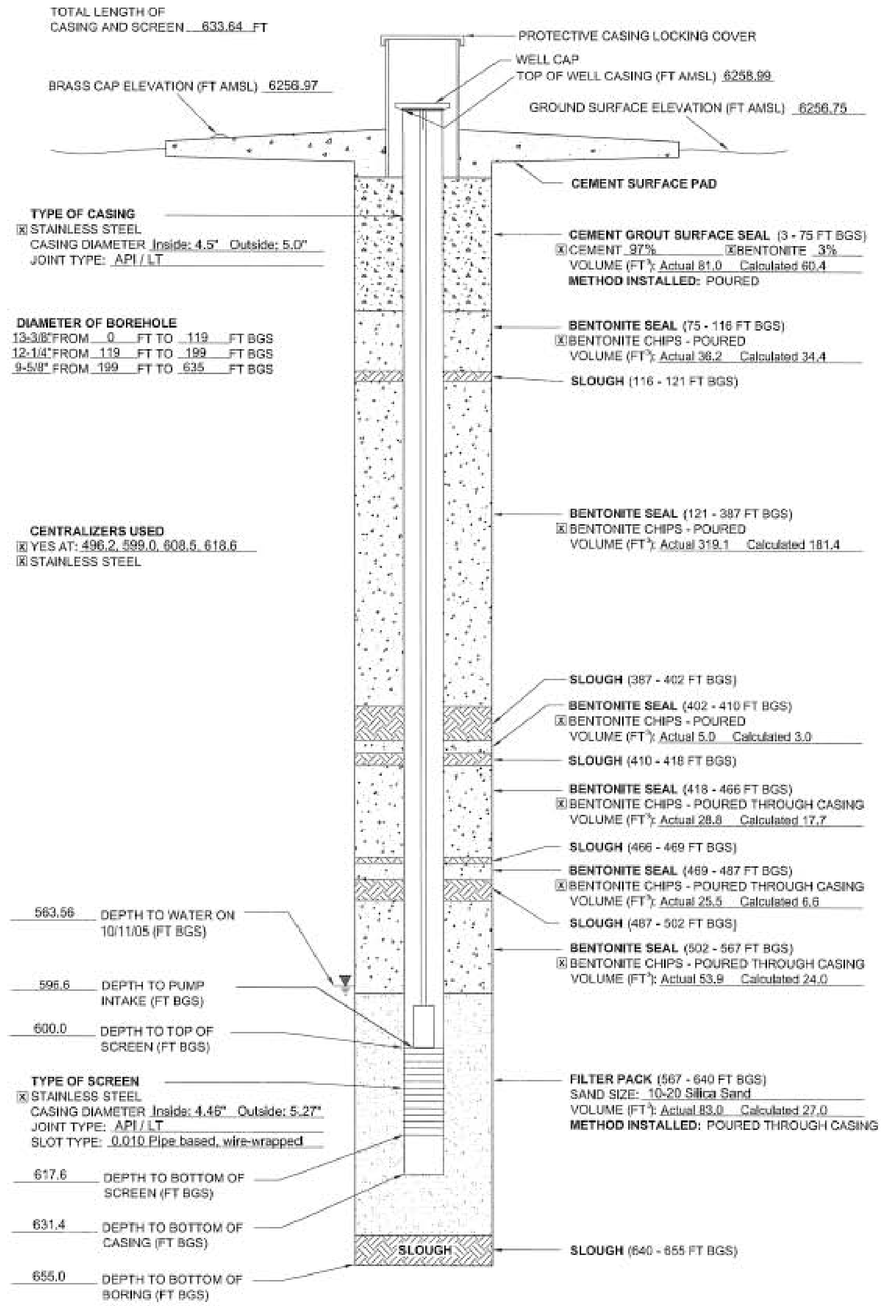
DRILLING METHOD
☐ HOLLOW-STEM AUGER
☒ AIR ROTARY
☐ MUD/WATER ROTARY
☐
☐

DRILLING FLUID TYPE
☐ BENTONITE ☒ WATER
☐ POLYMER ☒ AIR
QUIK-FOAM®, EZ-MUD®

DRILLING START / FINISH
DATE 09/13/05 TIME 14:05
DATE 09/27/05 TIME 09:50

Note:
Geologic contacts are preliminary and subject to change.

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET	FIGURE
Drawn By: C. Bhongir	Date: January 2006	**Characterization Well R-16r**	**6.1-1**
Project No.: 49436	Filename: Figure 6.1-1.dwg	Cañada del Buey	
Scale: not-to-scale	Revision: –	Los Alamos, New Mexico	



WELL DEVELOPMENT INFORMATION

WELL COMPLETION BEGAN
DATE 10/04/05 TIME 12:20
WELL COMPLETION FINISHED
DATE 10/11/05 TIME 12:37

WELL DEVELOPMENT BEGAN
DATE 10/12/05 TIME 09:15
WELL DEVELOPMENT FINISHED
DATE 10/17/05 TIME 16:44

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING ☒ PUMPING
TOTAL PURGE VOLUME 20,711 GALLONS

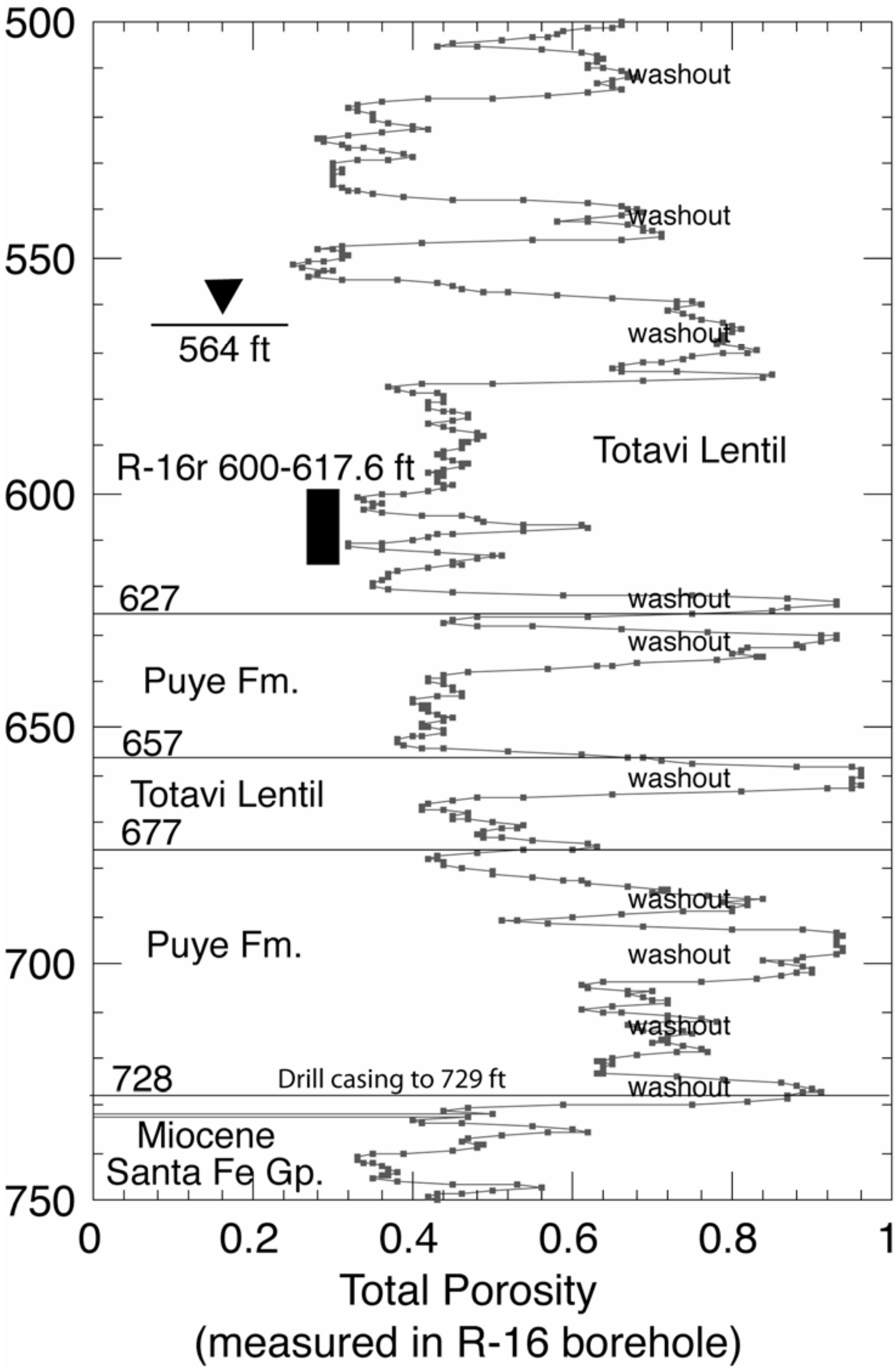
PARAMETER MEASUREMENTS
pH 8.07
TEMPERATURE 20.6 °C
SPECIFIC CONDUCTANCE 176 µS
TURBIDITY 4.28 NTU

KLEINFELDER

Drawn By: C. Bhongir	Date: January 2006
Project No.: 49436	Filename: Figure 7.2-1.dwg
Scale: not-to-scale	Revision: –

WELL SCHEMATIC
Characterization Well R-16r
Cañada del Buey
Los Alamos, New Mexico

FIGURE
7.2-1



Summary of R-16r Borehole Porosity Logs for the Top of Regional Aquifer

R-17 Well

R-17 Well		
	Description	Evaluation
Drilling Method	R-17 was drilled in two phases. Phase I involved coring to 300.9 ft. Phase II used air-rotary methods with foam to 1167-ft depth.	Core was collected with a 3.9-in.-I.D. core barrel to 232.9 ft; from 232.9- to 300.9-ft depth. A2.0-in. O.D. split spoon was used to improve core recovery. Open-hole air rotary with 12.25 in.-O.D. chisel-tooth bit from surface to 520-ft depth Open-hole air rotary with 12.25 in. down-the-hole hammer from 520- to 1167-ft depth R-17 was designed as a two-screen well. The screens are separable by packers and can be pumped separately. A Baski sampling system, which separates the screens with a packer to allow individual pumping, has been installed.
General Well Characteristics	R-17 is a two-screen well constructed of 4.5-in.-I.D./ 5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction (1057.0–1080.0 and 1124.0–1134.0)	The pipe-based screen is constructed of 4.5-in.-I.D./5.3-in. O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.020-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development is less effective in those areas that are not adjacent to holes in the well casing. However, the wire wrap on the R-17 well screens contains 0.020-in. slots that permit greater flow than 0.010-in. slots when surging and pumping the well during development. Development of the two screens at R-17 included swabbing, bailing, integral pumping, and separate pumping at each screen with a packer emplaced. At the end of development both screens were capable of producing water with NTUs < 4.

<table>
<tr><th colspan="3">R-17 Well (continued)</th></tr>
<tr><th></th><th>Description</th><th>Evaluation</th></tr>
<tr><td>Screen Lengths and Placement</td><td>The upper screen is 23.0 ft long, placed from 1057.0- to 1080.0-ft depth. The top of the upper screen is 19.3 ft below the water table (1037.7-ft depth on 1/26/2006, when the well had been completed).

The lower screen is 10.0 ft long, placed from 1124.0 to 1134.0 ft depth. The top of the lower screen is 86.3 ft below the water table (1037.7-ft depth on 1/26/2006).</td><td>Relevant stratigraphy:

Puye Fm (Tpf) from 768 to 1210 ft depth; pumiceous deposits of the upper Santa Fe Group from 1210 ft depth to TD (1327 ft).

Relevant geophysical log results:

Schlumberger logging tools were run open-hole from 30 ft depth (below conductor casing, which extends to 28.2 ft) to 1146 ft or 1150 ft depth (depending on the tool being run). The tools used were CMR, CNT, TLD, AIT, FMI, GPIT, NGS, and ECS. An ELAN was performed by Schlumberger using the log results. The ELAN analysis indicated likely top of regional saturation at ~1044-ft depth, although depth to water in the hole during logging ranged between 1038 and 1042 ft. The ELAN analysis indicated most productive intervals to be at 1056–1058, 1078–1083, 1093–1099, 1100–1110, 1124–1128, 1133–1137, 1140–1143, and possibly 1146–1152 ft (not all off the tools extended below 1146 ft). The upper screen at R-17 captures most of the two uppermost productive zones; the lower screen captures all of the zone at 1124–1128 ft and the top of the zone at 1133–1137 ft depth.

In addition to these zones beneath the water table, the Schlumberger analysis noted possible perched saturation at ~584–682- ft depth, at the top of the dacite lavas.

The LANL video tool was run four times, twice to 162- ft depth, once to 842 ft depth, and once to 1039-ft depth. The videos suggested (1) wet borehole wall at 139–147 ft but without indication of flow; (2) possible flow into the borehole at 495–506 ft (Guaje Pumice Bed); 513, 518, 529, and 560 ft (upper Puye Formation, above the dacite lavas); 584 and 670 ft (within the dacite lavas); and 840-ft depth (lower Puye Formation). In addition, the Kleinfelder gamma and induction tools were run from beneath the conductor casing (28.2 ft) to 881-ft depth.

Upper screen placement:

The upper screen was located to be close to the top of regional saturation yet submerged deep enough for aggressive development. This screen Is within Puye Formation fanglomerates. The upper screen length and placement were selected with the following goals in mind:

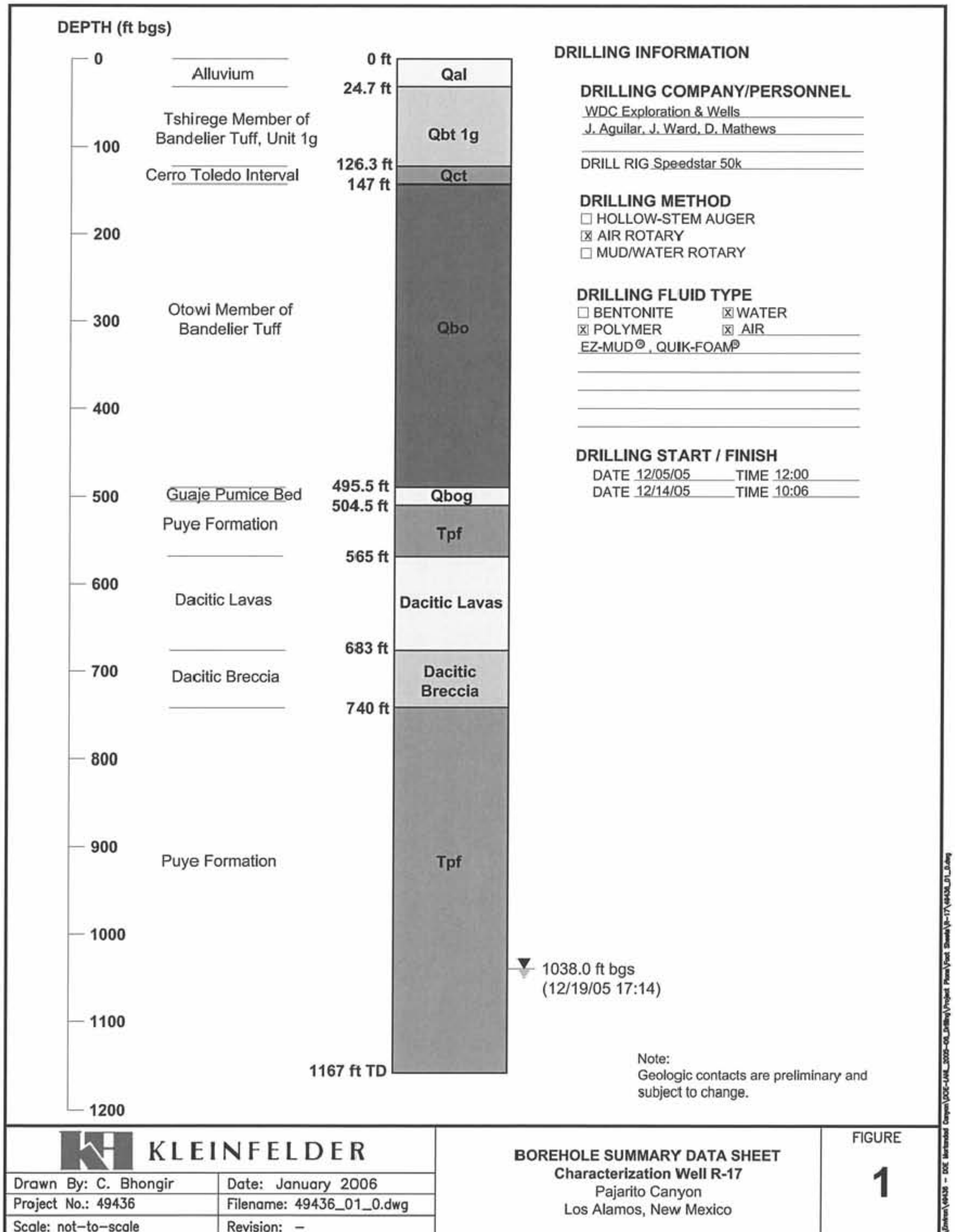
1. Provide a monitoring point for the uppermost part of the regional aquifer immediately downstream of the flood retention structure in Pajarito Canyon

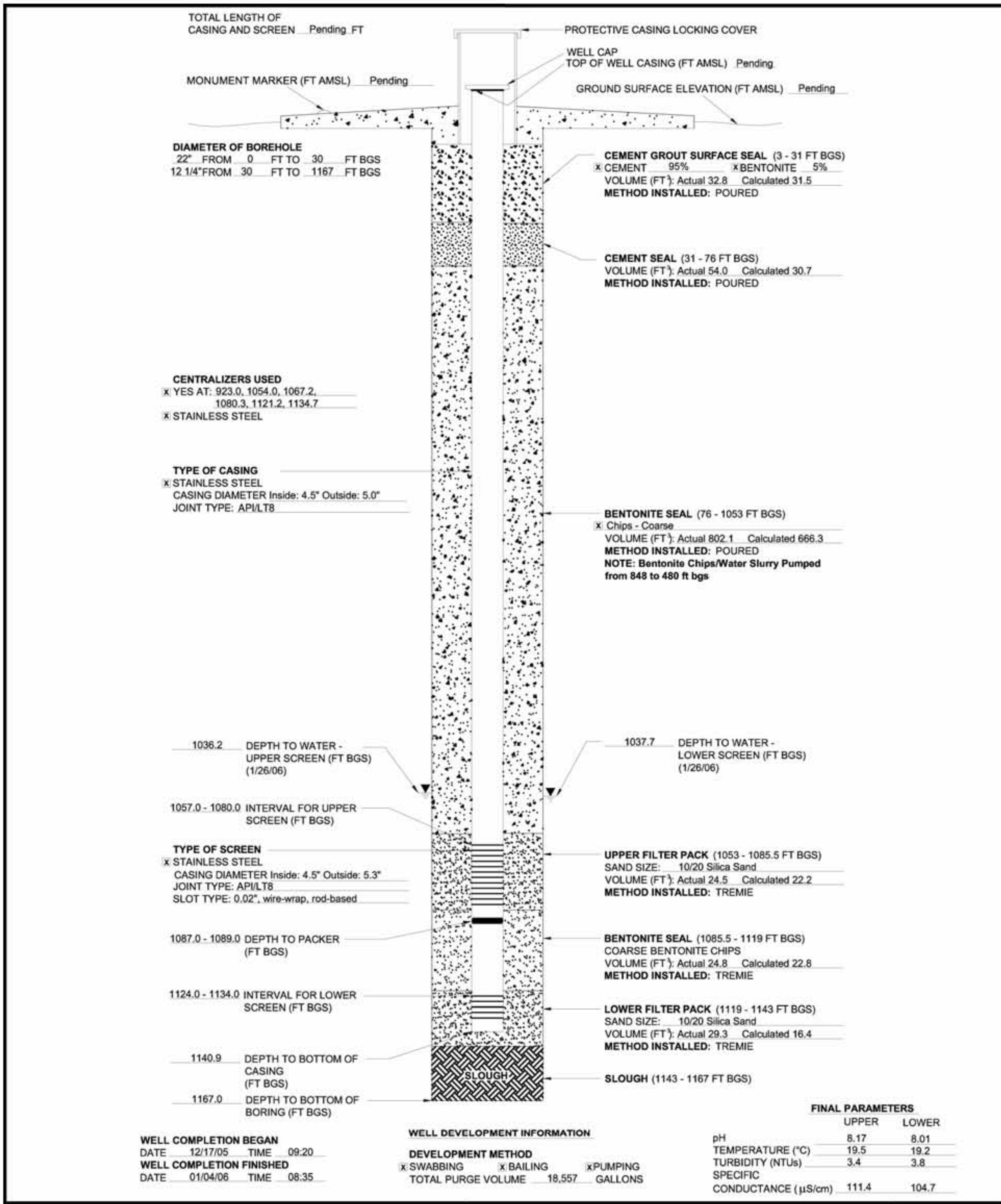
2. Submerge the screen fully to facilitate well development

3. Capture much of the two uppermost productive zones (1056–1058- and 1078–1083-ft depth) identified in the Schlumberger ELAN analysis</td></tr>
</table>

R-17 Well (continued)		
	Description	Evaluation
		Lower screen placement: The lower screen was placed to 1. monitor a deeper zone of the regional aquifer in the Puye Formation, 2. capture all of the productive zone at 1124–1128 ft and the top of the zone at 1133–1137-ft depth, and 3. provide greatest possible spacing from the upper screen to obtain head data relevant to the regional aquifer beneath a central part of LANL where few such data exist.
Filter Pack Materials and Placement *Upper screen:* (primary 1053.0–1085.5 ft; no secondary sand) *Lower screen:* (primary 1119.0–1143.0 ft; no secondary sand)	The primary filter pack is made up of 10/20 sand.	***Upper screen:*** Primary filter pack extends 4.0 ft above the screen openings and 5.5 ft below. ***Lower screen:*** Primary filter pack extends 5.0 ft above the screen openings and 9.0 ft below.
Sampling System	Baski packer with dual valve system and single pump	The Baski system is a conventional-flow sampling system that allows groundwater to be sampled from two well screens within a single well installation. Well screens are isolated by packers and sampled individually. Pressure-activated valves are situated at each screen and connected by 1-in. diameter pipe to the pump. The pump is located above the packer and is shrouded to isolate the pump to obtain water from whichever valve is open. The pump is capable of 12 gal/m, which provides quick conventional purging and sampling of each zone in the well. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water requires additional resources relative to low-flow sampling systems. The Baski packer system incorporates separate gage tubes that provide access to each screen zone using conventional transducer equipment and manual measurement methods.
Other Issues That Could Affect the Performance of the Well		None evident—Given the limited water-quality data record, the well performance will continue to be evaluated as new data are obtained.

R-17 Well (continued)		
	Description	Evaluation
Additives used		In Phase I drilling, no additives were used. In Phase II drilling, air-rotary drilling to 1167-ft depth was assisted by municipal water mixed with limited amounts of QUIK-FOAM and EZ-MUD, followed by defoamer. The well completion report provides the following information on additive use: • Municipal water—5,850 gal. • QUIK-FOAM—74 gal. • EZ-MUD—38 gal. • Defoamer—3 gal.
Annular fill other than filter and transition sands		Bentonite chips—802.1 ft^3 Cement seal—54 ft^3 Cement grout surface seal—32.8 ft^3
Water produced on development and testing		1,777 gal. was removed from both screens (no packer present) through bailing, swabbing, and pumping. ***Upper screen:*** 50 gal. bailed, 14,275 gal. pumped, and 12,055 gal. removed during aquifer testing with packer in place (total 26,380 gal. ***Lower screen:*** 7,323 gal. pumped and 4,528 gal. removed with packer in place during aquifer testing (11,851 gal. total)


DEPTH (ft bgs)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Alluvium
Tshirege Member of Bandelier Tuff, Unit 1g
Cerro Toledo Interval
Otowi Member of Bandelier Tuff
Guaje Pumice Bed
Puye Formation
Dacitic Lavas
Dacitic Breccia
Puye Formation
0 ft
24.7 ft
126.3 ft
147 ft
495.5 ft
504.5 ft
565 ft
683 ft
740 ft
1167 ft TD
Qal
Qbt 1g
Qct
Qbo
Qbog
Tpf
Dacitic Lavas
Dacitic Breccia
Tpf
1038.0 ft bgs (12/19/05 17:14)
DRILLING INFORMATION
DRILLING COMPANY/PERSONNEL
WDC Exploration & Wells
J. Aguilar, J. Ward, D. Mathews
DRILL RIG Speedstar 50k
DRILLING METHOD
☐ HOLLOW-STEM AUGER
☒ AIR ROTARY
☐ MUD/WATER ROTARY
DRILLING FLUID TYPE
☐ BENTONITE
☒ WATER
☒ POLYMER
☒ AIR
EZ-MUD®, QUIK-FOAM®
DRILLING START / FINISH
DATE 12/05/05 TIME 12:00
DATE 12/14/05 TIME 10:06
Note: Geologic contacts are preliminary and subject to change.
KLEINFELDER
Drawn By: C. Bhongir
Date: January 2006
Project No.: 49436
Filename: 49436_01_0.dwg
Scale: not-to-scale
Revision: –
BOREHOLE SUMMARY DATA SHEET
Characterization Well R-17
Pajarito Canyon
Los Alamos, New Mexico
FIGURE
1



KLEINFELDER

Drawn By: C. Bhongir	Date: May 2006
Project No.: 49436	Filename: 49436_02_0.dwg
Scale: not-to-scale	Revision: –

WELL SCHEMATIC
Characterization Well R-17
Pajarito Canyon
Los Alamos, New Mexico

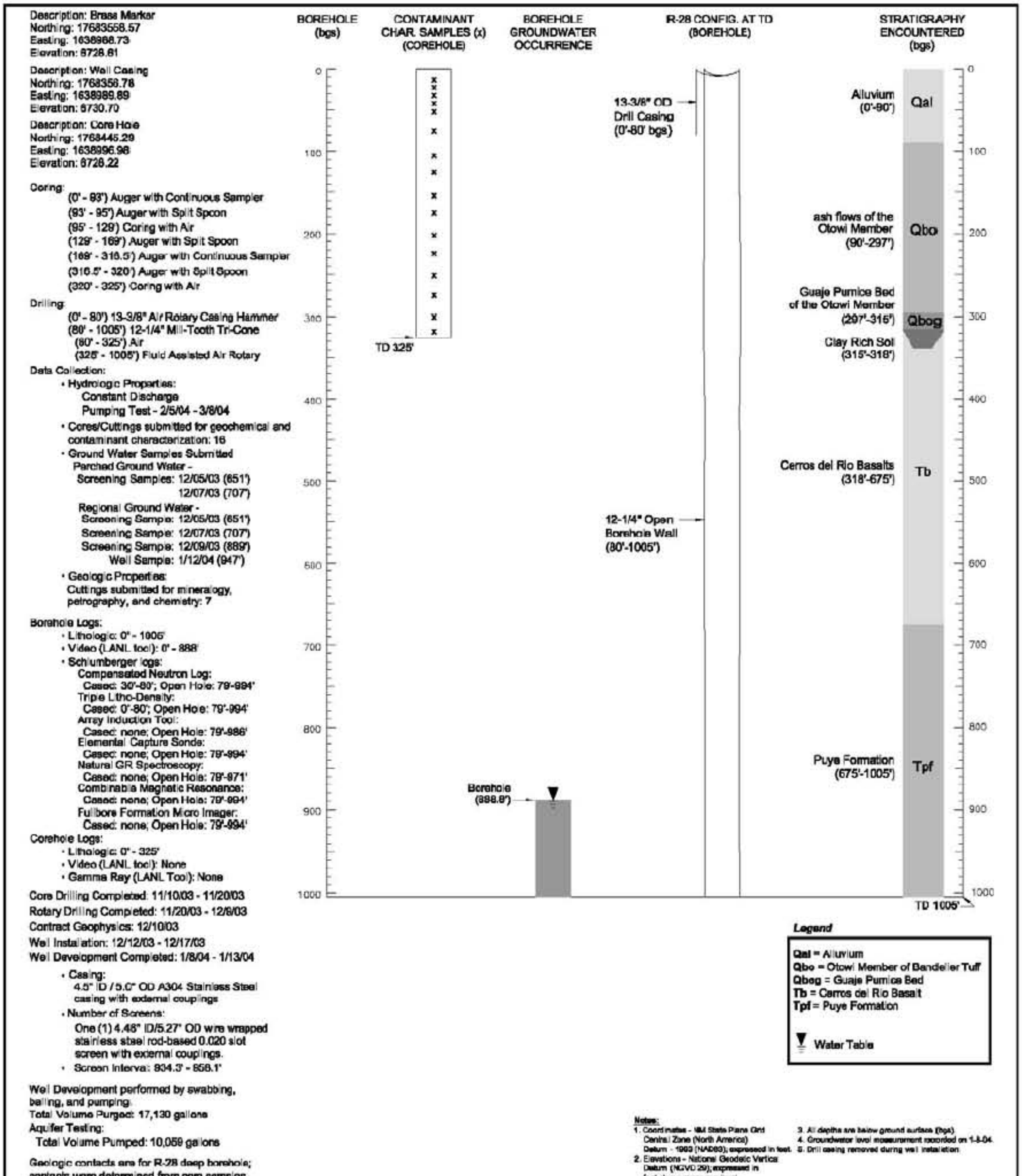
FIGURE
7.2-1

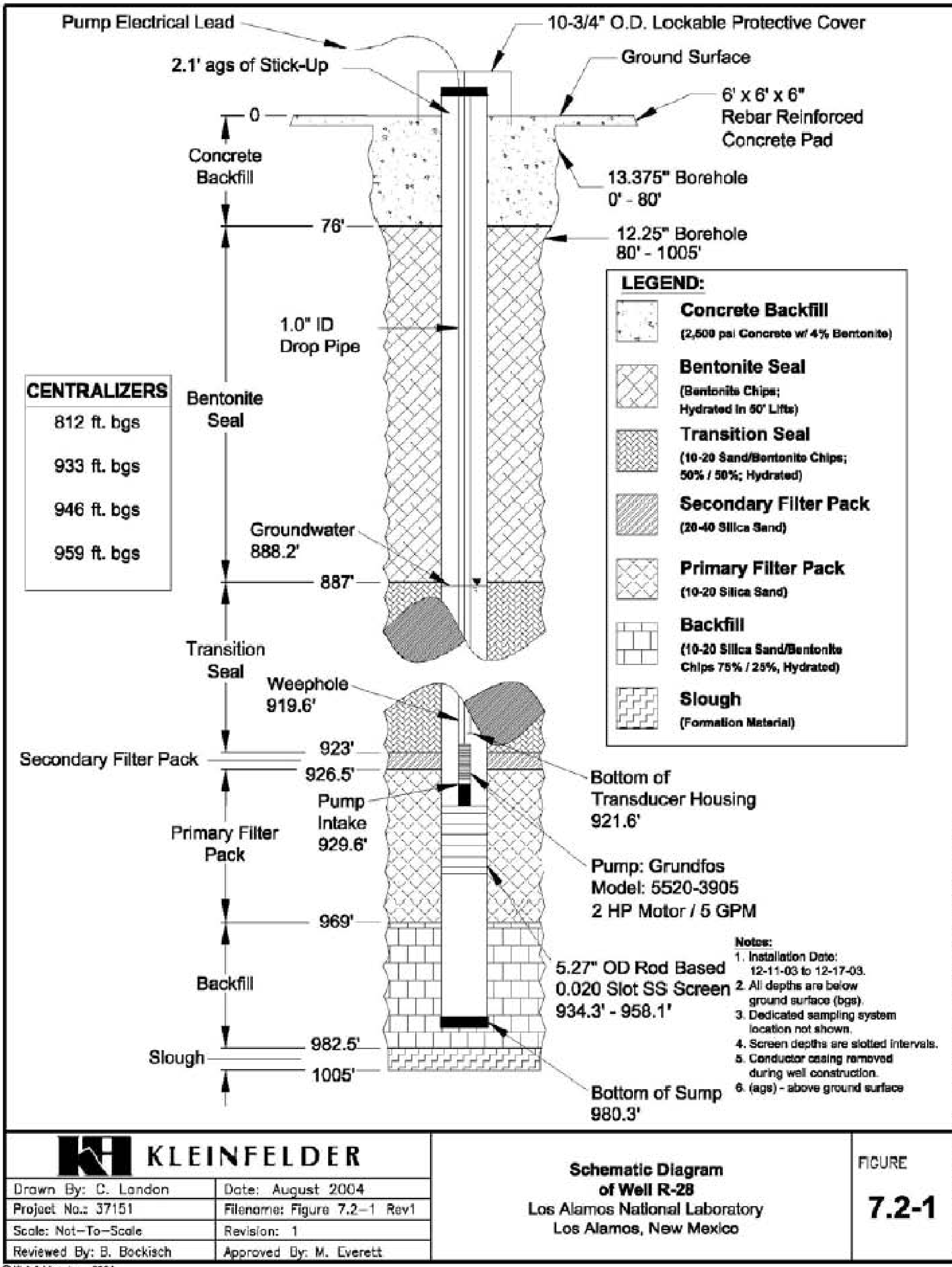
R-28 Well

R-28 Well		
	Description	Evaluation
Drilling Method	R-28 was drilled using fluid-assisted air-rotary methods.	R-28 was drilled by conventional-circulation, fluid-assisted, air-rotary methods with casing advance to 80 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1005 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives including QUIK-FOAM and EZ-MUD. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-28 because it is a single completion well; these types of wells are intrinsically easier to develop, and they can be purged before sampling.
General Well Characteristics	R-28 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless- steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-28 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling. The ability of 0.020-in. slot wire-wrapped screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-28 consistently yields water samples considered representative of groundwater conditions in the regional aquifer at this location (see Appendix B). Field parameters, including turbidity, are consistently within acceptable limits. These data indicate that the well screen is properly designed, installed, and developed.
Screen Length and Placement	The screen is 23.8 ft long. The well screen is placed from 934.3- to 958.1-ft depth. The top of the screen is 45 ft below the water table that is currently at a depth of 890 ft.	This screen length and its placement were selected with the following goals in mind: Provide a monitoring point for the regional aquifer along potential lateral groundwater flow paths approximately 1400 ft downgradient of where contaminants are believed to be entering the regional aquifer Screen across a long-enough stratigraphic interval that contaminants, if present, could be detected among several possible but unknown flow paths Submerge the screen fully to facilitate well development Install a well with a 50-yr service life in an area where municipal well drawdown is about 0.75 ft/yr (38 ft over 50 yr) The upper part of the regional aquifer at R-28 is comprised of Pliocene and Miocene sedimentary deposits. These deposits are poorly cemented volcaniclastic detritus that forms well-stratified, poorly sorted beds of silts, sands, gravels, and cobbles. Individual beds within the regional aquifer sequence range from a few inches to 5 ft thick. Pumice contents in these rocks increase downhole, particularly below 945 ft.

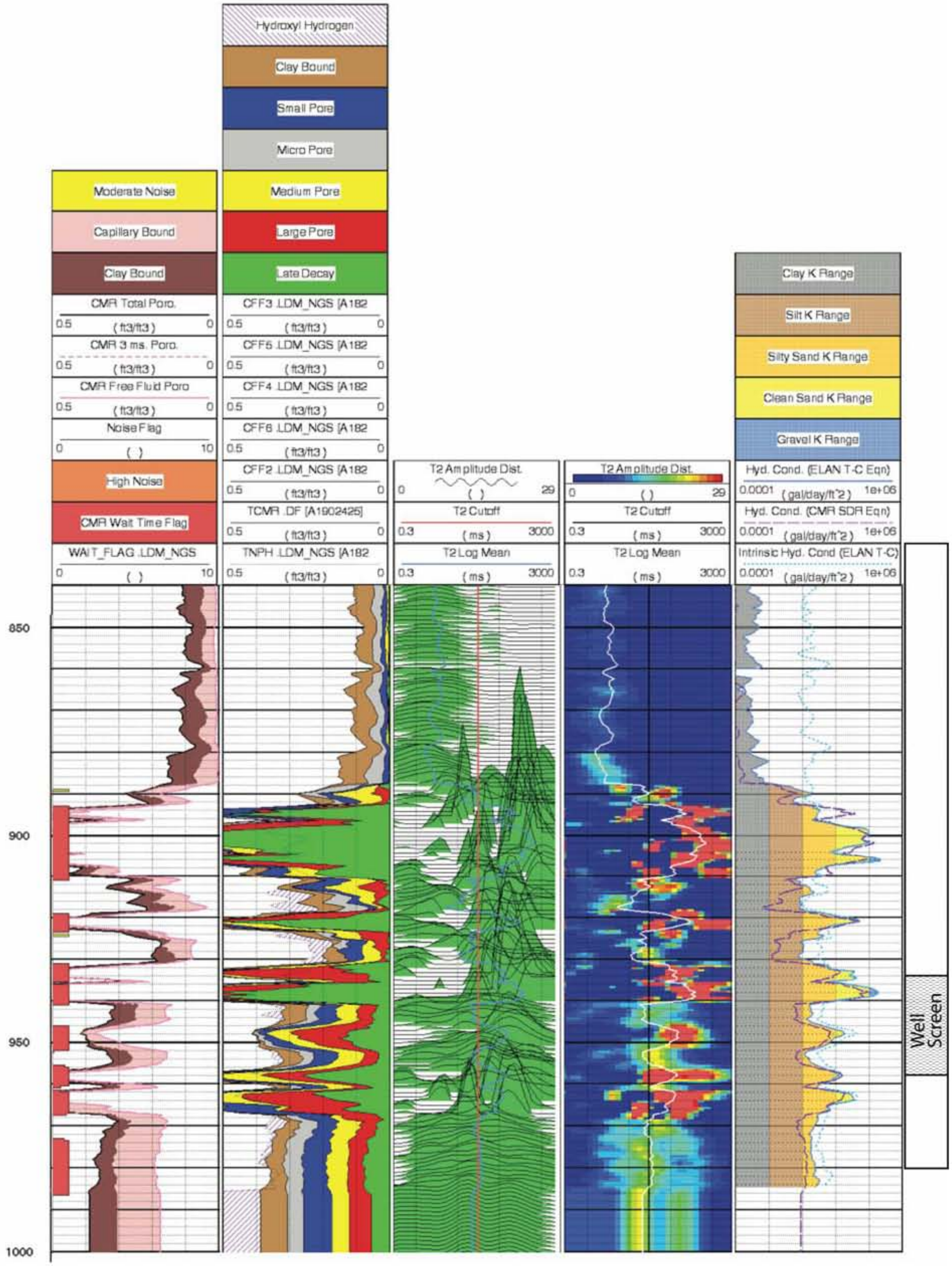
R-28 Well (continued)		
	Description	Evaluation
		According to the Schlumberger log evaluation, the geologic section from 890 ft to the bottom of the log interval (1002 ft bgs) is fully saturated with water throughout. The porosity across this interval is mostly in the range of 30%–40%of the total rock volume, although it is higher in borehole washouts. The most porous zone appears to be at the bottom of the well (932–1000 ft), with porosity reaching 40%. Moveable water content (effective porosity) ranges 12%–20% of total rock volume, reaching a maximum in the same porous zone. The placement of the well screen across the 934.3- to 958.1-ft-depth interval meets the goal for a monitoring well located about 1400 ft downgradient of where contaminants are believed to enter the aquifer. The well screen is located in a zone that contains rocks with high-effective porosity, and the presence of elevated chromium concentrations, chloride, perchlorate, tritium, nitrate, and sulfate (see Appendix B) in groundwater samples confirm that this well screen intercepts a contaminant pathway. The R-28 well is located approximately 1400 ft downgradient of contaminant transport pathways into the regional aquifer, and contaminants are expected to disperse as groundwater moves across the southwest- to south-dipping, stratified, heterogeneous sediments of the aquifer. Given these complexities, a relatively long well screen across multiple permeable horizons in the upper part of the groundwater system is probably the best strategy for detection monitoring at this location.
Filter Pack Materials and Placement	The primary filter pack is made up of 10/20 sand from 926.5 to 969 ft. A secondary filter packs of 20/40 sand was placed above the primary filter pack from 923 to 926.5 ft.	The primary filter pack extends 7.8 ft above and 10.9 ft below the well screen. The primary filter pack above and below the well screen is slightly longer than optimum (5 ft), but these longer sand packs evidently do not impair the ability of the well to detect contaminants (see Appendix B).
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of	None	n/a

R-28 Well (continued)		
	Description	Evaluation
the Well		
Additives used		Municipal water—15,200 gal. QUIK-FOAM—105 gal. EZ-MUD—39 gal. Fluids recovered during development—28,040 gal.
Annular fill other than filter and transition sands		Bentonite—3/8-in chips (5.5 bags) Transition seal of 10/20 sand and bentonite (47 bags of sand and 35 bags of bentonite) Surface seal of cement slurry (22 ft^3)

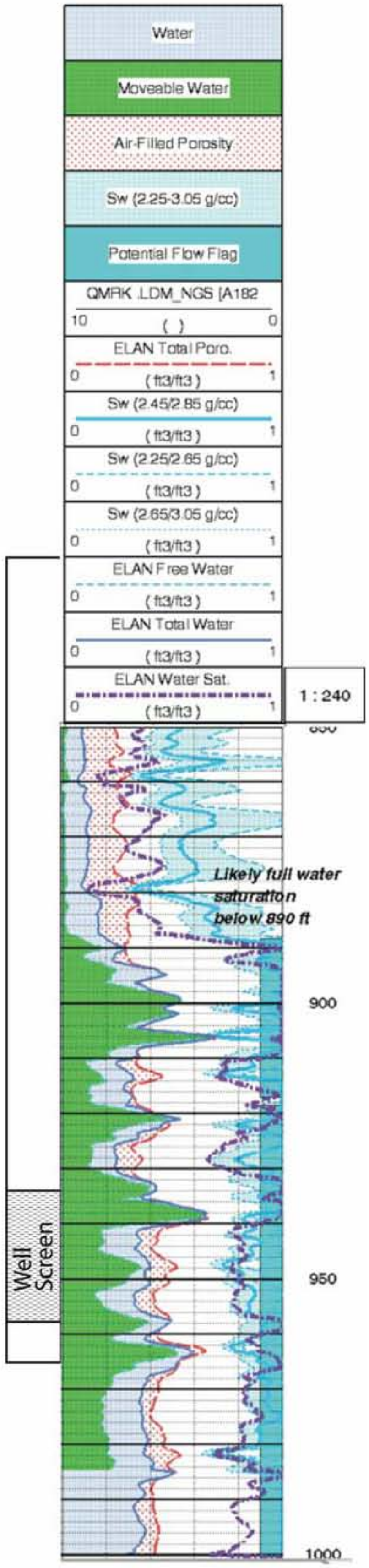

Description: Brass Marker
Northing: 17683558.57
Easting: 1638968.73
Elevation: 6728.61
Description: Well Casing
Northing: 1768356.78
Easting: 1638989.89
Elevation: 6730.70
Description: Core Hole
Northing: 1768445.29
Easting: 1638996.98
Elevation: 6728.22
Coring:
(0' - 93') Auger with Continuous Sampler
(93' - 95') Auger with Split Spoon
(95' - 129') Coring with Air
(129' - 169') Auger with Split Spoon
(169' - 316.5') Auger with Continuous Sampler
(316.5' - 320') Auger with Split Spoon
(320' - 325') Coring with Air
Drilling:
(0' - 80') 13-3/8" Air Rotary Casing Hammer
(80' - 1005') 12-1/4" Mill-Tooth Tri-Cone
(80' - 325') Air
(325' - 1005') Fluid Assisted Air Rotary
Data Collection:
• Hydrologic Properties:
Constant Discharge
Pumping Test - 2/5/04 - 3/8/04
• Cores/Cuttings submitted for geochemical and contaminant characterization: 16
• Ground Water Samples Submitted
Parched Ground Water -
Screening Samples: 12/05/03 (651')
12/07/03 (707')
Regional Ground Water -
Screening Sample: 12/05/03 (651')
Screening Sample: 12/07/03 (707')
Screening Sample: 12/09/03 (889')
Well Sample: 1/12/04 (947')
• Geologic Properties:
Cuttings submitted for mineralogy, petrography, and chemistry: 7
Borehole Logs:
• Lithologic: 0' - 1006'
• Video (LANL tool): 0' - 888'
• Schlumberger logs:
Compensated Neutron Log:
Cased: 30'-80'; Open Hole: 79'-994'
Triple Litho-Density:
Cased: 0'-80'; Open Hole: 79'-994'
Array Induction Tool:
Cased: none; Open Hole: 79'-986'
Elemental Capture Sonde:
Cased: none; Open Hole: 79'-994'
Natural GR Spectroscopy:
Cased: none; Open Hole: 79'-971'
Combinable Magnetic Resonance:
Cased: none; Open Hole: 79'-994'
Fullbore Formation Micro Imager:
Cased: none; Open Hole: 79'-994'
Corehole Logs:
• Lithologic: 0' - 325'
• Video (LANL tool): None
• Gamma Ray (LANL Tool): None
Core Drilling Completed: 11/10/03 - 11/20/03
Rotary Drilling Completed: 11/20/03 - 12/9/03
Contract Geophysics: 12/10/03
Well Installation: 12/12/03 - 12/17/03
Well Development Completed: 1/8/04 - 1/13/04
• Casing:
4.5" ID / 5.0" OD A304 Stainless Steel casing with external couplings
• Number of Screens:
One (1) 4.46" ID/5.27" OD wire wrapped stainless steel rod-based 0.020 slot screen with external couplings.
• Screen Interval: 934.3' - 958.1'
Well Development performed by swabbing, bailing, and pumping.
Total Volume Purged: 17,130 gallons
Aquifer Testing:
Total Volume Pumped: 10,059 gallons
Geologic contacts are for R-28 deep borehole; contacts were determined from core samples, cuttings, borehole video, and geophysical logs.
BOREHOLE (bgs)
CONTAMINANT CHAR. SAMPLES (x) (COREHOLE)
BOREHOLE GROUNDWATER OCCURRENCE
R-28 CONFIG. AT TD (BOREHOLE)
STRATIGRAPHY ENCOUNTERED (bgs)
0
100
200
300
400
500
600
700
800
900
1000
TD 325'
13-3/8" OD Drill Casing (0'-80' bgs)
12-1/4" Open Borehole Wall (80'-1005')
Borehole (888.8')
Alluvium (0'-90')
Qal
ash flows of the Otowi Member (90'-297')
Qbo
Guaje Pumice Bed of the Otowi Member (297'-315')
Qbog
Clay Rich Soil (315'-318')
Cerros del Rio Basalts (318'-675')
Tb
Puye Formation (675'-1005')
Tpf
TD 1005'
Legend
Qal = Alluvium
Qbo = Otowi Member of Bandelier Tuff
Qbog = Guaje Pumice Bed
Tb = Cerros del Rio Basalt
Tpf = Puye Formation
Water Table
Notes:
1. Coordinates - NM State Plane Grid Central Zone (North America) Datum - 1983 (NAD83); expressed in feet.
2. Elevations - National Geodetic Vertical Datum (NGVD 29); expressed in feet above mean sea level.
3. All depths are below ground surface (bgs).
4. Groundwater level measurement recorded on 1-8-04.
5. Drill casing removed during well installation.



Pump Electrical Lead
10-3/4" O.D. Lockable Protective Cover
2.1' ags of Stick-Up
Ground Surface
6' x 6' x 6"
Rebar Reinforced
Concrete Pad
0
Concrete
Backfill
13.375" Borehole
0' - 80'
76'
12.25" Borehole
80' - 1005'
LEGEND:
Concrete Backfill
(2,500 psi Concrete w/ 4% Bentonite)
Bentonite Seal
(Bentonite Chips;
Hydrated in 50' Lifts)
Transition Seal
(10-20 Sand/Bentonite Chips;
50% / 50%; Hydrated)
Secondary Filter Pack
(20-40 Silica Sand)
Primary Filter Pack
(10-20 Silica Sand)
Backfill
(10-20 Silica Sand/Bentonite
Chips 75% / 25%, Hydrated)
Slough
(Formation Material)
1.0" ID
Drop Pipe
CENTRALIZERS
812 ft. bgs
933 ft. bgs
946 ft. bgs
959 ft. bgs
Bentonite
Seal
Groundwater
888.2'
887'
Transition
Seal
Weephole
919.6'
923'
Secondary Filter Pack
926.5'
Bottom of
Transducer Housing
921.6'
Pump
Intake
929.6'
Primary Filter
Pack
Pump: Grundfos
Model: 5520-3905
2 HP Motor / 5 GPM
969'
Notes:
1. Installation Date:
12-11-03 to 12-17-03.
2. All depths are below
ground surface (bgs).
3. Dedicated sampling system
location not shown.
4. Screen depths are slotted intervals.
5. Conductor casing removed
during well construction.
6. (ags) - above ground surface
5.27" OD Rod Based
0.020 Slot SS Screen
934.3' - 958.1'
Backfill
982.5'
Slough
1005'
Bottom of Sump
980.3'
KLEINFELDER
Drawn By: C. London
Date: August 2004
Project No.: 37151
Filename: Figure 7.2-1 Rev1
Scale: Not-To-Scale
Revision: 1
Reviewed By: B. Bockisch
Approved By: M. Everett
Schematic Diagram
of Well R-28
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
7.2-1



Hydroxyl Hydrogen
Clay Bound
Small Pore
Micro Pore
Moderate Noise
Medium Pore
Capillary Bound
Large Pore
Clay Bound
Late Decay
Clay K Range
Silt K Range
Silty Sand K Range
Clean Sand K Range
Gravel K Range
CMR Total Poro.
CMR 3 ms. Poro.
CMR Free Fluid Poro
Noise Flag
High Noise
CMR Wait Time Flag
WAIT_FLAG.LDM_NGS
CFF3.LDM_NGS [A182
CFF5.LDM_NGS [A182
CFF4.LDM_NGS [A182
CFF6.LDM_NGS [A182
CFF2.LDM_NGS [A182
TCMR.DF [A1902425]
TNPH.LDM_NGS [A182
T2 Amplitude Dist.
T2 Cutoff
T2 Log Mean
Hyd. Cond. (ELAN T-C Eqn)
Hyd. Cond. (CMR SDR Eqn)
Intrinsic Hyd. Cond (ELAN T-C)
(ft3/ft3)
(ms)
(gal/day/ft^2)
0.5
0
10
29
0.3
3000
0.0001
1e+06
850
900
950
1000
Well Screen



Water
Moveable Water
Air-Filled Porosity
Sw (2.25-3.05 g/cc)
Potential Flow Flag
QMRK .LDM_NGS [A182
10 ( ) 0
ELAN Total Poro.
0 (ft3/ft3) 1
Sw (2.45/2.85 g/cc)
0 (ft3/ft3) 1
Sw (2.25/2.65 g/cc)
0 (ft3/ft3) 1
Sw (2.65/3.05 g/cc)
0 (ft3/ft3) 1
ELAN Free Water
0 (ft3/ft3) 1
ELAN Total Water
0 (ft3/ft3) 1
ELAN Water Sat.
0 (ft3/ft3) 1
1 : 240
Likely full water saturation below 890 ft
900
950
1000
Well Screen

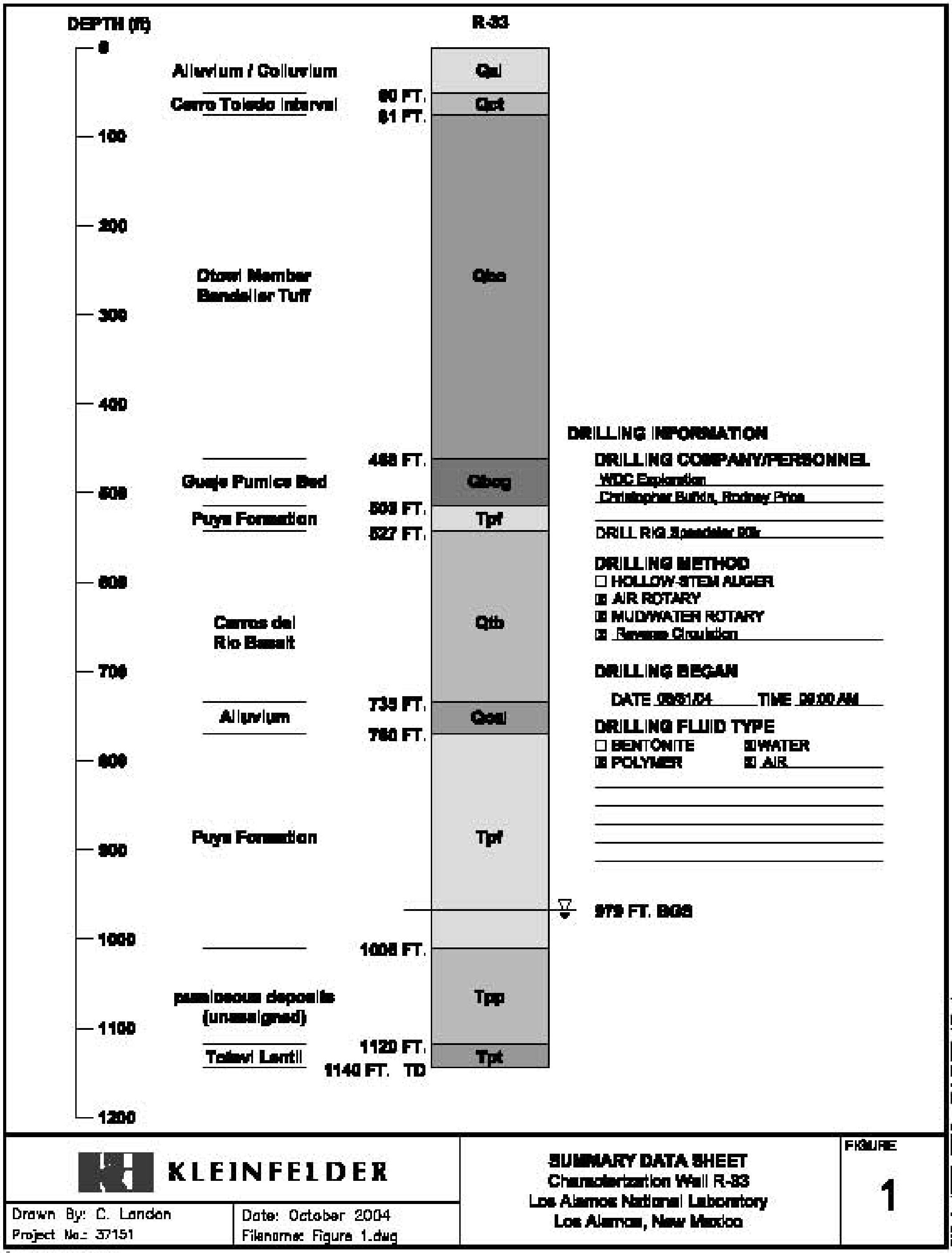
R-33 Well

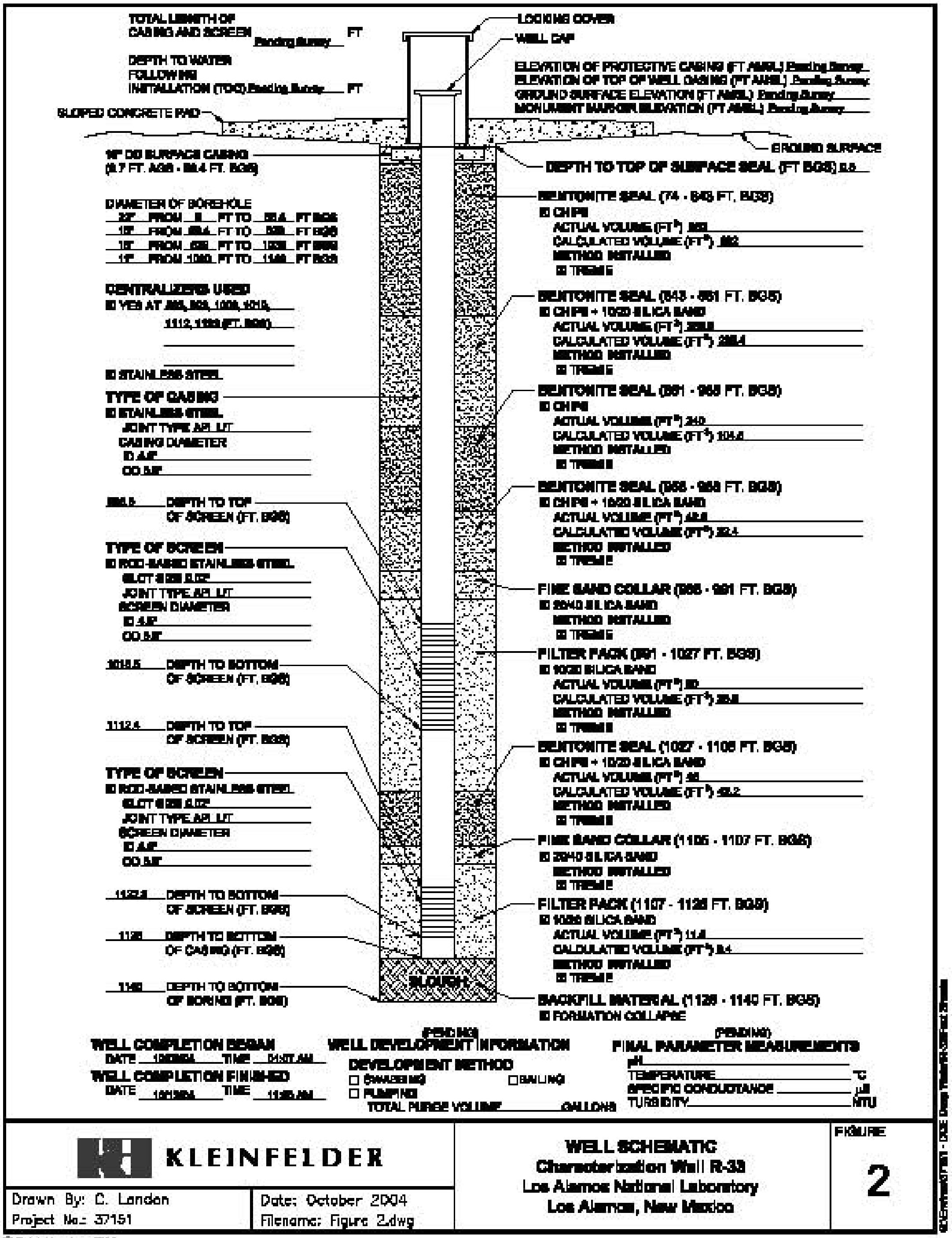
R-33 Well		
	Description	Evaluation
Drilling Method	R-33 was drilled using air-rotary, fluid-assisted air rotary, and air-rotary reverse circulation methods	Circulation of cuttings was primarily accomplished using conventional air-rotary methods using water only (0–285 ft) and water plus additives (QUIK-FOAM and EZ-MUD) (285–1030 ft); below 1030 ft reverse circulation was used to TD of 1140 ft. Drilling additives can adversely affect the ability to collect representative water samples, particularly where multiple screens are not isolated during development. At R-33 a packer was installed between the two screens to further develop the lower screen. An installed Barcad system limits purge volumes during sampling, which makes the groundwater sample more prone to water-quality problems due to residual drilling fluids in the formation around the well screen.
General Well Characteristics	R-33 is a two-screen well constructed of 4.5-in.-I.D./5-in. O.D. A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction (995.5–1018.5 ft and 1112.4–1122.3 ft)	The rod-based screen is constructed of 4.46-in.-I..D/5.27-in. O.D. wire-wrapped screens with 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-33 screens allow greater water movement during development than 0.010-in. screen openings. The ability of 0.020-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. Both screens at R-33 were developed using bailing, swabbing, and pumping. The geochemical evaluation in Appendix B does not identify any obvious drilling-related conditions in either screen. However, variably elevated concentrations of iron and nickel in water samples from both screens, and variably higher than average turbidities in the lower screen, suggest that the Barcad system does not allow the screen interval to be adequately purged so as to ensure the collection of water samples fully representative of the formation.
Screen Lengths and Placement	The upper screen is 23 ft long, placed from 995.5 to 1018.5 ft depth. The top of the upper screen is 16.5 ft below the water table (979 ft depth on 11/30/04). The lower screen is 9.9 ft long, placed from 1112.4 to 1122.3 ft depth. The top of the lower screen is 133.4 ft below the water table (979 ft depth on 11/30/04).	***Relevant stratigraphy:*** Fanglomerates of the Puye Formation extend from 731 to 964 ft depth, overlying pumiceous deposits of the upper Santa Fe Group from 964 to 1122 ft depth. The lower section consists of coarse river gravels, from 1122 ft depth to TD at 1140 ft depth. The river gravels showed significant increase of water production during drilling, but hole integrity could not be maintained within this unit and the lower screen was therefore placed just above it with a filter pack extending into it. ***Relevant geophysical log results:*** Schlumberger logs run at R-33 include CMR, CNT, TLD, AIT, FMI, GPIT, NGS, and ECS. The well water level was stable throughout the logging acquisition, remaining between 983 ft and 985 ft bgs during all four logging runs.

R-33 Well (continued)		
	Description	Evaluation
		984–1028 ft: Significantly washed-out zone characterized by very high total and water-filled porosity (50% to greater than 60%), as well as effective porosity (30% to greater than 60%). Total and water-filled porosity generally overlap in this zone and all zones below (indicating 100% water saturation). Unrealistically high log derived porosity peaks are associated with borehole washouts (984 to 986 ft bgs; 989 to 994, 997 to 1001, 1010 to 1017, and 1022 to 1024 ft). The ELAN integrated log analysis indicates that the interval of regional saturation does not contain much clay or other fine-grained material, as does the FMI image (overall very high resistivity in the scaled image); both the ELAN results and FMI imaging thus suggest very productive aquifer material. The very high total and effective porosity across this zone matches cuttings observation of pumice-rich material. 1028–1106 ft: Relatively uniform water-filled porosity, 36 to 44%. Minor amounts of clay inferred, perhaps slightly increased at 1074–1076 ft depth. 1106–1108 ft: The processed logs indicate a peak in total and effective porosity at this depth (43% and 24%, respectively). 1108–1122 ft: This zone is characterized by relatively low total and effective porosity, ranging 37% to 41% and 17 to 21%, respectively. The FMI and ELAN results indicate presence of clay and other fine-grained material, especially in the intervals 1108 to 1113 ft, and 1116 to 1120 ft. 1122–1126 ft: This zone is characterized by a significant decrease in total porosity to about 20%, indicative of a tight zone. 1126–1131 ft (bottom of log interval): Porosity appears to increase at the bottom of the log interval, reaching 40%. No direct information about effective porosity is available from the log measurements since this interval is below the bottom of the CMR log. The FMI and ELAN results (FMI log bottom is about 1128 ft) indicate the interval does not contain much clay and other fine-grained material, suggestive of productive aquifer material. Cuttings from this deeper horizon consisted of gravel and sand of well rounded volcanic and plutonic detritus. ***Upper screen placement:*** The upper screen length and its placement were selected with the following goals in mind: 1. Provide a monitoring point for the uppermost part of the regional aquifer within lower Ten Site Canyon, above the confluence with Mortandad Canyon 2. Submerge the screen fully to facilitate well development 3. Screen across a long enough stratigraphic interval so that contaminants, if present, could be detected among several possible but unknown flow paths, some of which may be related to the many washouts in the screened interval

R-33 Well (continued)		
	Description	Evaluation
		The upper screen meets the goals stated above. ***Lower screen placement:*** The lower screen was placed to 1. monitor a deeper productive zone of the regional aquifer that might contain contaminants from upgradient release sites, either from Ten Site Canyon or by deeper flow from upper Mortandad Canyon sources, and 2. provide greatest possible spacing from the upper screen to maximize evaluation of vertical hydraulic gradients in this part of the Laboratory. The lower screen has openings at the bottom of the pumiceous deposits and a filter pack extending 4 ft into underlying river gravels (the lower screen was placed as low as possible in the available borehole space).
Filter Pack Materials and Placement *Upper screen:* (primary 991–1027 ft; secondary 988–991 ft; no lower secondary sand) Lower screen: (primary 1107-1126 ft; secondary 1105–1107 ft; no lower secondary sand)	The primary filter pack is made up of 10/20 sand. Secondary filter packs of 20/40 sand were placed above both primary filter packs.	***Upper screen:*** Primary filter pack extends 4.5 ft above the screen openings and 8.5 ft below. ***Lower screen:*** Primary filter pack extends 5.4 ft above the screen openings and 3.7 ft below. Filter pack extends 4 ft into the river gravels, as does the lowermost ~0.3 ft of the lower screen.
Sampling System	BESST, Inc. Barcad dual pump with packer system	Barcad is a low-flow sampling system that allows groundwater to be sampled from two well screens within a single well installation. Well screens are isolated by packers and sampled individually. R-33 has the only Barcad sampling system in use at the Laboratory, and results are not satisfactory. It is a low-flow sampling system that is logistically difficult to install and maintain. The sample volume is limited, and a sampling event takes a day per well screen. Low-flow sampling systems that cannot be purged are particularly susceptible to water quality problems due to residual drilling fluids in the formation around the well screen. Water levels are measured through permanently installed transducers that cannot be replaced without pulling the entire sampling system. The transducer in the upper screen has failed and is currently unusable. Manual water-level measurements cannot be made with the sampling system installed.

R-33 Well (continued)		
	Description	Evaluation
Other Issues That Could Affect the Performance of the Well	Drilling into the river gravels below 1122 ft was difficult; slough prevented deeper placement of the lower screen.	Because of extensive sloughing of formation materials during well construction, no bentonite was emplaced below the primary filter pack because of a concern about mobilized slough flowing up into the well screen. The lack of bentonite below the filter pack should not adversely affect the well. Because the Barcad packer lost pressure over time, the isolation of the two well screens was compromised and groundwater samples collected before October 2006 were from the composite water in the well. Gas bottles are currently used on-site to maintain proper packer pressure. Automated groundwater level monitoring using the Barcad system has been plagued with problems since the transducers and associated data logging equipment was installed in February 2005. One of the signal conditioners failed when the system was installed and was replaced. The signal conditioners were calibrated to zero after installation of the transducers in the well, which caused all measurements to be zero until March 2006 when transducer calibration information was obtained from the manufacturer.
Additives used		Municipal water—36204 gal. QUIK-FOAM—446 gal. EZ-MUD—37 gal. Defoaming agent—4 gal.
Annular fill other than filter and transition sands		Bentonite chips mixed with 10/20 sand (45 bentonite to 55 sand by volume, 376.4 ft^3) Bentonite chips w/o sand (1200 ft^3) Surface seal of cement slurry (94.5 ft^3)
Water produced on development and testing		40 gal. was removed from the screens (no packer present) during initial bailing and swabbing. With a packer in place the following amounts of water were produced: ***Upper screen:*** 19,147 gal. (11/9–11/11/2004) 5,265 gal. (12/1–12/3/2004) ***Lower screen:*** 68,443 gal. (10/27–11/9/2004) 21,153 gal. (11/14–11/16/2004) 34,550 gal. (11/19–11/22/2004)


DEPTH (ft)
R-33
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Alluvium / Colluvium
Qal
60 FT.
Cerro Toledo interval
Qct
81 FT.
Otowi Member
Bandelier Tuff
Qbo
468 FT.
Guaje Pumice Bed
Qbog
503 FT.
Puye Formation
Tpf
527 FT.
Cerros del
Rio Basalt
Qtb
735 FT.
Alluvium
Qoal
760 FT.
Puye Formation
Tpf
979 FT. BGS
1008 FT.
pumiceous deposits
(unassigned)
Tpp
1120 FT.
Totavi Lentil
Tpt
1140 FT. TD
DRILLING INFORMATION
DRILLING COMPANY/PERSONNEL
WDC Exploration
Christopher Bufkin, Rodney Price
DRILL RIG Speedstar 50k
DRILLING METHOD
☐ HOLLOW-STEM AUGER
☒ AIR ROTARY
☒ MUD/WATER ROTARY
☒ Reverse Circulation
DRILLING BEGAN
DATE 08/31/04 TIME 09:00 AM
DRILLING FLUID TYPE
☐ BENTONITE
☒ WATER
☒ POLYMER
☒ AIR
KLEINFELDER
Drawn By: C. Landon
Project No.: 37151
Date: October 2004
Filename: Figure 1.dwg
SUMMARY DATA SHEET
Characterization Well R-33
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
1



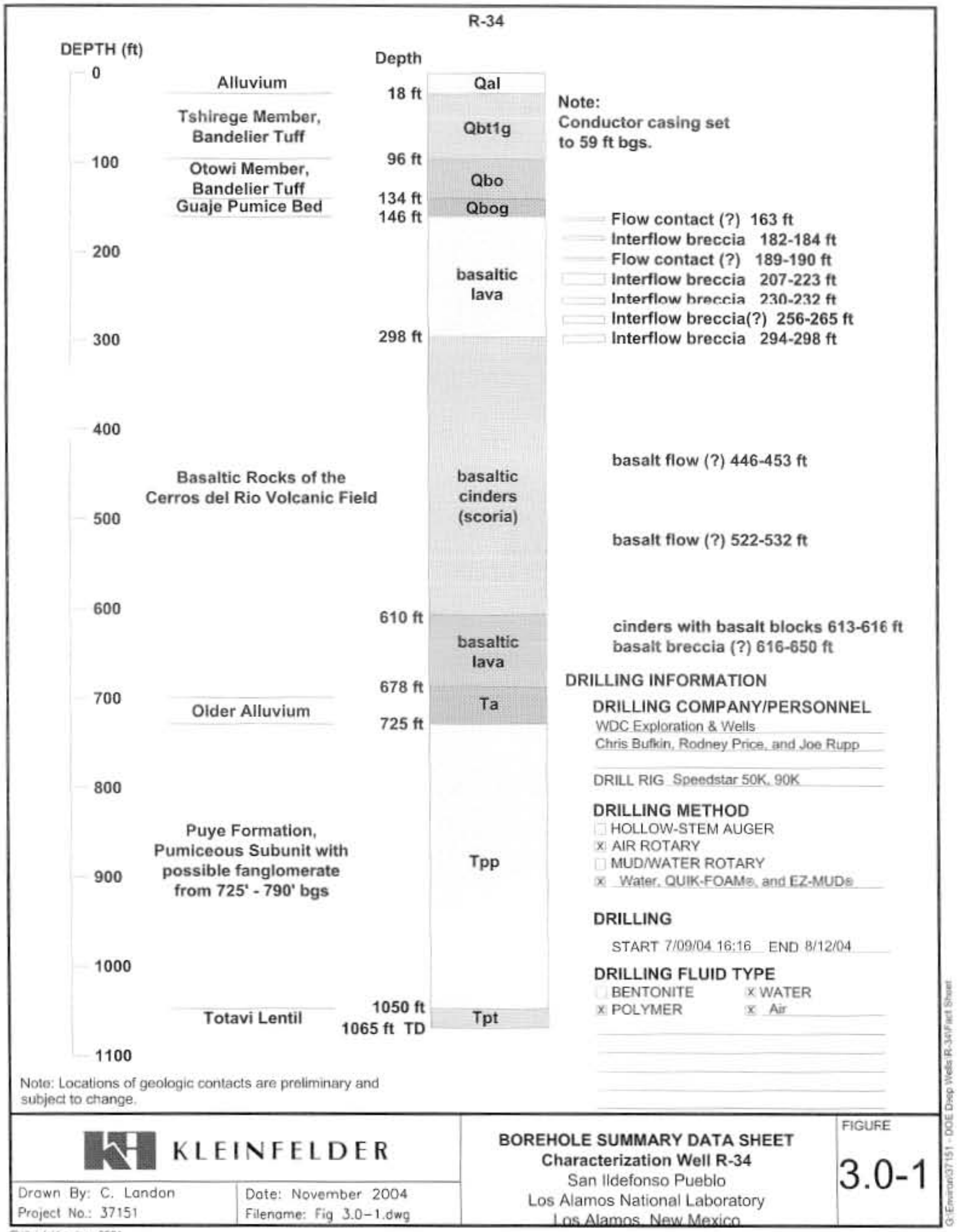
LOCKING COVER
WELL CAP
GROUND SURFACE
BENTONITE SEAL
FINE SAND COLLAR
FILTER PACK
BACKFILL MATERIAL (1126 - 1140 FT. BGS)
SLOUGH
TYPE OF CASING
TYPE OF SCREEN
DEPTH TO BOTTOM OF CASING (FT. BGS)
DEPTH TO BOTTOM OF BORING (FT. BGS)
WELL COMPLETION BEGAN
WELL COMPLETION FINISHED
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
FINAL PARAMETER MEASUREMENTS
TEMPERATURE
SPECIFIC CONDUCTANCE
TURBIDITY
KLEINFELDER
Drawn By: C. Landon
Project No.: 37151
Date: October 2004
Filename: Figure 2.dwg
WELL SCHEMATIC
Characterization Well R-33
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
2

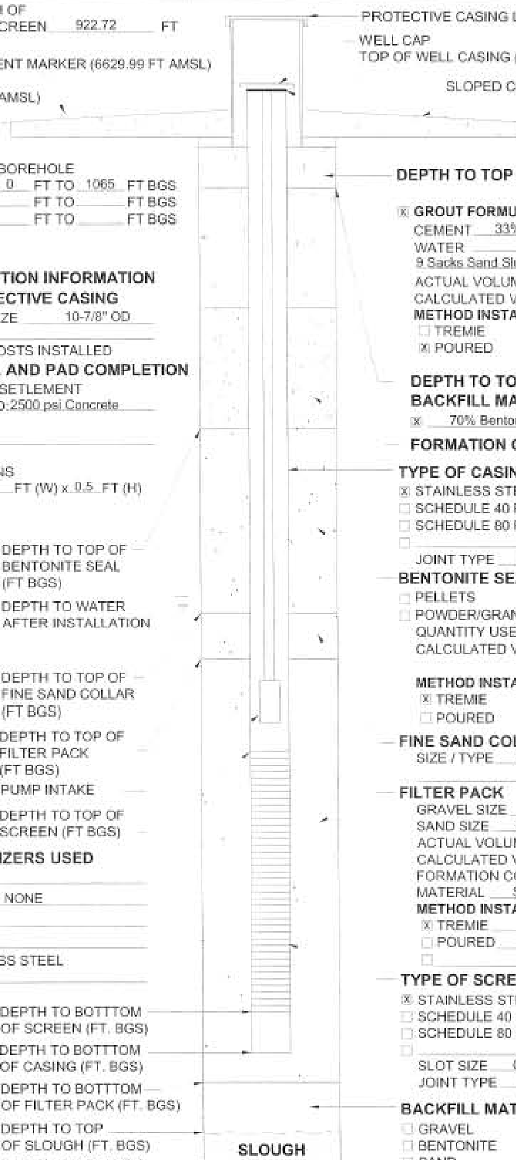
R-34 Well

R-34 Well		
	Description	Evaluation
Drilling Method	R-34 was drilled using fluid-assisted air-rotary methods.	R-34 was drilled by conventional-circulation fluid-assisted air-rotary methods with casing advance to 739 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1065 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives QUIK-FOAM and EZ-MUD. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-34 because it is a single completion well; these types of wells are intrinsically easier to develop, and they can be purged before sampling.
General Well Characteristics	R-34 is a single-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D.-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-34 well screen construction (0.020 wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 883.7 to 906.6 ft and has a length of 22.9 ft. The top of the screen is 89.7 ft below the water table (currently 794 ft below the surface).	The R-34 well screen length and placement were selected with the following goals in mind: Provide an off-site monitoring point for groundwater quality in the regional aquifer within a triangular piece of San Ildefonso Pueblo land that extends into the eastern part of the Laboratory Place a screen in upper part of the regional aquifer along potential lateral groundwater flow paths approximately 8200 ft downgradient of where contaminants are believed to be entering the regional aquifer in Mortandad Canyon Screen across a long-enough stratigraphic intervals that contaminants, if present, could be detected among several possible but unknown shallow flow paths Submerge the screen fully to facilitate well development The geology below the water table at R-34 is similar to the lower part of the stratigraphic sequence encountered in wells such as R-13, R-15, and R-28. However, poor recovery of cuttings and poor conditions during geophysical logging (numerous large washouts) resulted in larger than usual uncertainties associated with the position of geologic contact between the Puye Formation and underlying Miocene sedimentary rocks. The regional aquifer from 794 to 1065 ft is composed of well-stratified sands and gravels with relatively minor interbedded silts. FMI logs indicate that individual beds within the regional aquifer are mostly 0.5 to 5 ft thick. Beds dip predominantly to the southwest and southeast and dip angles are mostly less than 10°. No fractures were identified in the regional aquifer.

R-34 Well (continued)		
	Description	Evaluation
		The Schlumberger log interpretation indicates that all of the rocks beneath the water table to the bottom of the log interval (933 ft) are fully saturated and relatively porous. The porosity in the regional aquifer is mostly in the range of 25%–40%; however, porosities in the interval from 794 to 868 ft are poorly characterized because numerous washouts produce unreasonably high porosity values. Evaluation of this upper zone was hampered by poor recovery of cuttings from below the water table due to persistent circulation problems. Below 868 ft, borehole washouts are much less severe, and the geophysical logs produce data more representative of the rock formations. The interval 868 to 885 ft is made up of heterogeneous fanglomerate deposits with elevated clay contents. The well screen was placed from 883.7 to 906.6 ft because porosities were relatively high (25%–42%), with effective porosities ranging up to 30% to 35%. The screen interval includes an extremely porous pumice bed from 898 to 901 ft with a porosity of 58% in an interval that is not washed out. The FMI log indicates the screen interval contains numerous stratified sandy deposits. The well screen was not placed in shallower zones because the quality of the geophysical logs was poor, and screen placement would have been made in the absence of information needed to ensure achievement of all of the stated design goals. Additionally, it was a concern that the measured water level of 794 ft was considerably higher than the 915 ft predicted from existing water-level maps; this was an unusually large deviation from predicted water levels and it was considered possible that the aquifer was confined in this area. This concern was amplified when the preliminary evaluation of logs by Schlumberger suggested that full saturation of the rocks began below a depth of 868 ft based on divergence of induction and porosity logs. Subsequent log processing and water measurements after the well was installed resulted in the interpretation that saturation begins at a depth of 794 ft. The placement of a 22.9-ft well screen 89.7 ft beneath the water table in highly stratified and porous rocks satisfied all four of the design goals described above.
Filter Pack Materials and Placement	The primary filter pack is made up of 8/20 sand from 877 to 935 ft. A secondary filter packs of 20/40 sand was placed above the primary filter pack from 875 to 877 ft.	The primary filter pack extends 6.7 ft above and 28.4 ft below the well screen. The primary filter pack is longer than the nominal well design of 5 ft above and below the well screen, primarily to address concerns about sloughing while the well was being installed. Because the well screen is relatively short, the additional filter pack should not adversely affect the ability of the well to detect contaminants.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen

R-34 Well (continued)		
	Description	Evaluation
		in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	None	n/a
Additives used		Municipal water during drilling and well construction—36,691 gal. EZ-MUD—37 gal. QUIK-FOAM—446 gal. Fluids recovered—66,972 gal.
Annular fill other than filter and transition sands		Backfill—16 ft^3 of sand and bentonite (70:30 mix) Bentonite–chips (1226.1 ft^3) Transition seal—183.2 ft^3 of sand and bentonite (70:30 mix) Surface seal of cement slurry with 5% bentonite (114.8 ft^3) Borehole repair of vadose zone cinder beds on 7/27/04 because of borehole collapse: 8/20 silica sand—90 ft^3 Cement slurry—891 ft^3 Bentonite—80.4 ft^3


R-34
DEPTH (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
Depth
Alluvium
18 ft
Qal
Tshirege Member, Bandelier Tuff
Qbt1g
Note:
Conductor casing set to 59 ft bgs.
96 ft
Otowi Member, Bandelier Tuff
Qbo
134 ft
Guaje Pumice Bed
Qbog
146 ft
basaltic lava
Flow contact (?) 163 ft
Interflow breccia 182-184 ft
Flow contact (?) 189-190 ft
Interflow breccia 207-223 ft
Interflow breccia 230-232 ft
Interflow breccia(?) 256-265 ft
Interflow breccia 294-298 ft
298 ft
Basaltic Rocks of the Cerros del Rio Volcanic Field
basaltic cinders (scoria)
basalt flow (?) 446-453 ft
basalt flow (?) 522-532 ft
610 ft
basaltic lava
cinders with basalt blocks 613-616 ft
basalt breccia (?) 616-650 ft
678 ft
Older Alluvium
Ta
725 ft
Puye Formation, Pumiceous Subunit with possible fanglomerate from 725' - 790' bgs
Tpp
1050 ft
Totavi Lentil
Tpt
1065 ft TD
DRILLING INFORMATION
DRILLING COMPANY/PERSONNEL
WDC Exploration & Wells
Chris Bufkin, Rodney Price, and Joe Rupp
DRILL RIG Speedstar 50K, 90K
DRILLING METHOD
HOLLOW-STEM AUGER
X AIR ROTARY
MUD/WATER ROTARY
X Water, QUIK-FOAM®, and EZ-MUD®
DRILLING
START 7/09/04 16:16 END 8/12/04
DRILLING FLUID TYPE
BENTONITE
X WATER
X POLYMER
X Air
Note: Locations of geologic contacts are preliminary and subject to change.
KLEINFELDER
Drawn By: C. Landon
Project No.: 37151
Date: November 2004
Filename: Fig 3.0-1.dwg
BOREHOLE SUMMARY DATA SHEET
Characterization Well R-34
San Ildefonso Pueblo
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
3.0-1
© Kleinfelder, Inc. 2004



TOTAL LENGTH OF CASING AND SCREEN 922.72 FT

MONUMENT MARKER (6629.99 FT AMSL)

GROUND SURFACE (6629 FT AMSL)

PROTECTIVE CASING LOCKING COVER

WELL CAP

TOP OF WELL CASING (FT AMSL) 6632.01

SLOPED CONCRETE PAD / SURFACE SEAL

DIAMETER OF BOREHOLE
12-1/4" FROM 0 FT TO 1065 FT BGS
FROM ___ FT TO ___ FT BGS
FROM ___ FT TO ___ FT BGS

SURFACE COMPLETION INFORMATION

TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 10-7/8" OD
☐
☒ PROTECTIVE POSTS INSTALLED

SURFACE SEAL AND PAD COMPLETION
☒ CHECKED FOR SETLEMENT
MATERIAL USED: 2500 psi Concrete
REINFORCED
☒ YES: Rebar
☐ NO
PAD DIMENSIONS
5 FT (L) x 5 FT (W) x 0.5 FT (H)

717 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)

796 DEPTH TO WATER AFTER INSTALLATION

875 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)

877 DEPTH TO TOP OF FILTER PACK (FT BGS)

881.6 PUMP INTAKE

883.7 DEPTH TO TOP OF SCREEN (FT BGS)

CENTRALIZERS USED
☐ YES AT
NONE

☐ STAINLESS STEEL
☒ No

906.6 DEPTH TO BOTTTOM OF SCREEN (FT. BGS)

920.7 DEPTH TO BOTTTOM OF CASING (FT. BGS)

935 DEPTH TO BOTTTOM OF FILTER PACK (FT. BGS)

975 DEPTH TO TOP OF SLOUGH (FT. BGS)

1065 DEPTH TO BOTTTOM OF BORING (FT. BGS)

DEPTH TO TOP OF SURFACE SEAL (FT BGS) 0.7

☒ **GROUT FORMULA (PROPORTION OF EACH)**
CEMENT 33% BENTONITE 5%
WATER ___ OTHER 2% $CaCl_2$ 60% Sand
9 Sacks Sand Slurry
ACTUAL VOLUME 114.8 ft³
CALCULATED VOLUME 55.3 ft³
METHOD INSTALLED
☐ TREMIE ☐
☒ POURED ☐ NOT USED

DEPTH TO TOP OF BACKFILL MATERIAL (FT BGS) 82
☒ 70% Bentonite / 30% 8/20 Sand

FORMATION COLLAPSE (FT BGS) 667 - 717

TYPE OF CASING
☒ STAINLESS STEEL — CASING DIAMETER
☐ SCHEDULE 40 PVC — INSIDE 4.5 in.
☐ SCHEDULE 80 PVC — OUTSIDE 5.0 in.
☐
JOINT TYPE API Long Thread

BENTONITE SEAL
☐ PELLETS ☐ SLURRY
☐ POWDER/GRANULAR ☒ Chips + 8/20 Sand
QUANTITY USED 1226.1 ft³
CALCULATED VOLUME 397.8 ft³

METHOD INSTALLED
☒ TREMIE ☐
☐ POURED ☐ NOT USED

FINE SAND COLLAR (OPTIONAL)
SIZE / TYPE 20/40 Sand

FILTER PACK
GRAVEL SIZE
SAND SIZE 8/20
ACTUAL VOLUME 27.5 ft³
CALCULATED VOLUME 41.0 ft³
FORMATION COLLAPSE: ___ TO ___ FT BGS
MATERIAL Silica Sand
METHOD INSTALLED
☒ TREMIE
☐ POURED
☐

TYPE OF SCREEN
☒ STAINLESS STEEL — SCREEN DIAMETER
☐ SCHEDULE 40 PVC — INSIDE 4.5 in.
☐ SCHEDULE 80 PVC — OUTSIDE 5.0 in.
☐
SLOT SIZE 0.02 in. Wire Wrap
JOINT TYPE API Long Thread

BACKFILL MATERIAL
☐ GRAVEL ☒ FORMATION COLLAPSE (975 - 1065 ft bgs)
☐ BENTONITE MATERIAL
☐ SAND
☒ 70% Bentonite / 30% 8/20 Sand

WELL COMPLETION BEGAN
DATE 8/13/04 TIME 07:00

WELL COMPLETION FINISHED
DATE 8/20/04 TIME 17:00

WELL DEVELOPMENT INFORMATION

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 34,120 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 8.11
TEMPERATURE 20.7 °C
SPECIFIC CONDUCTANCE 189 µS
TURBIDITY 3.7 NTU

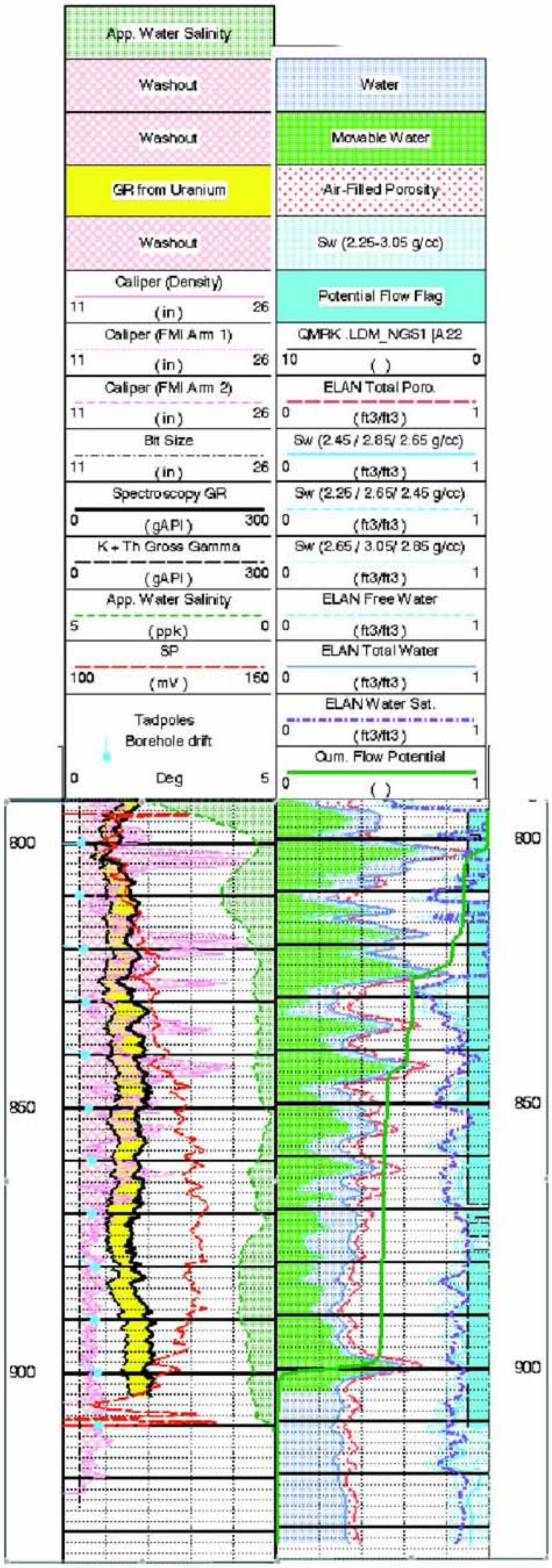
KLEINFELDER

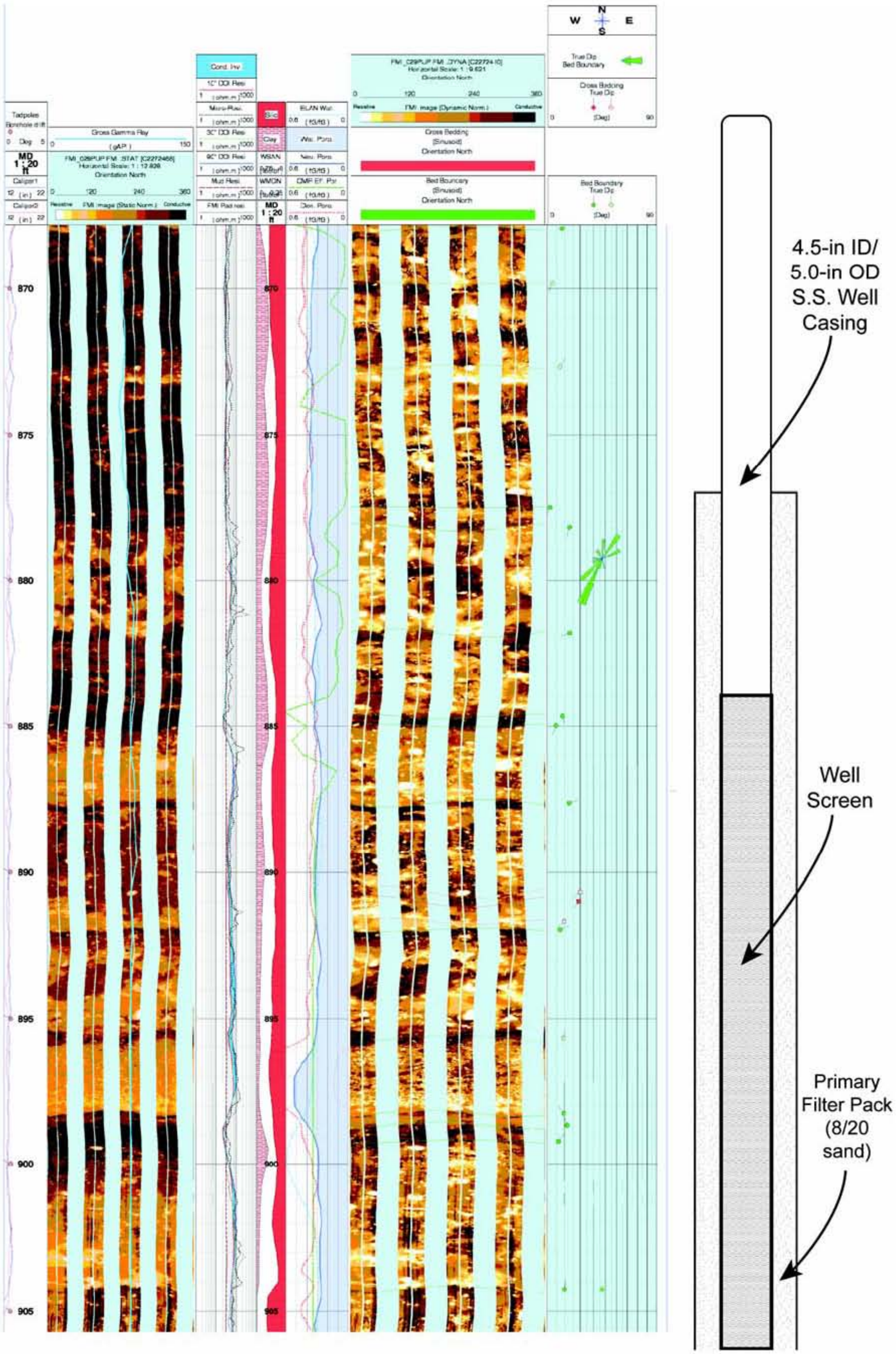
Scale: Not-To-Scale
Drawn By: C. Landon
Project No.: 37151
Date: September 2004
Filename: Figure 7.2-1.dwg

WELL SCHEMATIC
Characterization Well R-34
San Ildefonso Pueblo
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
7.2-1

G:\Environ\37151 - DOE Deep Wells\R-34\Fact Sheet


App. Water Salinity
Washout
Washout
GR from Uranium
Washout
Caliper (Density)
11 (in) 26
Caliper (FMI Arm 1)
11 (in) 26
Caliper (FMI Arm 2)
11 (in) 26
Bit Size
11 (in) 26
Spectroscopy GR
0 (gAPI) 300
K + Th Gross Gamma
0 (gAPI) 300
App. Water Salinity
5 (ppk) 0
SP
100 (mV) 160
Tadpoles
Borehole drift
0 Deg 5
Water
Movable Water
Air-Filled Porosity
Sw (2.25-3.05 g/cc)
Potential Flow Flag
QMRK .LDM_NGS1 [A22
10 ( ) 0
ELAN Total Poro.
0 (ft3/ft3) 1
Sw (2.45 / 2.85/ 2.65 g/cc)
0 (ft3/ft3) 1
Sw (2.25 / 2.65/ 2.45 g/cc)
0 (ft3/ft3) 1
Sw (2.65 / 3.05/ 2.85 g/cc)
0 (ft3/ft3) 1
ELAN Free Water
0 (ft3/ft3) 1
ELAN Total Water
0 (ft3/ft3) 1
ELAN Water Sat.
0 (ft3/ft3) 1
Cum. Flow Potential
0 ( ) 1
800
850
900



4.5-in ID/
5.0-in OD
S.S. Well
Casing
Well
Screen
Primary
Filter Pack
(8/20
sand)

R-35a, R-35b (Preliminary) Wells

R-35a, R-35b (Preliminary) Wells		
	Description	Evaluation
Drilling Method	R-35a was drilled to 765-ft depth using fluid-assisted air-rotary methods with nested casing advance (16-in. casing to 262-ft depth, 12-in. casing to 940 ft, 10-in. casing to TD at 1143-ft depth). Both tricone bits and down-the-hole-hammers were used. R-35b was also drilled using fluid-assisted air-rotary methods with nested casing advance (16-in. casing to 266-ft depth, 10-in. casing to TD at 892-ft depth). Both tricone bits and down-the-hole-hammers were used.	No core was collected at either R-35a or R-35b. Some bucket collections of the total cuttings stream were made within Puye Formation fanglomerates and Santa Fe Group sediments at R-35a. Drilling of the R-35a,b set of wells was conducted in three stages. First, R-35b was drilled to the top of the Cerros del Rio lavas at 266-ft depth, where examination for perched water was conducted (results negative). Second, R-35a was drilled to TD of 1143 ft. Third, the drill rig returned to R-35b to reach TD of 892 ft. ***R-35a:*** Air rotary with tricone and down-the-hole hammer bits. Fluid additives were limited to municipal water and AQF-2 foaming agent to 676-ft depth; only municipal water was used from 676 ft to the water table at 786 ft, and no fluids were added from 786 ft to TD at 1143 ft. R-35a was designed as a single-screen well. ***R-35b:*** Air rotary with tricone and down-the-hole hammer bits. Fluid additives were limited to municipal water and AQF-2 foaming agent to 603-ft depth; only municipal water was used from 603 ft to the water table at 788 ft and no fluids were added from 788 ft to TD at 892 ft. R-35b was designed as a single-screen well.
General Well Characteristics	R-35a and R-35b are both single-screen wells constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction ***R-35a:*** (1010–1050) ***R-35b:*** (825–845)	The rod-based wire-wrapped screens are constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless steel with stainless-steel wire wrap having 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-35a,b screens allow greater water movement during development than 0.010-in. screen openings. The ability of 0.020-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. Results for R-35a and R-35b are pending.

<table>
<tr><th colspan="3">R-35a, R-35b (Preliminary) Wells (continued)</th></tr>
<tr><th></th><th>Description</th><th>Evaluation</th></tr>
<tr><td>Screen Lengths and Placement</td><td>The screen at R-35a is 40 ft long, placed from 1010- to 1050-ft depth. The top of this screen is 223.7 ft below the water table (786.3-ft depth when total depth had been reached and prior to well installation). The top of the screen at R-35a is also 40 ft below the top of the louvers at production well PM-3, which is ~500 ft to the east.</td><td>Relevant stratigraphy:

Puye Formation fanglomerates from 602- to 880-ft depth; pumiceous unit of the upper Santa Fe Group from 880- to 900-ft depth; Santa Fe Group sands and gravels from 900- to 1141-ft depth; Miocene basalt from 1141 ft to R-35a TD at 1143-ft depth.

Relevant geophysical log results:

R-35a: A video log was run by LANL in open hole with the 16-in. casing pulled back above the Cerros del Rio lavas, in open hole from 265- to 666-ft depth, with no indication of perched water. The LANL induction tool was run from 265- to 670-ft depth. The LANL gamma tool was run from surface to 668-ft depth.</td></tr>
<tr><td></td><td>The screen at R-35b is 20 ft long, placed from 825- to 845-ft depth. The top of the upper screen is 37 ft below the water table (788-ft depth when total depth had been reached and prior to well installation).</td><td>Schlumberger logging tools were run in R-35a to 1150- ft depth with casing in place. The tools used were TLD, NGS, ECS, and CHFR. A preliminary ELAN by Schlumberger was used to refine screen placement at R-35a.

R-35b: Two video logs were run by LANL in open hole with the 16-in. casing pulled back above the Cerros del Rio lavas, in open hole on 4/11/07 from 269- to 585-ft depth where foam had accumulated-and on 4/12/07 to 603 ft after defoamer had been added, with no indication of perched water. The LANL induction tool was run from 269- to 611-ft depth. The LANL gamma tool was run - twice, from surface- to 611-ft depth on 4/12/07 and from surface- to 901-ft depth on 5/22/07.

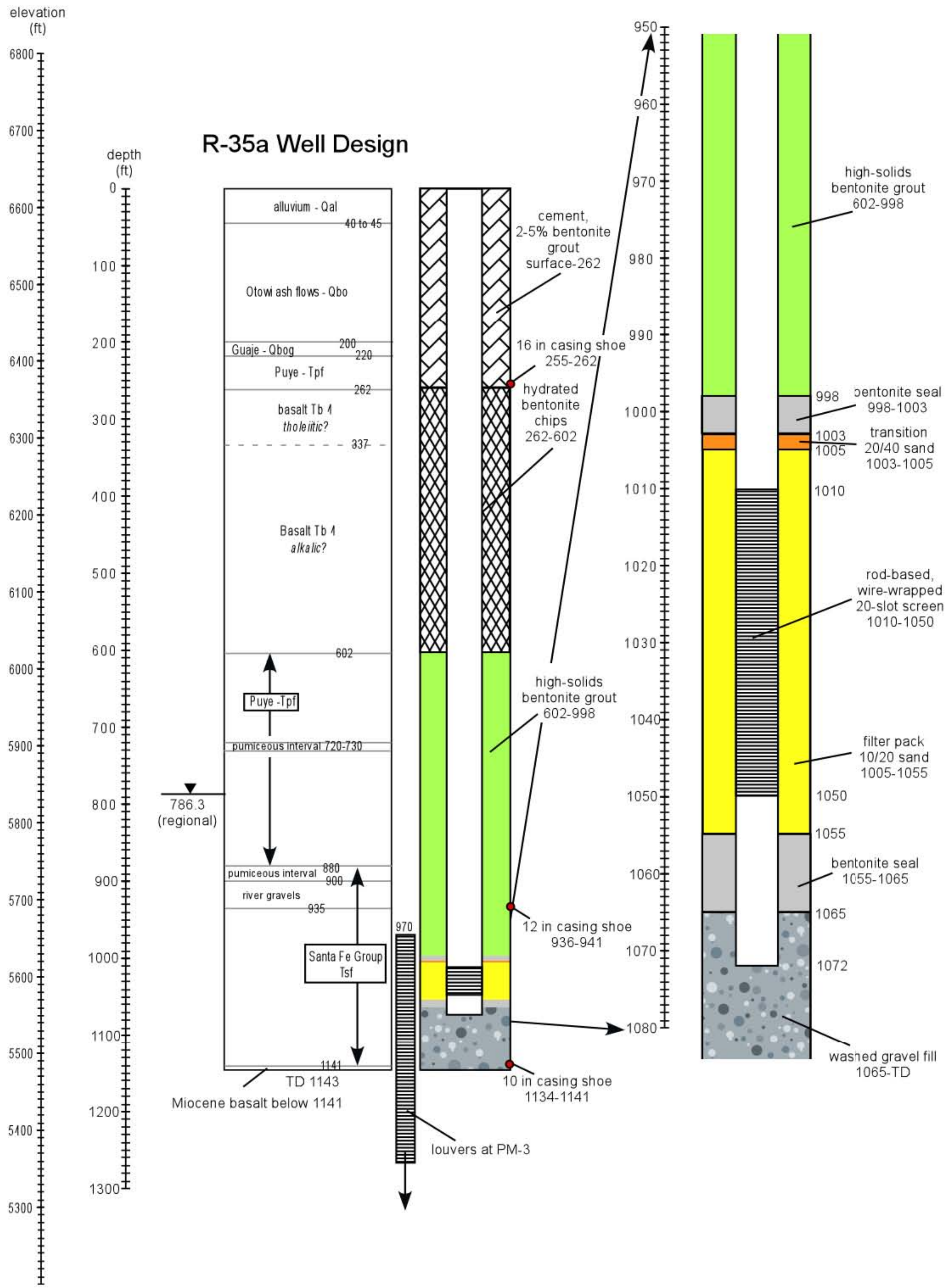
Schlumberger logging tools were not run in R-35b.

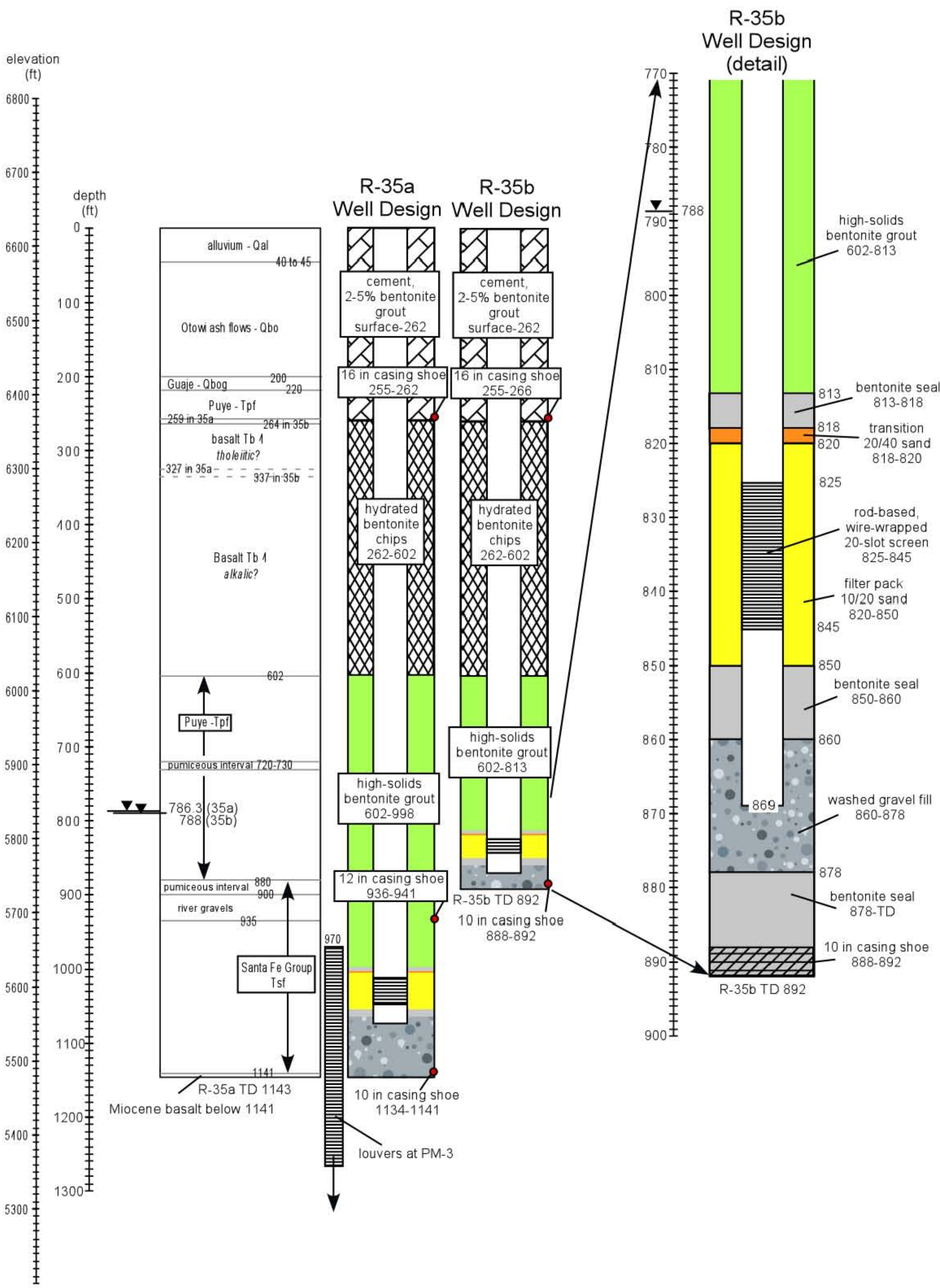
R-35a screen placement:

The driving goal of screen placement at R-35a is to provide a monitoring point for Cr contamination that may be moving at depth from upgradient sources toward the production louvers at well PM-3. Elevated Cr was not observed in any of the water samples collected during drilling of R-35a, but above background concentrations of Mo, Cl, SO4, and NO3 indicated that anthropogenic sources were reaching this site. The screen at R-35a was located with the following goals in mind:
1. A monitoring point is provided at a depth within the range of louvers at production well PM-3, which is ~500 ft to the east.
2. The screen of 1010- to 1050-ft targets the zone that includes some of the highest Mo concentrations opposite the louvers at PM-3. Molybdenum concentrations in this interval are variable, ranging from 14 to 90 ppb or μg/L.
3. The screen depth of 1010- to 1050-ft targets the zone below 1000-ft depth where both driller observations and Schlumberger analysis indicate that flow is enhanced opposite the louvers at PM-3.</td></tr>
</table>

R-35a, R-35b (Preliminary) Wells (continued)		
	Description	Evaluation
		R-35b screen placement: The driving goal of screen placement at R-35b is to provide a monitoring point for Cr contamination that may be moving near the top of regional saturation from western sources. Elevated Cr was not observed in any of the water samples collected during drilling of R-35b, but elevated Mo concentrations indicated that anthropogenic sources were reaching this site. The screen at R-35b was located with the following goals in mind: 1. Sufficient depth was provided beneath the top of regional saturation for aggressive screen development and sufficient screen length to allow future sampling despite drawdown of the regional aquifer over the life of the well. 2. The screen depth of 825- to 845-ft targets the zone that includes some of the highest molybdenum concentrations observed in sampling during the drilling of either R-35a or R-35b. Molybdenum concentrations in this interval range to >100 ppb or μg/L. 3. The screen depth of 825- to 845-ft targets two gravel zones at 820–830 ft and 835–840 ft where driller observations suggest that flow first increases below the top of regional saturation and Schlumberger analysis at nearby R-35a indicates that flow is enhanced.
Filter Pack Materials and Placement ***R-35a:*** (primary 1005–1055 ft; upper secondary sand 1003–1005, no lower secondary sand) ***R-35b:*** (primary 820–850 ft; upper secondary sand 818–820, no lower secondary sand)	The primary filter packs are made up of 10/20 sand. Secondary sand collars are made up of 20/40 sand.	***R-35a:*** Primary filter pack extends 5 ft above the screen openings and 5 ft below. ***R-35b:*** Primary filter pack extends 5 ft above the screen openings and 5 ft below.

R-35a, R-35b (Preliminary) Wells (continued)		
	Description	Evaluation
Sampling System	Submersible Pump	Both R-35a and R-35b are installed with submersible pumps. Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well		None evident, pending completion
Additives used		**R-35a:** Air-rotary drilling was assisted by municipal water mixed with limited amounts of QK-FOAM and defoamer. Additive use was limited to intervals >100 ft above the regional aquifer. Data on quantities pending completion. **R-35b:** Air-rotary drilling was assisted by municipal water mixed with limited amounts of QUIK-FOAM and defoamer. Additive use was limited to intervals >100 ft above the regional aquifer. Data on quantities pending completion.
Annular fill other than filter and transition sands		**R-35a:** Data pending completion. **R-35b:** Data pending completion.
Water produced on development and testing		**R-35a:** Data pending completion. **R-35b:** Data pending completion.

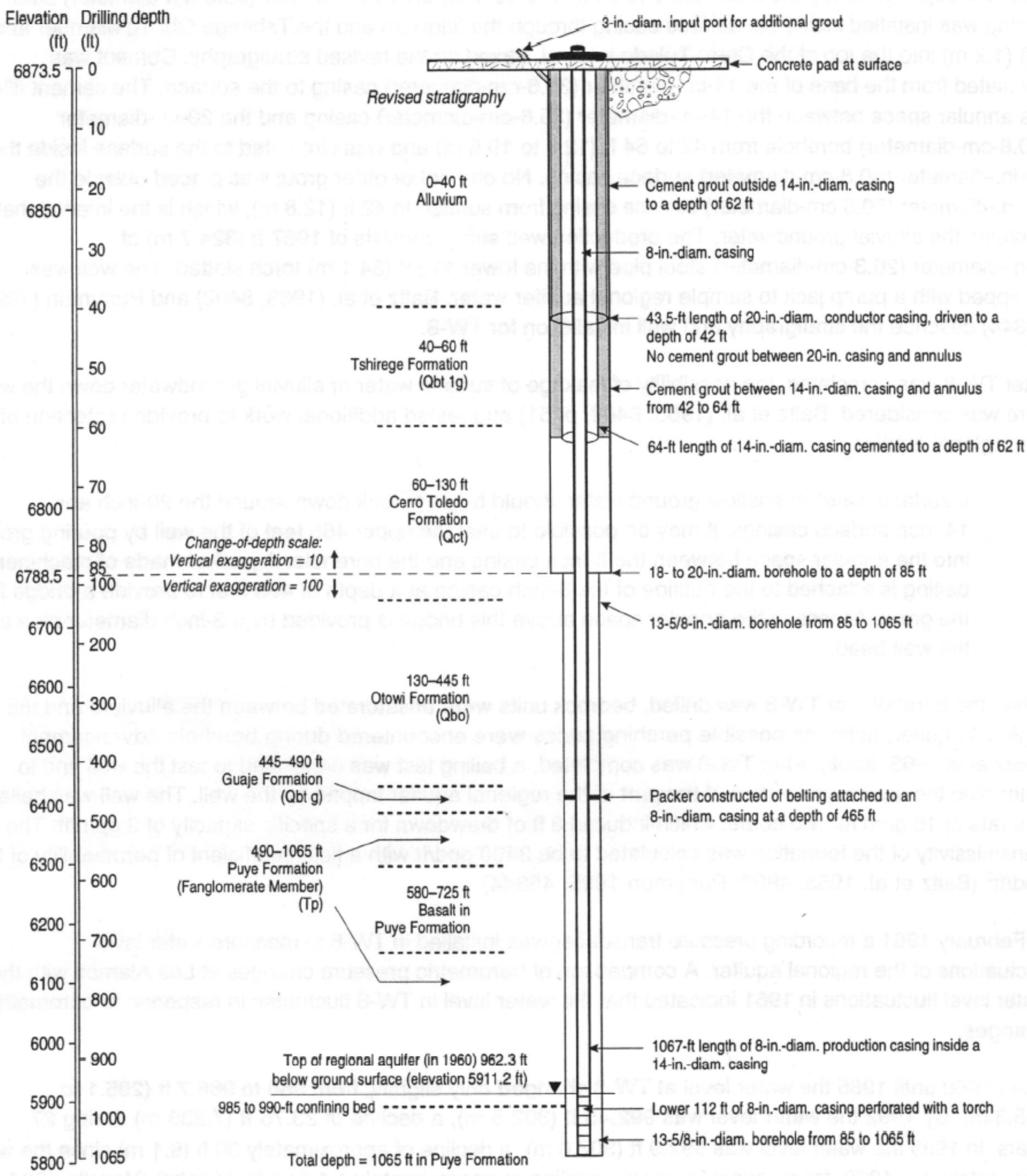

R-35a Well Design
elevation (ft)
depth (ft)
alluvium - Qal
40 to 45
Otowi ash flows - Qbo
Guaje - Qbog
200
220
Puye - Tpf
262
basalt Tb 4 tholeiitic?
337
Basalt Tb 4 alkalic?
602
Puye -Tpf
pumiceous interval 720-730
786.3 (regional)
pumiceous interval
880
900
river gravels
935
Santa Fe Group Tsf
970
1141
TD 1143
Miocene basalt below 1141
cement, 2-5% bentonite grout surface-262
16 in casing shoe 255-262
hydrated bentonite chips 262-602
high-solids bentonite grout 602-998
12 in casing shoe 936-941
10 in casing shoe 1134-1141
louvers at PM-3
high-solids bentonite grout 602-998
998
bentonite seal 998-1003
1003
1005
transition 20/40 sand 1003-1005
1010
rod-based, wire-wrapped 20-slot screen 1010-1050
filter pack 10/20 sand 1005-1055
1050
1055
bentonite seal 1055-1065
1065
1072
washed gravel fill 1065-TD


elevation (ft)
depth (ft)
R-35a Well Design
R-35b Well Design
R-35b Well Design (detail)
alluvium - Qal
40 to 45
Otowi ash flows - Qbo
Guaje - Qbog
200
220
Puye - Tpf
259 in 35a
264 in 35b
basalt Tb 4 tholeiitic?
327 in 35a
337 in 35b
Basalt Tb 4 alkalic?
602
Puye -Tpf
pumiceous interval 720-730
786.3 (35a)
788 (35b)
pumiceous interval 880 900
river gravels
935
Santa Fe Group Tsf
1141
R-35a TD 1143
Miocene basalt below 1141
970
louvers at PM-3
cement, 2-5% bentonite grout surface-262
16 in casing shoe 255-262
16 in casing shoe 255-266
hydrated bentonite chips 262-602
high-solids bentonite grout 602-998
high-solids bentonite grout 602-813
12 in casing shoe 936-941
R-35b TD 892
10 in casing shoe 888-892
10 in casing shoe 1134-1141
788
high-solids bentonite grout 602-813
813
bentonite seal 813-818
818
820
transition 20/40 sand 818-820
825
rod-based, wire-wrapped 20-slot screen 825-845
filter pack 10/20 sand 820-850
845
850
bentonite seal 850-860
860
869
washed gravel fill 860-878
878
bentonite seal 878-TD
10 in casing shoe 888-892
R-35b TD 892

TW-8 Well

TW-8 Well		
	Description	Evaluation
Drilling Method	TW-8 was drilled using a cable-tool method.	In 1960, TW-8 was drilled to a depth of 1065 ft using the cable-tool method. The borehole diameter is 18–20 in. to a depth of 85 ft and 13.625 in. from 85 ft to 1065 ft.
General Well Characteristics	TW-8 is a single-screen well. A 20-in.-diameter steel surface casing was driven to a depth of 42 ft to seal out surface water. Sixty-two feet of 14-in. casing was suspended inside the 20-in. casing and cemented in place. An 8-in. carbon-steel well casing was hung from the surface to the bottom of the borehole.	The use of carbon steel-well casing means that a well of this age is highly corroded. Furthermore, there is no annular fill outside the 20-in. surface casing the annular seal outside the 14-in. casing extends only to a depth of 60 ft. The remainder of the 8-in. well string is suspended in an 18–20 in. open borehole from 60- to 85-ft depth. From 85- to 1065-ft depth, the 8-in. well casing is hung inside a 13.625-in. open borehole. Provisions were made for the introduction of additional annular materials by attaching a packer of machinery belting to the outside of the 8-in. well casing at a depth 465 ft. This packer was intended to provide a bridge for grout introduced through a 3-in. diameter access pipe at the wellhead; however, there is no record that grout was introduced above the packer. The lack of annular fill for most of the length of the well means that the annulus between the well and borehole may act as a preferential pathway for movement of alluvial groundwater to the regional aquifer. Persistence of low-level contamination in groundwater from TW-8, coupled with the absence of contaminants in the properly constructed replacement well R-1, suggests that contaminants are leaking from the surface to the regional aquifer through pathways associated with the annulus of TW-8. Because of its age, construction, and possible contribution to contamination in the regional aquifer, TW-8 should be plugged and abandoned as soon as possible.
Well Screen Construction	The well screen consists of slots cut into the bottom of the 8-in. well casing that were created by using an acetylene torch. Slots are 6-in. long, 0.125-in. wide, and are spaced 90° horizontally. Vertical spacing of horizontal rows is 6 in.	The 0.125-in. slots cut into carbon steel are much wider than the 0.010-in. and 0.020-in. slot wire-wrapped screens that are in current use at the Laboratory. The wide slot size and lack of a sorted-sand filter pack probably means that the bottom of the well has filled with a considerable amount formation fines drawn through the well screen. The problem of silting up the well screen may explain the minimal well development that consisted of bailing the well for 3 h.
Screen Length and Placement	The well screen extends from about 953–1065 ft and has a length of 112 ft. It straddles the water table (currently 999 ft below the surface). The amount of submerged screen is 66 ft.	TW-8 was installed primarily to provide a monitoring point for the regional aquifer below the canyon floor where contaminants could be entering the regional aquifer. The monitoring function of TW-8 is superseded by the installation of R-1.

TW-8 Well (Continued)		
	Description	Evaluation
Filter Pack Materials and Placement	TW-8 was installed without a filter pack.	The lack of a filter pack coupled with large slot openings indicates that formation fine-grained material is probably drawn into the well screen during pumping.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	Corrosion of carbon-steel casing	Corrosion of carbon-steel casing could reduce the structural stability of the well string and affect the quality of groundwater sampled by the well. The geochemical evaluation of groundwater is a means for assessing corrosion of well materials (see Appendix B).
Additives used	Probably none	Cable-tool drilling does not introduce drilling additives.
Annular fill other than filter and transition sands		The annulus of 14-in. casing was cemented from the surface to 62 ft. No annular materials were introduced outside the 20-in. and 8-in. casings.


Elevation (ft)
Drilling depth (ft)
6873.5
6850
6800
6788.5
6700
6600
6500
6400
6300
6200
6100
6000
5900
5800
0
10
20
30
40
50
60
70
80
85
100
200
300
400
500
600
700
800
900
1000
1065
Revised stratigraphy
0–40 ft
Alluvium
40–60 ft
Tshirege Formation
(Qbt 1g)
60–130 ft
Cerro Toledo
Formation
(Qct)
Change-of-depth scale:
Vertical exaggeration = 10
Vertical exaggeration = 100
130–445 ft
Otowi Formation
(Qbo)
445–490 ft
Guaje Formation
(Qbt g)
490–1065 ft
Puye Formation
(Fanglomerate Member)
(Tp)
580–725 ft
Basalt in
Puye Formation
Top of regional aquifer (in 1960) 962.3 ft below ground surface (elevation 5911.2 ft)
985 to 990-ft confining bed
Total depth = 1065 ft in Puye Formation
3-in.-diam. input port for additional grout
Concrete pad at surface
Cement grout outside 14-in.-diam. casing to a depth of 62 ft
8-in.-diam. casing
43.5-ft length of 20-in.-diam. conductor casing, driven to a depth of 42 ft
No cement grout between 20-in. casing and annulus
Cement grout between 14-in.-diam. casing and annulus from 42 to 64 ft
64-ft length of 14-in.-diam. casing cemented to a depth of 62 ft
18- to 20-in.-diam. borehole to a depth of 85 ft
13-5/8-in.-diam. borehole from 85 to 1065 ft
Packer constructed of belting attached to an 8-in.-diam. casing at a depth of 465 ft
1067-ft length of 8-in.-diam. production casing inside a 14-in.-diam. casing
Lower 112 ft of 8-in.-diam. casing perforated with a torch
13-5/8-in.-diam. borehole from 85 to 1065 ft

Appendix B

Geochemical Performance of Network Wells

B-1.0 PURPOSE

This appendix presents the results obtained in the evaluation of the reliability and representativeness (R&R) of sample data collected from 20 candidate wells for the Mortandad Canyon and Technical Area (TA) 50 monitoring network. These 20 wells contain 28 screened intervals that provide water samples for chemical analysis. The objective of the evaluation is to determine whether these intervals are capable of providing data that are R&R of predrilling conditions for chemicals of potential concern (COPCs) that meet the objectives for the Mortandad Canyon and TA-50 monitoring network.

The evaluation is conducted following the approach described in the "Well Screen Analysis Report Revision 2" (hereafter, WSAR Rev. 2) (LANL 2007, 096330). After summarizing the outcome of the evaluation in Section B-2 and Table B-1, the rest of the appendix outlines the steps of the process applied and documents the data used to derive the evaluation results.

B-2.0 RESULTS OF GEOCHEMICAL PERFORMANCE EVALUATION

The capability of each screen to meet geochemical monitoring objectives is expressed by assignment of the screen to one of four categories.

- Meets geochemical monitoring objectives unconditionally—provides R&R samples for all COPCs
- Meets geochemical monitoring objectives conditionally—currently provides R&R samples for some COPCs. Classified as conditional for at least one of two reasons.
    - ❖ The post-development or post-rehabilitation data record spans less than a year, for which reason this screen is classified as conditionally meeting monitoring objectives, subject to the results of future data.
    - ❖ Data may have the potential to be biased high for some constituents and biased low for others at the present time, but this limitation is expected to be resolved within a reasonable time frame as the screen continues to improve
- Does not meet geochemical monitoring objectives—cannot provide R&R samples for any COPCs, and conditions do not show clear signs of improving within a reasonable time frame

Evaluation results are summarized below in terms of the present-day status of each screen interval with respect to its recovery from residual effects of drilling. The capability of each screen to provide water samples that are R&R for specific COPCs and other key analytes is tabulated in Table B-1.

<u>R-1</u> meets geochemical monitoring objectives unconditionally.

<u>R-10a</u> meets geochemical monitoring objectives unconditionally.

- Strontium concentrations are elevated above the upper threshold limit reported for this element to an extent similar to that observed in the perched intermediate well MCOI-6. Although this elevated concentration may indicate drilling-induced changes to carbonate-mineral stabilities in the interval, the trace metals with the potential to show a positive bias if this condition is present (Table B-3) are all below detection in the most recent samples, as is typical for background groundwater from the regional aquifer. Supporting that data from R-10a are R&R. The elevated strontium is most likely attributable to conditions unrelated to drilling.

- Barium concentrations are considerably elevated above the upper threshold limit reported for this element. The cause is unknown, but the stability of the elevated concentration suggests that it is representative of the groundwater at this location.
- R-10a is considered capable of providing R&R data for all COPCs.

R-10 Screen 1 meets geochemical monitoring objectives unconditionally.

R-10 Screen 2 meets geochemical monitoring objectives unconditionally.

R-11 meets geochemical monitoring objectives unconditionally.

- Magnesium concentrations are elevated above the upper threshold limit reported for this element. The cause is uncertain but the stability of the elevated concentration and the lack of any other indicators for residual effects of drilling suggest that the measured concentration is representative of the groundwater at this location.

R-12 Screen 1 meets geochemical monitoring objectives conditionally.

- Residual organics, manganese-reducing conditions, and carbonate-mineral disequilibria are present in this interval, affecting the R&R status of most COPCs. However, drilling-related conditions in the screen interval show a significant improvement relative to those that dominated prior to rehabilitation activities at this location in summer 2006.
- An important consideration is that the only post-rehabilitation water-quality data available are those obtained for the sample collected at the end of development (September 29, 2006). A single sample provides an inadequate basis for determining with confidence the current capability of the screen to provide R&R samples for all COPCs.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium, antimony, bis(2-ethylhexyl)phthalate, and 1,4-dioxane. It is capable of detecting nitrate, perchlorate, and uranium, but these data may be biased low. It is also capable of detecting ammonia and iron, but the data may be biased high. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated when additional data become available from future samples.

R-12 Screen 2 meets geochemical monitoring objectives conditionally.

- Residual organics and slightly reducing conditions may be present in this interval, potentially affecting the R&R status of some of the COPCs.
- An important consideration is that the only post-rehabilitation water-quality data available are those obtained for the sample collected at the end of development (October 1, 2006). A single sample provides an inadequate basis for determining with confidence the current capability of the screen to provide R&R samples.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium, antimony, lead, bis(2-ethylhexyl)phthalate, and 1,4-dioxane. It is capable of detecting nitrate, perchlorate, and uranium, but these data may be biased low. It is also capable of detecting ammonia and iron, but the data may be biased high. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated when additional data become available from future samples.

<u>R-12 Screen 3</u> does not meet geochemical monitoring objectives.

- Manganese-reducing conditions and carbonate-mineral disequilibria are present in this interval, potentially affecting the R&R status of some of the COPCs.
- Another consideration is that during rehabilitation activities, 623,000 gal. of groundwater from the perched intermediate aquifer entered the formation at screen 3 (Appendix A), making it difficult to evaluate the extent to which the present-day sample is representative of regional groundwater.

<u>R-13</u> meets geochemical monitoring objectives unconditionally.

<u>R-14 Screen 1</u> meets geochemical monitoring objectives conditionally.

- Manganese-reducing conditions are present in this interval, but the prognosis for complete recovery from drilling effects looks good, based on steadily improving trends for the key redox indicators and the absence of residual organic drilling fluids.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium, ammonia, antimony, lead, uranium, bis(2-ethylhexyl)phthalate, and 1,4-dioxane. It is capable of detecting perchlorate and chromium, but these data may be biased low. It is also capable of detecting iron, but the data may be biased high. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated when additional data become available from future samples.

<u>R-14 Screen 2</u> does not meet geochemical monitoring objectives.

- Iron-reducing conditions persist in this screen interval, rendering it incapable of providing R&R data for a majority of the COPCs. Although conditions show slow but steady improvement, complete recovery to predrilling conditions is highly unlikely within the next few years in the absence of rehabilitation efforts.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium and 1,4-dioxane. Data for ammonia may be biased high.

<u>R-15</u> meets geochemical monitoring objectives unconditionally.

<u>R-16 Screen 2</u> meets geochemical monitoring objectives conditionally.

- Manganese-reducing conditions are present in this interval, possibly as a result of mixing in the water column in the borehole during rehabilitation activities, but the prognosis for complete recovery from drilling effects looks good based on steadily improving trends for key redox indicators and the absence of residual organic drilling fluids. Nitrate and perchlorate appear to be the only COPCs that could not be reliably detected in the most recent sample, but this condition may be resolved in future samples if the screen interval continues to improve.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium, ammonia, antimony, lead, uranium, bis(2-ethylhexyl)phthalate, and 1,4-dioxane. It is capable of detecting perchlorate and chromium, but these data may be biased low. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated when additional data become available from future samples.

R-16 Screen 3 meets geochemical monitoring objectives conditionally.

- Elevated calcium, strontium, and uranium concentrations indicate that the carbonate-mineral system may not have yet recovered from rehabilitation activities at this screen. Otherwise, the prognosis for complete recovery from drilling effects looks good, based on steadily improving trends for the key redox indicators and the absence of residual organic drilling fluids.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for all except possibly uranium and lead. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated when additional data become available from future samples.

R-16 Screen 4 does not meet geochemical monitoring objectives.

- Residual organics and manganese-reducing conditions persist in this screen interval, rendering it incapable of providing R&R data for a majority of the COPCs. Conditions in the screen interval are significantly improved relative to those that dominated prior to rehabilitation activities at this screen, but post-rehabilitation geochemical trends are as yet inconclusive regarding future capabilities of this screen to provide R&R data for any COPC other than tritium. Even for the most optimistic scenario, recovery to predrilling geochemical conditions would most likely take much longer than just a couple years.
- Of the COPCs listed in Table B-1, this screen is currently capable of providing R&R data for tritium and 1,4-dioxane. These conditions and the capability of the screen to provide R&R data for other COPCs will be reevaluated if additional data become available from future samples.

R-16r meets geochemical monitoring objectives unconditionally.

- Barium, nickel, and strontium are slightly elevated above the threshold criteria, but the stability of these concentrations suggests that they are representative of the groundwater at this location.
- Elevated sulfide measured in samples collected in 2006 may indicate the presence of residual drilling impacts in the screen interval, although the cause and effect of the sulfide are not yet fully understood. In this case, it does not appear to indicate reducing conditions because all other redox tests consistently indicate oxic conditions and because there are no indications for the presence of residual organic fluids.

R-17 Screen 1 meets geochemical monitoring objectives conditionally.

- The geochemical evaluation does not indicate any obvious drilling-related conditions in this screen, and the overall trends are favorable. However, the post-development data record spans less than a year (October 2006 to April 2007) and is classified as conditionally meeting monitoring objectives for all COPCs, subject to the results of future data.
- Strontium concentrations are slightly below the test threshold and most likely reflect natural variations not captured by the limited types of groundwater used to derive these limits in the background groundwater investigation report.

R-17 Screen 2 meets geochemical monitoring objectives conditionally.

- Similar to the case for R-17 Screen 1, the geochemical evaluation does not indicate any obvious drilling-related conditions in this screen, and the overall trends are favorable. However, the post-development data record spans less than a year (October 2006 to April 2007), so this screen is classified as conditionally meeting monitoring objectives for all COPCs, subject to the results of future data.
- Identical to the case for R-17 Screen 1, strontium concentrations are slightly below the test threshold and most likely reflect natural variations not captured by the limited types of groundwater used to derive these limits in the background groundwater investigation report.

R-28 meets geochemical monitoring objectives unconditionally.

R-33 Screen 1 meets geochemical monitoring objectives conditionally.

- No obvious drilling-related conditions are present in this interval. Elevated concentrations of iron and nickel do not appear to point to the presence of iron-reducing conditions in this case because other redox tests indicate oxic conditions. Causes and effects of these excursions from background conditions are not yet fully understood. A likely possibility is that the low-flow Barcad system currently installed in this well does not allow the screen interval to be adequately purged so that the water sample is fully representative of aquifer conditions away from the screen.
- This screen is believed capable of providing R&R data for all of the COPCs listed in Table B-1, subject to the installation of a sampling system capable of adequate purging of an adequate volume of water prior to sample collection. This capability will be reevaluated when data become available from future samples.

R-33 Screen 2 meets geochemical monitoring objectives conditionally.

- Identical to the case for R-33 Screen 1, no obvious drilling-related conditions are present in this interval. Variably elevated concentrations of iron and nickel do not appear to point to the presence of iron-reducing conditions in this case because other redox tests indicate oxic conditions. Sample turbidities have also been variable and often higher than is generally observed for regional groundwater in which drilling effects are absent. Causes and effects of these excursions from background conditions are not yet fully understood. A likely possibility is that the low-flow Barcad system does not allow the screen interval to be adequately purged before sample collection.
- This screen is believed capable of providing R&R data for all of the COPCs listed in Table B-1, subject to the installation of a sampling system capable of adequate purging of an adequate volume of water prior to sample collection. This capability will be reevaluated when data become available from future samples.

R-34 meets geochemical monitoring objectives unconditionally.

<u>TW-8</u> meets geochemical monitoring objectives unconditionally.

- Evaluation of water-quality samples from TW-8 using the WSAR protocol does not reveal any obvious drilling-related conditions. However, although iron concentrations do not exceed the threshold value used to flag for steel corrosion, the concentrations are nonetheless higher than is typically observed in groundwater from the regional aquifer in the absence of drilling effects. Because this well was constructed in 1960 using carbon steel rather than stainless steel, some of the indicators used to detect stainless-steel corrosion are not suitable for detecting if corrosion is present at TW-8.

<u>MCOBT-4.4</u> meets geochemical monitoring objectives unconditionally.

- Total organic carbon concentrations that are very slightly elevated above the selected threshold condition are probably well within background levels for perched intermediate aquifers and are unlikely to reflect the presence of residual organic drilling fluids.
- Strontium concentrations are slightly elevated above the upper threshold limit (UTL) reported for this element in background groundwater from perched intermediate aquifers (LANL 2007, 096330, Table 4-3b). Although this elevated concentration may indicate drilling-induced changes to carbonate-mineral stabilities in the interval, its cause is uncertain. This condition, even if present as a drilling effect at this location, appears not to affect other trace metal concentrations, which are considered R&R. Based on the frequency with which this condition is encountered in the set of screens evaluated in this report, in conjunction with the stability of the strontium concentrations in these intervals, more probable explanations attribute the elevated strontium to natural variations not captured by the limited set of groundwater types used to derive the UTL in the "Groundwater Background Investigation Report, Rev. 2" (LANL 2007, 094856). Background concentration of strontium in perched intermediate groundwater was established at springs discharging within the Sierra de los Valles consisting of the Bandelier Tuff and Tschicoma Formation. Background water chemistry for the Cerros del Rio basalt in perched intermediate groundwater is not known.
- A more significant issue is that the groundwater sample yield has declined over the past several years and has been insufficient in the past 2 yr to obtain samples for analysis.

<u>MCOI-4</u> meets geochemical monitoring objectives unconditionally.

- Total organic carbon concentrations that are slightly elevated above the selected threshold condition are probably well within background levels for perched intermediate aquifers and are unlikely to reflect the presence of residual organic drilling fluids.
- As in the case of MCOBT-4.4, strontium concentrations are slightly elevated above the UTL. Although this elevated concentration may possibly indicate drilling-induced changes to carbonate-mineral stabilities in the interval, its cause is uncertain and is more likely to be attributable to conditions unrelated to drilling, as described for MCOBT-4.4.

<u>MCOI-5</u> meets geochemical monitoring objectives unconditionally.

<u>MCOI-6</u> meets geochemical monitoring objectives unconditionally.

- Total organic carbon concentrations that are slightly elevated above the selected threshold condition are probably well within background levels for perched intermediate aquifers and are unlikely to reflect the presence of residual organic drilling fluids.

- Strontium concentrations are elevated above the UTL to a slightly greater extent than observed in the other wells in the perched intermediate aquifer beneath Mortandad Canyon. Although this elevated concentration may indicate drilling-induced changes to carbonate-mineral stabilities in the interval, its cause is uncertain and could be attributed to conditions unrelated to drilling, as described for MCOBT-4.4.

MCOI-8 does not meet geochemical monitoring objectives.

- There are several geochemical problems with water samples from this borehole, including persistent iron-reducing conditions with the potential to affect the majority of the inorganic COPCs.
- Another major issue with this well is that it does not yield water other than a very small amount that sometimes appears in the sump. Sample volume from this well has never been sufficient to analyze the suite required to conduct a complete evaluation of geochemical performance. There are inadequate data to determine whether the groundwater at this screen has degraded to sulfate-reducing conditions, and no analytical data that could be used to evaluate whether residual organic drilling fluids are present.
- This screen can provide R&R data for tritium and 1,4-dioxane, subject to water being present. The R&R status for other COPCs needs to be evaluated for each individual sample.

B-3.0 APPROACH

The evaluation summarized above was conducted following the approach described in Section 4 of WSAR Rev. 2 (LANL 2007, 096330). Analytical data are compared against threshold levels for about 30 geochemical indicator species, which serve as test criteria for identifying the presence of residual drilling effects. The threshold levels are defined based on levels measured in background samples assumed to be representative of water quality in perched intermediate water or in the regional aquifer, as reported in the “Groundwater Background Investigation Report, Rev. 2” (LANL 2007, 094856). The test criteria are used to identify samples that appear to be unreliable and/or are not representative of predrilling groundwater chemistry because of residual effects of drilling fluids. Site groundwater contamination for each well is also considered in this process. The residual effects are classified into six categories (LANL 2007, 096330).

- Category A—Residual inorganic constituents from drilling, construction, and development products
- Category B—Residual organic components from drilling products
- Category C—Modification of in situ redox conditions
- Category D—Modification of surface-active mineral surfaces with the effect of enhancing adsorption, such as onto drilling clays
- Category E—Carbonate-mineral disequilibria
- Category F—Corrosion of stainless-steel well components
- A seventh category includes general water-quality indicators—pH, alkalinity, and turbidity. Anomalous values for these constituents commonly accompany other indicators of residual drilling effects, but these excursions generally cannot be attributed with confidence to any single cause.

B-4.0 ANALYSIS OF RESIDUAL EFFECTS OF DRILLING

The results of each step of the geochemical performance evaluation are summarized in four tables, for which supporting details are documented in WSAR Rev. 2 (LANL 2007, 096330) and in additional tables at the end of this appendix.

- Table B-2 identifies test indicators that are not applicable for the R&R evaluation in specific sampling intervals because they are present as contaminants in that interval, which can bias the test outcome. The most common contaminants detected in the candidate monitoring wells are mobile anions—chloride, perchlorate, nitrate, and sulfate—which are present in 12 of the 28 intervals, including the 7 perched intermediate zones. Also present but with less frequency are fluoride, chromium, sodium, calcium, and nickel. Elevated alkalinity, magnesium, and uranium concentrations are present in one or two wells each.
- Table B-3 summarizes the current status of each sampling interval for any residual effects of drilling, accounting for trends over time and focusing on the results for the most recent samples. Where appropriate, the status is taken directly from WSAR Rev. 2 (LANL 2007, 096330, Table 6-1). Detailed evaluations of wells which were not covered by that report, and of water-quality samples for which data became available after that report had been prepared, are provided in tables at the end of this appendix.
    - ❖ Table B-5. General Water-Quality Indicators (tritium, pH, alkalinity, turbidity)
    - ❖ Table B-6. Organic Indicators (acetone, ammonia, total Kjeldahl nitrogen, total organic carbon)
    - ❖ Table B-7. Inorganic Nonmetal Indicators (barium, calcium, chloride, fluoride, magnesium, nitrate, oxygen-reduction potential, dissolved oxygen, perchlorate, phosphate, sodium, sulfate, sulfide)
    - ❖ Table B-8. Trace Metal Indicators (chromium, iron, manganese, molybdenum, nickel, strontium, uranium, zinc)
    - ❖ Table B-9 provides a visual synopsis of the detailed data assessment tables in Tables B-5 through B-8. In this table, raw data and data qualifiers shown in the preceding tables have been stripped out, leaving only the Pass/Fail outcomes for each test. Tests are grouped by category of drilling effects; for example, all of the tests to evaluate redox conditions are grouped together in Category C.
    - ❖ Table B-10 lists for each sample the individual test criteria that failed, again grouped by category of drilling effects. The identification of consistent outcomes for the different test categories is the basis for determining what residual drilling effects are present.
- Table B-4 lists the COPCs and identifies which residual drilling effects, if any, have the potential to impact the data reliability and representativeness. This table is based on information tabulated in WSAR Rev. 2 (LANL 2007, 096330, Appendix A).
- The result of the evaluation process was presented earlier as Table B-1, which summarizes the capability of each interval for producing R&R samples for each COPC. This table is constructed by combining the test outcomes (Table B-3) with the COPC list (Table B-4).

B-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Del Signore, J.C., and R.L. Watkins, May 2005. "Radioactive Liquid Waste Treatment Facility Annual Report for 2004," Los Alamos National Laboratory document LA-UR-05-4395, Los Alamos, New Mexico. (Del Signore and Watkins 2005, 092547)

LANL (Los Alamos National Laboratory), September 1997. "Work Plan for Mortandad Canyon," Los Alamos National Laboratory document LA-UR-97-3291, Los Alamos, New Mexico. (LANL 1997, 056835)

LANL (Los Alamos National Laboratory), October 2006. "Mortandad Canyon Investigation Report," Los Alamos National Laboratory document LA-UR-06-6752, Los Alamos, New Mexico. (LANL 2006, 094161)

LANL (Los Alamos National Laboratory), February 2007. "Groundwater Background Investigation Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-0755, Los Alamos, New Mexico. (LANL 2007, 094856)

LANL (Los Alamos National Laboratory), May 2007. "Well Screen Analysis Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-2852, Los Alamos, New Mexico. (LANL 2007, 096330)

Longmire, P., M. Dale, D. Counce, A. Manning, T. Larson, K. Granzow, R. Gray, and B. Newman, July 2007. "Radiogenic and Stable Isotope and Hydrogeochemical Investigation of Groundwater, Pajarito Plateau and Surrounding Areas, New Mexico," Los Alamos National Laboratory report LA-14333, Los Alamos, New Mexico. (Longmire et al. 2007, 096660)

National Library of Medicine, June 11, 2007. "Bis(2-Ethylhexyl)phthalate," online search results from the Hazardous Substances Data Bank (HSDB) on TOXNET (Toxicology Data Network), http://toxnet.nlm.nih.gov/. (National Library of Medicine 2007, 096557)

National Library of Medicine, June 11, 2007. "1,4-Dioxane," online search results from the Hazardous Substances Data Bank (HSDB) on TOXNET (Toxicology Data Network), http://toxnet.nlm.nih.gov/. (National Library of Medicine 2007, 096556)

Table B-1
Capability of Screen to Provide Reliable and Representative Samples For Selected Chemicals of Potential Concern

Well	Port depth (ft)	Scr	3H	NH_4	NO_3	ClO_4	Cr	Fe	Mn	Ni	Sb	Pb	U	Bis(2-ethylhexyl) phthalate	Dioxane [1,4]	PCE and TCE
R-1	1031	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-10a	690	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-10	874	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-10	1042	2	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-11	855	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-12	468	1	■	■+	■−	■−	—?	■+	—?	—?	■	—?	■−	■	■	—
R-12	507	2	■	■+	■−	■−	—?	■+	—?	—?	■	■	■−	■	■	—
R-12	811	3	■?	■?	■?	■?	■?	■?	■?	■?	■?	■?	■?	■?	■?	—
R-13	958	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-14	1204	1	■	■	—	■−	■−	■+	—	—	■	■	■	■	■	—
R-14	1288	2	■	■+	—	—	—	—	—	—	—	—	—	—	■	—
R-15	959	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-16	866	2	■	■	■−	■−	■−	■+	—	—	■	■	■	■	■	—
R-16	1018	3	■	■	■	■	■	■	■	■	■	—	■?	■	■	■
R-16	1238	4	■	—	—	—	■−	■+	—	—	■	—	■−	■	■	—
R-16r	600	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-17	1057	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-17	1124	2	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-28	934	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
R-33	995	1	■	■	■	■	■	—	■	—	■	■	■	■	■	■
R-33	1112	2	■	■	■	■	■	—	■	—	■	■	■	■	■	■
R-34	895	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
TW-8	953	1	■	■	■	■	■	■+	■	■	■	■	■	■	■	■
MCOBT-4.4	485	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MCOI-4	499	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MCOI-5	689	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MCOI-6	686	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■
MCOI-8	665	1	■	—?	—	—	—	—	—	—	—?	—	—	—	■	—

Source: Derived from Tables B-3 and B-4, modified as documented in Section B-2 and supporting tables.

■ = Screen can provide reliable and representative sample for this COPC.

■ + = Screen can provide samples in which this analyte can be detected, if present, but measured concentrations may be biased high due to residual effects of drilling. Note: Analytes to which this flag may be applied are limited to ammonia and iron.

■− = Screen has provided one or more recent samples in which this analyte was detected, but measured concentrations may be biased low due to residual effects of drilling. Note: Analytes to which this flag may be applied are limited to the redox-sensitive species in the above table: nitrate, perchlorate, chromium, and uranium.

■? = Screen probably can provide reliable and representative sample for this COPC, but there is uncertainty associated with this judgment.

— = Screen cannot provide reliable and representative sample for this COPC.

—? = Screen probably cannot provide reliable and representative sample for this COPC, but there is uncertainty associated with this judgment.

COPC = Chemical of potential concern, PCE = tetrachloroethylene; TCE. = trichloroethylene.

Table B-2
Indicators That May Not Be Applicable Due to Presence As a Contaminant

Well	Port Depth (ft)	Scr #	Watershed	Local Contamination[a]	Contaminants Present in Screened Intervals[c]												
					^3H[b]	Alkalinity	Cl	ClO_4	F	Cr	Ca	Mg	Na	Ni	NO_3	SO_4	U
R-1	1031	1	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-10a	690	1	Sandia	Present	—	—	■	■	—	—	■	—	—	—	■	■	■
R-10	874	1	Sandia	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-10	1042	2	Sandia	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-11	855	1	Sandia	Present	Yes	—	■	■	—	■	—	—	—	—	■	■	—
R-12	468	1	Sandia	Present	Yes	—	■	■	■	—	—	—	■	—	■	■	—
R-12	507	2	Sandia	Present	Yes	—	■	■	■	—	—	—	—	—	■	■	—
R-12	811	3	Sandia	Present	Yes	—	■	■	—	—	—	—	—	—	■	■	—
R-13	958	1	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-14	1204	1	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-14	1288	2	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-15	959	1	Mortandad	Present	Yes	—	■	■	—	■	—	—	—	—	■	■	—
R-16	866	2	Cañada del Buey	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-16	1018	3	Cañada del Buey	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-16	1238	4	Cañada del Buey	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-16r	600	1	Cañada del Buey	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-17	1057	1	Pajarito	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-17	1124	2	Pajarito	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-28	934	1	Mortandad	Present	Yes	—	■	■	—	■	■	■	—	■	■	■	—
R-33	995	1	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-33	1112	2	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
R-34	895	1	Mortandad	None	—	—	—	—	—	—	—	—	—	—	—	—	—
TW-8	953	1	Mortandad	None[d]	—	—	—	—	—	—	—	—	—	—	—	—	—
MCOBT-4.4	485	1	Mortandad	Present	Yes	—	■	■	■	■	■	—	■	■	■	■	—

Table B-2 (continued)

Well	Port Depth (ft)	Scr #	Watershed	Local Contamination[a]	Contaminants Present in Screened Intervalsc												
					^3H[b]	Alkalinity	Cl	ClO_4	F	Cr	Ca	Mg	Na	Ni	NO_3	SO_4	U
MCOI-4	499	1	Mortandad	Present	Yes	—	■	■	■	■	■	—	■	■	■	■	—
MCOI-5	689	1	Mortandad	Present	Yes	—	■	■	■	■	■	—	■	—	■	■	—
MCOI-6	686	1	Mortandad	Present	Yes	■	■	■	■	■	■	■	■	■	■	■	—
MCOI-8	665	1	Mortandad	Present	Yes	■	■	■?	■	■	—	—	■?	—	■?	■	—

Sources: Identification of contaminants in unshaded table cells is taken from WSAR Rev. 2 (LANL 2007, 096330, Table 2-1). The source table in WSAR Rev. 2 was purposefully limited to the identification of only the most mobile contaminants and is expanded above to include less mobile contaminants as well.

Identification of contaminants in shaded table cells is based on the “Mortandad Canyon Investigation Report” (LANL 2006, 094161, Section 7.2.2) updated with more recent data and expanded to include indicator species (such as Ca and Mg) that were also present in canyon discharges, based on information presented in the “Work Plan for Mortandad Canyon” (LANL 1997, 056835, Section 3.8.1), and in the “Radioactive Liquid Waste Treatment Facility Annual Report for 2004” (Del Signore and Watkins 2005, 092547, Table 4-1). In addition, revised thresholds for identifying the presence of tritium as a contaminant in perched intermediate aquifers and the regional aquifer are described in footnote b.

[a] Present = One or more contaminants are recognized as being present in this screen interval.

None= No contaminant is known with certainty to be present in this screen interval.

[b] Yes = Tritium (3H) is present as a potential contaminant. Threshold values of 17 pCi/L for perched groundwater, and 1 pCi/L for regional groundwater, are based on Longmire et al. (2007, 096660).

— = Tritium (3H) is not present above the threshold values described above.

[c] ■ = Constituent is recognized as being present as a contaminant in the screened interval.

■? = Constituent is expected to be present at elevated concentrations at this location as a contaminant, but incontrovertible evidence for this origin is not possible because of limited sample volume and/or residual effects from well drilling or construction.

— = Constituent is either not present as a contaminant, or else its presence as a contaminant is indeterminate with the information available at this time.

[d] Assessment for TW-8 is based on that for R-1.

Table B-3
Summary of Evaluation Outcomes for Most Recent Sample

Well Screen			Conditions Present in Screen Interval									
Well	Port depth (ft)	Scr #	Modern Water	Contaminant	Outside pH-Alk Range	Resid Inorg	Resid Org	Redox Stage	Enhanced Adsorption	Fe Mineral	CO_3 Mineral	Steel Corrosion
R-1	1031	1	—	—	—	—	—	Oxic	—	—	—	—
R-10a	690	1	—	■	■?	—	—	Oxic	—	—	■	—
R-10	874	1	—	—	—	—	—	Oxic	—	—	—	—
R-10	1042	2	—	—	—	—	—	Oxic	—	—	—	—
R-11	855	1	■	■	—	—	—	Oxic	—	—	—	—
R-12	468	1	■	■	■	—	■	Mn	—	—	■	—
R-12	507	2	■	■	■	—	■	Mn	—	—	—	—
R-12	811	3	■	■	—	—	—	Mn	—	—	■	—
R-13	958	1	—	—	—	—	—	Oxic	—	—	—	—
R-14	1204	1	—	—	—	—	—	Mn	—	—	—	—
R-14	1288	2	—	—	—	■	—?	Fe	—	■	■	—
R-15	959	1	■	■	—	—	—	Oxic	—	—	—	—
R-16	866	2	—	—	■	—	—	Mn	—	—	—	—
R-16	1018	3	—	—	—	—	—	Oxic	—	—	■	—
R-16	1238	4	—	—	■	—	■	Mn	—	—	■	—
R-16r	600	1	—	—	—	—	—	Oxic	—	—	—?	—
R-17	1057	1	—	—	—	—	—	Oxic	—	—	—	—
R-17	1124	2	—	—	—	—	—	Oxic	—	—	—?	—
R-28	934	1	■	■	—	—	—	Oxic	—	—	—?	—
R-33	995	1	—	—	—	—	—	Oxic	—	—	—	—
R-33	1112	2	—	—	—	—	—	Oxic	—	—	—	—
R-34	895	1	—	—	—	—	—	Oxic	—	—	—	—
TW-8	953	1	—	—	—	—	—	Oxic	—	—	—	—
MCOBT-4.4	485	1	■	■	—	—	—?	Oxic	—	—	—?	—
MCOI-4	499	1	■	■	—	—	—	Oxic	—	—	—?	—
MCOI-5	689	1	■	■	—	—	—	Oxic	—	—	—	—
MCOI-6	686	1	■	■	—	—	—?	Oxic	—	—	—?	—
MCOI-8	665	1	■	■	—	—	No data	Fe	—	—	—	—

Source: Test outcomes for unshaded rows are taken from WSAR Rev. 2 (LANL 2007, 096330, Table 6-1). Some entries have been modified from the original source, either based on results for a more recent sample (see Tables B-5 through B-10 for data evaluation) or for other reasons described in Section B-2 of this report.

Test outcomes for shaded rows are based on the detailed evaluations in Tables B-5 through B-10.

■ = This residual effect of drilling is inferred as likely to be present in the screen interval. The criteria for designating a condition as being present are summarized in WSAR Rev. 2 (LANL 2007, 096330, Table 6-1 footnotes).

■? = This residual effect of drilling is possibly present in the screen interval, but uncertainty associated with this interpretation is described in Section B-4 of this report.

— = This residual effect of drilling does not appear to be present in the screen interval.

—? = This residual effect of drilling is probably not present in the screen interval, but uncertainty associated with this interpretation is described in Section B-2 of this report.

Table B-4
Effects of Residual Drilling Impacts on Selected Chemicals of Potential Concern

Analyte	Relevance		Outside Range of Background pH or Alkalinity[a]	Category A	Category B	Category C				Category D					Category E	Category F
	COPC	Test Indicator		Residual Inorganics	Residual Organics	SO_4	Fe	Mn	NO_3	Sr	U	Ba	Zn	None[b]	Carbonate-Mineral Disequilibria	Steel Corrosion
Tritium	Yes	Yes	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alkalinity	Yes	Yes	—	■	■	■	■	■	—	—	—	—	—	—	—	—
Ammonia	Yes	Yes	—	—	■	—	—	—	—	—	—	—	—	—	—	—
Antimony	Yes	No	—	■	—	■	—	—	—	—	—	—	—	—	—	—
Calcium	Yes	Yes	—	—	—	■	■	—	—	■	—	—	—	—	■	—
Chloride	Yes	Yes	—	■	—	—	—	—	—	—	—	—	—	—	—	—
Chromium	Yes	Yes	—	■	—	■	■	■	—	—	—	—	—	—	—	■ (CP)
Fluoride	Yes	Yes	—	■	—	—	—	—	—	—	—	—	—	—	—	—
Iron	Yes	Yes	■	■	—	■	■	■	—	—	—	—	■	—	■	■ (CP)
Lead	Yes	No	—	■	—	■	■	—	—	—	—	—	■	—	■	■ (Ads)
Manganese	Yes	Yes	—	■	—	■	■	■	—	—	—	—	■	—	■	■ (CP)
Molybdenum	Yes	Yes	—	■	—	■	■	—	—	—	—	—	—	—	—	■ (CP)
Nickel	Yes	Yes	—	■	—	■	■	■	—	—	—	—	■	—	■	■ (CP)
Nitrate	Yes	Yes	—	■	—	■	■	■	■	—	—	—	—	—	—	—
Perchlorate	Yes	Yes	—	—	—	■	■	■	—	—	—	—	—	—	—	—
Sulfate	Yes	Yes	—	■	—	■	—	—	—	—	—	—	—	—	—	—
Uranium	Yes	Yes	■	■	—	■	■	—	—	—	■	—	—	—	■	—

Table B-4 (continued)

Analyte	Relevance		Outside Range of Background pH or Alkalinity[a]	Category A	Category B	Category C				Category D					Category E	Category F
	COPC	Test Indicator		Residual Inorganics	Residual Organics	SO_4	Fe	Mn	NO_3	Sr	U	Ba	Zn	None[b]	Carbonate-Mineral Disequilibria	Steel Corrosion
Bis(2-ethylhexyl)phthalate[c]	Yes	No	—	—	—	—	—	—	—	—	—	—	—	■	—	—
1,4-Dioxane[d]	Yes	No	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetrachloroethylene	Yes	No	—	—	—	■	■	■	■	—	—	—	—	—	—	—
Trichloroethylene	Yes	No	—	—	—	■	■	■	■	—	—	—	—	—	—	—

Source: Compiled from WSAR Rev. 2 (LANL 2007, 096330, Tables 603, A-1, A-2, and A-8), modified as noted above.

■ = Analytical data for this analyte may not be reliable or representative of predrilling conditions if this residual effect of drilling is present.

— = The reliabiliity or representativeness of this analyte is not affected by this residual effect of drilling.

[a] An entry in this column signifies only that the analyte's speciation may differ significantly from that expected under pH and alkalinity conditions that are characteristic of native groundwater, such that assumptions about the analyte's behavior in the presence of a residual drilling effect from drilling may not be valid.

[b] An entry in this column signifies that the analyte may adsorb onto residual bentonite but that it has not suitable indicator species to judge whether or not this effect is present.

[c] Bis(2-ethylhexyl)phthalate is included in WSAR Rev.. 2, (LANL 2007, 096330, Table A-8), in which it is indicated as being affected by Categories C and possibly D. This assessment is updated by information for this analyte from the National Library of Medicine's (NLM's) TOXNET data base (National Library of Medicine 2007, 096557), which indicates that (1) this chemical adsorbs strongly onto soils and sediments, with measured organic-carbon partition coefficients (K_{oc} values) ranging on the order of 105 mL/g C, and (2) this chemical biodegrades readily under aerobic conditions, with reported degradation half-lives ranging from 3 to 80 d in soils and groundwaters. Under anaerobic conditions, no biodegradation of this chemical occurs. Hence, detection of this chemical will not be affected if reducing conditions are present in a screen interval.

[d] 1,4-Dioxane was not included in WSAR Rev. 2 (LANL 2007, 096330, Appendix A). The evaluation tabulated above is based on information for this analyte from the NLM's TOXNET data base (National Library of Medicine 2007, 096556), which indicates that this chemical is highly soluble, is not expected to adsorb onto clays or minerals, and is very slow to biodegrade under either aerobic or anaerobic conditions.

COPC = Chemical of potential concern, CP = corrosion product, Ads = adsorption (onto iron corrosion product).

Table B-5
General Water-Quality Indicators

Well	Port depth (ft)	Scr #	Sample Collection Date	Tritium (pCi/L)	Modern Water?	Field pH		Low pH?	High pH?	Test Gen-1	Alkalinity (mg/L $CaCO_3$)		Test Gen-2	Turbidity (NTU)	Test Gen-3
					>UL			>LL	<UL				<UL		<UL
					1			6.94	8.65				105		5
					1			6.73	8.80				52		5
R-1	1031	1	7-Mar-07	-0.03	No	7.76		Yes	Yes	P	65	CL	P	0.35	P
R-10a	690	1	20-Feb-07	0.1	No	8.01		Yes	Yes	P	106	CL	Fail	1.43	P
R-10	874	1	21-Feb-07	0.03	No	8.03		Yes	Yes	P	91	CL	P	0.02	P
R-10	1042	2	21-Feb-07	0.3	No	7.98		Yes	Yes	P	80	CL	P	0.03	P
R-11	855	1	13-Feb-07	11.1	Yes	7.98		Yes	Yes	P	70	CL	P	0.49	P
R-13	958	1	28-Feb-07	-0.1	No	8.2		Yes	Yes	P	58	CL	P	0.21	P
R-14	1289	2	1-Mar-07	0.1	No	7.71		Yes	Yes	P	75	E6	P	0.88	P
R-15	959	1	28-Feb-07	28	Yes	8.1		Yes	Yes	P	55	CL	P	0.89	P
R-16	866	2	8-Mar-07	-0.16	No	8.72		Yes	No	Fail	77	CL	P	0.48	P
R-16	1018	3	5-Mar-07	0.192	No	8.67		Yes	Yes	P	85	CL	P	0.41	P
R-16	1238	4	6-Mar-07	-0.32	No	8.22		Yes	Yes	P	110	CL	Fail	2.26	P
R-16r	600	1	14-Mar-07	–	ND	8.17		Yes	Yes	P	76	CL	P	0.45	P
R-17	1057	1	22-Feb-07	0.2	No	7.54	CL	Yes	Yes	P	58	CL	P	—	ND
R-17	1057	1	25-Apr-07	–	ND	7.95		Yes	Yes	P	59	CL	P	4.22	P
R-17	1124	2	22-Feb-07	-0.2	No	7.45	CL	Yes	Yes	P	64	CL	P	—	ND
R-17	1124	2	25-Apr-07	–	ND	7.96		Yes	Yes	P	53	CL	P	0.38	P
R-28	934	1	6-Mar-07	189	Yes	7.82		Yes	Yes	P	70	CL	P	0.35	P
R-33	996	1	13-Mar-07	–	ND	7.82		Yes	Yes	P	70	E6	P	1.61	P
R-33	1112	2	13-Mar-07	–	ND	7.67		Yes	Yes	P	70	E6	P	0.67	P
R-34	895	1	13-Mar-07	–	ND	8.25	CL	Yes	Yes	P	68	CL	P	—	ND
TW-8	953	1	2-May-00	–	ND	7.6		Yes	Yes	P	64	CL	P	—	ND
TW-8	953	1	4-Jun-01	–	ND	7.36		Yes	Yes	P	57.3	CL	P	1.37	P
TW-8	953	1	17-May-02	–	ND	7.89		Yes	Yes	P	43.2	CL	P	1.14	P
TW-8	953	1	31-Jul-03	4.2	Yes	7.83		Yes	Yes	P	67.2	CL	P	0.99	P
TW-8	953	1	16-Jun-04	6.1	Yes	8.15		Yes	Yes	P	54.6	CL	P	25.6	Fail
TW-8	953	1	28-Mar-05	–	ND	7.18	E6	Yes	Yes	P	60	E6	P	—	ND
TW-8	953	1	3-Oct-05	–	ND	8.14	E6	Yes	Yes	P	65	E6	P	3.1	P
TW-8	953	1	24-Jan-06	15.7	Yes	8.2		Yes	Yes	P	53	Fld	P	1.5	P
TW-8	953	1	27-Jun-06	3	Yes	8.32		Yes	Yes	P	66.6	CL	P	2.35	P
TW-8	953	1	24-Oct-06	–	ND	8.31		Yes	Yes	P	61.6	CL	P	4.99	P
TW-8	953	1	12-Mar-07	0.3	No	8.42		Yes	Yes	P	58	CL	P	2.1	P
MCOI-4	499	1	23-Jun-05	12900	Yes	6.66		No	Yes	Fail	47	E6	P	31.9	Fail

Table B-5 (continued)

Well	Port depth (ft)	Scr #	Sample Collection Date	Tritium (pCi/L)	Modern Water?	Field pH		Low pH?	High pH?	Test Gen-1	Alkalinity (mg/L $CaCO_3$)		Test Gen-2	Turbidity (NTU)	Test Gen-3
					>UL			>LL	<UL				<UL		<UL
					1			6.94	8.65				105		5
					1			6.73	8.80				52		5
MCOI-4	499	1	13-Sep-05	11800	Yes	6.54		No	Yes	Fail	38	CL	P	18	Fail
MCOI-4	499	1	24-Jan-06	12500	Yes	6.83		Yes	Yes	P	110	Fld	Fail	8.41	Fail
MCOI-4	499	1	27-Jun-06	11700	Yes	6.84		Yes	Yes	P	44	CL	P	2	P
MCOI-4	499	1	24-Oct-06	12500	Yes	6.98		Yes	Yes	P	40	CL	P	0.75	P
MCOI-4	499	1	2-Mar-07	11200	Yes	6.99		Yes	Yes	P	38	CL	P	0.2	P
MCOI-5	689	1	9-Jun-05	4480	Yes	9.38		Yes	No	Fail	62	CL	Fail	83.6	Fail
MCOI-5	689	1	9-Sep-05	4310	Yes	7.19		Yes	Yes	P	46	CL	P	16.6	Fail
MCOI-5	689	1	27-Jan-06	5370	Yes	6.98		Yes	Yes	P	106	Fld	Fail	17.1	Fail
MCOI-5	689	1	26-Jun-06	5160	Yes	7.94		Yes	Yes	P	57	CL	Fail	5.52	Fail
MCOI-5	689	1	19-Oct-06	5150	Yes	7.98		Yes	Yes	P	52	CL	P	1.05	P
MCOI-5	689	1	5-Mar-07	–	ND	8.24		Yes	Yes	P	–		ND	0.69	P
MCOI-6	686	1	15-Jun-05	13100	Yes	7.57		Yes	Yes	P	72	E6	Fail	4.86	P
MCOI-6	686	1	1-Sep-05	13100	Yes	7.38		Yes	Yes	P	72	E6	Fail	6.41	Fail
MCOI-6	686	1	31-Jan-06	12400	Yes	7.4		Yes	Yes	P	114	Fld	Fail	1.39	P
MCOI-6	686	1	29-Jun-06	12100	Yes	7.12		Yes	Yes	P	73	CL	Fail	4.9	P
MCOI-6	686	1	25-Oct-06	11600	Yes	7.27		Yes	Yes	P	71	CL	Fail	1.3	P
MCOI-6	686	1	26-Feb-07	11400	Yes	7.02	CL	Yes	Yes	P	75	CL	Fail	–	ND
MCOI-8	665	1	16-Jun-05	136	Yes	7.46		Yes	Yes	P	148	E6	Fail	38.8	Fail
MCOI-8	665	1	30-Jan-06	–	ND	6.31		No	Yes	Fail	174	Fld	Fail	31	Fail
MCOI-8	665	1	30-Jun-06	–	ND	6.48		No	Yes	Fail	92	CL	Fail	33.6	Fail
MCOI-8	665	1	20-Oct-06	–	ND	7.1		Yes	Yes	P	–		ND	–	ND
MCOI-8	665	1	27-Feb-07	–	ND	7.36		Yes	Yes	P	–		ND	23.5	Fail

Source: WQDB http://wqdbworld.lanl.gov.

P and blue shading both indicate that the data pass the test criterion.

Fail and pink shading both indicate that the data do not pass the test criterion.

ND and a dash both indicate no data.

CL = Contract analytical laboratory; E6 = EES-6 analysis; FLD = field analysis; LL = lower limit; ND = no data; NTU = nephelometric turbidity units; P = pass; UL = upper limit.

Table B-6
Organic Indicators

Well	Port Depth (ft)	Scr #	Sample Collection Date		Acetone (µg/L)	Test B1		NH3-N (mg/L)	Test B2		TKN (mg/L)	Test B3		TOC (mg/L)	Test B4
						<UL			<UL			<UL			<UL
						5			0.05			0.28			1
						5			0.05			0.28			1
R-1	1031	1	7-Mar-07		2.4	P	<	0.01	P	<	0.033	P		0.425	P
R-10a	690	1	20-Feb-07	<	5	P	<	0.01	P	<	0.029	P	<	0.544	P
R-10	874	1	21-Feb-07	<	5	P	<	0.01	P	<	0.01	Rej		0.343	P
R-10	1042	2	21-Feb-07	<	5	P			ND	<	0.01	Rej	<	0.33	P
R-11	855	1	13-Feb-07		1.7	P	<	0.01	P	<	0.01	P		0.339	P
R-13	958	1	28-Feb-07	<	2.8	P	<	0.01	P	<	0.01	P		0.555	P
R-14	1289	2	1-Mar-07		—	ND		—	ND		—	ND		—	ND
R-15	959	1	28-Feb-07	<	6.5	DL	<	0.01	P	<	0.01	P		0.717	P
R-16	866	2	8-Mar-07	<	5	P	<	0.041	P	<	0.06	P		0.657	P
R-16	1018	3	5-Mar-07	<	5	P	<	0.01	P	<	0.01	P		0.516	P
R-16	1238	4	6-Mar-07	<	5	P		0.306	Fail		0.428	Fail		0.999	P
R-16r	600	1	14-Mar-07		3.2	P	<	0.01	Rej	<	0.01	P		0.442	P
R-17	1057	1	22-Feb-07	<	3.1	P	<	0.01	P		0.091	P		0.562	P
R-17	1057	1	25-Apr-07		1.9	P	<	0.03	P	<	0.029	P		0.598	P
R-17	1124	2	22-Feb-07	<	4.3	P	<	0.01	P		—	ND	<	0.33	P
R-17	1124	2	25-Apr-07	<	5	P	<	0.03	P	<	0.029	P		0.46	P
R-28	934	1	6-Mar-07		3.8	P	<	0.01	P		0.063	P		0.574	P
R-33	996	1	13-Mar-07		—	ND		—	ND		—	ND		—	ND
R-33	1112	2	13-Mar-07		—	ND		—	ND		—	ND		—	ND
R-34	895	1	13-Mar-07		3	P		—	ND	<	0.02	P		0.447	P
TW-8	953	1	2-May-00		—	ND		—	ND		—	ND		—	ND
TW-8	953	1	4-Jun-01	<	5	P		—	ND		—	ND		—	ND
TW-8	953	1	17-May-02		—	ND		—	ND		—	ND		—	ND
TW-8	953	1	31-Jul-03		—	ND		—	ND		—	ND		—	ND
TW-8	953	1	16-Jun-04	<	5	P		—	ND		—	ND		—	ND
TW-8	953	1	28-Mar-05		—	ND		—	ND		—	ND		—	ND
TW-8	953	1	3-Oct-05		—	ND		—	ND		—	ND		—	ND
TW-8	953	1	24-Jan-06	<	5	P	<	0.1	Rej	<	0.01	Rej		—	ND
TW-8	953	1	27-Jun-06	<	5	P		0.067	Fail	<	0.01	P	<	0.33	P
TW-8	953	1	24-Oct-06		2	P	<	0.01	Rej	<	0.03	P		0.462	P
TW-8	953	1	12-Mar-07	<	5	Rej	<	0.02	Rej		0.018	P		0.614	P

Table B-6 (continued)

Well	Port Depth (ft)	Scr #	Sample Collection Date		Acetone (µg/L)	Test B1		NH3-N (mg/L)	Test B2		TKN (mg/L)	Test B3		TOC (mg/L)	Test B4
						<UL			<UL			<UL			<UL
						5			0.05			0.28			1
						5			0.05			0.28			1
MCOI-4	499	1	23-Jun-05	<	5	P		—	ND		0.05	P		1.05	Fail
MCOI-4	499	1	13-Sep-05		3.5	P		—	ND	<	0.185	P	<	1.37	DL
MCOI-4	499	1	24-Jan-06	<	5	P	<	0.05	Rej		0.053	P		—	ND
MCOI-4	499	1	27-Jun-06	<	5	Rej	<	0.077	DL	<	0.01	P		0.673	P
MCOI-4	499	1	24-Oct-06	<	5	P		0.189	Fail		0.174	P	<	1.05	DL
MCOI-4	499	1	2-Mar-07		4.3	P	<	0.01	P	<	0.117	P		1.07	Fail
MCOI-5	689	1	9-Jun-05	<	5	Rej		—	ND		0.258	P		1.54	Fail
MCOI-5	689	1	9-Sep-05	<	5	Rej		—	ND	<	0.122	P		1.05	Fail
MCOI-5	689	1	27-Jan-06	<	5	P	<	0.05	Rej	<	0.01	P		—	ND
MCOI-5	689	1	26-Jun-06	<	5	P	<	0.083	DL		0.076	P		0.652	P
MCOI-5	689	1	19-Oct-06	<	7.2	DL	<	0.01	P		—	ND		0.61	P
MCOI-5	689	1	5-Mar-07		—	ND	<	0.05	Rej	<	0.1	Rej		—	ND
MCOI-6	686	1	15-Jun-05	<	5	P		—	ND		0.203	P		1.64	Fail
MCOI-6	686	1	1-Sep-05	<	5	P		—	ND	<	0.054	P		1.16	Fail
MCOI-6	686	1	31-Jan-06	<	5	P		—	ND	<	0.015	P		—	ND
MCOI-6	686	1	29-Jun-06	<	1.4	P	<	0.037	P		0.179	P		2.52	Fail
MCOI-6	686	1	25-Oct-06	<	3	P	<	0.016	P		0.129	P	<	2.45	DL
MCOI-6	686	1	26-Feb-07		4	P	<	0.01	P		0.045	P	<	1.79	DL
MCOI-8	665	1	16-Jun-05		—	ND		—	ND		—	ND		—	ND
MCOI-8	665	1	30-Jan-06		—	ND		—	ND		—	ND		—	ND
MCOI-8	665	1	30-Jun-06		—	ND		—	ND		—	ND		—	ND
MCOI-8	665	1	20-Oct-06		—	ND		—	ND		—	ND		—	ND
MCOI-8	665	1	27-Feb-07		—	ND		—	ND		—	ND		—	ND

Source: WQDB http://wqdbworld.lanl.gov.

P and blue shading both indicate that the data pass the test criterion.

Fail and pink shading both indicate that the data do not pass the test criterion.

ND and a dash both indicate no data.

DL = Indeterminate outcome due to inadequate detection limit; LL = lower limit; ND = no data; P = pass; Rej = analysis rejected in validation and verification review; UL = upper limit.

Table B-7
Inorganic Nonmetal Indicators

Well	Port depth (ft)	Scr #	Sample collection date	Ba mg/L	Test D3	Test E2	Ca mg/L	Test E1a	Test E1b	E1	Cl mg/L	Test A1	F mg/L	Test A2	Mg mg/L	Test E4	NO3-N mg/L	Test C11	ORP mV	Test C3	DO	Test C12	ClO4 ug/L	Test C6	PO4-P	Test A3	Na mg/L	Test A4	SO4 mg/L	Test C1	Test A5	Sulfide	Test C2
					>LL	<UL		>LL	<UL	range		<UL		<UL		<UL		>LL		>LL		>LL		>LL		<UL		<UL		>LL	<UL		<UL
					4.6	70		8.66	24.1			3.75		0.53		4.81		0.1		0		2		0.17		0.3		28.55		0.8	6.22		0.01
					1.4	72		4.39	17.3			1.75		0.23		6.12		0.1		0		2		0.17		0.08		12.19		1.07	4.48		0.01
R-1	1031	1	7-Mar-07	15.4	P	P	11.4	Yes	Yes	P	1.9	P	0.19	P	4.1	P	0.32	P	140	P	4.9	P	0.386	P	0.022	P	12	P	2.9	P	P	—	ND
R-10a	690	1	20-Feb-07	92.3	P	Fail	31	Yes	No	Ctmt	6.09	Ctmt	0.43	P	4.5	P	2.08	Ctmt	300	P	4.0	P	0.646	Ctmt	< 0.039	P	16	P	10.2	P	Ctmt	—	ND
R-10	874	1	21-Feb-07	51.2	P	P	19.7	Yes	Yes	P	2.84	P	0.30	P	4.1	P	0.57	P	—	ND	—	ND	0.56	P	< 0.031	P	12	P	1.84	P	P	—	ND
R-10	1042	2	21-Feb-07	44	P	P	21.4	Yes	Yes	P	3.18	P	0.28	P	4.5	P	0.53	P	—	ND	—	ND	0.553	P	< 0.032	P	13	P	3.77	P	P	—	ND
R-11	855	1	13-Feb-07	38.9	P	P	21.4	Yes	Yes	P	4.65	Ctmt	0.46	P	5.8	Fail	5.61	Ctmt	213.6	P	6.5	P	0.72	Ctmt	< 0.02	P	12	P	9.31	P	Ctmt	—	ND
R-13	958	1	28-Feb-07	26.6	P	P	14	Yes	Yes	P	2.25	P	0.30	P	3.5	P	0.48	P	378	P	5.2	P	0.363	P	< 0.01	P	11	P	1.95	P	P	—	ND
R-14	1289	2	1-Mar-07	81.8	P	Fail	10.9	Yes	Yes	P	2.6	P	0.28	P	2.8	P	< 0.002	Fail	—	ND	—	ND	< 1	DL	0.37	Fail	13	P	1.81	P	P	0.004	P
R-15	959	1	28-Feb-07	29.7	P	P	13.9	Yes	Yes	P	4.23	Ctmt	0.18	P	3.9	P	2.88	Ctmt	415	P	5.9	P	5.34	Ctmt	< 0.033	P	11	P	6.05	P	Ctmt	—	ND
R-16	866	2	8-Mar-07	29.8	P	P	18.8	Yes	Yes	P	2.57	P	0.36	P	1.9	P	0.094	Fail	—	ND	—	ND	0.128	Fail	0.01	P	16	P	3.52	P	P	<0.003	P
R-16	1018	3	5-Mar-07	65.6	P	P	25	Yes	No	Fail	2.44	P	0.38	P	1.7	P	0.28	P	—	ND	—	ND	0.304	P	0.088	P	14	P	3.28	P	P	<0.003	P
R-16	1238	4	6-Mar-07	57.8	P	P	30	Yes	No	Fail	2.71	P	0.34	P	2.4	P	< 0.01	Fail	—	ND	—	ND	< 0.05	Fail	0.195	P	16	P	1.89	P	P	0.004	P
R-16r	600	1	14-Mar-07	71.6	P	Fail	20.1	Yes	Yes	P	2.36	P	0.38	P	0.8	P	0.44	P	221.2	P	4.9	P	0.391	P	< 0.062	P	17	P	4.19	P	P	—	ND
R-17	1057	1	22-Feb-07	36.9	P	P	9.44	Yes	Yes	P	2.09	P	0.23	P	2.8	P	0.25	P	—	ND	—	ND	0.296	P	< 0.066	P	13	P	4.2	P	P	—	ND
R-17	1057	1	25-Apr-07	35.4	P	P	9.17	Yes	Yes	P	1.98	P	0.25	P	2.7	P	0.26	P	—	ND	—	ND	0.256	P	0.034	P	13 E	P	4.2	P	P	—	ND
R-17	1124	2	22-Feb-07	30.3	P	P	8.65	No	Yes	Fail	1.69	P	0.20	P	2.8	P	0.38	P	—	ND	—	ND	0.284	P	< 0.045	P	10	P	1.8	P	P	—	ND
R-17	1124	2	25-Apr-07	28.9	P	P	8.3	No	Yes	Fail	1.7	P	0.20	P	2.7	P	0.35	P	—	ND	—	ND	0.25	P	0.044	P	10 E	P	1.75	P	P	—	ND
R-28	934	1	6-Mar-07	60	P	P	39.5	Yes	No	Ctmt	25.7	Ctmt	0.31	P	10.1	Ctmt	5.04	Ctmt	149.5	P	6.2	P	0.946	Ctmt	< 0.01	P	14	P	38.8	p	Ctmt	—	ND
R-33	996	1	13-Mar-07	30.5	P	P	11	Yes	Yes	P	3.46	P	0.25	P	3.7	P	0.80	P	—	ND	—	ND	< 1	DL	0.02	P	12	P	4.75	P	P	<0.003	P
R-33	1112	2	13-Mar-07	34.4	P	P	10.5	Yes	Yes	P	3	P	0.24	P	3.9	P	0.40	P	—	ND	—	ND	< 1	DL	0.03	P	11	P	3.5	P	P	<0.003	P
R-34	895	1	13-Mar-07	37.9	P	P	15.7	Yes	Yes	P	2.32	P	0.35	P	3.5	P	0.36	P	—	ND	—	ND	0.318	P	< 0.053	P	11	P	2.55	P	P	—	ND
TW-8	953	1	2-May-00	6 NF	P	P	11.534 NF	Yes	Yes	P	1.76	P	0.88	Fail	3.86 NF	P	0.35	P	—	ND	—	ND	< 4	DL	< 0.03	P	10 NF	P	1.89	P	P	—	ND
TW-8	953	1	4-Jun-01	7.78 NF	P	P	11 NF	Yes	Yes	P	1.77	P	0.188	P	3.78 NF	P	0.23	P	—	ND	—	ND	3.26	Err	0.06	P	10 NF	P	1.96	P	P	—	ND
TW-8	953	1	17-May-02	6.83 NF	P	P	11.4 NF	Yes	Yes	P	2.06	P	0.19	P	4.04 NF	P	0.22	P	—	ND	—	ND	< 1.45	DL	< 0.011	P	10 NF	P	2.15	P	P	—	ND
TW-8	953	1	31-Jul-03	6.27 NF	P	P	11.8 NF	Yes	Yes	P	1.92	P	0.079	P	4.31 NF	P	0.17	P	—	ND	—	ND	< 0.989	DL	< 0.065	P	11 NF	P	1.81	P	P	—	ND
TW-8	953	1	16-Jun-04	8.51 NF	P	P	11.7 NF	Yes	Yes	P	1.92	P	< 0.055	P	4.11 NF	P	0.23	P	—	ND	—	ND	0.346	P	< 0.04	P	11 NF	P	1.98	P	P	—	ND
TW-8	953	1	28-Mar-05	5.1	P	P	10.7	Yes	Yes	P	1.83	P	0.14	P	2.97	P	0.12	P	—	ND	2.4	P	—	ND	0.029	P	9	P	1.81	P	P	—	ND
TW-8	953	1	3-Oct-05	5.6	P	P	11.1	Yes	Yes	P	1.85	P	0.13	P	3.84	P	0.15	P	112	P	2.5	P	< 0.5	DL	0.01	P	10	P	1.89	P	P	—	ND
TW-8	953	1	24-Jan-06	6.1	P	P	11.5	Yes	Yes	P	2.21	P	0.141	P	4	P	0.10	P	169.5	P	3.4	P	0.268	P	< 0.223	P	10	P	2.28	P	P	—	ND
TW-8	953	1	27-Jun-06	6.5	P	P	12.2	Yes	Yes	P	2.02	P	< 0.239	P	4.15	P	0.22	P	118.6	P	3.58	P	0.301	P	< 0.03	P	11	P	2.29	P	P	—	ND
TW-8	953	1	24-Oct-06	< 6.7	DL	P	11.2	Yes	Yes	P	1.78	P	0.156	P	3.9	P	0.12	P	207	P	2.76	P	0.16	Fail	< 0.017	P	10	P	1.87	P	P	—	ND
TW-8	953	1	12-Mar-07	5.9	P	P	11.2	Yes	Yes	P	1.82	P	0.177	P	3.75	P	0.16	P	124.9	P	3.11	P	0.211	P	< 0.04	P	9	P	2.01	P	P	—	ND
MCOI-4	499	1	23-Jun-05	14.8	P	P	32.7	Yes	No	Ctmt	20.7	Ctmt	0.24	Ctmt	5.3	P	13	Ctmt	—	ND	1.6	Fail	145	Ctmt	< 0.075	P	20	Ctmt	31.8	Ctmt	Ctmt	—	ND
MCOI-4	499	1	13-Sep-05	19.4	P	P	36.5	Yes	No	Ctmt	19.4	Ctmt	0.23	P	5.72	P	14.2	Ctmt	158.6	P	5.64	P	159	Ctmt	0.108	Fail	24	Ctmt	29.2	Ctmt	Ctmt	—	ND
MCOI-4	499	1	24-Jan-06	16.1	P	P	34.9	Yes	No	Ctmt	21	Ctmt	0.205	P	5.54	P	14.1	Ctmt	267	P	6.84	P	166	Ctmt	< 0.078	P	22	Ctmt	29.1	Ctmt	Ctmt	—	ND
MCOI-4	499	1	27-Jun-06	14.6	P	P	34.2	Yes	No	Ctmt	18.9	Ctmt	< 0.307	DL	5.31	P	17.7	Ctmt	215.3	P	6.77	P	164	Ctmt	< 0.065	P	20	Ctmt	27.6	Ctmt	Ctmt	—	ND
MCOI-4	499	1	24-Oct-06	14.2	P	P	31.8	Yes	No	Ctmt	18.8	Ctmt	0.227	P	4.91	P	17.4	Ctmt	63.2	P	4.96	P	163	Ctmt	< 0.051	P	20	Ctmt	26.4	Ctmt	Ctmt	—	ND
MCOI-4	499	1	2-Mar-07	14.8	P	P	32.7	Yes	No	Ctmt	18.8	Ctmt	0.237	Ctmt	5.2	P	14.9	Ctmt	263	P	7.16	P	136	Ctmt	< 0.01	P	20	Ctmt	25.5	Ctmt	Ctmt	—	ND
MCOI-5	689	1	9-Jun-05	26.9	P	P	19	Yes	No	Ctmt	5.89	Ctmt	0.235	Ctmt	3.66	P	3.17	Ctmt	-27.5	Fail	2.1	P	88.1	Ctmt	< 0.04	P	13	Ctmt	10.8	Ctmt	Ctmt	—	ND
MCOI-5	689	1	9-Sep-05	26.2	P	P	20.1	Yes	No	Ctmt	6.7	Ctmt	0.327	Ctmt	3.78	P	4.22	Ctmt	302.4	P	3.68	P	104	Ctmt	< 0.076	P	14	Ctmt	14.1	Ctmt	Ctmt	—	ND
MCOI-5	689	1	27-Jan-06	24.4	P	P	20.5	Yes	No	Ctmt	6.87	Ctmt	0.333	Ctmt	3.89	P	4.43	Ctmt	209.3	P	3.98	P	112	Ctmt	< 0.177	DL	15	Ctmt	14.5	Ctmt	Ctmt	—	ND
MCOI-5	689	1	26-Jun-06	24.6	P	P	22.1	Yes	No	Ctmt	7.25	Ctmt	0.271	Ctmt	4.27	P	5.13	Ctmt	150.9	P	5.51	P	110	Ctmt	< 0.059	P	14	Ctmt	16.8	Ctmt	Ctmt	—	ND
MCOI-5	689	1	19-Oct-06	21.2	P	P	22.7	Yes	No	Ctmt	6.82	Ctmt	< 0.313	DL	4.37	P	4.8	Ctmt	236.9	P	2.77	P	132	Ctmt	< 0.049	P	14	Ctmt	14.2	Ctmt	Ctmt	—	ND
MCOI-5	689	1	5-Mar-07	—	ND	ND	—	—	—	ND	—	ND	—	ND	—	ND	—	ND	102.1	P	5.26	P	—	ND	—	ND	—	ND		Ctmt	Ctmt	—	ND

Table B-7
Inorganic Nonmetal Indicators

Well	Port depth (ft)	Scr #	Sample collection date	Ba mg/L	Test D3	Test E2	Ca mg/L	Test E1a	Test E1b	E1	Cl mg/L	Test A1	F mg/L	Test A2	Mg mg/L	Test E4
					>LL	<UL		>LL	<UL	range		<UL		<UL		<UL
					4.6	70		8.66	24.1			3.75		0.53		4.81
					1.4	72		4.39	17.3			1.75		0.23		6.12
MCOI-6	686	1	15-Jun-05	32.8	P	P	46.6	Yes	No	Ctmt	24	Ctmt	0.568	Ctmt	9.38	Ctmt
MCOI-6	686	1	1-Sep-05	33.1	P	P	48.1	Yes	No	Ctmt	22.9	Ctmt	0.552	Ctmt	9.65	Ctmt
MCOI-6	686	1	31-Jan-06	31.4	P	P	46.8	Yes	No	Ctmt	22.1	Ctmt	0.593	Ctmt	9.49	Ctmt
MCOI-6	686	1	29-Jun-06	30.2	P	P	45.6	Yes	No	Ctmt	21.5	Ctmt	0.635	Ctmt	9.09	Ctmt
MCOI-6	686	1	25-Oct-06	30.1	P	P	42.8	Yes	No	Ctmt	22.3	Ctmt	0.546	Ctmt	8.49	Ctmt
MCOI-6	686	1	26-Feb-07	32.2	P	P	47.5	Yes	No	Ctmt	22.3	Ctmt	0.537	Ctmt	9.75	Ctmt
MCOI-8	665	1	16-Jun-05	63 NF	P	P	25.3 NF	Yes	No	NF	13.2	Ctmt	1.73	Ctmt	6.0 NF	P
MCOI-8	665	1	30-Jan-06	54	P	P	18.7	Yes	No	Fail	—	ND	—	ND	3.83	P
MCOI-8	665	1	30-Jun-06	36.7	P	P	14.3	Yes	Yes	P	11.1	Ctmt	1.88	Ctmt	3.12	P
MCOI-8	665	1	20-Oct-06	30.4	P	P	14.3	Yes	Yes	P	—	ND	—	ND	3.69	P
MCOI-8	665	1	27-Feb-07	31	P	P	13.8	Yes	Yes	P	—	ND	—	ND	3.9	P

Well	Sample collection date	NO3-N mg/L	Test C11	ORP mV	Test C3	DO	Test C12	ClO4 ug/L	Test C6	PO4-P	Test A3	Na mg/L	Test A4	SO4 mg/L	Test C1	Test A5	Sulfide	Test C2
			>LL		>LL		>LL		>LL		<UL		<UL		>LL	<UL		<UL
			0.1		0		2		0.17		0.3		28.55		0.8	6.22		0.01
			0.1		0		2		0.17		0.08		12.19		1.07	4.48		0.01
MCOI-6	15-Jun-05	15	Ctmt	—	ND	2.9	P	185	Ctmt	< 0.076	P	21	Ctmt	39.5	Ctmt	Ctmt	—	ND
MCOI-6	1-Sep-05	16.4	Ctmt	316	P	5.04	P	246	Ctmt	0.182	Fail	22	Ctmt	37.6	Ctmt	Ctmt	—	ND
MCOI-6	31-Jan-06	19	Ctmt	176.6	P	6.17	P	176	Ctmt	< 0.128	DL	21	Ctmt	35.5	Ctmt	Ctmt	—	ND
MCOI-6	29-Jun-06	20	Ctmt	180.3	P	6.42	P	167	Ctmt	< 0.059	P	20	Ctmt	36.5	Ctmt	Ctmt	—	ND
MCOI-6	25-Oct-06	18.2	Ctmt	108.3	P	5.77	P	188	Ctmt	< 0.06	P	20	Ctmt	34.7	Ctmt	Ctmt	—	ND
MCOI-6	26-Feb-07	16.9	Ctmt	—	ND	—	ND	150	Ctmt	< 0.074	P	21	Ctmt	34.8	Ctmt	Ctmt	—	ND
MCOI-8	16-Jun-05	< 0.003	Fail	13.6	P	1.02	Fail	< 0.05	Fail	0.046	P	45 NF	Fail	23.5	P	Ctmt	—	ND
MCOI-8	30-Jan-06	—	ND	-68.2	Fail	4.4	P	—	ND	—	ND	43	Fail	—	ND	ND	—	ND
MCOI-8	30-Jun-06	—	ND	-42.6	Fail	1.27	Fail	—	ND	—	ND	35	Fail	19.5	P	Ctmt	—	ND
MCOI-8	20-Oct-06	—	ND	68.8	P	3.58	P	< 0.05	Fail	—	ND	31	Fail	—	ND	ND	—	ND
MCOI-8	27-Feb-07	—	ND	384	P	8	P	—	ND	—	ND	27	Fail	—	ND	ND	—	ND

Source: WQDB http://wqdbworld.lanl.gov.

P and blue shading both indicate that the data pass the test criterion.

Fail and pink shading both indicate that the data do not pass the test criterion.

Ctmt = Indeterminate outcome because of presence of indicator as a contaminant at this location; DL = Indeterminate outcome due to inadequate detection limit;

LL = Lower limit; ND = No data; P = Pass; NF = Nonfiltered sample; UL = Upper limit.

Table B-8
Trace Metal Indicators

Well	Port depth (ft)	Scr #	Sample collection date	Cr (F) µg/L	Test C10	Cr (NF) µg/L	Test F3	Ratio Cr (NF/F)	Test F4	Fe (F) µg/L	Test C4	Fe (NF) µg/L	Test F1	Ratio Fe(NF/F)	Test F2	Mn (F) µg/L	Test C5	Mo (F) µg/L	Test C9	Ni (F) µg/L	Test C8	Test F5	Sr ug/L	Test D1	Test E3	U µg/L	Test C7, D2	Test E5	Zn µg/L	Test D4
					>LL		<UL		<UL		<UL		<UL		<UL		<UL		<UL		<UL	<UL		>LL	<UL		>LL	<UL		>LL
					1		10		5		102		500		10		16		4		2	50		44.9	180		0.2	1.52		1
					1		5		5		102		500		10		16		4		2	50		19.1	155		0.1	0.72		1
R-1	1031	1	7-Mar-07	< 4.6	DL	< 4.7	P	—	NA	< 18	P	35.1	Yes	—	NA	< 2	P	< 2.1	P	1.1	P	P	50.5	P	P	0.75	P	P	3.3	P
R-10a	690	1	20-Feb-07	5.6	P	5	P	0.9	NA	< 75	P	357	Yes	—	NA	< 2	P	2.9	P	1	P	P	236	P	Fail	3.4	P	Ctmt	28.8	P
R-10	874	1	21-Feb-07	2.7	P	2.7	P	—	NA	< 18	P	< 31.3	Yes	—	NA	< 2	P	< 2	P	0.68	P	P	108	P	P	1.4	P	P	11.4	P
R-10	1042	2	21-Feb-07	2.7	P	2.6	P	—	NA	< 18	P	< 18	Yes	—	NA	< 2	P	< 2	P	0.71	P	P	110	P	P	1.5	P	P	10.4	P
R-11	855	1	13-Feb-07	33.2	Ctmt	35.1	Ctmt	1.1	NA	< 18	P	< 18	Yes	—	NA	< 2	P	< 2	P	< 0.5	P	P	87.4	P	P	0.75	P	P	16.5	P
R-13	958	1	28-Feb-07	3.8	P	8.4	P			< 18	P	22.5	Yes	—	NA	< 2	P	< 2	P	< 0.5	P	P	52.3	P	P	0.4	P	P	< 4	DL
R-14	1289	2	1-Mar-07	1.4	P	1.6	P	1.1	NA	1040	Fail	1165	No	1.12019	P	185	Fail	2.1	P	1.3	P	P	85.2	P	P	< 0.2	Fail	Red	4.1	P
R-15	959	1	28-Feb-07	7.5	Ctmt	7	P			< 18	P	67.8	Yes	—	NA	< 2	P	< 2	P	< 0.5	P	P	61.1	P	P	0.42	P	P	< 4.3	DL
R-16	866	2	8-Mar-07	1.2 J	P	3.3	P	2.8	NA	< 18	P	75.2	Yes	—	NA	17.8	Fail	2.8	P	0.56	P	P	179	P	P	0.6	P	P	24.4	P
R-16	1018	3	5-Mar-07	< 4.4	DL	< 7.1	P	1.6	NA	< 18	P	< 18	Yes	—	NA	< 2	P	< 2.1	P	1	P	P	252	P	Fail	1.7	P	Fail	15.8	P
R-16	1238	4	6-Mar-07	1.6 J	P	1.7	P	1.1	NA	52.7	P	51.6	Yes	—	NA	52.9	Fail	< 7.4	DL	1.4	P	P	306	P	Fail	< 0.074 J	Fail	Red	10.2	P
R-16r	600	1	14-Mar-07	6.3	P	6.9	P	1.1	NA	< 18	P	40.1	Yes	—	NA	< 2	P	< 4.6	DL	2.1	Fail	P	199	P	Fail	1.2	P	P	< 11.8	DL
R-17	1057	1	22-Feb-07	1.8	P	8.6	P	4.8	NA	234	Fail	1430	No	6.11111	P	4.4	P	2.7	P	2.4	Fail	P	42.5	Fail	P	0.66	P	P	22.5	P
R-17	1057	1	25-Apr-07	2.8	P	12.9	Fail	4.6	P	98.9	P	470	Yes	—	NA	< 2	P	3	P	3.5	Fail	P	40.9	Fail	P	0.65	P	P	9	P
R-17	1124	2	22-Feb-07	3.1	P	13.6	P	4.4	NA	< 66.9	P	< 105	Yes	—	NA	< 2	P	< 2	P	10.4	Fail	P	41.6	Fail	P	0.46	P	P	3.1	P
R-17	1124	2	25-Apr-07	4.5	P	5.4	P	1.2	NA	< 18	P	42.9	Yes	—	NA	< 2	P	< 2	P	4.1	Fail	P	40.2	Fail	P	0.42	P	P	< 2	DL
R-28	934	1	6-Mar-07	446	Ctmt	430	Ctmt	1.0	NA	< 18	P	< 18	Yes	—	NA	< 2	P	2.7	P	7.6	Ctmt	P	147	P	P	1.1	P	P	3.8	P
R-33	996	1	13-Mar-07	9.7	P	10.2	Fail	1.1	P	188	Fail	201	Yes	—	NA	12.5	P	2.1	P	10.8	Fail	P	46.3	P	P	0.84	P	P	6.9	P
R-33	1112	2	13-Mar-07	6.2	P	6.3	P	1.0	NA	121	Fail	225	Yes	—	NA	3.7	P	1.2	P	16.4	Fail	P	45.8	P	P	0.88	P	P	14.6	P
R-34	895	1	13-Mar-07	5	P	5.9	P	1.2	NA	< 18	P	227	Yes	—	NA	3.6	P	< 2.5	P	< 0.5	P	P	66.7	P	P	0.45	P	P	< 5.5	DL
TW-8	953	1	2-May-00	—	ND	< 5	P	—	NA	< 30 NF	P	< 30	Yes	—	NA	< 1 NF	P	< 6 NF	DL	< 10 NF	DL	P	50 NF	P	P	—	ND	ND	397 NF	NF
TW-8	953	1	4-Jun-01	—	ND	3.73	P	—	NA	121 NF	NF	121	Yes	—	NA	< 1.97 NF	P	2.01 NF	P	< 0.815 NF	P	P	54.1 NF	P	P	—	ND	ND	328 NF	NF
TW-8	953	1	17-May-02	—	ND	3.98	P	—	NA	70.1 NF	P	70.1	Yes	—	NA	< 0.296 NF	P	< 1.43 NF	P	< 0.69 NF	P	P	51.5 NF	P	P	—	ND	ND	334 NF	NF
TW-8	953	1	31-Jul-03	—	ND	4.28	P	—	NA	108 NF	NF	108	Yes	—	NA	< 1.55 NF	P	< 1.43 NF	P	< 1.45 NF	P	P	53.3 NF	P	P	0.52 NF	P	P	432 NF	NF
TW-8	953	1	16-Jun-04	—	ND	7.92	P	—	NA	1210 NF	NF	1210	No	—	ND	9.52 NF	P	< 1.43 NF	P	1.8 NF	P	P	54.3 NF	P	P	0.845 NF	P	P	460 NF	NF
TW-8	953	1	28-Mar-05	2.9	P		ND	—	NA	30	P	—	ND	—	ND	4.6	P	< 1	P	< 1	P	P	48	P	P	0.4	P	P	310	P
TW-8	953	1	3-Oct-05	1.8	P		ND	—	NA	40	P	—	ND	—	ND	2.3	P	< 1	P	< 1	P	P	50	P	P	0.4	P	P	160	P
TW-8	953	1	24-Jan-06	< 4.7	DL	< 5.1	P	1.1	NA	40.4	P	102	Yes	—	NA	< 2	P	< 2	P	< 1.1	P	P	51.7	P	P	0.55	P	P	392	P
TW-8	953	1	27-Jun-06	< 6.1	DL	< 7.1	P	1.2	NA	33.2	P	164	Yes	—	NA	< 2	P	< 2	P	1	P	P	54.9	P	P	0.56	P	P	383	P
TW-8	953	1	24-Oct-06	5.4	P	5.8	P	1.1	NA	92.4	P	484	Yes	—	NA	2.9	P	< 3.1	P	< 1.6	P	P	49.6	P	P	0.46	P	P	261	P
TW-8	953	1	12-Mar-07	6.8	P	7.4	P	1.1	NA	79.3	P	205	Yes	—	NA	< 2	P	< 3.3	P	1.9	P	P	52.4	P	P	0.46	P	P	468	P
MCOI-4	499	1	23-Jun-05	25	Ctmt	135	Ctmt	5.4	NA	< 18	P	1150	No	63.8889	Fail	15.9	P	1.4	P	4.1	Ctmt	P	161	P	Fail	< 0.2 NF	DL	NA	141	P
MCOI-4	499	1	13-Sep-05	29.4	Ctmt	61.3	Ctmt	2.1	NA	28.5	P	507	No	17.7895	Fail	7.5	P	< 2	P	5.1	Ctmt	P	177	P	Fail	0.23	P	P	52.9	P
MCOI-4	499	1	24-Jan-06	22.8	Ctmt	47.1	Ctmt	2.1	NA	< 18	P	253	Yes	—	NA	5.6	P	< 2	P	4.8	Ctmt	P	169	P	Fail	0.075	Fail	Red	24.7	P
MCOI-4	499	1	27-Jun-06	16.7	Ctmt	18	Ctmt	1.1	NA	< 18	P	18.8	Yes	—	NA	3.5	P	< 2	P	2.8	Ctmt	P	159	P	Fail	0.12	P	P	294	P
MCOI-4	499	1	24-Oct-06	21.5	Ctmt	19.5	Ctmt	0.9	NA	< 18	P	53.3	Yes	—	NA	3.2	P	< 2	P	3.9	Ctmt	P	158	P	Fail	< 0.05	Fail	Red	22.6	P
MCOI-4	499	1	2-Mar-07	15.4	Ctmt	15.2	Ctmt	1.0	NA	< 18	P	< 18	Yes	—	NA	< 2	P	< 2	P	2.3	Ctmt	P	157	P	Fail	< 0.14	DL	NA	12.9	P
MCOI-5	689	1	9-Jun-05	3.5	Ctmt	770	P	220	NA	62.4	P	6980	No	111.859	Fail	157	Fail	8.1	Fail	55.8	Fail	Fail	90.2	P	P	—	ND	ND	145	P
MCOI-5	689	1	9-Sep-05	3.1	Ctmt	545	P	176	NA	69.8	P	4360	No	62.4642	Fail	123	Fail	7.8	Fail	62.2	Fail	Fail	92.4	P	P	0.15	P	P	137	P
MCOI-5	689	1	27-Jan-06	2.2	Ctmt	218	P	99	NA	69.5	P	1880	No	27.0504	Fail	65.8	Fail	5.8	Fail	55.8	Fail	Fail	94.2	P	P	0.13	P	P	123	P
MCOI-5	689	1	26-Jun-06	2.9	Ctmt	30.5	P	10.5	NA	< 24.4	P	2100	No	86.0656	Fail	21.1	Fail	2.6	P	2.5	Fail	P	104	P	P	0.41	P	P	< 11	DL
MCOI-5	689	1	19-Oct-06	2.1	Ctmt	3.7	P	1.8	NA	< 18	P	78.5	Yes	—	NA	2.7	P	2.5	P	1.5	P	P	104	P	P	0.18	P	P	10	P
MCOI-5	689	1	5-Mar-07	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	—	ND	ND	—	ND	ND	—	ND	ND	—	ND

Table B-8
Trace Metal Indicators

Well	Port depth (ft)	Scr #	Sample collection date	Cr (F) µg/L	Test C10	Cr (NF) µg/L	Test F3	Ratio Cr (NF/F)	Test F4	Fe (F) µg/L	Test C4	Fe (NF) µg/L	Test F1	Ratio Fe(NF/F)	Test F2	Mn (F) µg/L	Test C5	Mo (F) µg/L	Test C9	Ni (F) µg/L	Test C8	Test F5	Sr ug/L	Test D1	Test E3	U µg/L	Test C7, D2	Test E5	Zn µg/L	Test D4
					>LL		<UL		<UL		<UL		<UL		<UL		<UL		<UL		<UL	<UL		>LL	<UL		>LL	<UL		>LL
					1		10		5		102		500		10		16		4		2	50		44.9	180		0.2	1.52		1
					1		5		5		102		500		10		16		4		2	50		19.1	155		0.1	0.72		1
MCOI-6	686	1	15-Jun-05	51.2	Ctmt	52.2	Ctmt	1.0	NA	< 18.2	P	107	Yes	—	NA	25.1	Fail	1.9	P	2.9	Ctmt	P	212	P	Fail	0.3 NF	P	P	74.2	P
MCOI-6	686	1	1-Sep-05	57.2	Ctmt	56.8	Ctmt	1.0	NA	< 18	P	49.9	Yes	—	NA	11.6	P	2.5	P	5.9	Ctmt	P	218	P	Fail	0.5	P	P	51.5	P
MCOI-6	686	1	31-Jan-06	53.4	Ctmt	54.6	Ctmt	1.0	NA	< 18	P	< 35.7	Yes	—	NA	6.6	P	< 2.5	P	5.3	Ctmt	P	204	P	Fail	0.38	P	P	51.6	P
MCOI-6	686	1	29-Jun-06	43.9	Ctmt	42.7	Ctmt	1.0	NA	< 18	P	101	Yes	—	NA	8.5	P	< 2	P	5.1	Ctmt	P	196	P	Fail	0.35	P	P	149	P
MCOI-6	686	1	25-Oct-06	41.2	Ctmt	44	Ctmt	1.1	NA	32.3	P	123	Yes	—	NA	9.9	P	< 2	P	8.8	Ctmt	P	196	P	Fail	0.32	P	P	88.4	P
MCOI-6	686	1	26-Feb-07	29.4	Ctmt	33.8	Ctmt	1.1	NA	23.1	P	157	Yes	—	NA	7.9	P	< 2	P	5.2	Ctmt	P	208	P	Fail	0.4	P	P	111	P
MCOI-8	665	1	16-Jun-05	< 1 NF	Fail	< 1	Red	—	NA	30	P	—	ND	—	ND	940 NF	Fail	150 NF	Fail	27 NF	Fail	P	170 NF	P	Fail	1.6 NF	NF	NF	50 NF	NF
MCOI-8	665	1	30-Jan-06	< 1	Fail	938	Ctmt	—	NA	12800	Fail	20200	No	1.57813	P	1270	Fail	56.1	Fail	7.7	Fail	P	104	P	P	0.33	P	P	19.3	P
MCOI-8	665	1	30-Jun-06	< 1.7	DL	167	Ctmt	—	NA	5890	Fail	10100	No	1.71477	P	1090	Fail	32.2	Fail	11.2	Fail	P	75.5	P	P	0.19	P	P	46.1	P
MCOI-8	665	1	20-Oct-06	< 1	Fail	396	Ctmt	—	NA	800	Fail	6380	No	7.975	P	953	Fail	26	Fail	33.6	Fail	P	75.6	P	P	< 0.21	DL	NA	112	P
MCOI-8	665	1	27-Feb-07	21.3	Ctmt		Ctmt	—	NA	1130	Fail	—	ND	—	ND	997	Fail	19.1	Fail	44.8	Fail	P	77.6	P	P	0.11	P	P	86.4	P

Source: WQDB http://wqdbworld.lanl.gov.

P and blue shading both indicate that the data pass the test criterion.

Fail and pink shading both indicate that the data do not pass the test criterion.

ND and a dash both indicate No data.

Ctmt = Indeterminate outcome because of presence of indicator as a contaminant at this location; DL = Indeterminate outcome due to inadequate detection limit; LL = Lower limit; NA = Test is not applicable; ND = No data; P = Pass; NF = Nonfiltered sample; or test outcome is indeterminate for nonfiltered sample; UL = Upper limit

Table B-9
Summary of Test Outcomes

Well	Port depth (ft)	Screen		General Indicators				Category A Inorganic Indicators					Category B Organic Indicators				Category C1 Redox (SO4)			Category C2 Redox (Fe/Mn)							Category C3 Redox (NO3)		Category D Adsorption				Category E Carbonate minerals					Category F Metal corrosion				
			Sample date	Mod water	Gen-1	Gen-2	Gen-3	A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4	C5	C6	C9	C8	C7	C10	C11	C12	D1	D2	D3	D4	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5
			Units	3H	pH	Alk	Trb	Cl	F	PO4	Na	SO4	Ace	NH3	TKN	TOC	SO4	S	ORP	Fe	Mn	ClO4	Mo	Ni	U	Cr	NO3	DO	Sr	U	Ba	Zn	Ca	Ba	Sr	Mg	U	FeT	FeR	CrT	CrR	Ni
			Test	>UL	In	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	>LL	<UL	>LL	<UL	<UL	>LL	<UL	<UL	>LL	>LL	>LL	>LL	>LL	>LL	>LL	>LL	In	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL
			Regional	1	range	105	5	3.75	0.53	0.3	28.6	6.22	5	0.05	0.28	1	0.8	0.01	0	102	16	0.17	4	2	0.2	1	0.1	2	44.88	0.2	4.6	1	range	70	179.8	4.81	1.52	500	10	10	5	50
			Perched	1		52	5	1.75	0.23	0.08	12.2	4.48	5	0.05	0.28	1	1.07	0.01	0	102	16	0.17	4	2	0.1	1	0.1	2	19.1	0.1	1.4	1		72	154.8	6.12	0.72	500	10	5	5	50
R-1	1031	1	7-Mar-07	No	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	P	P	P	P	P	P	P	DL	P	P	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
R-10a	690	1	20-Feb-07	No	P	Fail	P	Ctmt	P	P	P	Ctmt	P	P	P	P	P	ND	P	P	P	Ctmt	P	P	P	P	Ctmt	P	P	P	P	P	Ctmt	Fail	Fail	P	Ctmt	Yes	NA	P	NA	P
R-10	874	1	21-Feb-07	No	P	P	P	P	P	P	P	P	P	P	Rej	P	P	ND	ND	P	P	P	P	P	P	P	P	ND	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
R-10	1042	2	21-Feb-07	No	P	P	P	P	P	P	P	P	P	ND	Rej	P	P	ND	ND	P	P	P	P	P	P	P	P	ND	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
R-11	855	1	13-Feb-07	Yes	P	P	P	Ctmt	P	P	P	Ctmt	P	P	P	P	P	ND	P	P	P	Ctmt	P	P	P	Ctmt	Ctmt	P	P	P	P	P	P	P	P	Fail	P	Yes	NA	Ctmt	NA	P
R-13	958	1	28-Feb-07	No	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	P	P	P	P	P	P	P	P	P	P	P	P	P	DL	P	P	P	P	P	Yes	NA	P		P
R-14	1289	2	1-Mar-07	No	P	P	P	P	P	Fail	P	P	ND	ND	ND	ND	P	P	ND	Fail	Fail	DL	P	P	Fail	Fail	Fail	ND	P	Fail	P	P	P	Fail	P	P	Red	No	P	P	NA	P
R-15	959	1	28-Feb-07	Yes	P	P	P	Ctmt	P	P	P	Ctmt	DL	P	P	P	P	ND	P	P	P	Ctmt	P	P	P	Ctmt	Ctmt	P	P	P	P	DL	P	P	P	P	P	Yes	NA	P		P
R-16	866	2	8-Mar-07	No	Fail	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	P	Fail	Fail	P	P	P	P	Fail	ND	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
R-16	1018	3	5-Mar-07	No	P	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	P	P	P	P	P	P	DL	P	ND	P	P	P	P	Fail	P	Fail	P	Fail	Yes	NA	P	NA	P
R-16	1238	4	6-Mar-07	No	P	Fail	P	P	P	P	P	P	P	Fail	Fail	P	P	P	ND	P	Fail	Fail	DL	P	Fail	P	Fail	ND	P	Fail	P	P	Fail	P	Fail	P	Red	Yes	NA	P	NA	P
R-16r	600	1	14-Mar-07	ND	P	P	P	P	P	P	P	P	P	Rej	P	P	P	ND	P	P	P	P	DL	Fail	P	P	P	P	P	P	P	DL	P	Fail	Fail	P	P	Yes	NA	P	NA	P
R-17	1057	1	22-Feb-07	No	P	P	ND	P	P	P	P	P	P	P	P	P	P	ND	ND	Fail	P	P	P	Fail	P	P	P	ND	Fail	P	P	P	P	P	P	P	P	No	P	P	NA	P
R-17	1057	1	25-Apr-07	ND	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	ND	P	P	P	P	Fail	P	P	P	ND	Fail	P	P	P	P	P	P	P	P	Yes	NA	Fail	P	P
R-17	1124	2	22-Feb-07	No	P	P	ND	P	P	P	P	P	P	P	ND	P	P	ND	ND	P	P	P	P	Fail	P	P	P	ND	Fail	P	P	P	Fail	P	P	P	P	Yes	NA	P	NA	P
R-17	1124	2	25-Apr-07	ND	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	ND	P	P	P	P	Fail	P	P	P	ND	Fail	P	P	DL	Fail	P	P	P	P	Yes	NA	P	NA	P
R-28	934	1	6-Mar-07	Yes	P	P	P	Ctmt	P	P	P	Ctmt	P	P	P	P	p	ND	P	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	P	Ctmt	P	Yes	NA	Ctmt	NA	P
R-33	996	1	13-Mar-07	ND	P	P	P	P	P	P	P	P	ND	ND	ND	ND	P	P	ND	Fail	P	DL	P	Fail	P	P	P	ND	P	P	P	P	P	P	P	P	P	Yes	NA	Fail	P	P
R-33	1112	2	13-Mar-07	ND	P	P	P	P	P	P	P	P	ND	ND	ND	ND	P	P	ND	Fail	P	DL	P	Fail	P	P	P	ND	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
R-34	895	1	13-Mar-07	ND	P	P	ND	P	P	P	P	P	P	ND	P	P	P	ND	ND	P	P	P	P	P	P	P	P	ND	P	P	P	DL	P	P	P	P	P	Yes	NA	P	NA	P
TW-8	953	1	2-May-00	ND	P	P	ND	P	Fail	P	P	P	ND	ND	ND	ND	P	ND	ND	P	P	DL	DL	DL	ND	ND	P	ND	P	ND	P	NF	P	P	P	P	ND	Yes	NA	P	NA	P
TW-8	953	1	4-Jun-01	ND	P	P	P	P	P	P	P	P	P	ND	ND	ND	P	ND	ND	NF	P	Err	P	P	ND	ND	P	ND	P	ND	P	NF	P	P	P	P	ND	Yes	NA	P	NA	P
TW-8	953	1	17-May-02	ND	P	P	P	P	P	P	P	P	ND	ND	ND	ND	P	ND	ND	P	P	DL	P	P	ND	ND	P	ND	P	ND	P	NF	P	P	P	P	ND	Yes	NA	P	NA	P
TW-8	953	1	31-Jul-03	Yes	P	P	P	P	P	P	P	P	ND	ND	ND	ND	P	ND	ND	NF	P	DL	P	P	P	ND	P	ND	P	P	P	NF	P	P	P	P	P	Yes	NA	P	NA	P
TW-8	953	1	16-Jun-04	Yes	P	P	Fail	P	P	P	P	P	P	ND	ND	ND	P	ND	ND	NF	P	P	P	P	P	ND	P	ND	P	P	P	NF	P	P	P	P	P	No	ND	P	NA	P
TW-8	953	1	28-Mar-05	ND	P	P	ND	P	P	P	P	P	ND	ND	ND	ND	P	ND	ND	P	P	ND	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	ND	ND	NA	P
TW-8	953	1	3-Oct-05	ND	P	P	P	P	P	P	P	P	ND	ND	ND	ND	P	ND	P	P	P	DL	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	ND	ND	ND	NA	P
TW-8	953	1	24-Jan-06	Yes	P	P	P	P	P	P	P	P	P	Rej	Rej	ND	P	ND	P	P	P	P	P	P	P	DL	P	P	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
TW-8	953	1	27-Jun-06	Yes	P	P	P	P	P	P	P	P	P	Fail	P	P	P	ND	P	P	P	P	P	P	P	DL	P	P	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
TW-8	953	1	24-Oct-06	ND	P	P	P	P	P	P	P	P	P	Rej	P	P	P	ND	P	P	P	Fail	P	P	P	P	P	P	P	P	DL	P	P	P	P	P	P	Yes	NA	P	NA	P
TW-8	953	1	12-Mar-07	No	P	P	P	P	P	P	P	P	Rej	Rej	P	P	P	ND	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Yes	NA	P	NA	P
MCOI-4	499	1	23-Jun-05	Yes	Fail	P	Fail	Ctmt	Ctmt	P	Ctmt	Ctmt	P	ND	P	Fail	Ctmt	ND	ND	P	P	Ctmt	P	Ctmt	DL	Ctmt	Ctmt	Fail	P	DL	P	P	Ctmt	P	Fail	P	NA	No	Fail	Ctmt	NA	P
MCOI-4	499	1	13-Sep-05	Yes	Fail	P	Fail	Ctmt	P	Fail	Ctmt	Ctmt	P	ND	P	DL	Ctmt	ND	P	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	P	P	No	Fail	Ctmt	NA	P
MCOI-4	499	1	24-Jan-06	Yes	P	Fail	Fail	Ctmt	P	P	Ctmt	Ctmt	P	Rej	P	ND	Ctmt	ND	P	P	P	Ctmt	P	Ctmt	Fail	Ctmt	Ctmt	P	P	Fail	P	P	Ctmt	P	Fail	P	Red	Yes	NA	Ctmt	NA	P
MCOI-4	499	1	27-Jun-06	Yes	P	P	P	Ctmt	DL	P	Ctmt	Ctmt	Fail	DL	P	P	Ctmt	ND	P	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	P	P	Yes	NA	Ctmt	NA	P
MCOI-4	499	1	24-Oct-06	Yes	P	P	P	Ctmt	P	P	Ctmt	Ctmt	P	Fail	P	DL	Ctmt	ND	P	P	P	Ctmt	P	Ctmt	Fail	Ctmt	Ctmt	P	P	Fail	P	P	Ctmt	P	Fail	P	Red	Yes	NA	Ctmt	NA	P
MCOI-4	499	1	2-Mar-07	Yes	P	P	P	Ctmt	Ctmt	P	Ctmt	Ctmt	P	P	P	Fail	Ctmt	ND	P	P	P	Ctmt	P	Ctmt	DL	Ctmt	Ctmt	P	P	DL	P	P	Ctmt	P	Fail	P	NA	Yes	NA	Ctmt	NA	P
MCOI-5	689	1	9-Jun-05	Yes	Fail	Fail	Fail	Ctmt	Ctmt	P	Ctmt	Ctmt	ND	ND	P	Fail	Ctmt	ND	Fail	P	Fail	Ctmt	Fail	Fail	ND	Ctmt	Ctmt	P	P	ND	P	P	Ctmt	P	P	P	ND	No	Fail	P	NA	Fail
MCOI-5	689	1	9-Sep-05	Yes	P	P	Fail	Ctmt	Ctmt	P	Ctmt	Ctmt	ND	ND	P	Fail	Ctmt	ND	P	P	Fail	Ctmt	Fail	Fail	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	P	P	P	No	Fail	P	NA	Fail
MCOI-5	689	1	27-Jan-06	Yes	P	Fail	Fail	Ctmt	Ctmt	DL	Ctmt	Ctmt	P	Rej	P	ND	Ctmt	ND	P	P	Fail	Ctmt	Fail	Fail	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	P	P	P	No	Fail	P	NA	Fail
MCOI-5	689	1	26-Jun-06	Yes	P	Fail	Fail	Ctmt	Ctmt	P	Ctmt	Ctmt	P	DL	P	P	Ctmt	ND	P	P	Fail	Ctmt	P	Fail	P	Ctmt	Ctmt	P	P	P	P	DL	Ctmt	P	P	P	P	No	Fail	P	NA	P
MCOI-5	689	1	19-Oct-06	Yes	P	P	P	Ctmt	DL	P	Ctmt	Ctmt	DL	P	ND	P	Ctmt	ND	P	P	P	Ctmt	P	P	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	P	P	P	Yes	NA	P	NA	P

Table B-9
Summary of Test Outcomes

Well	Port depth (ft)	Screen		General Indicators				Category A Inorganic Indicators					Category B Organic Indicators				Category C1 Redox (SO4)		
			Sample date	Mod water	Gen-1	Gen-2	Gen-3	A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3
			Units	3H	pH	Alk	Trb	Cl	F	PO4	Na	SO4	Ace	NH3	TKN	TOC	SO4	S	ORP
			Test	>UL	In	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	>LL	<UL	>LL
			Regional	1	range	105	5	3.75	0.53	0.3	28.6	6.22	5	0.05	0.28	1	0.8	0.01	0
			Perched	1		52	5	1.75	0.23	0.08	12.2	4.48	5	0.05	0.28	1	1.07	0.01	0
MCOI-6	686	1	15-Jun-05	Yes	P	Fail	P	Ctmt	Ctmt	P	Ctmt	Ctmt	P	ND	P	Fail	Ctmt	ND	ND
MCOI-6	686	1	1-Sep-05	Yes	P	Fail	Fail	Ctmt	Ctmt	Fail	Ctmt	Ctmt	P	ND	P	Fail	Ctmt	ND	P
MCOI-6	686	1	31-Jan-06	Yes	P	Fail	P	Ctmt	Ctmt	DL	Ctmt	Ctmt	P	ND	P	ND	Ctmt	ND	P
MCOI-6	686	1	29-Jun-06	Yes	P	Fail	P	Ctmt	Ctmt	P	Ctmt	Ctmt	P	P	P	Fail	Ctmt	ND	P
MCOI-6	686	1	25-Oct-06	Yes	P	Fail	P	Ctmt	Ctmt	P	Ctmt	Ctmt	P	P	P	DL	Ctmt	ND	P
MCOI-6	686	1	26-Feb-07	Yes	P	Fail	ND	Ctmt	Ctmt	P	Ctmt	Ctmt	P	P	P	DL	Ctmt	ND	ND
MCOI-8	665	1	16-Jun-05	Yes	P	Fail	Fail	Ctmt	Ctmt	P	Fail	Ctmt	ND	ND	ND	ND	P	ND	P
MCOI-8	665	1	30-Jan-06	ND	Fail	Fail	Fail	ND	ND	ND	Fail	ND	ND	ND	ND	ND	ND	ND	Fail
MCOI-8	665	1	30-Jun-06	ND	Fail	Fail	Fail	Ctmt	Ctmt	ND	Fail	Ctmt	ND	ND	ND	ND	P	ND	Fail
MCOI-8	665	1	20-Oct-06	ND	P	ND	ND	ND	ND	ND	Fail	ND	ND	ND	ND	ND	ND	ND	P
MCOI-8	665	1	27-Feb-07	ND	P	ND	Fail	ND	ND	ND	Fail	ND	ND	ND	ND	ND	ND	ND	P

Well	Port depth (ft)	Screen		Category C2 Redox (Fe/Mn)							Category C3 Redox (NO3)		Category D Adsorption				Cetegory E Carbonate minerals					Category F Metal corrosion				
			Sample date	C4	C5	C6	C9	C8	C7	C10	C11	C12	D1	D2	D3	D4	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5
			Units	Fe	Mn	ClO4	Mo	Ni	U	Cr	NO3	DO	Sr	U	Ba	Zn	Ca	Ba	Sr	Mg	U	FeT	FeR	CrT	CrR	Ni
			Test	<UL	<UL	>LL	<UL	<UL	>LL	>LL	>LL	>LL	>LL	>LL	>LL	>LL	In	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL
			Regional	102	16	0.17	4	2	0.2	1	0.1	2	44.88	0.2	4.6	1	range	70	179.8	4.81	1.52	500	10	10	5	50
			Perched	102	16	0.17	4	2	0.1	1	0.1	2	19.1	0.1	1.4	1		72	154.8	6.12	0.72	500	10	5	5	50
MCOI-6	686	1	15-Jun-05	P	Fail	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-6	686	1	1-Sep-05	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-6	686	1	31-Jan-06	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-6	686	1	29-Jun-06	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-6	686	1	25-Oct-06	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	P	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-6	686	1	26-Feb-07	P	P	Ctmt	P	Ctmt	P	Ctmt	Ctmt	ND	P	P	P	P	Ctmt	P	Fail	Ctmt	P	Yes	NA	Ctmt	NA	P
MCOI-8	665	1	16-Jun-05	P	Fail	Fail	Fail	Fail	NF	Fail	Fail	Fail	P	NF	P	NF	NF	P	Fail	P	NF	ND	ND	Red	NA	P
MCOI-8	665	1	30-Jan-06	Fail	Fail	ND	Fail	Fail	P	Fail	ND	P	P	P	P	P	Fail	P	P	P	P	No	P	Ctmt	NA	P
MCOI-8	665	1	30-Jun-06	Fail	Fail	ND	Fail	Fail	P	DL	ND	Fail	P	P	P	P	P	P	P	P	P	No	P	Ctmt	NA	P
MCOI-8	665	1	20-Oct-06	Fail	Fail	Fail	Fail	Fail	DL	Fail	ND	P	P	DL	P	P	P	P	P	P	NA	No	P	Ctmt	NA	P
MCOI-8	665	1	27-Feb-07	Fail	Fail	ND	Fail	Fail	P	Ctmt	ND	P	P	P	P	P	P	P	P	P	P	ND	ND	Ctmt	NA	P

Source: Tables B-5 to B-8

P and blue shading both indicate that the data pass the test criterion.

Fail and pink shading both indicate that the data do not pass the test criterion.

ND and a dash both indicate No data.

Ctmt = Indeterminate outcome because of presence of indicator as a contaminant at this location;

DL = Indeterminate outcome due to inadequate detection limit; LL = Lower limit; NA = Test is not applicable; ND = No data; NF = Test outcome is indeterminate for nonfiltered sample; P = Pass; Rej = Analytical data rejected; UL = Upper limit.

Table B-10
Failed Indicator Tests for Each Sample

Well	Port depth (ft)	Screen	Sample date	General Indicators	Category A Residual Inorganics	Category B Residual Organics	Category C Redox Conditions									Cat D	Cat E Minerals	Cat F Corrision
							SO4-Reducing	Fe/Mn-Reducing							NO3-Reducing			
								Fe	Mn	ClO4	Mo	Ni	U	Cr				
R-1	1031	1	7-Mar-07															
R-10a	690	1	20-Feb-07	+Alk													+Ba, +Sr	
R-10	874	1	21-Feb-07															
R-10	1042	2	21-Feb-07															
R-11	855	1	13-Feb-07														+Mg	
R-13	958	1	28-Feb-07															
R-14	1289	2	1-Mar-07			No data		Fe	Mn				U	Cr	NO3	U	+Ba	
R-15	959	1	28-Feb-07															
R-16	866	2	8-Mar-07						Mn	ClO4					NO3			
R-16	1018	3	5-Mar-07														+Ca, +Sr, +U	
R-16	1238	4	6-Mar-07			NH3, TKN			Mn	ClO4			U		NO3	U	+Ca, +Sr	
R-16r	600	1	14-Mar-07									Ni					+Ba, +Sr	
R-17	1057	1	22-Feb-07					Fe				Ni				Sr		
R-17	1057	1	25-Apr-07									Ni				Sr		
R-17	1124	2	22-Feb-07									Ni				Sr	-Ca	
R-17	1124	2	25-Apr-07									Ni				Sr	-Ca	
R-28	934	1	6-Mar-07															
R-33	996	1	13-Mar-07			No data		Fe				Ni						
R-33	1112	2	13-Mar-07			No data		Fe				Ni						
R-34	895	1	13-Mar-07															
TW-8	953	1	2-May-00		F	No data												
TW-8	953	1	4-Jun-01															
TW-8	953	1	17-May-02			No data												
TW-8	953	1	31-Jul-03			No data												
TW-8	953	1	16-Jun-04	Turb														
TW-8	953	1	28-Mar-05			No data												
TW-8	953	1	3-Oct-05			No data												
TW-8	953	1	24-Jan-06															
TW-8	953	1	27-Jun-06			NH3												
TW-8	953	1	24-Oct-06							ClO4								
TW-8	953	1	12-Mar-07															
MCOI-4	499	1	23-Jun-05	-pH, Turb		TOC									DO		+Sr	
MCOI-4	499	1	13-Sep-05	-pH, Turb	PO4												+Sr	
MCOI-4	499	1	24-Jan-06	+Alk, Turb									U			U	+Sr	
MCOI-4	499	1	27-Jun-06			Acetone											+Sr	
MCOI-4	499	1	24-Oct-06			NH3							U			U	+Sr	
MCOI-4	499	1	2-Mar-07			TOC											+Sr	
MCOI-5	689	1	9-Jun-05	+pH, +Alk, Turb		TOC	ORP		Mn		Mo	Ni						
MCOI-5	689	1	9-Sep-05	Turb		TOC			Mn		Mo	Ni						
MCOI-5	689	1	27-Jan-06	+Alk, Turb					Mn		Mo	Ni						
MCOI-5	689	1	26-Jun-06	+Alk, Turb					Mn			Ni						
MCOI-5	689	1	19-Oct-06															

Table B-10
Failed Indicator Tests for Each Sample

Well	Port depth (ft)	Screen	Sample date	General Indicators	Category A Residual Inorganics	Category B Residual Organics	Category C Redox Conditions									Cat D	Cat E Minerials	Cat F Corrision
							SO4-Reducing	Fe/Mn-Reducing							NO3-Reducing			
								Fe	Mn	ClO4	Mo	Ni	U	Cr				
MCOI-6	686	1	15-Jun-05	+Alk		TOC			Mn								+Sr	
MCOI-6	686	1	1-Sep-05	+Alk, Turb	PO4	TOC											+Sr	
MCOI-6	686	1	31-Jan-06	+Alk													+Sr	
MCOI-6	686	1	29-Jun-06	+Alk		TOC											+Sr	
MCOI-6	686	1	25-Oct-06	+Alk													+Sr	
MCOI-6	686	1	26-Feb-07	+Alk													+Sr	
MCOI-8	665	1	16-Jun-05	+Alk, Turb	Na	No data			Mn	ClO4	Mo	Ni		Cr	NO3, DO		+Sr	
MCOI-8	665	1	30-Jan-06	-pH, +Alk, Turb	Na	No data	ORP	Fe	Mn		Mo	Ni		Cr			+Ca	
MCOI-8	665	1	30-Jun-06	-pH, +Alk, Turb	Na	No data	ORP	Fe	Mn		Mo	Ni			DO			
MCOI-8	665	1	20-Oct-06		Na	No data		Fe	Mn	ClO4	Mo	Ni		Cr				
MCOI-8	665	1	27-Feb-07	Turb	Na	No data		Fe	Mn		Mo	Ni						

— = No tests failed in this category. (Note: this includes cases for which there are no suitable indicator data).

[a] Abbreviations used in category for general indicators: Alk = Alkalinity; -pH = pH below lower limit; +pH = pH above upper limit; Turb = turbidity.

[b] Convention used in Category E: + means the indicator is elevated above the upper limit; −means the element is below the lower limit.

Appendix C

Evaluation of Location of Networks and Screening

C-1.0 INTRODUCTION

This appendix briefly describes the process applied and the results obtained in the analysis of the ability of the Los Alamos National Laboratory (Laboratory) regional aquifer groundwater monitoring network to detect contaminants coming from anticipated infiltration areas reaching the regional aquifer due to sources within the Mortandad Canyon watershed. Appendixes A and B of this report address the ability of intermediate and regional wells in the vicinity of and downgradient of Mortandad Canyon to detect contaminants if contaminants arrive at those wells. This section analyzes the location of each regional well to determine if it is in the right location to intercept contaminants.

As stated in the main body of this report, the objective of the network is to be able to capture at least 95% of the potential plumes arising from Material Disposal Area (MDA) C or the Technical Area (TA) 50 Radioactive Liquid Waste Treatment Facility (RLWTF) outfall from now until a final groundwater monitoring network is designed and installed as part of the corrective measures evaluations (CMEs) for these sites.

For the TA-50 evaluation, contaminant particle transport was modeled from an infiltration window consistent with the conceptual model discussed in Section C-2.0. These particles were allowed to flow out from this infiltration window for 3 yr from the present (the CME time frame). Interceptions by regional characterization/monitoring wells, water-supply production wells, and the Laboratory boundary were noted. Note that not all particles were intercepted because of the limited time element; some were too slow to reach a well or a boundary during this period, thus resulting in a “inconclusive plume.”

Some wells already detect contamination (i.e., R-15 and R-28) and are therefore in the right location. Most wells have not detected contamination and therefore must be shown to be in a likely path of potential future contaminant migration. A model of regional aquifer groundwater flow and contaminant transport was used to estimate likely contaminant travel paths arising from the two main sources identified in the conceptual model section of the main report—MDA C and TA-50 RLWTF.

No analytical detection limit or regulatory limits were used in this analysis because the groundwater flow and transport model used unit values for contaminants in their introduction to the regional aquifer instead of absolute concentrations. Therefore, the initial arrival years for each well are computed as the first year that the concentration in a well or at the boundary is greater than zero (i.e., initial particle arrival).

The regional groundwater model used for this analysis did not consider vadose-zone travel times; instead, contaminant particle movement was modeled beginning with an introduction directly to the regional aquifer water table. In the present analysis, vadose-zone travel times and the initial release date for each anticipated infiltration area were used to adjust simulation times to actual dates.

In Table C-1 the initial year of release and vadose-zone travel time estimations are provided (Birdsell et al. 2006, 094399; Longmire et al. 2007, 096660).

According to Table C-1, contaminants released from MDA C should arrive at the water table long after year 2048. In addition, the planned MDA C vadose-zone monitoring network is designed to detect contaminants prior to their arrival at the water table. Therefore, additional information regarding the efficiency of the current well placement is not necessary. Instead, the vadose-zone travel time is sufficient to allow the design of a final MDA C monitoring network to take place in the forthcoming MDA C CME process.

For the TA-50 RLWTF outfall, the first 22 yr after introduction to the regional aquifer was used in the simulation, which correspond to the period from 1988 to 2010.

This work utilizes the results of a recent regional groundwater model that analyzed potential contaminant transport from 21 anticipated infiltration areas across Laboratory property. One of those areas corresponds with the TA-50 RLWTF outfall. Because this was a model of only the regional aquifer, this anticipated infiltration area was projected onto the water table as the starting point for contaminant migration. Simulated plumes were based on a unit concentration at each of these areas. Therefore, the model produced relative concentrations (0–1) at monitoring and production wells. Consistent with the conceptual model outlined in the main body of this report, the movement of a nonsorbing conservative tracer was simulated. In recognition of uncertainty in key model parameters, a Monte Carlo analysis was performed where 1000 sets of parameter input values were sampled and used as input to 1000 simulations. The results are 1000 possible plume locations that this analysis uses to evaluate the locations of the existing regional wells in and near Mortandad Canyon.

The groundwater-flow model used in this analysis was two-dimensional and accounts for the possibility that most contaminants flow laterally along the top of the water table. The potential effects of pumping on contaminant transport were simulated by defining a variable and uncertain capture radius for each pumping well. This radius varied from 25 to 1000 m. Thus, while the hydraulic effects of pumping are not explicitly stated in this model, the potential for pumping wells to capture nearby plumes is included.

The anticipated infiltration area located in Mortandad Canyon used for the present study is the polygon labeled “MOR3,” located in the lower part of the canyon. This represents the infiltration breakthrough location at the regional aquifer for liquid releases from outfalls associated with the TA-50 RLWTF. This area is shown on the map in Figure C-1.

C-2.0 MONITORING METRICS

A monitoring well must not only be in the potential path of a future plume to be successful but also be capable of detecting contaminants prior to their arrival at production wells or to their crossing Laboratory boundaries. In a more general sense, there are a number of possible scenarios for each simulation (or plume).

Undetected plumes are plumes that reach either a production well or the Laboratory boundary without being detected by any monitoring well.

Correct detections are plumes that first reach a monitoring well and after that reach a production well or the Laboratory boundary.

Late detections are plumes that first reach a production well or the Laboratory boundary and after that arrive at a monitoring well.

Plumes of concern are plumes that reach either a production well or the Laboratory boundary. They include the plumes that fall into any of the definitions given above. Here the word “concern” applies to monitoring only for the period of time between now and the completion of the CME. Plumes that do not reach a production well or the Laboratory boundary in this time frame may well be important in defining the nature and extent of contamination for the CME, and the CME will address the possibility that at a later time these plumes may reach production wells or the Laboratory boundary.

False alarms are plumes that reach a monitoring well but don’t reach a production well or the Laboratory boundary.

Detected plumes are plumes that arrive at the monitoring wells. They include correct detections; late detections, and false alarms.

Inconclusive plumes are plumes that don't arrive at the production wells, the Laboratory boundary, or any monitoring well in the time frame of the analysis.

Finally, *efficiency* was computed as the number of correct detections divided by the number of plumes of concern.

C-3.0 RESULTS

Shown in Figure C-2 and Table C-2 are the efficiencies (%) of each regional well in detecting potential plumes before they arrive at a production well or leave Laboratory property. In addition, Table C-2 lists the efficiency of the overall groundwater monitoring well network (regional wells only) in detecting plumes from each of the two anticipated infiltration areas. For wells having more than one screen, the results in this table represent the upper screen because the underlying numerical model is a two-dimensional representation near the top of the regional aquifer.

Note that efficiency is a measure of two primary factors:

1. Effect of well locations: Whether plumes reach a production well or the boundary without prior detection by a regional monitoring well

2. Effect of the simulation time limit: Whether the plume reaches any well or boundary before the end of the simulation period (i.e., the estimated CME completion time frame). Some plumes are still traveling when the simulation period ends.

For TA-50 RLWTF, this analysis has demonstrated that over 97% of plumes would be detected prior to their arrival at a production well or leaving the Laboratory boundary. In addition, these analyses are based on a unit concentration initial condition. Therefore, these results do not indicate whether any of the plumes are associated with concentrations that exceed regulatory standards or even detection limits.

C-3.1 Analysis of Results

The TA-50 RLWTF outfall anticipated infiltration area was analyzed up to the year 2010. From the 1000 plumes analyzed, 82% could potentially impact production wells, and 63% could potentially arrive at Laboratories boundaries. However, the monitoring well network would detect *97.2%* of those plumes, mainly by wells R-15 (83%) and R-28 (74%). Other wells having detections are R-35 (16.3%), R-33 (10%), R-11 (5.2%), R-13 (0.6%), R-1 (0.2%), TW-8 (0.2%), and R-12 (0.1%). Finally, wells that do not see any particles prior to a production well or the boundary are R-10a, R-14, R-16, R-17, and R-34.

Note that wells that have low efficiencies are not necessarily "bad" wells. It means that they did not intercept a plume before that plume reached a production well, boundary, OR stopped because of the time limit of the simulation. It may also mean that the well is far from MOR3. Such wells may serve as background wells or monitoring wells for other watersheds/sources, and may have served as able characterization wells. For this study, some were included to provide control points outside the flow path for the simulation.

Details of the efficiency calculation for each anticipated infiltration area are shown below in Table C-3. Details include the number of plumes of concern, total detections, correct and late detections, and false alarms for each monitoring well.

C-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Birdsell, K., B. Newman, M.O. Gard, D. Krier, D. Rogers, D. Katzman, and V. Vesselinov, 2006. "Selected Key Contaminant Sources from Los Alamos National Laboratory Including Liquid Outfalls and Material Disposal Areas," Los Alamos Scientific Laboratory document LA-UR-06-8481, Los Alamos, New Mexico. (Birdsell et al. 2006, 094399)

Longmire, P., M. Dale, D. Counce, A. Manning, T. Larson, K. Granzow, R. Gray, and B. Newman, July 2007. "Radiogenic and Stable Isotope and Hydrogeochemical Investigation of Groundwater, Pajarito Plateau and Surrounding Areas, New Mexico," Los Alamos National Laboratory report LA-14333, Los Alamos, New Mexico. (Longmire et al. 2007, 096660)

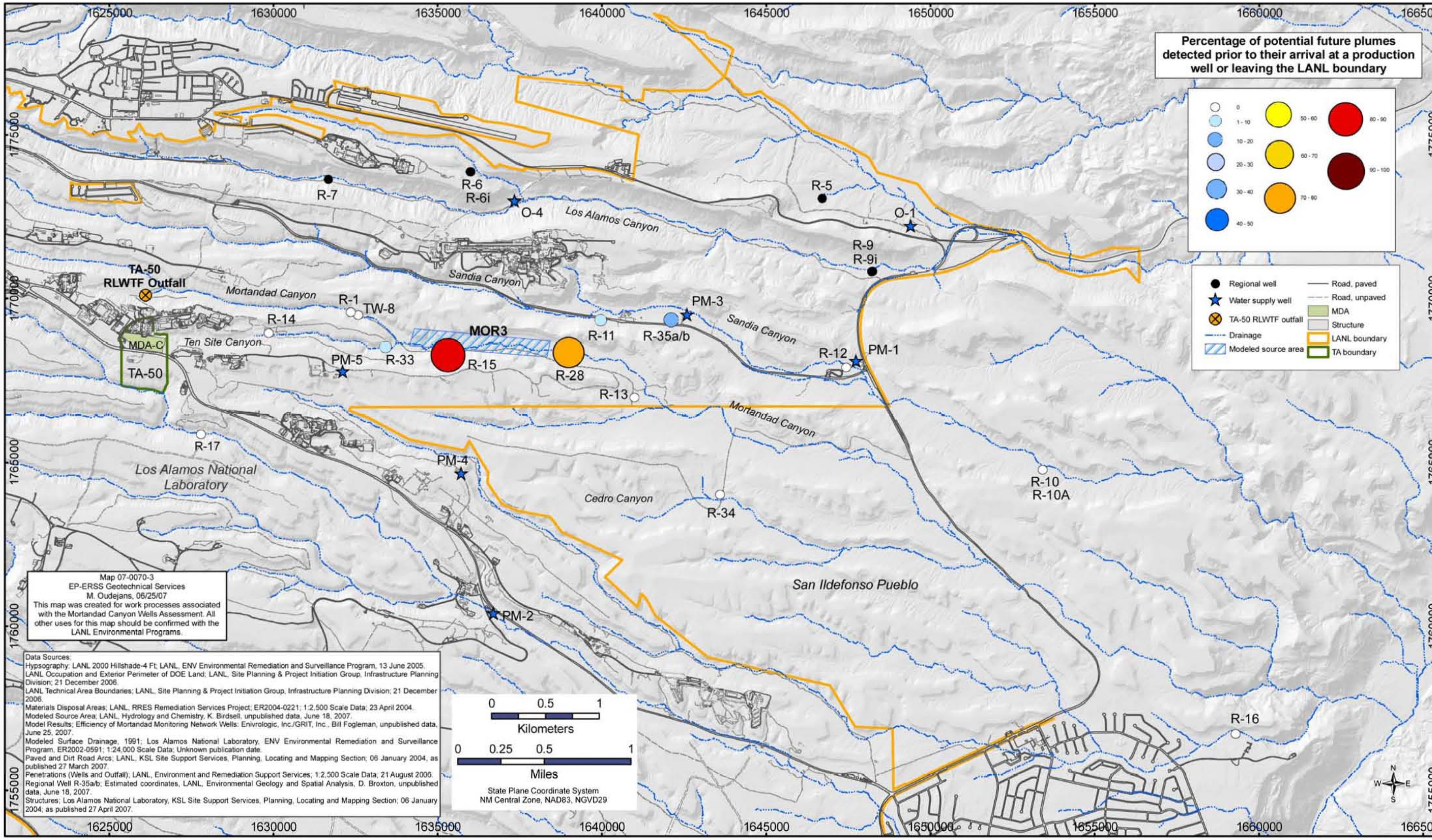


Figure C-1 Infiltration breakthrough area (MOR3) and well efficiencies for the TA-50 RLWTF outfall

Table C-1
Initial Release Date and Estimated Vadose-Zone Travel Times

Source	Initial Release Date	Vadose- Zone Travel Times (yr)	Arrival to Regional Aquifer in Year
MDA C	1948	100 (*)	2048
TA-50 RLWTF outfall (Represented by infiltration area MOR3)	1963	25	1988

(*) = Actual travel times for dry mesas are much greater than 100 yr; in spite of that, 100 yr was used in the calculations.

Table C-2
Efficiency (%) for Regional Monitoring Network and Regional Monitoring Wells

	TA-50 RLWTF Outfall
Monitoring Well	Efficiency %
All Monitoring Wells	97.2%
R-1	0.24%
R-10a	0.0%
R-11	5.2%
R-12	0.12%
R-13	0.60%
R-14	0.0%
R-15	83.0%
R-16	0.0%
R-17	0.0%
R-28	74.2%
R-33	10.0%
R-34	0.0%
R-35	16.3%
TW-8	0.24%

Table C-3
Detail of Efficiency Calculation for TA-50 RLWTF Outfall Including Number of Plumes of Concern; Total Detections; Correct and Late Detections, and False Alarms for Each Monitoring Well

Plumes of concern	833				
Monitoring Well	Total Detections	Correct Detections	Late Detections	False Alarms	Efficiency %
All Monitoring Wells	984	810	23	151	97.2%
R-1	166	2	164	0	0.24%
R-10a	35	0	35	0	0.0%
R-11	501	43	458	0	5.2%
R-12	296	1	294	1	0.12%
R-13	384	5	379	0	0.60%
R-14	12	0	12	0	0.0%
R-15	943	691	122	130	83.0%
R-16	2	0	2	0	0.0%
R-17	2	0	2	0	0.0%
R-28	905	618	186	101	74.2%
R-33	431	83	343	5	10.0%
R-34	4	0	4	0	0.0%
R-35	687	136	548	3	16.3%
TW-8	204	2	202	0	0.24%