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Work Plan for R-Well Rehabilitation and Replacement, Revision 2

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Prepared by the Environmental Programs Directorate

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Responsible project leader:

Ardyth Simmons	[signature]	Project Leader	Environmental Programs	7-28-07
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

Susan G. Stiger	[signature]	Associate Director	Environmental Programs	7/28/07
Printed Name	Signature	Title	Organization	Date

Responsible DOE representative:

David R. Gregory	[signature]	Project Director	DOE-LASO	7-30-07
Printed Name	Signature	Title	Organization	Date

EXECUTIVE SUMMARY

The “Work Plan for R-Well Rehabilitation and Replacement, Revision 2,” responds to the New Mexico Environment’s (NMED’s) comments on Revision 1 of the original 2006 work plan. Revisions 1 and 2 capitalize on lessons learned from the 2006 pilot well rehabilitation study at wells R-12, R-16, and R-20. This plan also reflects an evolution in the approach to determining the monitoring locations needed by area assessments, which will then guide the selection of well locations for those areas and determination whether certain R-wells require rehabilitation or replacement.

This work plan revision deals heavily with the methods used for well redevelopment and the rationale for selecting the Baski sampling system in wells that will be converted to dual-screen wells. The work plan also refers to the actions to be taken at wells R-12, R-14, R-16, R-20, R-22, R-25, R-32, and R-33 and to the measures needed to evaluate the degree of success of rehabilitation.

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Acronyms and Abbreviations

3-D	3-dimensional
AE	acid enhancer
APS	accelerator porosity probe
bgs	below ground surface
BH	borehole
CMR	combinable magnetic resonance
COPC	chemical of potential concern
DHH	downhole hammer
DO	division office
DOE	Department of Energy (U.S.)
DP	Delta Prime
DQO	data quality objective
ELAN	elemental log analysis program
EP	Environmental Programs Directorate
EPA	Environmental Protection Agency (U.S.)
ER	environmental restoration
ERSS	Environment and Remediation Support Services
FY	fiscal year
GDAP	Groundwater Data Adequacy Project
GPIT	general purpose inclinometer tool
GR	gross gamma-ray tool
HE	high explosives
HNGS	hostile environment gamma-ray sonde

HWP	Hydrogeologic Workplan
ICPMS	inductively coupled plasma mass spectroscopy
ICPOES	inductively coupled plasma optical emission spectroscopy
I.D.	inside diameter
K	hydraulic conductivity
LANL	Los Alamos National Laboratory
LCM	lost circulation material
LWSP	LANL Water Stewardship Project
md	millidarcy
MDA	material disposal area
MGA	modified granular acid
NGR	natural gamma radiation
NIST	National Institute of Standards Technology
NL	not listed
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
ORP	oxidation-reduction potential
P&A	plug and abandon
Pe	photoelectric effect
ppm	parts per million
PFD	phosphate-free dispersant
QA	quality assurance
QP	quality procedure
RC	reverse circulation
RDX	1,3,5-trinitro-1,3,5-triazacyclohexane
RLW	radioactive liquid waste
RPF	Records Processing Facility
SAP	sampling and analysis plan
SAPP	sodium acid pyrophosphate
SOP	standard operating procedure
T	transmissivity
T(R)	transmissivity from recovery data
T(RR)	transmissivity from residual recovery data
TA	technical area
TD	total depth
T(i)	transmissivity based on injection water-level data

TKN	total Kjehldahl nitrogen
TLD	triple lithodensity
T(r)	transmissivity based on recovery water-level data
TOC	total organic carbon
WQH	Water Quality and Hydrology (an ERSS group)
WSAR	Well Screen Analysis Report
XRD	x-ray diffraction

1.0 INTRODUCTION

The "Hydrogeologic Workplan" (HWP) (1998, 059599) outlined a program that was conducted from 1998 to 2005 to characterize the hydrogeology, geochemistry, and flow pathways beneath Los Alamos National Laboratory (LANL or the Laboratory). It was understood that results of the HWP would be used, along with other information and knowledge, to design a groundwater-monitoring network for the Laboratory.

As part of the HWP, 33 regional groundwater wells (called R-wells) were drilled within the Laboratory boundary and surrounding area. These wells are shown in Figure 1-1. (Note that a few of the 33 R-wells had different prefixes, such as CdV and MCOBT; also note that R-wells continued to be drilled following completion of the HWP.) Objectives were developed individually for each well to address questions about the hydrogeologic and geochemical framework beneath the Laboratory, groundwater flow directions in the regional aquifer and perched intermediate zone, aquifer characteristics, ranges in hydraulic properties of different lithologic units, and other aspects of characterization. The Laboratory, the U.S. Department of Energy (DOE), the New Mexico Environment Department (NMED), and an external advisory group all agreed to the purpose and objectives for the wells. It was anticipated and assumed by all that eventually these wells might become part of a groundwater-monitoring network, even though they were constructed for characterization purposes.

During the later years of the HWP and culminating in 2005, numerous parties, both within and outside the Laboratory, raised concerns that some of the multiple-screen R-wells might not be suitable for monitoring because fluids and additives used in drilling and well construction appeared to have been incompletely removed by development in some of the wells. These residual fluids impact the ability of those wells to provide representative groundwater data and hence compromise their ability to detect reactive contaminants. As a result of these collective concerns, the Laboratory analyzed the geochemical performance of all of the R-wells on a screen-by-screen basis to determine which screens appeared to be impacted by residual drilling fluids and to what extent (LANL 2005, 091121; LANL 2007, 096330).

The Well Screen Analysis Report (WSAR) used a geochemical approach to assessing groundwater reliability and representativeness. The results of the WSAR (LANL 2007, 096330) indicated that for the most recent sample taken as of December 2006, as shown in Figure 1-2, 25 out of the 80 screens evaluated are characterized by oxidizing conditions and show no residual impacts from the use of drilling fluids. Another 21 screens show an impact for one or two test categories, the most common impact being the presence of organic constituents. A higher frequency of residual drilling fluid effects is present in the remaining 34 screens, which are generally characterized by iron-reducing and sulfate-reducing conditions. Single-screen wells show far fewer impacts of residual drilling fluids than do multiple-screen wells.

1.1 Purpose of Report

This report is the "Work Plan for R-well Rehabilitation and Replacement, Revision 2." Revision 0 (LANL 2006, 092535) was directed by NMED's notice of disapproval on the Interim Facility-wide Groundwater Monitoring Plan, which required a "*plan for rehabilitation of all wells where fluids were utilized and where construction problems (e.g., misplaced screens/grout or excessive filter pack lengths) are documented"* (NMED 2005, 091828). Revision 1 of the work plan (LANL 2007, 097419) was motivated in part by a need to update plans for well rehabilitation to include results of the pilot rehabilitation study (LANL 2007, 095889) and by NMED's comments on April 5, 2007 (NMED 2007, 095999). Revision 2 responds to NMED's comments on Revision 1 (NMED 2007, 097461). (Note that although "replacement" appears in the title of the work plan, this revision concentrates on rehabilitation and well conversion.)

1.2 Organization

This work plan discusses methods that will be used to rehabilitate different types of wells and approaches to be taken at specific wells as the Laboratory proceeds in further development and design of the monitoring well network. Section 2 provides a comparison between Revision 0 and subsequent work plan revisions and describes an evolving strategy for determining the need to rehabilitate wells based on specific area assessments. Section 2 also discusses the results of the pilot study summary report. Section 3 discusses the conversion of multiple-screen wells to single-screen or dual-screen wells or their maintenance as multiple-screen wells. The selection of sampling systems is also discussed. Methods to be employed for potentially successful well rehabilitation are detailed in section 3. Section 3 also discusses the geochemical sampling frequency and analyte suites, other tests that assist in determining the improvement of geochemical trends in the screened intervals, and the means of evaluating rehabilitation effectiveness. Section 4 lists those screens that will be rehabilitated at particular wells and those screens that will be abandoned, based on priorities approved by NMED. Section 5 describes how, when, and where the rehabilitation results will be reported and provides a summary of the report. Appendixes A and B are retained from the original report. Appendix A provides well construction and development information, objectives, and the geologic and geophysical conditions encountered. Appendix B provides updated illustrations of the depth and conditions of well screens with respect to their ability to provide representative groundwater quality.

2.0 BACKGROUND

2.1 Recommendations in Original Work Plan

As previously stated, the original “Work Plan for R-well Rehabilitation and Replacement” (LANL 2006, 092535) was required by NMED’s notice of disapproval of the “Interim Facility-wide Groundwater Monitoring Plan” (NMED 2005, 091828). The approach taken by the original work plan to identify and prioritize the wells that needed to be rehabilitated and the redevelopment methods to be used was derived from the overall plan for demonstrating groundwater data adequacy. The original data quality objectives for the HWP wells were revisited, along with objectives for monitoring known at that time. The original assessment included examining the drilling methods and fluids appropriate for the depths required and lithologies encountered, having a multiple-screen well versus clustered well-monitoring points, and groundwater sampling systems appropriate for multiple-screen or single-screen wells completed at great depths. At the culmination of this assessment, a decision peer review in April 2006 resulted in a prioritized list of wells for proposed corrective action. The candidate wells were those that failed more than 60% of the geochemical tests they were subjected to in the WSAR, Revision 0 (LANL 2005, 091121). The final ranking of wells proposed for rehabilitation in the original work plan included these high-priority wells: (1) R-12 (which became part of the pilot study), (2) R-32, (3) R-14, (4) R-26, (5) R-22, and (6) R-25. The wells proposed for rehabilitation and conversion in Revision 0 that are not discussed in Revisions 1 and 2 of the work plan will be tracked internally.

2.2 Motivation for Revision and Changes to Original Work Plan

Revisions 1 and 2 of this work plan reflect a shift in strategy from the concept of evaluating well screens for use in a sitewide network capable of detecting all chemicals of potential concern (COPCs) to a strategy approved by NMED of determining a well screen’s utility for monitoring COPCs in a specific area, based on results of area assessments (e.g., for Technical Area [TA] 54) that will be forthcoming in 2007 and for TA-16 (LANL 2007, 095787). The area assessments examine the existing network of wells surrounding an area and their location along regional flowpaths as well as the ability of each screen to detect COPCs for that area.

2.3 Results of Pilot Study Summary Report

During the summer and autumn of 2006, well-redevelopment activities were conducted in a pilot study at wells R-20, R-16, and R-12 (LANL 2007, 095889). These wells were selected because their screens exhibited a variety of stages of geochemical reliability, they could be accessed easily, and they did not represent major technical challenges in redevelopment. Following redevelopment at R-16, the Westbay sampling system was reinstalled; to date, sampling systems have not been installed in R-20 or R-12. Plans for these two wells are discussed in section 4.

Revision 0 of this work plan (LANL 2006, 092535) acknowledged that the final measure of rehabilitation success could only be determined at least 6 months after reinstallation of the Westbay system to see whether future performance water samples retained the chemistry of the latest development sample or had degraded to less representative conditions. The Westbay system was reinstalled in R-16 in late August 2006, and the most recent sample for which data are available was collected in December 2006. The December sample indicated a slight degradation of conditions at Screen 2, which showed the presence of residual inorganic chemicals and manganese-reducing conditions that had not been present before rehabilitation efforts had been made. In contrast, Screen 3 improved slightly by returning to oxidizing conditions with slight signs of carbonate mineral instability. Screen 4 showed many effects of residual drilling fluids before redevelopment of the screen; the December sample showed only slight improvement. The sample was outside the background range of pH and alkalinity and showed residual inorganic chemicals, manganese-reducing conditions, and changes to carbonate mineral instability. (Screen 1 is isolated behind drill casing and therefore was not part of the pilot study.) The next samples from R-16 will be available after the June 2007 sampling campaign.

The “Pilot Well Rehabilitation Study Summary Report” (LANL 2007, 095889) concluded that multiple-screen R-wells could be redeveloped effectively on an individual screen basis using conventional mechanical techniques. However, this preliminary conclusion was based on experiences at three wells. Well purging allowed for collecting representative groundwater at the three wells during the tests, so a more precise conclusion is that extensive purging of wells impacted by residual drilling and development fluids has the potential to improve sample quality. At R-20, the first of the three wells where redevelopment was attempted, the overly aggressive Hydropuls technique was detrimental to hydraulic conductivity and filter pack stability. For this reason, the method was not used at R-16 and R-12, and only extensive purging was carried out at those two wells. The results of the pilot study suggest that sampling systems that can effectively purge the well before sample collection is as important, if not more important, than redevelopment of a well (see section.3.3).

3.0 WELL CONVERSION AND REHABILITATION METHODS

3.1 Conversion and Rehabilitation Decision Factors

When decisions are made about rehabilitation of wells to be included in a monitoring network, technical, strategic, and feasibility considerations come into play. The location of wells along a groundwater flow pathway in an area to be monitored, the position of screens at depths appropriate for monitoring the flow of contaminants in groundwater, that is, whether one or more screens are needed, and the ability to collect a sample that provides representative water-quality data are factors to be considered in deciding the needs for redevelopment and potential for successful rehabilitation. Well-construction issues, the sampling system used, and contaminants of concern, among other factors, must also be considered in the well evaluations to identify wells that need rehabilitation or replacement. Although some multiple-screen wells with low-flow–low-purge systems provide representative groundwater quality (LANL 2007, 096330), it has generally been recognized that the ability to purge a well before a sample is collected vastly improves the probability of obtaining representative groundwater quality in a sample. Therefore, the approach taken here is to convert as many as possible of the multiple-screen wells needed for monitoring to dual- and single-screen wells that can be purged before sampling. As discussed in section 3.2, different conversion approaches may be feasible depending upon which screens in a multiple-screen well need to be retained for monitoring purposes.

3.2 Conversion of Multiple-Screen Wells

The conversion of a multiple- (three or more) screen well to a dual- or single-screen well involves removal of the existing no-purge–low-flow Westbay sampling system, reduction of the number of effective screen intervals, redevelopment of select screen(s) (one or two total), and installation of an active purge sampling system (i.e., a single submersible pump or a dual-screen sampling system).

A single- or dual-screen well has a number of advantages that include

- the ability to purge stagnant water rapidly and in large quantities from immediately around the well bore, and
- the greatly improved ability to collect a representative groundwater sample by accessing water farther out in the formation, away from the impacted zone around the wellbore.

The disadvantages of converting a multiple-screen well to a single- or dual-screen well include

- the loss of some screen intervals from future sampling and monitoring if the lost screen intervals are needed, and
- handling and storing potentially large volumes of purge water that will require characterization and periodic waste inspections.

3.2.1 Assumptions

The maximum number of screen intervals that can be retained in conversion of a well to one that allows active-purge sampling is two screens. If more than two screens need to be retained, then the no-purge–low-flow Westbay system must be retained because no active-purge systems are currently available for wells with more than two screens.

For a multiple-screen well to be converted successfully to a single-screen or dual-screen well, the following assumptions are made.

- Well construction and hydraulic properties of existing well screen intervals can support an active-purge system (i.e., Baski).
- Hydraulic properties of the screen intervals allow them to be adequately redeveloped.
- Screen intervals that are abandoned can be effectively isolated from the screen intervals that are to be retained.

3.2.2 Limitations to Well Conversion

Typical construction of regional wells utilized stainless-steel casing with an inside diameter (I.D.) of 4.5 in. The I.D.s of screen intervals are in most instances also 4.5 in. because the same casing was used to fabricate a pipe-based screen as was used for the well casing. This I.D. limits the amount and size of pipe, tubing, and pumps that can be installed.

The original pipe-based design originated immediately following screen strength issues arising from the R-25 regional well. Three varieties have been used in regional wells at the Laboratory. All designs start with the use of stainless-steel 4.5-in.–I.D./5.0-in.-O.D. casing that is purchased by the Laboratory and shipped to the screen manufacturer. The manufacturer drills a specified hole pattern in the pipe and then proceeds to fabricate a rod-based vee-wire sleeve outside the pipe. The slot size of the wire-wrap screen is 0.010-in. (10 slot).

The basic difference in the 2 types of pipe-based screen used is the hole pattern drilled into the casing blanks:

Type 1 – 0.375-in.-diameter holes or 0.5-in.-diameter holes on 2-in. centers, 84 holes per linear ft

Type 2 – 0.5-in.-diameter holes on 1-in. centers, 168 holes per linear ft

Table 3-1 distinguishes the type of pipe-based screen used at each well. More screen-strength requirements for screen use at the Laboratory are provided by David Schafer & Associates (2002, 097468).The report by Schafer & Associates describes the Laboratory's level of effort in addressing screen issues for deep-well installation. Type 1 evolved to Type 2 screens to address concerns related to well development, that is, to increase the percent of open area of the pipe-based portion of the screen to promote more efficient development.

Abandonment options of select screens will be evaluated on an individual well basis. If the lowermost screen(s) in a well are to be abandoned, then the placement of impermeable materials into the well at the lower screen depths may be the simplest option. If a middle or upper screen is to be abandoned, then the conversion may need to consider the feasibility of adding additional packers to isolate these screens. Two screens in a dual-screen well do not need to be adjacent; one screen can be isolated between two that are desired for monitoring. However, isolation of more than one screen between two target screens would require too many packers.

3.2.3 Conversion of a Multiple-Screen to a Single-Screen Well

Reduction of a multiple-screen well to a single-screen well involves the following steps:

1. Removal of the Westbay sampling system
2. Run of a video well log to assess current screen conditions
3. Redevelopment of the screen interval that is to be retained for sampling (see section 3.4)
4. Plugging and abandoning lowermost screen intervals (if the decision is to place impermeable materials)
5. Installation of an appropriately sized submersible pump
6. Placement of packers above the pump if the lowermost screen is the monitoring target

3.2.4 Conversion of a Multiple-Screen to a Dual-Screen Well

Reduction of a multiple-screen well to a dual-screen well involves the following steps:

1. Removal of the Westbay sampling system
2. Run of a video well log to assess current screen conditions
3. Redevelopment of screen intervals that are to be retained for sampling (see section 3.4)
4. Abandonment of lowermost screen intervals (if the decision is to place impermeable materials)
5. Installation of a Baski-designed sampling system (see section 3.3)
6. Pumping of some amount of water to reduce impacts from the mixing of waters of the two screens. The volume to be pumped may be calculated from the flow rate from the higher elevation screen to the lower elevation screen during the time the packers are deflated.
7. Retrofit of surface casing to accommodate new system hardware.

3.2.5 Maintenance as a Multiple-Screen Well

If more than two screens are determined to be vital to long-term monitoring objectives, then the following steps will be implemented:

1. Removal of the Westbay sampling system
2. Run of a video well log to assess current screen conditions
3. Redevelopment of all screen intervals

3.3 Sampling Systems

A key consideration in the conversion of wells is the sampling systems to be used. Therefore, the Laboratory evaluated the different types of sampling systems installed in multiple-screen wells with respect to the relative merits of the elements of each system under Laboratory-specific site conditions (Koch and Pearson 2007, 096372). The objective of the evaluation was to determine which sampling system was optimal for converting multiple-screen to dual-screen wells. The primary consideration to be satisfied was the ability of a sampling system to purge groundwater actively during well development and monitoring. Elements included in the evaluation were sampling system design, materials, installation, cost, sampling and monitoring characteristics, and operational history. These elements were then used as criteria for comparing and ranking the sampling systems. The ranking was from 1 to 5, with 5 being best. The information and length of history available for each system varied, so ranking was sometimes difficult and subjective. Additional experience with each system may prompt future changes in the rankings. However, based on the following discussion, the two Baski multiple-screen systems ranked the highest and were selected for wells that will be converted to dual-screen monitoring wells. The ranking system was used to make the sampling system determination shown in Table 4-1.

Table 3-2 summarizes the rating evaluation criteria (Koch and Pearson 2007, 096372). Table 3-3 summarizes the ranking outcomes for each sampling system. A brief discussion of each criterion and ranking for each system follows.

3.3.1 System Design

The Westbay MP system is technically advanced and capable of monitoring multiple zones in a well. Additionally, the Westbay casing design is unique, and the operation of the sampling and transducer equipment is technically advanced and relatively complex. The Baski-packer/dual-valve system (installed at wells R-10 and R-17) is also technically advanced, with control lines for operating the two valves and a single submersible pump capable of pumping from either zone. In addition, the Baski-packer/dual-pump system (R-23i) is technically advanced and was designed specifically for the groundwater characteristics at R-23i but could be installed at other dual-completion wells. The dual-pump design utilizes a submersible electric pump below the packer and a dual-action piston pump above the packer. Both Baski-packer systems incorporate separate gage tubes that allow manual measurement of groundwater levels and use of conventional transducer equipment. These three systems rated the highest with respect to design.

The Barcad-packer/dual-"pump" design (installed at R-33) is much simpler than the other systems. The pump is actually a foot valve, which is the only moving part in the system. This design may not be the best system for the deep wells at the Laboratory that have a relatively low ratio of water column to total depth. For this reason, the HydroBooster was designed into the Barcad system, but the HydroBooster does not significantly overcome the inherit design. The Barcad system was also not designed for manual measurement of the water levels, which is another drawback.

The FLUTe sampling system is similar to the Barcad system in design and relatively simple compared with the other systems. The U-tube and ball valves allow recharge of the tubing through gravity flow of groundwater from the formation. The design of the U-tube sampling system at the bottom of the well, rather than at the ports, allows for more water to recharge the system than the Barcad system, but the design may not be the best system for the deep wells at the Laboratory that have a relatively low ratio of water column to total depth. The FLUTe system is not designed for manual measurement of the groundwater levels, but it does utilize conventional transducers.

3.3.2 System Materials

All of the systems use durable, nonreactive materials and were ranked similarly, with the exception of the Barcad system. The Barcad system utilizes relatively few materials compared with the other systems, making direct comparison difficult.

3.3.3 System Cost

For cost comparison purposes, it was assumed that the systems were installed in an 1100-ft well with 4.5-in.-diameter casing and two screens, similar to R-33 at the Laboratory. The Barcad and FLUTe systems are the most cost-effective, both because of the simplicity of design and the nature of the materials. The two Baski systems are intermediate in cost-effectiveness, and the Westbay is the most expensive, with double the cost of some other systems.

3.3.4 System Installation and Removal

Installation and removal of the Westbay sampling system is complex and to date has only been performed by Westbay personnel. The installation takes several days. Because of the complex nature of the system installation, the Westbay installation was rated low.

Installation of the Baski-packer/dual-valve system is also complex and takes several days, but it can be performed by a person experienced in well operations, rather than requiring company personnel. The tubing and plumbing connections for the operation of the packer and valves are complex, with multiple connections. Pressure testing all fittings during installation is required and is time-consuming. The installation of water-level gage tubes somewhat complicates the installation. The Baski-packer/dual pump system (R-23i) is simpler to install than the packer/dual-valve system, with fewer control lines, and the packer pressure line is not complicated by connection to the two valves.

The Barcad system installation is much simpler than the Westbay and Baski systems, especially because there are no pipe connections to the surface. Whereas the installation of the other systems requires a water-well-type derrick rig, installation and removal of the Barcad system could utilize a smaller power reel system. Installation and removal of the FLUTe system is relatively quick and simple and is accomplished in less than a day.

3.3.5 System Maintenance

Maintenance of the Westbay sampling system has primarily involved the surface equipment used for sampling and transducer operations. The relatively complex equipment needed to support the system requires regular maintenance. A vacuum pump is required for sampling. The transducers must be removed from the Westbay system each time samples are collected, which is an additional maintenance burden.

The Baski-packer systems require maintenance of compressed gas at the well head to provide pressure to the packer and valves, but as long as the submersible pumps function appropriately, little maintenance should be required. Conventional transducer equipment is relatively easily removed and serviced.

The Barcad system also requires maintenance of compressed gas at the well head to provide pressure to the packer. The fiber optic transducers are permanently installed, so maintenance requires removal of the system. The data loggers have been shown to be temperamental and have required routine maintenance.

The FLUTe system requires virtually no maintenance; however, the water level in the liner needs to be checked before each sampling event. The transducers require routine operational inspection; removal and replacement would be relatively simple.

3.3.6 Groundwater Sample Quality

The Westbay sampling system is a low-flow–no-purge system that is capable of collecting an average of about 4 L/h (~1 gal./h) for the deep Laboratory wells. Sampling of the deep multiple screen wells at the Laboratory typically takes two to three personnel 3 to 5 days, and thus is labor and time intensive.

The Barcad sampling system at R-33 is also a low-flow–no-purge system capable of producing about 6 L/h (1.6 gal./h) from Screen 1 and about 9.3 L/h (2.5 gal./h) from Screen 2. A large volume of stagnant water in the casing is virtually impossible to purge with this system. Sampling of this dual completion well typically takes 2 days.

The Baski-packer and submersible pump systems are capable of sampling groundwater at a rate ranging from 1.3 to 10 gal./min. These systems allow for conventional purging and sampling of a well, and the dual completion wells can be sampled in 1 day.

Groundwater sampling using the FLUTe system is similar to the Barcad system except the sampling devices are located at the bottom of the well where additional water is available for faster recharge of the system with higher flow rates. The sampling port is adjacent to the screen so no stagnant water is present in the well casing as in the Barcad (and possibly Westbay) systems. Sampling is low-flow–no-purge of the well casing, but purging of the system tubing (two cycles) is required before collecting samples. Flow rates are reported to be about 2 L/min, which is about 10 times faster than Barcad and Westbay systems. However, stacked U-tubes are needed for deeper wells, which require cycling of alternate U-tube systems, resulting in slightly more complex sampling, and potentially lower flow rates.

3.3.7 Groundwater-Level Monitoring

The Westbay system incorporates transducers connected in series to monitor pressure at selected zones in a well. The system does not allow for manual measurement of water levels but does provide for collecting water-level data from more zones than is possible with the other systems. This method has provided data for seven zones in R-25, which has provided a unique data set for the regional aquifer that is not available using the other systems.

The Baski-packer systems incorporate separate gage tubes that provide access to each screen zone using conventional transducer equipment and manual measurement methods.

The Barcad system is installed with fiber optic transducers that cannot be removed without removing the entire system. No gage tubes were installed to allow for manual measurements, although it might be possible to retrofit the Barcad system to include gage tubes similar to those in the Baski-packer systems.

The FLUTe system incorporates conventional transducers attached to the tubing and connected to each port. Groundwater levels cannot be measured manually on a routine basis. Tubes could possibly be installed from the surface to the U-tube for a two-port well, but the ball valves in the U-tube system would not allow real-time groundwater-level measurements. However, this system would allow measurement of the groundwater level after purging the tubing and allowing equilibration with groundwater.

3.3.8 Operational History

The Westbay sampling system has been in operation at the Laboratory for 7 yr and for the most part has operated according to the manufacturer’s specifications. Routine maintenance and repair and replacement of parts have been required.

The Barcad system operates according to manufacturer specifications; however, the data loggers are temperamental and have failed several times, requiring repair and replacement.

The operational history of the Baski-packer/dual-valve systems at R-10 and R-17 and the Baski-packer/dual-pump system at R-23i are less than 2 yr. Testing after installation indicated that the systems operated according to the manufacturer’s specifications. The FLUTe system functioned appropriately in the 280-ft-deep LAWS-01 well for 3 yr. This system has not been used in a deep regional aquifer well at the Laboratory but is expected to be more effective than the Barcad system in that environment.

3.3.9 Long-Term Operational Issues

The Westbay system requires significantly more surface support equipment than other systems that will also continue to require maintenance, repair, and replacement. The Baski-packer/dual-valve system relies on the integrity of the downhole pump and valves, the long-term reliability of which will determine the long-term viability of the system. The Baski-packer/dual-pump system also relies on the integrity of the two downhole pumps; the vibration created by the Bennett piston pump may impact long-term operation issues. The Barcad system is reported to have long-term serviceability. However, pressure data recorded during a pumping event indicated that a small leak may have occurred at the Barcad valve. Technical support from the Barcad manufacturer has been limited. The FLUTe system has relatively little maintenance requirements, so long-term operational issues should be minimal.

3.3.10 Summary of Sample System Evaluation

Nine elements were evaluated for five different types of sampling systems currently in use at the Laboratory (Koch and Pearson 2007, 096372). The rating criteria, shown in Table 3-2, were based on the requirements of a deep regional aquifer well at the Laboratory, specifically on a 4.5-in.-diameter two-screen well that is 1100 ft deep with a water level at about 1000 ft. Based on the evaluation, the Baski-packer and submersible-pump systems ranked the highest, followed by the FLUTe and the Westbay systems. The Barcad system was ranked the lowest. However, this evaluation and ranking is based on operational history and experience at the Laboratory and is for application in deep regional aquifer wells with a deep water table. This evaluation does not address the suitability of these systems at other sites; in other hydrogeological settings, any of the evaluated systems might be the best suited.

3.4 Well Redevelopment Methods

In general, the same redevelopment methods will be used as were employed in the pilot study (LANL 2007, 095889), with the exception of Hydropulsing, which proved to be too aggressive and destructive a technique. In some cases, additional methods beyond those used in the pilot study may be required. Pressure data from well screens will be used during the course of redevelopment to estimate hydrologic properties and the degree of connectivity/communication with adjacent screens and with the atmosphere. This information may be useful in predicting the likely effectiveness of rehabilitation. Compiled pressure data will be examined, along with the extent to which individual screens respond to pumping.

The methods that are proposed to be implemented are as follows:

1. Collect baseline water-quality data. These data include major cations and anions, trace elements, total organic carbon (TOC), volatile and semivolatile compounds, total Kjehldahl nitrogen (TKN), stable isotopes (in particular, nitrogen and carbon), radionuclides, and total dissolved chromium. The data also include field-measured parameters: pH, temperature, dissolved oxygen, sulfide, specific conductance, oxidation-reduction potential (ORP), and turbidity. Solids (including fine-grained material) will also be collected by filtration and acid-digest for major- and trace-element analyses.
2. Remove the Westbay sampling system from the well and install rehabilitation tools. A downhole video of the well will be made after the Westbay system is removed.
3. Test the specific capacity at each screen in a 3-h test. The specific capacity tests will be performed on each screen that is to be retained for future sampling by using a submersible pump and packer system (single or dual, depending on screen location). Pumping will be performed at a constant rate for approximately 3 hr. Measurements of the field parameters (pH, temperature, specific conductivity, turbidity, ORP and dissolved oxygen) will be collected at intervals ranging from 5 to 15 min during the specific capacity test. Groundwater samples will be collected for laboratory analysis for select parameters (e.g., sulfate, manganese, iron) and transferred from the field location under chain of custody to the Laboratory's Geology and Geochemistry laboratory. Near the beginning of the specific capacity test, 5-gal. carboys of groundwater may be collected for particulate analysis.

4. Perform redevelopment of those screens selected to be retained. The methods shall include the following.

    a. Surging and Bailing. Surging will induce water to flow both from the well out into the formation and from the formation into the well. This type of movement should facilitate dislodging sediment that may be bridged across the screen openings. Use of surge blocks on rods should be more effective than operating the surge block on a weighted wireline because more energy can be transferred to the filter-pack formation on the downstroke rather than just the upstroke when using a wireline.

    b. Pumping/Overpumping. The well will be pumped at variable rates, up to the maximum that the well will produce, while still preventing the water level to decline to the level of the pump intake. Pumping will be performed with single- and dual-packer arrangements so that the screen interval being pumped can be isolated from the other screen intervals in the well. This isolation will enhance the effectiveness of the pumping effort. Field parameters and geochemical samples will generally be collected during pumping periods. Specific capacity data will be collected during constant rate pumping periods.

    c. Jetting and simultaneous pumping. If applied correctly (i.e., appropriate jetting velocities while maintaining maximum number of jetting ports, rotation of jetting ports), jetting, should be capable of rearranging the fine-grained fractions of sediment and loosening potential residual drilling fluids that may still reside in the filter pack and near the well bore. Note that jetting is not as effective when applied to pipe-based screens as when applied to rod-based wire-wrap screens; zones behind the pipe-based portion of the screen may be little affected by the jetting action.

    These methods may be repeated as often as deemed necessary upon analysis of the real-time data collected in the field. Additional mechanical methods may be warranted and will continue to be evaluated in discussion with NMED. If all of the mechanical techniques prove to be unsuccessful, the use of chemical techniques will also be evaluated and discussed with NMED.

5. After redevelopment methods have been completed, the well will undergo isolation pumping to collect final specific capacity data, field parameters, and geochemical samples.

Throughout the redevelopment effort, the water removed from the well will be containerized and managed in accordance with the notice of intent decision tree (2006).

3.5 Geochemical Sampling

Groundwater samples will be collected and analyzed as needed through the various steps of the well redevelopment process: (1) during initial specific capacity testing; (2) during development pumping/overpumping; (3) during final specific capacity testing. The results should indicate the extent to which the different development methods contribute to the screen cleaning; however, some analytical results may not be available before initiating the next step of development.

Groundwater parameters from pumping will be collected with a flow-through cell that has data logging capabilities. Parameters to be collected with the data loggers will consist of pH, temperature, conductivity, ORP, and dissolved oxygen. Turbidity data will be collected at specified time intervals.

Samples will be filtered, while solids will be collected and analyzed chemically (method to be determined) and mineralogically (by x-ray diffraction). The results of the combined chemical and mineralogical analysis should differentiate between which chemical constituents are being drawn out of aquifer formation materials during well development (e.g., clay minerals native to the formation) and which are associated with the residual well construction materials or drilling fluids (e.g., bentonite clay).

Table 3-4, taken from Table C-3 of the 2007 Interim Facility-wide Groundwater Monitoring Plan (LANL 2007, 096665), describes instrument measurements and methods for field parameters and provides additional details. The following describes methods for in-house analyses. Sulfate is measured by ion chromatography following U.S. Environmental Protection Agency (EPA) SW846 Method 300. Equipment blanks, duplicate samples, and a standard reference material are also analyzed. Charge and balance errors are calculated for filtered samples. TOC is analyzed by EPA SW846 method 960 using a TOC analyzer. Oxidation is now used; before 2007, combustion was used. Manganese is analyzed by EPA SW846 Methods 6019 (ICPOES) and 6020 (ICPMS). Duplicate samples and equipment blanks are analyzed with primary samples. Quality assurance (QA) standard SRM 1640 is also analyzed. Iron is analyzed by SW846 method 6010 (ICPOES). SRM 1640 is analyzed. Duplicate samples and equipment blanks are analyzed with primary samples. Sulfate, iron, and manganese samples are filtered through 0.45 micrometer membranes. They are acidified with 7N nitric acid to a pH = 2. TOC is collected in glass bottles and is not filtered or acidified.

3.6 Evaluation of Rehabilitation Effectiveness

Specific capacity data will be examined to determine if the applied redevelopment methods have had a net positive or net negative effect on the hydraulic properties of the well. The specific capacity data will not be used to determine an endpoint to the redevelopment effort. The analytical data (field parameters and screening data) collected during redevelopment and periodically after the new sampling system has been installed will be subjected to the well screen analysis methodology. The results of this geochemical analysis will verify whether residual drilling fluids have been removed to the extent that groundwater chemistry can be considered representative around the screened interval. The tests described in this section, including the listed field parameters and in-house analyses, will be used only to direct the field operations during well rehabilitation. The final assessment of whether the well rehabilitation is successful will be determined according to the procedures and criteria specified in the Revision 2 of the WSAR, approved by NMED.

3.6.1 Assessing Geochemistry—Methodology

Four primary geochemical indicators will be used to determine the effectiveness of well rehabilitation and redevelopment methods: turbidity; TOC; specific conductance; and concentrations of sulfate, iron, sodium, and manganese.

The turbidity measurements will give an on-site indicator of redevelopment progress. The turbidity will be measured during each stage of the redevelopment process except during surging and bailing when qualitative visual estimates will be made. The target value for turbidity after redevelopment is a value less than 5 nephelometric turbidity units (NTUs).

The TOC levels will be analyzed by an on-site laboratory. A baseline TOC level will be determined before redevelopment and compared with TOC levels measured during and after redevelopment activities. The target value for TOC is less than 2 parts per million (ppm), which is the background level at the Laboratory.

Specific conductance is measured in the field and is an indicator of the amount of dissolved solute. When the background value of 278 µS/cm is approached for the regional aquifer, the sample may be considered stable and representative of formation water.

Sulfate, sodium, manganese, and iron concentrations in groundwater indicate the degree that drilling fluids have affected ambient groundwater chemistry in the vicinity of a well screen. Sulfate concentrations are diminished, and iron and manganese concentrations increase as bacteria in the aquifer degrade organic polymers. Sulfate and sodium concentrations are elevated in groundwater when screened zones are affected by bentonite. The presence of these constituents at concentrations above or below ambient background levels is an important well redevelopment performance measure.

Additional field and bench-scale laboratory tests may be conducted to provide a better site-specific confidence of geochemical conditions around a well screen interval than can be determined through application of the well screen analysis methodology. The nature and design of such tests will be specific to conditions at a particular screen interval.

3.6.2 Assessing Long-Term Effectiveness

Postrehabilitation samples will be collected and compared with historical data and with the groundwater samples collected before and during redevelopment. Groundwater samples will be collected monthly for 3 months and quarterly thereafter for 9 months. The samples will undergo a full suite analysis at months 1, 6, and 12; otherwise, the sample sets will undergo a performance suite analysis, as defined by the Interim Facility-wide Groundwater Monitoring Plan (LANL 2006, 094043). The data from the samples will be evaluated using the well-screen analysis methodology (LANL 2007, 096330). The time frame for groundwater quality to return to representative conditions around a screened interval will vary. For this reason, the wells undergoing rehabilitation will be monitored closely before making conclusions about the effectiveness of the rehabilitation.

4.0 PROPOSED IMPLEMENTATION FOR SELECTED WELLS

Table 4-1 shows recommendations for specific actions at the wells discussed and prioritized in NMED's letters of April 5, 2007 (NMED 2007, 095999) and April 27, 2007 (NMED 2007, 095832), the pilot study wells, and others needed in the next year. Other wells not included in Revision 1 but recommended for actions in Revision 0 of this work plan may still be considered for rehabilitation or replacement based on results of area assessments. These wells (CdV-R-15-3, CdV-R-37-2, R-5, R-7, R-8, R-9i, R-19, R-26, and R-31) will be considered in 2008 for actions in 2009. Only actions in 2007 and 2008 are included in Table 4-1. Area-specific evaluations based on flow patterns will determine whether the wells in a particular area will be needed; geochemical assessments will determine whether screens in those wells are reliable for monitoring objectives with respect to contaminants specific to that area. Determination of well rehabilitation activities for those wells will follow in recommendations from those area assessments. The well diagrams in Appendix B help illustrate the well conditions (see Figure 4-1 for a visualization of the water table with respect to the well locations).

5.0 REPORTING AND DOCUMENTATION

A work plan for these individual wells will identify the objectives for the well, along with specific methods to be used and requirements to be met. After the work has been completed, a summary report will document the field activities and field parameters measured at each well or well screen. The report will document all field activities, including variations from the work plan, redevelopment and sampling procedures, and recommendations, if any, for consideration in follow-up rehabilitation activities at other wells.

The Laboratory will report the results of the redevelopment process in letter report updates as well rehabilitation and conversion progress. Water-quality data collected as part of well rehabilitation will be compared with results compiled in the WSAR. Changes in and improvements to hydrologic parameters will be noted. Pre- and postrehabilitation specific capacity test results will be compared. Insights from analysis of solids and from any site-specific laboratory tests will also be reported.

6.0 REFERENCES

The following list includes all documents cited in this work plan. 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's Hazardous Waste Bureau; the DOE–Los Alamos Site Office; EPA, 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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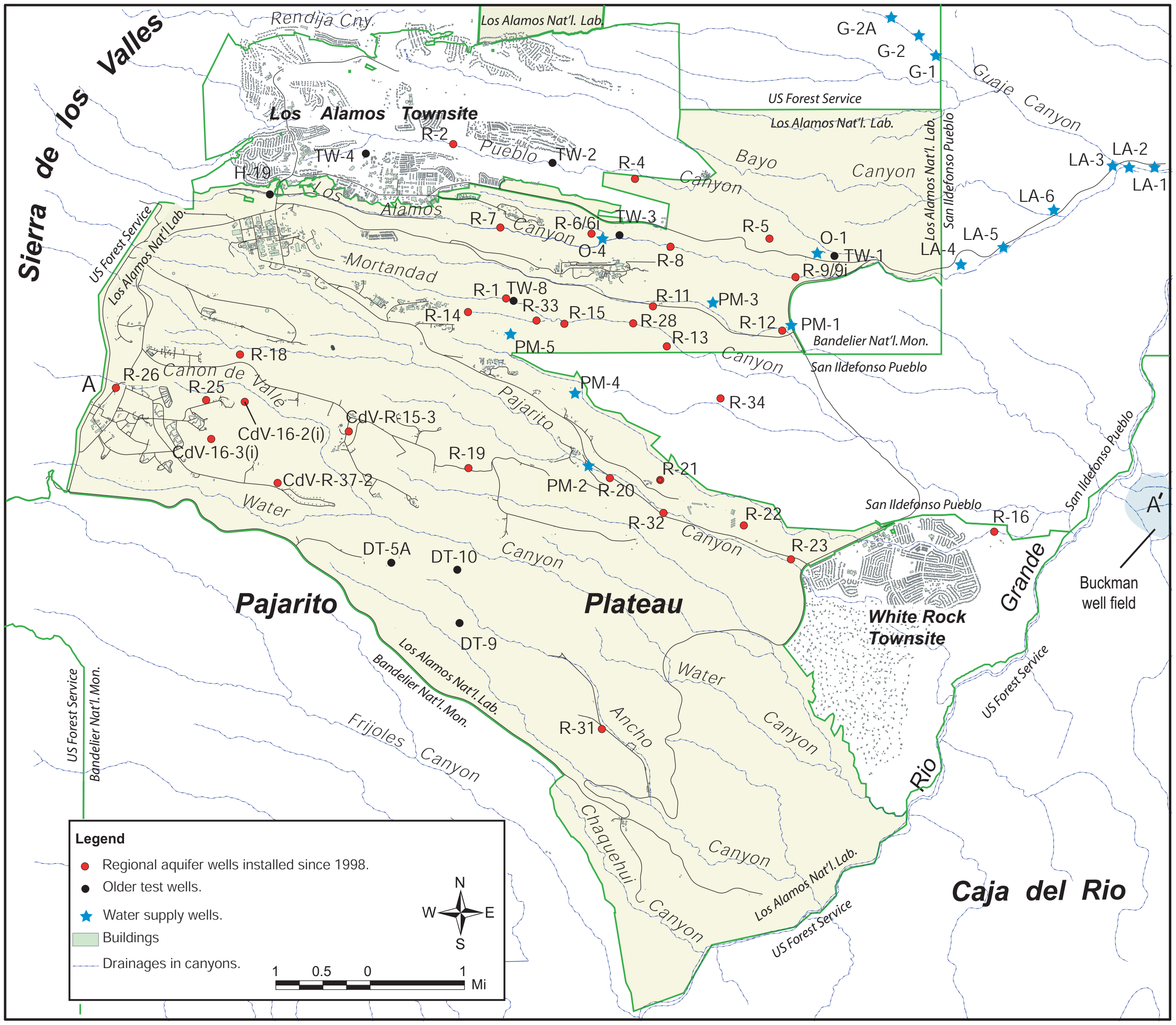

Figure 1-1 Map showing location of wells constructed under the Hydrogeologic Workplan

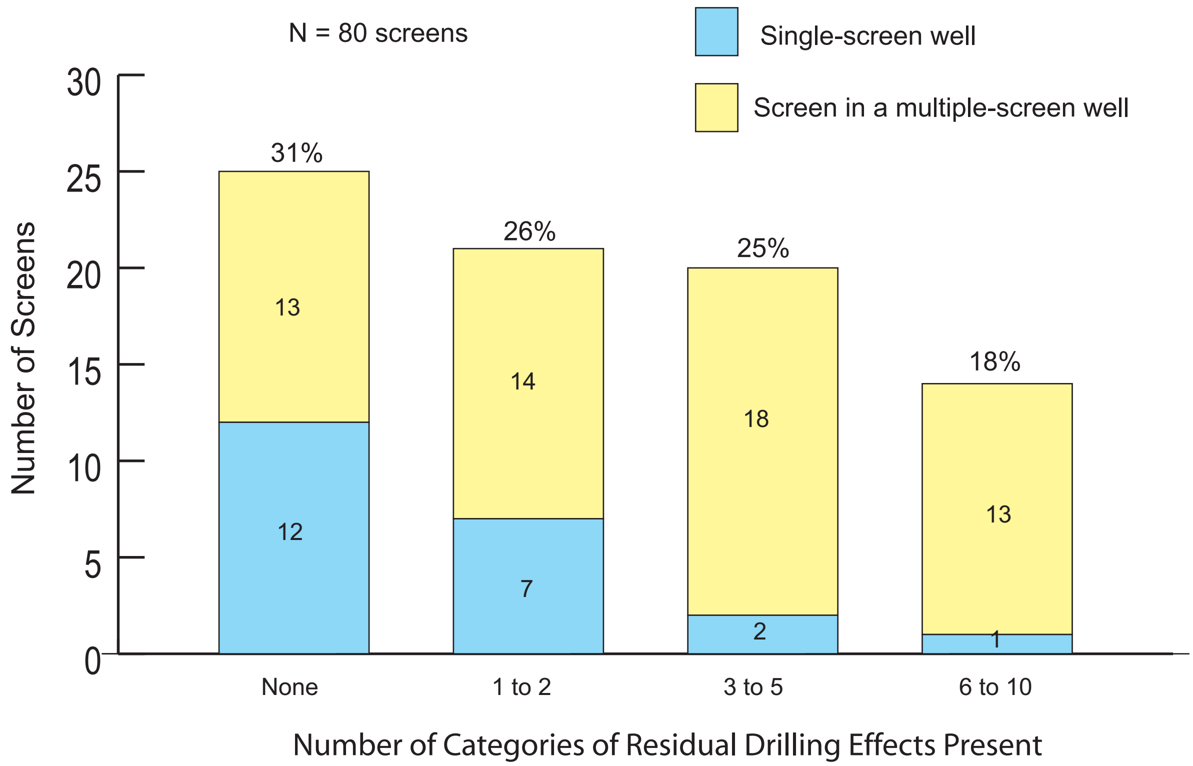

Figure 1-2 Number of categories of residual drilling effects present in the most recent sample (as of December 31, 2006) (LANL 2007, 096330)

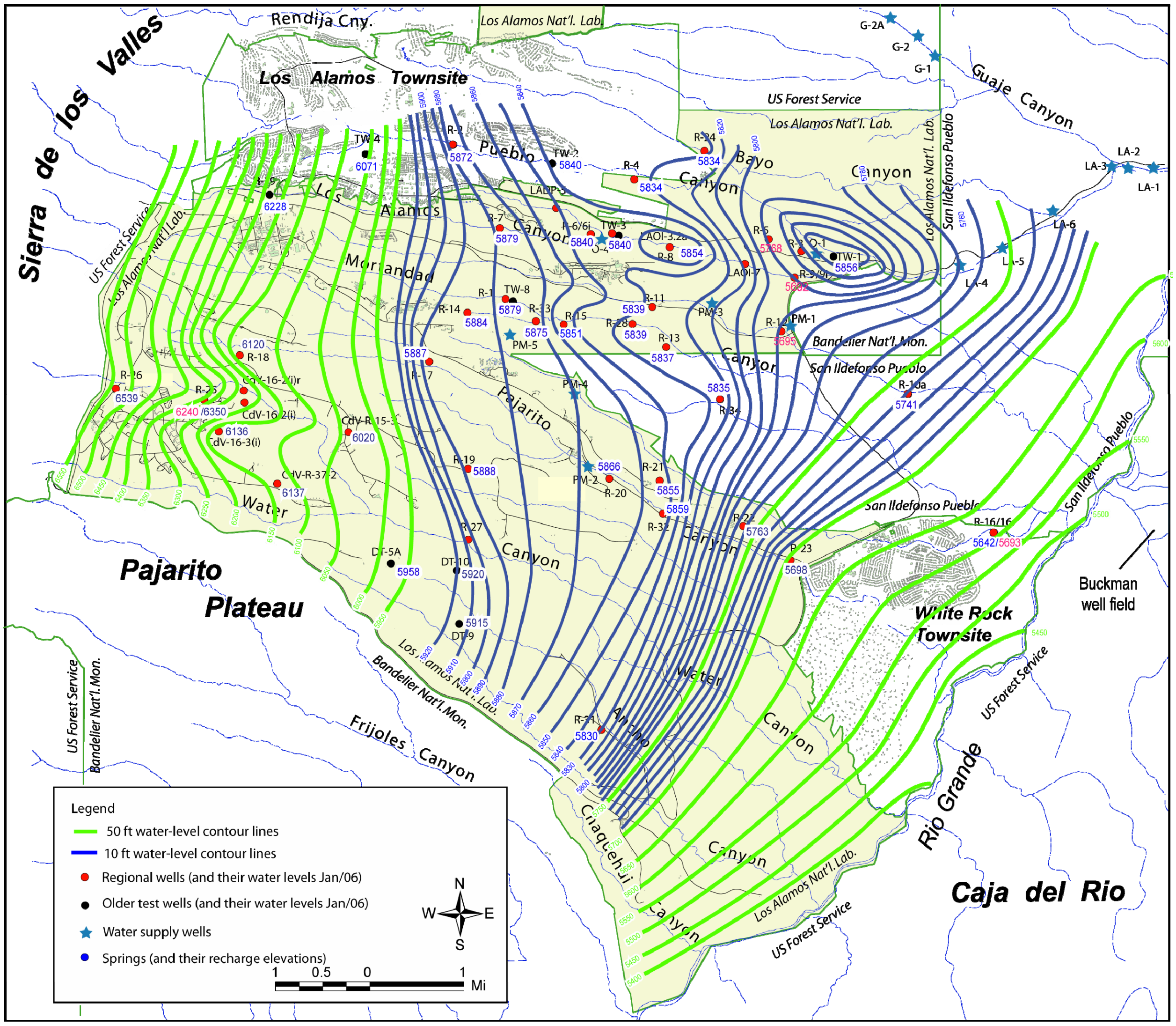

Figure 4-1 Water table elevation and location of Hydrogeologic Workplan wells

Table 3-1
Screen Construction Details, Functional Status, and Sampling Method

Screen ID	Well	Screen #	Water Production Status[a]	Casing ID (in.)	Screen Depth (ft) Port Depth	Top	Bottom	Screen Type[b]	Type 1 or 2[c]	Sample Collection Method
1	CdV-16-1(i)	1	Functional	4.5	624	624	634	Rod	n/a[d]	Submersible
2	CdV-16-2(i)r	1	Functional	4.5	850	850	859.7	Rod	n/a	Submersible
3	CdV-R-15-3	1	Dry	4.5	621	617.7	624.5	Pipe	1	n/a
4	CdV-R-15-3	2	Dry	4.5	804	800.8	807.8	Pipe	1	n/a
5	CdV-R-15-3	3	Dry	4.5	973	964.8	980.9	Pipe	1	n/a
6	CdV-R-15-3	4	Functional	4.5	1254.4	1235	1279	Pipe	1	Westbay
7	CdV-R-15-3	5	Functional	4.5	1350.1	1348	1355	Pipe	1	Westbay
8	CdV-R-15-3	6	Functional	4.5	1640.1	1638	1645	Pipe	1	Westbay
9	CdV-R-37-2	1	Dry	4.5	935	914.4	939.5	Pipe	1	n/a
10	CdV-R-37-2	2	Functional	4.5	1200.3	1189	1214	Pipe	1	Westbay
11	CdV-R-37-2	3	Functional	4.5	1359.3	1354	1377	Pipe	1	Westbay
12	CdV-R-37-2	4	Functional	4.5	1550.6	1549	1556	Pipe	1	Westbay
13	MCOBT-4.4	1	Functional	4.5	485.4	482.1	524.0	Pipe	1	Submersible
14	R-1	1	Functional	4.5	1031.1	1030	1057	Rod	n/a	Submersible
15	R-2	1	Functional	4.5	918	906.5	929.6	Rod	n/a	Submersible
16	R-3i	1	Functional	2.0	215.2	215.2	220.0	Slotted	n/a	Bennett Pump
17	R-4	1	Functional	4.5	792.9	792.9	816	Rod	n/a	Submersible
18	R-5	1	Dry	4.5	329	326.4	331.5	Pipe	1	n/a
19	R-5	2	Functional	4.5	383.9	372.8	388.8	Pipe	1	Westbay
20	R-5	3	Functional[e]	4.5	718.6	676.9	720.3	Pipe	1	Westbay
21	R-5	4	Functional	4.5	860.9	858.7	863.7	Pipe	1	Westbay
22	R-6	1	Functional	4.5	1205	1205	1228	Rod	n/a	Submersible
23	R-6i	1	Functional	4.5	602	602	612	Rod	n/a	Submersible
24	R-7	1	Dry	4.5	378	363.2	379.2	Pipe	1	n/a
25	R-7	2	Dry	4.5	738.4	730.4	746.4	Pipe	1	n/a
26	R-7	3	Functional	4.5	915.1	895.5	937.4	Pipe	1	Westbay
27	R-8	1	Functional	4.5	711.1	705.3	755.7	Pipe	1	Westbay
28	R-8	2	Functional	4.5	825	821.3	828	Pipe	1	Westbay
29	R-9	1	Functional	4.5	684	684	704	Rod	n/a	Submersible
30	R-9i	1	Functional	4.5	198.8	189.1	199.5	Rod	n/a	Westbay
31	R-9i	2	Functional	4.5	278.8	269.6	280.3	Rod	n/a	Westbay
32	R-10	1	Functional	4.5	874	874	897	Rod	n/a	Baski
33	R-10	2	Functional	4.5	1042	1042	1065	Rod	n/a	Baski
34	R-10a	1	Functional	4.5	690	690	700	Rod	n/a	Submersible
35	R-11	1	Functional	4.5	855	855	877.9	Rod	n/a	Submersible

Table 3-1 (continued)

Screen ID	Well	Screen #	Water Production Status[a]	Casing ID (in.)	Screen Depth (ft) Port Depth	Top	Bottom	Screen Type[b]	Type 1 or 2[c]	Sample Collection Method
36	R-12	1	Functional	4.5	468.1	459	467.5	Rod	n/a	Westbay
37	R-12	2	Functional	4.5	507	504.5	508	Rod	n/a	Westbay
38	R-12	3	Functional	4.5	810.8	801	839	Rod	n/a	Westbay
39	R-13	1	Functional	4.5	958.3	958.3	1019	Pipe	1	Submersible
40	R-14	1	Functional	4.5	1204.5	1201	1233	Pipe	2	Westbay
41	R-14	2	Functional	4.5	1288.5	1287	1293	Pipe	2	Westbay
42	R-15	1	Functional	4.5	958.6	958.6	1020	Pipe	1	Submersible
43	R-16	1	Cased off	4.5	644.8	641	648.6	Pipe	2	n/a
44	R-16	2	Functional	4.5	866.1	863.4	870.9	Pipe	2	Westbay
45	R-16	3	Functional	4.5	1018.4	1015	1022	Pipe	2	Westbay
46	R-16	4	Functional	4.5	1238	1237	1245	Pipe	2	Westbay
47	R-16r	1	Functional	4.5	600	600	617.6	Pipe	2	Submersible
48	R-17	1	Functional	4.5	1057	1057	1080	Rod	n/a	Baski
49	R-17	2	Functional	4.5	1124	1124	1134	Rod	n/a	Baski
50	R-18	1	Functional	4.5	1358	1358	1381	Rod	n/a	Submersible
51	R-19	1	Dry	4.5	835.4	827.2	843.6	Pipe	1	n/a
52	R-19	2	Functional	4.5	909.3	893.3	909.6	Pipe	1	Westbay
53	R-19	3	Functional	4.5	1190.7	1171	1215	Pipe	1	Westbay
54	R-19	4	Functional	4.5	1412.9	1410	1417	Pipe	1	Westbay
55	R-19	5	Functional	4.5	1586.1	1583	1590	Pipe	1	Westbay
56	R-19	6	Functional	4.5	1730.1	1727	1734	Pipe	1	Westbay
57	R-19	7	Functional	4.5	1834.7	1832	1840	Pipe	1	Westbay
58	R-20	1	Functional	4.5	907	904.6	912.2	Pipe	2	Westbay
59	R-20	2	Functional	4.5	1149.7	1147	1155	Pipe	2	Westbay
60	R-20	3	Functional	4.5	1330	1329	1337	Pipe	2	Westbay
61	R-21	1	Functional	6	888.8	887.8	907.8	Rod	n/a	Submersible
62	R-22	1	Functional	4.5	907.1	872.3	914.2	Pipe	1	Westbay
63	R-22	2	Functional	4.5	962.8	947	988.9	Pipe	1	Westbay
64	R-22	3	Functional	4.5	1273.5	1272	1279	Pipe	1	Westbay
65	R-22	4	Functional	4.5	1378	1378	1385	Pipe	1	Westbay
66	R-22	5	Functional	4.5	1448.2	1447	1452	Pipe	1	Westbay
67	R-23	1	Functional	4.5	816	816	873.2	Pipe	2	Submersible
68	R-23i	1	Not developed	2.0	400.3	400.3	420	Rod	n/a	n/a
69	R-23i	2	Functional	4.5	470.2	470.2	480.1	Rod	n/a	Baski
70	R-23i	3	Functional	4.5	524	524	547	Rod	n/a	Baski
71	R-24	1	Functional	4.5	825	825	848	Rod	n/a	Submersible

Table 3-1 (continued)

Screen ID	Well	Screen #	Water Production Status[a]	Casing ID (in.)	Screen Depth (ft)			Screen Type[b]	Type 1 or 2[c]	Sample Collection Method
					Port Depth	Top	Bottom			
72	R-25	1	Functional	5.17	754.8	737.6	758.4	Rod	n/a	Westbay
73	R-25	2	Functional	5.17	891.8	882.6	893.4	Rod	n/a	Westbay
74	R-25	3	Dry	5.17	1063	1055	1065	Rod	n/a	n/a
75	R-25	4	Functional	5.17	1192.4	1185	1195	Rod	n/a	Westbay
76	R-25	5	Functional	5.17	1303.4	1295	1305	Rod	n/a	Westbay
77	R-25	6	Functional	5.17	1406.3	1405	1415	Rod	n/a	Westbay
78	R-25	7	Functional	5.17	1606	1605	1615	Rod	n/a	Westbay
79	R-25	8	Functional	5.17	1796	1795	1805	Rod	n/a	Westbay
80	R-25	9	Plugged off	5.17	n/a	1895	1905	Rod	n/a	n/a
81	R-26	1	Functional	4.5	659.3	651.8	669.9	Pipe	2	Westbay
82	R-26	2	Screen clogged	4.5	1433	1421.8	1445	Rod	n/a	n/a
83	R-27	1	Functional	4.5	852	852	875	Rod	n/a	Submersible
84	R-28	1	Functional	4.5	934.3	934.3	958.1	Rod	n/a	Submersible
85	R-31	1	Dry	4.5	446.8	439.1	454.4	Rod	n/a	n/a
86	R-31	2	Functional	4.5	532.2	515	545.7	Rod	n/a	Westbay
87	R-31	3	Functional	4.5	670	666.3	676.3	Rod	n/a	Westbay
88	R-31	4	Functional	4.5	830	826.6	836.6	Rod	n/a	Westbay
89	R-31	5	Functional	4.5	1011	1007	1017	Rod	n/a	Westbay
90	R-32	1	Functional	4.5	870.9	867.5	875.2	Pipe	2	Westbay
91	R-32	2	Limited use[f]	4.5	933.4	931.8	934.8	Pipe	2	n/a
92	R-32	3	Functional	4.5	976	927.9	980.6	Pipe	2	Westbay
93	R-33	1	Functional	4.5	995.5	995.5	1018.5	Rod	n/a	Barcad
94	R-33	2	Functional	4.5	1112.4	1112.4	1122.3	Rod	n/a	Barcad
95	R-34	1	Functional	4.5	895.152	883.7	906.6	Rod	n/a	Submersible

Source: Modified from LANL 2007 (096330), Table B-5.

[a] Water production comments were provided by A. Banar (ENV-WQH) on August 15 and 24, 2005. “Functional” indicates that the screen interval produces an adequate volume of groundwater for chemical analysis.

[b] Screen types: “Rod” = rod-based 0.020” slot screen; “Pipe”= pipe-based.

[c] Type 1 = Pipe-based and is 84 holes per linear ft of pipe (0.375 in. or 0.5 in.). Type 2 = Pipe-based and is 168 holes per linear ft of pipe (0.5 in.).

[d] n/a = Not applicable.

[e] At R-5 screen 3, port 3B is functional.

[f] The port at screen 2 of R-32 is not designed for sample collection but is intended only for pressure readings.

Table 3-2
Sample System Rating Criteria

	Sample System Ratings for Applicability for Regional Aquifer Monitoring Wells				
Rating	**1**	**2**	**3**	**4**	**5**
System Design	Entirely inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate
System Materials	Entirely inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate
System Cost	Prohibitively expensive	Relatively expensive	Cost effective	Relatively inexpensive	Prohibitively inexpensive
Installation/Removal	Very complex	Complex	Intricate	Relatively simple	Very simple
Maintenance	Very complex	Complex	Intricate	Relatively simple	Very simple
Groundwater Sample Quality	Inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate
Groundwater-Level Monitoring	Inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate
Operational History	Inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate
Long-Term Operational Issues	Inadequate	Functional but inadequate	Functional	Functional and adequate	Most adequate

Table 3-3
Sample System Rankings

	Sample System Ratings				
Evaluation Criteria	Westbay Multiple Port	Barcad Dual Pump Packer	Baski Packer Dual Valve	Baski Packer Dual Pump	FLUTe Sampling System
System Design	4	2	4	4	3
System Materials	4	3	4	4	4
System Cost	2	4	3	3	4
Installation/Removal	2	4	3	3	4
Maintenance	2	3	4	4	4
Groundwater Sample Quality	2	1	5	5	2
Groundwater Level Monitoring	3	1	3	3	3
Operational History	4	1	3	3	3
Long-Term Operational Issues	3	2	3	3	3
Total	26	21	32	32	30

Table 3-4
Instrument Measurements

Field Parameter	Method Description	EPA-Approved Methods	Field Instrument(s)	Flow-Through Cell Used/Type	Description
pH	Hydrogen Ion, pH (pH units): Electrometric measurement	EPA Method 150.1 Standard Methods, 4500-H^+ B Editions 18th, 19th, 20th	Beckman 255 or YSI 556 Multiprobe	Geotech Multiprobe Flowcell Sampling System or YSI 556 cell	Samples will be analyzed for pH and temperature as soon as possible in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. A calibration check is performed on the meter using the manufacturer's instructions with standard buffers traceable to National Institute of Standards and Technology (NIST) and recorded. Standards are purchased from commercial vendors.
Temperature	Temperature Thermometric, (C^o)	EPA Method 170.1 Standard Methods, 2550 B Editions 18th, 19th, 20th	Beckman 255 (pH meter parameter) or YSI 556 Multiprobe	Geotech Multiprobe Flowcell Sampling System or YSI 556 cell	Samples will be analyzed for temperature concurrently with pH measurement as soon as possible in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation.
Specific Conductance	Electrical Conductance, (micromhos/cm at 25°C): Wheatstone bridge	EPA Method 120.1 Standard Methods, 2510 B Editions 18th, 19th, 20th	Hach Sension 5 or YSI 556 Multiprobe	Geotech Multiprobe Flowcell Sampling System or YSI 556 cell	Samples will be analyzed for specific conductance as soon as possible in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. A calibration check is performed on the meter using the manufacturer's instructions with standard buffers traceable to NIST and is recorded. Standards are purchased from commercial vendors.
Dissolved Oxygen	Oxygen, Dissolved, (mg/L): Electrode	EPA Method 360.1 Standard Methods, 4500-O G Editions 18th, 19th, 20th	WTW Oxi 330i or YSI 85/10ft or YSI 556 Multiprobe	Geotech Multiprobe Flowcell Sampling System or YSI 556 cell	Samples will be analyzed for dissolved oxygen as soon as possible in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. The meter is calibrated using the manufacturer's instructions and is recorded.

Table 4-1
Proposed Well Conversion and Rehabilitation Actions

Well No.	Screens to Retain	Screen to Abandon[a]	Development Techniques Applied	Proposed Sample System	Proposed Schedule for Completion
R-12	#1 and #2	#3	Jetting, isolation pumping (#1 only)	Baski	10/30/07
R-14[b]	#1	#2	Surge/bail; jetting/pumping; isolation pumping/overpumping	Submersible pump	3/31/08
R-16	All	None	No further action	Westbay	n/a
R-20	#1 and #2	#3	Surge/bail; jetting/pumping; isolation pumping/overpumping	Baski	12/07/07
R-22	#2 and #3	#1, #4, and #5	Surge/bail; jetting/pumping; isolation pumping/overpumping	Baski	1/31/08
R-25	#6, #7, and #8	#1, #2, #3, #4, #5, and #9	Covered in TA-16 assessment	?	?
R-32[c]	#1	#2 and #3	Surge/bail; jetting/pumping; isolation pumping/overpumping	Submersible pump	9/30/07
R-33[b]	#1 and #2	n/a	Surge/bail; jetting/pumping; isolation pumping/overpumping	Baski	2/28/08

[a] Replacement wells will be discussed in specific area assessments.

[b] Contingent upon approval of the Mortandad Canyon network evaluation, submitted to NMED June 28, 2007.

[c] Completion of R-32 is contingent upon ability to place Baski order in 2007.

n/a = Not applicable, ? = unknown, FY = fiscal year.

Appendix A

Well Screen Parameters and Characteristics

Appendix A consolidates in one place information about construction and development of the R-wells and their objectives. Appendix A provides a synopsis of the physical conditions of the R-wells, and Appendix B shows the chemical conditions as of December 2006 of the screens that are potential candidates for redevelopment or replacement. Table A-1 provides information on well construction and development. Table A-2 describes the geology and geophysics of the screened interval. Table A-3 summarizes well screen conditions and provides aquifer test data.

Table A-1
Well Construction and Development Information

CdV-R-15-3, Data Quality Objectives

This well was installed east of Cañon de Valle, within TA-15.

- The well was constructed primarily to investigate the extent of contamination in deep perched and regional groundwater systems associated with HE presumably derived from Potential Release Site 16-021(c)-99, the Building 260 Outfall.
- In addition, the objectives included determining how fast any contamination detected is moving downgradient of the Pajarito well field or other exposure points.
- The objective was also to investigate the directions of groundwater flow and the hydrologic gradients within the regional aquifer and deep-perched saturated zones in and around TA-16.
- Screens 1, 2, and 3 were set opposite suspected perched water zones.
- Screen 4 spans the surface of the regional aquifer.
- Screens 5 and 6 are set in middle and deep parts of the regional aquifer in the Puye Formation.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screens/Zones in Communication[c]
Screen 1 (604–626)	Water, QUIKFOAM, EZ-MUD 0–1722: open hole, air rotary, dual-wall reverse circulation	None	Water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals	Wire brushing	46 days (Aug. 6–Sept 19, 2000)
Screen 2 (785–806)					
Screen 3 (944–975)					
Screen 4 (1212–1287)				Wire brushing, bailing, pumping; 8860 gal. removed by pumping.	
Screen 5 (1321–1349)				Wire brushing, bailing, pumping; 7700 gal. removed by pumping.	
Screen 6 (1604–1649)				Wire brushing, bailing, pumping; 16,160 gal. removed by pumping.[d]	

Note: The data shown in this table were taken from (Kopp et al. 2002, 073179). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; it does not include transitional sand pack adjacent to sealing materials.

[b] Includes an additional 7040 gal. pumped from the sump during development to equal the total amount removed as listed in the completion report.

[c] From completion of well development to completion of Westbay installation.

Pumping was conducted without packers; pump placement was within screened interval during development. Pipe tally error resulted in annular seal material opposite portions of Screens 3 and 5.

[d] 740 gal. bailed; 7050 gal. pumped from sump. Total removed from bailing and pumping = 40,510 gal.

HE = High explosives, LCM = lost circulation material(s).

CdV-R-37-2, Data Quality Objectives

This well was installed within TA-37 and lies approximately 200 ft north of K-Site Road at the western boundary of TA-37, on the southern rim of Cañon de Valle.

- The well was constructed as part of the Corrective Measures Study for Potential Release Site 16-021(c)-99.
- The primary objective is to help determine if the HE contamination detected in the perched and regional aquifers at Well R-25 (in TA-16) extends to the southeast.
- The objective was to determine how fast water and contamination, if present, have been moving downgradient toward the Pajarito well field or toward other potential exposure points.
- The direction of groundwater flow and the hydraulic gradients was investigated within the regional and perched aquifers in the western portion of the Laboratory.
- The objective was to meet the design and construction requirements for a regional-aquifer characterization well as described in the Hydrogeologic Workplan and possibly to be incorporated into the Laboratory-wide groundwater monitoring program.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screens/Zones in Communication[b]
Screen 1 (904.2–943.8) (dry)	Water, EZ-MUD, QUIKFOAM 0–794: open hole, air rotary 794–825: casing advance 825–1208: open hole, air rotary 1208–1404: open hole, DHH 1404–1664: open hole, air rotary	None	Water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals Approx. 15,000 gal. of municipal water used.	Wire brushing (Screen dry)	17 days (Sept. 21 to Oct. 8, 2001)
Screen 2 (1179.6–1221)				Wire brushing, bailing, surging (wireline) (Screen not productive enough to pump)	
Screen 3 (1343–1382)				Wire brushing, bailing, surging, pumping 17,480 gal. removed by pumping.	
Screen 4 (1539.7–1560.7)				9860 gal. removed by pumping.[c]	

Note: The data shown in this table were taken from (Kopp et al. 2003, 088803). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation. Pumping was conducted without packers; pump placement was between and within Screens 3 and 4.

[c] 100 gal. bailed from well. Total removed by bailing and pumping = 27,440 gal.

TA = Technical area, HE = high explosives, DHH = downhole hammer, LCM = lost circulation material(s).

R-5, Data Quality Objectives

This well was installed on the southern side of lower Pueblo Canyon, about 3000 ft west-northwest of supply well Otowi-1 and about 4700 ft southeast of the Bayo Canyon Sewage Treatment Plant.

- The primary purpose of the well is to provide water-quality, geochemical, hydrologic, and geologic information that would contribute to understanding the hydrogeologic setting beneath the Laboratory.
- The well was also designed to help determine whether Laboratory releases and sewage treatment plant effluents may be present in the regional aquifer beneath lower Pueblo Canyon, and if so, the extent to which contaminants may have affected groundwater quality.
- Other goals include implementing a Laboratory-wide groundwater monitoring network and monitoring a possible perched saturation zone in the Puye Formation identified from geophysics (Screen 1), a possible saturation zone in the Puye Formation (Screen 2), the top of the regional zone of saturation in Santa Fe Group sediments (Screen 3), and a deeper part of the regional zone of saturation in Santa Fe Group basalts (Screen 4).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., Solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[c]	Time Screens/Zones in Communication[b]
Screen 1 (316.5–338.0) (dry)	Air rotary drilling was assisted at times with municipal water mixed with polymer additives such as EZ-MUD and QUIKFOAM. 0–130: casing advance, DHH 130–547: open hole, DHH 130–547: casing advance 547–570: casing advance, DHH 570–828: open hole, DHH 570–825: casing advance, DHH 870–902: open hole, air rotary, fluid assisted	None mentioned	Water for filter pack, water for chip seals, water plus EZ-MUD for pellet seals below water table.	Wire brushing	28 days (June 21 to July 19, 2001)
Screen 2 (364.5–399.5) (not productive)				Wire brushing	
Screen 3 (666.5–727.0)				Wire brushing, swabbing/surging, bailing, pumping 1095 gal. removed by pumping (no packers).	
Screen 4 (851.0–902.0) (not productive)				Wire brushing, swabbing/surging, bailing, pumping 985 gal. removed by pumping (no packers). 9130 gal. removed by pumping below Screen 4 (no packers).	

Note: The data shown in this table were taken from (LANL 2003, 080925). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] 3020 gal. bailed; total volume removed from bailing and pumping = 14,230 gal.

DHH = Downhole hammer, LCM = lost circulation material(s).

R-7, Data Quality Objectives					
This well was installed in upper Los Alamos Canyon, approximately 1 mi upstream of its confluence with DP Canyon to • provide a well east of TA-02 and south of TA-21 where contaminated effluent has been released, • characterize the occurrence and quality of water in the intermediate perched zones (Screens 1 and 2), • permit sampling at the top of the regional zone of saturation (Screen 3), and • possibly incorporate the well into the Laboratory-wide groundwater-monitoring program.					
Effective Screen Interval[a] (ft)	**Drilling Fluids and Method(s) Used**	**Additives (i.e., solids, LCM)**	**Well Installation Fluids**	**Well Development Methods and Volumes Added/Removed**	**Time Screen/Zones in Communication[b]**
Screen 1 (355.6–383.6) (dry)	Water, EZ-MUD, QUIKFOAM 11–26: open hole, DHH 26–290: casing advance with DHH 290–342: open hole, air-rotary casing set to 290. 287–382: open hole, air rotary 382–1084: open hole, air rotary 1084–1097: open hole, air rotary	None mentioned	Water for filter pack, water for chip seal	Wire brushing only	17 days (Feb. 8 to Feb. 25, 2001)
Screen 2 (725–754) (dry)			Water for filter pack, water plus EZ-MUD for pellet seal	Wire brushing only	
Screen 3 (880–946.8)			Water for filter pack, water plus EZ-MUD for pellet seal	Wire brushing and bailing (screens not isolated). 3000 gal. removed.	

Note: The data shown in this table were taken from (Stone et al. 2002, 072717). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DP = Delta Prime, TA = technical area, DHH = downhole hammer, LCM = lost circulation material(s).

R-8, Data Quality Objectives

Note: The well completed in a second borehole, BH2 (located hydraulically upgradient) when the first borehole, BH1, had to be abandoned.

This well is located in Los Alamos Canyon, approximately 3300 ft downstream of the confluence with DP Canyon, in the northeastern portion of the Laboratory. The well was designed to

- provide hydrogeologic and water-quality data on the regional groundwater and to assess the impact of Laboratory activities on the Los Alamos Canyon watershed;
- gather geologic, hydrologic, geochemical, and water-quality information to contribute to further understanding of the Laboratory's subsurface hydrogeologic setting, including the locations of possible intermediate perched water zones and the distribution of any contaminants downgradient of TA-21;
- sample the top of the regional zone of saturation (Screen 1); and
- monitor a deeper, more productive zone within the regional aquifer (Screen 2).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[c]	Time Screen/Zones in Communication[b]
Screen 1 (687.4–796.8) (actual slotted interval 705.3–755.7)	Water, QUIKFOAM, EZ-MUD 0–90: casing advance, DHH 90–684: casing advance, DHH 684–862: open hole, air rotary 706–880: open hole, air rotary 750–809: casing advance, DHH	None	Water for filter packs and bentonite chip and pellet seals	Wire brushing, bailing, swabbing and injecting, surging/bailing	10 days (Feb. 14 to Feb. 24, 2002)
Screen 2 (812.3–832.4)				Wire brushing, bailing, swabbing and injecting, surging/bailing 12,740 gal. removed by pumping (no packers).	

Note: The data shown in this table were taken from (LANL 2003, 079594).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials; includes slough material resulting from unstable borehole.

[b] From completion of well development to completion of Westbay installation.

[c] Pumping was conducted without packers; pump placement was within Screen 2. 7000 gal. removed by bailing. Total removed by bailing and pumping =19,740 gal. removed by pumping.

DP = Delta Prime, DHH = downhole hammer.

R-9i, Data Quality Objectives					
This well is located near the eastern boundary of the Laboratory in Los Alamos Canyon. The well is designed to • characterize temporal variations in water quality and water levels for the two uppermost intermediate-depth perched groundwater zones at this location, • satisfy requirements of the work plan for Los Alamos and Pueblo Canyons and the Laboratory's Hydrogeologic Workplan, • monitor the uppermost intermediate-depth perched groundwater in the Cerros del Rio basalt that could be connected upgradient with surface water and alluvial groundwater in Los Alamos Canyon (Screen 1), and • monitor a small perched zone at the base of the Cerros del Rio basalt that contains elevated uranium concentrations (Screen 2).					
Effective Screen Interval[a] (ft)	**Drilling Fluids and Method(s) Used**	**Additives (i.e., solids, LCM)**	**Well Installation Fluids**	**Well Development Methods and Volumes Added/Removed**	**Time Screen/Zones in Communication[b]**
Screen 1 (185.5–200.7)	No fluids specifically mentioned but included water and QUIKFOAM 0–332: open hole, air rotary	None	Water for filter packs and bentonite chip and pellet seals	Bailing/surging and pumping; 250 gal. removed by bailing/surging. 2850 gal. removed by pumping. Screens not isolated.	8 days (Apr. 7 to Apr. 15, 2000)
Screen 2 (266.4–282.1)				Bailing/surging and pumping; 300 gal. removed by bailing/surging. 1615 gal. removed by pumping. Screens not isolated.	

Note: The data shown in this table were taken from (Broxton et al. 2001, 071251). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

Pumping was conducted without packers; pump placement was within screened intervals during development.

LCM = Lost circulation material(s).

R-12, Data Quality Objectives

This well was installed in Sandia Canyon near the eastern boundary of the Laboratory as part of the Hydrogeologic Workplan to

- provide information about the quality of groundwater at the eastern boundary of the Laboratory;
- provide early warning of contaminants reaching the upper part of the regional aquifer near water-supply well PM-1;
- gather water-quality and water-level data for the potential intermediate-depth perched zones and from the regional aquifer downgradient of numerous contaminant source areas in upper Los Alamos, Sandia, and Mortandad Canyons (Aggregates 1 and 7 in the Hydrogeologic Workplan);
- support a completion strategy for BH R-9;
- possibly be incorporated into the Laboratory-wide groundwater-monitoring program;
- monitor the upper part of the perched groundwater zone within the Cerros del Rio basalt (Screen 1);
- monitor the lower part of the perched groundwater zone within the old alluvium sediments (Screen 2); and
- monitor the top of the regional zone of saturation (Screen 3).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids[b]	Well Development Methods and Volumes Added/Removed[c]	Time Screen/Zones in Communication[d]
Screen 1 453–481	Mainly casing advancement, some open-BH RC or DHH drilling in basalt Water and EZ-MUD, some foam	None mentioned	NL	Jetting	41 days (Feb. 6 to Mar. 19, 2000)
Screen 2 495–522	Casing advancement Water and EZ-MUD, some foam	None mentioned	NL	Jetting	
Screen 3 793–856	Casing advancement Water and EZ-MUD, some foam	None mentioned	NL	Jetting, pumping	

Note: The data shown in this table were taken from (Broxton et al. 2001, 071252). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Not listed in well completion report (Broxton et al. 2001, 071252).

[c] Jetting: a total of 2000 gal. of municipal supply water was used to jet all three screens. Pumping: a total of 1613 gal. was pumped. Pumping was conducted without packers; pump placement was below 805 ft SWL (424 ft for perched, 805 ft for regional).

[d] From completion of well development to completion of Westbay installation.

BH = Borehole, RC = reverse circulation, DHH = downhole hammer, LCM = lost circulation material(s), NL = not listed, SWL = standing-water line.

R-14, Data Quality Objectives

This well was installed in Ten Site Canyon, a tributary to Mortandad Canyon in the east-central portion of the Laboratory. R-14 is downgradient of the active RLW treatment facility at TA-50 and the former RLW and septic facilities at TA-35. The well was designed to

- determine if releases and effluents may be present in and around the Mortandad Canyon watershed, and if so, the extent to which contaminants affect groundwater quality,
- monitor near the top of the regional zone of saturation (Screen 1),
- monitor a deeper productive zone within the regional aquifer (Screen 2),
- collect data for evaluating the hydrogeologic setting of Mortandad Canyon, and
- contribute to implementing a Laboratory-wide groundwater-monitoring network.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (1196.8–1240.2)	From 848–1315 ft bgs: Water, QUIKFOAM, Liqui-Trol 12.2–306: open hole, air rotary fluid assisted 306–1068: open hole, air rotary fluid assisted (ream) 1068–1225: open hole, air rotary fluid assisted 1225–1285: open hole, mud rotary (set casing) 1285–1327: casing advance, DHH	Soda ash, Pac-L, N-Seal, magma fiber	Water for filter packs, water and EZ-MUD for bentonite pellet seals Approximately 13,631 gal. of water used to place annular fill	Wire brushing, surging/bailing, pumping with screen isolated, surging/bailing, chemical treatment, surging/bailing, pumping 5610 gal. removed.	7 days (Nov. 18 to Nov. 25, 2002)
Screen 2 (1281.0–1299.0)				Wire brushing, surging/bailing, pumping with screen isolated, surging/bailing, chemical treatment, surging/bailing, pumping 173,760 gal. removed.	

Note: The data shown in this table were taken from (LANL 2003, 076062). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Modified granular acid (MGA), acid enhancer (AE), and phosphate-free dispersant (PFD) added to each screen interval followed by surging/bailing; when the pH stabilized, pump development started. 800+ gal. of chemical treatment applied to both screens. 11,550 gal. water removed by bailing at both screens. 9200 gal. water removed by composite pumping at both screens. A total of 205,010 gal. removed by bailing and pumping.

[c] From completion of well development to completion of Westbay installation.

RLW = Radioactive liquid waste, TA = technical area, DHH = downhole hammer, LCM = lost circulation material(s).

R-16, Data Quality Objectives

This well was installed in Cañada del Buey as part of the Hydrogeologic Workplan to

- determine the water table and vertical gradient for the regional aquifer near the Rio Grande,
- act as a monitoring point between TA-54 and the Rio Grande,
- determine the relationship between the regional water table and springs in White Rock Canyon, and
- contribute to understanding flow paths between Mortandad Canyon and springs in White Rock Canyon.

The screen intervals were selected to monitor the top of regional aquifer (Screen 1) and deeper more productive zones within the regional aquifer (Screens 2–4).

Effective Screen Interval[a] (ft)	Drilling Method(s) Used	Drilling Fluids and Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 634.5–653.4	Mud rotary for this interval	Water, Quick-Gel, Liqui-Trol, QUICKFOAM, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Interval isolated behind abandoned drill casing.	n/a
Screen 2 852.1–877.5	Mud rotary for this interval	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated). Acid and dispersant added. Pumping with and without packer isolation. 7590 gal. pumped.	6 days (Dec. 4 to Dec. 10, 2002)
Screen 3 1006.7–1028.5	Mud rotary for this interval	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated). Acid and dispersant added. Pumping with and without packer isolation. 3270 gal. pumped.	
Screen 4 1211.7–1287	Mud rotary for this interval	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated) and jetting. Acid and dispersant added. Pumping with and without packer isolation 56,760 gal. pumped.	

Note: The data shown in this table were taken from (LANL 2003, 076061). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Pumping was conducted with and without packers; composite pumping was conducted near Screen 4. Total volume removed = 76,850 gal. 4755 gal. bailed from well. 1200 gal. of chemicals used to treat all three screens.

[c] From completion of well development to completion of Westbay installation.

TA = Technical area, LCM = lost circulation material(s).

R-19, Data Quality Objectives

This well was installed atop the mesa separating Threemile and Potrillo Canyons, east of firing site IJ. Well R-19 was primarily designed to provide water-quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of HE contaminant release sites at TA-16. It was also designed to

- sample possible perched groundwater (Screens 1, 2) that could be connected upgradient with HE-contaminated perched water at R-25,
- sample the top of the regional zone of saturation (Screen 3),
- sample high-permeability zones that might act as fast pathways for contaminants in the regional system (Screens 5, 6, 7),
- provide spatial coverage for sampling the thick sequences of less permeable rocks in the upper part of the regional zone of saturation (Screen 4);
- help evaluate the nature and extent of HE contamination originating at TA-16, and
- increase the understanding of the hydrogeology of a little-studied part of the Laboratory and to update the sitewide conceptual hydrogeologic model.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (802.2–858.6)	EZ-MUD, QUIKFOAM slurries 16–143: casing advance (dry) 143–227: casing advance, fluid assisted. 225–1902.5: open hole, air-rotary fluid assisted	None mentioned	Water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals	Washing and jetting	54 days Jul. 19 to Sept. 11, 2000 (estimated development completion date)
Screen 2 (868.3–926.0)				Washing and jetting	
Screen 3 (1149.8–1240.5)				Washing, air jetting, airlifting, and pumping 13,834 gal. removed by airlifting and pumping[c].	
Screen 4 (1380.0–1445.5)				Washing, jetting, airlifting, and pumping. Screens not isolated 14,918 gal. removed by airlifting and pumping[c].	
Screen 5 (1557.9–1606.8)				Washing, jetting, airlifting, and pumping. Screens not isolated 17,243 gal. removed by airlifting and pumping[c].	
Screen 6 (1675.9–1779.8)				Washing, jetting, airlifting, and pumping. Screens not isolated 16,143 gal. removed by airlifting and pumping[c].	
Screen 7 1828.2–1848.4)				Washing, jetting, airlifting, and pumping. Screens not isolated. 18,793 gal. removed by airlifting and pumping[c].	

Note: The data shown in this table were taken from (Broxton et al. 2001, 071254). Also see (Broxton et al. 2002, 076006) and (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] The well completion report (Broxton et al. 2001, 071254) states that 63,000 gal. of fluids was generated during drilling. The assumption is that most of the water was derived from Screens 3 through 7. 8000 gal. water was introduced during jetting.

TA = Technical area, HE = high explosives, LCM = lost circulation material(s).

R-20, Data Quality Objectives

This well was installed east of TA-18, on the south side of Pajarito Road in Pajarito Canyon to

- provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54,
- function primarily as a monitoring well between MDA L at TA-54 and supply well PM-2,
- provide data for the Laboratory hydrologic and geologic conceptual models, and
- contribute to implementing a Laboratory-wide groundwater monitoring system.

Screen 1 was designed to monitor near the top of the regional aquifer in cinder beds of the Cerros del Rio lavas. Screen 2 was designed to monitor within the regional aquifer in pumiceous Puye Formation fanglomerate. Screen 3 was designed to monitor within the regional aquifer in the Santa Fe Group sediments.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (895.2–926.5)	(Below 780 ft bgs) Mud rotary Water, Quick-Gel, Liqui-Trol	Pac-L, N-Seal, magma fiber	Water for filter pack, water and EZ-MUD for bentonite (Benseal, Pelplug) seals. Approx. 41,400 gal. of municipal water used for installation.	Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 113 gal. pumped.	27 days (Dec. 22 to Jan. 18, 2003)
Screen 2 (1132.5–1165.5)				Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 5255 gal. pumped.	
Screen 3 (1320.6–1344.5)				Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 11,775 gal. pumped.	

Note: The data shown in this table were taken from (LANL 2003, 079600). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Chemical treatments involved PFD, MGA, and AE solutions. Pumping conducted with and without packers; pump placement without packers varied and was positioned below each screen. 7,965 gal. of water bailed. 1850 gal. of chemicals introduced. 63,750 gal. of water in composite pumping. Total water removed = 87,008 gal.

[c] From completion of well development to completion of Westbay installation.

TA = Technical area, MDA = material disposal area, AE = acid enhancer, LCM = lost circulation material(s), MDA = material disposal area, MGA = modified granular acid, PFD = phosphate-free dispersant.

R-22, Data Quality Objectives

This well was installed atop the mesa separating Cañada del Buey and Pajarito Canyon as part of the Hydrogeologic Workplan to

- provide water-quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of the waste disposal facility at TA-54;
- collect geologic, hydrologic, and geochemical data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory;
- sample the top of the region zone of saturation (Screens 1 and 2); two intervals were necessary since two distinct static water levels were observed;
- sample within the upper Puye Formation fanglomerate (Screen 3);
- sample within the older basalt (Screen 4); and
- sample within the lower fanglomerate tentatively assigned to the Puye Formation (Screen 5).

The well was designed to also meet the requirements of a monitoring well as defined in the Hazardous Waste Facility Permit. Incorporation into a Laboratory-wide monitoring network was to be evaluated later.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (862.0–922.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD	None mentioned	Water for filter pack. Water plus EZ-MUD for pellet seals	Wire brushing	19 days (Nov. 19 to Dec. 8, 2000)
Screen 2 (937.5–1007.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD			Wire brushing, bailing[c]	
Screen 3 (1243.5–1284)	Casing advance, DHH, water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing. Pump developed with and without packer isolation. A total of 7365 gal. removed.	
Screen 4 (1368.5–1387.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing with screens not isolated. Pump developed without isolation. A total of 15,785 gal. removed.	
Screen 5 (1437–1478.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing. Pump developed without isolation. A total of 3526 gal. removed. [c] Sump also pumped and 8086 gal. removed.	

Note: The data shown in this table were taken from (Ball et al. 2002, 071471). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] 4115 gal. bailed from well. Total volume of water removed = 38,877 gal.

TA = Technical area, DHH = downhole hammer, LCM = lost circulation material(s).

R-25, Data Quality Objectives

This well was installed in on the south rim of Cañon de Valle, within TA-16, near the southwestern boundary of the Laboratory to

- provide water-quality and water-level data for intermediate-depth perched groundwater and the regional aquifer in a previously poorly characterized area of the Laboratory;
- provide geologic and hydrologic information that will contribute to the understanding of the hydrogeologic setting beneath the Laboratory;
- establish the distribution of HE contaminants in the upper zone of saturation and determine vertical head data for this zone (Screens 1, 2, 3);
- determine whether the alternating wet and dry zone from 1132 to1286 ft is hydraulically connected to the upper saturated zone or the regional aquifer (Screen 4);
- determine the water quality and water level at the top of the regional zone of saturation (Screen 5), and
- determine the vertical extent of contamination and establish vertical head data for the regional zone of saturation (Screens 6, 7, 8, and 9).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Repair and Development Methods	Well Development Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (732–762)	0–588: Casing advance air rotary (drilled without fluids) 588–1427: casing advance air rotary fluid assisted Water, Tork-Ease, bentonite products[c]	Fibrous materials: cellophane, mag fiber, nylon	Water for filter pack 610–1026: bentonite placed with plain water. Above 610: Bentonite placed in annulus dry.	Prior to screen repairs Screens 1, 2, 4, 5, 6, 7, and 8 were pressure-washed with water and SAPP. Some purging of the well below Screen 3 was performed. Screens 2 and 8 were partially developed by airlifting. Purging introduced 900 gal. of water and the removal of 1200 gal. Development included airlifting 39,000 gal. for the interval between Screens 8 and 9 and airlifting 500 gal. from a depth corresponding to Screen 2. Following repairs: Screens 1 and 2 were wire brushed, after which all screens, except 3 and 9, were jetted. Then the well was purged with a pump set at 1760. Two months later, Screens 1 and 2 were wire brushed again. The well was airlifted from just above replacement Screen 9 and the screens pumped starting at 4 and working downward. Screens 4 to 6 were scrubbed and the intervals pumped. Development was interrupted by the Cerro Grande fire for 5 months and the screens were pump developed again. A total of 192,000 gal. removed following screen repairs.	Airlifting and pumping	425 days (March 10, 1999, to Sept. 29, 2000)
Screen 2 (878–897)					Airlifting and pumping	
Screen 3[d] (1046–1070)			Water for filter pack 1026–1942: Bentonite placed with transport fluid of bentonite, water, and catalyst retardant.		n/a	
Screen 4 (1180–1191)					Airlifting and pumping	
Screen 5 (1290–1307)					Airlifting and pumping	
Screen 6 (1398–1415)					Airlifting and pumping	
Screen 7 (1600–1618)	1427–1942: casing advance, air rotary water, QUIKFOAM, EZ-MUD, bentonite products[e], cellophane, MF-1[f]	Cellophane, MF-1[f]			Airlifting and pumping	
Screen 8 (1786–1805)					Airlifting and pumping	
Screen 9[d] (1862.2–1930)					Airlifting and pumping	

Note: The data shown in this table were taken from (Broxton et al. 2002, 072640). Also see (LANL 2005, 089397) and (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] A total of 232,700 gal. removed from R-25.

[c] Estimated from completion of well installation to completion of Westbay installation; 67 days of actual well development completed.

[d] Bentonite products include Ben-Seal, Bentonite Gel, Aqua-Guard Bentonite, and Pel-Plug.

[e] Screens 3 and 9 damaged during installation. Replacement Screen 9 installed at 1871.5–1875 ft in well with packer just above screen, sealing off zone from well. Screen 3 sealed off with Portland cement/micro matrix plug and interval redrilled.

[f] MF-1 is a flocculent.

TA = Technical area, HE= high explosives, LCM = lost circulation material(s), SAPP = sodium acid pyrophosphate n/a = not applicable.

R-26, Data Quality Objectives

Well R-26 is located in Cañon de Valle, just east of State Highway 4 and upgradient of TA-16.

- The well was installed as part of the Hydrogeologic Workplan. Characterization and sampling activities were conducted in accordance with the SAP for drilling and testing characterization wells R-2, R-4, R-11, and R-26.
- The well provides background water chemistry for perched and regional groundwater upgradient of Laboratory activities in the TA-16 vicinity.

Well R-26

- monitored the intermediate perched zone in the Cerro Toledo interval of the Bandelier Tuff penetrated by existing wells R-25 and SHB-3 (Screen 1), and
- monitored the regional zone of saturation in the Puye Formation upgradient of Laboratory activities in the TA-16 vicinity (Screen 2).

This well is located on the downthrown block of the Pajarito fault system. Data will be used to evaluate the influence of the Pajarito fault system on the regional aquifer piezometric surface and provide information on the role of faults in recharge.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (620–672)	Water, QUIKFOAM, EZ-MUD, drilling mud[c,d] 0–77: casing advance, air rotary 77–140: open hole, air rotary 140–147: open hole air rotary (air only) 147–205: open hole, DHH (water only) 205–1000: open hole air rotary, fluid assisted. At 1000 ft bgs, lost circulation problems; drill casing set to 1005 ft bgs 1000–1490.5: mud rotary.	Aqua-Gel, N-seal, Pac-L, soda ash	Water for filter packs and bentonite chip seals	Airlifting to remove drilling mud. 3872 gal. removed. October–November 2003: Bailing, swabbing, bailing /surging pumping. 8948 gal. removed. July 2004: Pumping prior to Westbay installation (screens not isolated).[e] 41,818 gal. removed.	239 days (Nov. 16, 2003, to July 17, 2004)
Screen 2 (1411–1450)				October–November 2003: Bailing, swabbing, bailing /surging pumping. 29,259 gal. removed. July 2004: Pumping prior to Westbay installation (Screens not isolated).[e] 3733 gal. removed.	

Note: The data shown in this table were taken from (Kleinfelder 2005, 087846). Also see (Vaniman et al. 2002, 072615; Stone and McLin 2003, 076003; LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] Drilling mud is a mixture of water, bentonite, soda ash, and Pac-L.

[d] Minimum amount, no volumes listed for amounts added or removed during washing/jetting or airlifting.

[e] Additional pump development to address high turbidity noted from camera survey.

TA = Technical area, DHH = downhole hammer, ft bgs = feet below ground surface, LCM = lost circulation material(s).

R-32, Data Quality Objectives

This well was installed in Pajarito Canyon, within TA-36, on the northern side of Pajarito Road and southwest of MDA G in TA-54 to

- provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54,
- provide data for the Laboratory hydrogeologic and geologic conceptual models and contribute to implementing a Laboratory-wide groundwater monitoring system,
- monitor the regional aquifer in river gravels present above the Cerros del Rio basalt (Screen 1),
- monitor the uppermost part of the Puye Formation in the regional aquifer (Screen 2), and
- monitor the regional aquifer in deepest part of the Puye Formation penetrated by the borehole (Screen 3).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (862.5–879.2)	0–792: open hole, fluid assist: water, quick-gel, Liqui-Trol, QUIKFOAM Casing installed to 797 808–908: open hole, fluid assist 908–1008: Mud rotary, open hole water, quick-gel, EZ–MUD. Liqui-Trol, QUIKFOAM	0–792: Soda ash	Water for filter pack Water plus EZ-MUD for pellet seals 12,200 gal. of water used to place annular fill materials.	Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 4450 gal. pumped.	7 days (Nov. 1 to Nov. 10, 2002)
Screen 2 (925.2–938.7)		908–1008 Pac-L, N-Seal, Magma-Fiber		Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 3015 gal. pumped.	
Screen 3 (961.7–978.2)				Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 24,810 gal. pumped.	

Note: The data shown in this table were taken from (LANL 2003, 079602). Also see (McLin and Stone 2004, 089552) and (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Chemical treatments involved phosphate-free dispersant (PFD), modified granular acid (MGA) and acid enhancer (AE) solutions. Pumping was conducted with and without packers; pump placement without packers was generally near Screen 3. 11,300 gal. of water bailed from well. 730 gal. of chemicals introduced to screens. Composite pumping = 72,125 gal. Total volume removed = 114,970 gal.

[c] From completion of well development to completion of Westbay installation.

TA = Technical area, MDA = material disposal area, LCM = lost circulation material(s).

R-33, Data Quality Objectives

This well was installed within Ten Site Canyon, upgradient of the confluence with Mortandad Canyon.

- The well is intended to serve as a monitoring point for municipal water supply well PM-5 and lower Ten Site Canyon.
- Data will be used to evaluate the nature and extent of potential contamination in the regional aquifer in Ten Site and Mortandad Canyons relative to former release sites in TA-48, TA-35, and TA-50.
- The two screens were designed to monitor potential contaminants and groundwater chemistry in the two uppermost productive zones of the regional aquifer and to determine if vertical hydraulic gradients are present in this part of the Laboratory.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screens/Zones in Communication[c]
Screen 1 (991–1027)	Water, QUIKFOZM, EZ-MUD, defoaming agent 56.4–285: open hole, air rotary (water only) 285–530: open hole, air rotary fluid assisted 530–1030: open hole, DHH 1030–1140: open hole, air rotary fluid assisted	None	Water for filter pack and bentonite chip seals	Bailing/swabbing, pumping (aquifer testing). An additional 5265 gal. removed as result of aquifer test.	62 days (Oct. 5 to Dec. 3, 2004, and Feb. 3 to Feb. 5, 2005)
Screen 2 (1107–1126)				Bailing/swabbing, pumping (aquifer testing), pumping 34,550 gal. pumped with packer isolation. An additional 21,153 gal. removed as result of aquifer test.	

Note: The data shown in this table were taken from (Kleinfelder 2005, 092385). Also see (LANL 2005, 091121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Pumping was conducted with and without packers. 40 gal. bailed from well. 87,590 gal. removed by composite pumping. A total of 148,598 gal. removed as a result of development and aquifer testing.

[c] Packer installed after well development to isolate screens; packer removed immediately before Barcad installed.

TA = Technical area, LCM = lost circulation material(s), DHH = downhole hammer.

Table A-2
Geology and Geophysics of Screened Interval

CdV-R-15-3, Geology and Geophysics of Screened Interval

CdV-R-15-3 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (604–626)	Otowi Member, Bandelier Tuff Nonwelded vitric tuff with abundant feldspar and quartz phenocrysts.	Neutron logging (CMR and APS readings) and TLD formation porosity readings were used to identify six potentially productive regions. The six screens were placed adjacent to, or at the bottom of, these regions. The HNGS and total GR probe provided geochemical information throughout the borehole. The GR tool helped define subdivisions of the Bandelier Tuff and identify the Cerro Toledo interval. In the Puye Formation and the deep pumiceous unit, the HNGS could identify gamma potassium-uranium-thorium subdivisions not seen on any other tool. The Pleistocene Cerro Toledo was determined to be much thicker (200 ft) than the thickness predicted by the 3-D geologic model. The borehole video provided a record of clast sizes through the interval. Neither video nor geophysical logs showed evidence for any saturation in the Cerro Toledo. Borehole caliper logging indicated significant washout from about 120 ft to 154 ft; the APS measurements suggested numerous washouts from 1496 ft to 1680 ft.	Possible perched water at 598–611, unconfirmed on borehole video. CMR log indicated higher moisture at 610–620 ft. Water samples at 602 ft and 662 ft gave positive result on field HE detection kit (later confirmed as an artifact).
Screen 2 (785–806)	Contact of Guaje Pumice Bed and Puye Formation Vitric pumice fall, pumice fragmented in cuttings. Puye Formation – sand and gravel.		Borehole video indicates that coarse cobbles exceeding the 30-cm borehole diameter are present. CMR log indicated highest vadose zone water content at 790-800 ft, in lower Guaje Pumice Bed.
Screen 3 (944–945)	Cerros del Rio dacite (963–980) and basalt (980–1012). (Puye Formation 800–963: sand and gravel. Borehole video indicates that coarse cobbles exceeding the 30-cm borehole diameter are present.)		Borehole video indicates flow-top rubble from 963 to 966 and massive from 966 to 987 and perched water at 960–990. Approx 10% free-fluid porosity 968–984.
Screen 4 (1212–1287)	Puye Formation (Tpf) Fanglomerate 1207–1232: Medium to fine sand. 1232–1262: Gravel and coarse sand. 1262–1272: Medium to fine sand. 1272–1282: Gravel and coarse sand. 1282–1317: Medium to fine sand.		Borehole video indicates coarsest cobbles are approx 10 cm in diameter. Borehole video indicates washouts and possible perched water at 1242–1249. High-K zone at 1260–1266.
Screen 5 (1321–1349)	Puye Formation (Tpf) Fanglomerate 1317–1367: Gravel and coarse sand.		Borehole caliper logs indicate numerous washouts from 1496 to 1680. Borehole video indicates washouts. High-K zone at 1337–1347.
Screen 6 (1604–1649)	Pumiceous unit (Tpp) 1562–1612: Gravel. 1612–1622: Gravel with coarse sand and pumice. 1622–1647: Gravel and coarse sand with vitric pumice.		Higher porosity below 1518 corresponding to gravel zones within the Puye. Numerous washouts from 1496 to1680.

Note: The data shown in this table were taken from (Kopp et al. 2002, 073179). Also see (LANL 2005, 091121).

APS = Accelerator porosity probe, CMR = combinable magnetic resonance, TLD = triple lithodensity, GPIT = general purpose inclinometer tool, GR = gross gamma-ray tool, HE = high explosives, HNGS = hostile environment gamma-ray sonde, K = hydraulic conductivity, TD = total depth, 3-D = 3 dimensional.

CdV-R-37-2, Geology and Geophysics of Screened Interval			
CdV-R-37-2 Screen (Sand Interval ft bgs)	**Lithology at Screen Interval**	**General Geophysical Interpretation (depths in ft bgs)**	**Geophysical Indication of Screened Interval (depths in ft bgs)**
Screen 1 (904.2–943.8) Dry	Puye Formation (Tpf) 902–922: Gravel (GW) broken to subrounded clasts. 922-–942: Gravel (GW) mainly angular clasts. 942–947: Gravel with sand (GW).	The following important results can be seen from the processed geophysical logs: 1. The depth of the regional aquifer water table appears to coincide with the water level in the well at the time of logging (1195 ft), based on the integrated log analysis results. In CdV-R-37-2, the processed geophysical log results display a distinct boundary at 1195 ft between mostly saturated and unsaturated conditions, as detected by the combination of the logs. 2. The formation in the bottom section of the well (1365–1665 ft) has high total and effective porosity, averaging 35%–40%, indicating very high groundwater flow capacity. The formation appears to be highly heterogeneous: very fractured and fragmented, with sharp vertical changes in mineralogy and porosity. The inferred mineralogy is rich in plagioclase and quartz, with significant amounts of heavy mafic minerals, likely of volcanic origin (e.g., a dacitic flow deposit). 3. The interval of 1075–1365 ft has lower porosity, in general (as low as 5%), than the bottom zone, although it is also highly heterogeneous and has zones with porosity greater than 40%. The inferred mineralogy is similar to the zone below but contains a consistently higher amount of heavy mafic minerals. 4. The interval of 895–1075 ft appears to be clay-rich, containing zones with as much as 50% clay volume fraction. Total and water-filled porosity average about 20% and 10%, respectively. Inferred mineralogy is similar to the zone below, other than the presence of montmorillonite and possibly silica glass, which replaces much of the quartz. 5. The start (in the upward direction) of the volcanic tuff/pumice sequence is clearly distinguished on the logs at 895 ft, including a marked increase in thorium, potassium, and uranium. As seen in most of the Los Alamos characterization and monitoring wells drilled to date, the tuff/pumice sequence is directly underlain by a thin clay layer. 6. Bed boundaries between 1195 ft and 1655 ft have a wide range of dip azimuths (direction beds are dipping to), but a predominant amount are in the sector 40–180 degrees (the mean is 111 degrees). Fractures from this interval have a similar range of dip azimuths, but the majority dip between 130 and 210 degrees (the mean is 176 degrees), with lesser numbers in the sectors 90–100 degrees and 30–70 degrees. Both bed boundaries and fractures dip quite steeply, with mean dip angles of 15 and 33 degrees, respectively, but both have a large spread of dip angles. Throughout this interval, the electrical resistivity image shows highly fragmented beds, with large chunks of broken rock visible, and zones with extensive fracturing.	875–1075: Appears to be relatively clay-rich, containing zones with as much as 50% modeled clay volume fraction. Volume of clay 20%–40% in 940–947 and 913–922 ft bgs intervals. 900-1074: Total porosity drops to 10–20% average. Water content rises to 15%–20% coincident with high clay content intervals.
Screen 2 (1179.6–1221)	Tschicoma Formation (Tt) 1162–1192: Dacite with local hydrothermal alterations. 1192–1207: Dacite 1207–1214: Dacite/Clastic sediments; broken to subrounded clasts of tuffaceous siltstone. 1214–1229: Dacite plus fragments of tuffaceous siltstone.		Depth of regional aquifer coincides with the water level at time of logging (1196.7 ft bgs). 1075–1365: Has lower porosity than the bottom zone, although it is also highly heterogeneous and contains some zones whose porosity is >40%. 1074–1278: Total and water-filled porosity increase swiftly to 28% at 1195. Above 1195, water-filled porosity drops to 10%–15%, total porosity stays at 25%–35%.
Screen 3 (1343–1382)	Tschicoma Formation (Tt) 1324–1364: Dacite, possibly fractured or brecciated. 1364–1379: Dacite, broken fragments and subrounded clasts. 1379–1389: Dacite/Clastic sediments, broken to subrounded clasts 5%–10% waxy clay.		1278-1330: Total and water-filled porosity decrease to <10% at 1220 but reach >35% in short intervals.
Screen 4 (1539.7–1560.7)	Tschicoma Formation (Tt) 1529–1564: Dacite, groundmass locally bleached, sericitized, or pitted corroded.		1365–1665: Has high total and effective porosity, averaging 35%–40%, indicating very high groundwater flow capacity. Total and water-filled porosities average 35%–40% but vary between 10%–60%.

Note: The data shown in this table were taken from (Kopp et al. 2003, 088803). Also see (LANL 2005, 091121).

R-5, Geology and Geophysics of Screened Interval

R-5 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (316.5-338.0) (Dry)	Lower Puye 312–317: Gravel (GW) with sand. 317–327: Gravel (GW) with sand. 327–332: Silty gravel (GM) with sand. First appearance of Precambrian (PreC) lithologies denotes stratigraphic top of axial river gravels of Puye Formation. 332-342: Silty gravel. (GM) with sand.	Open portion of the borehole at time of Schlumberger logging 850–898 ft bgs Above 534 ft the estimated water saturation is consistently below 50%, indicating that there are no significant perched water zones above this depth and the regional aquifer groundwater level lies below. The water level in the borehole, both inside and outside the free-standing casing, was 711 ft at the time the geophysical logs were acquired. The estimated water saturation is 100% or quite high through much of the section below this depth. However, there are also zones showing full saturation above 711 ft and below 534 ft. These results, interpreted independent of other data sources, suggest that the regional aquifer groundwater level may lie at 711 ft or that there could be saturated conditions as high as 534 ft. The highest water-filled porosities are near the bottom of the log interval from 711 to 850 ft, varying from about 25% to 45%, with the highest values at the top and bottom of the zone. The lowest water-filled porosities (5%–10%) are at the top of the log interval (39–120 ft) and in the zone 560–670 ft. The total and air-filled porosity is high in the top zone and low in the bottom zone. Significant geologic contacts appear to be present at 73 ft, 152 ft, 338 ft, 534 ft, 612 ft, 723 ft, 790 ft, 849 ft, and 860 ft—marked by changes in the lithology/mineralogy of the optimized mineral-fluid model that is estimated from the integrated log analysis. There are zones in the R-5 log interval where the bulk density and total porosity (derived from bulk density) are unreasonably low and high, respectively, for natural geologic formations, indicating the likelihood of problematic standoff. Because of the limited geophysical logging suite acquired in R-5, a quantitative analysis of clay volume could not be performed.	Above 534 ft the estimated water saturation is consistently below 50%, indicating that there are no significant perched water zones above this depth. Extremely high total porosity (100%) and low water content (0%) anomalies in the zones 330–338 ft and 473–482 ft, probably corresponding to large air-filled voids behind the casing.
Screen 2 (364.5–401.0) (Not Productive)	Lower Puye 362–372: Clastic sediments, silty gravel with sand. 372–377: Silty gravel (GM) with sand. 10–15% PreC rounded granite and quartzite clasts. 377–382: Silty gravel with sand, much lower % of PreC clasts than interval above. 382–387: Clayey gravel (GC) with sand. 387–397: Silty gravel with sand. 397–402: Silty gravel (GM) with sand.		Generally constant water content (20%) from 340 to 532 ft.
Screen 3 (666.5–727.0)	Lower Puye 670–675: Clayey sand (SC) F- VC sand. 675–680: Clayey sand (SC) mainly CG sand. 680–685: Sand (SW) with clay and gravel. 685–690: Sand (SW) with clay. 690–695: Clayey sand with gravel. 695–700: Clayey sand (SC). 700–705: Sand (SW) with gravel. 705–715: Gravel (GW) with sand. 715–720: Clayey sand (SC) with gravel. 720–735: Basaltporphyritic, slightly vesicular.		The regional aquifer groundwater level may lie at 711 ft or there could be saturated conditions as high as 534 ft The highest water-filled porosities are near the bottom of the log interval from 711 to 850 ft, varying from about 25% to 45%, with the highest values at the top and bottom of the zone. Low water-filled porosity (5%–10%) in the zone 560–670 ft. 711–726 ft, apparent water content of 30% or greater, the top 8 ft of which likely correspond with a large water-filled void behind the casing. Generally low water content (10%–15%) from 532 to 672 ft. Constant water content of 20% from 672 to 711 ft. Decreasing water content from 90% at 711 ft to 12% at 749 ft likely corresponding to voids behind casing.

R-5, Geology and Geophysics of Screened Interval (continued)			
R-5 Screen (Sand Interval ft bgs)	**Lithology of Interval**	**Geophysical Logging Summary (depths in ft bgs)**	**Geophysical Indication of Screened Interval (depths in ft bgs)**
Screen 4 (851.0–902.0) (Not Productive)	Santa Fe Group Basalt. 850–892: Basalt. 892–897: Gravel (GW) with sand. 897–902: Clayey sand (SC) with gravel.		The highest water-filled porosities are near the bottom of the log interval from 711 ft to 850 ft, varying from about 25% to 45% with the highest values at the top and bottom of the zone. Much lower water content (15%–20%) at the bottom of the log interval (849–866 ft) A quantitative analysis of clay volume could not be performed.

Note: The data shown in this table were taken from (LANL 2003, 080925). Also see (LANL 2005, 091121).

ft bgs = Feet below ground surface.

R-7, Geology and Geophysics of Screened Interval

R-7 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (Dry) (355.6–383.6)	Puye: Pumice-poor fanglomerate. 352–367 Silty to clayey gravel (GM/GC). 367–382: Similar to above (lower % fines?). 382–397: Silty to sandy gravel (GM).	Well water level varied considerably over the course of the geophysical logging, between 865 ft and 899 ft. The depth of the regional aquifer water table is not clear from the logging results due to high moisture content and possible perched water zones, in the vadose zone. As a best guess, the water table was somewhat arbitrarily chosen as 894 ft, based on the integrated log analysis performed and on density log response. Relatively high moisture content above the presumed regional aquifer water table, especially below 734 ft, where total and effective water-filled porosity averages about 20% and between 5% and 10%, respectively. Above 734 ft, total water-filled porosity averages between 7% and 20%, but effective water-filled porosity averages much less than 5%. Estimated water saturation averages about 50% below 675 ft, 30% from 530 to 675 ft, 10% from 420 to 530 ft, and 30 to 50% from 275 to 420 ft. Indication of the presence of clay throughout the logged section (275–1050 ft), with high clay volume fractions (10%–60%) from 318 to 525 ft, moderate clay volumes (5%–30%) in the intervals 525–680 and 940–1050 ft, and low clay volumes (less than 10%) from 680 to 940 ft. Notable spectral natural gamma ray characteristics at 875–915 ft (large uranium peak), 285–325 ft (large thorium and uranium peak), 865 ft and 875 ft (step increase in thorium and potassium, respectively, in the up-hole direction), and 730 ft (step increase in thorium/potassium ratio in the up-hole direction). Bed boundaries between 865 ft and 1054 ft have predominant dip directions between south and north, with most beds dipping between 230–310 degrees (west). More than 90% of these interpreted bed boundaries have dip angles less than 10 degrees. The electrical resistivity image shows thinly laminated beds of alternating clays and sands through this interval.	The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft), remaining, on average, 10% or higher from 260 to 734 ft. Water-filled porosity increases from a low (less than 10% between 450 and 530 ft) to 20% at the top of the logged section at 260 ft. There is low effective water-filled porosity (less than 5%) above 697 ft. The hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 360–362, 344–347, and 336–338 ft. The estimated water saturation of close to or greater than 50% (above the picked regional groundwater table of 894 ft) in the intervals 356–358 ft and 331–337 ft (the high saturation at the top of the logged section is an artifact of the ELAN processing, not considered valid).
Screen 2 (Dry) (725–754)	Puye: Pumice-poor fanglomerate 717–737: Sandy gravel (GW). 737–742: Silty sandy gravel (GM). 742–767: Sandy gravel (GW).		The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft), remaining, on average, near 20% from 900 ft to 734 ft and 10% or higher from 734 to 260 ft. The highest water-filled porosity is at the bottom of the borehole (30%–40%) and decreases slowly going up the borehole to the lowest values in the interval 450 to 530 ft (less than 10%). Above 890 ft the effective water-filled porosity is close to or greater than 10% in the intervals 735–740 ft and 697–699 ft. Hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 747–816 ft and 734–740 ft. The estimated water saturation is close to or greater than 50% (above the picked regional groundwater table of 894 ft) in the intervals 746–825 ft and 722–731 ft.
Screen 3 (880–946)	Puye: Pumiceous Fanglomerate 862–887: Sand (SW) 887–892: Sand (SP) 892–912: Sandy gravel (GW) 912–927: Sandy gravel (GW) 927–937: Sandy gravel (GW) 937–952: Sandy gravel (GW)		The depth of the regional groundwater table is very difficult to determine with the log results alone. The depth of the water table was chosen somewhat arbitrarily as 894 ft in the ELAN log processing, based on performing the ELAN analysis with water only (no air) and seeing at what depth there start to be major departures between the modeled and measured log responses (especially density). The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft), remaining, on average, near 20% from 900 ft to 734 ft and 10% or higher from 734 ft to 260 ft. The highest water-filled porosity is at the bottom of the borehole (30%–40%) and decreases slowly going up the borehole to the lowest values in the interval 450 ft to 530 ft (less than 10%). The highest effective water-filled porosity is below 890 ft (10%–20% or higher). The hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 1017–1040, 998–1008, 948–992, 930–940, 904–913, 900–902, 892–894, and 860–879 ft. The estimated water saturation is close to or greater than 50% (above the picked regional groundwater table of 894 ft) in the interval 833–900 ft.

Note: The data shown in this table were taken from (Stone et al. 2002, 072717). Also see (LANL 2005, 091121) .

ft bgs = Feet below ground surface, ELAN = elemental log analysis program.

R-8, Geology and Geophysics of Screened Intervals

R-8 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (687.4–796.8)	Lower Puye (Tpf) 682–762: Alternating sequences of clayey gravels (GC), clayey sands (SC), gravels (GW), gravels with sand and clay. Expansive clay at 706.	Schlumberger logs run in (abandoned) BH1 to a depth of about 764 ft bgs. 1. A significant shift in water content at 642 ft (decreasing from 25% to 30% below to 10%–15% above) and a corresponding significant decrease in water saturation from near-full saturation below to well-below-full saturation above. These results, interpreted independently of other data sources, suggest that this depth may correspond to the regional aquifer groundwater level or the top of a thick perched zone, although the results could be an artifact of borehole conditions behind the casing. 2. The highest water-filled porosities are at the bottom and top of the well, averaging 25%–30% from 642 to 750 and 30 to 96 ft. The bottom interval could be in the regional aquifer or a thick perched zone (see above point) and the top interval is likely within a volcanic tuff/pumice sequence. The processed logs indicate the top interval is not even close to full water saturation as a result of very high total porosity, characteristic of the Los Alamos tuffs. 3. The lowest water-filled porosities are in the zone 100–175 ft, averaging 5%–10%. This zone also has very high air-filled porosity, possibly elevated because of a large air-filled annulus behind the casing. Directly above is a large thorium peak and high water content (see point 2 above), possibly indicative of a clay-rich layer that corresponds to a permeability barrier (note that clay does not show in the integrated log analysis results at this depth due to required model constraints). 4. A significant geologic contact exists at 92 ft, marked by a significant increase (in the upward direction) in thorium, uranium, thorium/potassium ratio, and water content. The inferred mineralogy changes from the section below by a reduction in heavy mafic minerals, augite, and plagioclase feldspar, and a large increase in hornblende. This interval likely corresponds to the presence of volcanic tuff or pumice deposits, based on similar log response in other wells. 5. A distinct geologic/lithologic zone exists from 186 to 367 ft, marked by a decrease in potassium and silicon and an increase in iron and titanium. The inferred mineralogy contains a relatively large amount of heavy iron-bearing mafic minerals and augite and minimal amounts of hypersthene, likely corresponding to a massive basalt flow.	Schlumberger logs run in (abandoned) BH1 to a depth of about 764 ft bgs. There are zones in the R-8 log interval where the bulk density and total porosity (derived from bulk density) are unreasonably low and high, respectively, for natural geologic formations, indicating the likelihood of problematic standoff. Intervals where density porosity is above 60% and/or bulk density is below 1.5 g/cc include (from bottom to top): 740–746, 632–640, 597–607, 496–512, 210–287, and 63–173 ft. In these intervals the bulk density measurement may not be representative of true formation bulk density and, consequently, the total porosity estimate may not be valid due to fluid- or air-filled annulus behind casing. The processed log results do indicate a significant shift in water content at 642 ft from 10% to15% above to 25%–30% below, and a corresponding significant increase in water saturation from well-below-full saturation above to near-full saturation below. These results, interpreted by themselves, suggest that this depth may correspond to the regional aquifer groundwater level or the top of a thick perched zone, although the results could be an artifact of borehole conditions behind the casing. R-8 porosity summary log shows zones with apparent water content of 30% or greater by volume at 42–86 ft and 362–366 ft. The R-8 porosity log shows an extremely high total porosity (95%) and low water content (0%) anomaly in the zone 740–746 ft, probably corresponding to a large air-filled void behind the casing and a similar, less severe high total porosity (70%) and low water content (10%) anomaly in the zone 632–640 ft, probably corresponding to a large void behind the casing. The spectral gamma ray log shows a large U peak (maximum 7.1 ppm) in the 630–644 ft interval. Th and K increase slightly from 628 to 634 ft. The interval coincides with a very large porosity spike (ELAN total porosity reaching greater than 70%), likely a large washout behind the casing, and it is possible U-rich bentonite drilling mud is present in the washout.
Screen 2 (821.3–832.4)	Lower Puye (Tpf) 807–827: Sand (SW) with silt and gravel. 827–832: Sand (SW) with gravel and silt.		

Note: The data shown in this table were taken from (LANL 2003, 079594). Also see (LANL 2005, 091121).

BH = Borehole, ELAN = elemental log analysis program.

R-9i, Geology and Geophysics of Screened Interval

R-9i Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (185.5–200.7)	Cerros del Rio basalt; upper alkalic basalt 180–206: Scoriaceous olivine basalt, approximately 20% vesicles range from 5 mm to 3 cm; some have clay coatings or infillings.	No logging performed.	No logging performed.
Screen 2 (266.4–282.1)	Cerros del Rio basalt; lower alkalic basalt 245–274: Very fine-grained olivine basalt, microfractured to the size of coarse sand rare clay. 274–282: Vesicular olivine basalt, clay aggregates >1 cm with rounded basaltic fragments several cm in diameter. This zone appears to mark a flow base.		

Note: The data shown in this table were taken from (Broxton et al. 2001, 071251). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).

ft bgs = Feet below ground surface.

R-12, Geology and Geophysics of Screened Interval

R-12 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 453–481	Lower alkalic basalt of the Cerros del Rio Volcanic Field 450–488.2: Saturated, massive basalt. Slightly vesicular near base, with some calcite infilling. Fractured, based on drilling performance. Water encountered at 443, static at 424. Probably in hydraulic communication with groundwater in underlying perched zone.	Note: This well was logged using a color video camera, NGR and caliper tools. The Cerros del Rio basalt has a significantly lower NGR than the overlying Otowi Member (102–112 ft). The NGR for the basalt from 136 to 280 ft was uniform at 15 cps. The NGR remains low and uniform throughout the thickness of the basalt. Below the basalt, the NGR count rate gradually increases from 15 cps in the old alluvium (at 492 ft) to values of 74 cps at depths of 600–670 ft in the Puye Formation. Caliper measurements were made on the inside of the drill casing to inspect for the presence of clay-rich cutting buildup, which might cause anomalous NGR readings. The caliper shows that a buildup only occurred at a depth greater than 645 ft and any impact on the NGR was limited to 645–660 ft.	Only video, natural gamma, and caliper measurements were made.
Screen 2 495–522	Older alluvium 495–509: Sandy gravel. 509–519.1: Fine to medium sand; silt and clay rich. 519.1–535.5: Micaceous claystone. Dry below 520 ft. Some zones contain fine sand. 519: Claystone subunit of old alluvium forms perching layer. Probably in hydraulic communication with groundwater in overlying basalts.		Only video, natural gamma, and caliper measurements were made.
Screen 3 793–856	Santa Fe Group basalt 784–803: Slightly scoriaceous, coarse-grained basalt with very irregular vesicles to 1 mm. Saturated zone encountered at 804 ft. 830–866: Slightly vesicular, coarse-grained basalt with round to slightly elongate vesicles to 6 mm, some with white clay coatings.		Only video, natural gamma, and caliper measurements were made.

Note: The data shown in this table were taken from (Broxton et al. 2001, 071252). Also see (LANL 2005, 091121).

ft bgs = Feet below ground surface, NGR = natural gamma radiation.

R-14, Geology and Geophysics of Screened Interval

R-14 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (1196.8–1240.2)	Puye Formation (Tpf) lower section 1185–1210: Volcaniclastic sediments: Silty sands (SW) and silty sand (SM). Pumiceous Fanglomerates. 1210–1245: Clastic sediments: Silty sand (SM), sand (SW) with clay, clayey sand (SC).	Schlumberger logs only run from 12.2 ft to approximately 1070 ft. Only Laboratory video and natural gamma tools run to TD (1327 ft). The inferred water saturation remains below 75% through most of the logged section, with no significant fully saturated intervals. These results, interpreted independently of other data sources, suggest that the regional aquifer groundwater level lies somewhere below the bottom of the log interval (1063 ft) and that there are no significant perched water zones within the logged section. Water-filled porosity is less than 20% through most of the logged section, ranging from a low of 3% to a high of 31%. The highest water-filled porosities (greater than 20%) occur in the zones 524–534 ft, 975–1000 ft, 1024–1030 ft, and 1062–1066 ft, which also have high total (air plus water) porosity. Effective water-filled porosity (moveable water) is less than 3% through most of the logged section (averaging less than 1%), ranging from a low of 0% to a high of 26%. Correspondingly, the inferred hydraulic conductivity is generally very low. The highest effective water-filled porosities (greater than 2%) occur in the zones 212–240, 520–534, 584–588, 597–602, 607–620, and 771–783 ft; the top two intervals are likely within the Bandelier Tuff sequence (the second likely corresponding to the Guaje Pumice Bed) and from the integrated log analysis, appear to be directly underlain by clays, which possibly act as inhibitors to downward flow. As would be expected, inferred hydraulic conductivity is highest in these zones, although it is also high (relative to other intervals) in the zones 975–1000 ft and 1062–1066 ft, which have high total water-filled porosity. The integrated log analysis shows a dense, low total porosity (less than 10%) and mafic-mineral rich zone from 623 to 767 ft that likely corresponds to a massive basalt and is surrounded by zones with similar mineral content but higher porosity that are likely composed of fractured basalt. Toward the bottom of the log interval the amount of heavy mafic minerals decreases, replaced by small amounts of hornblende but otherwise the inferred mineral composition remains relatively constant. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (10–534 ft) is clearly distinguished by the logs. The borehole was largely washed out throughout the log interval, the diameter ranging from 17 to 22 in. compared with a 16-in. bit size. However, the washouts were no worse than most other Los Alamos wells and the borehole rugosity was less.	n/a. This section of well was not logged.
Screen 2 (1281.0–1299.0)	Puye Formation (Tpf) Lower section 1265–1290: Lost circulation, no cuttings. 1290–1300: Sand (SW) with silt. Pumiceous.		n/a. This section of well was not logged.

Note: The data shown in this table were taken from (LANL 2003, 076062). Also see (LANL 2005, 091121).

ft bgs = Feet below ground surface, n/a = not applicable, TD = total depth.

R-16, Geology and Geophysics of Screened Interval			
R-16 Well Screens (Sand interval ft bgs)	**Lithology at Screen Interval**	**General Geophysical Interpretation (depths in ft bgs)**	**Geophysical Indication of Screened Intervals (depths in ft bgs)**
Screen 1 (634.5–653.4)	n/a	The estimated water saturation (fraction of pore space filled with water) remains high through most of the logged section, never dropping below 50% of total pore volume. These processed log results, interpreted by themselves, suggest that the entire interval from 311 to 1285 ft may lie within the regional aquifer, below the water table, although the results could be an artifact of borehole conditions behind the casing within the cased hole section. No information about the water content or the water table above the well water level can be inferred from the geophysical logs; it is possible the well water level at the time of the logging (311 ft) corresponds to the water table. In the open-hole log interval (731–1285 ft) water content and total porosity averages around 32% of total volume, varying between 20% and 70%; the highest water content and total porosity occurring just below the bottom of the casing from 731 to 788 ft bgs, ranging predominantly 40%–70%, but the measured porosity could be elevated because of significant washouts in this interval. In the cased hole log interval (146–731 ft) there are many zones with unrealistically high estimated water content and total porosity (greater than 50%), likely caused by washouts behind casing. The integrated log analysis indicates highly heterogeneous mineralogy across the open-hole log interval (731–1285 ft) but an overall high silica content (quartz and silica glass) as high as 70% dry weight fraction. The inferred mineralogy includes significant, highly variable amounts of montmorillonite clay (0%–70% by volume) throughout this interval. The processed logs indicate the geologic formation across this interval consists of a thinly bedded sequence of silica-clastic sediments with highly variably grain size (alternating clay to sand/gravel beds). In the cased hole log interval an accurate estimate of the mineralogy from the processed logs is not possible due to the limited number of valid log measurements. Interpreted bed boundaries across the imaged interval 768–1290 ft have dip azimuths (direction beds are dipping to) predominantly in the sector 230–330 degrees, with the highest concentration falling in the 10 degree range 290–300 degrees. The mean dip azimuth across this interval is 278 degrees. The interpreted bed boundaries have a wide range of dip angles (degrees of dip) from zero to 60 degrees, although more than 80% have dip angles less than 20 degrees and the average dip angle is 6 degrees. No fractures were discernible across this interval. Throughout this interval the electrical resistivity image shows a well-bedded, thinly bedded alternating sand-silt-clay stratigraphy. The borehole was enlarged and/or washed out in the top half of the open-hole log interval (731–975 ft), but it appears only the severe washouts (as large as 19-in. borehole diameter) just below the casing (731–804 ft) caused any possible impact on geophysical log quality. However, washouts were likely present in a number of zones within the cased hole log interval (145–731 ft), causing the log measurements to be heavily influenced by the annular space between the casing and formation. Borehole deviation is measured with the GPIT, run as part of the FMI across the interval 790–1290 ft. The maximum deviation of the borehole across the log interval it was measured (790–1290 ft) is only 2.5 degrees; the azimuth of deviation is to the southeast.	n/a. Screen 1 was isolated behind drive casing.
Screen 2 (852.1–877.5)	Santa Fe Group (Tsf) 852–857: Clayey sand (SC) with gravel. 857–862: No recovery. 862–867: Sand (SW) with clay. 867–1047: No recovery, lost circulation.		Below the bottom of the free-standing casing (731 ft), the processed log results clearly indicate fully saturated conditions throughout most of the open-hole interval. In the open-hole log interval (731–1285 ft) water content and total porosity averages around 32%, varying between 20% and 70%. The processed logs indicate the geologic formation across this interval consists of a thinly bedded sequence of silica-clastic sediments with highly variably grain size (clay to sand/gravel beds) and bed dip magnitudes.
Screen 3 (1006.7–1028.5)	Santa Fe Group (Tsf) 867–1047: No recovery, lost circulation.		
Screen 4 (1211.7–1287)	Santa Fe Group (Tsf) 1207–1287: Clastic sediments, sand (SW) with clay and gravel, clayey sands (SC), gravel (GW) with clay and sand near TD.		

Note: The data shown in this table were taken from (LANL 2003, 076061). Also see (LANL 2005, 091121).

ft bgs = Feet below ground surface, GPIT = general purpose inclinometry tool, n/a = not applicable, TD = total depth.

R-19, Geology and Geophysics of Screened Interval

R-19 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (802.2–858.6)	Otowi Member of the Bandelier Tuff 603–830. Puye Formation, upper fanglomerate 840–925.	In general, the formation containing the greatest amount of porosity as shown by the density porosity is the Guaje Pumice Bed from 808 ft to 840 ft. The formation containing the least porosity is the massive Cerros del Rio basalt unit from 925 ft to 1000 ft. Formations containing the highest amount of permeability are the Guaje Pumice Bed (808–840 ft) and the lower Puye Formation (1178–1902 ft). Notable porosity zones are as follows: <u>830- to 840-ft interval</u> This interval from about 830 ft to 840 ft within the Guaje Pumice Bed exhibits a lower formation density than the overlying Otowi Member and an elevated density porosity up to 20%. The CMR log data indicate total porosity up to 40% in this interval, a free fluid porosity of up to 28%, and a calculated permeability up to 1000 md. However, flowing water was not encountered in this zone and the increased moisture content may be unsaturated moisture contained within the formation, which may have been introduced during drilling. The deep resistivity curves show higher resistivity and separation from the shallow curves from 834 to 838 ft, which indicates some near-borehole formational changes possibly caused by drilling. <u>896- to 912-ft interval</u> A 16-ft interval from 896 ft to 912 ft in the upper Puye Formation above the Cerros del Rio basalt also exhibits higher porosity values. The density porosity ranges from 30% to 60%. The relative neutron moisture content increases by a factor of about 3 compared with the adjacent zones within the Puye Formation. The open-hole video log shows an increase in moisture on the walls of the borehole between 900 ft and 910 ft. The total CMR porosity increases from an average in the formation of 6% to 20%, with a high of about 35%. The calculated permeability from 906 ft to 910 ft is from 1 to 10 md. Below 912 ft the porosity curves return to 4% to 6% with no detectable calculated permeability. The CMR pore-water data show that the majority of the water in this interval is bound to fine-grained sediments, small-pore, micro-pore, and clay-bound. <u>998- to 1030-ft interval</u> A 32-ft interval corresponds to the zone of volcaniclastic sediments between two massive basalt flows in the Cerros del Rio basalt. The red scoria zone from 1018 ft to 1030 ft is differentiated from the breccia zone above by a higher gamma value of 140 API units compared with about 100 API units in the breccia zone. The lower part of the breccia zone from 1006 ft to 1018 ft contains density porosity of 50% to 60% and corresponding CMR total porosity of 17% to 25%. The scoria zone contains density porosity of 20% to 30% and CMR total porosity of 10% to 20%. However, the CMR free-fluid porosity in the breccia zone is about 5%, which increases up to 15% in the scoria zone. The neutron log indicates some level of elevated moisture content in the breccia zone, which decreases downward in the scoria zone. The CMR log shows limited permeability in the breccia zone but permeability ranging from 1 to 10 md in the scoria zone. The CMR bound water data indicate that moisture in this zone is primarily bound up in clay-sized pores.	830–840: Elevated density porosity up to 20%. The CMR log indicates total porosity up to 40%, a free-fluid porosity of up to 28% and a K of up to 1000 md. Driller noticed water returning with cuttings at 837 ft.
Screen 2 (868.3–926.0)	Puye Formation, upper fanglomerate 840–925.		896–912: Density porosity ranges from 30% to 60%. The video log shows increased moisture on walls between 900 and 910 ft bgs. The CMR porosity increases from an average of 6 up to 205 with a high of 35%. Calculated K for 906–910 ft ranges from 1 to 10 md. The gamma log indicates a change to finer-grained materials. CMR pore water data indicates majority of water in this interval is bound to fine-grained sediments.
Screen 3 (1149.8–1240.5)	Puye Formation, lower fanglomerate facies 1080–1530. Washout zone: 1194–1197.		1178–1550: Upper part of regional aquifer exhibits 24%–30% porosity on the neutron log and 30–40% on density log. The CMR log indicates porosity of about 20% with 2–8% free-fluid porosity. However, porosity is generally from smaller pore sizes. The calculated K varies from 1 to 10 md CMR log indicates a high unbound water content zone at 1216–1220 ft.
Screen 4 (1380.0–1445.5)	Puye Formation, lower fanglomerate facies 1080–1530.		Total porosity = 21.7%, calculated K = 1.01 md
Screen 5 (1557.9–1606.8)	Pumiceous sedimentary deposits, unassigned 1530–1902.5.		1530–1900: The neutron log shows average porosities of 35%–40%. The CMR log shows 24%–40% total porosity with an average of 4%–20% free fluid porosity. The calculated K varies generally from 0.1 to 177.8 md, with the highest porosity and permeability zones at 1634–1638 and 1733–1736 ft bgs. Total porosity = 31.6%, calculated K = 178.77 md. The CMR log indicates a modest rise in porosity at 1581–1595 ft.

R-19, Geology and Geophysics of Screened Interval (continued)			
R-19 Well Screen (Sand Interval ft bgs)	**Lithology at Screen Interval**	**Geophysical Logging Summary (depths in ft bgs)**	**Geophysical Indication of Screened Interval (depths in ft bgs)**
Screen 6 (1675.9–1779.8)	Pumiceous sedimentary deposits, unassigned 1530–1902.5. Washout zone: 1774–1778.	<u>1064- to 1072-ft interval</u> This 8-ft interval is present directly beneath the lower massive basalt flow and may represent a basalt breccia zone similar to the breccia zone from 998 to 1018 ft. This zone exhibits increased moisture content on the neutron log, density porosity of 35% to 40%, CMR total porosity of 16% to 20%. However, the CMR log does not indicate the presence of significant free-fluid porosity, nor does the CMR log indicate the presence of significant calculated permeability. There is some separation in the resistivity curve, indicating that the formation contains low permeability. <u>Regional aquifer</u> The water level of the regional aquifer was encountered at 1178 ft at the time of the Schlumberger logging. The neutron moisture and CMR data indicate less than 1 ft of capillary fringe above the water level. The permeability, as interpreted from the geophysical logs, at the top of the water table, is very low (1 to 10 md). <u>1178- to 1530-ft interval</u> The upper part of the regional saturation from 1178 to about 1550 ft exhibits 24% to 30% porosity on the neutron log and 30% to 40% porosity on the density log with the highest porosity zone at 1242 ft to 1246 ft. The total porosity shown on the CMR averages about 20%, with 2% to 8% free-fluid porosity. The porosity through this zone is generally from smaller pore sizes from clay to micro-pore size. Calculated permeability shown on the CMR log varies generally from 1 to 10 md. The resistivity curves track very closely showing the saturated nature of the formation; the only separation is in the deep resistivity in zones of less porosity, where some higher resistivity values are present at deeper distances from the borehole. <u>1530- to 1900-ft interval</u> The deeper part of the regional saturation from 1530 to 1900 ft exhibits higher porosity values than the zone described above. The neutron log shows average porosity values of approximately 35% to 40% and the density log shows 40% to 50% average porosity. The CMR log shows 24% to 40% total porosity, with an average of 4% to 20% free-fluid porosity. Average calculated permeability shown on the CMR log varies generally from 0.1 to 177.8 md, with the highest porosity and permeability zones at 1634 ft to 1638 ft and 1733 ft to 1736 ft. The resistivity curves track very close to showing the saturated nature of the formation; the only separation is in the deep resistivity in zones of less porosity, where some higher resistivity values are present. This lower zone appears to be a more transmissive part of the regional aquifer in R-19.	Total porosity = 34.9%, calculated K = 131.79 md. The CMR log indicates a significant rise in pore-held water from 1730 to 1740 ft.
Screen 7 1828.2–1848.2)	Pumiceous sedimentary deposits, unassigned 1530–1902.5.		Total porosity = 34.3%, calculated K = 92.68 md. CMR log indicates a moderately high pore-water content in a broad zone from 1815 to 1845 ft.

Note: The data shown in this table were taken from (Broxton et al. 2001, 071254). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).

CMR = Combinable magnetic resonance, ft bgs = feet below ground surface, K = hydraulic conductivity, md = millidarcy.

R-20, Geology and Geophysics of Screened Interval

R-20 Screen (Sand interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (895.2–926.5)	Cerros del Rio Basalt (Tb 4) Scoria/sediments, scoria (altered and bleached). 915–920: No recovery.	A significant shift in water saturation occurs at 755 ft; the location of the borehole fluid level at the time of the logging. However, another large shift in the water content occurs at 827 ft, decreasing from 15% to 50% below to 5%–15% above, with a corresponding equivalent decrease in total porosity associated with a significant lithology change. The low porosity formation above 827 ft has low hydraulic conductivity and thus is not an aquifer. These processed geophysical log results, interpreted by themselves, suggest that the top of the regional groundwater aquifer likely is 827 ft, with the tight bed above acting as a confining layer. It is possible the confining layer is saturated up to the depth of 755 ft. The measured near wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft and is less than 20% and predominantly below 10% through most of the interval 46–828 ft. In the upper interval there are two major zones where the water content is elevated compared with surrounding zones: 132–286 and 398–546 ft, reaching 20% and 30% total rock volume fraction (matrix plus pore space), respectively. The highest water-filled porosities (greater than 30%) occur in the major zones 858–877 ft, 1086–1089 ft, and 1136–1244 ft. Effective water-filled porosity (moveable water) is generally 5% or less through most of the logged section, ranging from a low of 0% to a high of 26%. Correspondingly, the estimated hydraulic conductivity is generally low. The highest effective water-filled porosities (greater than 10%) occur in the zones 1086–1090 and 1127–1240 ft, with a peak of 26% of total volume at 1194 ft. The integrated log analysis shows a mafic-mineral-rich and quartz/silica-glass deficient interval from 393 to 924 ft that likely corresponds to a basalt lava flow sequence. The interval 397–630 ft has very high matrix grain density (2.8–3.1 g/cc) and significant heavy mafic mineral content (10%–22% dry weight fraction) but widely varying total (air and water-filled) porosity ranging from 11% to 55% volume fraction. The high-porosity zones must be highly fractured and broken up (e.g., volcanic breccias), highly vesicular, or of .aa-texture. The remaining sections of the logged section contain a significant amount of quartz/silica glass. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (54–390 ft) is clearly distinguished by the logs and is characterized by • very high total porosity (60%) in the bottom 15 ft (275–390 ft), which likely corresponds to the Guaje Pumice Bed; • lower, but still high, porosity (50%–55%) in the uphole direction from 172–275 ft; • a distinct drop in the gross gamma log and bulk density across the zone 158–172 ft, for which the integrated log analysis shows decreased total porosity (average 35%) and increased amounts of clay, likely corresponding to a formation/lithology change; and • very high total porosity (48%–60%) across the interval 54–158 ft.	These processed geophysical log results suggest that the top of the regional groundwater aquifer intersected by R-20 likely is 827 ft, with the tight bed above acting as a confining layer. It is possible the confining layer is saturated up to the depth of 755 ft or that 755 ft is the potentiometric head of the regional aquifer (the static water level in the well). Zones with apparent water content of 30% or greater by volume occur at 884–886 ft and 983–987 ft. The measured near-wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The highest water-filled porosities (greater than 30%) occur in the major zones 858–877 ft, 1086–1089 ft, and 1136–1244 ft. Effective water-filled porosity (moveable water) is generally 5% or less through most of the logged section, ranging from a low of 0% to a high of 26%. Correspondingly, the estimated hydraulic conductivity is generally low. Pe is consistently above 3 from 392 to 924 ft and mostly above 4 (often 5 or above) from 400 to 830 ft. The dense upper section 397–630 ft is probably basalt lava flow material. The lower interval, 630–924 ft, also likely comprises basaltic rock, although with a lower heavy mafic mineral content. The ELAN analysis predicts variable amounts of clay/montmorillonite throughout most of the logged section. Above 975 ft there are a few zones with clay content above 20%, but most of the logged interval contains 15% or less, with many zones containing no clay.

R-20, Geology and Geophysics of Screened Interval (continued)

R-20 Screen (Sand interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 2 (1132.5–1165.5)	Top of pumiceous Puye Formation (Tpp). Fanglomerate. volcaniclastic sediments, mainly clayey sand (SC) with gravel and clayey sand (SC).	The integrated log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%. Above 975 ft there are a few zones with clay content above 20%, but most of the logged interval contains 15% or less, with many zones containing no clay. Interpreted bed boundaries across the imaged interval 777–1370 ft have dip azimuths (direction beds are dipping to) predominantly in the sector 180–260 degrees, with the highest concentration falling in the 10-degree range 210–220 degrees. The mean dip azimuth across this interval is 226 degrees. The interpreted bed boundaries have a wide range of dip angles (degrees of dip) from zero to 60 degrees, although more than 90% have dip angles less than 20 degrees and the mean dip angle is 6 degrees. A number of fractures were discernible across this interval, having dip azimuths mostly in the sector 170–220 degrees and a mean dip azimuth of 192 degrees. The fracture dip angles ranged 20–90 degrees, with a mean of 47 degrees. Across much of the imaged interval (928–1370 ft) the electrical resistivity image shows a well-bedded, thinly bedded alternating gravel-sand-silt-clay stratigraphy. Above this, the image exhibits much more massive bedding, likely corresponding to basalt lavas. A significant portion of the borehole was washed out in the top half of the log interval (46–775 ft), the diameter ranging from 17 in. (the bit size) to 25 in. The bottom half of the logged interval (775–1370 ft) contains only one interval of significant washouts (826–876 ft). Some of the washouts are abrupt, possibly cavities. The shallow-reading log measurements, predominantly the porosity reading ones, were adversely affected in a relatively few zones that contained abrupt washouts and/or high hole rugosity. The maximum deviation of the borehole across the log interval measured (777–1370 ft) is 3.5 degrees; the azimuth of deviation is to the north-northeast.	The measured near wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The highest effective (moveable) water-filled porosities (greater than 10%) occur in the zones 1086–1090 and 1127–1240 ft, with a peak of 26% of total volume at 1194 ft. The ELAN log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%.
Screen 3 (1320.6–1344.5)	Santa Fe Group (Tsf) Volcaniclastic sediments, sand (SW) with clay.		The measured near-wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The ELAN log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%.

Note: The data shown in this table were taken from (LANL 2003, 079600). Also see (LANL 2005, 091121).

ELAN = Elemental log analysis program, ft bgs = feet below ground surface, Pe = photoelectric effect (a measure of porosity).

R-22, Geology and Geophysics of Screened Interval			
R-22 Well Screen (Sand Interval ft bgs)	**Lithology at Screen Interval**	**Geophysical Logging Summary (depths in ft bgs)**	**Geophysical Indication of Screened Interval (depths in ft bgs)**
Screen 1 (862.0–922.0)	Cerros del Rio basalt (Tb) 780–893 dark gray, massive, minor vesicles to 1 mm, some red-yellow oxidation. 893–903: No recovery. 903–908: Porphyritic with aphanitic groundmass, massive, rare small vesicles. 908–928: Local fractures with Fe/Mn coatings.	The well had a water level of 955 ft and a probable regional groundwater level of 886 ft at the time of logging (October 2000). Increased vadose zone moisture content in the intervals 50–180 ft (on average 5%) and 350–715 ft (on average 10% or greater). Increased saturated zone porosity (greater than 40%) in the interval 1405–1478 ft (log total depth), corresponding to the Lower Puye Formation. Clearly defined stratigraphic/lithologic boundaries from the spectral gamma and geochemical logs. The analysis predicts clay (montmorillonite) only below the bottom of the Cerros del Rio Formation (1164 ft), primarily within the Upper and Lower Puye Formation. The clay volume (and weight %) within these intervals is generally less than 20%, although there are a few isolated peaks above 40% dry clay volume. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye. The high clay volume/weight % at the bottom of the borehole is an unreal artifact and should be disregarded. Large intervals where density porosity is above 60%, and/or bulk density is below 1.5 g/cc including (from bottom to top) 1263–1285, 1093–1158, 1026–1059, 877–887, 667–867, 523–595, 255–357, and 189–208 ft. Thus, it is apparent that in large sections of the cased hole section of R-22 the bulk density measurement is not representative of formation bulk density and, consequently, the total porosity estimate is not valid due to water- or air-filled annulus.	Very low volumetric moisture content (less than 5%) in the intervals 745–864 ft, and 876–886 ft. Relatively high water saturated porosities (greater than 35%) in the interval 887–901 ft. Elevated total porosity (greater than 60%) in the intervals 716–864 ft, 876–886 ft, probably due to the presence of water- and/or air-filled annulus between the drill string casing and the formation.
Screen 2 (937.5–1007.0)	Cerros del Rio basalt (Tb) As above with Fe or Mn coatings on fractures at 958–963. 970–973: Local fracture surfaces show oxidation ± silica coating.		Relatively high water-saturated porosities (greater than 35%) in the interval 956–962 ft.
Screen 3 (1243.5–1284)	Puye Formation (Tpf) Volcaniclastic sediments: Sand, sands with gravel, and silty sand with gravel.		Relatively high water saturated porosities (greater than 35%) in the interval 1264–1290 ft. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye.
Screen 4 (1368.5–1387.0)	Santa Fe Group basalt Porphyritic, nonvesicular 1382–1392: With 10% clay.		Relatively lower-saturated porosity (averaging about 30%) and elevated chlorinity (averaging about 2 parts-per-thousand) across the “Older Basalt” unit (1337–1406 ft).
Screen 5 (1437–1478.0)	Puye Formation (Tpf) Clastic sediments: Sandy gravel, pebble gravel, sands.		Relatively high water-saturated porosities (greater than 35%) in the interval 1405–1478 ft. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye.

Note: The data shown in this table were taken from (Ball et al. 2002, 071471). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).
ft bgs = Feet below ground surface.

R-25, Geology and Geophysics of Screened Interval

R-25 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (732–762)	Otowi Member of Bandelier Tuff Nonwelded ash-flow tuff. Video log shows subvertical open fractures with maximum apertures of 0.5 in.	Gamma activity is highly variable through the Cerro Toledo interval (384–509 ft). This probably reflects varying proportions of tuff and dacite detritus that make up individual beds in this deposit. The Otowi Member undergoes several distinct step-wise increases in gamma activity as a function of depth. Increases occur at the top of the unit (about 600 ft), at 650 ft, and at 725 ft. A significant decrease occurs at 790 ft and is coincident with faint horizontal layer observed in the video log and may represent a depositional break within the Otowi Member. The Guaje Pumice Bed exhibits a low gamma spike just above the abrupt gamma decrease associated with the geologic contact with the top of the Puye Formation. The borehole video shows the spike is coincident with lithic-rich beds from 844 to 846 ft. The natural gamma activity in the upper part of the Puye Formation varies little down to a depth of 1180 ft. Gamma activities decrease systematically from 1180 to 1450 ft and then remain constant to about 1655 ft. At 1655 ft, gamma activity increases correspond to the top of the Rendija Canyon fan deposits. Another increase at about 1870 ft may mark the top of the older fan deposits. Neutron logging identified zones of high water content that may indicate bridging in the annual fill (1250–1256, 1398–1404, 1444–1446, 1668–1672 ft). Westbay pressure readings confirmed the isolation of the screens. Logging was unable to delineate bentonite seals due to low potassium content of bentonite product used. Logging indicated an upper groundwater system from 711 to 1132 ft. Alternating wet-dry zones were encountered from 1132 to 1286 ft. Regional aquifer was encountered at 1286 ft.	Borehole video shows an abrupt increase in moisture on the borehole wall at 718 ft. Water first recognized at 747 ft. Video also shows subvertical open fractures, with maximum apertures of 0.5 in. Neutron logging identified zones of high water content that may indicate bridging in the annual fill (1250–1256, 1398–1404, 1444–1446, 1668–1672 ft bgs). Westbay pressure readings indicate confirmed isolation of the screens. Unable to delineate bentonite seals due to low potassium content of bentonite. Saturated 747–1132 ft bgs (Screens 1–3).
Screen 2 (878–897)	Puye Formation fanglomerate Cobbles and boulders derived mainly from the upper dacite of Pajarito Mountain. Minor amounts of sand, some clay present at depth intervals 851–853, 901–903, 997–1002, 1012–1016 and 1022–1026.		
Screen 3 (1046–1070)			
Screen 4 (1180–1191)			Alternating wet and dry zones 1132–1286 ft bgs.
Screen 5 (1290–1307)			Saturated below 1286 ft bgs. (Screens 5–9)
Screen 6 (1398–1415)			
Screen 7 (1600–1618)			
Screen 8 (1786–1805)			
Screen 9 (1862.2–1930)			

Note: The data shown in this table were taken from (Broxton et al. 2002, 072640). Also see (LANL 2005, 089397) and (LANL 2005, 091121).
ft bgs = Feet below ground surface.

R-26, Geology and Geophysics of Screened Interval

R-26 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (620–672)	Cerro Toledo interval (Qct) Volcaniclastic sediments: 615–645: Well-graded fine to very coarse grained sand (SW) with gravel. 645–655: Silty sand (SM) with gravel. 655–660: No returns. 660–680: Well-graded fine to very coarse grained sand (SW) with gravel.	1. The Puye Formation fanglomerate at the bottom of the well (953–1490.5 ft) is likely fully saturated with water throughout. The porosity across this interval is mostly in the range of 20%–30% of the total rock volume, although there are a number of zones with higher porosity. The most porous zones (in which logs are not affected by hole conditions) appear to be 1075–1108 ft and 1186–1200 ft, with porosity mostly ranging 30%–40% and a peak of over 50% at 1102 ft. Both these zones have high moveable water content (effective porosity) of 15%–20% of total rock volume. 2. The high porosity glass/tuff pumice beds and volcaniclastic sediments of the Cerro Toledo interval and Otowi member (472–955 ft) lying above the Puye Formation are likely not fully saturated with water through most of the section, although they have very high water content (30–50% of total rock volume) from 570 to 955 ft. The general trend is an increase in water content with depth – culminating at 52% of total rock volume at the bottom of the Guaje Pumice Bed at 955 ft. The moveable water content is relatively high as well (5%–25% of total rock volume, except 40% at the bottom of the Guaje Pumice Bed). Although much of the glass tuff/pumice interval may not be fully saturated with water, the total and moveable water content suggests that, in general, the water is quite mobile. Likely, water in this interval is connected (in a broad sense) to the saturated Puye Formation below. 3. Three heterogeneous fanglomerate-type beds within the Cerro Toledo interval are clearly delineated by the logs at 505–524, 530–544, and 779–828 ft. These beds have significantly lower porosity (mostly 20%–30% of the total rock volume) than the surrounding sediments (mostly 40%–50% of total rock volume). The processed logs indicate that some zones within these beds may be fully saturated with water–particularly the interval 780–827 ft – but the moveable water content is highly variable and mostly less that 5% of total rock volume. 4. The crystalline tuff beds (60–472 ft) generally have very low porosity (10%–20%) of total rock volume) and water content (5–10%). Some zones within this interval appear to be fully saturate with water, but the low movable water content (5% of total rock volume) likely limits the slow of water. The total porosity above 134 ft appears to be much higher (35–45%). 5. Fractures were identified from the electrical image log (acquired across the interval 390–1390 ft) at 412, 681, 687, 690, 700, 701, 710, 870, 880, 882, 883, 947.5, 950, 952, and 1363.5 ft. All are in the volcanic tuff sequence, except the deepest one is in the Puye Formation. 6. Clay-rich beds occur in the zones 1023–1026, 1051–1053, 1080–1114 ft, 1135–1143 ft, 1171–1177 ft, and 1187–1200 ft.	The processed logs indicate high water-filled porosity within the porous, volcaniclastic sediments and glass tuff/pumice sections of R-26 from 575 to 955 ft – ranging from 30% to 52% of the total rock volume. However, the processed logs indicate quite strongly that most of this interval is no fully saturated with water. The total porosity (estimated from ELAN integrated log analysis) ranges from 40% to over 50% of the total rock volume-resulting in saturations of generally 50–80%. The highest estimated water saturation across this interval of water-rich sediments and glass tuff/pumice occurs in the following zones: 620–640: Water saturation ranges from 85%–90%, due to a decrease in total porosity to 30% to 40%, with water-filled porosity averaging 30%. 642–662: Water saturation reaches over 90% as a result of increased water-filled porosity as high as 42%, due to a decrease in total porosity to 30% to 40%. With water-filled porosity averaging 30%. The estimated moveable water content is generally quite high across this water-rich sediments and glass tuff/pumice interval, ranging from 5% to 25% of total rock volume. Although much of the 575–955-ft interval may not be fully saturated with water, the high total and moveable water content suggests that, in general, the water table is quite mobile. Likely, water in this interval is connected (in a broad sense) to the saturated Puye Formation below.
Screen 2 (1411–1450)	Puye Formation (Tpf) fanglomerates. Volcaniclastic sediments. 1405–1420: Poorly graded very fine-fine grained sand (SP). 1420–1430: Poorly graded very fine-fine sand with silt (SP-SM). 1430—1440 No returns. 1440–1445: Poorly graded very fine-fine sand with silt (SP-SM). 1445–1455: Well graded very fine to medium sand (SW).		The estimated pore volume water saturation computed from ELAN analysis is very high (mostly over 85%) from 954 to the bottom for the log interval (1484 ft). Water-filled and total porosity mostly ranges from 20% to 30% across the interval, although there are a number of zones with elevated porosity. 1422–1452: Elevated porosity of 30%–35% possibly associated with a slight change in lithology (indicated by a drop in potassium content). There is a thin “tight” streak at 1490 ft. Estimated water-filled effective porosity (moveable water) generally varies from 7% to 15% of the total rock volume across this interval. The hydraulic conductivity estimated from ELAN integrated log analysis (largely based on the CMR moveable water measurement) generally ranges from 0.1–1 gal./d/ft^2 in a few zones – most notably 1100–1108 ft and 1186–1200 ft.

Note: The data shown in this table were taken from (Kleinfelder 2005, 087846). Also see (LANL 2005, 091121).
ft bgs = Feet below ground surface CMR = combinable magnetic resonance, ELAN = elemental log analysis program.

R-31, Geology and Geophysics of Screened Interval

R-31 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (432.8–460.6)	Cerros del Rio lavas Clay-rich sediment bed.	R-31 was logged with geophysical tools twice. A precompletion (February 2000) geophysical logging was conducted to provide an in situ evaluation of formation properties (hydrogeology and geology) intersected by the well. The primary objective of the postcompletion logging (March 2000) was to evaluate the integrity of the well completion condition of casing and screens and the placement of bentonite and sand fill behind the casing, as well as the location, behind the inner casing, of a dropped section of drill casing and a lost sounding rod. The precompletion logging (February 2000), which were run through drill casing, appear to be severely influenced by water between the casing and the borehole wall below the well water level – resulting in highly elevated water-filled porosity measurements in many intervals within the saturated portion of the borehole. However, the moisture measurements above the water level and the spectral gammaray measurements throughout the well are generally unaffected by these annular voids. The precompletion log results indicate the following: • A regional groundwater level at 530 ft depth at the time of logging • Increased moisture content around 110 ft and 225 ft • Low moisture content (on average 10% or less) extending from 285 to 530 ft • Increased moisture content and low concentrations of K and Th from 590 to 626 ft, roughly corresponding with the entire “alluvial scoria” stratigraphic interval • Decreased moisture content from 626 to 695 ft, corresponding with most of the lower Cerros del Rio lavas (Tcb-A) The postcompletion logging (March 2000) results indicate the following. • A dropped section of drill casing outside the inner 5¼-in. casing resides at a depth of 882–952 ft, and a dropped copper sounding rod is suspected to reside at a depth of 382.5–391 ft. • At a number of zones, air/water-filled voids are present behind the casing. • Most of the screened intervals appear to contain sand fill and are surrounded above and below by clay-rich fill. • The casing and screens are geometrically intact, with possible slight ovalization in the joints above Screens 3 and 5. The ELAN analysis estimates significant volumes of clay throughout the well – consistently above 20%–30%. It is believed that the high clay volume is largely due to the presence of minerals and glasses of volcanic origin – not included in the ELAN model – that have elevated thorium concentrations and neutron capture cross-sections similar to those of the clay minerals that are included in the ELAN model. Thus, the model is “forced” to increase clay volumes to match the measured response and estimates of clay volume cannot be used in a quantitative manner, only in a qualitative manner (e.g., looking at relative changes.)	Clay-rich sediment occurring at 444 to 450 ft represents a hiatus in volcanic activity. The borehole video indicated accumulation of water above the sediment and flow along the borehole wall.
Screen 2 (496.3–551.3)	Cerros del Rio lavas Basalt: Flow breccia in interval, monitored zone across clay-altered zone contact with flow sequence C and B.		This represents the contact between alkalic-basalt flow sequence C and the basaltic andesites of flow sequence B.
Screen 3 (659.0–677.0)	Cerros del Rio lavas Basalt: Columnar jointed in monitored zone.		Borehole video images show continuous columnar jointing, without evidence of clay infilling. The hydraulic conductivity of approximately 7 ft/day measured in this zone is attributed to fracture connection.
Screen 4 (780.5–842.0)	Puye Formation Totavi river gravels plus fanglomerates.		Neutron-based analyses of water-filled porosity have values of only 30%. Interval is within the river gravels of the Puye Formation.
Screen 5 (873.7–1072.6)	Puye Formation Totavi river gravels plus fanglomerates.		Neutron-based analyses of water-filled porosity have values of approximately 50% for this screened interval. Interval crosses a more variable section of the riverine gravel deposits of the Puye Formation.

Note: The data shown in this table were taken from (Vaniman et al. 2002, 072615). Also see (Stone and McLin 2003, 076003) and (LANL 2005, 091121).

ft bgs = Feet below ground surface, ELAN = elemental log analysis program.

R-32, Geology and Geophysics of Screened Interval			
R-32 Well Screen (Sand Interval ft bgsl)	**Lithology at Screen Interval**	**Geophysical Logging Summary (depths in ft bgs)**	**Geophysical Indication of Screened Interval (depths in ft bgs)**
Screen 1 (862.5–879.2)	Cerros del Rio basalts (Tb4) Basalts, interbedded river gravels and clastic sediments. River gravels interpreted for 863–870.	Note: This well was logged to a depth of about 800 ft. The estimated water saturation (only fraction of pore space filled with water) remains below 75% through most of the logged section with no significant fully saturated intervals. These results, interpreted independently of other data sources, suggest that the regional aquifer groundwater level lies somewhere below the bottom of the log interval (800 ft) and that there are no significant perched water zones within the logged section. The measured near-wellbore water-filled porosity is less than 20% of total formation volume through most of the logged section, ranging from a low of 3% to a high of 40%. The highest water-filled porosities (greater than 20%) occur in the zones 145–149, 276–286, 403–415, 449–480, 646–654, 660–664, and 722–800 ft. The bottom moist zone, which corresponds with the water-filled section of the borehole at the time of the logging, has the highest estimated water saturation of these zones (averaging about 75%). Effective water-filled porosity (moveable water) is less than 3% through most of the logged section, ranging from a low of 0% to a high of 30%. Correspondingly, the estimated hydraulic conductivity is generally very low. The highest effective water-filled porosities (greater than 10%) occur in the zones 145–149, 276–286, and 722–800 ft. The top two zones are likely within the Bandelier Tuff sequence (the second likely corresponding to the Guaje Pumice Bed) and, from the integrated log analysis, appear to be directly underlain by clays that likely inhibit downward flow and cause the accumulation of moisture above. The bottom zone coincides with the water-filled section of the borehole that also contains significant washouts; it is likely that the measured moveable water content is unrepresentative of true formation conditions (reading too high) due to the measuring of water-filled washouts. As would be expected, estimated hydraulic conductivity is highest in these zones, especially in the interval 726–748 ft. The integrated log analysis shows a mafic-mineral rich and quartz/silica glass deficient zone from 290 to 800 ft that likely corresponds to a basalt lava flow sequence. The zone from 290 to 654 ft is very dense (matrix grain density of 2.8–3.0 g/cc) and heavy-mafic-mineral rich with intervals of low total porosity interspersed with a number of fractured and altered zones. The zone from 654 to 800 ft is less dense, contains significant amounts of clay, and has higher porosity—likely highly fractured and altered basalt. The washed out, high-porosity zones in both intervals likely correspond to fractured, broken-up altered zones, possibly “rubble” zones. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (55–286 ft) is clearly distinguished by the logs. The borehole was largely washed out throughout the log interval, the diameter ranging from 16 in. (the bit size) to greater than 20 in. Many of the washouts are abrupt, possibly cavities. The shallow-reading log measurements, predominantly the bulk density, were adversely affected in zones with high rugosity.	Note: This well was logged only to a depth of approximately 800 ft. No specifics are available for the screened intervals.
Screen 2 (925.2–938.7)	Puye Formation (Tpf) No cuttings returned. Contact of basalt with sediments interpreted at 923 ft.		
Screen 3 (961.7–978.2)	Puye Formation (Tpf) No cuttings returned.		

Note: The data shown in this table were taken from (LANL 2003, 079602). Also see (McLin and Stone 2004, 089552) and (LANL 2005, 091121).

ft bgs = Feet below ground surface, CMR = combinable magnetic resonance, Pe = photoelectric effect (a measure of porosity).

R-33, Geology and Geophysics of Screened Interval

R-33 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (991–1027)	Pumiceous Unit, Unassigned, Tpp (964–1122) Volcaniclastic sediments: Silty sands, sands, gravels.	1. The well water level was stable throughout the logging acquisition, remaining between 983 ft bgs and 985 ft during all four logging runs. 2. The processed logs indicate that the intersected geologic section from 984 ft to the bottom of the log interval (1131 ft) is fully saturated with water throughout, possibly representing the top of the regional aquifer. The porosity across this interval is mostly in the range of 35% to 55% of the total rock volume, although it is higher in borehole washouts, which are especially prevalent in the interval 984 ft to 1028 ft. Most of the saturated log interval appears to be porous and, likely, productive. The most porous, potentially productive zone delineated by the logs is 984 to 1028 ft, an inferred pumice-rich zone with over 50% porosity (even after accounting for washouts). Other likely productive (albeit less prolific) zones are 1028 to 1050, 1056 to 1078, 1100 to 1104, and 1106 to 1108 ft. A low-porosity, tight zone appears to exist at 1122 to 1126 ft, although porosity seems to increase again at the bottom of the log interval. 3. The processed logs do not indicate any significant fully water-saturated (perched) zones above 984 ft. Estimated water saturation is mostly below 60%, except in very low porosity basalt zones, where the overall water content is very low anyway. 4. Above the log-inferred groundwater level (984 ft), the processed logs identify a thick section of heterogeneous alluvium/fanglomerate with low estimated water saturation (mostly less than 50% of pore space containing water) – overlain at 730 ft by a basalt lava flow sequence.	The estimated pore-volume water saturation (fraction of the total pore volume containing water) computed from the ELAN analysis is very high (mostly above 90%) from 984 ft to the bottom of the log interval (1131 ft), compared with 40% to 60% in the interval directly above 984 ft. 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-measured/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 model results indicate that the interval does not contain much clay and other fine-grained material, as does the FMI image (overall very high resistivity in the scaled image) – also suggestive of very productive aquifer material. The very high total and effective porosity across this zone are indicative of pumice-rich material.
Screen 2 (1107–1126)	Stream Gravels (1122–1140) Volcaniclastic sediments: Silty sands with trace of gravel.	5. The basalt lava flow sequence intersected by the well (530 ft to 730 ft, as delineated from the logs) primarily consists of dense, low-porosity zones (average about 12% total porosity) but also contains some higher-porosity zones (20 to 30% total porosity) containing slightly higher water content (maximum 12% of total rock volume). The most significant higher-porosity basalt zones are at 530 to 573 and 643 to 665 ft. 6. The geophysical log response in the zone 466 ft to 473 ft is characteristic of the Guaje Pumice Bed, with extremely high total porosity (60%), relatively high water-filled porosity (20%) that decreases in the upward direction, and the presence of moveable water (17%). The pumice bed is overlain by slightly less-porous volcanic tuff (total porosity ranging 40 % to 52%). 7. A section of heterogeneous alluvium/fanglomerate beds is clearly delineated from the processed logs between the bottom of the Guaje Pumice Bed and the top of the basalt lava flow sequence (484 ft to 530 ft), as delineated from the logs). 8. Interpreted bed boundaries across the electrically imaged interval from 984 to 1127 ft have dip azimuths (direction to which beds are dipping) predominantly to the southwest, and have dip angles (angle from horizontal) mostly less than 15 degrees. One fracture was identified in this interval – an apparently open fracture (estimated aperture of 0.04 in.) at 994 ft (within pumiceous fanglomerate) that dips 40 degrees to the east.	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 lower 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 ft to 1113 ft, and 1116 ft 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.

Note: The data shown in this table were taken from (Kleinfelder 2005, 092385). Also see (LANL 2005, 091121).

ft bgs = Feet below ground surface, CMR = combinable magnetic resonance, ELAN = elemental log analysis program, FMI = formulation microimager.

Table A-3
Well Screen Evaluation

CdV-R-15-3, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested (dry)	Yes	NL	NL	NL
Screen 2	Not tested (dry)	Yes	NL	NL	NL
Screen 3	Not tested (dry)	Yes	NL	NL	NL
Screen 4	Not tested, straddles regional aquifer	Yes	97% Pass	High	Stable
Screen 5	Straddle-packer/injection test K = 0.25 ft/day (Theis analysis)	Yes	63% Pass	High	Stable
Screen 6	Straddle-packer/injection test K = 0.10 ft/day (Bouwer and Rice analysis)	Yes	84% pass	High	Improving

Note: The data shown in this table were taken from (Kopp et al. 2002, 073179).

DQO = Data quality objective, WSAR = Well Screen Analysis Report, K = hydraulic conductivity, NL = not listed, WSAR = Well Screen Analysis Report (LANL 2007, 096330).

CdV-R-37-2, Well Screen Evaluation					
Screen	**Aquifer Parameters***	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested (dry)	Yes	NL	NL	NL
Screen 2	Not tested, straddles regional aquifer	Yes	52% Pass	High	Stable
Screen 3	Straddle-packer tests K = 7.0 ft/day	Yes	91% Pass	High	Stable
Screen 4	Straddle-packer tests K =11.4 ft/day	Yes	74% Pass	High	Stable

Note: The data shown in this table were taken from (Kopp et al. 2003, 088803).

* Hydraulic conductivity results are for Bouwer-Rice analysis.

DQO = Data quality objective, WSAR = Well Screen Analysis Report, K = hydraulic conductivity, NL = not listed.

R-5, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Screen dry	No	NL	NL	NL
Screen 2	Screen not productive enough for testing	Yes	75% Pass	High	Stable
Screen 3	Screen straddles regional water table	Yes	79% Pass	Moderate	Stable
Screen 4	Screen not productive enough for testing	No?	70% Pass	Moderate	Stable

DQO = Data quality objective, WSAR = Well Screen Analysis Report, NL = not listed.

R-7, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	n/a	1, 2 –Yes. Water sample was collected from the zones during well drilling	n/a	n/a	n/a
Screen 2	n/a	1 – Yes. 2 – No. No water sample collected from this zone during drilling	n/a	n/a	n/a
Screen 3	No hydraulic testing performed	1, 2 , 3 – Yes	64% Pass	High	Stable

Note: The data shown in this table were taken from (Stone et al. 2002, 072717).

DQO = Data quality objective, WSAR = Well Screen Analysis Report, K = hydraulic conductivity, n/a = not applicable, NL = not listed.

R-8, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested	Yes	94% Pass	High	Stable
Screen 2	Three injection tests performed. Preliminary results indicate this zone has a production capacity exceeding 23.8 gpm.	Yes	89% Pass	Moderate	Stable

Note: The data shown in this table were taken from (LANL 2003, 079594).

DQO = Data quality objective, WSAR = Well Screen Analysis Report, gpm = gallons per minute.

R-9i, Well Screen Evaluation					
Screen	**Aquifer Parameters***	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	(Screen tested twice) K = 4.87, 3.88 K = 3.71, 3.07 K = 4.57, 3.46 T = 49.4 T = 315.3 T = 13.2	Yes	62% Pass	Moderate	Improving
Screen 2	K = 0.11 K = 0.18 K = 0.12	Yes	72% Pass	Moderate	Improving

Note: The data shown in this table were taken from (Broxton et al. 2001, 071251). Also see (Stone and McLin 2003, 076003).

* Hydraulic conductivity results (ft/day) are for Bouwer-Rice, Cooper-Bredehoeft-Papadopolous, and Hvorslev analysis, respectively. Transmissivity values (ft^2/day) are for Theis, Neuman (early), and Neuman (late) analysis, respectively.

DQO = Data quality objective, WSAR = Well Screen Analysis Report, K = hydraulic conductivity, T = transmissivity.

R-12, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested	1, 2, 3, 4 –Yes. Four water samples were collected from the zones during well drilling. 5 – Probably met	64% Pass	Moderate	Improving
Screen 2	Not tested		84% Pass	Moderate	Improving
Screen 3	Not tested		88% Pass	Moderate	Improving

Note: The data shown in this table were taken from (Broxton et al. 2001, 071252).
DQO = Data quality objective, n/a = not applicable.

R-14, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested	Yes	97% Pass	Moderate	Improving
Screen 2	K (minimum) = 0.9 ft/day (Theis RR) K (minimum) = 1.1 ft/day (specific-capacity method) T (minimum) = 142.5 ft^2/day (Theis RR) T (minimum) =-177.2 ft^2/day (specific-capacity method)	No	71% Pass	High	Stable

Note: The data shown in this table were taken from (LANL 2003, 076062).
DQO = Data quality objective, K = hydraulic conductivity (Theis RR analysis), T = transmissivity, Theis RR = Theis residual recovery analysis.

R-16, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	n/a	5 – No. Screen isolated behind abandoned drive casing.	n/a	n/a	n/a
Screen 2	3 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 - No	78% Pass	Moderate	Degrading
Screen 3	3 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 – Yes	83% Pass	Moderate	Improving
Screen 4	2 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 – No	68% Pass	Moderate	Improving

Note: The data shown in this table were taken from (LANL 2003, 076061).
DQO = Data quality objective, n/a = not applicable.

R-19, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Screen dry	Yes	NL	NL	NL
Screen 2	NL	Yes	82% Pass	Moderate	Stable
Screen 3	NL	Yes	94% Pass	Moderate	Stable
Screen 4	NL	Yes	97% Pass	Moderate	Stable
Screen 5	NL	Yes	52% Pass	Moderate	Stable
Screen 6	From straddle-packer injection tests: K = 17.5 ft/day*	Yes	68% Pass	Moderate	Stable
Screen 7	From straddle-packer injection tests: K = 19.6 ft/day*	Yes	43% Pass	Moderate	Stable

Note: The data shown in this table were taken from (Broxton et al. 2001, 071254). Also see (Stone and McLin 2003, 076003).

* Cooper–Jacob method analysis.

DQO = Data quality objective, K = hydraulic conductivity, NL = not listed.

R-20, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	81% Pass	Moderate	Improving
Screen 2	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	89% Pass	High	Improving
Screen 3	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	69% Pass	High	Improving

Note: The data shown in this table were taken from (LANL 2003, 079600).

DQO = Data quality objective.

R-22, Well Screen Evaluation					
Screen	Aquifer Parameters*	DQOs Met?	Condition of Screen	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested	Yes	38% Pass	High	Stable
Screen 2	Straddle-packer/injection test K = 0.04 (ft/day) K = 0.06 K = 0.05	Yes	100% Pass	High	Stable
Screen 3	Straddle-packer/injection test K = 0.21 (ft/day) K = 0.53 K = 0.25	Yes	75% Pass	High	Stable
Screen 4	Straddle-packer/injection tests (two) K = 0.54; 0.72 (ft/day) K = 0.66; 0.66 K = 0.61, 0.76	Yes	52% Pass	High	Stable
Screen 5	Straddle-packer/injection test K = 0.27 (ft/day) K = 0.64 K = 0.39	Yes	52% Pass	High	Stable

Note: The data shown in this table were taken from (Ball et al. 2002, 071471). Also see (Stone and McLin 2003, 076003).

* Hydraulic conductivity results are listed vertically for Bouwer-Rice, Cooper-Bredehoeft-Papadopolous (C-B-P), and Hvorslev analyses, respectively.

DQO = Data quality objective, K = hydraulic conductivity.

R-25, Well Screen Evaluation					
Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Slug-injection testing failed	Yes	66% Pass	Low	Degrading
Screen 2	Slug-injection testing failed	Yes	47% Pass	Low	Degrading
Screen 3	n/a	Maybe	NL	NL	n/a
Screen 4	Slug-injection testing failed	Yes	77% Pass	Low	Indeterminate
Screen 5	Slug-injection testing failed	Yes	77% Pass	Low	Improving
Screen 6	Slug-injection testing failed	Yes	92% Pass	Low	Indeterminate
Screen 7	Slug-injection testing failed	Yes	96% Pass	Low	Indeterminate
Screen 8	Slug-injection testing failed	Yes	94% Pass	Low	Stable
Screen 9	n/a	n/a	NL	NL	n/a

Note: The data shown in this table were taken from (Broxton et al. 2002, 072640). Also see (LANL 2005, 089397).

DQO = Data quality objective, n/a = not applicable, NL = not listed.

R-26, Well Screen Evaluation					
Screen	**Aquifer Parameters**	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Adjacent to borehole K (ave) = 1.7 ft/day Further from borehole K = 2.4–3.7 ft/day Upper range values considered most reliable. Aquifer limited in areal extent and not well connected to lower regional aquifer.	Yes	100% Pass	High	Stable
Screen 2	K = 0.0022 ft/day with a lower bound of 0.003 ft/day	No	NL	NL	NL

Note: The data shown in this table were taken from (Kleinfelder 2005, 087846).

DQO = Data quality objective, K = hydraulic conductivity, NL = not listed.

R-31, Well Screen Evaluation					
Screen	**Aquifer Parameters***	**DQOs Met?**	**Condition of Screen from WSAR**	**Confidence in Screen Rating from WSAR**	**Prognosis of Screen from WSAR**
Screen 1	Not tested	n/a Screen dry	n/a	n/a	n/a
Screen 2	Not tested	Yes	52% Pass	High	Stable
Screen 3	Straddle-packer/injection tests K = 0.41 (ft/day) K = 0.48 K = 0.53 T(i) = 5.50 (ft^2/d) T(r) = 5.90 (ft^2/d)	No	69% Pass	Moderate	Stable
Screen 4	Straddle-packer/injection tests K = 1.23 (ft/day) K = 1.40 K = 1.48	No	97% Pass	Moderate	Stable
Screen 5	Straddle-packer/injection tests Conducted after only initial (incomplete) development K = 0.75 (ft/day) K = 1.35 K = 0.88	No	97% Pass	Moderate	Stable

Note: The data shown in this table were taken from (Vaniman et al. 2002, 072615). Also see (Stone and McLin 2003, 076003).

* Hydraulic conductivity results are for Bouwer-Rice, Cooper-Bredehoeft-Papadopoulos, and Hvorslev, respectively.

DQO = Data quality objective, K = hydraulic conductivity, n/a = not applicable, T(i) = transmissivity based on injection water-level data.

T(r) = Transmissivity based on recovery water-level data.

R-32, Well Screen Evaluation					
Screen	Aquifer Parameters*	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	T (R) = 29.0 ft^2/day T (RR) =29.5 ft^2/day Spec. capacity = 29.5 K (R) = 4.1 ft/day K (RR) = 4.2 ft/day Spec. capacity =4.2	Yes	97% Pass	High	Stable
Screen 2	Not tested	Unknown	78% Pass	High	Improving
Screen 3	T (RR) = 105.2 ft^2/day Spec. capacity = >104 K (RR) = >1.2ft/day Spec. capacity = >1.2	Yes	90% Pass	High	Stable

Note: The data shown in this table were taken from (LANL 2003, 079602). Also see (McLin and Stone 2004, 089552).

* K and T values are for Theis analysis of results. T and K values listed are those recommended in the hydraulic test report for this well (LANL 2004, 89552).

DQO = Data quality objective, K = hydraulic conductivity, K (R) = from recovery data, K (RR) = from residual recovery data, T = transmissivity, T(R) = from recovery data, T(RR) = from residual recovery data.

R-33, Well Screen Evaluation					
Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Low	The piezometric level of the upper zone was 7.4 ft higher than the composite water level. Strong downward gradient indicated by the difference in piezometric levels with an intervening aquitard between the two screens. Constant-rate pumping tests K = 4.5–7.0 ft/day	Yes	90% Pass	High	Stable
Screen 2	The piezometric water level for lower zone is 18.9 ft lower than the composite water level. Constant-rate pumping tests K = 1.3–2.4 ft/day	Yes	89% Pass	High	Stable

Note: The data shown in this table were taken from (Kleinfelder 2005, 092385).

DQO = Data quality objective, K = hydraulic conductivity.

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 New Mexico Environment Department–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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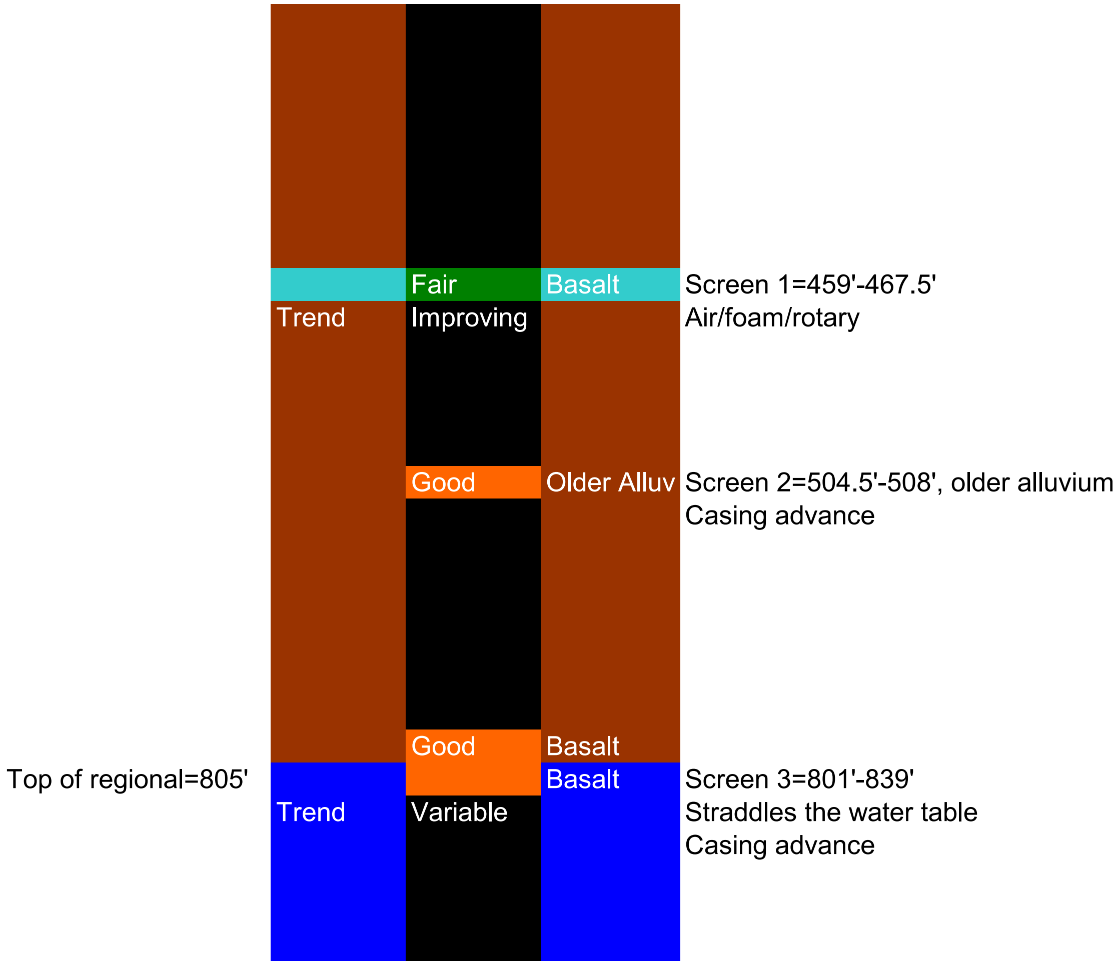
Appendix B

Depth and Condition of Well Screens



Note: This figure shows the depth of well screens, their rating in the Well Screen Analysis Report (WSAR) as of December 2006 (color-coded), thickness of unsaturated zone (brown), top of the regional aquifer, regional aquifer (blue), geochemical trend (variable, improving, etc.), sampling system, drilling methods, and other notes. The WSAR (LANL 2007, 096330) deleted the formal use of ratings in preference to including the number of test categories that a sample from a screen passed. In that sense, "poor" refers to a screen with samples that passed <60%; "fair" passed 60%–80%; "good" passed 80%–90%; and "very good" passed 90%–100%.

Figure B-1 Position and condition of well screens in R-12

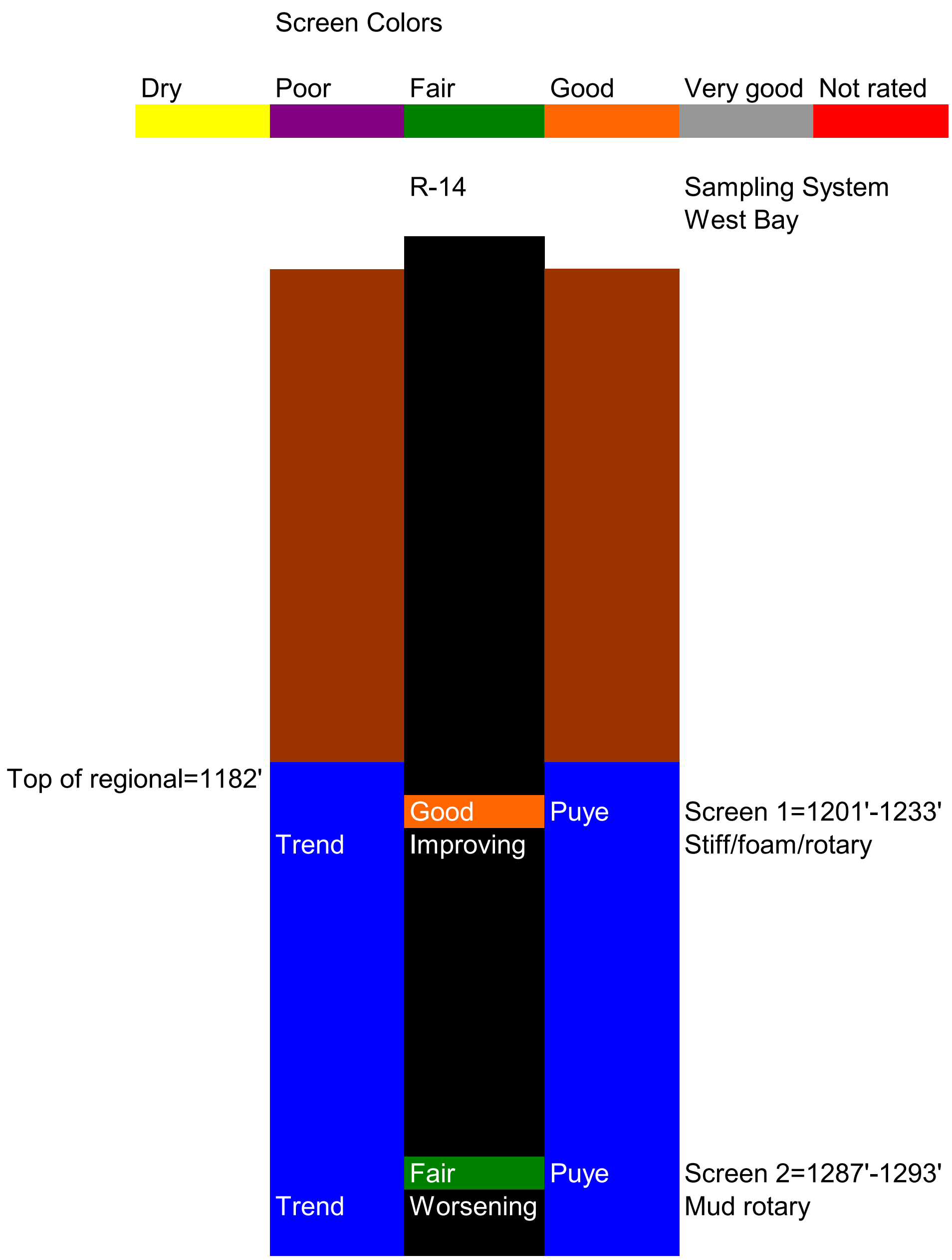


Figure B-2 Position and condition of well screens in R-14 (see note in Figure B-1)

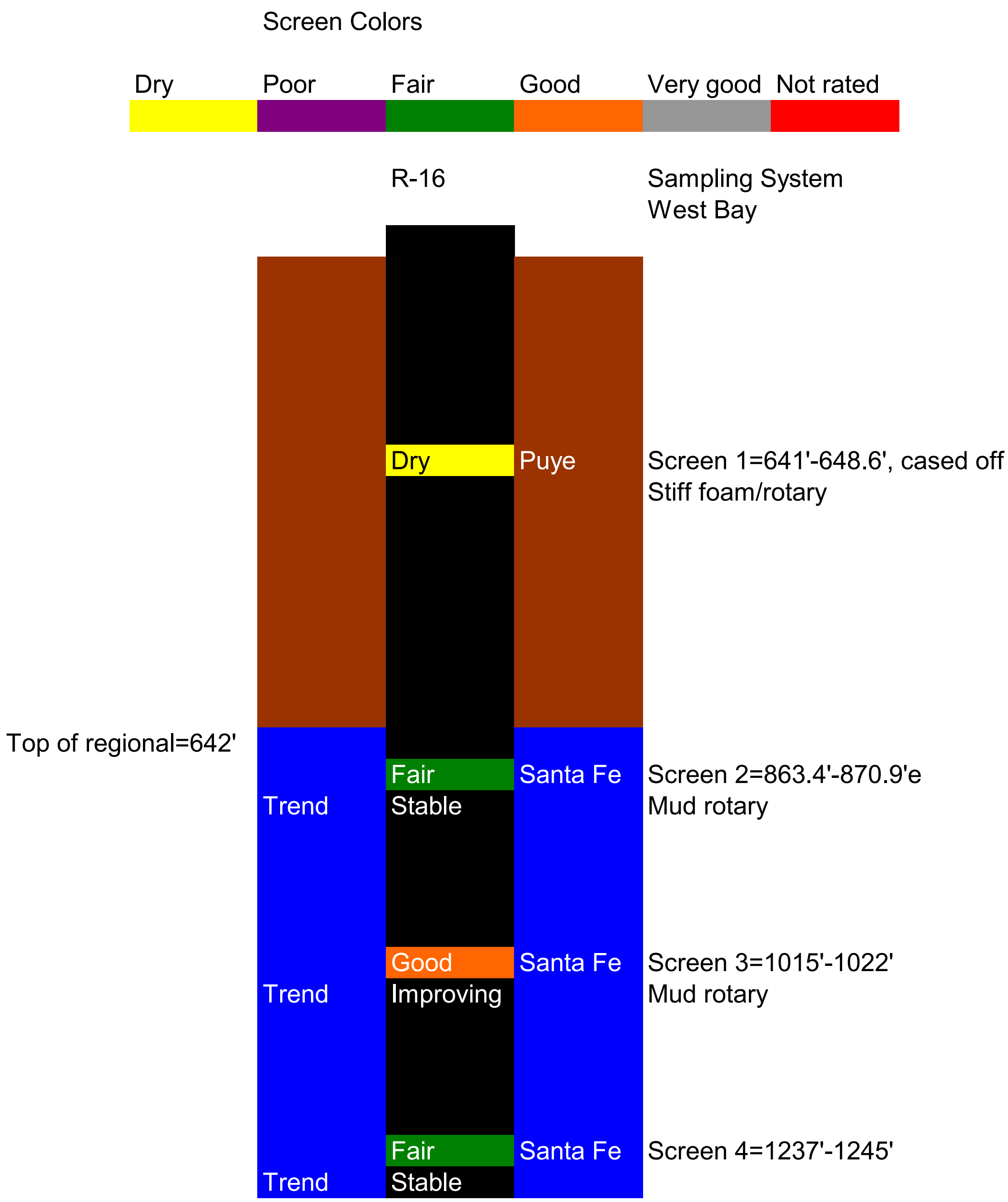


Figure B-3 Position and condition of well screens in R-16 (see note in Figure B-1)

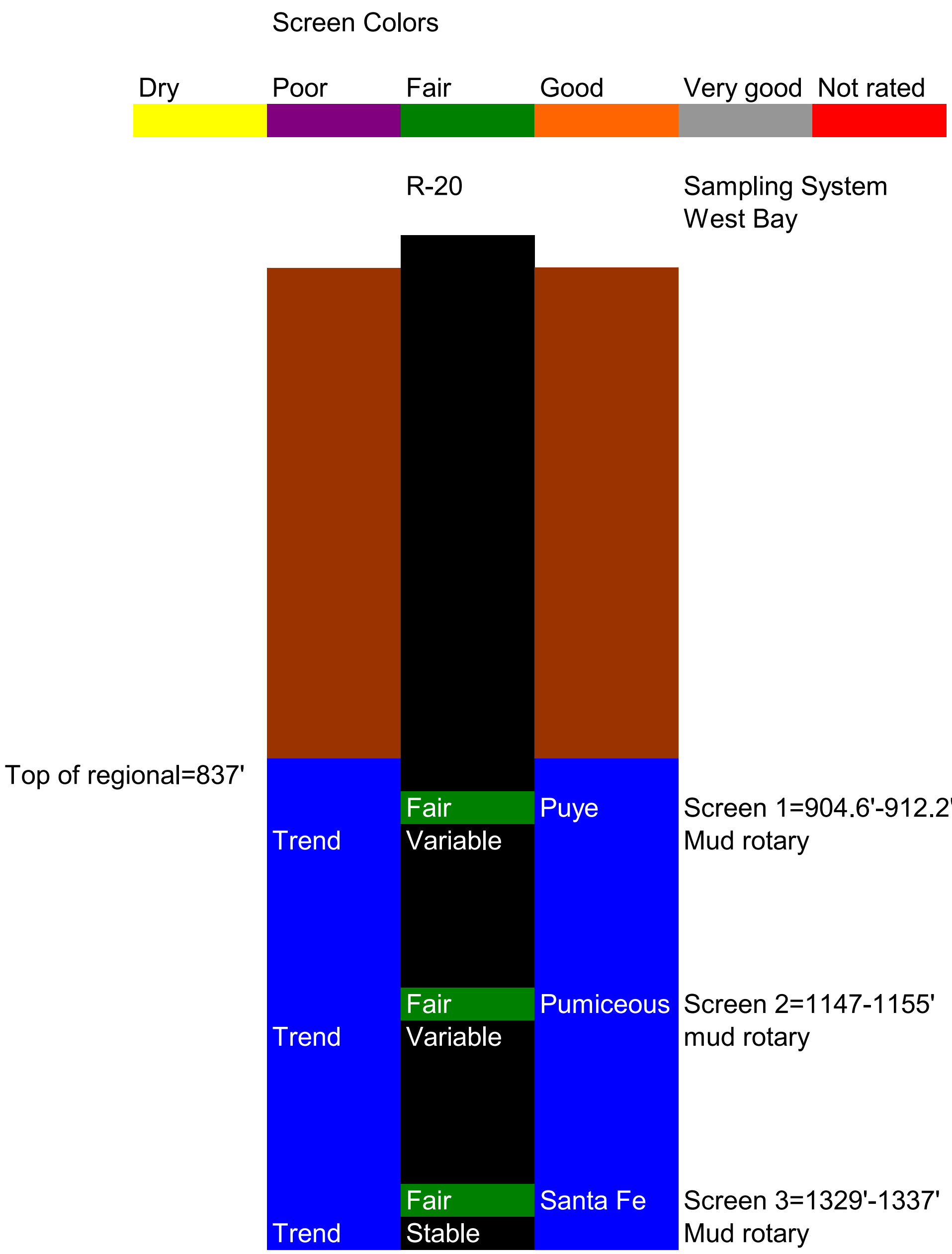


Figure B-4 Position and condition of well screens in R-20 (see note in Figure B-1)

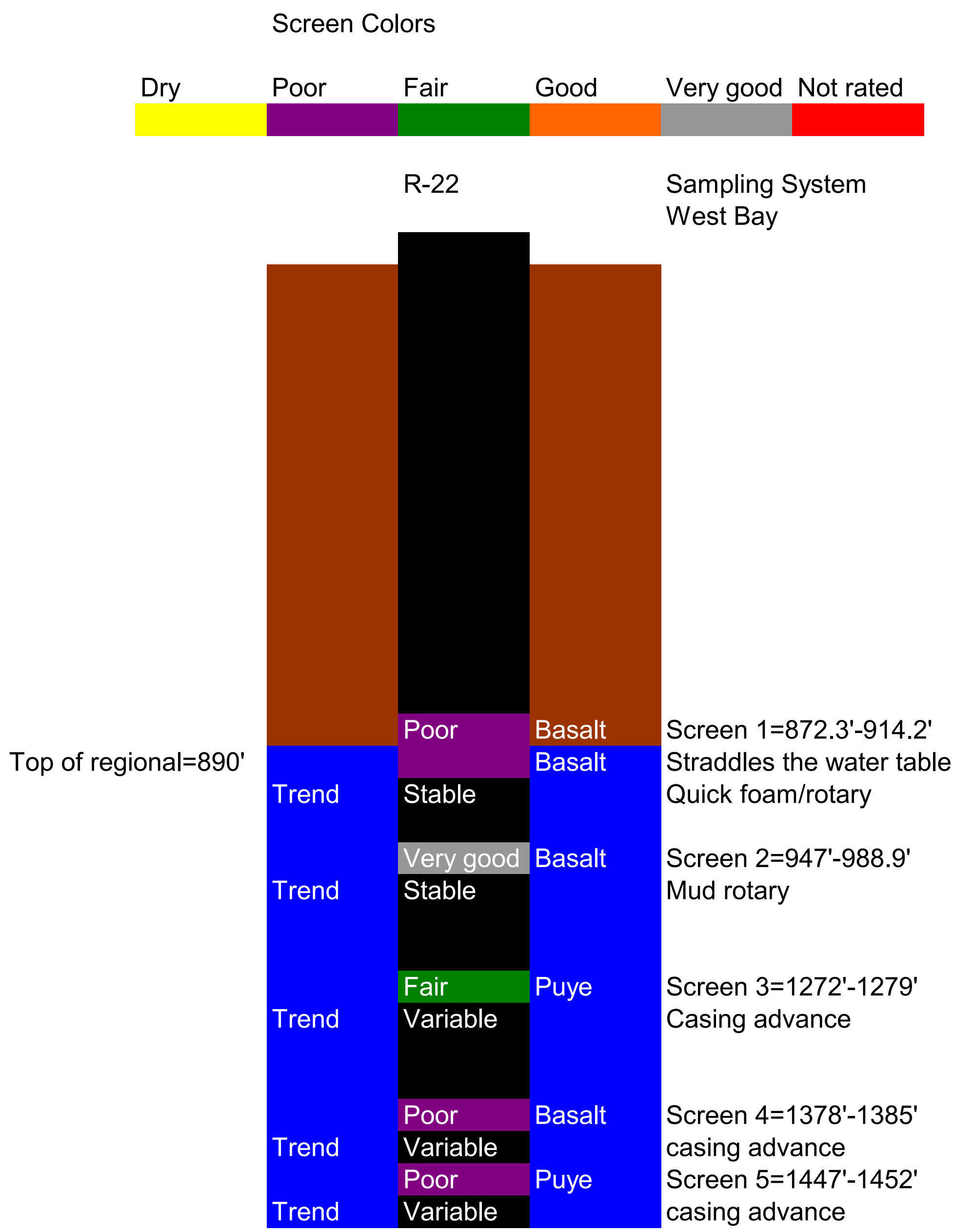


Figure B-5 Position and condition of well screens in R-22 (see note in Figure B-1)

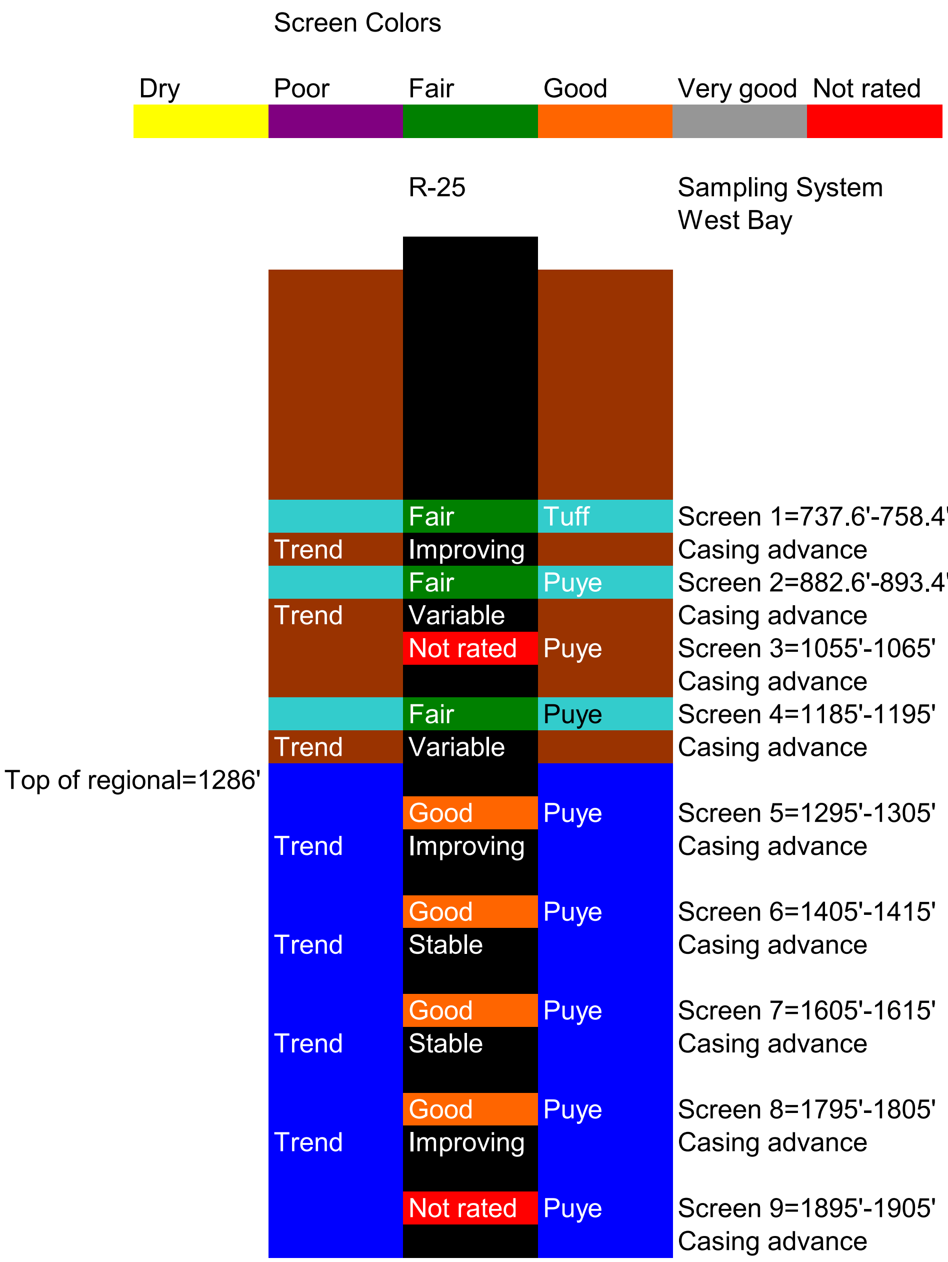


Figure B-6 Position and condition of well screens in R-25 (see note in Figure B-1)

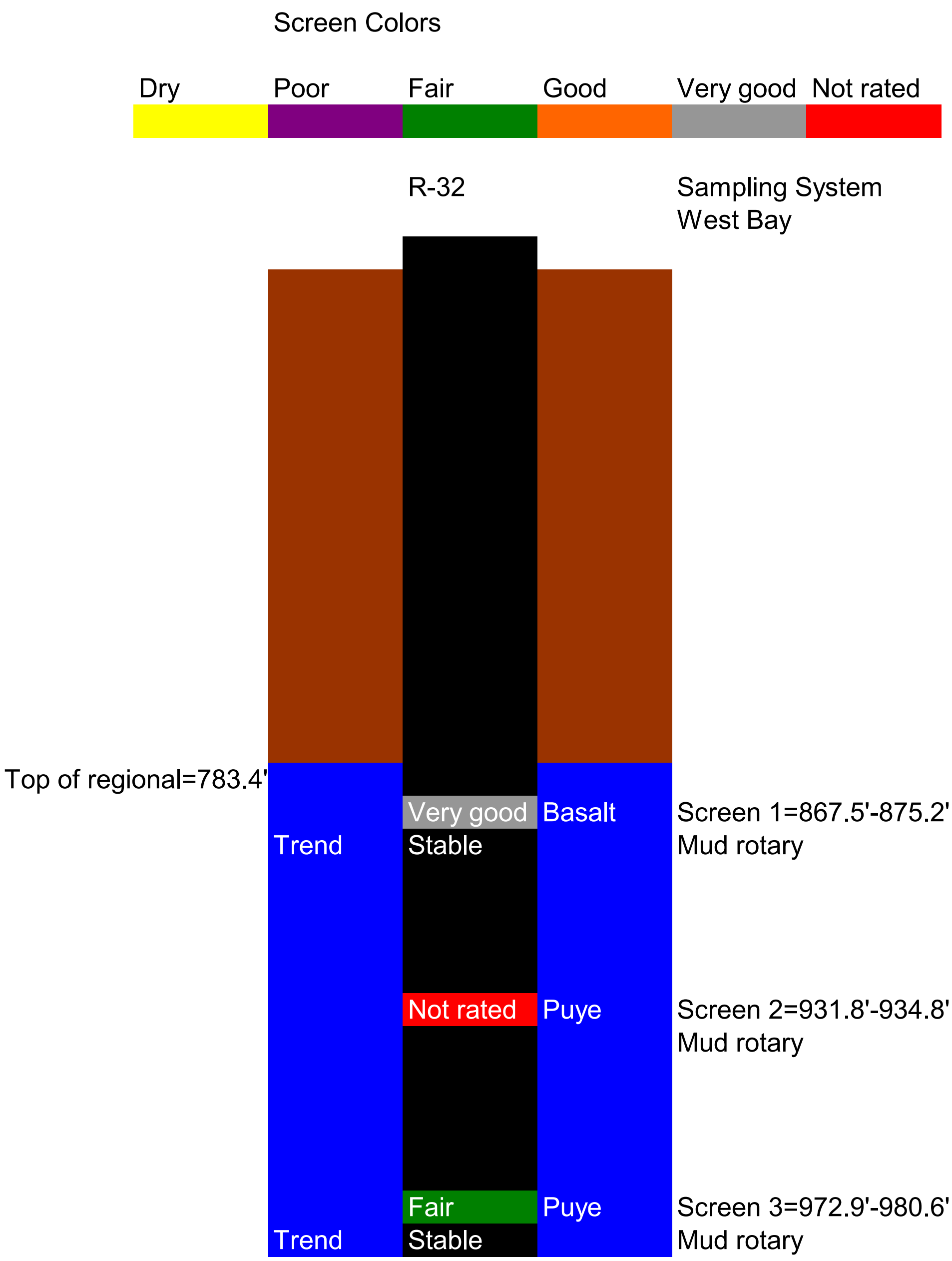


Figure B-7 Position and condition of well screens in R-32 (see note in Figure B-1)

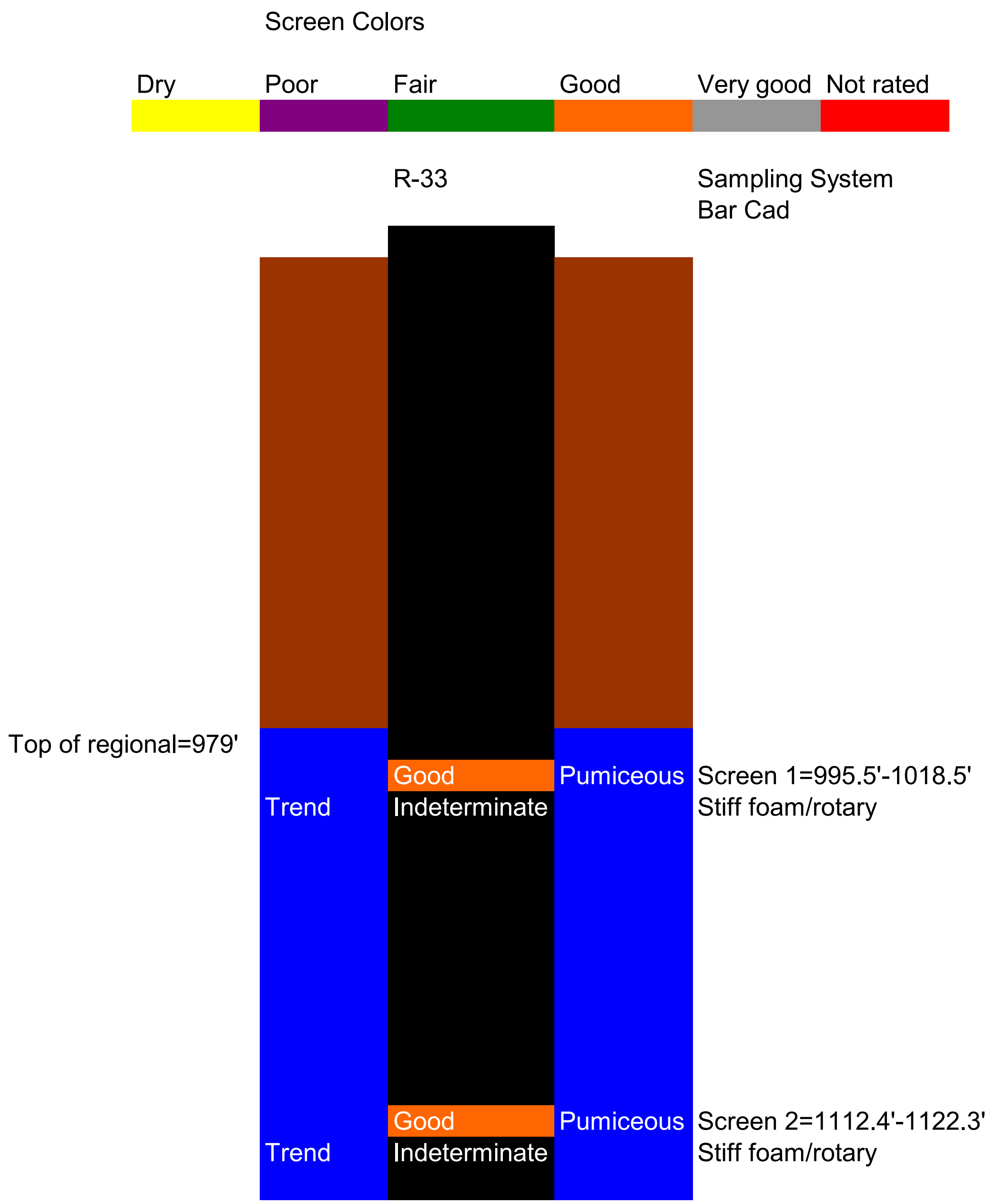


Figure B-8 Position and condition of well screens in R-33 (see note in Figure B-1)

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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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