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Response to Concerns About Selected Regional Aquifer Wells at Los Alamos National Laboratory

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EXECUTIVE SUMMARY

Since 1998 Los Alamos National Laboratory (LANL or the Laboratory) has been implementing a hydrogeologic characterization program, as described in the "Hydrogeologic Workplan" (LANL, 1998). To date, the characterization program has included the installation, testing, and sampling of 25 wells in the regional aquifer beneath the Pajarito Plateau. Concerns about the quality or representativeness of the data obtained by sampling some of these wells have been raised in an unpublished report, "Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory" by Robert Gilkeson (Presented to Northern New Mexico Citizen's Advisory Board, June 9, 2004). The following questions and answers summarize the Laboratory's response to the issues raised by Mr. Gilkeson.

Question 1: What is the regulatory purpose of recently constructed wells at LANL and do the wells meet regulatory requirements?

The purpose of recently constructed wells is to investigate hydrologic properties, groundwater, and groundwater contamination that will lead to and support the appropriate RCRA monitoring and corrective action decisions that have yet to be made at LANL. The wells constructed to date are for characterization purposes and meet the requirements that are detailed in the RCRA permit (primarily the HSWA module VIII) and also in the NMED-approved Hydrogeologic Workplan. To meet characterization objectives, the wells are constructed to answer basic hydrogeological questions, characterize natural water chemistry, and to identify contamination from past releases. Some of the characterization wells may be converted to RCRA monitoring wells in the future.

Question 2: Are the screens in regional aquifer wells at Los Alamos National Laboratory placed in appropriate permeable hydrogeologic units and are they too long for monitoring purposes?

The screens in regional aquifer wells are placed in hydrogeologic units considered important for hydrogeologic characterization and the screen lengths are appropriate for routine monitoring, if necessary. The well design team typically includes representatives from DOE, LANL, and the drilling contractor. NMED and DOE-OB review and approve the well design prior to well construction. Each of the wells cited by Mr. Gilkeson achieved the primary objective of providing information about the regional aquifer water table and all have screens located within representative hydrostratigraphic units.

Question 3: What are the impacts of drilling fluids on the wells mentioned in Mr. Gilkeson's Report and what is being done about these concerns?

LANL uses drilling fluids as part of its drilling methods that are consistent with industry standards and approved by regulators. Without use of these fluids and drilling methods, drilling of some wells may not have been possible. The majority of wells and screens are not impacted by residual drilling fluid. The chemical and biological effects of residual drilling fluids on water quality samples are recognized and closely monitored to determine when the effects of drilling have dissipated. The trend data presented in this report show improvement in sample quality over time, although the length of time to required to reach pre-drilling conditions is specific to each well. The Laboratory has identified and documented the effects of residual drilling fluids within specific screens during public meetings, in annual status reports, and in geochemistry reports.

Question 4: How does Los Alamos National Laboratory develop regional aquifer wells to mitigate the effects of drilling on in situ conditions?

Any type of drilling necessarily disturbs the subsurface environment, including the introduction of drilling fluids. The LANL drilling program has adapted well development procedures along with the drilling strategy and techniques to overcome the unique geologic and drilling problems inherent on the Pajarito Plateau. The well development procedures at LANL are consistent with industry standards. LANL has gone beyond industry practice by ensuring that no additives were used without complete analytical characterization, and by making the concentration of total organic carbon a performance criterion for satisfactory well development. Obtaining high quality data has been a high priority and ultimate end goal of the well development process. Changes in drilling methods were analyzed and corresponding changes were made in the well development program to address impacts resulting from the drilling methods.

Question 5: What do groundwater data show regarding technetium-99, strontium-90, and other contaminants that Mr. Gilkeson focuses on?

Geochemical data from wells R-7 and R-22 show that contaminants cited by Gilkeson (2004) are not present at detectable levels in the regional aquifer. Specifically, the regional aquifer water at wells R-7 and R-22 does not contain americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, or technetium-99 in measurable quantities. LANL acknowledges that the regional aquifer at TA-16, Pueblo, Los Alamos, Sandia, and Mortandad Canyons contains a limited number of contaminants (nitrate, perchlorate, tritium, uranium, and high explosive compounds [RDX, TNT] and degradation products associated with TNT).

Question 6: How Does Los Alamos National Laboratory provide the public with groundwater information?

LANL has informed the regulators and the public about the activities under the Hydrogeologic Workplan, including the issues raised by Gilkeson (2004), in several ways since 1997:

- Four quarterly public meetings every year (24 documented meetings to date) with distribution of meeting minutes to an extensive mailing list;
- Six Annual Status Reports summarizing the work accomplished in the previous year;
- Eight Semi-Annual Reports of the External Advisory Group;
- Well Completion Reports for R-1, R-9, R-7, R-22, MCOBT-4.4, MCOBT-8.5, R-25, R-15, R-9i, R-2, R-4, R-11, R-28, R-5, R-8, R-14, R-13, R-16, R-20, R-23, R-26, R-31, R-32; and
- Geochemistry Reports for R-15, R-9/R-9i, R-22, R-12, R-19, and R-7.
- All water quality data are available over the internet at www.wqdbworld.lanl.gov
- Annual Environmental Surveillance reports provide the analytical results of surface water and groundwater sampling at the Laboratory and in northern New Mexico.

The issues and concerns expressed in the Gilkeson (2004) report have been extensively discussed over a period of eight years with regulators and the public.

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Introduction

Since 1998 Los Alamos National Laboratory (LANL or the Laboratory) has been implementing a hydrogeologic characterization program, as described in the "Hydrogeologic Workplan" (LANL, 1998). To date, the characterization program has included the installation, testing, and sampling of 25 wells in the regional aquifer beneath the Pajarito Plateau. Concerns about the quality or representativeness of the groundwater quality data obtained by sampling these wells have been raised in an unpublished report, "Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory" (Gilkeson, 2004). Appendix A to this report contains the text of Mr. Gilkeson's report in its entirety with side notations that indicate where in this report his concerns are addressed.

Throughout the duration of the hydrogeologic characterization effort, the Laboratory has, at one time or another, identified the same concerns described in the Gilkeson report. The concerns are addressed by implementing mitigative actions, such that the data collected from the drilling, sampling, and testing of the wells are adequate for decision-making, or the data are identified as not meeting quality criteria and are not used for making decisions. This report describes the Laboratory's proactive solutions to these issues and provides an account of the sound scientific basis for LANL's approach to installation and sampling of the wells.

Background

Drilling and installation of wells in the regional aquifer as described in the Hydrogeologic Workplan began in 1998. Since that time, twenty-five regional aquifer wells and six intermediate zone wells have been completed for hydrogeologic characterization (Table 1). The drilling program has evolved in response to geologic conditions encountered. All significant aspects of the drilling program have been discussed at quarterly and annual meetings to identify issues and potential solutions.

Table 2 briefly describes the drilling methods used since the beginning of the drilling program. The earliest wells were drilled using air-rotary drilling methods with casing advance and the minimal use of fluids other than air. Because of significant problems associated with stuck casing, unstable boreholes, and lost circulation, small amounts of drilling fluids were used to improve lubricity, borehole stabilization, and cuttings circulation. Continuing drilling problems made total reliance on air-rotary drilling with casing advance impracticable for meeting drilling objectives. It became apparent that the depth of the wells and the difficult drilling environment required that more drilling techniques be added to the drilling "tool box" in order to respond to the complex hydrogeologic conditions that characterize the Pajarito Plateau. All of the drilling methods used at LANL are used in standard industry practice and are described by the American Society for Testing and Materials (ASTM). The drilling methods and well construction are addressed in more detail in the responses to questions 2 and 4.

Table 1. Los Alamos National Laboratory Hydrogeologic Characterization Wells

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (feet below ground surface)	Number of Screens
R-1	Mortandad Canyon	November 2003	Conventional-circulation fluid-assisted air-rotary methods with casing advance to 90 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1165 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1165	1
R-2	Pueblo Canyon	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 403 ft followed by conventional-circulation mud rotary drilling to TD at 943 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD in the upper part and municipal water mixed with bentonite, soda ash, PAC-L in the lower part	943	1
R-4	Pueblo Canyon	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 266 ft followed by conventional-circulation mud rotary drilling to TD at 844 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD in the upper part and municipal water mixed with bentonite, soda ash, PAC-L in the lower part	844	1
R-5	Pueblo Canyon	June 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 870 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 902 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	902	4
R-7	Los Alamos Canyon	February 2001	Reverse-circulation fluid-assisted air-rotary methods with casing advance to 290 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1097 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1097	3
R-8	Los Alamos Canyon	February 2002	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 809 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 880 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	880	2

Table 1 (continued).

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (feet below ground surface)	Number of Screens
R-9	Los Alamos Canyon	October 1999	A combination of reverse- circulation air-rotary methods in open hole and with casing advance to 710 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 771 ft.	Air in upper part of the borehole and air with municipal water mixed with Quik-FOAM, EZ-MUD in the lower part	771	1
R-11	Sandia Canyon	August 2004	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 927 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	927	1
R-12	Sandia Canyon	January 2000	A combination of reverse- circulation air-rotary methods in open hole and with casing advance to 710 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 771 ft.	Air and municipal water in the upper part and air with municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD in the lower part	886	3
R-13	Mortandad Canyon	September 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to TD at 1133 ft	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1133	1
R-14	Ten Site Canyon	July 2002	Reverse- circulation fluid-assisted air-rotary methods in open hole to 1225 ft with hole cased to 1050 ft; conventional-circulation mud rotary drilling in open hole from 1225–1285 ft; reverse-circulation fluid-assisted air-rotary methods with casing advance from 1285 ft to TD at 1327 ft.	Air and municipal water mixed with EZ-MUD in the upper part and municipal water mixed with soda ash, bentonite, LIQUI-TROL, in the lower part	1327	2
R-15	Mortandad Canyon	February 2000	Reverse-circulation fluid-assisted air-rotary methods with casing advance to TD at 1107 ft	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1107	1

Table 1 (continued).

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (feet below ground surface)	Number of Screens
R-16	White Rock Overlook	August 2002	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 729 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to 867 ft. Hole completed using conventional-circulation mud rotary methods from 867 ft to TD at 1287 ft.	Air and municipal water mixed Quick-gel, LIQUI-TROL, Quick-FOAM, and soda ash in the upper part and municipal water mixed Quick-gel, EZ-MUD, LIQUI-TROL, magma-fiber, n-seal in the lower part	1287	4
R-19	Mesa above Potrillo Canyon	April 2000	Reverse- circulation fluid-assisted air-rotary methods with casing advance to 227 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1902 ft.	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1902	7
CdV-R-15-3	Cañon de Valle	September 2000	Reverse-circulation fluid-assisted air-rotary methods with casing advance to 722 ft; install casing; complete hole by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1722 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD plus polymers	1722	6
CdV-R-37-2	Mesa North of Water Canyon	October 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 825 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1664 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1664	4
R-20	Pajarito Canyon	January 2003	Conventional-circulation mud rotary drilling to TD at 1365 ft.	Municipal water mixed Quick-gel, LIQUI-TROL, Quik-FOAM, soda ash, PAC-L, n-seal (mineral fiber)	1365	3
R-21	Cañada del Buey	January 2003	Conventional-circulation air-rotary drilling in an open hole to 237 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 995 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	995	1

Table 1 (continued).

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (feet below ground surface)	Number of Screens
R-22	Mesa above Pajarito Canyon	December 2000	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 1345 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1489 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1489	5
R-23	Pajarito Canyon	January 2003	A combination of conventional mud-rotary drilling, reverse-circulation fluid-assisted air-rotary drilling in open hole, and reverse-circulation fluid-assisted air-rotary drilling with casing advance to TD of 935 ft.	Municipal water mixed with bentonite, Quick-gel, LIQUI-TROL, Quik-FOAM, soda ash, magna-fiber, PAC-L, n-seal and air with municipal water mixed with Quick-gel, LIQUI-TROL, Quik-FOAM, and soda ash	935	1
R-25	Mesa above Cañon de Valle	February 1999	Reverse-circulation fluid-assisted air-rotary drilling with casing advance to TD of 1942 ft	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1942	9
R-26	Cañon de Valle	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 1000 ft; casing installed to 1000 ft; borehole completed by conventional-circulation mud-rotary drilling in an open hole to TD at 1490.5 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1490.5	2
R-28	Mortandad Canyon	December 2003	Conventional- circulation fluid-assisted air-rotary methods with casing advance to 80 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1005 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1005	1
R-31	Ancho Canyon	March 2000	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 787 ft followed by reverse- circulation fluid-assisted air-rotary methods with casing advance to TD at 1103 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1077	5

Table 1 (continued).

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (feet below ground surface)	Number of Screens
R-32	Pajarito Canyon	January 2003	Reverse-circulation fluid-assisted air-rotary drilling in open hole to 908; install casing; complete hole by conventional-circulation mud rotary drilling in an open hole to TD at 1008 ft.	Air and municipal water mixed with Quick-gel, LIQUI-TROL, Quik-FOAM, and soda ash in the upper part and municipal water mixed with Quick-gel, LIQUI-TROL, EZ-MUD, magma-fiber, PAC-L, n-seal in the lower part	1008	3
MCOBT-4.4	Mortandad Canyon	June 2001	Reverse-circulation fluid-assisted air-rotary drilling using casing advance to 130 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 767 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	767	1
MCOBT-8.5	Mortandad Canyon	June 2001	Reverse-circulation fluid-assisted air-rotary drilling using casing advance to 130 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 740 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	740	—
R-9i	Los Alamos Canyon	March 2000	Reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 322 ft.	Air and municipal water mixed with EZ-MUD	322	2
CdV-16-1(i)	Cañon de Valle	November 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 683 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	683	1
CdV-16-2(i)	Mesa South of Cañon de Valle	December 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1063 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1063	2
CdV-16-3(i)	Mesa South of Cañon de Valle	January 2004	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1405 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1405	—

Table 2. Drilling Methods Used for Hydrogeologic Characterization Wells at Los Alamos National Laboratory

Drilling Method	Description	Benefits	Drawbacks
Air rotary ASTM D5782-95; D5781-95	A drill pipe or drill stem coupled to a drill bit that rotates and cuts through soils, alluvium, and rock. The cuttings produced from the rotation of the drilling bit are transported to the surface by compressed air or by compressed air augmented by municipal water mixed with drilling additives. In conventional air-rotary drilling, the compressed air is forced down the borehole through the drill pipe and returns to the surface up through the annular space. In reverse air rotary, a dual tube drilling system is used and drilling fluids are forced down the outer tube and returns up the center tube, where the cuttings are discharged through cyclone velocity dissipater. The circulation of drilling fluids not only removes cuttings from the borehole but also cools the drill bit.	Air rotary drilling in an open hole is the fastest and least expensive drilling method in the unsaturated zone. It is best suited for stable, hard rock formations with good circulation characteristics. Open hole drilling allows for the collection of an extensive suite geophysical logs for the characterization of hydrogeologic properties.	Experience gained in the early part of the drilling program showed that air rotary drilling in an open hole is not always a suitable method for drilling at depths greater than 150 ft below the regional aquifer water table. The use of municipal water with drilling additives is almost always required to improve borehole stability and circulation of cuttings. Use of these drilling fluids can alter the natural properties of the rocks and it is not possible to collect pristine water samples while drilling. Generation of dust at the surface is a problem unless dust-suppression equipment is used and/or municipal water is added to the circulation fluid.
Casing advance ASTM 5876-95	Air-rotary drilling using an under reamer cutting system (rotary bits or downhole hammer) to create a hole large enough for a heavy-walled casing to slide down behind the drill bit. The casing is advanced simultaneously while drilling the hole. Compressed air or compressed air augmented by municipal water mixed with drilling additives are used to remove the cuttings from the bottom of the borehole. When the borehole has reached total depth, the well is constructed inside the heavy walled casing, as the casing is incrementally removed.	The drill casing stabilizes the borehole when drilling through poorly consolidated materials and improves circulation in highly porous or fractured rocks. The cased hole provides a stable environment for the construction of the well. There is relatively little disturbance to the borehole walls and relatively undisturbed samples of rock and water are obtained during drilling.	The heavy-wall casing frequently becomes stuck and is difficult to extract from the borehole. Casing that can not be extracted must be abandoned in the hole, possibly impacting the use of some well screens. The cost is high and drilling rates are often very slow. The use of municipal water with drilling additives is almost always required to provide lubricity between the casing and the borehole wall and to improve borehole stability and the circulation of cuttings. Use of heavy-walled casing severely limits the geophysical methods that can be used for hydrogeologic characterization.
Mud rotary ASTM D5783-95	A bit is rotated to cut through the rock while mud is the circulating fluid pumped down through the drill pipe and returned back up the borehole through the annular space. The mud-filled hole stabilizes the borehole wall and cools the drill bit. Circulation of the mud carries the cuttings up to the surface.	Rapid and effective drilling methods. Can be used to maintain borehole stability in poorly consolidated sediments of the saturated zone. Open hole drilling allows for the collection of an extensive suite geophysical logs for the characterization of hydrogeologic properties.	Does not work well in vadose zone due to lost circulation zones in fractured basalts and in highly porous tuffs and sediments. Masks the recognition of water-bearing zones while drilling. Slow circulation of mud mixes cuttings from throughout the borehole, hampering geologic characterization. Addition of drilling muds and fluids changes the geochemical environment around the borehole. Requires extensive development.

Question 1: What is the regulatory purpose of recently constructed wells at LANL and do the wells meet regulatory requirements?

The purpose of recently constructed wells is to investigate hydrologic properties, groundwater, and groundwater contamination to support appropriate RCRA monitoring and corrective action decisions. Gilkeson (2004) expressed concerns that specific regional aquifer wells do not comply with Resource Conservation and Recovery Act (RCRA) requirements for *monitoring* wells. The RCRA monitoring requirements do not yet apply to LANL, because this investigation phase comes before, and provides the basis for, formal RCRA monitoring. The wells constructed to date are for characterization purposes and meet the requirements that are detailed in the RCRA permit (primarily the HSWA module VIII) and also in the NMED-approved Hydrogeologic Workplan (LANL, 1998). To meet characterization objectives, the wells are constructed to answer basic hydrology, geology, and geochemistry questions and to identify contamination from past releases.

The Hydrogeologic Workplan describes a 7-year characterization effort for groundwater on a Laboratory-wide basis with the objective of developing sufficient understanding of the hydrogeology to design an adequate detection monitoring network or to reapply for groundwater monitoring waivers for some or all of the RCRA units. The hydrogeologic characterization was intended to respond to four "fundamental hydrogeologic issues/questions that remain unresolved at LANL" (NMED letter dated August 17, 1995):

- Individual zones of saturation beneath LANL have not been adequately delineated and the "hydraulic interconnection" between these is not understood.
- The recharge area(s) for the regional and intermediate aquifers have not been identified.
- The groundwater flow direction(s) of the regional aquifer and intermediate aquifers, as influenced by pumping of production wells are unknown.
- Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility.

The data collection activities for hydrogeologic characterization consist primarily of installing wells to understand the hydrostratigraphy, hydrologic properties, and water quality at selected locations at LANL. The well construction has followed RCRA monitoring well design guidance where possible. Many of the characterization wells are expected to be used as monitoring wells and may become part of different RCRA monitoring systems that will be established at LANL in the future. For example, one of these possible systems is RCRA monitoring around TA-54 (Areas G, H, and L), which is considered a RCRA regulated unit. Wells that are part of that system will meet all RCRA requirements for monitoring of an operating facility.

The groundwater monitoring requirements for RCRA-regulated units at Los Alamos National Laboratory are held in abeyance until the completion of the site-wide hydrogeologic characterization (NMED letter, August 17, 1995) described in the Hydrogeologic Workplan approved by NMED on May 22, 1998.

The regulatory requirements for constructing monitoring wells fall from two different sources: the RCRA regulations for owners and operators of hazardous waste treatment, storage, and disposal facilities as defined by 40 CFR 264 and the RCRA/HSWA permit issued to the Laboratory in 1994. Requirements for monitoring wells at a RCRA treatment, storage, and disposal (TSD) facility are not applicable to the regional aquifer wells installed at LANL under the Hydrogeologic Workplan, because those wells are for characterization purposes. The design for monitoring wells at a TSD facility focuses on early detection of potential releases, typically from an operating TSD facility. However, the characterization wells were designed to meet RCRA requirements so that they could be used as monitoring wells in the future, if necessary.

In the Laboratory's existing 1994 HSWA module of the RCRA permit, two subsections within Section C "Special Permit Conditions" proscribe well specifications:

- Section 1: "Perched Water Monitoring" specifies the installation of 14 wells in saturated alluvium of seven canyons. The well construction requirements are specifically for these 14 alluvial wells and they include casing materials, borehole size, screen lengths of no more than 10 ft, filter pack no more than 2 ft above the screen, and sealing and grouting.
- Section 4: "Protection of the Main Aquifer" specifies that borings that reach the regional aquifer shall ensure that the regional aquifer is hydraulically isolated from perched aquifers with conductor casing or bentonite seals.

Additionally, the New Mexico Environment Department (NMED) has repeatedly expressed a preference for LANL to install well screens that straddle the regional water table (letters dated March 1, 2002; April 18, 2003).

Question 2: Are the screens in regional aquifer wells at Los Alamos National Laboratory placed in appropriate permeable hydrogeologic units and are they too long for monitoring purposes?

The screens in regional aquifer wells are placed in hydrogeologic units considered important for hydrogeologic characterization and the screen lengths are intended to be appropriate for routine monitoring if necessary. The report by Gilkeson (2004) included concerns that specific regional aquifer wells have screens that are too long for monitoring or are in the wrong location for monitoring and for representing high permeability zones. All well designs consider multiple sources of information gathered during drilling as well as data obtained from nearby wells. Each well design seeks to fulfill the data quality objectives described in the Sampling and Analysis Plan for the well while taking into account the local conditions found while drilling the borehole. The well design team typically includes representatives from DOE, LANL, and the drilling contractor. Preliminary interpretations of geophysical logs by Schlumberger experts are also considered designing the well, although final interpreted logs from Schlumberger are not available in the necessary time frame for well design. A well must be designed and constructed rapidly or there is a serious risk of borehole failure before the well can be built. NMED and DOE-OB review and approve the well design prior to well construction. Our approach has been to place screens within zones where the aggregate hydrologic properties indicate rocks with greater permeability, thus maximizing chances for intersecting a preferred contaminant pathway. To provide data for flow and transport numerical models, some screens in multi-screen wells are placed in geologic units that represent significant portions of the regional aquifer, but have relatively poor hydraulic characteristics that need to be characterized in order to support a comprehensive understanding of site hydrology.

This response describes the general considerations used in designing the regional aquifer wells, and specifically addresses the screen location and screen length. Finally, the design of wells specifically cited by Gilkeson is addressed.

General Considerations in Well Design

In designing a well, the two salient decisions for the purpose of intersecting and understanding hydrologic pathways are: where to place the screen (or screens) and how long each screen should be. The decision on location of a screen takes into account the characteristics of the aquifer that may affect contaminant flow and transport (e.g., hydraulic conductivity, permeability, water level). The decision on the length of the screen takes into account how large an interval of the aquifer is accessed by the screen and, if near the water table, whether the water table is expected to decline during the life of the well.

It is also important to note that the wells referenced in the Gilkeson (2004) report are primarily for hydrogeologic characterization. Some screens are installed to provide hydrogeologic data from units about which little is known. These data are important for constructing three-dimensional models that provide a comprehensive understanding of flow and transport at the Laboratory. In addition, specific horizons may be selected for screen emplacement where the local features require special consideration. An example of this situation is R-16, where the three lowest screens were located below the elevation of the Rio Grande in order to intercept horizons and pathways that could flow beneath the river toward the Buckman well field.

After the objectives for the well are reviewed, the well design typically takes into account:

- Driller's observations of water production and drilling characteristics,
- Geophysical logs indicating likely productive zones and stratigraphy,
- Geologic descriptions of drill cuttings and core,
- Borehole video evidence of likely productive zones,
- Water level measurements in the borehole,
- Preliminary water quality data from the borehole, and
- Historic water level declines in nearby wells.

The well design team, including representatives from DOE, LANL, and the drilling contractor, will develop a draft well design. The draft design is provided to NMED and DOE-OB to review and approve the well design prior to well construction.

Screen Location

Screens are generally placed at or near the water table and in units of interest below the water table. Until about 2002, most wells installed as part of the Hydrogeologic Workplan (including R-7, R-15, R-16, and R-22) were installed with a well screen that straddled the regional aquifer water table, in compliance with the RCRA/HSWA permit requirements and NMED preference. There are two problems with screens that straddle the water table:

- They are more difficult to develop because of dewatering of the screen during pumping.
- Hydrologic testing results are less certain because of dewatering effects.

Therefore, wells installed since 2002 have been constructed with fully submerged screens that are located as close as possible to the regional water table. The placement of screens just below the regional aquifer water table has been discussed with NMED both in quarterly meetings and in correspondence.

For screens in horizons below the regional aquifer water table, screen location is determined by selecting intervals of higher transmissivity, based on geophysical data (e.g., targeting porous zones with large pore sizes and high water contents as identified by magnetic resonance, electrical, density, neutron, and elemental capture logging). Unless other considerations lead to screen placement in a poorly known unit that requires characterization, our approach has been to place screens within zones where the aggregate hydrologic properties indicate rocks with greater permeability, thus maximizing chances for intersecting a preferred contaminant pathway.

Within screened intervals there is fine-scale stratigraphic variability in most aquifer units, which Gilkeson (2004) defined as "multiple hydrogeologic units". For example, Figure 1 shows a Schlumberger Formation Microimager (FMI) log of sedimentary clast sizes, shapes, and layering within the Puye Formation at drill hole CdV-R-15-3. The strip on the left (depth: 1254–1274 ft) shows the aquifer material within the 43.8 ft screen that straddles the 1245-ft deep water table. The strip on the right shows a deeper zone of even finer-scale stratigraphic variation, including multiple thin beds of fine silt or clay (dark bands). These images show that heterogeneity is an intrinsic characteristic of the Puye Formation on scales as small as 1 ft or less and that few beds of homogeneous lithology are more than 3 ft thick. Because there are no *a priori* methods for selecting which of these many depositional layers represent preferred contaminant pathways, geophysical logs are used to identify representative sections of high permeability.

Screen Length

EPA guidance documents and the RCRA/HSWA permit recommend short (10–20 ft) screen lengths. Short screen intervals are thought to be necessary so that contaminant concentrations, if present, are not diluted by excess water coming into the screen from a longer interval. However, justification for selecting longer length screens at the water table is found in EPA guidance documents (see side text boxes). Further, the NMED has recognized the need for longer screened intervals at the water table in their "Request for Supplemental Information" for the Hydrogeologic Workplan (1998), which said:

> **EPA Technical Enforcement Guidance Document (TEGD)** states "Long term structural integrity, i.e., 30 or more years, is essential to the collection of unbiased groundwater samples over the lifetime of the facility and post-closure period" (EPA, 1986, p. 81).

> **RCRA Groundwater Monitoring: Draft Technical Guidance** states "Unconfined aquifers with widely fluctuating water tables may warrant the use of longer well screens for adequate detection monitoring." (EPA, 1992, p. 5-7).

> *"The screened interval in wells advanced to the regional aquifer should be determined on a site-by-site basis. Where LANL can document significant drawdown of the regional aquifer, the screened interval shall not exceed 60 feet. In areas of the Laboratory where little or no drawdown is documented, the screened interval shall be 20 feet according to the Groundwater Technical Enforcement Guidance Document (TEGD, 1986) and the draft Groundwater Monitoring (1992) guidance."*

To ensure a 50-year design life, longer screens are installed at the water table in wells near pumping centers. Based on water level data, wells in the regional aquifer near active production wells have had significant drawdown. Water level decline in test wells ranges from 0.1 to >1 ft/yr (Koch et al., 2004) (Figure 2). Further, the rate of drawdown has accelerated over 10 years for some test wells (e.g., TW-2, TW-3, and DT-10) in response to changes in pumping patterns among the supply wells. Characterization wells within the influence of a production well must have a long screen at the water table to be useful for 50 years. The length of screens at or near the water table varies from 7.6 to 65 ft, and the average screen length for screens at or near the water table is 36 ft.

For screen intervals below the regional aquifer water table, long screens are generally avoided. Up to 2003, there had been 39 non-water-table screens installed. The average length of screen is 10 ft, but varies between 3 and 40 ft. Only eight of the non-water-table screens are longer than 10 ft and of these 7 are in zones of perched groundwater where the longer screen is intended to represent the entire thickness of the zone of saturation. The single regional aquifer screen longer than 10 ft was required because the transmissive units were difficult to define or were of uncertain lateral connectivity.

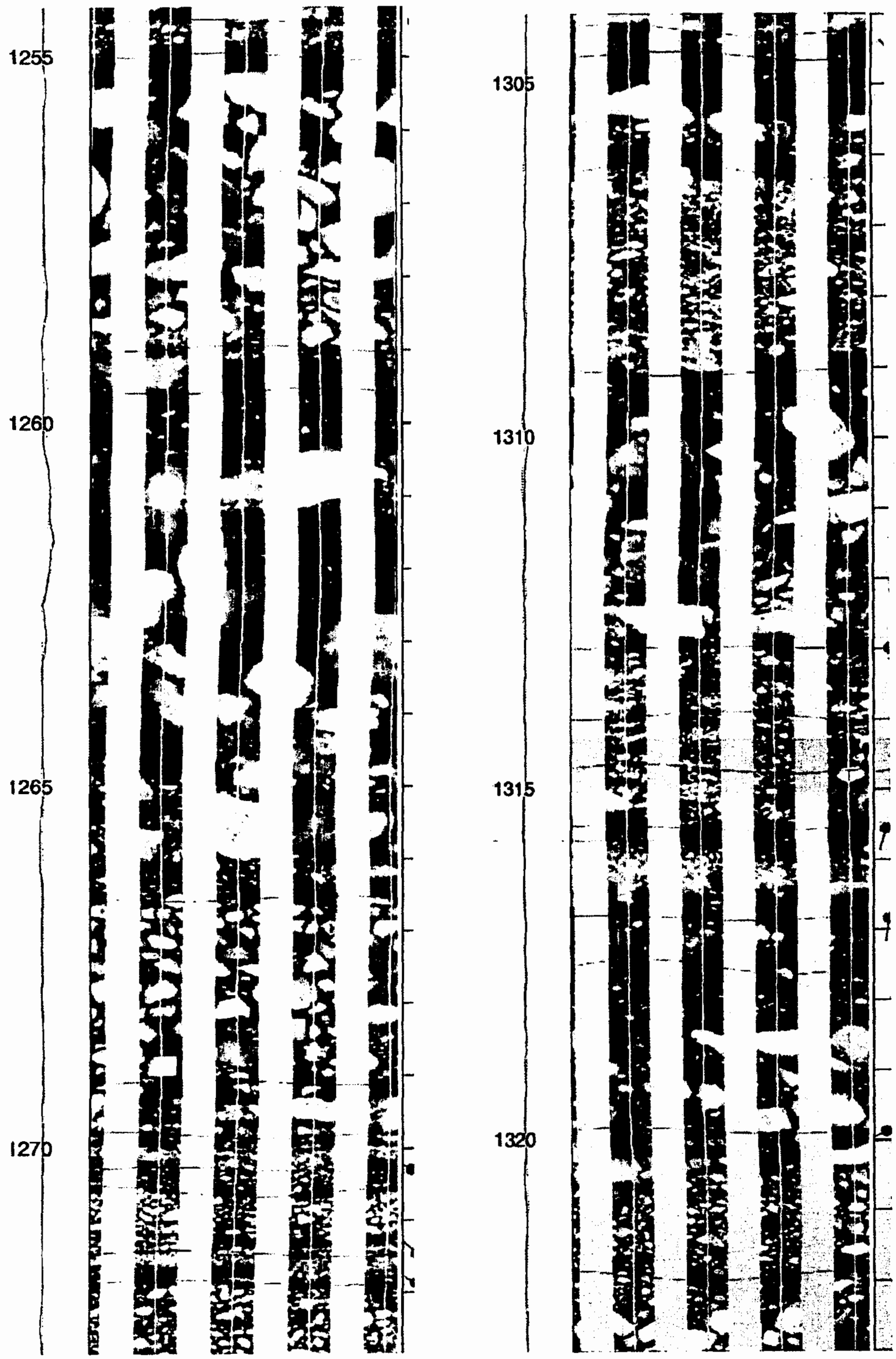


Figure 1. **Schlumberger Formation Microimage (FMI) of two 20-ft depth intervals within Puye Formation fanglomerates at well CdV-R-15-3**

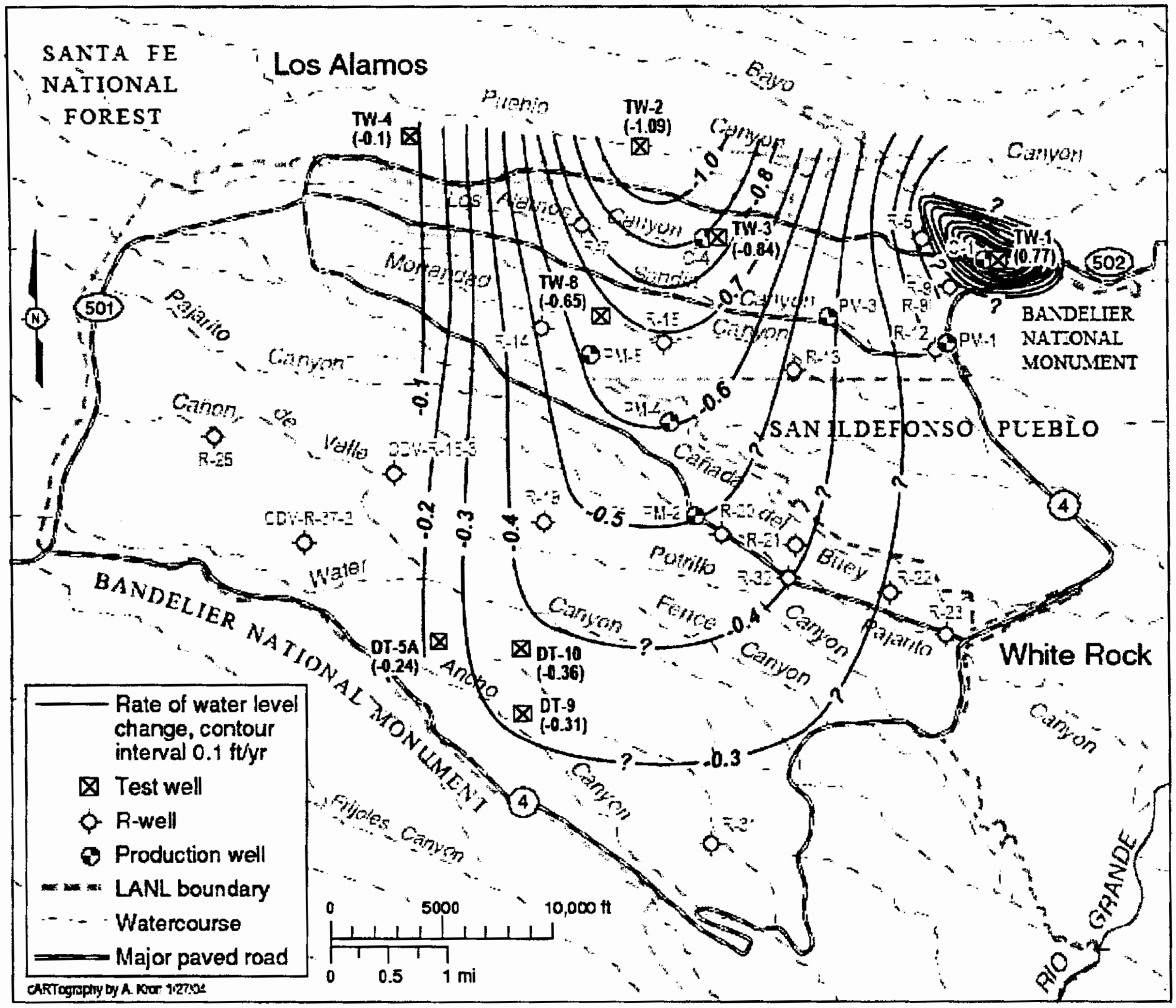


Figure 2. **Annual rate of change of water level in test wells, 1992-2003 (ft/yr) from Koch et al. (2004)**

Well Design at Specific Wells

The specifics of well drilling, hydrogeologic conditions, and well design for the wells cited by Gilkeson (2004) are provided in Table 3. Each of these wells achieved the primary objective of providing access to the regional aquifer either near the water table or within representative hydrostratigraphic units.

Table 3. Drilling Conditions, Hydrology, and Well Design for Selected Regional Aquifer Wells

Well Number	Location	Drilling History	Hydrogeologic Conditions	Screen Location and Rationale	Screen Length and Rationale
R-7	Los Alamos Canyon, at a location south of TA-21.	Phase 1: auger within alluvium to a depth of 13 ft to install conductor casing. Phase 2: fluid-assisted air-rotary methods with reverse circulation to drill to a depth of 1097 ft.	Drilling became exceptionally difficult when the Totavi Lentil (river gravels) was encountered (1087 ft) and caused collapsing conditions in the borehole.	***Screen 1***: located at 363.2–379.2 ft depth to target perched zone beneath the alluvium ***Screen 2:*** located at 730.4–746.4 ft depth to target zone of apparent saturation at the contact between pumice-poor and pumiceous sediments ***Screen 3:*** located at 895.5–937.4 ft depth to target regional aquifer water.	Screen 1 length: 16 ft; perched zone thickness. Screen 2 length: 16 ft; perched zone thickness. Screen 3 length: 41.9 ft straddles water table in area near water supply wells. Designed to allow sampling at the regional aquifer water table down canyon from and close to the Omega West reactor contaminant source. **Figure 3** shows this screened interval relative to four geophysical logs: the total water-filled porosity varies little despite stratigraphic complexity and the screen interval plus filter pack includes one of the highest intervals of intrinsic permeability near the water table. A screen could not be placed within the highly productive river gravels below 1087 ft because of unstable borehole.
R-15	Mortandad Canyon, at a location east-northeast of production well PM-5.	Phase 1: auger to 420 ft to collect core samples. Phase 2: air-rotary open borehole methods (upper 125 ft), air-rotary coring (limited to the base of the Cerros del Rio lavas at 740–751.5 ft depth), and casing advance with an air-rotary under-reamer to the total depth of 1107 ft. Casing-	Drilling became exceptionally difficult when Totavi Lentil (river gravels) was encountered at 1100 ft depth, where the borehole began collapsing. Perched water was detected at about 646–740 ft depth in the Cerros del Rio lavas, above clay-rich silt and silty sands. Perched water was sealed off with 13-in. casing set into	Single screen (958.6 to 1020.3 ft) across the top of the regional aquifer at 964 ft depth to allow analysis for contamination that might be moving downward naturally from the perched zone.	A 60-foot screen length was selected because R-15 is surrounded by water supply wells PM-3, PM-4, PM-5, and O-4. The drawdown is expected to be approximately 50 ft over 50 years. The screened interval provides access to strata with representative hydraulic conductivity. **Figure 4** shows several logs; the APS Array Far Porosity geophysical log indicates

Table 3 (continued).

Well Number	Location	Drilling History	Hydrogeologic Conditions	Screen Location and Rationale	Screen Length and Rationale
		advance drilling required lubrication of the casing with a mixture of TORKEASE and EZ-MUD polymer slurries.	a cement plug poured at 722–746 ft depth. No screen was placed in the perched horizon to ensure that cross contamination did not occur.		that porosity is consistent (0.15–0.3) throughout the screened interval, despite the occurrence of a stratigraphic contact at 973 ft between Puye pumice-poor fanglomerates and a deeper pumice-rich deposit. There is no indication of any hydrologic barrier between the two, as suggested by Gilkeson (2004). The only zone of higher transmissivity was within the Totavi Lentil river gravels below 1100 ft depth that could not be penetrated safely.
R-16	South rim of Cañada del Buey; east of the sewage treatment plant in White Rock	Fluid-assisted reverse-circulation air-rotary methods to 783 ft depth. Conventional mud-rotary methods to total depth of 1287 ft. The switch to mud-rotary drilling was made because of the difficulty and risk in drilling with air-rotary methods in Santa Fe Group sands.	55-ft-thick sequence of lakebed clays that occur between Cerros del Rio lava flows caused repeated bridging from 107–130 ft depth. An 11.75-in. casing was advanced through this interval to 729 ft depth. From 729–1287 ft there were intervals of lost circulation without cuttings returns at 867–887 ft and 903–1047 ft depth. The casing was seized by the lakebed clay interval and could not be removed. The stuck casing extends below screen 1, making that screen unusable.	***Screen 1***: the top of the regional aquifer in Puye fanglomerates (641.0–648.6 ft) - this screen cannot be used because it is behind the stuck casing ***Screen 2:*** regional aquifer in Santa Fe Group sands (863.4–870.9) ***Screen 3***: regional aquifer in Santa Fe Group sands (1014.8–1022.4 ft) ***Screen 4***: regional aquifer in Santa Fe Group sands (1237.0–1244.6 ft). The three lowest screens were positioned to sample potential flowpaths beneath the Rio Grande and toward the Buckman well field.	Screens 2, 3, and 4 (7-ft long) were placed in representative horizons within relatively homogeneous Santa Fe Group sediments. Greater screen lengths were not required in this relatively thin-bedded and homogeneous unit.

Table 3 (continued).

Well Number	Location	Drilling History	Hydrogeologic Conditions	Screen Location and Rationale	Screen Length and Rationale
R-22	East of the TA-54 waste disposal areas on Mesita del Buey.	Phase 1: auger within mesa-top Bandelier Tuff to a depth of 47 ft to install conductor casing. Phase 2: fluid-assisted air-rotary methods with dual-wall reverse circulation to 510 ft depth. Open hole drilling methods 510 ft to 1258 ft. Caving conditions (1160–1258 ft; near the base of Cerros del Rio lavas) were addressed by redrilling with casing advance to 1345 ft depth. Lost circulation and loss of sample returns occurred from 1178-1183 ft depth and 1191-1237 ft depth. Down-hole hammer used to drill open-hole from 1345 ft to TD at 1489 ft	No perched water was encountered at R-22. The first measurement of the top of regional saturation was at 883 ft depth. However, when the borehole was completed the depth to water was 955 ft. Geophysical logs indicated high saturation starting at 886 ft depth. These two alternative depths to the top of regional saturation were addressed with a final well design that had screens at each of these two depths.	***Screen 1*** (872.3–914.2) and ***Screen 2*** (947.0–988.9) were located to cover two conflicting interpretations of elevation for the regional water table. Note that intervals with higher permeability do occur in the Cerros del Rio basalt below screens 1 and 2; not all such intervals can be screened in every drill hole and in this case is was considered to be more important to capture the top of regional saturation so close to Area G. ***Screen 3*** (1272.2–1278.9) targeted Puye fanglomerates; this unit had two zones of lost circulation, but available cuttings and geophysical logs indicate Puye Formation throughout. The permeability log (**Figure 5**) indicates that the interval of lost circulation at 1191–1237 does not correspond with permeable river gravels as suggested by Gilkeson (2004). Screen 3 is located where the estimated permeability is highest (**Figure 5**). ***Screen 4*** (1447.3–1452.3) is in a portion of the Miocene lavas indicated by geophysical logging to have slightly low water-filled porosity but potentially greater capability for fracture transmissivity (high density, possibly corresponding with a fractured lava-flow interior). ***Screen 5*** (1447.3–1452.3 ft depth) is within older fanglomerates, with an extended lower sand pack that captures zones of relatively high estimated permeability.	Screens 1 and 2, targeting alternate interpretations of water table elevation, are 42 ft long to allow for water table decline under pumping effects from nearby wells. Screens 3, 4, 5 are <10 ft; greater screen lengths were not required in these specific hydrogeologic targets.

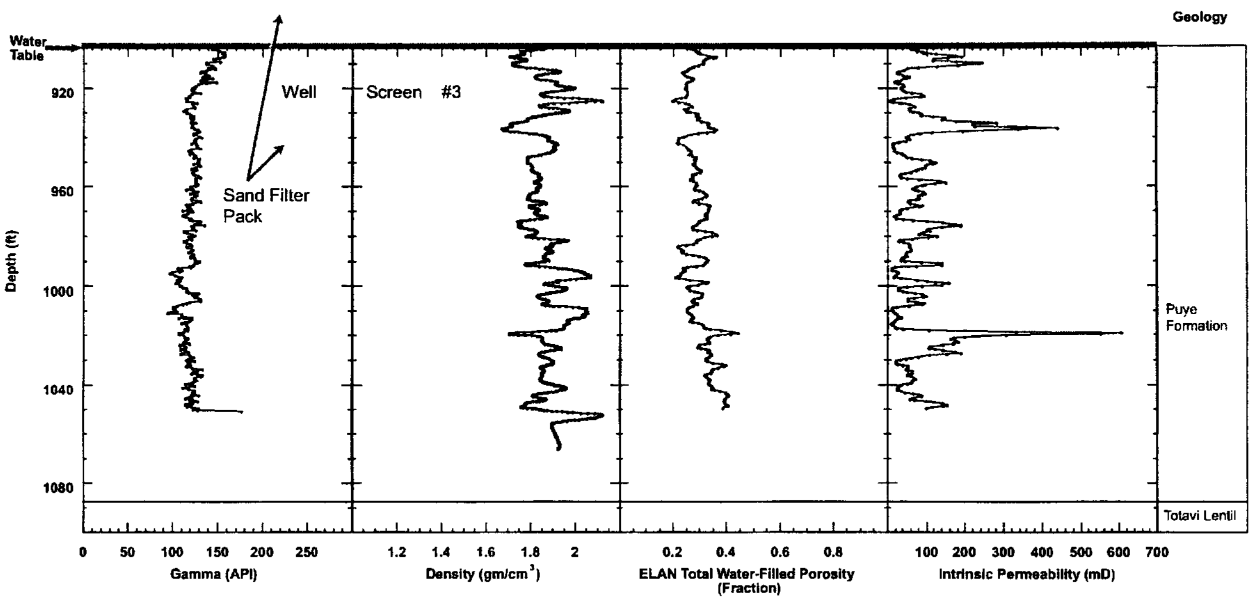


Figure 3. Geophysical logs and well screen location in the regional zone of saturation for well R-7

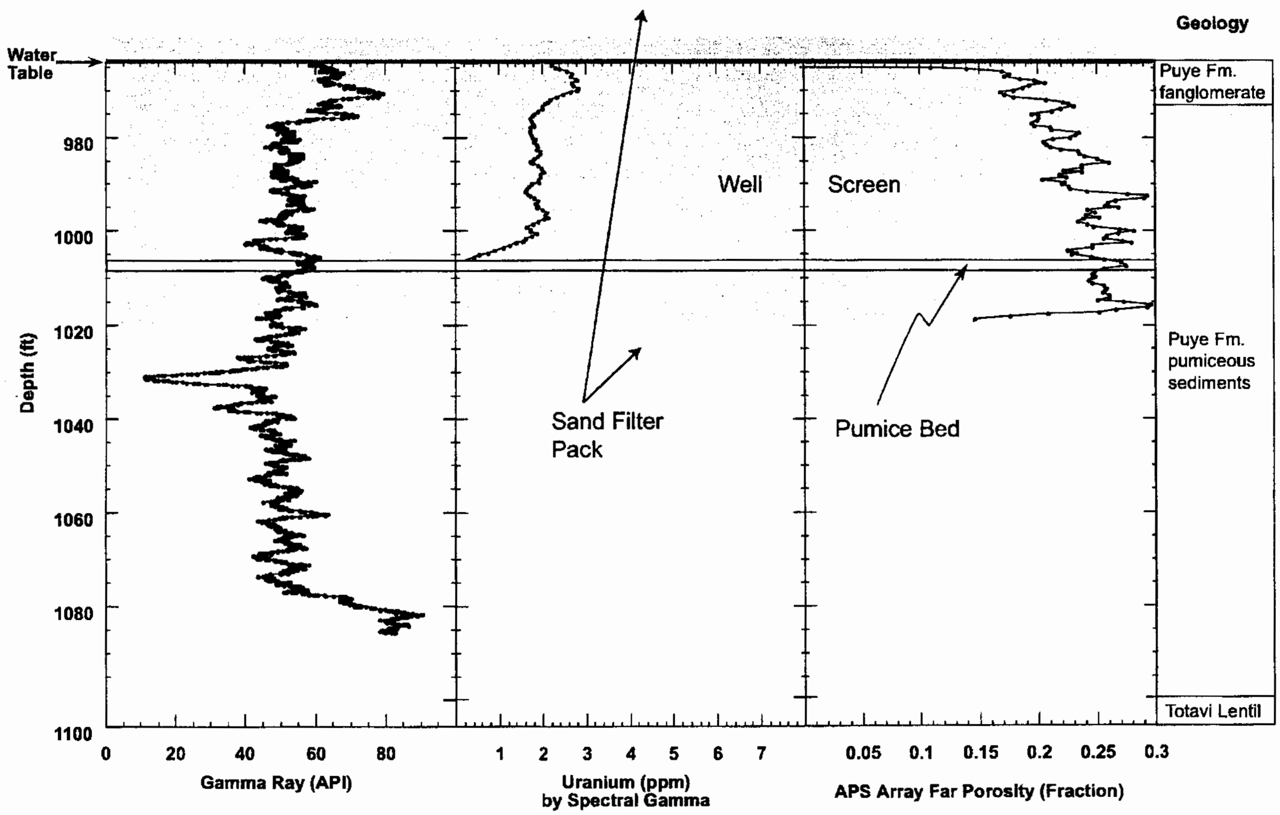


Figure 4. **Geophysical logs and well screen location in the regional zone of saturation for well R-15**

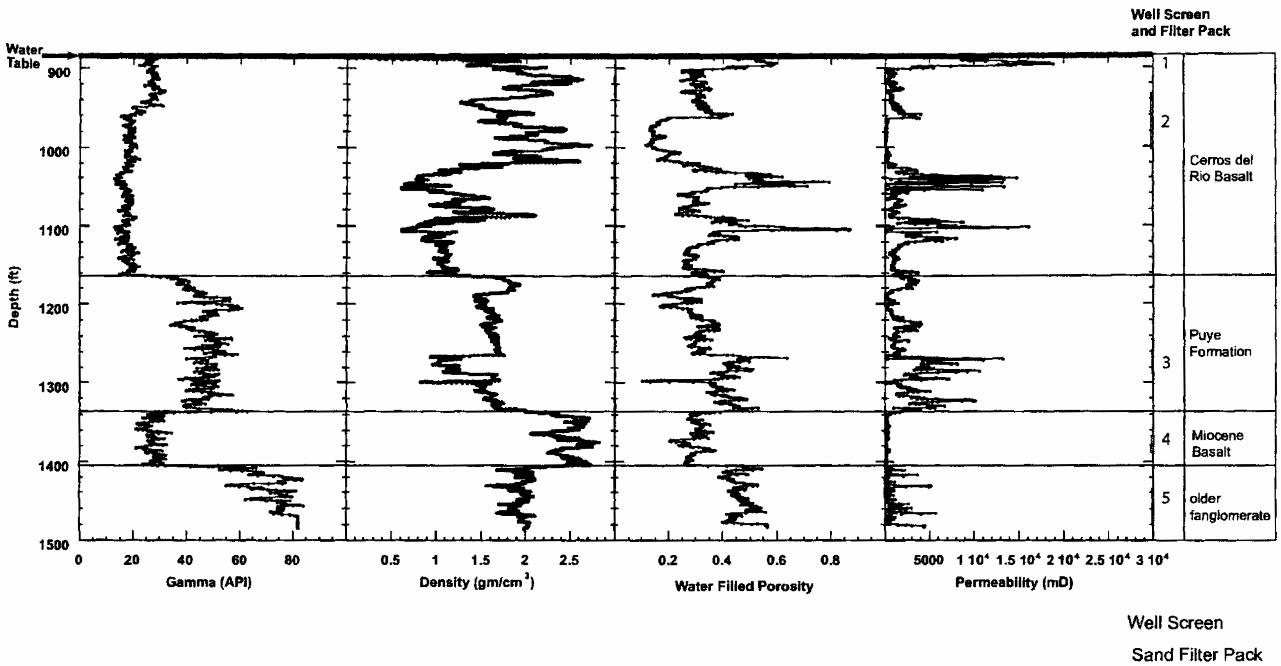


Figure 5. **Geophysical logs and well screen location in the regional zone of saturation for well R-22**

Question 3: What are the impacts of drilling fluids on the wells mentioned in Mr. Gilkeson's Report and what is being done about these concerns?

LANL used drilling fluids as part of its drilling methods as is standard industry practice for drilling deep wells. Without use of these fluids and drilling methods, drilling of some wells may not have been possible. The impacts of drilling fluids on groundwater chemistry have been described in geochemistry reports for each well (Longmire, 2002a, 2002b, 2002c, 2002d, 2002e and Longmire and Goff, 2002). The chemical and biological effects of residual drilling fluids on water quality samples are recognized and closely monitored to determine when the effects of drilling have dissipated. Mr. Gilkeson's report was concerned about the geochemical changes associated with drilling fluids (Gilkeson 2004, sections 4.0, 4.1, and 4.2). The majority of wells and screens are not impacted by residual drilling fluid and they have been identified and documented in Quarterly Meetings and geochemistry reports. Well development (described in response to Question 4) removes most of the fluids introduced during drilling.

The Laboratory has identified and documented the effects of residual drilling fluids within specific screens during public meetings, in annual status reports, and in geochemistry reports. The trend data presented in this report show improvement in sample quality over time, although the length of time to required to reach pre-drilling conditions is specific to each well. Well R-22 contains residual polymer-based drilling fluid producing reducing conditions in screens 1, 4, and 5 (Longmire, 2002e). Screen 3 is affected by bentonite and Screen 2 is unaffected by residual drilling fluids. Wells R-9 and R-15 provide chemical data largely representing pre-drilling conditions.

Drilling fluids can be defined as the fluid placed or circulated in the drilled hole during drilling operation. It is necessary to use drilling fluids to perform functions that include: cleaning the cuttings of the bit and the bottom of the borehole; transporting the cuttings to the surface; provide borehole stability, and cool the bit and lubricate the drill string. The two main types of drilling fluids are water-based fluids and air, generally with additives to improve the performance characteristics. Rotary drilling techniques cannot be employed without the use of drilling fluids.

Effects of Drilling Fluids on Groundwater Samples

When organic and inorganic substances used during drilling are added to groundwater, geochemical reactions occur that result in changes to the original water chemistry near the well. These reactions occur because the "system" is out of equilibrium with natural conditions. Eventually, equilibrium will be restored as groundwater near the well approaches its original or baseline composition. The type of reaction that takes place depends on the original (or baseline) condition of the groundwater and the chemistry and reactivity of the substances added.

Groundwater compositions are affected by adsorption/desorption, precipitation/dissolution, solution composition, partial pressures of gases (oxygen, nitrogen, and carbon dioxide), pH, temperature, and oxidation-reduction reactions. The effects of drilling additives on these processes are illustrated in Figures 6 and 7.

Under the natural or baseline conditions, groundwater within the regional aquifer is oxidizing. Naturally occurring dissolved oxygen, sulfate, and nitrate are stable under oxidizing conditions and dissolved concentrations of iron and manganese are less than 0.5 parts per million (ppm). As shown in Figures 6 and 7, dissolved, precipitated, and adsorbed species are present under the baseline oxidizing conditions. The dissolved species do not completely adsorb onto the aquifer materials. Under oxidizing conditions and neutral pH, naturally occurring dissolved species include calcium, sodium, magnesium, potassium, bicarbonate, chloride, and sulfate plus trace solutes (iron, manganese, uranium, nickel, and chromium). If present, some contaminants including perchlorate, tritium, and nitrate are stable as dissolved species because of their relatively high solubility and poor ability to adsorb onto aquifer solids.

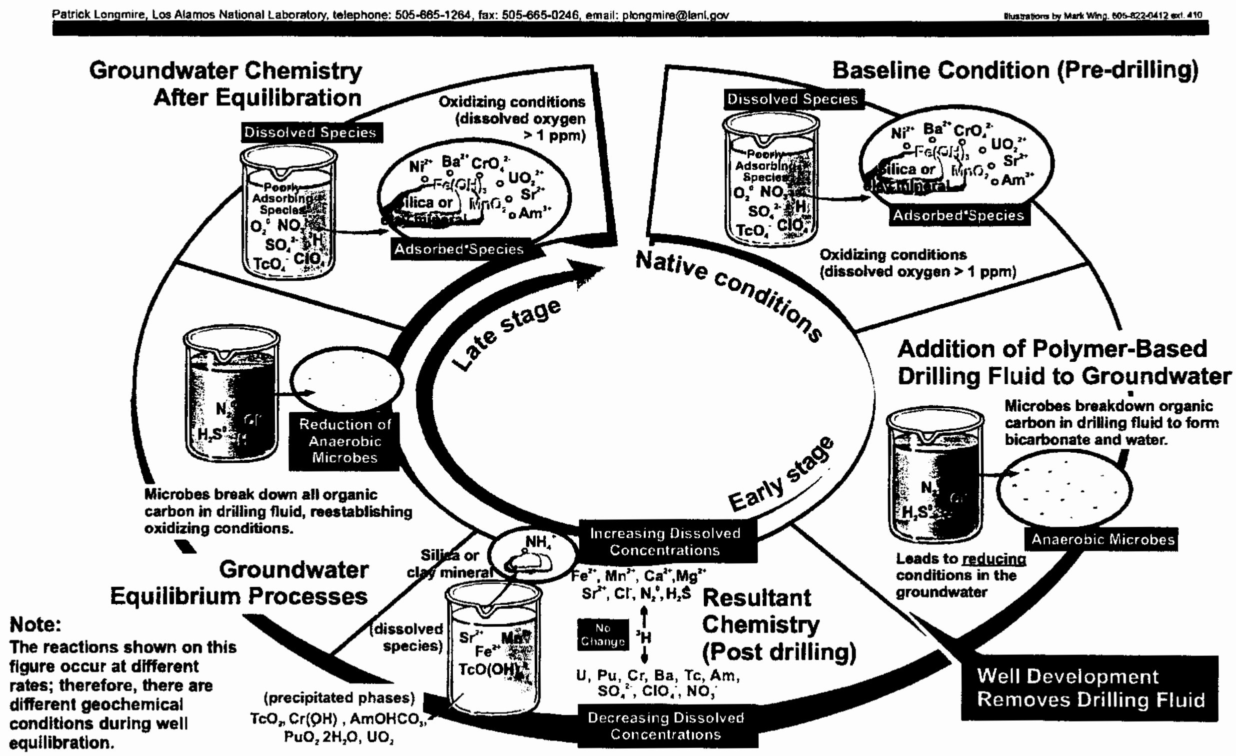


Figure 6. Effects of polymer-based drilling fluids on groundwater chemistry

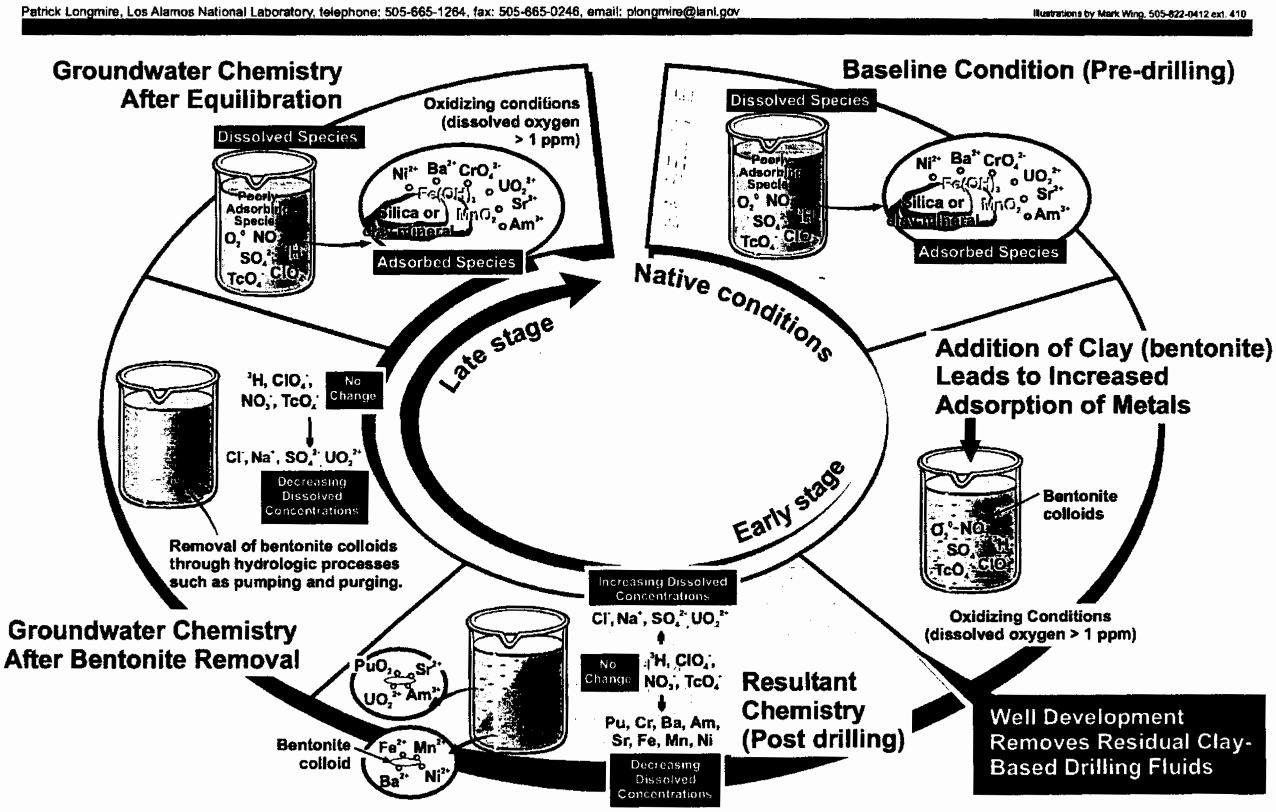


Figure 7. Effects of clay-based drilling fluids on groundwater chemistry

Adsorbed species interact with aquifer materials by adsorbing onto particles coated with ferric oxyhydroxide (rust) and/or manganese oxide. Many metals, for example, barium, chromium, nickel, uranium, and strontium normally adsorb onto coated particles within the groundwater when pH values are between 6 to 9 (Figure 6). If present, other radionuclides including plutonium, americium, and strontium adsorb onto aquifer solids.

The addition of organic-based drilling fluid (polymers) provides a nutrient source that allows naturally-occurring anaerobic microbes to grow. The consumption of the organic portions of the drilling fluid by these microbes changes the ordinarily oxidizing groundwater conditions to reducing conditions. The reducing environment causes a number of water chemistry changes illustrated in Figure 6:

- The particle coatings dissolve, so iron and manganese that made up the coatings are released into the water, thus concentrations of dissolved iron and manganese increase.
- Many of the constituents (metals and radionuclides) that were adsorbed to the iron and manganese coatings (uranium, plutonium, nickel, barium, chromium, and strontium) are released when the coatings dissolve. These constituents desorb, react, and either precipitate from solution (uranium, chromium, and plutonium) or can be dissolved in groundwater (strontium, nickel, chromium, arsenic, barium).
- Sulfate, nitrate plus nitrite, and perchlorate become reduced to hydrogen sulfide, ammonium and/or nitrogen gas, and chloride, respectively, which results in concentration decreases of nitrate, perchlorate, and sulfate. Hydrogen sulfide gas resulting from the reduction of sulfate has been observed when sampling at wells R-7 (Longmire and Goff, 2002) and R-22 (Longmire, 2002c)
- Concentrations of total organic carbon (TOC), which includes dissolved organic carbon (DOC) initially increase above the baseline concentration of 2 parts per billion (ppb) as the polymer-based drilling fluid dissolves. Well development removes water from the screen until the TOC measures as close to 2 ppb as possible (see Question 4 response). The residual TOC is converted to bicarbonate, which results in increases in the concentration of total alkalinity.
- Concentrations of total Kjeldahl nitrogen (TKN) (organic nitrogen) increase as the polymer drilling fluid dissociates or breaks down.
- Total dissolved solids (TDS) (includes total alkalinity) increase because of partial dissolution of aquifer material and oxidation of residual drilling fluids (TOC converted to bicarbonate).

All of the changes that result from the introduction of drilling fluids are ultimately reversible, although kinetics of chemical reactions and hydrologic properties of aquifer material are factors that control how fast reversal occurs. After polymer-drilling fluids are removed by well development or broken down over time by microbes, oxidizing conditions are re-established and re-precipitation of ferric oxyhydroxide and manganese oxide takes place. Dissolved concentrations of metals and trace elements should decrease and return to pre-drilling conditions. The dissolved metals may re-adsorb onto the newly precipitated solids near the well screen and other areas where residual fluids are breaking down. Dissolved uranium concentrations are expected to increase as oxidizing conditions are restored near the well screens because the reduced, precipitated uranium is no longer stable and dissolves during reoxidation.

Figure 7 illustrates the geochemical changes that occur when bentonite mud is added to groundwater. The soluble constituents of bentonite are dissolved in groundwater water, increasing the concentration of chloride, sodium, sulfate, and uranium. Uranium naturally occurs in bentonite used for well drilling and construction. Metals that were dissolved in the groundwater adsorb to the bentonite colloids, which results in decreasing concentrations of those metals, such as manganese, nickel, plutonium, iron, strontium, barium, americium, chromium. Once the bentonite colloids are removed by well development and pumping, pre-drilling conditions should be re-established. Constituents such as tritium, perchlorate, nitrate, and pertechnetate (TcO_4^-) are not affected by the presence of bentonite because they do not adsorb onto bentonite.

Empirical observations of these reactions are documented a series of geochemistry reports which address the impact of residual drilling fluid on groundwater chemistry (Longmire, 2002a, 2002b, 2002c, 2002d, 2002e, and Longmire and Goff, 2002). Some examples of these observations are:

- **Total carbonate alkalinity (Figure 8)**: This parameter in wells R-7 (screen 3), R-9, and R-15 are within LANL background range, but are higher than background in well R-12 (screen 3) and well R-22 (screen 4). Background in based on 91 background water samples with a mean equal to 190 ± 118 mg/L [2 σ] or 2 standard deviations.
- **Dissolved iron (Figure 9), manganese (Figure 10), and organic carbon (TOC) (Figure 11):** at wells R-9 and R-15 these parameters are generally within LANL background. Concentrations of these analytes in wells R-7 (screen 3), R-12 (screen 3), and R-22 (screen 4) are much higher than background.
- **Uranium:** Wells R-7 (screen 3) and R-22 (screens 1, 4, and 5) have uranium concentrations below LANL background. These very low uranium values suggest uranium precipitation and are most likely caused by the presence of residual drilling fluid (113 background samples average 1.1 ppb). The uranium precipitation process was documented in wells R-7 (Longmire and Goff, 2002), R-9i (Longmire, 2002b) and R-22 (Longmire, 2002c). When the pre-drilling oxidizing environment is restored, dissolved concentrations of uranium will approach pre-drilling levels for both natural and LANL-derived uranium.

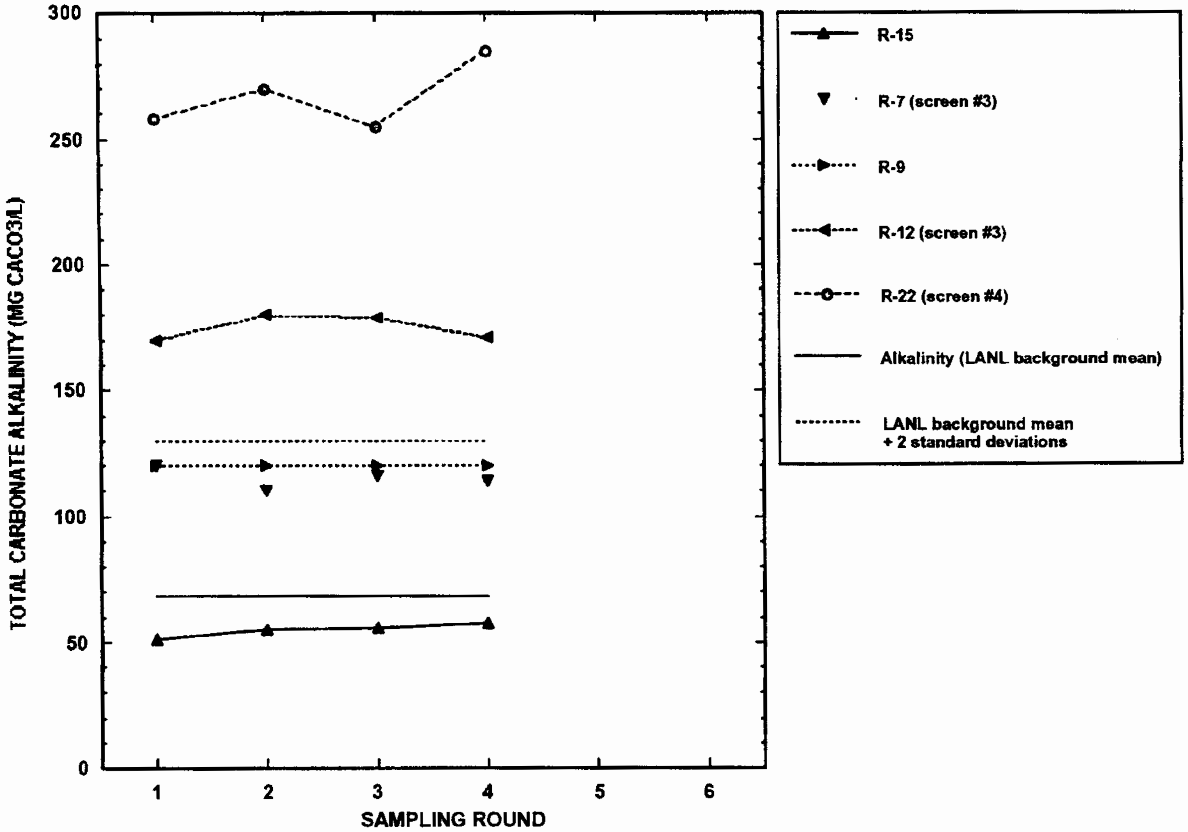
> Two **standard deviations** indicate that 95 out of 100 samples have concentrations within the indicated range (e.g., 12 ± 3) in a normal or "bell shaped" distribution. Two standard deviations is also symbolized as 2σ.

Environmental Tracers in Decision-Making

Recognizing that data from certain well screens are not yet reliable due to the presence of residual drilling fluids, certain conservative tracers (nitrate, tritium, perchlorate) are used to evaluate the potential for contamination to be present. Conservative tracers are non-reactive chemicals that have reached groundwater. These tracers move at the speed of the groundwater. The most important of these tracers is tritium (some of which is present in all waters <60 yr old because of global atmospheric testing), but nitrate and perchlorate are also useful tracers under oxidizing conditions.

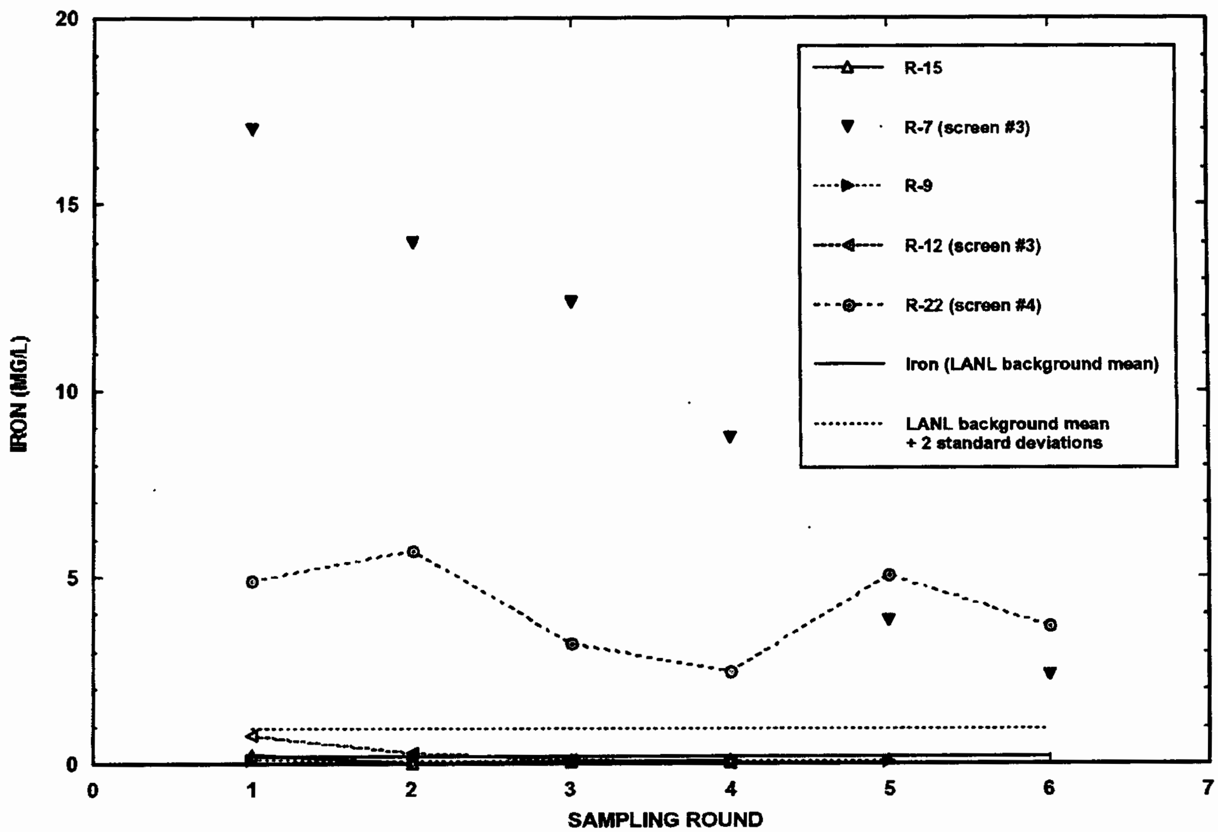
If these tracers are present, it suggests that some of the water is less than 60 years old and there is a potential that other contaminants are present. If none of the tracers are present, especially tritium, the groundwater is quite old and there is little chance that Laboratory-derived contaminants could be present. For example, if mobile radionuclides such as tritium and pertechnetate are not detected in groundwater containing residual drilling fluid, then it is very unlikely that other more strongly adsorbing radionuclides, including strontium-90, cesium-137, americium-241, and plutonium-238,239,240, are present or affected by the drilling fluid.

On the other hand, if tritium is present in a well containing residual drilling fluids and other radionuclides were detected during drilling and their concentrations decreased during characterization sampling, then the analytical results would be extremely biased. These data would be of limited use for decision making and monitoring purposes for adsorbing radionuclides. Table 4 summarizes the geochemical status of each well cited by Gilkeson (2004).



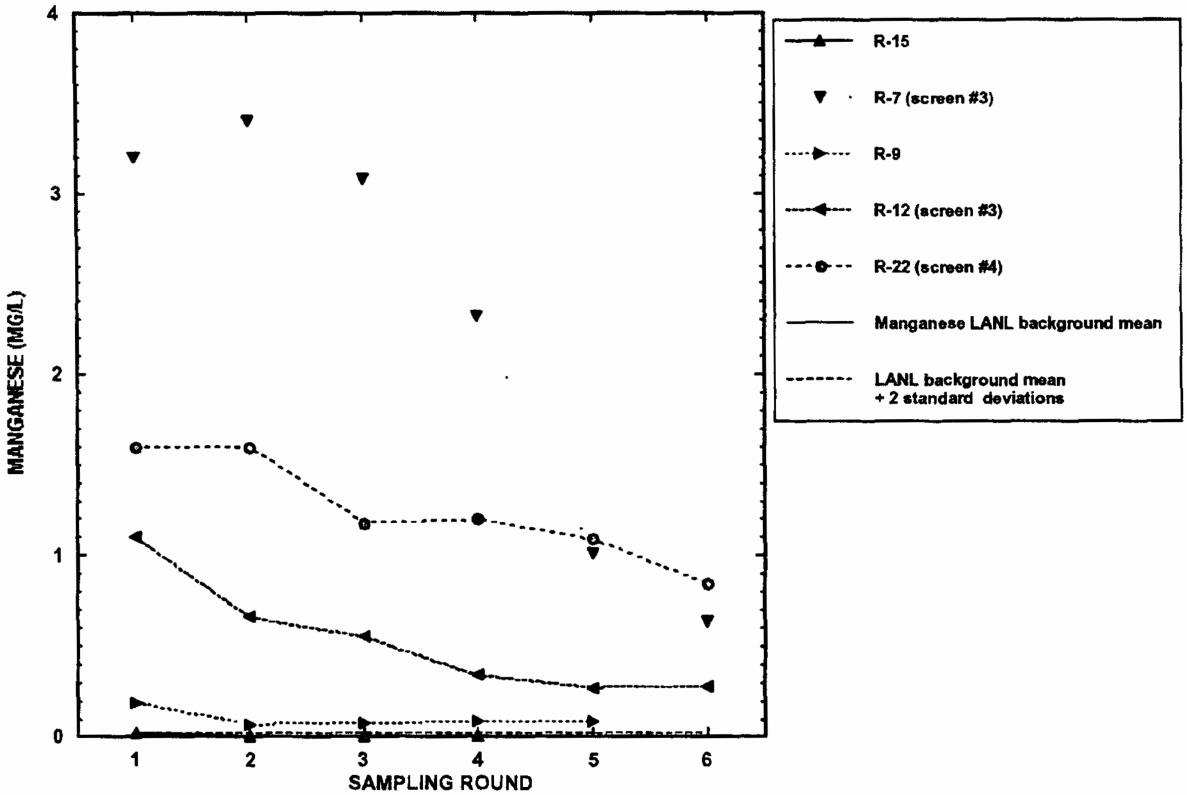
Note: LANL background for total alkalinity consists of 91 groundwater samples. Two standard deviations plus the mean indicate that 95 out of 100 background samples analyzed for total alkalinity will fall within a normal distribution.

Figure 8. Concentrations of total alkalinity (mg $CaCO_3$/L) in wells R-7, R-9, R-12, R-15, and R-22 during characterization sampling



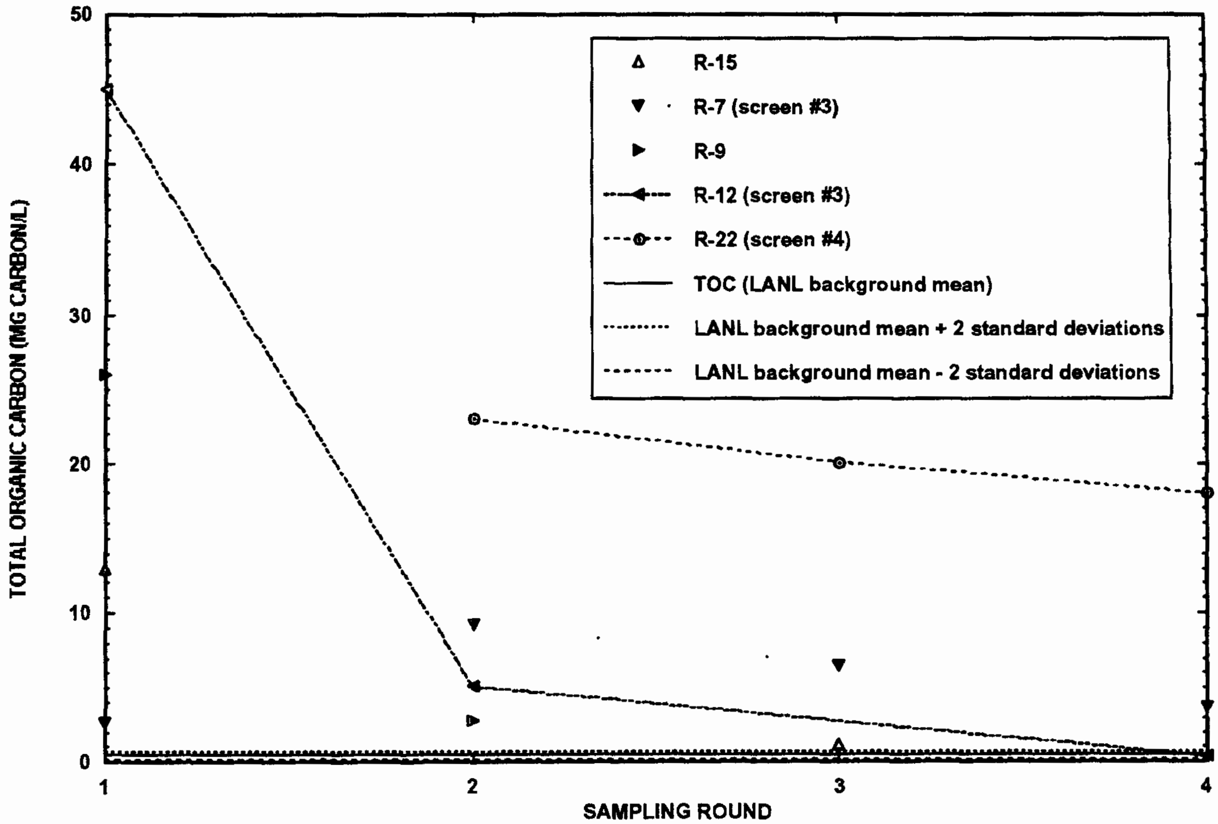
Note: LANL background iron consists of 91 groundwater samples. Non-filtered samples were collected from wells R-7, R-9, R-12, R-15, and R-22 during fifth and sixth sampling rounds. Two standard deviations plus the mean indicate that 95 out of 100 background samples analyzed for dissolved iron will fall within a normal distribution.

Figure 9. Concentrations of dissolved iron (mg/L) in wells R-7, R-9, R-12, R-15, and R-22 during characterization sampling



Note: LANL background manganese consists of 91 groundwater samples. Non-filtered samples were collected from wells R-7, R-9, R-12, R-15, and R-22 during fifth and sixth sampling rounds. Two standard deviations plus the mean indicate that 95 out of 100 background samples analyzed for dissolved manganese will fall within a normal distribution.

Figure 10. Concentrations of dissolved manganese (mg/L) in wells R-7, R-9, R-12, R-15, and R-22 during characterization sampling



Note: LANL background TOC consists of 15 groundwater samples. Two standard deviations plus the mean indicate that 95 out of 100 background samples analyzed for TOC will fall within a normal distribution.

Figure 11. Concentrations of total organic carbon (TOC) (mg carbon/L) in wells R-7, R-9, R-12, R-15, and R-22 during characterization sampling

Table 4. Status of Selected Wells with Respect to Geochemical Conditions

Well	Chemistry with Respect to Expected Baseline Conditions	Representative Chemistry?
R-7	**Screen 1:** Nitrate, iron, strontium, and manganese concentrations consistent with background. **Screen 2:** Dry **Screen 3:** Presence of TOC & DOC; elevated iron and manganese concentrations; and dissolved nitrate, sulfate and uranium are below background (not detected).	Screen1 is representative of pre-drilling water chemistry; Screen 3 is not yet representative.
R-9	Nitrate, iron, total carbonate alkalinity, and strontium concentrations are consistent with background.	Single screen is representative of pre-drilling water chemistry.
R-9i	**Screen 1:** Presence of TOC & DOC; elevated iron and manganese concentrations; and dissolved nitrate are below background (very low or not detected) **Screen 2**: Presence of TOC & DOC; elevated iron and manganese concentrations; dissolved nitrate below background (very low or not detected)	Screens 1 and 2 are not yet representative of pre-drilling chemistry. Uranium-nitrate reduction, possible impact from Cerro Grande fire.
R-15	Total carbonate alkalinity, iron, strontium, and manganese concentrations are consistent with background.	Single screen is representative of pre-drilling chemistry. Presence of elevated nitrate and perchlorate concentrations (LANL-derived) demonstrates that the screen is not impacted by residual drilling fluids.
R-16	**One sampling round available.** **Screen 2:** Nitrate, iron, and manganese concentrations are consistent with background. Elevated concentrations of sodium, strontium, sulfate, and ammonium indicate residual bentonite. **Screen 3:** Nitrate, iron, and manganese concentrations are consistent with background. Elevated concentrations of sodium, strontium, sulfate, ammonium, and uranium indicate residual bentonite. **Screen 4:** Nitrate, iron, and manganese concentrations are consistent with background. Elevated concentrations of sodium, strontium, sulfate, ammonium, and uranium indicate residual bentonite.	Screens 2, 3, 4 are not yet representative of pre-drilling chemistry, they are affected by bentonite mud
R-22	**Screen 1**: Presence of TOC, DOC, elevated concentrations of iron and manganese, non-detection of dissolved sulfate and nitrate, and uranium below background. **Screen 2:** Major ion chemistry consistent with background and low concentrations of iron, manganese, and TOC. **Screen 3:** Nitrate, iron, and manganese concentrations consistent with background. Elevated concentrations of sodium and sulfate indicate residual bentonite is present. **Screen 4:** Presence of TOC, DOC, elevated concentrations of iron and manganese, non-detection of dissolved sulfate and nitrate, and uranium below background. **Screen 5:** Presence of TOC, DOC, elevated concentrations of iron and manganese, non-detection of dissolved sulfate and nitrate, and uranium below background.	Screens 1, 3, 4, 5 are not yet representative, although residual drilling fluid is breaking down through oxidation reactions and concentrations of sulfate are returning above detection. Screen #2 is the least affected by residual drilling fluid and has representative water chemistry.

Question 4: How does Los Alamos National Laboratory develop regional aquifer wells to mitigate the effects of drilling on in situ conditions?

The well development procedures at LANL are consistent with industry standards. LANL has gone above and beyond industry by ensuring that no additives were used without complete analytical characterization and by making the concentration of TOC a performance criterion for satisfactory well development. Mr. Gilkeson expressed concerns that the well development process at LANL was inadequate at specific wells. Obtaining high quality data has been the ultimate goal of the well development process. Changes in drilling methods were analyzed and corresponding changes were made in the well development program to address impacts resulting from the drilling method.

The LANL drilling program has adapted the well development procedures along with the drilling strategy and techniques to overcome the unique geology and drilling problems inherent with the Pajarito Plateau. Every drilling method will impact the natural groundwater chemistry or formation properties, some methods more than others. Well development is the combination of processes used to restore the borehole wall damaged during well drilling. Well development restores or improves porosity and permeability of the formation materials around the well screen. Ultimately the well will yield groundwater samples representative of the natural groundwater. The LANL drilling program has expended much time and effort in refining the well development process to achieve these goals. Table 5 summarizes the development techniques used in the wells cited in the report by Gilkeson (2004).

Prior to their consideration for use in LANL drilling activities, samples of each drill additive were requested from the distributor/manufacturer and submitted to outside laboratories for analytical characterization. This was done for the following reasons:

1. To determine if any hazardous constituents were present that would preclude their use in LANL wells.
2. To understand the chemical makeup of the additive and what chemical reactions or interactions could potentially take place to affect the natural ground water chemistry at the well site.
3. To determine what to monitor for during well development to ensure maximum removal of all introduced additives by well development.

Standard operating procedures (SOPs) for well development were used to ensure that the development process is consistent and the water quality parameters meet the performance criteria specified in the SOP. To monitor the effectiveness of well development, a suite of ground water parameters are carefully and frequently measured. These parameters are those typically monitored for well development and they include: temperature, pH, specific conductance, and turbidity. However, an additional parameter, TOC was added to specifically identify the presence of residual drill fluid during the development process. Table 5 includes the well development parameter values at the conclusion of development.

Table 5. Well Development Methods, Volume of Fluid Used, and Well Development Parameters in Selected Regional Aquifer Wells

Well	Development Methods	Volume of Fluids				Final Parameters Measured at Completion of Well Development in Each Screen				
		Used During Drilling (gal.)	Removed During Development (gal.)	Removed During Testing (gal.)	Total Volume of Fluid Removed (gal.)/% of Fluid Added	pH	Temp (°C)	Specific Conductance (µS/cm)	Turbidity (NTU)	Total Organic Carbon (mgC/L)
R-14	Wire brushing, surging and bailing, pumping w/ packer isolation of zones, chemical development (AQUA-CLEAR MGA and AE)	126,500	205,010	4,750	209,760/ 165%	#1: 6.9 #2: 6.7	#1: 22.9 #2: 23.2	#1: 132 #2: 130	#1: <1 #2: <1	#1: 2.44 #2: 1.95
R-20	Wire brushing, surging and bailing, chemical development (AQUA-CLEAR MGA and AE), pumping	85,400	87,008	8,840	95,848/ 112%	#1: 7.3 #2: 7.0 #3: 6.7	#1: 23.4 #2: 21.8 #3: 20	#1: 132 #2: 128 #3: 108	#1: 1.11 #2: 2.8 #3: 4.2	#1: 1.82 #2: 2.13 #3: 2.77
R-23	Wire brushing, bailing and surging, pumping	55,000	31,870	Na	31,870/ 58%	7.3	18.9	107	1.4	<1
R-32	Wire brushing, surging and bailing, pumping w/ packer isolation of zones, chemical development (AQUA-CLEAR MGA and AE)	98,000	114,970	28,900	143,890/ 146%	#1: 6.9 #2: 6.8 #3: 6.8	#1: 24.4 #2: 23.6 #3: 22.4	#1: 251 #2: 143 #3: 97	#1: 3.7 #2: 3.3 #3: 1.9	#1: 4.58 #2: 8.43 #3: 5.77
R-16	Wire brushing, swabbing, surging and bailing, jetting, chemical development (AQUA-CLEAR MGA and AE), pumping w/ packer isolation of zones	74,150	76,850	22,800	99,650/ 134%	#2: 8.0 #3: 7.8 #4: 8.1	#2: 24.3 #3: 24.6 #4: 21.9	#2: 170 #3: 194 #4: 182	#2: 1.34 #3: <1 #4: 1.9	#2: 1.57 #3: 1.90 #4: 2.18
R-21	Wire brushing, bailing and surging, pumping	19,000	3,205	13,337	16,542/ 87%	7.9	22.6	137	2.3	5.90

Members of the External Advisory Group (EAG) reviewed the well development procedures and compared them to industry standards (Powell and Schafer, 2002). Their report had the following conclusions:

> *"Development procedures used heretofore at LANL are standard and appropriate procedures, consistent with ASTM standards and accepted groundwater industry practice. However, the unique conditions at LANL require that additional development measures be considered as presented previously in this report. Included in this approach are the following:*
>
> - *Having the ability to isolate the screened zones in multiple completion wells for all development methods*
> - *In consultation with the drilling contractor select a development method(s) based on its effectiveness, practicality, and cost/benefit ratio.*
> - *Have the final development step be pumping the individual isolated screened zones as vigorously as possible".*

New well development procedures, based on the recommendations in the Powell and Schafer (2002) review, were implemented. The new procedures emphasized development immediately after the wells were installed, in order to remove the wall cake from the borehole. Additional development techniques involved:

- Using packers to isolate screens to pump directly from that interval in the multi-screened well installations,
- Using standard development chemicals to break down the additives used during drilling,
- Experimental jetting at the R-16 well
- Removing significantly large volumes of water during the pumping phase of well development. An average of 135% more groundwater/water was removed than was added in the multiple screened wells (Table 5).

Polymer-based fluids, such as EZ-MUD and TORKEASE, were used in all of the wells to provide lubrication between the casing advance system and the borehole wall. All products were chemically analyzed to determine their potential impact on the natural ground water chemistry. Relatively small quantities were in use during the drilling of the earliest wells in the program. Larger quantities have been used on the more recent wells, as they have been very effective at controlling the drilling problems that are frequently encountered. Once the water table is encountered, the use of additive is greatly reduced so that impact to the natural groundwater chemistry is minimized.

Fluid-assisted air and mud rotary drilling methods were used to drill R-14, R-16, R-20, R-23, and R-32 along with approved additives that addressed specific drill problems at each site (see Table 1). The exception is the R-21 well which was drilled by fluid-assisted air-rotary methods in an open hole. Representatives from the drilling additive manufacturer were on site to provide expertise on the proper use and formulation of their products during drilling of these wells. This additional oversight was invaluable to the successful drilling of these wells.

Well development methods (Table 5) were further revised to address the use of bentonite- based drill fluids. Additional time and care were used to remove bentonite and minimize any adverse impacts to the natural ground water chemistry and formation properties. In addition, Mr. David Schafer (a member of the

EAG) observed a portion of the development activities and provided recommendations on how to improve the development processes.

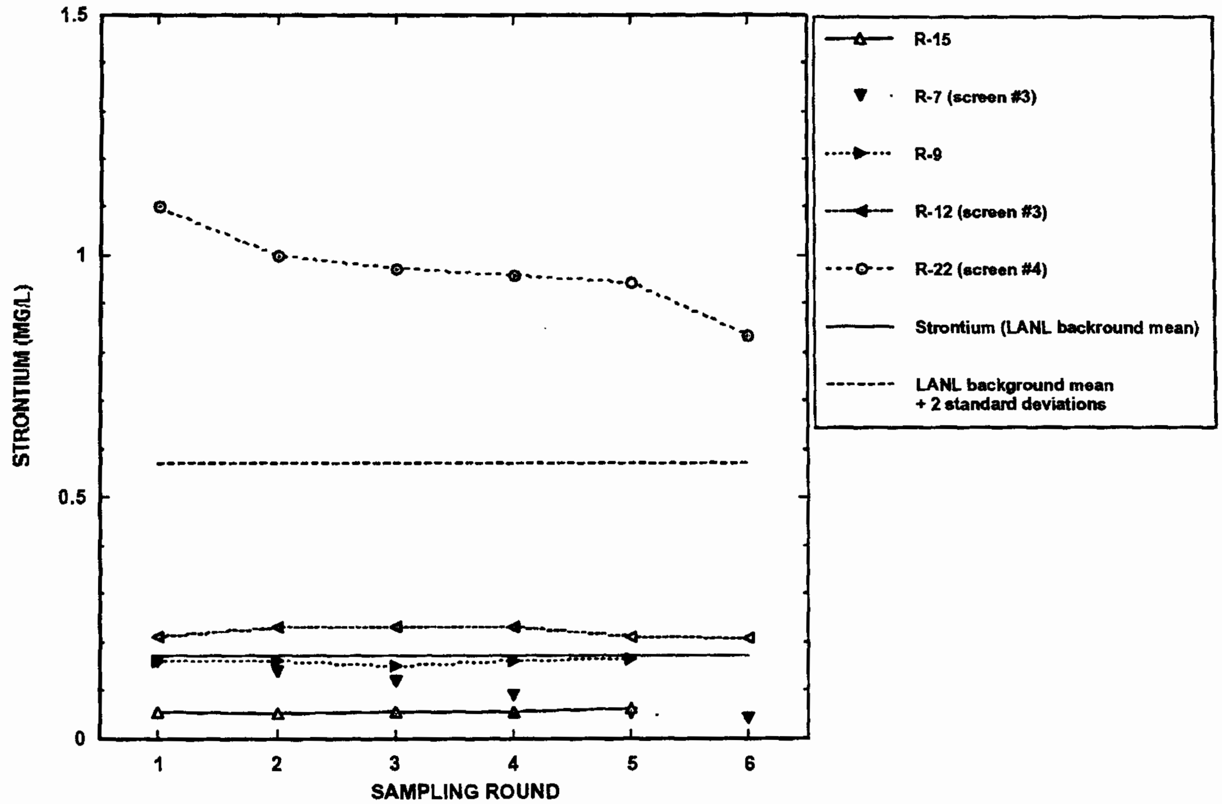
Question 5: What do groundwater data show regarding technetium-99, strontium-90, and other contaminants that Mr. Gilkeson focuses on?

Geochemical data from wells R-7 and R-22 show that contaminants cited by Gilkeson (2004) are not present at detectable levels in the regional aquifer. Gilkeson's report (2004, sections 5.0, 6.0, 7.0, and 9.0) suggests that specific contaminants are actually present in the regional aquifer at wells R-7 and R-22 where they have been reported as not detected. Mr. Gilkeson also discusses contaminants in the perched zone at well R-9i and the regional aquifer at well R-15, the presence of which has been previously reported by LANL and is not disputed here. LANL acknowledges impacts to the regional aquifer at five general locations or canyon systems (TA-16, Pueblo, Los Alamos, Sandia, and Mortandad Canyons). A limited number of contaminants (nitrate, perchlorate, tritium, uranium, and high explosive compounds [RDX, TNT] and degradation products associated with TNT) have been measured in the regional aquifer beneath these five areas. However, groundwater samples collected and analyzed from the regional aquifer at wells R-7 and R-22 do not contain americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, or technetium-99 in measurable quantities. This response addresses the geochemical conditions at R-7 and R-22.

Well R-7

Well R-7 is located in upper Los Alamos Canyon. The primary purpose of the well was to assess groundwater chemistry/water quality down-gradient from TA-2. Strontium-90, tritium, cesium-137 and other radionuclides were released from TA-2 in the past. These radionuclides are present in channel sediments and alluvial groundwater. For example, the concentration of tritium in an up gradient alluvial well LAO-1 was 16,000 pCi/L in 1994 (EPG, 1995). However, the regional aquifer at R-7 is remarkably untouched by the contamination at the surface. Concentrations of tritium in the regional aquifer at well R-7 (screen 3) ranged from 1.34 to 2.52 pCi/L during characterization sampling, suggesting that the regional aquifer at this location does not have a significant portion of water younger than 60 years and is not impacted by Laboratory-derived contamination (Longmire and Goff, 2002). Concentrations of the other radionuclides in the regional aquifer were below detection limits at well R-7. This strongly suggests that the regional aquifer at the location of well R-7 has not been impacted from past releases from TA-2.

Figure 5 in the report by Gilkeson (2004) is a graph showing concentration of natural strontium and strontium-90 over a period from May 2001 to February 2002. Actually, the points on Mr. Gilkeson's graph represent the instrument detection limit (IDL) for strontium-90 using gas proportional counting. There is an apparent decrease during that period because the method detection limit (MDL) for this analytical method decreased as the matrix interferences diminished. Matrix interference reduces the accuracy of analytical results and comes from increased solutes in the water after drilling. These solutes are alkaline earth elements, and include magnesium, calcium, strontium and other beta-emitting isotopes that can cause interferences with strontium-90 analysis. Concentrations of natural strontium (Figure 12), magnesium, and calcium decreased during characterization sampling at well R-7 (screen 3) (Longmire and Goff, 2002). These concentration decreases are due to removal of residual drilling fluid as equilibrium conditions become re-established. The similar trend in all of these elements explains the decrease in matrix interference and accompanying lowering of the IDL for strontium-90. There has been no analytical detection of strontium-90 in regional aquifer samples from well R-7, despite the decreased IDL and concomitant increased ability to detect it.



Note: LANL background strontium consists of 91 groundwater samples. Non-filtered samples were collected from wells R-7, R-9, R-12, R-15, and R-22 during fifth and sixth sampling rounds. Two standard deviations plus the mean indicate that 95 out of 100 background samples analyzed for dissolved strontium will fall within a normal distribution.

Figure 12. Concentrations of dissolved strontium (mg/L) in wells R-7, R-9, R-12, R-15, and R-22 during characterization sampling

Natural strontium and strontium-90 have the same adsorption/desorption characteristics. Natural strontium is present at elevated levels in the regional aquifer at well R-7 (screen 3), most likely the effect of residual drilling fluid. If strontium-90 were present, it would be elevated by the same geochemical processes as effected natural strontium. The detection of natural strontium at R-7, but no detections of strontium-90 indicates that strontium-90 is not present in the regional aquifer at well R-7.

Strontium-90 is not present in the regional aquifer at well R-7. This conclusion is based on consistent analytical non-detection of strontium-90 at well R-7 and is supported by the geochemical data described above and by Longmire and Goff (2002).

Well R-22

Characterization well R-22 is located east of the TA-54 waste disposal areas on Mesita del Buey. The primary purpose of the well was to assess water chemistry on the down-gradient boundary of Material Disposal Area (MDA) G in TA-54, a low-level radioactive waste disposal area.

Well R-22 is completed with 5 screened intervals in the regional aquifer. No intermediate perched groundwater is present at this location. The characterization sampling has been completed and a geochemistry report has been published describing the analytical results (Longmire, 2002c). As described in the geochemistry report (Longmire, 2002c) and in the answer to Question 3 in this document, screens 1, 3, 4, and 5 have not equilibrated and are affected by residual drilling fluids. However, screen 2 provides water samples that are probably representative of pre-drilling conditions.

A summary of what has been found and reported at R-22 by Longmire (2002c):

- There have been no detections of americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, or strontium-90 in any groundwater samples from R-22.
- Technetium-99 was only detected in water from well R-22 at concentrations of 4.3 pCi/L (screen 4) and 4.9 pCi/L (screen 3) during the first characterization sampling round (Longmire, 2002c). These values are near the IDL and are not 100% certain. Technetium-99 was not detected in the subsequent 5 sampling rounds at well R-22.
- Natural uranium above background is present in screen 3; uranium below background is present in screens 1, 4, and 5. Uranium at background levels is present in screen 2.
- Tritium is present in screens 1 and 5. The most consistent concentrations occur in screen 5, which is 565 ft below the regional water table.
- Thirty-one volatile and semivolatile organic compounds have also been detected in water from well R-22. Only two of these, pentachlorophenol (1 detection, 6.2 ppb, MCL = 1 ppb) and benzo(a)pyrene (2 detections, 0.24 ppb, MCL = 0.2 ppb), were present at concentrations above the MCL (Longmire, 2002c). Monitoring for organic compounds at R-22 will continue.

Gilkeson (2004) suggests that radionuclides (americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, and technetium-99) are present in the regional aquifer at the location of well R-22. However, with the exception of technetium-99, none of these radionuclides have been detected in groundwater samples from well R-22.

Gilkeson (2004) presents a graph of technetium-99 values over time. As with R-7, most of the points on the graph actually are the method detection limits for technetium-99. The two detected values of technetium-99 are in the first round of sampling in screens 3 and 4, although the values are uncertain based on low concentrations of this isotope near the instrument detection limit using gamma spectroscopy. The instrument detection limit decreases during that period because matrix interferences decreased as the well equilibrates with groundwater. After the first sampling round, technetium-99 was not detected, despite the improved ability to detect it.

At this time in R-22, there are no detectable concentrations of americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, or technetium-99. There are measurable concentrations of tritium, volatile organic compounds, and semivolatile organic compounds which warrant continued monitoring.

Question 6: How does Los Alamos National Laboratory provide the public with groundwater information?

Concerns that regulators and the public have been misinformed about the activities under the Hydrogeologic Workplan are expressed in the Gilkeson (2004) report. Extensive information, including the issues raised by Gilkeson (2004), have been presented and discussed with regulators and the public in several ways since 1997:

- Four quarterly meetings every year (24 documented meetings to date) with distribution of meeting minutes to an extensive mailing list
- Annual status reports summarizing the work accomplished in the previous year (Nylander et al., 1998, 1999, 2000, 2001, 2002, and 2003)
- Semi-Annual Reports of the External Advisory Group (1998, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, and 2002)
- Well Completion Reports for R-2, R-4, R-5, R-7, R-8, R-9, R-11, R-12, R-13, R-14, R-15, R-16, R-20, R-23, R-22, R-25, R-28, R-31, R-32, MCOBT-4.4, MCOBT-8.5, and R-9i.
- Geochemistry Reports for R-7, R-9/R-9i, R-12, R-15, R-19, and R-22.
- All water quality data are available over the internet at www.wqdbworld.lanl.gov.
- Annual Environmental Surveillance reports provide the analytical results of surface water and groundwater sampling at the Laboratory and in northern New Mexico.

Table 6 shows issues discussed at the quarterly meetings as documented in the minutes for each meeting. It is clear from this table that the issues and concerns expressed in the Gilkeson (2004) report have been extensively discussed in public forums over a period of eight years.

Table 6. Frequency of Selected Issues Discussed at Quarterly Meetings

Meeting Date (LANL file number)	Issues Discussed					
	Screen Length	Screen Location	Well Development	Residual Drilling Fluids	Multiple Screens in Wells	Regional Aquifer Impacts
3/30/98 (LAAME 6BK-010)	X	X	X		X	X
6/29/98 (ESH-18/WQ&H: 98-0233)		X	X	X	X	X
10/27/98 ESH-18/WQ&H: 98-0443)			X		X	X
2/9/99 (ESH-18/WQ&H: 99-0066)		X		X	X	X
3/29/99 (ESH-18/WQ&H: 99-0162)			X	X	X	X
6/23/99 (ESH-18/WQ&H: 99-0275)	X	X	X	X	X	X
10/13/99 (ESH-18/WQ&H: 99-0451)	X	X	X	X	X	X
1/27/00 (ESH-18/WQ&H: 00-0056)		X	X	X	X	X
3/29/00 (ESH-18/WQ&H: 00-0267)	X	X	X	X	X	X
6/22/00 (ESH-18/WQ&H: 00-0425)		X	X	X	X	X

Table 6 (continued).

Meeting Date (LANL file number)	Issues Discussed					
	Screen Length	Screen Location	Well Development	Residual Drilling Fluids	Multiple Screens in Wells	Regional Aquifer Impacts
10/3/00 (ESH-18/WQ&H: 00-0403)	X	X	X	X	X	X
1/30/01 (ESH-18/WQ&H: 01-051)		X			X	X
3/20/01 (ESH-18/WQ&H: 01-126)	X	X	X	X	X	X
6/27/01 (ESH-18/WQ&H: 01-284)		X	X	X	X	X
10/16/01 (ESH-18/WQ&H: 01-410)			X	X	X	X
1/30/02 (ESH-18/WQ&H: 02-114)		X	X	X	X	X
4/10/02 (RRES-DO: 02-25)	X		X	X	X	X
7/24/02 (RRES-GWPP: 02-03)			X	X		X
10/29/02 (RES-GPP-02-021)	X	X	X	X	X	X
1/22/03 (RES-GPP-03-013)	X	X	X	X	X	X
3/18/03 (RES-GPP-03-053)	X	X	X	X	X	X
10/27/03 (RRES-GPP-03-101)		X	X	X	X	X
1/28/04 (RES-GPP-04-0023)		X	X	X	X	X
4/12/04 (RRES-GPP-04-0023)	X	X	X		X	X

Conclusions

The Gilkeson report (2004) expressed concerns about the quality of data from specific wells at LANL based on five issues: 1) wells not compliant with RCRA requirements for monitoring; 2) wells designed with screens that are too long or in the wrong location for monitoring; 3) using drilling fluids changes the geochemical environment around the wells; 4) well development practices are inadequate to restore the geochemical environment, and 5) presence of contaminants in the regional aquifer is masked by altered geochemical environment.

This report demonstrates that the issues in the Gilkeson report (2004) and their resolutions have been extensively published, presented, and discussed by LANL over eight years. The primary purpose of the regional aquifer wells at LANL is hydrogeologic characterization and although RCRA monitoring requirements do not yet apply at LANL, the wells are intended to be compliant with RCRA such that they can be used for future RCRA monitoring, if necessary. The length of screens at the regional water table and below the water table is within the specifications provided in the RCRA guidance. The screens are located within units of interest in hydrogeologic characterization. These screened units generally have higher permeability (based on geophysical logs) and they are selected because they represent potential faster flow pathways.

Drilling fluids are necessary to drill boreholes and install wells to the depths required at LANL. After wells are installed, they are developed to remove the fluids that were added and to restore the subsurface environment to the greatest extent possible. The small amount of residual drilling fluid left after development has short-term impact on the geochemical environment surrounding each well. The impacts are known and monitored, to determine when groundwater samples are representative of pre-drilling conditions. Data presented in this report for important geochemical parameters show significant improvement, trending toward background (pre-drilling) conditions.

The contaminants (Tc-99, Sr-90) cited by Gilkeson (2004) to be present in the regional aquifer at R-7 and R-22, respectively, have not been detected over five sampling rounds (a duration of one and a half years), despite successively increased ability to detect them with lower detection limits.

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Appendix A

Text of Gilkeson Report (2004) with Crosswalk to this Report

Title **Author**	GROUNDWATER CONTAMINATION IN THE REGIONAL AQUIFER BENEATH THE LOS ALAMOS NATIONAL LABORATORY Robert H. Gilkeson, Registered Geologist P.O. Box 670 Los Alamos, NM 87544 505-412-1930 RHGilkeson@aol.com	**Relevant Discussion Sections in this Report**
Abstract	In the past several years, the Los Alamos National Laboratory (LANL) has installed an extensive network of monitoring wells for detection of chemical and radioactive contaminants in the regional aquifer. Unfortunately, misinterpretation of the sampling data and inadequate installation of the monitoring wells have concealed the fact that radionuclide and chemical contaminants are present in the regional aquifer beneath canyon and mesa settings. Although the current levels of these contaminants are probably below any harmful level, it is the apparent inability to acquire reliable data and to interpret it properly that generate concern. This report documents the installed features of the monitoring wells that distort the data and particular trends in the data that reveal a failure to recognize the situation. There is an immediate need for installation of additional monitoring wells at critical locations.	Question 5
	LANL's investigation of the regional aquifer is intended to comply with the Resource Conservation and Recovery Act (RCRA). However, many of the LANL monitoring wells do not meet RCRA requirements. One requirement of RCRA is that monitoring wells shall provide groundwater samples that are representative of the groundwater in the aquifer strata. The majority of the LANL monitoring wells were drilled using polymer-based drilling fluids and/or bentonite clay muds that may prevent the detection of contamination and/or introduce false indications of contamination.	Question1
	The drilling fluids caused the groundwater chemistry at the immediate location of many monitoring wells to change from oxidizing to strongly reducing. The new, unnatural chemistry that surrounds the monitoring wells will remove many contaminants including radionuclides from groundwater entering the wells by chemical processes that include adsorption, precipitation, coprecipitation, and reductive precipitation. Uranium is an important radionuclide contaminant at LANL that is removed from groundwater entering many monitoring wells by reductive precipitation and adsorption. Perchlorate is an important chemical contaminant at LANL that is removed from groundwater by the unnatural reducing chemistry that surrounds many monitoring wells.	Question 3
	The bentonite clay in drilling muds is a strong adsorbent to remove many radionuclide contaminants from the groundwater. Furthermore, the bentonite clay muds and drilling fluids also reduce the permeability of the aquifer strata near the wells, with the result that water samples are collected from the stagnant zone that surrounds the wells and do not represent the chemistry of the groundwater in the aquifer. LANL is aware of the unnatural chemistry that surrounds the screened intervals in many monitoring wells, and predicts that the altered chemistry will be present for the next three to ten years. However, LANL reports to the public do not adequately represent this uncertainty.	Question 3

	This report presents findings from the trend analyses of LANL contaminant data for groundwater samples collected from the recently installed set of monitoring wells. The trend analyses confirm that the radionuclide contaminants strontium-90 and technetium-99 are present in groundwater in the regional aquifer and illustrate the action that would be expected by the injection of drilling fluids and bentonite clay muds into the aquifer strata. The trend analyses prove the presence of the radionuclide contaminants in the regional aquifer beneath the Laboratory facility but do not reveal the level of contamination actually present in the groundwater.	Question 5
	This report presents findings that technetium-99 and chemical contaminants are present in groundwater beneath the LANL low-level radioactive waste disposal landfill, MDA G. It is possible that other radionuclide contaminants are present in the regional aquifer beneath MDA G.	Question 5
	This report presents a review of the design of LANL monitoring wells and an evaluation of selected data, showing that at many monitoring well locations, screens were not installed in the aquifer strata having the highest hydraulic conductivity (i.e., permeability). The strata with the highest hydraulic conductivity are expected to have the highest levels of contamination and are the fast pathways for travel of contaminated groundwater. One example of LANL's inability to install well screens in aquifer strata that have high hydraulic conductivity is the monitoring well that is installed for monitoring the impact of MDA G on the regional aquifer. At this well the screens were not installed in the high hydraulic conductivity strata present in the basalt and in gravels of the channel of the ancestral river that are present below MDA G.	Question 2
	The poor understanding of groundwater contamination beneath MDA G creates concerns for the continued operation of the RCRA disposal facility and for DOE's strategy to leave the large volume of legacy wastes "buried in place" at many locations on the Laboratory facility.	Question 5
1.0 Executive Summary	The regional aquifer beneath the Los Alamos National Laboratory (LANL) is a valuable groundwater resource. Beneath canyon and mesa settings, groundwater in the regional aquifer is contaminated with radionuclide and chemical contaminants. Presently, the nature and extent of the groundwater contamination is poorly understood. There is also insufficient knowledge of the physical setting of the regional aquifer with a special need for the study of aquifer strata that are fast pathways for contaminated groundwater.	Question 5
	LANL's investigation of the regional aquifer is intended to comply with RCRA. However, many of the LANL monitoring wells do not meet RCRA requirements. The monitoring wells were installed in boreholes drilled with drilling fluids and bentonite clay muds. The fluids and bentonite clay capture many radionuclide and chemical contaminants and remove them from groundwater entering the wells. In addition, many LANL monitoring wells have the well screens installed in inappropriate aquifer strata; water samples do not come from strata most likely to be contaminated.	Question 1
	LANL reports to the public claim the only radionuclide contaminant in the regional aquifer to be low levels of tritium. Trend analyses in this report confirm that the radionuclide contaminants technetium-99 and strontium-90 are present in the regional aquifer. Other radionuclide contaminants may be present. The improper installation of monitoring wells prevent an accurate understanding of the type and levels of radioactive and chemical contaminants that are present.	Question 5

	The principal source for radionuclide and chemical contamination in the canyon settings are the large volumes of liquid wastes from Laboratory operations that were discharged to the canyons over the past 60 years. The data in LANL reports show that strontium-90 contamination is present in the regional aquifer beneath Los Alamos and Mortandad Canyons. Other radionuclide contaminants may be present. The chemical contaminants include perchlorate, semivolatiles and volatiles (solvents).	Question 5
	The principal source of contamination for mesa settings are the many landfill disposal sites (LANL MDAs) that contain large volumes of radioactive and chemical wastes. Landfill disposal of chemical and radioactive wastes has been a disposal practice since the early years of Laboratory operations.	
	MDA G is a 65-acre landfill that has been in operation since 1955. Large volumes of chemical and radioactive wastes are disposed of in trenches and shafts at MDA G. Presently, MDA G is the Laboratory's active facility for landfill disposal of low-level radioactive waste. Trend analyses confirm the presence of the radionuclide contaminant technetium-99 in the regional aquifer beneath MDA G. Other radionuclide contaminants that may be present include iodine-129 and uranium. The chemical contaminants in the regional aquifer beneath MDA G include semivolatiles and volatiles (solvents).	
	The poor understanding of groundwater contamination beneath MDA G creates concerns for the continued operation of the RCRA disposal facility and for DOE's strategy to leave the large volume of legacy wastes "buried in place" at many locations on the Laboratory facility.	Question 1
2.0 Introduction	LANL, the United States Department of Energy (DOE), and the New Mexico Environment Department (NMED) are performing an investigation across the 43-square mile Laboratory facility to characterize the physical setting of the regional aquifer and to determine the presence or absence of radionuclide and chemical contaminants in groundwater.	Question 1
	The Laboratory facility is underlain by a thick interval of unsaturated strata. The depth to the top of the regional aquifer is commonly greater than 500 ft (ranging up to greater than 900 ft) for canyon settings and greater than 800 ft (ranging up to greater than 1200 ft) for mesa landscapes. Perched zones of saturation may occur within the thick section of unsaturated strata.	
	The strategy and schedule for the investigation of the regional aquifer are described in the LANL Hydrogeologic Workplan document.[1] An important mission of the Hydrogeologic Workplan is to characterize the regional aquifer sufficiently to satisfy the Hazardous and Solid Waste Amendments (HSWA) portion of the Laboratory's United States Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) operating permit.[2] A requirement of RCRA is for the Laboratory facility to have a network of monitoring wells that are installed in aquifer strata where contaminants may be present. The Hydrogeologic Workplan includes a schedule for installation of 32 monitoring wells in the regional aquifer below the RCRA facility.	Question 1
	Through year 2003, LANL has installed more than 20 monitoring wells in the regional aquifer. Figures 1 and 2 are maps for the locations of 18 of the LANL monitoring wells. The wells are R-5, R-7, R-9, R-12, R-13, R-14, R-15, R-16, R-19, R-20, R-21, R-22, R-23, R-25, R-31, R-32, CDV-R-15, and CDV-R-37. The majority of the wells are multiple-screened with Westbay sampling apparatus for collection of groundwater samples from discrete screened intervals installed at different depths in the regional aquifer.	Background

	Many of the LANL monitoring wells do not meet RCRA requirements. This report documents the non-compliance with RCRA for LANL monitoring wells R-7, R-9i, R-15, and R-22. The findings presented in this report are from information in the LANL well completion and well geochemistry reports for the four wells.	Question 1
3.0 RCRA Requirements for Monitoring Wells	The United States Environment Protection Agency (EPA) has published a document that describes RCRA requirements for the installation of monitoring wells on RCRA facilities. The document is titled "RCRA Groundwater Monitoring: Draft Technical Guidance"[3] (referred to in this report as "the EPA RCRA document").	Question 1
	The following list presents RCRA requirements for the installation of monitoring wells at LANL. 1. A RCRA requirement under 40 CFR Part 264 Subpart F Sect. 264.97 is for LANL to install a groundwater monitoring system that yields representative groundwater samples from the uppermost aquifer beneath the Laboratory facility.	Question 1
	Many of the LANL monitoring wells do not produce representative groundwater samples because of 1. the use of drilling fluids and bentonite clay muds in the boreholes for the wells, and 2. the installation of long well screens that cause mixing and dilution of contamination present in discrete intervals of aquifer strata. This report describes the nonrepresentative groundwater samples that are collected from LANL monitoring wells R-7, R-9i, R-15, and R-22.	Question 3, Question 2
	EPA has identified the "uppermost aquifer" as the geologic strata nearest the ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected within the facility's property boundary. "Aquifer" is defined as the geologic strata that are capable of yielding a significant amount of groundwater to wells or springs (40 CFR Sect. 260.10). Many groundwater supply wells in the region of LANL are installed at a depth of greater than 1800 ft below the water table into the regional aquifer. Therefore, at LANL a minimum requirement of RCRA is to characterize the upper several hundred feet of the regional aquifer to identify and install monitoring wells in the aquifer strata that are capable of yielding a significant amount of water; the aquifer strata that have a high hydraulic conductivity and are fast pathways for groundwater travel.	Question 2
	LANL monitoring well R-22 is located close to MDA G, the Laboratory's active landfill for disposal of low-level radioactive waste. Well R-22 is a example of LANL's failure to identify, characterize, and install well screens in the discrete aquifer strata that are capable of significant yields of groundwater. See the findings for well R-22 in section 7.0 of this report. LANL monitoring wells R- 7 and R-15 are also examples of LANL's failure to characterize and install well screens in the uppermost aquifer. The boreholes for these wells were drilled into the top of productive aquifer strata. However, LANL did not characterize the aquifer strata or install a monitoring well in the strata. The boreholes were sealed back and a screen was installed at a shallow depth in the regional aquifer. See the findings for wells R-7 and R-15 in sections 5.0 and 6.0 of this report.	Question 2

	2. Groundwater monitoring shall include measurement, sampling, and analytical methods that accurately assess groundwater quality, and that provide early detection of hazardous constituents released to groundwater – A requirement of RCRA 40 CFR Sections 264.97(d) and 264.97(e). ***The performance of groundwater monitoring at LANL are a violation of this RCRA requirement for several factors: the use of drilling fluids and bentonite clay muds in the boreholes that cause changes to the chemistry of the groundwater samples; the installation of long well screens that cause dilution of contamination; the failure to install well screens in the aquifer strata that have high hydraulic conductivity; the failure to successfully develop the well screens to establish efficient hydraulic communication with the aquifer strata; and the collection of groundwater samples from the stagnant zone with altered chemistry that surrounds the screened intervals. All of these factors prevent accurate assessment of groundwater quality and early detection of contaminants in groundwater.***	Question 2, Question 3
	3. Install monitoring wells close to the down-gradient side of hazardous waste management units (LANL MDAs), and locate screened intervals in all transmissive zones that may act as contaminant transport pathways – a RCRA requirement under 40 CFR Sections 264.95(a) and 264.97(a)(3). ***The transmissive zones are the aquifer strata that have high hydraulic conductivity and are the fast pathways for travel of contaminated groundwater. LANL has not installed screened intervals in the transmissive zones in the regional aquifer beneath MDA G, the Laboratory's active landfill for disposal of low-level radioactive waste. LANL has installed monitoring wells at locations that are in close proximity to only a few of the 26 MDAs that are present on the RCRA facility.***	Question 2
	4. As a general rule, monitoring well screens shall not have a length greater than 10 ft because long well screens may cause dilution of contamination - the LANL HSWA Permit[2] limits well screens in monitoring wells to a length of not greater than 10 feet. ***Many of the LANL monitoring wells have screened lengths greater than 10 feet; screen lengths of 40 feet are common and LANL well R-15 has a screen length of 60 feet. See the discussion of LANL well R-16 in section 6.0 of this report.***	Question 2
	The EPA RCRA document[3] contains basic guidance to assist in the selection of drilling procedures, the design and installation of monitoring wells, and the characterization of the uppermost aquifer pursuant to 40CFR Part 264, Subpart F, as follows:	
	A. Drilling should be performed in a manner that preserves the natural properties of the subsurface materials. ***LANL's use of polymer-based drilling fluids and bentonite clay drilling muds has resulted in a great change to the physical and chemical properties of the aquifer strata that surround the monitoring wells.***	Question 4
	B. The drilling method should allow for the collection of representative samples of rock, unconsolidated materials, and soil. ***The use of the mud rotary drilling method at LANL has resulted in long intervals in boreholes in the regional aquifer where no samples are recovered of the aquifer strata***	Question 2

	C. The drilling method should allow for the collection of representative groundwater samples. Drilling fluids (including air) should be used only when minimal impact to the surrounding formation and groundwater can be ensured. ***The use of polymer-based drilling fluids and bentonite clay drilling muds in the boreholes for many LANL monitoring wells are preventing the collection of representative groundwater samples.***	Question 4
	D. All monitoring wells should be developed to create an effective filter pack around the well screen, to rectify damage to the formation caused by drilling, to remove fine particles from the formation near the borehole, to remove any foreign materials (drilling fluids, bentonite clay muds, etc.) that may have been introduced into the borehole during drilling and well installation, and to assist in restoring the formation around the screen as well as the filter pack, so that mobile fines, silts, and clays are pulled into the well and removed. ***The successful development of a well is extremely important to ensuring the collection of representative groundwater samples – a requirement of 40 CFR Part 264, Subpart F Sect. 264.97 (see requirement 1 above). A failure at LANL is the incorrect belief that drilling fluids and bentonite clay drilling muds can effectively be removed from the invaded strata that surround the screened intervals. Ensuring the collection of representative groundwater samples precludes the use of drilling fluids and bentonite clay drilling muds for drilling the boreholes for monitoring wells. Well development may accomplish an adequate flow of groundwater into the monitoring well for collection of samples. However, the chemistry of the groundwater samples are still affected by a long residence time in the aquifer strata that are invaded by the fluids and bentonite clay muds.***	Question 4
	E. The design and installation of monitoring wells should determine groundwater flow directions and hydraulic gradient - a RCRA requirement under 40 CFR Sect. 264.97(f). ***The network of LANL monitoring wells have greatly improved the contour map of the water table on the regional aquifer. However, RCRA requires that the groundwater flow directions and hydraulic gradients are determined for the discrete aquifer strata that have high hydraulic conductivity and are fast pathways for groundwater travel. For the regional aquifer beneath MDA G, RCRA requires that the groundwater flow directions and hydraulic gradients are determined for the aquifer strata in the basalt and in the Puye sediments (the river gravel strata) that have high hydraulic conductivity. The hydrogeologic setting beneath MDA G is described in section 7.0 of this report. LANL has not installed monitoring wells in the important aquifer strata beneath MDA G.***	Question 2
	F. The hydraulic conductivities of the discrete aquifer strata that comprise the uppermost aquifer and its confining units should be measured, preferably with appropriate field methods. ***The regional aquifer beneath LANL is heterogeneous and anisotropic. For this hydrostratigraphic setting, knowledge of the variation in hydraulic conductivity as a function of vertical position in the discrete aquifer strata is essential to understanding the potential migration of contaminants. LANL well R-22 is a god example of LANL's failure to measure the hydraulic conductivities of the discrete strata below MDA G that have high hydraulic conductivity Section 8.0 of this report describes LANL's failure to gain knowledge of aquifer strata that have high hydraulic conductivity.***	Question 2

	G. The vertical position of monitoring well screens are functions of: a. hydrogeologic factors that determine the distribution of, and fluid/vapor phase transport within, potential pathways of contaminant migration to and within the uppermost aquifer, and b. the chemical and physical characteristics of contaminants that control their distribution in the subsurface. ***At LANL, factors a and b require that screened intervals in monitoring wells are installed in 1. appropriate strata at a shallow depth in the regional aquifer to ensure early detection of hazardous constituents that are released to the unsaturated zone and travel down to the top of the regional aquifer and 2. at depth intervals within the regional aquifer in aquifer strata with high hydraulic conductivity. Concerning factor a, LANL has installed long screens at the top of the regional aquifer. The long well screens are not focused on the water quality at a shallow depth in the regional aquifer.***	Question 2
	Concerning factor b. LANL has failed to install screened intervals in the upper several hundred feet of the regional aquifer in the discrete strata that have high hydraulic conductivity. Examples of this failure are in sections of this report for wells R-7, R-15, and R-22.	Question 2
4.0 Issues Concerning the use of Bentonite Clay Muds and Drilling Fluids in the Boreholes of LANL Monitoring Wells	Drilling fluids and/or bentonite clay drilling muds were used during drilling the boreholes for all but one of the LANL monitoring wells. The only well where drilling fluids and muds were not used is well R-9.	Question 4
4.1 Concerns for Mud Rotary Drilling Methods	Presently, LANL is using the mud rotary drilling method for installation of monitoring wells. The LANL wells on Figures 1 and 2 that were installed in boreholes drilled with mud rotary methods that used bentonite clay drilling muds include R-14, R-16, R-20, R-21, R-23, and R-32.	Question 4
	The EPA RCRA document[3] for the construction of RCRA monitoring wells states the following concern for boreholes drilled with bentonite clay muds: *"Bentonite muds may adsorb metals, potentially reducing contaminant concentrations and affecting the reliability of sampling results."* *"Drilling fluid invasion of permeable zones may compromise validity of subsequent monitoring well samples."*	Question 1
	LANL established a team of experts as the External Advisory Group (EAG) to review activities conducted by the Hydrogeologic Workplan. The EAG Semi-Annual Report dated Dec. 23, 1999[4] lists 17 disadvantages for installing monitoring wells in boreholes that were drilled with the mud rotary method. The EAG report contains the following summary statements concerning use of the mud rotary drilling method: *" The use of mud rotary drilling techniques is largely inappropriate for the goal of the LANL Hydrogeologic Workplan. Drilling with mud carries the risk of adsorbing contaminants onto the bentonite that permeates into the pore space around the well screen and is not removed by well development. Should this occur, it could result in reduced concentrations or non-detects on contaminants that are actually present in the vicinity of the well."*	Question 4

	"The artificial entrainment of bentonite clay drilling muds in the pore space around a monitoring well is clearly not desirable. This is because these materials can remove from solution the very constituents that need to be monitored by the well. This is a significant concern for LANL since radionuclides are known to be adsorbed by these clays. That the drilling mud, i.e., bentonite, penetrates into the aquifer strata is not disputed. It is reasonable to assume that fairly extensive intrusion of the bentonite into the aquifer strata can be expected. It is argued that well development, via high-flow pumping, using surge blocks, etc. is sufficient to remove blockage and create adequate flow through the well screen when a well has been drilled with mud. This is generally true. However, sufficient water flow is not the only consideration here. It is extremely unlikely that such well development techniques can remove the extruded bentonite sufficiently to assure that residual clay materials are not present in the pore space around the wells and serving as an adsorptive barrier to contaminant detection and quantification. Unfortunately, if no contamination is detected then there is simply no way (without drilling another well by a different technique) to determine whether the contaminant is truly absent at this point or whether it is being adsorbed by residual drilling fluids."	Question 3
	"The EAG would therefore caution LANL about using mud drilling techniques for the installation of the deep regional monitoring wells. If bentonite clay drilling mud is to be used, it should be used sparingly (e.g., as a lubricant only) and it would be best to avoid it altogether when drilling zones where the well screens will be located."	Question 3, Question 4
	Large amounts of bentonite muds were introduced into the permeable strata in the regional aquifer in the LANL boreholes that were drilled with the mud rotary method. The bentonite clay drilling mud can not be recovered from the aquifer by well development methods.	Question 4
	The LANL wells on Figures 1 and 2 that were installed in boreholes drilled with mud rotary methods that used bentonite clay drilling muds include R-14, R-16, R-20, R-21, R-23, and R-32. Figure 2 shows that all of the monitoring wells surrounding MDAs G and L were installed in boreholes drilled with the mud rotary method using bentonite clay muds. The exception is well R-22 that is installed in a borehole drilled with polymer-based drilling fluids. The unreliable contaminant data from well R-22 is discussed in section 7.0 of this report. All of the monitoring wells that surround MDAs G and L are unreliable for detection of many contaminants of concern for the wastes disposed of in the two MDAs.	Question 3, Question 5
	Figures 1 and 2 show that the three LANL monitoring wells that are located between MDA G and the Santa Fe Buckman well field are wells R-22, R-23, and R-16. The improper construction of the three wells makes them unreliable for the detection of many radionuclide and chemical contaminants in groundwater.	Question 1, Question 2
	The next section of this report describes the mud rotary drilling of LANL monitoring well R-16. The discussion of LANL well R-16 is based on the LANL Well R-16 Completion Report.[5]	Question 4

LANL Monitoring Well R-16	Figures 1 and 2 show that LANL well R-16 is located between the Laboratory's low-level radioactive waste disposal facility (MDA G) and the Santa Fe Buckman well field. The monitoring well is a multiple-screen completion with three screened intervals located at different depths in the regional aquifer. A Westbay groundwater sampling system is installed in the well. The Westbay system produces a small volume of groundwater at a slow rate which prevents collection of groundwater from aquifer strata outside of the zone of the invaded drilling muds and fluids. The use of bentonite clay drilling muds and polymer drilling fluids in the borehole for LANL well R-16, the use of chemical additives for development of the well screens, and the collection of groundwater samples with the Westbay system have a combined effect of making the well unreliable for the detection of many radionuclide and chemical contaminants in groundwater.	Question 3
	During the mud rotary drilling of the borehole for LANL well R-16 the mud rotary drilling lost circulation of drilling fluids for the depth interval of 867 ft to 1047 ft within the regional aquifer.[5] The lost circulation indicates a depth interval of aquifer strata with high permeability. The lost circulation shows that there was a great invasion of bentonite clay drilling muds into the highly permeable strata. The total amount of drilling fluid used for drilling the borehole in the regional aquifer at well R-16 was greater that 38,350 gallons of water to which greater than 31,100 lb of bentonite clay drilling mud was added.[5] In addition, organic polymer drilling fluids were used during drilling the borehole in the regional aquifer.[5] The RCRA concerns for the use of polymer-based drilling fluids are discussed in section 4.2 of this report.	Question 2, Question 4
	LANL used chemical additives during the development of the monitoring wells that were installed in the mud rotary boreholes. The additives increased the dispersion of the bentonite clays in the aquifer strata, increasing the total surface area of bentonite clays for adsorption (removal from groundwater) of dissolved metal and radioactive contaminants.	Question 4
	The EPA RCRA document[3] contains the following statement concerning boreholes drilled with bentonite muds, and use of chemical additives for well development: *"Bentonite muds form a filter cake on the sides of the borehole, thus reducing the effective porosity of formations in the borehole, and compromising the design of the well. Bentonite may also affect local ground-water pH. Additives to modulate viscosity and density may also introduce contaminants to the system or force large, unrecoverable quantities of mud into the formation."*	Question 4
	The issues that are presented in this report show the poor reliability of contaminant analyses for groundwater samples collected from LANL monitoring wells that are installed in boreholes drilled with the mud rotary method.	
4.2 Concerns for Boreholes Drilled With Drilling Fluids and Foams	The majority of the LANL monitoring wells displayed on Figure 1 were installed in boreholes drilled with polymer-based drilling fluids and drilling foams. Changes in the chemistry of the groundwater and in the chemistry of the aquifer strata were initiated at the time of introduction of the drilling fluids and foams into the strata as the borehole was drilled. In general, well development activities were several months after the drilling fluids were injected into the aquifer strata. A large change in the chemistry of groundwater and chemistry of the aquifer strata occurred before the first groundwater samples were collected from the monitoring wells for contaminant analyses. The unnatural chemistry in the zone surrounding the screened interval in many LANL monitoring wells is depicted in Figure 3. The altered chemistry results in removal of contaminants from groundwater that enters the well by the set of chemical processes that are shown on Figure 3.	Question 3

	The EPA RCRA document[3] for monitoring well construction contains the following guidance against the use of drilling fluids in boreholes for RCRA monitoring wells: *"Drilling fluids, drilling fluid additives, or lubricants that impact the analysis of hazardous constituents in groundwater samples should not be used. Some organic polymers and compounds provide an environment for bacterial growth, which reduces the reliability of sampling results."*	Question 3
	The drilling fluids and foams used in the boreholes of the LANL monitoring wells provided an environment for bacterial growth. The bacterial growth caused the development of a zone of strong reducing chemistry in groundwater and in aquifer strata for an unknown radius around the borehole.	Question 3
	The development methods that were used in many of the LANL monitoring wells were insufficient to establish efficient mixing of groundwater in the zone of unnatural chemistry with groundwater in the regional aquifer. The poor mixing is shown on Figure 4. The result for LANL multiple-screened monitoring wells equipped with Westbay sampling apparatus is that groundwater samples are collected from the zone of stagnant groundwater in the aquifer strata that surrounds the screened intervals. The Westbay sampling system does not purge large volumes of groundwater before collection of groundwater samples for contaminant analyses. LANL is aware of the altered zone of chemistry that surrounds the screened intervals in many LANL monitoring wells and predicts that the altered chemistry will be present for a period of the next 3 to 10 years.[6]	Question 4
	The nonrepresentative groundwater samples collected from many LANL monitoring wells are a violation of RCRA.	Question 1
	The October 2002 Semi-Annual Report of the EAG[7] contains the following discussion of the use of drilling fluids in the boreholes of monitoring wells: *"Give careful consideration to the geochemical DQOs for each monitor well to be drilled; consider using drilling methods that would have fewer detrimental impacts on aqueous/contaminant geochemistry when appropriate, even though this approach might be much more expensive during the drilling process."* *"The EAG realizes that drilling conditions on the Pajarito Plateau are extremely difficult, time-consuming and expensive. It must be argued, however, that drilling wells inexpensively and quickly that* *1. require increasingly energetic/time-consuming/expensive development procedures to remove entrained drilling materials,* *2. alter aqueous chemistry for two to 10 years (based on estimates of drilling fluid degradation rate* *3. might alter aquifer material surface chemistry for an unknown radius around the well bore for an unknown time (e.g., potentially resulting in the reductive precipitation of uranium and other radionuclides, much like an in situ remediation around the monitoring well), and* *4. continue to require expensive periodic analytical suites during the re-equilibration period that might result in data of questionable quality and errors in interpretation, should perhaps not be considered so inexpensive after all."* *"For certain canyons, it might be less expensive overall to drill in a more expensive manner and have increased confidence in the chemistry data sooner, rather than having to wait several additional years to attain the needed level of confidence."*	Question 4
	The impact of the zone of unnatural chemistry to cause the collection of nonrepresentative samples of groundwater from LANL monitoring wells R-7, R-9i, R-15, and R-22 are discussed in the following sections of this report.	Question 3

5.0 Groundwater Contamination in the Regional Aquifer Beneath Los Alamos Canyon at LANL Well R-7	The information presented in this section is from the LANL Well R-7 Completion Report[8] and the LANL Well R-7 Geochemistry Report.[9] LANL monitoring well R-7 is a multiple-screen well with three screened intervals that is located in upper Los Alamos Canyon. Screen no. 3 has a length of 42 feet and is installed at the top of the regional aquifer. Information in the LANL reports[8,9] show that the filter pack sediments and aquifer strata that surround screen no. 3 are not well developed. The Westbay sampling system in well R-7 collects groundwater samples from the stagnant zone of groundwater that surrounds screen no. 3.	Question 5
	Figure 5 shows the gradual decline in levels of strontium-90 and strontium that has occurred for screen no. 3 in well R-7 for groundwater samples collected over a one-year period because of the zone of altered chemistry that is caused by the use of drilling fluids. The unnatural chemical processes that lower the levels of strontium and strontium-90 in groundwater were introduced in the drilling fluids several months before the first groundwater samples were collected for contaminant analyses. The actual activity of strontium-90 in the regional aquifer is not known and may be much greater than the low values that are reported in the LANL geochemistry report.[9]	Question 5
	Strontium is a chemical that is commonly present in groundwater. The source of strontium in groundwater is the natural occurrence of strontium in the aquifer strata. Groundwater samples from properly installed monitoring wells will show little change in strontium levels between quarterly sampling events. For example, drilling fluids were not used in the borehole for LANL monitoring well R-9. For this well, strontium levels in four succeeding quarterly groundwater samples show little change and are 160, 160, 150, and 160 ppb, respectively.[10]	Question 5
	Strontium and strontium-90 have identical chemical properties. The pronounced decline in strontium and strontium-90 levels shown in Figure 5 is because of the removal of these constituents from groundwater in the zone of unnatural chemistry that surrounds well R-7. The trend analyses presented in Figure 5 of the analytical results for well R-7 confirm that the radionuclide contaminant strontium-90 is present in the regional aquifer below Los Alamos Canyon.	Question 3, Question 5
	Other radionuclide contaminants that were measured at low levels in groundwater samples collected from well R-7 include americium-241; cesium-137; plutonium-238; plutonium-239,240; technetium-99; and uranium-235.[9] Some of the measured low levels of contamination may be because of analytical error; the contaminants may not be present in groundwater. However, the use of drilling fluids in the R-7 borehole, the poor development of the well screen and the possible dilution effects of the 42-foot long well screen prevent an accurate understanding of the presence or absence of the radionuclide contaminants in the regional aquifer beneath Los Alamos Canyon.	Question 5
	LANL Well R-7 is located in upper Los Alamos Canyon where Laboratory effluent has been released, including radionuclides and inorganic chemicals. Known groundwater contaminants in the shallow alluvial sediments in upper Los Alamos Canyon include americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-235; and uranium-238.[11] Note the close comparison of this list of known contaminants in Los Alamos Canyon to the list of radionuclide contaminants recorded at low levels in the regional aquifer at LANL monitoring well R-7.	Question 5

	The strong reducing chemistry at LANL well R-7 causes the uranium analyses in groundwater samples from well R-7 to be anomalously low. The uranium analyses on groundwater samples from monitoring well R-7 are not valid for knowledge of uranium levels in groundwater in the regional aquifer beneath Los Alamos Canyon. The effect of the reducing chemistry on uranium in groundwater is discussed in section 9.0 of this report.	Question3, Question 5
6.0 Groundwater Contamination in the Regional Aquifer Beneath Mortandad Canyon at LANL Well R-15	The information presented in this section is from the LANL Well R-15 Completion Report[11] and the LANL Well R-15[12] Geochemistry Report. Groundwater samples collected from LANL monitoring well R-15 show that radionuclide and chemical contamination is present in the regional aquifer beneath Mortandad Canyon. A validated (>3 sigma) strontium-90 activity of 1.51 pCi/L was measured in the third quarter round of groundwater samples.[12] The radionuclide contamination recorded at low levels include americium-241; cesium-137; plutonium-238; and plutonium-239,240.[12] Some of the measured low levels may be due to analytical error; some of the recorded contaminants may not be in groundwater.	Question 5
	LANL records show that known groundwater contaminants in the shallow, saturated alluvial sediments in Mortandad Canyon include americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-235; uranium-238; nitrate; chloride; sulfate; and other inorganic solutes.[11] Note the close comparison of this list of known radionuclide contaminants in the shallow groundwater to the list of radionuclide contaminants that are recorded in groundwater samples from the regional aquifer at LANL well R-15.	Question 5
	Perchlorate levels in groundwater samples collected from monitoring well R-15 range from <2.80 to 4.19 ppb.[12] A proposed drinking water standard for perchlorate is 1 ppb. Perchlorate levels as high as 200 parts per billion have been measured in the groundwater in the alluvial sediments in Mortandad Canyon and a perchlorate level of 20 parts per billion was measured in perched groundwater present in the borehole for well R-15.[11]	Question 5
	Radionuclides that were detected in the perched groundwater present in the R-15 borehole include americium-241 and tritium; the measured tritium level in the perched groundwater was 3,770 pCi/L.[11]	Question 5
	Issues for the construction of LANL well R-15 that impact the reliability of analytical results are the use of drilling fluids in the borehole and the installation of a 60-ft long screen that straddles the top of the water table and spans intervals of aquifer strata with differing values of hydraulic conductivity. Figure 6 shows that the 60-ft screen crosses a layer of clayey fine-grained sediments that is present at a depth of 1007 to 1009 feet below land surface. Figure 6 shows the large change in static water level that has occurred since construction of the monitoring well. The installation of the long well screen across the fine-grained sediments is allowing groundwater from above the fine-grained layer to drain down inside the well and mix with groundwater present below the fine-grained layer. The mixing will dilute contaminant levels that are present at the top of the regional aquifer. LANL monitoring well R-15 does not meet RCRA requirements for representative groundwater samples.	Question 2
	For the location of LANL well R-15 it is very important to have early detection of contaminants that travel beneath Mortandad Canyon and enter the coarse sediments with high hydraulic conductivity that are present at the top of the regional aquifer. Accurate information on the presence of contamination at the top of the regional aquifer below Mortandad Canyon requires that monitoring wells are installed at the top of the aquifer with a screen length that does not cross confining layers and that allows for collection of groundwater samples from the appropriate strata at the top of the regional aquifer. It is also important that drilling fluids and bentonite clay muds are not used in the borehole interval that is drilled into the regional aquifer.	Question 2

	An immediate activity that should be performed at LANL monitoring well R- 15 are remedial measures to stop the downward flow of groundwater in the well The successful performance of remedial measures should restore the original water table on the regional aquifer at a depth of 964 feet. After restoration of the original water table a low-flow sampling system should be installed in well R-15 to collect groundwater samples from the top of the regional aquifer. Replacement of well R-15 with a RCRA-compliant monitoring well will be necessary if the remedial measures are unsuccessful.	
	The RCRA requirement to install monitoring wells in Mortandad Canyon to a depth of several hundred feet in the regional aquifer is described in section 3.0 of this report. The borehole log in the LANL Well R-15 Completion Report[11] shows that Totavi Lentil sediments are present in the depth interval of 1100 to 1107 feet, the total depth of the borehole. These sediments are known to have very high hydraulic conductivity. For well R-15, the top of the regional aquifer is at a depth of 964 feet and the top of the Totavi Lentil sediments is at a depth of 136 feet in the regional aquifer.	Question 2
	The LANL Well R-15 Completion Report[11] predicts that the Totavi Lentil sediments at the location of well R-15 have a total thickness of 65 feet. It is unfortunate that the R-15 borehole did not drill through the total thickness of the Totavi Lentil sediments and install a monitoring well in this interval of important aquifer strata. Presently, groundwater contamination and groundwater hydrology are poorly understood for the regional aquifer beneath Mortandad Canyon.	Question 2
7.0 Groundwater Contamination in the Regional Aquifer Beneath MDA G at LANL Well R-22	The information presented in this section is from the LANL Well R-22 Completion Report[13] and the LANL Well R-22 Geochemistry Report.[14] LANL monitoring well R-22 is located atop Mesita del Buey immediately east of Material Disposal Area G (MDA G), the Laboratory's active landfill for disposal of low-level radioactive waste. The location of MDA G is shown on Figure 2. Well R-22 is a multiple-screen completion with five screened intervals installed at depths ranging from the top of the regional aquifer to a depth of 500 feet in the aquifer. The drilling fluids that were used in the borehole for this monitoring well have caused the development of a strong reducing chemistry in the groundwater that enters the well at screen no. 1, 2, and 4. Information in the LANL well R-22 Completion Report[13] shows that screens no. 1 and 2 are poorly developed. The Westbay sampling system collects water samples from the stagnant zone of groundwater that surrounds the screened intervals.	Question 3
	Trend analyses show that the radionuclide contaminant technetium-99 is present in groundwater in the regional aquifer beneath MDA G. Technetium-99 activities in groundwater samples from screen no.3 and no.4 were validated levels (>3sigma) of 4.9 and 4.3 pCi/L, respectively.[14] The trend analyses in figure 6 show the declining levels of technetium-99 that occur over four quarterly sampling events for three of the screened intervals in well R-22. The declining levels of technetium-99 were shown in all five screened intervals in the well. The declining levels illustrate the action that is expected because of the use of drilling fluids in the borehole.	Question 5
	Other radionuclide contaminants that were recorded at low levels in the groundwater samples collected from monitoring well R-22 include americium-241; cesium-137; iodine-129; plutonium-238; plutonium-239,240; and strontium-90.[14] Some of the measured low levels of contamination may be because of analytical error; some of the contaminants that were recorded at low levels may not be present in the regional aquifer. However, the unnatural chemistry that surrounds well R-22 prevents an accurate understanding of the presence of contamination in the regional aquifer beneath MDA G.	Question 5

	The strong reducing chemistry in the zone that surrounds well R-22 is responsible for the anomalously low values of uranium in groundwater samples. The uranium analyses on groundwater samples from well R-22 are not valid for understanding the presence of uranium contamination in the regional aquifer beneath MDA G. Uranium chemistry is discussed in section 9.0 of this report.	Question 3, Question 5
	A large quantity of the radionuclide contaminant iodine-129 is disposed of at MDA G.[15] Iodine-129 is mobile for transport through the unsaturated zone beneath MDA G,[15] and it is possible that this radionuclide is present in the regional aquifer. Iodine-129 was measured at a value of 18 pCi/L in the first quarter of groundwater samples collected from screen no. 3.[14]	
	Volatile and semivolatile chemical contaminants are present in groundwater samples collected from well R-22.[14] The volatile contaminants are commonly known as solvents. In the past, a large volume of solvents were disposed of in trenches at MDA G. The LANL geochemistry report for well R-22 assigns the degradation of the drilling fluids as being the source of the chemical contaminants detected in groundwater from well R-22.[14] The use of drilling fluids in the borehole for well R-22 prevent an accurate understanding of the chemical and radionuclide contamination in the regional aquifer beneath MDA G. An important issue for LANL well R-22 (and many other LANL monitoring wells) is the failure to install screened intervals in aquifer strata that are fast pathways for groundwater travel. The fast pathway strata also have the greatest potential for the presence of contamination, and the highest levels of contamination.[16] Figure 8 displays the depth intervals for screened intervals in LANL well R-22. The figure shows that the screened intervals are installed in aquifer strata with low hydraulic conductivity and that screens were not installed in aquifer strata within the Cerros del Rio basalt and coarse gravels in the Puye sediments that have very high hydraulic conductivity. Because of MDA G, there is a special need to characterize chemical and radionuclide contamination in the fast groundwater pathways. The measured values of hydraulic conductivity that are posted on Figure 8 are from the LANL Hydrologic Tests Report.[17]	Question 5, Question 2
	There is a need to understand the direction and rate of groundwater travel in the fast groundwater pathways that are present below MDA G. The thick interval of river gravels in the R-22 borehole shows that an ancestral channel of the Rio Grande River is located below MDA G. The hydrostratigraphic setting of the ancestral channel is shown on Figure 9. The direction of groundwater flow in the coarse gravels that are in the ancestral channel may be southward; a markedly different flow direction from the easterly direction shown by the contour map of the water table on the regional aquifer in Figure 1. Similarly, the directions of groundwater flow in the fast pathways in the basalt strata beneath MDA G are not known. Presently, groundwater contamination and groundwater hydrology are poorly understood for the regional aquifer beneath MDA G.	Question 2

8.0 Failure of LANL to Acquire Accurate Knowledge of Aquifer Properties	Activities that have been performed for the LANL Hydrogeologic Workplan[1] are not developing an accurate understanding of the physical properties of the regional aquifer. The physical property that has received greatest study in LANL monitoring wells is hydraulic conductivity. Unfortunately, many measured values of hydraulic conductivity are anomalously low because of 1. the incomplete development of the screened intervals in the monitoring wells, 2. the failure to install screened intervals in aquifer strata that have high hydraulic conductivity (see Figure 8), 3. the failure of pumping tests to discharge groundwater at a high enough rate to stress the aquifer, 4. the use of the wrong analytical methods to calculate aquifer properties from injection test data, and 5. most pumping tests are in monitoring wells (and supply wells) with long screen intervals that span aquifer strata with differing values for hydraulic conductivity; the pumping tests determine an average value for hydraulic conductivity that greatly underestimates the hydraulic conductivity of the highly permeable strata that are fast pathways for travel of groundwater.	Question 2
	The information presented in this report for monitoring wells R-7. R-15 and R-22 shows the failure of LANL to gain knowledge of aquifer strata that have high hydraulic conductivity. Additional information on the poor knowledge that LANL has of fast pathways in the regional aquifer is shown by Table 4.3.2. – "Hydraulic Conductivity Estimates" in the LANL Report, "Groundwater Annual Status Report for Fiscal Year 2002".[18] The table shows the hydraulic conductivity of basalt to range from 0.04 ft/day to 14.87 ft/day. The table does not capture the high hydraulic conductivity that is present in the basalt strata in the regional aquifer beneath MDA G where estimated values of 200 and 400 ft/day are based on the borehole log in the LANL Well R-22 Completion Report,[13] a conversation with the driller,[19] and a review of aquifer properties.[16,20,21]	Question 2
	In Table 4.3.2 the hydraulic conductivity values for the Totavi Lentil sediments range from 0.54 ft/day to 32.29 ft/day. The table does not capture the high hydraulic conductivities of the Totavi Lentil sediments that are present in the regional aquifer beneath Los Alamos and Mortandad Canyons, and beneath MDA G. An estimated value of 500 ft/day for the Totavi Lentil sediments in the regional aquifer beneath MDA G is based on the borehole log in the LANL well R-22 Completion Report, a conversation with the driller,[19] and a review of aquifer properties.[16,20,21]	Question 2
	Two of the hydraulic conductivity values listed in Table 4.3.2 are for injection tests in Totavi Lentil sediments present in LANL monitoring well R-31.[22] The listed values of 1.23 and 0.75 ft/day are incorrect because of the use of wrong analytical methods to interpret the test data and because the two screened intervals are surrounded by a thick interval of sloughed sediments that flowed around the well screens as the drill casing was retracted.[22] The injection test measured the hydraulic conductivity of the sloughed sediments. A review of information in the LANL Well R-31 Completion Report[22] of the description of drilling activities in the Totavi Lentil sediments in the borehole of well R-31 and a review of the borehole log establish an estimated hydraulic conductivity for the thick section of Totavi Lentil Sediments in the regional aquifer at LANL monitoring well R-31 to range from 250 to 500 ft/day.	Question 2

	During 1995 to 1996, a field study measured the hydraulic properties of the unsaturated strata beneath MDA G and MDA L. The locations of the two MDAs are shown on Figure 2. The findings from the study are published in a journal article by Neeper.[23] The field study determined the unsaturated Cerros Del Rio Basalt beneath MDA G and MDA L to have a hydraulic conductivity greater than 1,000 Darcies (greater than 2,400 feet/day). The stratigraphy beneath MDA G is shown in Figure 8. Hydraulic conductivity is a physical property of aquifer strata that is independent of the fluid in the strata being either water or air. The measured value of hydraulic conductivity in the unsaturated basalt strata show that the estimated values posted on Figure 8 for hydraulic conductivity values of the basalt strata in the regional aquifer are conservative.	
9.0 Reductive Precipitation of Uranium From Groundwater	Over the past 60 years, research at LANL has used large quantities of uranium. There is a need for accurate knowledge of the levels of uranium in the regional aquifer.	
	A review of uranium analyses for groundwater samples collected from LANL monitoring wells where drilling fluids were used shows that the drilling fluids are causing removal of uranium from groundwater by the chemical process known as reductive precipitation. The drilling fluids were used in a large number of the monitoring wells. Uranium is a natural constituent in the regional aquifer and is generally present at levels of approximately 1 part per billion.[24] Groundwater samples collected from many of the LANL monitoring wells show anomalously low values for dissolved uranium. The validity of uranium analyses in all of the wells where drilling fluids were used is questionable.	Question 3
	The review of chemical analyses for the LANL monitoring wells included in this report shows that reductive precipitation is removing uranium from groundwater at wells R-7, R-9i, and R-22. The values of dissolved uranium in groundwater samples from these wells are not representative of levels in the aquifer.	Question 3
9.1 Anomalous Uranium Levels in LANL Well R-7	At LANL well R-7, the polymer-based drilling fluids caused the development of a strong reducing chemistry in the zone surrounding screen no. 3 at the top of the regional aquifer. The strong reducing chemistry is shown by the very low values for dissolved sulfate and the presence of a hydrogen sulfide odor at the well site during the collection of groundwater samples.[9] Because of the strong reducing chemistry groundwater in the regional aquifer has very high levels for dissolved iron (17mg/L) and manganese (3.4 mg/L).[9] Because of reductive precipitation, dissolved uranium is at an anomalously low value of 0.051 ppb in groundwater samples collected from screen no. 3.[9] For comparison, a groundwater sample collected at the top of the regional aquifer in the borehole for well R-7 had a uranium level of 2.1 ppb.[8]	Question 3
9.2 Anomalous Uranium Levels in LANL Well R-9i	LANL monitoring wells R-9 and R-9i are located in Los Alamos Canyon near the eastern boundary of the Laboratory facility. Drilling fluids were not used in the borehole for well R-9. Groundwater was present in two perched zones during the drilling of the borehole. Chemical analyses on groundwater samples collected from the two perched zones measured uranium values of 1.22 parts per billion (ppb) for the upper zone and 48.4 ppb for the lower zone, respectively.[25] The proposed EPA maximum contaminant level for uranium in drinking water is 7 ppb. In addition, plutonium-238 was detected at a validated level of 0.76 pCi/L in a groundwater sample collected from the lower perched zone in the borehole for well R-9.[25] At well R-9 the two perched zones were sealed off and the well has a single screen at the top of the regional aquifer.	Question 3

	Because of the presence of plutonium-238 and the high level of uranium in the lower perched zone, monitoring well R-9i was installed at a location close to well R-9 with screened intervals installed in the two perched zones.[26] Drilling fluids were used in the borehole for well R-9i. Groundwater samples for contaminant analyses were collected on a quarterly schedule from well R-9i for a one-year period. For the lower perched zone, the measured levels of uranium for successive quarters were 0.068, 0.04, 0.02, and <0.003 ppb, respectively.[10] The declining trend of the very low values is because of the removal of uranium from groundwater samples entering the well by reductive precipitation. For comparison, note that a uranium value of 48.4 ppb was measured in the groundwater sample collected from the lower perched zone in the well R-9 borehole.[25]	Question 3
	For the lower perched zone in well R-9i, analyses of the quarterly groundwater samples recorded very low values of plutonium-238 ranging from <0.006 pCi/L to -0.001 pCi/L.[10] Note that a much higher plutonium-238 value of 0.76 pCi/L was measured in a groundwater sample collected from the lower perched zone in the well R-9 borehole.[25]	Question 3
	For the upper perched zone in well R-9i, a trend analysis shows declining levels of dissolved uranium from a value of 0.588 ppb for the first quarterly groundwater sample to a value of 0.194 ppb for the groundwater sample collected in the fourth quarter.[10] Note that the groundwater sample collected from the upper perched zone in the R-9 borehole had a measured value for dissolved uranium of 1.22 ppb.[25]	Question 3
	Comparison of the analytical data from the R-9 borehole to the R-9i monitoring well is instructive in showing the large decline in contaminant analyses for plutonium and uranium that occurred because of the use of drilling fluids. It is important to note that a very large decline in contaminant levels for plutonium and uranium occurred at monitoring well R-9i before the first groundwater samples were collected for contaminant analyses. A similar large decline in contaminants may have occurred at many of the LANL monitoring wells that were installed in boreholes where drilling fluids were used.	Question 3
9.3 Anomalous Uranium Levels in LANL Well R-22	At LANL well R-22, the polymer-based drilling fluids caused the development of a strong reducing chemistry in the zone surrounding well screens no. 1, 2, and 4. For screen no. 1, located at the top of the regional aquifer, the strong reducing chemistry is shown by the very low values for dissolved sulfate and the presence of hydrogen sulfide odors at the well site when groundwater samples are collected from screen no.1[14]. Because of the reducing chemistry very high values for dissolved iron (14.9 mg/L) and manganese (4.4 mg/L) are present in groundwater samples from screen no.1.[14] Dissolved uranium values are very low and show a declining trend to 0.02 ppb. The anomalously low values of dissolved uranium in groundwater samples from well R-22 are because of reductive precipitation that is caused by the use of drilling fluids in the R-22 borehole. The levels of total dissolved uranium and isotopic uranium in groundwater below MDA G are not accurately known.	Question 3

10.0 Affect of High Levels of Dissolved Iron and Manganese on Contaminant Chemistry in LANL Monitoring Wells and on Well Development	The very high levels of dissolved iron and manganese in LANL monitoring wells are because the strong reducing chemistry dissolves these constituents from the aquifer strata. The natural dissolved iron and manganese levels in groundwater are very low (0.05 mg/L or less) in the oxidizing chemistry that is naturally present in the regional aquifer. Presently, the high levels of dissolved iron and manganese are causing the precipitation of iron and manganese oxide/hydroxide coatings on the surfaces of the aquifer strata , on the filter pack sediments that surround the well screen, and also on the well screen. The coatings are a "slimy" gelatinous substance that obstruct the flow of groundwater through the aquifer strata, the filter pack sediments, and the well screen. The coatings increase the difficulty to develop the screened intervals and the coatings continue to be deposited after the well development activities were terminated.	Question 3
	The precipitation of the iron and manganese from groundwater also has potential to remove dissolved contaminants from groundwater by the chemical process coprecipitation[27]. In addition, the pervasive presence of the iron and manganese oxide/hydroxide coatings in the zone surrounding the monitoring wells are a serious issue for removing radionuclide contaminants from groundwater because the coatings have strong adsorption properties for many of these dissolved contaminants.[27] The coatings are stable in the normal oxidizing groundwater environment which means that the coatings may be present for decades and will lower the validity of contaminant analyses of groundwater samples collected from the monitoring wells.	Question 3
11.0 Misleading Information in LANL Reports and Meetings with the Public	The analytical data presented in this report are from the LANL geochemistry reports for the R-series monitoring wells. The analytical data show that nonrepresentative groundwater samples are collected from many of the LANL monitoring wells where the drilling methods used drilling fluids and foams. For many of the monitoring wells, the LANL geochemistry reports describe the unnatural chemistry in groundwater that is caused by the drilling fluids. However, the LANL reports do not acknowledge that the analyses on groundwater samples collected from these monitoring wells are unreliable to provide accurate knowledge of the levels of many radionuclide and chemical contaminants.	Question 3
	For example, the LANL Well R-22 Geochemistry Report[14] contains the following statement: "Activities of technetium-99 were less than detection in groundwater samples collected from screens #1 and #2. Based on these findings, it is not likely that the isotope migrated from TA-54 (MDA G) because it was not observed at the regional water table at well R-22."	Question 6
	The trend analyses in Figure 7 of this report are evidence that technetium-99 is present in groundwater samples collected from screen #1 in well R-22. The low values of technetium-99 in groundwater collected from the screen are because of the unnatural chemistry that is caused by the use of drilling fluids in the borehole for well R-22 The actual level of technetium-99 in groundwater at the top of the regional aquifer beneath MDA G is not known.	Question 5
	Another example of the misleading information that is present in the LANL reports is the following statement from the LANL Well R-7 Geochemistry Report:[9] "Americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; technetium-99; and uranium-235 were not detected in the groundwater samples collected from well R-7."	Question 6

	The term "not detected" is commonly used in the LANL geochemistry reports and will lead many readers to believe that the contaminants are not present in groundwater. In reality, the term "not detected" means that the contaminant was detected by the analytical method at a low level; a low level that is possibly an error of the analytical method. However, the low levels may be a result of the unnatural chemistry that surround many of the monitoring wells. The trend analyses in Figure 5 of this report are evidence that strontium-90 is present in the regional aquifer at well R-7. All of the radionuclide contaminants that are listed as "not detected" in the LANL Well R-7 Geochemistry Report will be removed from groundwater by the unnatural chemistry that surrounds screen #3.	Question 5
	At a public meeting held on January 7, 2004, LANL and DOE presented a proposed strategy for an accelerated schedule for completion of the investigation of environmental contamination at the Laboratory facility. A claim by LANL and DOE is that radionuclide contamination in the regional aquifer is limited to low levels of tritium. The presence of strontium-90 and technetium-99 in the regional aquifer beneath the Laboratory facility was not mentioned at the public meeting.	Question 6
	Concerning MDA G, DOE and LANL assured the people at the public meeting that an "intensive study" had not found releases of contamination. A LANL study of MDA G identified technetium-99 as one of the most mobile contaminants disposed of in trenches at MDA G.[15] However, the LANL study concluded that releases of technetium-99 from MDA G would not reach the top of the regional aquifer for a period of 600 years.[15] The measurement in groundwater samples from well R-22 of technetium-99 and chemical contamination in the regional aquifer beneath MDA G was not mentioned at the public meeting. Figure 7 shows the presence of technetium-99 in the regional aquifer beneath MDA G.	Question 5
	A document delivered to the public that attended the DOE and LANL meeting displayed the LANL monitoring wells as monitoring wells for contamination in the regional aquifer.[28] The document did not explain that improper well construction practices make many of the wells unreliable for detection of contamination in the regional aquifer. The LANL estimate that many of the wells will not provide groundwater samples with an unaltered chemistry for a period as great as 10 years[6] was not mentioned at the public meeting.	Question 1, Question 2, Question 3, Question 4
	The DOE and LANL accelerated cleanup strategy proposes to leave the large volume of legacy wastes disposed of in trenches and shafts at many locations across the Laboratory facility "buried in place" with little additional investigation. DOE and LANL claim that this is a correct strategy because a careful study shows that contamination has not been released from MDA G to the regional aquifer and therefore, by analogy contamination is being contained at the other MDAs where radioactive and chemical wastes are disposed of in trenches and shafts. The validity of the accelerated cleanup strategy is now in question because of the presence of radionuclide and chemical contamination in the regional aquifer beneath MDA G. There is a need to install monitoring wells in the regional aquifer in the immediate vicinity of the other LANL MDAs that contain large volumes of legacy radioactive and chemical wastes. Presently, monitoring wells in the regional aquifer are not installed at locations that are close to many of the LANL MDAs that contain legacy wastes.	Question 1

	The presence of radionuclide and chemical contamination in the regional aquifer below MDA G raises a serious concern for the continued use of MDA G as a licensed disposal facility for low-level radioactive waste. An immediate investigation is needed to characterize the nature and extent of contamination in the regional aquifer below MDA G. This investigation will require the installation of several RCRA-compliant monitoring wells to characterize the radionuclide and chemical contamination present at the top of the regional aquifer and in the fast groundwater pathways in the aquifer strata beneath the landfill disposal facility. The fast pathways are shown on Figure 8. It is also important to determine the direction and rate of travel for groundwater in the fast pathways.	Question 1
	LANL operations are regulated by RCRA. The RCRA facility does not have a network of monitoring wells that meet RCRA requirements. There is a poor understanding of the nature and extent of radionuclide and chemical contamination in the regional aquifer beneath the Laboratory facility. There is also a poor understanding of the fast pathways for groundwater travel in the regional aquifer.	Question 1
	A technical review of activities conducted for the Hydrogeologic Workplan is necessary. A study of each of the LANL monitoring wells is required to determine their future value. This review should be conducted by a panel of experts in the following disciplines: • Hydrogeology (with emphasis in measurement of aquifer properties and contaminant hydrology), • Geochemistry (with emphasis in monitoring well installation requirements to acquire reliable information on contaminant chemistry), • Geophysics (with emphasis in groundwater borehole geophysics), and • Groundwater modeling of regional groundwater flow in aquifer strata that are anisotropic and heterogeneous.	
12.0 Sentry Monitoring Wells for the Protection of Groundwater Supply Wells	The poor understanding at LANL of groundwater contamination and groundwater hydrology requires the installation of early warning monitoring wells (sentry wells) to protect the groundwater resources of San Ildefonso Pueblo and Pueblo de Cochiti. Sentry wells are also needed for the Santa Fe Buckman well field, and the supply wells that provide water to the Laboratory facility, to the communities of Los Alamos, White Rock, and to Bandelier National Monument. It is very important that drilling fluids, foams, and muds are not used during drilling of the boreholes into the regional aquifer. The sentry wells shall collect groundwater samples that are representative of the fast pathways within the regional aquifer. The groundwater samples shall be suitable for the detection of low levels of chemical and radionuclide contamination.	Question 1
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