03-022 TA 00

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Date: December 23, 2003
Refer to: ER2003-0784

Mr. John Young, Corrective Action Project Leader
Permits Management Program
NMED – Hazardous Waste Bureau
2905 Rodeo Park Drive East
Building 1
Santa Fe, NM 87505-6303

SUBJECT: SUBMITTAL OF THE LOS ALAMOS CANYON AND PUEBLO CANYON INTERMEDIATE AND REGIONAL AQUIFER GROUNDWATER WORK PLAN

Dear Mr. Young:

Enclosed please find two copies of the "Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan," and associated Certification by Risk Reduction and Environmental Stewardship – Remedial Services (RRES-RS).

This groundwater work plan describes the investigation activities Los Alamos National Laboratory (LANL) believes are needed to complete characterization of the nature and extent of contaminants in the LA/Pueblo Canyon systems. The work plan augments the investigation activities described in the "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon" dated September 1995 (LA-UR-95-2053), and the "Los Alamos and Pueblo Canyons work Plan Addendum, Surface Water and Alluvial Groundwater Sampling and Analysis Plan," dated February 2002 (LA-UR-02-759). This plan is based on data and a sound technical approach. NMED's review of this plan will result in concurrence with LANL's approach.

The groundwater work plan contains information on radioactive materials and proposed work activities for investigation of radionuclide materials that is provided for information purposes only to the New Mexico Environmental Department-Hazardous Waste Bureau (NMED-HWB). The management of radioactive materials is regulated under the Atomic Energy Act and is specifically excluded from regulation under the Resource Conservation and Recovery Act (RCRA) and the New Mexico Hazardous Waste Act. The DOE conducts investigations of radioactive materials in parallel with the corrective action investigations conducted under RCRA and, therefore, the information on radioactive material is included in this work plan as a matter of efficiency and not for approval by the NMED-HWB.

If you have any questions, please contact John McCann at (505) 665-1091 or Tom Whitacre at (505) 665-5042.

Sincerely,

David McInroy, Deputy Project Director
Remediation Services
Los Alamos National Laboratory

Sincerely,

David Gregory, Project Manager
Department of Energy
Los Alamos Site Operations

DM/DG/JM/jr

Enclosure: (1) Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan (ER2003-0784)
(2) Certification by RRES-RS

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CERTIFICATION

CERTIFICATION BY THE RISK REDUCTION AND ENVIRONMENTAL STEWARDSHIP-REMEDIATION SERVICES (RRES-RS) PROJECT TECHNICAL REPRESENTATIVES

Document Title: Los Alamos and Pueblo Groundwater Investigation Work Plan

I certify under penalty of law that these documents and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

Name: ______________________ for   Date: 12/23/03

David McInroy, Deputy Project Director
Remediation Services
Los Alamos National Laboratory

or

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Beverly A. Ramsey, Division Leader
Risk Reduction and Environmental Stewardship Division
Los Alamos National Laboratory

______________________   Date: Dec 23, 2003

David Gregory, Project Manager
Environmental Restoration Program
Department Of Energy/Los Alamos Site Office

or

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Herman LeDoux,
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Department Of Energy/Los Alamos Site Office

Los Alamos
NATIONAL LABORATORY

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LA-UR-03-9191
December 2003
ER2003-0784

Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan

Los Alamos
NATIONAL LABORATORY

Los Alamos NM 87545

DISCLAIMER

This document contains data on radioactive materials, including source, special nuclear, and by-product material. The management of these materials is regulated under the Atomic Energy Act and is specifically excluded from regulation under the Resource Conservation and Recovery Act and the New Mexico Hazardous Waste Act. These data are provided to the New Mexico Environment Department for informational purposes only.

Produced by Risk Reduction and Environmental Stewardship Division–Remediation Services

LA-UR-03-9191
ER2003-0784

Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan

December 2003

Responsible Project Leader:

John McCann	[signature]	Project Team Leader	RRES-GPP	12-23-03
Printed Name	**Signature**	**Title**	**Organization**	**Date**

Responsible University of California representative:

David McInroy	[signature]	Deputy Project Director	RRES-RS	12/23/03
Printed Name	**Signature**	**Title**	**Organization**	**Date**

Responsible Department of Energy representative:

Mathew Johansen	for [signature]	Groundwater Program Compliance Manger	DOE-LASO	12/23/03
Printed Name	**Signature**	**Title**	**Organization**	**Date**

EXECUTIVE SUMMARY

The groundwater investigation described in this work plan is an addendum to the previously submitted Resource Conservation and Recovery Act (RCRA) facility investigation work plan for Los Alamos Canyon and Pueblo Canyon. This groundwater investigation work plan provides the technical approach, methodology, scope, and rationale for further investigation of the intermediate and regional aquifer groundwater in the Los Alamos and Pueblo Canyon system at Los Alamos National Laboratory (the Laboratory). This groundwater work plan updates the scope of work necessary to complete implementation of the original work plan for Los Alamos Canyon and Pueblo Canyon. The objectives of this groundwater work plan are to

- further define the extent of contamination in perched intermediate groundwater at well R-9i and in the regional aquifer at supply well Otowi (O)-1;
- evaluate the presence and uncertainties of other contaminants known to have been released in the upper reaches of Los Alamos Canyon and Pueblo Canyon; and
- evaluate the transport pathways that have resulted in the presence of contaminants in water supply well O-1 and in investigation wells R-9 and R-9i.

The "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon" (LANL 1995, 50290) was first submitted by the Laboratory to the New Mexico Environment Department (NMED) in November 1995. The NMED issued a Notice of Deficiency (NOD) on the submitted work plan on March 17, 1997. The Laboratory response to the NOD was dated April 18, 1997. Following the Laboratory's response to the NOD, the NMED approved the work plan on June 3, 1997. On February 28, 2002, an addendum to the Los Alamos Canyon and Pueblo Canyon "Los Alamos and Pueblo Canyons Work Plan Addendum, Surface Water and Alluvial Groundwater Sampling and Analysis Plan" (LANL 2002, 70235) was submitted to the NMED and provided an update for the scope of additional surface water and alluvial groundwater investigations. The NMED approved the addendum on May 28, 2002.

Objectives developed for this addendum to investigate the intermediate-perched and regional groundwater zones and how they are addressed are provided in Table ES-1.

Table ES-1
Work Plan Objectives for Los Alamos Canyon and Pueblo Canyon

Groundwater Addendum Objectives	How Addressed
Determine nature and extent of potential contamination within the regional aquifer downstream of the Acid Canyon and Pueblo Canyon confluence in Pueblo Canyon.	R-2 was drilled in October 2003. R-3 is proposed in this work plan addendum to be installed near Otowi-1.
Determine nature and extent of potential contamination within the regional aquifer immediately north of TA-73 in Pueblo Canyon.	R-4 was drilled in August 2003.
Determine nature and extent of contamination within the Cerros del Rio basalt/Puye Formation between wells R-8 and R-9i.	Well LAOI-7, as proposed in this work plan addendum, is located between wells R-8 and R-9i. The information from wells R-8 and R-9 are sufficient for regional aquifer characterization.
Determine background/baseline water chemistry for Los Alamos Canyon and Pueblo Canyon.	Wells R-26 and R-7 serve as background wells for the Laboratory including Los Alamos Canyon and Pueblo Canyon.

One regional aquifer well (R-3) and one intermediate well (LAOI-7) are proposed for drilling and sampling as part of this groundwater work plan. During the drilling of the boreholes, core samples will be collected from one intermediate depth well and one regional aquifer well. Groundwater samples will be collected during drilling in addition to two rounds of characterization sampling from each well. The samples will be analyzed for metals, anions (including perchlorate), radionuclides, organic compounds, and stable isotopes. Data and information obtained from the additional investigation will serve as input for making decisions regarding characterization, contaminant transport, regulatory compliance, pathway analysis, human health and ecological risk assessment, and monitoring. An investigation report, including the results of sampling all the intermediate and regional wells of this canyon system, will be prepared and delivered to the NMED by June 16, 2006. The submittal date is based on drilling and completing the wells proposed in this groundwater work plan in calendar year 2005 and conducting two quarters of sampling rounds at the wells.

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1.0 INTRODUCTION

This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) groundwater work plan describes additional investigations to be conducted in the Los Alamos/Pueblo Canyon system as part of the Risk Reduction and Environmental Stewardship Remediation Services (RRES-RS) Project at Los Alamos National Laboratory (the Laboratory). This groundwater work plan for Los Alamos Canyon and Pueblo Canyon describes work in addition to the "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon" (LANL 1995, 50290) and "Los Alamos and Pueblo Canyons Work Plan Addendum, Surface Water and Alluvial Groundwater Sampling and Analysis Plan" (LANL 2002, 70235).

The "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon" (LANL 1995, 50290) was first submitted by the Laboratory to the New Mexico Environment Department (NMED) in November 1995. The NMED issued a Notice of Deficiency (NOD) on the submitted work plan on March 17, 1997. The Laboratory response to the NOD was dated April 18, 1997. Following the Laboratory's response to the NOD, the NMED approved the work plan on June 3, 1997. On February 28, 2002, an addendum to the Los Alamos Canyon and Pueblo Canyon "Los Alamos and Pueblo Canyons Work Plan Addendum, Surface Water and Alluvial Groundwater Sampling and Analysis Plan" (LANL 2002, 70235) was submitted to the NMED to address additional surface water and alluvial groundwater investigations. The NMED approved the addendum on May 28, 2002.

Information on radioactive materials and proposed work activities for investigation of radionuclide materials is provided in this work plan for information purposes only. The management of radioactive materials is regulated under the Atomic Energy Act and is specifically excluded from regulation under the RCRA and the New Mexico Hazardous Waste Act. The US Department of Energy conducts investigations of radioactive materials in parallel with the corrective action investigations conducted under RCRA and therefore, the radioactive material information is included in this work plan as a matter of efficiency and not for approval by the NMED Hazardous Waste Bureau (HWB).

The objectives of this groundwater work plan are to

- further define the extent of contamination in perched intermediate groundwater at well R-9i and in the regional aquifer at supply well Otowi (O)-1;
- evaluate the presence and uncertainties of other contaminants known to have been released in the upper reaches of Los Alamos Canyon and Pueblo Canyon; and
- evaluate the transport pathways that have resulted in the presence of contaminants in water supply well (O)-1 and in investigation wells R-9 and R-9i.

Data and information obtained from these additional investigations will serve as input for making decisions regarding characterization, regulatory compliance, pathway analysis, risk assessment, and monitoring. Core and water samples will be collected from boreholes and wells to determine the nature and extent of contaminants. Data and information collected will support decisions regarding corrective action or no further action (NFA) for Los Alamos Canyon and Pueblo Canyon.

The objectives developed for this groundwater work plan to further investigate nature and extent of known groundwater contamination within intermediate-perched and regional groundwater zones in Los Alamos Canyon and Pueblo Canyon and how they are addressed are summarized in Table 1.

2.0 BACKGROUND AND SITE CONDITIONS

2.1 Background

Los Alamos Canyon is located in the northern part of the Laboratory. It is an east-west trending canyon that originates on US Forest Service land in the Sierra de los Valles at an elevation of 9950 ft above sea level (asl). The drainage extends about 16 mi from the headwaters to its confluence with the Rio Grande at an elevation of 5550 ft asl and has a drainage area of about 11 mi^2. Los Alamos Canyon crosses both the western and eastern Laboratory boundaries. It crosses San Ildefonso Pueblo land for about 3.5 mi before joining the Rio Grande. The canyon passes through or is adjacent to Laboratory TAs -2, -3, -21, -41, -43, 62, -72, and -73.

Pueblo Canyon originates on US Forest Service land, and has a total drainage area of about 6.5 mi^2. It extends across northern Los Alamos County and into the northeastern part of the Laboratory, where it joins Los Alamos Canyon. The Pueblo Canyon drainage contains most of the Los Alamos townsite. The canyon passes through or is adjacent to TA-72 and TA-74. The lower broad portion of the canyon is located on Laboratory-controlled land. Laboratory activities within or affecting these canyons are discussed in the "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon" (LANL 1995, 50290).

Los Alamos Canyon and Pueblo Canyon have received effluents from the Laboratory since the early 1940s (LANL 1995, 50290). These effluents, discharged from former TA-1, -2, -21, -41, -43, and -53, have contained a variety of contaminants, including nitrate, perchlorate, tritium, cesium-137, strontium-90, americium-241, and several isotopes of uranium and plutonium (LANL 1995, 50290). There are several active outfalls discharging to Los Alamos Canyon and Pueblo Canyon. These include outfalls at TA-43, TA-53, and the Los Alamos Medical Center. A municipal wastewater treatment facility, known as the Bayo Wastewater Treatment Plant, actively discharges treated effluent to Pueblo Canyon.

The former Environmental Restoration (ER) Project (now Risk Reduction and Environmental Stewardship Remediation Services Project [RRES–RS]) and the RRES–Groundwater Protection Program (GPP) have drilled one perched intermediate well and six regional aquifer wells in Los Alamos Canyon and Pueblo Canyon. This work was part of the approved "Work Plan for Los Alamos Canyon Operable Unit (OU) 1049" and the "Hydrogeologic Work Plan" (LANL 1995, 50290; LANL 1998, 59599). These include intermediate depth well R-9i and regional aquifer wells R-2, -4, -5, -7, -8, and -9. Figure 1 shows locations of these wells and proposed wells, in addition to previously installed monitoring wells in Los Alamos Canyon and Pueblo Canyon.

Analytical results from groundwater samples collected from well R-9i showed 69.4 to 246 pCi/L tritium (Longmire 2002, 72713). Activities of tritium measured in this well are elevated above those measured in supply wells (ESP 2001, 73876; ESP 2002, 71301). This intermediate well is located west of well R-9 (Figure 1). The well has two screens set in perched zones within the Cerros del Rio basalt at depths of 199 and 279 ft below ground surface (bgs) (Longmire 2002, 72713).

Well R-7, upstream from the DP Canyon and Los Alamos Canyon confluence, has not shown contamination in the regional aquifer during drilling and/or subsequent characterization sampling (Longmire and Goff 2002, 75905). Perched groundwater at 378 ft bgs contained 2.55 to 3.38 pCi/L tritium during characterization sampling (Longmire and Goff 2002, 75905).

Regional aquifer well R-9 contained 4.84 to 14.68 pCi/L tritium in groundwater sampled at a depth of 741 ft bgs (Longmire 2002, 72713). Typical concentrations of tritium observed in supply wells are less than 1 pCi/L (ESP 2000, 68661; ESP 2001, 73876; ESP 2002, 71301). Perched groundwater encountered at a depth of 279 ft bgs during the drilling of R-9 contained 0.0484 mg/L dissolved uranium (Broxton et al. 2001, 71250). This perched groundwater is in the lower portion of the Cerros del Rio basalt. Subsequent sampling of uranium in well R-9i has shown dissolved concentrations of uranium less than 0.001 mg/L (Longmire 2002, 72713).

Regional Aquifer well R-8 located downstream of the DP Canyon and Los Alamos Canyon confluence will be sampled during implementation of the work plan. A borehole water sample collected from borehole R-8 contained 16 pCi/L tritium and concentrations of perchlorate were less than 0.004 mg/L using ion chromatography for the screening sample.

Regional aquifer wells R-2 and R-4 located in Pueblo Canyon have been sampled after development and the analytical results are pending. Well R-5 has been sampled during well development and one characterization sampling round has been conducted. Concentrations of tritium and nitrate (as nitrogen) were 0.29 pCi/L and 2.52 mg/L, respectively, within a perched zone at 384 ft bgs. Concentrations of tritium and nitrate (as nitrogen) were less than 5 pCi/L and 2 mg/L, respectively, within the regional aquifer at the well. Concentrations of other contaminants, including uranium, nickel, chloride, and sulfate, were lower than state and federal standards. Concentrations of strontium-90, americium-241, and plutonium-238 were less than detection during sampling. Concentrations of plutonium-239,240 were 0.0216 and 0.0188 pCi/L, respectively, within a perched zone (384 ft bgs) and in the regional aquifer (719 ft bgs).

During 2001, groundwater samples were collected and analyzed from water supply well O-1. The samples contained 1.3 mg/L nitrate (nitrate as nitrogen), 0.00112 to 0.00585 mg/L perchlorate, and 29.06 to 40.23 pCi/L tritium (ESP 2002, 73876). This well is used for industrial purposes and is not currently used as a source of drinking water for the Laboratory or the community of Los Alamos. Nitrate and tritium have been detected in wells TW-1a and TW-1, indicating that these wells have experienced recharge from surface water and alluvial and perched intermediate groundwater (ESP 2001, 71301; ESP 2002, 73876).

2.2 Site Conditions

This section describes the site conditions for Los Alamos Canyon and Pueblo Canyon including bedrock geology and hydrology. The vadose zone consists of the volume of hydrogeologic material from land surface to the regional water table and includes perched intermediate groundwater. The Los Alamos Canyon and Pueblo Canyon work plan (Chapter 3) contains a description of surface site conditions including topography, drainages, vegetation, erosional features, and basins (LANL 1995, 50290). The work plan for Los Alamos Canyon and Pueblo Canyon and well completion reports for wells R-7 (Stone et al. 2002, 72717), R-9 (Broxton et al. 2001, 71250) and R-9i (Broxton et al. 2001, 71251) discuss subsurface hydrostratigraphy including the alluvium, the Bandelier Tuff, the Cerro Toledo interval, the Puye Formation, the Cerros del Rio basalt, the older alluvium, the Totavi Lentil, and the Santa Fe Group basalt. Additional information on geochemistry of saturated zones is contained in the geochemistry reports for wells R-9 and R-9i (Longmire 2002, 72713) and R-7 (Longmire and Goff 2002, 75905) and annual Laboratory surveillance reports (ESP 2002, 71301; ESP 2001, 73876).

Stratigraphic units of Los Alamos Canyon include alluvium and colluvium overlying the Bandelier Tuff, Puye Formation, and Cerros del Rio basalt within the floor of Los Alamos Canyon. Alluvial deposits of varying thickness become saturated during wet periods including snow melt and summer storm events. The saturated thickness of the alluvium also varies seasonally. Groundwater flows east-southeastward within the alluvium and is generally along the axis of the canyon.

Ash-flow tuffs of the Tshirege Member of the Bandelier Tuff form the bedrock outcrops in Los Alamos Canyon and underlie the alluvial deposits west of TA-2. The Cerro Toledo interval is a bedded valley-fill deposit that underlies the Tshirege Member in Los Alamos Canyon.

The Otowi Member of the Bandelier Tuff underlies the Cerro Toledo interval in Los Alamos Canyon and subcrops the canyon floor east of TA-2. Ash-flow tuffs of the Otowi Member fill a north-south trending paleovalley and well R-7 is in the axial portion of that paleovalley. The Guaje Pumice Bed, a fall deposit, underlies the Otowi Member throughout the Los Alamos Canyon area. Perched groundwater has been encountered within the Guaje Pumice Bed at wells H-19, LAOI-1.1, and LADP-3 (LANL 1995, 50290).

The Cerros del Rio basalt is intercalated with the Puye Formation. The Cerros del Rio basalt is a wedge-shaped stack of lava flows that thicken eastward. The maximum measured thickness of these lava flows in Los Alamos Canyon is 280 ft at well R-9 and diminishes to 72 ft at test well (TW)-3. Two perched groundwater zones encountered in Los Alamos Canyon at well R-9i and borehole R-9 are both associated with the Cerros del Rio basalt. Additional perched zones were encountered within the underlying Puye Formation during drilling of R-9.

The regional aquifer water table encountered at well R-7 at a depth of 903 ft bgs is in the lower Puye Formation or in an unassigned pumiceous unit throughout the central portion of the Laboratory, including Los Alamos Canyon (Stone et al. 2002, 72717). The lower Puye Formation at well R-7 is approximately 350 ft. A highly transmissive series of river gravels, related to the Totavi Lentil, occurs at the base of the Puye Formation in well R-7 but its thickness is not known. The regional aquifer water table encountered at well R-9 is in the Santa Fe Group basalt at a depth of 688 ft bgs.

Stratigraphic units of Pueblo Canyon include alluvium and colluvium overlying the Puye Formation, Bandelier Tuff, and Cerros del Rio basalt within the floor of Pueblo Canyon. Alluvial groundwater occurs within Pueblo Canyon upstream and downstream of the Bayo Wastewater Treatment Plant and groundwater quality is monitored at several alluvial wells. Groundwater flows east-southeastward within the alluvium and is generally along the axis of Pueblo Canyon.

Ash-flow tuffs of the Tshirege Member of the Bandelier Tuff and the Cerro Telodo interval form the bedrock outcrops in Pueblo Canyon. The Otowi Member of the Bandelier Tuff also forms outcrops throughout the canyon and subcrops the canyon floor west of Hamilton Bend. East of Hamilton Bend, the canyon floor is underlain by the Puye Formation and Cerros del Rio basalt.

The Cerros del Rio basalt is intercalated with the Puye Formation. The maximum measured thickness of these lava flows in Pueblo Canyon is 230 ft at O-1 and and these basalts were not encountered at wells R-2 and R-4. Perched groundwater zones encountered in Pueblo Canyon at wells POI-4 and TW-1a are associated with the Cerros del Rio basalt. A perched zone within the Puye Formation is present at TW-2a at a depth of 110 ft bgs. Tritium, nitrate, and other chemicals have been detected in groundwater samples collected from TW-1a, TW-2a, and POI-4 (ESP 2002, 71301; ESP 2001, 73876).

The regional aquifer water table encountered at wells O-1, R-2, and R-4 is in the Puye Formation. The Puye Formation is highly variable in its hydraulic properties based on grain size and sorting. During well development at R-2, it was noted that the section of Puye Formation was not transmissive and produced only 1.5 gallons per minute during well development.

3.0 SCOPE OF PROPOSED ACTIVITIES

This section describes the additional investigation of intermediate and regional groundwater zones in the Los Alamos-Pueblo Canyon system. The strategy for sampling perched intermediate groundwater and the regional aquifer is described below. Borehole cores will also be sampled and analyzed to determine contaminant geochemistry and hydraulic properties. A total of two wells are proposed for installation: one intermediate well (LAOI-7) and one regional aquifer well (R-3).

3.1 Proposed Field Activities

The proposed field activities detailed in this work plan represent continued characterization of the nature and extent of contaminants detected in previously installed wells. The activities include drilling and sampling of groundwater wells. Each well described in this work plan has its own set of characterization objectives for both the unsaturated zone and the groundwater as reflected in the data quality objectives (DQOs) in Table 2.

Core samples will be collected from the intermediate well and the regional aquifer well to determine vertical distributions of contaminants and moisture in the upper portions of the vadose zone. If saturation is not encountered within the target depth, the intermediate borehole (LAOI-7) will be backfilled with native materials and plugged and abandoned according to Laboratory procedures and requirements. No other intermediate wells or boreholes are planned for at this location.

3.2 Well Installation and Sampling Locations

The proposed locations of the intermediate well and the regional aquifer well are shown in Figure 1. Geologic, hydrologic, geochemical, and geophysical data will be collected at each well site.

Tritium, sodium-22, molybdenum, and other solutes have been released from TA-53 into Los Alamos Canyon. Alluvial wells LAO-2, -3.5, -4, -4.5C, and -6A are downgradient from TA-53 releases and there were no constituents of interest that exceeded NMED groundwater standards and EPA drinking water standards in alluvial groundwater during 2001 (ESP 2001, 73876). Perched intermediate groundwater within the Cerros del Rio basalt at well R-9i has been sampled four times and no contaminants have exceeded applicable NMED and EPA standards. Concentrations of perchlorate, plutonium-238, plutonium-239,240, strontium-90, cesium-137, and americium-241 were less than detection at well R-9i. The proposed well LAOI-7 will provide an additional monitoring station, if saturation is encountered, between wells R-8 and R-9. Four rounds of characterization sampling have been conducted at well R-9 and tritium has been detected at concentrations ranging from 4.84 to 14.68 pCi/L (Longmire 2002, 72713). Concentrations of perchlorate, plutonium-238, plutonium-239,240, strontium-90, cesium-137, and americium-241 were less than detection at well R-9.

Based on available sampling results for alluvial and perched intermediate groundwater and the regional aquifer in Los Alamos Canyon, the regional aquifer presently shows the least amount of impact from Laboratory discharges. Dilution and adsorption of contaminants should decrease contaminant concentrations along groundwater flow paths within the vadose zone and regional aquifer. Because of these two physico-chemical processes, a significant variation in water chemistry including contaminant concentrations is not expected to occur within the regional aquifer between wells R-8 and R-9. An additional R well between R-8 and R-9 probably will not reduce uncertainty in contaminant transport and risk analysis based on groundwater monitoring data collected in Los Alamos Canyon.

A proposed intermediate well, LAOI-7, is located between wells R-8 and R-9. It will target the Cerros del Rio basalt with the primary purpose of further characterizing the nature and extent of known contaminants in intermediate perched water. If perched water is encountered in strata above the Cerros del Rio basalt, that water will be collected and analyzed during drilling to determine presence or absence of contamination. If perched water is not encountered above or within the Cerros del Rio basalt, the borehole will be extended 100 ft within the underlying Puye Formation immediately beneath the Cerros del Rio basalt to test for presence of perched water. If saturation is not encountered, the borehole will be backfilled. No other boreholes or intermediate wells are planned for in this location of Los Alamos Canyon.

The regional aquifer well includes R-3, which will be located near and upgradient of water supply well O-1 in Pueblo Canyon. The primary purpose of R-3 is to identify the transport pathways that have resulted in the presence of contaminants in O-1.

A background well (R-6) was proposed for upper Los Alamos Canyon under the Hydrogeologic Workplan (LANL 1998, 59599). Well R-26 was recently completed at a location upgradient of Laboratory operations. Well R-26 was completed and developed successfully indicating that it will provide high-quality samples for background chemical analyses. Preliminary results of sampling of well R-26 water indicate background concentrations of analytes are in the expected range. The construction of well R-26 also provides a technically defensible basis for establishing background conditions for the regional aquifer. Therefore, an additional background well in Los Alamos Canyon and Pueblo Canyon is not proposed in this work plan.

Well R-7 and other regional aquifer wells not showing contamination will also serve to augment well R-26 to provide background data for Los Alamos Canyon and Pueblo Canyon. Four rounds of characterization sampling conducted at well R-7 have shown that tritium concentrations were less than 3 pCi/L and other Laboratory contaminants including strontium-90, americium-241, plutonium-238, plutonium-239, and perchlorate have not been detected (Longmire and Goff 2002, 75905). This suggests that the regional aquifer at well R-7 has not been impacted from Laboratory discharges.

Results of sampling to date (ESP 2001, 73876, LANL 1995, 50290, Longmire 2002, 72713, Longmire and Goff 2002, 75905) indicate that there are contaminants of concern in Los Alamos Canyon. The expected risk and fate and transport evaluations based on available data, however, probably will not be complex enough to require a background well located specifically in Los Alamos Canyon. A proposal to drill a background well, however, will be considered at any time during the implementation of this work plan, or during monitoring and characterization, when a contaminant issue arises that will justify a background well located specifically in Los Alamos Canyon.

3.3 Analysis of Core and Groundwater Samples

The proposed wells provide the opportunity to evaluate the geochemistry of groundwater and unsaturated and saturated geologic materials within Los Alamos Canyon and Pueblo Canyon. During drilling operations, core, cuttings, and groundwater samples will be collected for geochemical and contaminant characterization as described in Tables 3, 4, and 5. The depths of samples will depend on the hydrologic and geologic conditions found during drilling and the quality of core recovered. After each well is completed and developed, two rounds of groundwater samples will be collected during a six-to-eight-month period and analyzed for metals, anions including perchlorate, organic compounds, radionuclides, stable isotopes, total organic carbon (TOC), and dissolved organic carbon (DOC) fractionation analysis (Tables 6 and 7).

3.3.1 Sampling and Analysis of Core

During coring of the boreholes for the intermediate and regional aquifer wells, anion, cation, metal, stable isotope, radionuclide, and tritium profiles will be determined from the level of the canyon floor to depths specified in Table 3 or depth of core refusal. Sample intervals are similar for all proposed wells. For the upper 100 ft, samples will be collected every 10 ft. For depths greater than 100 ft, samples will be collected at a frequency of one per 50 ft. The intermediate and regional aquifer boreholes will be cored to depths appropriate for obtaining data required to determine nature and extent of contamination on solid samples. The analytical suite, analytical methods, and estimated detection limits for geochemical and contaminant characterization of intermediate and regional aquifer core samples are shown in Tables 3 and 4.

3.3.2 Sampling and Analysis of Groundwater

Up to five borehole groundwater screening samples will be collected during drilling of each well for geochemical and contaminant characterization. These screening samples will provide an early indication of whether contaminants could be present in perched and regional groundwater before characterization samples are collected from the completed well. The analytical suite, sample volume, and containerization requirements for samples to be collected are specified in Table 5.

Characterization sampling will be conducted for two rounds at the wells. The analytical suite, estimated detection limits, half-life for radionuclides, analytical methods, and analytical protocols for inorganic chemicals and radionuclides in groundwater for characterization sampling conducted after well development are shown in Tables 6 and 7. Samples will be analyzed for volatile and semivolatile organic compounds, polychlorinated biphenyls, and pesticides after each well has been developed. Groundwater samples will also be analyzed for TOC and DOC (fractionation analysis). The chemical parameters to be measured in the field during characterization sampling after well development are shown on Table 8.

After they are completed, the wells will be sampled twice as part of this groundwater work plan. The two rounds of sampling will be scheduled to evaluate potential variations in contaminant concentration over a six-to-eight-month period.

3.3.3 Borehole Geophysics

Borehole geophysical logs will be collected in the intermediate and regional wells to determine the geologic and hydrologic characteristics of the vadose zone, perched saturated zones, and the regional aquifer. A wire-line logging service will be used to obtain a suite of borehole geophysical logs. The number and types of logs will vary as a function of borehole condition, the presence or absence of drill or well casing, and technical issues being addressed by a particular logging run. Table 9 provides a typical suite of logs that have been run by wire-line logging services in cased and uncased boreholes during installation of previous hydrogeologic work plan wells.

4.0 INVESTIGATION METHODS

4.1 Drilling

One intermediate well and one regional aquifer well will be drilled with a combination of coring, air rotary/foam assist and fluid assisted drilling methods, as needed. A brief description of these methods is provided below. More information can be found in SOP 04.01, "Drilling Methods and Drill Site Management," the Drilling Plan to be submitted by the drilling contractor, and the SAP that will be prepared for this field effort.

4.1.1 Coring

Continuous coring will be performed at both well site locations to a maximum depth of 350 feet. The coring will be completed using hollow stem auger and Geobarrel (HQ-size) coring. Coring will proceed without the addition of fluids other than air. The augers will be advanced to refusal, after which the HQ system will be advanced. Lexan tubes will be loaded into the sample tube prior to placement in the auger. Prior to removal of the lexan tubes from the sampling tube, the percent recovery will be noted. After the tubes are removed from the sampler, the lithology will be logged on the boring log.

Core collected will be handled per Laboratory SOP 6.26, using sample containers (plastic bags and ProtecCore^{TM}). Samples will be submitted to the SMO using the Laboratory Chain of Custody documentation. Samples will be collected at the following intervals: 10, 20, 30, 40, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, and 350 ft. Samples collected will be analyzed for anions, cations, moisture content, tritium, radionuclides, and stable isotopes. After sampling, all remaining HQ-sized core will be placed in lay-flat plastic tubing, labeled, and stored in standard Laboratory core boxes. The core boxes will be labeled with the well name, box number and the footage range for the box. The core boxes will be transported to the Field Support Facility.

4.1.2 Rotary/Foam Drilling

The proposed method for drilling the deep well boreholes is direct air-rotary with foam assist. The well boreholes will be offset from the core holes at each location and will be a nominal 12¼-inch diameter. A 16-inch surface conductor will be set inside a minimum 24-inch borehole to approximately 50 feet. The drilling contractor will attempt to identify and sample perched water. If perched water is encountered, a sample will be submitted for rapid turn-around screening analysis. Drilling additives will be available for use as needed. Only approved Baroid drilling products will be used during the drilling and completion of these wells. Drilling additives are discussed in the SAP and Drilling Plan for this effort.

4.1.3 Drilling Contingencies

The drilling contractor will attempt to drill each borehole with the methods described above. However, drilling conditions may require the conversion to alternative drilling methods. If the borehole begins to cave in, one possible modification could be to lower casing into the borehole and drill through the bottom of the casing. This casing is then removed during construction of the well. Permanent conductor casing may be used when unstable conditions exist and removal of the casing could compromise the final well completion design. Mud-rotary methods could be employed when flowing sand conditions inhibit borehole advancement, and DQOs dictate greater depths be attempted. Both casing and mud-rotary methods will be available on site.

4.2 Sampling and Analytics

4.2.1 Core

Core is collected by means of a core barrel included at the bottom of the drill string. As the drill bit is advanced, the core barrel "shoe" (beveled cutting edge) slightly precedes the advancing drill bit. The core barrel assembly is stationary within the rotating drill string. In this fashion, undisturbed geologic materials are pushed up into the hollow core barrel and not pulverized by the drill bit. When the core barrel is filled, the drilling is halted and the core barrel is retrieved. If contaminants are anticipated, portable field instruments are used to monitor the cuttings from the cored interval for radioactivity and volatile organic compounds. Guidance for collection, preservation and storage of core can be found in SOP 06.10, "Hand

Auger and Thin-Wall Tube Sampling;" SOP 0.6.24, "Sample Collection From Split-Spoon Samplers and Shelby Tube Samplers;" and SOP 06.26, "Core Barrel Sampling for Subsurface Earth Materials."

Once the core is removed from the core barrel, it is screened in the field for gross radiation. Upon determining that the core is safe to handle, the core is measured and marked to determine core loss and the depth interval the core was collected from. The core is logged to document stratigraphic contacts, lithology, and any structural features.

Portions of the core will be removed for analysis. Samples for chemical analysis are placed in appropriate containers and transported to the Sample Management Office (SMO) for off-site analysis or to Laboratory analytical labs.

Geologic samples are removed from the core and placed in appropriate containers, usually zip-type plastic bags. The types of geologic analysis include binocular microscope and thin section petrography (SOP09.11), X-ray diffraction analysis (SOP 09.03), and X-ray fluorescence analysis (SOP 09.13). Geologic samples are kept in the Laboratory Earth and Environmental Sciences Sample Storage Area.

The volumes and sample handling requirements for core and cuttings are specified in Table 3. Analytical suites for core and cuttings are specified in Table 4.

4.2.2 Water

Water samples are collected from the borehole during drilling and from the completed well. The procedure that is used for sampling water during drilling (screening samples) is different from the procedure for sampling from the completed well (characterization samples). Both methods are described in this section.

Collection of Water Samples during Drilling

If saturation is encountered as a borehole advances, drilling will be stopped to determine whether the water represents natural fluids and if a sufficient volume is available to analyze the water quality. These analyses will include metals, anions, perchlorate, alkalinity, organic carbon, total inorganic carbon, total dissolved solids, and radiochemical constituents. Generally the total volume required is approximately 0.5-0.1 liter. Of this volume, 100 mL is unfiltered and unpreserved; another 100 mL is filtered and preserved with nitric acid. If this minimum volume of groundwater cannot be collected, the borehole will be continued to the planned TD or until saturation is encountered again and the process is repeated. Insufficient water sample volumes from discreet depths will not be composited to make the required volume for screening analysis.

Analytical suites for groundwater collected during drilling of intermediate and regional aquifer wells are specified in Table 5.

Collection of Water Samples from a Completed Well

Wells will be either single screen completion or multiple screen completion instrumented with the Westbay MP System®. The different sampling methods for single screen and multiple screen wells are described in this section. Guidance for collection of ground water samples can be found in SOP 06.01, "Purging and Sampling Methods for Single Completion Wells" and SOP 0.6.32, "Multi-level Groundwater Sampling of Monitoring Wells-Westbay MP System."

The first step in collecting a groundwater sample at a single completion well is to measure the static water level. This information, in conjunction with the total depth and diameter of the well, is used to calculate the volume of water that must be purged before collecting a sample. The water is purged with either a submersible pump or a bailer. The total volume of water purged is noted as are periodic measurements of discharge rate and water level. Field parameters are measured at the start of purging and several times thereafter. The well is ready to sample when three casing volumes have been removed, the field parameters have stabilized, and the turbidity is stable. Field parameters are also measured with each sample run.

The field parameters for groundwater samples include temperature, conductivity, pH, alkalinity, dissolved oxygen, and turbidity (see Table 8). Field parameters are considered stabilized when pH varies by less than 0.2 units or the variation in the other parameters over a series of four readings is within 10%. If the field parameters do not stabilize, a sample is still collected and the field parameters are recorded so that the analytical data may be placed in the proper context.

In wells with single screens, a submersible pump or bailer is used to remove the water from the well. After shutting down the pump or completion of bailing and sampling, the water level draw down in the well is noted. In multiple-screen wells, the MOSDAX sampler/monitoring probe is attached to the end of the cable winch line and is lowered to each screen in succession. The pressure in noted in each screen before the sample is collected. Multiple one-liter stainless steel sampling bottles, attached to the probe, are then filled with water from the screen and hoisted to the surface. Subsamples are collected from the sampling bottles for laboratory analyses. A 0.45 μm pore size filter is used to filter samples that are to be analyzed for dissolved constituents.

Once the groundwater sample has been collected and processed, water samples are placed in appropriate containers and preserved according to SOP 01.02, "Sample Container and Preservation." Groundwater samples for chemical analysis are placed in appropriate secondary containers and transported to the SMO for shipment to off-site analytical laboratories or to Laboratory analytical labs for more rapid local analysis; see SOP 01.03, "Handling, Packaging, and Shipping of Samples" for more details.

Analytical suites, estimated detection limits, and EPA analytical protocols for inorganic chemicals in post-development well sampling are specified in Table 6. Analytical suites, half lives, detection emission, minimum detectable activity, and analytical methods for radionuclides in post-development well sampling are specified in Table 7.

4.4 Borehole Geophysics

Borehole geophysical studies will be pursued to determine the distribution of saturation, to aid in the interpretation of stratigraphy and lithology, and to aid in well design. Geophysical instruments fielded by the drilling contractor using Laboratory methods or by a geophysical logging contractor may be deployed, depending on the types of geophysical data to be obtained.

Laboratory Geophysical Methods

Methods contributed by the drilling contractor using Laboratory geophysical tools include natural gamma, induction, caliper, and borehole video following SOP 05.07, "Operation of LANL Owned Borehole Logging Trailer." These tools will be used as necessary to supplement the information obtained from a geophysical logging contractor or in lieu of contractor data collection in wells where limited depth and constrained objectives do not justify the more expensive suite of contractor tools.

The Laboratory natural gamma tool is used to measure naturally-occurring variations in cumulative gross gamma radiation from K, U, and Th. Use of the Laboratory natural gamma tool will be advantageous where a contractor geophysical suite is not deployed and there is a need to refine geologic contacts.

The Laboratory induction tool provides information on conductivity and resistivity. This information will be important for comparison with core or cuttings in determining that component of rock resistivity/conductivity attributable to degree of saturation. The Laboratory induction tool will not be required if a logging contractor Array Induction Tool (AIT) is used to meet resistivity/conductivity characterization objectives.

The Laboratory caliper tool is a three-arm system that provides information about hole diameter to a maximum of 29 in. It is not anticipated that this tool will be used because the logging contractor's caliper tool will be used in those boreholes where diameter measurements are needed for defining washout intervals, critical for the evaluation of data from other tools in the contractor's suite.

The Laboratory borehole video camera provides an axial downward view along the borehole in either unsaturated conditions or within saturation where the water is clear enough. This tool is not replicated in the standard contractor's suite and it provides unique information on borehole wall conditions (or condition of casing and screens in a completed well), moist or flowing intervals within the vadose zone, and fracture distributions. It can also supplement other tools in defining depth to water and lithology.

Contracted Geophysical Methods

Contracted geophysical logging services will follow SOP 04.4, "Contract Geophysical Logging." Contracted geophysical methods are based on an extensive array of advanced tool designs. This suite of tools will be used primarily in the deeper borehole, particularly the holes that will intercept the regional aquifer (R-3) or are likely to encounter perched water (I-series holes). Table 9 specifies whether a tool can be used in cased hole, open hole, or both. The suite of contractor tools most likely to be used includes the following (tool names may vary depending on the contractor used, but the methods are similar).

Gross Gamma Ray (GR): This tool is equivalent to the Laboratory natural gamma tool; it is used with the instruments listed below (except the Natural Gamma Spectroscopy tool) in order to match logging runs to each other.

Combinable Magnetic Resonance (CMR): This tool uses nuclear magnetic resonance to evaluate total and effective (potentially movable) water-filled porosity. The data obtained are valuable for identification of perched saturation and locating the most likely productive zones for placing well screens.

Triple-detector Litho-density (TLD): This tool determines bulk density, from which measures of porosity can be derived using inferred grain densities. It is also very useful for lithologic characterization (e.g., determination of fracture or rubble zones between denser lavas in the Cerros del Rio).

Caliper: This is a multi-arm tool that determines rugosity of the borehole wall. Washouts can affect the interpretations of data obtained from tools that must apply sources or detectors close to the borehole wall.

Epithermal Compensated Neutron Tool (CNT): This tool is sensitive to total water content and is useful in the evaluation of relative distribution of borehole moisture.

Array Induction Tool (AIT): This tool determines electrical resistivity at five different depths into the borehole wall, providing information on invasion of drilling fluid, presence of persistent natural moisture, and/or presence of clay zones. The data from this tool or the Laboratory induction tool will be required in those boreholes (R-3) that target zones of differing resistivity detected by surface geophysics.

Formation Micro-Imager (FMI): This tool uses multiple electrical contacts on pads to provide an accurate image of the borehole wall with a resolution of ~0.5 cm in saturated or moist borehole conditions. The resulting images provide useful data on sediment clast sizes and shapes, bedding (including strike and dip), structure, and fracture distributions. The FMI is run with the General Purpose Inclinometry Tool (GPIT), which measures borehole deviation and azimuth, parameters that can affect well design and are used for orienting the FMI images.

Natural Gamma Spectroscopy (NGS): This tool uses a bismuth germanate (BGO) detector to measure those portions of the natural gamma signal attributable to K, U, and Th. The relative proportions of these three elements are useful in determining different lithologies and identifying zones of alteration.

Elemental Capture Spectroscopy (ECS): This tool uses an active Am-Be neutron source to generate gamma-ray signals, measured by a BGO detector, which can be used to estimate the abundances of H, Si, S, Cl, K, Ca, Ti, Fe+Al, and Gd in the borehole formations. These data aid in the characterization of mineralogy and lithology.

5.0 MONITORING PROGRAM

Based on the results of the investigations conducted in Los Alamos Canyon and Pueblo Canyon, a surface water and groundwater monitoring recommendation will be developed, and monitoring will be conducted under the interim facility-wide groundwater monitoring plan. The recommendation for long-term monitoring will be included in the Los Alamos Canyon and Pueblo Canyon Investigation Report.

6.0 SCHEDULE, DOCUMENTATION, DELIVERABLES, AND REPORTING

6.1 Schedule

The activities presented in this schedule are contingent upon regulatory approval of this work plan. The schedule is also contingent upon the availability of funding, resources, and contractual mechanisms at the appropriate times to complete fieldwork and comply with reporting requirements.

6.2 Investigation Report

An investigation report will be prepared following collection and analysis of environmental data and is currently scheduled for delivery to the NMED by June 16, 2006. The submittal date is based on drilling and completing the wells proposed is this work plan in calendar year 2005 and the conducting two quarters of sampling rounds at the wells. The report, will document results of field investigations including

- details of well construction;
- analytical results of borehole core, surface water, and groundwater sampling;
- results of the DC geophysical survey;
- results of the human health and ecological risk assessments;
- a revised conceptual model;

- recommendations for long-term monitoring; and
- other conclusions and recommendations.

Supplemental reports detailing results of geophysical investigations, infiltration studies, modeling, and geochemistry and contaminant chemistry investigations will be provided separately.

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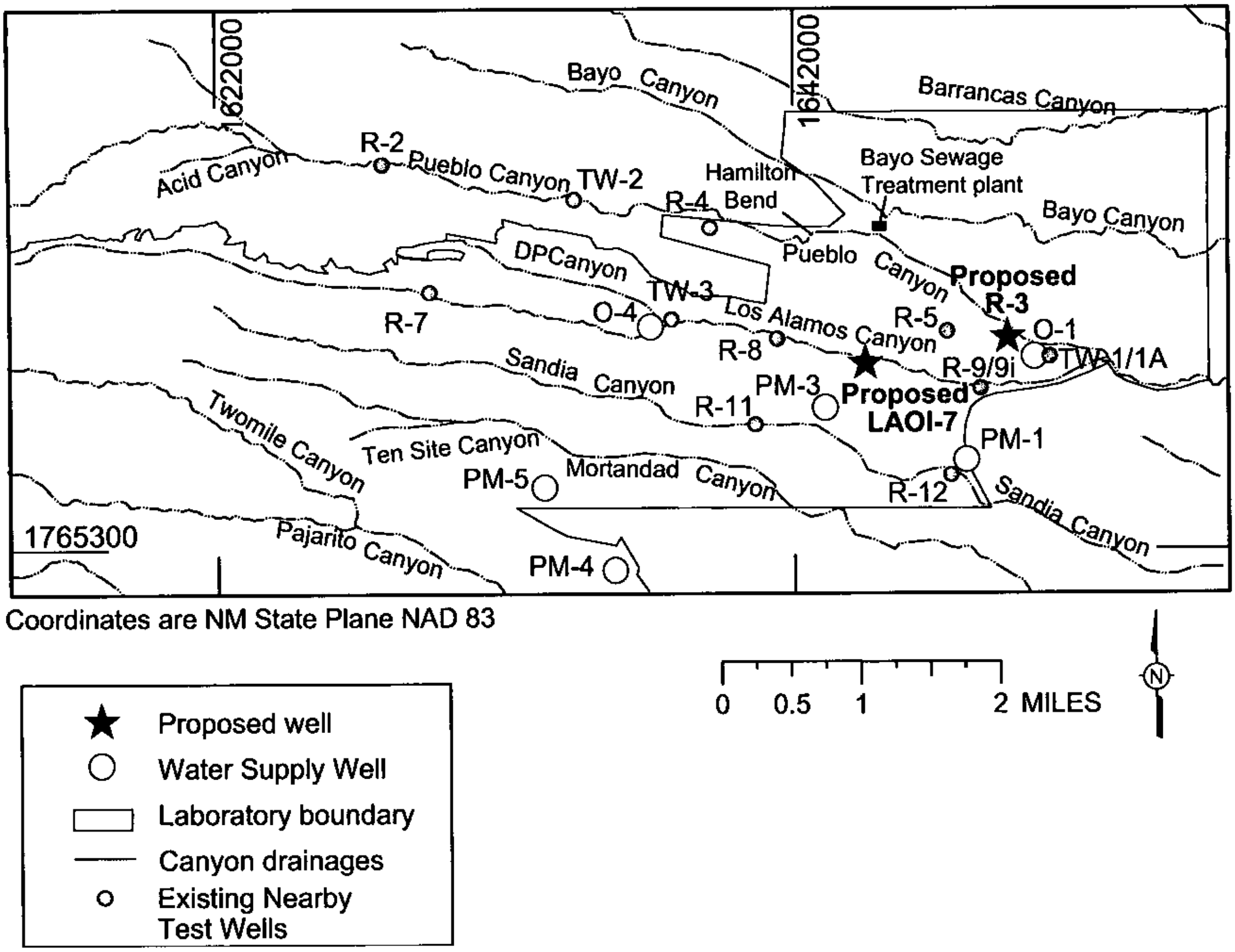

Figure 1. Location of Proposed Wells in Los Alamos Canyon and Pueblo Canyon

Table 1
Addendum Objectives for Los Alamos Canyon and Pueblo Canyon

Groundwater Addendum Objectives	How Addressed
Determine nature and extent of potential contamination within the regional aquifer downstream of the Acid Canyon and Pueblo Canyon confluence in Pueblo Canyon.	R-2 was drilled in October 2003 R-3 is proposed in this work plan addendum to be installed near Otowi-1.
Determine nature and extent of potential contamination within the regional aquifer immediately north of TA-73 in Pueblo Canyon.	R-4 was drilled in August 2003.
Determine nature and extent of contamination within the Cerros del Rio basalt/Puye Formation between wells R-8 and R-9i.	Well LAOI-7, as proposed in this work plan, is located between wells R-8 and R-9i. The information from wells R-8 and R-9 are sufficient for regional aquifer characterization.
Determine background/baseline water chemistry for Los Alamos Canyon and Pueblo Canyon.	Wells R-26 and R-7 serve as background wells for the Laboratory including Los Alamos Canyon and Pueblo Canyon.

Table 2
DQO Matrix for Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Wells

	Well LAOI-7	Well R-3
Primary Purpose	LAOI-7 will further refine the western limits on contaminants detected in perched intermediate groundwater in wells R-9 and R-9i. It is downgradient of numerous potential Laboratory sources, including TA-53, TA-21, TA-2, and TA-41.	Determine the zone(s) within the regional aquifer that contain the contaminants (nitrate, perchlorate, and tritium) that have been detected in O-1. Assess the contaminant transport pathways from surface sources to the regional aquifer. Measure the hydrologic parameters and water quality in saturated zone(s).
Projected Depth	300-400 ft; penetrate below base of Cerros del Rio basalt into the Puye Formation (100 ft) if perched water not detected within basalt; well will be completed without penetrating base of the basalt if perched water is detected in the Cerros del Rio basalt. If no saturation is encountered, the borehole will be backfilled.	1800 ft; penetrate approximately 800 ft below regional water table. Top of screen in O-1 is at 1017 ft bgs and bottom of screen is at 2477 ft bgs. This provides guidance for the screen interval in R-3.
Geology	Determine thickness and composition of stratigraphic units encountered.	Characterize alteration and resolve stratigraphic uncertainties presented by poor cuttings quality at O-1.
Hydrology	Determine hydraulic gradient, hydraulic conductivity, flow direction, and extent of saturation in Cerros del Rio basalt or adjacent strata, if feasible, with well R-9i.	Determine hydraulic gradient, hydraulic conductivity, and flow direction in the regional aquifer upgradient of O-1, if feasible, with other wells.
Geochemistry/ Contaminant Chemistry	Evaluate hydrochemistry of Cerros del Rio basalt or Puye Formation.	Evaluate hydrochemistry and contaminant distributions (nitrate, perchlorate, and tritium) in productive zones within the regional aquifer along the screened section in O-1.
Vadose Zone Sampling	Collect vadose zone core and analyze for anions, metals, radionuclides, and stable isotopes. Collect water samples if perched water is encountered during drilling.	Collect vadose zone core and analyze for anions, metals, radionuclides, and stable isotopes. Collect water samples if perched water is encountered during drilling.
Core Needs	Collect core samples from surface to core refusal, or a maximum depth of 320 ft, for contaminant, metal, and anion analyses. Cuttings will be used to determine lithology and stratigraphy below core refusal depth.	Collect core samples from surface to core refusal, or a maximum depth 300 ft, for contaminant, metal, and anion analyses. Cuttings will be used to determine lithology and stratigraphy below core refusal depth.
Hydraulic Testing	Conduct slug test and/or injection/straddle packer test in the screen completely within the perched zone.	Conduct slug test, single-step pumping test, or injection/straddle packer test in the screen completely below the regional water table.
Water Sampling	Collect screening water samples during drilling at the top of the perched intermediate groundwater, if encountered. Install well screen to collect water quality data for the perched intermediate groundwater, if encountered.	Collect screening water samples during drilling at the top of the regional aquifer. Install well screens to collect water quality data for the regional aquifer.

Table 2 (continued)

	Well LAOI-7	Well R-3
Geophysical Testing	Suite and timing of geophysical logging to depend on borehole conditions. Laboratory borehole video camera to be used when open hole conditions in the vadose zone are favorable for logging.	Suite and timing of geophysical logging to depend on borehole conditions. Laboratory borehole video camera to be used when open hole conditions in the vadose zone are favorable for logging.
Number of Well Screens	One screen in the Cerros del Rio basalt or Puye Formation.	Up to 3 screens at locations selected based on productive zones in the regional aquifer.

Table 3
Sampling of Core and Cuttings During Drilling of Intemediate and Regional Aquifer Wells

Sample Description	Test	Sample Size	Container	Sample Frequency
Coring				
Core	Anions and moisture	0.4 ft of 2-in. diameter core	8 oz pre-weighed glass jar	For upper 100 ft: Every 10 ft when drilling dry For below 100 ft: Every 50 ft to refusal
	Tritium	0.5 ft of 2-in. diameter core	Sealed plastic bag wrapped with tape and core-protected	For upper 100 ft: 10 samples will be collected when drilling dry For below 100 ft: Every 50 ft to refusal
	Radiological screening for gross alpha, beta, and gamma (for off-site transport of samples)	0.2 ft of 2-in. diameter core	Sealed plastic bag	Every 50 ft
	Radionuclides	0.5 ft of 2-in. diameter core	Sealed plastic bag and core-protected	For upper 100 ft: 10 samples to be collected when drilling dry For below 100 ft: Every 50 ft to refusal
	Metals and cations	0.5 ft of 2-in. diameter core	Sealed plastic bag and core protected	For upper 100 ft: 10 samples will be collected when drilling dry For below 100 ft: Every 50 ft to refusal
	Stable isotopes	0.5 ft of 2-in diameter core	Sealed plastic bag and core protected	For upper 100 ft: 10 samples will be collected when drilling dry For below 100 ft: Every 50 ft to refusal
Drilling				
Cuttings	Bulk cuttings systematically collected for archival purposes and for supplemental sample needs	500–700 ml	Plastic ziplock bag	One sample every cuttings run (nominally every 5 ft), beginning at the bottom of the core hole or throughout the hole if no core is collected
	Sieved cuttings for lithology description, binocular microscope examination	Enough to partly fill trays	Plastic chip trays	One sample every cuttings run (nominally every 5 ft), including overdrilling of the core hole. Normally, an unsieved sample, a >10 mesh sample, and a >35 mesh sample every cuttings run
	Sieved cuttings for x-ray diffraction (XRD), x-ray fluorescence (XRF), petrography	200–300 ml sieved, or bulk if necessary	Plastic ziplock bag	One >10-mesh sample every cuttings run (nominally every 5 ft); finer sizes or bulk split will be substituted where >10-mesh size cannot be obtained

Note: Priority of sample core collection when recovery is less than 100% should be anions, moisture, and stable isotopes; radionuclides and tritium; and radiological screening, cations, and metals.

Table 4
Analysis of Core and Cuttings During Drilling of Intermediate and Regional Aquifer Wells

Analyte	EDL[a]	Analytical Technique	Analytical Method
Anions and Cations[b]/Stable Isotopes			
Bromide, chloride, fluoride, iodide, nitrate, nitrite, oxalate, phosphate, sulfate	0.02 mg/L	IC	SW-846-EPA Method 300
Carbonate Alkalinity	1 mg/L	Titration	SW-846 – EPA Method 310.1
Perchlorate	0.004 mg/L[c] 0.00006 mg/L[d]	IC	SW-846-EPA Method 300 LCMS/MS[e]
Arsenic, strontium, uranium	0.001 mg/L	Inductively coupled mass spectrometry (ICPMS)	SW-846-EPA Method 6020
Aluminum, calcium, iron, magnesium, manganese, sodium, potassium	0.01 mg/L	Inductively coupled optical emission spectroscopy (ICPOES)	SW-846-EPA Method 6010B
$^{18}O/^{16}O$	n/a[f] (permil)	Isotope ratio mass spectrometry	Generic – oxygen isotope ratio
$^{2}H/^{1}H$	n/a (permil)	Isotope ratio mass spectrometry	Generic – deuterium ratio
$^{15}N/^{14}N$	n/a (permil)	Isotope ratio mass spectrometry	Generic – nitrogen isotope ratio
Contaminant Characterization Constituents			
Tritium	700 pCi/L	Liquid scintillation counting	EPA Method 906.0
Tritium	0.5 pCi/L	Direct counting or electrolytic enrichment	Generic low-level tritium
Americium-241	0.05 pCi/g	α-spectrometry	HASL-300: americium-241
Plutonium-238	0.05 pCi/g	α-spectrometry	HASL-300: isotopic plutonium
Plutonium-239,240	0.05 pCi/g	α-spectrometry	HASL-300: isotopic plutonium
Strontium-90	0.5 pCi/g	Gas proportional counting	EPA Method 905.0
Technetium-99	5 pCi/g	Gas proportional counting	HASL-300: Technetium-99
Uranium-234	0.1 pCi/g	α-spectrometry	HASL-300: isotopic uranium
Uranium-235,236	0.1 pCi/g	α-spectrometry	HASL-300: isotopic uranium
Uranium-238	0.1 pCi/g	α-spectrometry	HASL-300: isotopic uranium
Gamma spectroscopy	1.0 pCi/g	γ-spectroscopy	EPA Method 901.1

[a] EDL= Estimated detection limit, listed as milligrams per liter for anions and picocuries per gram for radionuclide constituents except tritium (which is listed in picocuries per liter) in extracted or leached water.
[b] Anion and cation analyses will be performed on the leachate formed from a deionized water slurry of the homogenized core sample.
[c] Offsite laboratory.
[d] Onsite screening.
[e] LCMS/MS = Liquid chromatography mass spectrometry/mass spectrometry; used for low-level perchlorate analysis (0.06 μg/L).
[f] n/a = Not applicable.

Table 5
Sampling and Analysis of Intermediate and Regional Aquifer Groundwater during Drilling

Estimated Number of Water Samples/ Borehole	Analysis	Container	Preservation	Filtered Through Acetate 0.45 Micrometer	Volume of Each Sample (L)	Collect Archival Sample	Archival Sample Volume (L)
5	Metals (dissolved)	100 ml plastic	HNO_3 to pH 2, 4°C	Yes	0.25		
5	Anions (dissolved)	100 ml plastic	No field preservation	Yes	0.25		
5	γ spec, ^{241}Am, ^{137}Cs, $^{238,239,240}Pu$, $^{234,235,238}U$, ^{90}Sr	1 gal. plastic	HNO_3 to pH 2, 4°C	No	3.78	X	3.78
5	Stable isotopes ($^{18}O/^{16}O$, D/H)	30 ml glass w/ poly-seal cap	Ambient temperature	No	0.03	X	0.03
5	Stable isotopes ($^{15}N/^{14}N$)	1 gal. plastic	HCL or H_2SO_4 to pH 2, 4°C	No	3.78	X	3.78
5	Tritium[a]	500 ml poly	Ambient temperature	No	0.5	X	0.5
5	Tritium (low-level or direct-counting)[a]	500 ml poly	Ambient temperature	No	0.5	X	1
5	Gross α,β ,γ (for off-site shipping)	500 ml poly	Ambient temperature	No	0.5	X	0.5
5	TKN	1 L poly	H_2SO_4 to pH 2, 4°C[b]	No	1	X	1
5	ClO_4^-	250 ml poly	Ambient temperature	Yes	0.25	X	0.25
Total volume of each sample event: filtered and nonfiltered					10.84		10.84
Part of total volume to be filtered					0.75		

[a] Initially analyze tritium using liquid scintillation. If activity is less than 300 pCi/L, analyze archival sample using direct counting or electrolytic enrichment at University of Miami.

[b] No preservation for ClO_4^-, Br^-, Cl^-, F^-, NO_3^-, NO_2^-, SO_4^{2-}, and PO_4^{3-}.

Table 6
Analytical Suite, Estimated Detection Limits. Analytical Methods, and Analytical Protocols for Inorganic Chemicals in Groundwater Samples for Post-Development Characterization Sampling

Analyte	EDL (μg/L)	Analytical Method	Analytical Protocol[b]
Metals (total and dissolved)			
Aluminum	10	ICPMS	SW-6020
Antimony	0.1	ICPMS	SW-6020
Arsenic	1	ICPMS	SW-6020
Barium	2	ICPMS	SW-6020
Beryllium	5	ICPMS	SW-6020
Boron	10	ICPMS	SW-6020
Cadmium	0.1	ICPMS	SW-6020
Calcium	10	ICPES	SW-6010B
Chromium	2	ICPMS	SW-6020
Cobalt	2	ICPMS	SW-6010B
Copper	2	ICPMS	SW-6020
Iron	10	ICPMS	SW-6020
Lead	0.1	ICPMS	SW-6020
Magnesium	10	ICPES	SW-6010B
Manganese	2	ICPMS	SW-6020
Mercury	0.2	CVAA	SW-7470A
Nickel	2	ICPMS	SW-6020
Potassium	10	ICPES	SW-6010B
Selenium	0.2	ICPMS	SW-6020
Silver	0.2	ICPMS	SW-6020
Sodium	50	ICPES	SW-6010B
Thallium	0.1	ICPMS	SW-6020
Uranium	0.1	ICPMS	SW-6020
Vanadium	2	ICPMS	SW-6020
Zinc	1	ICPMS	SW-6020
Anions (dissolved)			
Bromide	20	IC	SW-300
Chlorate	20	IC	SW-300
Chloride	20	IC	SW-300
Fluoride	20	IC	SW-300
Nitrate	40	IC	SW-300
Nitrite	40	IC	SW-300
Perchlorate	4	IC	SW-300
Orthophosphate	20	IC	SW-300
Sulfate	100	IC	SW-300
Other Inorganic Chemicals (dissolved)			
Silica	200	Colorimetry	EPA Method 370.1
Total cyanide	50	Colorimetry	SW-9012A

[a] Both nonfiltered (total) and filtered (dissolved) water samples will be collected. Water samples will be filtered at the time of collection to remove particles larger than 0.45 μm.
[b] EPA SW-846 Method (EPA 1986, 31732) or equivalent.

Table 7
Analytical Suite, Half-Life, Detection Emission, Minimum Detectable Activity, and Analytical Method for Radionuclides in Groundwater Samples for Post-Development Characterization Sampling

Analyte	Half-Life (yr)	Detected Emission	MDA (pCi/L)	Analytical Method
^{241}Am	432.2	α	0.05	α-Spectrometry
^{238}Pu	87.7	α	0.05	α-Spectrometry
^{239,240}Pu[b]	2.411 x 10^4	α	0.05	α-Spectrometry
^{90}Sr	28.7	β	1.0	GPC
Tritium	12.3	β	250	LSC
Tritium (low level)	12.3	β	1	Electrolytic enrichment/DC
^{99}Tc	2.13 x 10^5	β	5	LSC
^{234}U	2.46 x 10^5	α	0.1	α-Spectrometry[c]
^{235}U	7.04 x 10^8	α	0.1	α-Spectrometry[c]
^{236}U[d]	2.342 x 10^7	α	0.1	TIMS
^{238}U	4.47 x 10^9	α	0.1	α-Spectrometry[c]
Gamma spectroscopy[e]	n/a[f]	γ	10[g]	γ-Spectroscopy
Gross-alpha	n/a	α	1.0	GPC or LSC
Gross-beta	n/a	β	1.0	GPC or LSC
Gross-gamma	n/a	γ	20	NaI(Tl) or HPGe detection

[a] Both filtered and nonfiltered samples will be collected for radionuclide analyses, excluding tritium and Tc-99.
[b] The ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.
[c] Radionuclide may also be analyzed by ICPMS.
[d] Water sampling for ^{236}U analysis should use clean protocols including EPA 1669 or United States Geological Survey 94-539.
[e] The gamma spectroscopy analyte list includes gamma-emitting isotopes including Cs-137.
[f] n/a = Not applicable.
[g] The MDA for ^{137}Cs is 15 pCi/L; the MDAs for other analytes will vary.

Table 8
Parameters to be Measured in the Field During Characterization Groundwater Sampling

Measurement	Precision[a]
pH	±0.02
Specific conductance	±1 µmho/cm (25 °C)
Dissolved oxygen	0.1 mg/L
Carbonate alkalinity	mg $CaCO_3$/L
Temperature	±1 °C
Turbidity (nephelometric)	±1 NTU[b]

[a] Precision with which measurement shall be recorded.
[b] NTU = Nephelometric turbidity unit.

Table 9
Typical Wire-Line Geophysical Logging Tools

Cased Hole	Cased Hole	Open Hole	Uncased Hole
Array Induction Tool		X	Measures open-hole formation conductivity with multiple depths of investigation at varied vertical resolution
Triple LithoDensity Tool	X	X	Evaluates formation porosity where grain density can be estimated
Combinable Magnetic Resonance Tool (CMR)		X	Provides information on water content and relative abundance of hydrous minerals and capillary-bound versus mobile water
Natural Gamma Tool	X	X	Used to distinguish lithologies by their gross gamma signature; also used to calibrate depth of other geophysical tool readings
Natural Gamma Ray Spectrometry Tool (also called the spectral gamma tool)	X	X	Used to distinguish lithologies where formations vary in relative and overall concentrations of potassium, thorium and/or uranium
Epithermal Compensated Neutron Log	X	X	Measures moisture content in unsaturated conditions and porosity in saturated conditions
Caliper		X	Measures rugosity of borehole wall
Fullbore Formation Microimager		X	Provides high-quality image of borehole based on electrical properties; used to determine lithologies, bedding attitudes, fracture characteristics, and borehole deviation
Elemental Capture Spectrometer	X	X	Determines formation lithology from bulk geochemistry; primary use in determining elemental concentrations of Si, Ca, Fe, Ti and Gd

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