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Corrective Measures Evaluation Report for Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54

Los Alamos
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EXECUTIVE SUMMARY

This report documents the corrective measures evaluation (CME) conducted for Material Disposal Area (MDA) H, Solid Waste Management Unit (SWMU) 54-004. MDA H is composed of nine subsurface shafts used for the disposal of security-classified solid-form waste. SWMU 54-004 is collocated with one Resource Conservation and Recovery Act–regulated unit (Shaft 9). This CME is part of a comprehensive, integrated approach to remediate and close these nine subsurface disposal shafts. The goal of this CME is to recommend a corrective measures alternative for closure of SWMU 54-004 and the regulated unit, and to address the associated releases in accordance with the Compliance Order on Consent (Consent Order).

The objectives of this CME are to identify and evaluate potential remedial alternatives to address the hazardous wastes and hazardous constituents released from the SWMU and the regulated unit at MDA H, and to recommend a preferred remedy that is protective of human health and the environment as well as to attain the appropriate cleanup goals for these wastes and hazardous constituents. To meet these objectives, the long-term performance of various technologies was assessed in accordance with U.S. Environmental Protection Agency, U.S. Department of Energy, and New Mexico Environment Department risk-assessment guidance.

A conceptual site model was developed to evaluate primary and secondary release mechanisms from the source area. Current and potential future pathways were identified and technologies were evaluated to reduce any potential adverse exposure to hazardous wastes or hazardous constituents. The conceptual site model identified buried waste in the nine shafts as the source. The remedial action objectives for MDA H are as follows:

- prevent future human health and ecological exposure to waste through inadvertent excavation, and
- prevent future disruption and dispersal of waste by physical disruption or infiltration of moisture.

The general types of technologies evaluated in this report include containment, in situ treatment, source removal, and ex situ treatment of waste.

Technologies were originally screened against the threshold criteria defined in section VII.D.4.a of the Consent Order. The technologies that passed the threshold criteria were then screened against the balancing criteria in section VII.D.4.b of the Consent Order. These technologies were then ranked against the balancing criteria, and the highest-ranking technologies were combined into alternatives. These alternatives were screened against the balancing criteria and combined into a recommended alternative.

The recommended alternative includes constructing an evapotranspiration cover over the shafts and implementing institutional controls to prevent human intrusion. Implementation of the recommended alternative satisfies all remedial action objectives.

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1.0 INTRODUCTION

This report documents the corrective measures evaluation (CME) conducted for Material Disposal Area (MDA) H, Solid Waste Management Unit (SWMU) 54-004, at Los Alamos National Laboratory (LANL or the Laboratory). This CME was developed and is submitted pursuant to the Compliance Order on Consent (Consent Order).

The Laboratory is a multidisciplinary research facility owned by the U.S. Department of Energy (DOE) and managed by Los Alamos National Security, LLC. The Laboratory is located in north-central New Mexico, approximately 60 mi northeast of Albuquerque and 20 mi northwest of Santa Fe. The Laboratory site covers 40 mi^2 of the Pajarito Plateau, which consists of a series of fingerlike mesas that are separated by deep canyons containing perennial and intermittent streams running from west to east. Mesa tops range in elevation from approximately 6200 ft to 7800 ft above mean sea level (amsl). The eastern portion of the plateau stands 300 ft to 1000 ft above the Rio Grande.

The Laboratory is divided into numerous technical areas (TAs) based upon facility operations. Several TAs include MDAs where waste was previously disposed. MDA H subsurface disposal units are located within the boundaries of TA-54 (Figures 1.0-1 and 1.0-2). MDA H is defined as the subsurface disposal shafts contained within SWMU 54-004 that are subject to corrective action under the Consent Order. One of these shafts, Shaft 9, is a regulated unit as defined in 40 CFR 264.90(a)(2) and is discussed below. SWMU 54-004 was used for the disposal of security-classified solid-form waste.

The objectives of this CME are to identify and evaluate potential remedial alternatives to address any hazardous wastes and hazardous constituents released from the SWMU and the regulated unit at MDA H, and to recommend a preferred remedy that is protective of human health and the environment as well as to attain the appropriate cleanup goals for these wastes and hazardous constituents. To meet these objectives, the long-term performance of various technologies was assessed in accordance with U.S. Environmental Protection Agency (EPA), DOE, and New Mexico Environment Department (NMED) risk assessment guidance.

The Laboratory's ongoing management of hazardous and mixed wastes is regulated by the NMED under a Hazardous Waste Facility Permit issued pursuant to the New Mexico Hazardous Waste Act (NMHWA). The Consent Order addresses corrective action for the hazardous component of wastes disposed of at MDA H. The Consent Order fulfills the corrective action requirements in sections 3004(u) and (v) and 3008(h) of the federal Resource Conservation Recovery Act (RCRA); sections 74-4-4(A)(5)(h) and (i), 74-4-4.2(B), and 7-7-10(E) of the NMHWA; the federal and state implementing regulations in 40 CFR Part 264, Subpart F, and 20.6.2.3103 New Mexico Administrative Code (NMAC), respectively. The Consent Order is the sole enforceable instrument for corrective action relating to the Laboratory except as provided in section III.W.1.

The requirements of the Consent Order do not apply to radionuclides, including, but not limited to, source, special nuclear or byproduct material as defined in the amended Atomic Energy Act of 1954, or the radioactive portion of mixed waste. DOE's authority to regulate nuclear safety is governed by the provisions of 10 CFR Parts 830 through 835. Pursuant to these regulations, DOE is required to review and approve all activities and work related to radionuclides, including activities and work under the Consent Order.

The RCRA-regulated unit at MDA H is a subset of the SWMU. A "regulated unit" is defined in 40 CFR 264.90(a)(2) as "any landfill, surface impoundment, waste pile or land treatment facility that received wastes after July 26, 1982 or that certified closure after July 26, 1983." Closure under Subpart F of

Parts 264 and 265 for regulated units is prescriptive, including design requirements for caps on land disposal units and post-closure care (including cap maintenance and groundwater monitoring). The EPA recognized that complex sites, such as MDA H, are potentially subject to two different sets of RCRA requirements that apply to a single release if both regulated units and SWMUs have contributed to the release. To avoid unnecessary impediments to cleanups while ensuring that both SWMUs and regulated units are cleaned up in a manner that is protective of human health and the environment, 40 CFR 264.110(c) provides EPA and authorized states, such as New Mexico, with the discretion to prescribe alternative closure requirements. MDA H meets the requirements for the application of 40 CFR 264.110(c) on the following grounds.

- MDA H consists of Shafts 1 through 8, which comprise a SWMU listed in module VIII of the Laboratory’s Hazardous Waste Facility Permit. Shaft 9 received hazardous waste after July 26, 1982, and is considered a “regulated unit.” This regulated unit is situated among the shafts in the subsurface SWMU.
- NMED has directed the Laboratory to address all nine disposal shafts under corrective action per 20.4.1.500 NMAC (NMED 2000, 068569).
- The alternative closure and post-closure requirements for MDA H are set out in the Consent Order, which is an “enforceable document” as defined in 40 CFR 270.1(c)(7).

This CME is organized according to the Consent Order requirements. Table 1.0-1 summarizes the Consent Order requirements and identifies where the applicable requirements are addressed within this report. Section 1 provides an overview of the CME. Section 2 provides a brief site history, discusses the waste inventory, and summarizes the results of previous investigations. Section 3 describes surface and subsurface site conditions. Section 4 summarizes the conceptual site model (CSM) and includes a description of sources, pathways, and receptors. Section 5 details the regulatory criteria for the CME, including applicable cleanup standards, risk-based screening levels, and risk-based cleanup goals for each pertinent medium at MDA H subsurface units. In section 6, the potential corrective measure technologies are identified and evaluated for applicability at MDA H. The retained technologies are screened against the threshold criteria in section 7. Technologies that meet the threshold criteria are evaluated further in section 8 against the balancing criteria. The recommended corrective measures alternative is discussed in section 9. The design criteria to meet cleanup objectives are presented in section 10, the proposed schedule is provided in section 11, and references and map data sources are included in section 12.

2.0 BACKGROUND INFORMATION

TA-54 is situated in the east-central portion of the Laboratory on Mesita del Buey (Figure 1.0-1). TA-54 includes four MDAs designated as G, H, J, and L; a waste characterization, container storage, and transfer facility (TA-54 West); active radioactive waste storage and disposal operations at Area G; active hazardous and mixed-waste storage operations at Area L; and administrative and support areas. The transfer facility is located at the western end of TA-54, and MDAs H and J are located approximately 500 ft and 1000 ft, respectively, southeast of the transfer facility. Area L is located approximately 1 mi southeast of the transfer facility. MDA G is located approximately 0.5 mi southeast of Area L.

MDA H is a 70-ft by 200-ft (0.3-acre) fenced area located on Mesita del Buey, a small mesa that lies between Pajarito Canyon and Cañada del Buey (Figure 2.0-1). Mesita del Buey is a 100- to 140-ft-high finger-shaped mesa that trends southeast. The elevation of Mesita del Buey ranges from 6885 to 6890 ft at MDA H. The mesa is approximately 500-ft wide and is bounded by the basin of Cañada del Buey (450 ft to the north) and the basin of Pajarito Canyon (360 ft to the south) (Figure 1.0-2).

The following subsections provide a summary of site information. Further information about the current site conditions at MDA H are detailed in the MDA H RCRA Facility Investigation (RFI) Report (LANL 2001, 070158), the Addendum to the RFI report (LANL 2002, 073270), and quarterly periodic monitoring reports (PMRs) for pore gas (LANL 2010, 111123). These documents describe the site and include information on the disposal units, waste inventories, characterization activities, analytical sampling results, and assessments of potential present-day risks to human health and the environment.

2.1 Site History

MDA H operated from May 1960 until August 1986 as the Laboratory's designated disposal area for classified, solid-form waste. Disposal of solid-form waste materials was restricted to items or materials that were determined by authorized personnel to be both classified and no longer required for their intended use. This determination was recorded on disposal forms that accompanied the waste to MDA H. Liquids were prohibited from disposal (Clayton 1960, 011515; Dickason 1960, 011514).

MDA H is a 70-ft by 200-ft (0.3-acre) fenced area located on Mesita del Buey, a small mesa that lies between Pajarito Canyon and Cañada del Buey. The MDA consists of nine inactive vertical disposal shafts arranged in a line approximately 15 ft inside the southern fence (Figure 2.0-1). Each shaft is cylindrical with a diameter of 6 ft and a depth of 60 ft. Shafts 1 through 8 were filled with waste to within 6 ft of the surface, then covered with 3 ft of concrete and brought to grade with 3 ft of crushed tuff. Shaft 9 was also filled with waste to within 6 ft of the surface, but brought to grade with 6 ft of concrete.

To protect against the possible impacts of mesa-edge instability, all MDA H disposal shafts were located a minimum of 60 ft from the mesa edge. The surface of MDA H is vegetated with native grasses that stabilize the soil against erosion. In addition, the surface is contoured to redirect stormwater runoff around the site and into a single drainage to Pajarito Canyon. Because the material disposed of at MDA H was classified, double packaging with an opaque outer material, such as plastic bags or drums, was required. Lightweight wastes were dropped into the shafts, while heavier materials were lowered in by heavy equipment. Many of the solid-form classified materials disposed of at MDA H contained residues of liquids or gases. Based on early disposal records, the density of waste materials varied from 5 to over 400 lb per cubic foot in the shafts. Between waste disposal events, each shaft was covered with a locked steel plate to prevent unauthorized access to classified materials and minimize collection of precipitation and runoff.

Title 10 of the Code of Federal Regulations (CFR) Part 830 (10 CFR 830), Subpart B "Safety Basis Requirements" and Section 204 of 10 CFR 830, "Documented Safety Analysis" (DSA), require documented safety analysis for each nuclear environmental site (NES) at LANL. The NES are inactive below-ground sites containing sufficient material generated from historical Laboratory activities to warrant categorization as nuclear facilities. On November 26, 2003, the National Nuclear Security Administration (NNSA) concurred with the Laboratory's initial hazard assessment of MDA H as a NES. The NES consists of waste disposal units that contain the governed material and an Inventory Isolation System (IIS). The IIS is charged with protection of the governed material from potential impacts associated with disturbance or accidents.

MDA H is posted as a NES and is surrounded by an 8-ft-high chain-link fence. MDA H is under the control of the DOE and the Laboratory, which plan, control, and restrict MDA H land use and activities. Access is gained through a locked gate maintained by the NES Facility Operations Director (FOD). No on-site activity may be conducted without prior FOD review against the current DSA and approval. Activities outside of the NNSA-approved DSA must be supported by a Hazard Assessment in accordance with section 204 of 10 CFR 830.

2.2 MDA H Waste Inventory

As described above, waste was disposed of in the MDA H shafts over approximately 26 yr. During this period, disposal events were recorded in a single Los Alamos Scientific Laboratory (LASL) logbook (LASL 1960–1986, 070034) that contains brief, unclassified descriptions of the waste, including approximate weights. The logbook was transcribed into a spreadsheet, which was reproduced as Appendix B. The waste descriptions include information sufficient to identify the types of potentially hazardous and radioactive waste at MDA H, and to assist in evaluating the alternatives in this CME.

The logbook shows that a variety of wastes were disposed of in the shafts. Logbook entries include waste that potentially meets the RCRA definition of characteristic hazardous waste such as lithium hydride and high explosives (HE). Additional potentially hazardous wastes or constituents not listed in logbook entries are expected to be present based on process knowledge. These materials, including barium, cadmium, chromium, lead, mercury, and silver, were used as shielding, solders, parts, or coatings. Other hazardous constituents, such as beryllium and copper, are also listed in logbook entries. Volatile organic compounds (VOCs) were not listed in the logbook entries, but are detected in trace amounts in vapor-phase sampling at MDA H (e.g., LANL 2010, 111123). Radionuclides listed in or identified from the logbook entries include tritium, uranium-234, uranium-235/236, uranium-238, plutonium-238, plutonium-239/240, plutonium-241, and plutonium-242.

The largest component of the MDA H waste inventory is metal (57%), both radioactive (24% depleted uranium [DU]) and nonradioactive (33% other metals). Potentially reactive materials, such as lithium compounds, represent approximately 1% of the inventory. Graphite represents approximately 9% of the inventory, and radioactive materials other than DU account for approximately 24% of the inventory. Plastics account for approximately 9% of the inventory; paper and HE each constitute less than 1% of the inventory (LASL 1960–1986, 070034). Table 2.2-1 and Figure 2.2-1 summarize the inventory of waste disposed of at MDA H. Appendix B details the waste inventory for each disposal shaft. The total mass of all waste in the MDA H disposal shafts is estimated to be 391,229 lb[1] (Omicron 2003, 075940). A review was conducted by subject matter experts on the characteristics of the complex mixture of waste disposed of in the shafts (Appendix C). It was determined that the waste is sensitive to sparks, friction, heat, physical impact, pinching, air, and/or moisture.

2.3 Site Description

2.3.1 Surface Soils

The soils of Mesita del Buey are derived from the weathering of the Tshirege Member tuffs (phenocrysts and phenocryst fragments, devitrified glass, and minor lithic fragments) and from wind-blown sources. Soils on the flanks of the mesa are developed on Tshirege Member tuffs and colluviums with additions from wind-blown and water-transported sources. Native soils have been disturbed by waste management operations over much of the surface of Mesita del Buey, but when present, native soils are generally deeper near the center of the mesa and shallower toward the edges.

In general, soils on the mesa surface are thin and poorly developed; they tend to be sandy near the surface and more clay-like beneath. More highly developed soil profiles exist on the north-facing slopes,

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[1] Weights provided within the logbook are missing for approximately 2% of the entries.

and they tend to be richer in organic matter. Soil profiles on the south-facing slopes tend to be poorly developed. Soil-forming processes have been identified along fractures in the upper part of the mesa, and the translocation of clay minerals from surface soils into fractures has been described at Mesita del Buey (Newman 1996, 059118).

The original soils near MDA H were also poorly developed, which is typical of soils derived from Bandelier Tuff and formed under semi-arid climate conditions (Nyhan et al. 1978, 005702, p. 24). In general, undisturbed soils on the mesa tops are composed of a few loams: the Carjo loam, the Hackroy loam, and the Seaby loam.

Canyon bottoms (i.e., Cañada del Buey and Pajarito Canyon) near MDA H are covered with colluvium and alluvium that has eroded from the tuff and soils on the mesa top and canyon walls. The canyon rims and slopes are composed of soils from the Hackroy-Rock outcrop complex; the canyon bottoms are composed of Tocal loam, a very fine, sandy loam. Since disposal activities began at Area H, Cañada del Buey has experienced a period of accretion, and eroded soils from Area H as well as other areas at TA-54 have been deposited on the canyon bottom and stream banks. Potentially, these soils may be redistributed downstream during stormwater runoff events.

2.3.2 Subsurface Geology

A brief description of the local geologic conditions at MDA H is summarized in this section. A generalized stratigraphic column for MDA H is shown in Figure 2.3-1. A north-south geologic cross-section in the vicinity of MDA H is shown in Figure D-2.1-2. Appendix D-2.0 describes the site-wide geology for TA-54.

MDA H is located on Mesita del Buey, an erosional high stand of Bandelier Tuff on the Pajarito Plateau. The caprock of the mesa is formed of moderately-welded tuff of Unit 2 (Qbt 2) of the Tshirege Member of the Bandelier Tuff. Below the surface, tuff and sedimentary units pass from Qbt 2 into nonwelded devitrified Tshirege tuff (Qbt1v), nonwelded vitric Tshirege tuff (Qbt 1g), thin basal-Tshirege Tsankawi fall deposits (Qbtt), Cerro Toledo sediments (Qct) of variable thickness, Otowi Member nonwelded vitric ash flows (Qbo), and Guaje Pumice Bed (Qbog) fall deposits. Beneath the tuff and sediment is a thick and varied sequence of alkalic basalt of the Cerros del Rio volcanic field (Tb4). Although this volcanic series is dominated by lava flows, the MDA H area overlies a site of considerable variety in Tb4 components including lavas, flow breccias, scoria, and interflow sediments.

Sedimentary deposits of the Puye Formation (Tpf) underlie the Cerros del Rio volcanic series. These sediments transition from fanglomerates beneath the western part of TA-54 to axial river gravels of the Totavi Lentil to the east. These two faces interfinger and the transition between the two is both lithologically varied and discontinuous. Miocene pumice-rich Jemez alluvial fan deposits (Tjfp) lie beneath the Puye Formation in the vicinity of MDA H. These older alluvial fan deposits, which pinch out eastward in the vicinity of MDA L, are underlain by sands and silty sands of the Chamita Formation (Tcar) of the Santa Fe Group. Sediments beneath the Cerros del Rio volcanic series at TA-54 are thus highly varied, including coarse fanglomerates derived from volcanic centers to the west, coarse gravel to sand in river channel deposits derived from sources to the north, and relatively fine and variably calcite-cemented Santa Fe Group sediments from the northeast.

2.3.3 Surface Water

No streams flow on Mesita del Buey; water flows only as stormwater, snowmelt runoff on the mesa, and in small drainages off the mesa to the north and the south. Stormwater flows in a number of points along the perimeter of TA-54 as identified and characterized in the “TA-54 Storm Water Pollution Prevention

Plan" (LANL 2009, 109438) prepared for the Laboratory's National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit. Therefore, flooding at the site is not a concern. As a result of runoff, surface erosion occurs primarily as shallow sheet erosion on the relatively flat parts of the mesa, and as channel erosion in major drainages from the mesa top. The surface of MDA H is contoured to direct stormwater runoff around MDA H and into a single drainage toward Pajarito Canyon (LANL 2001, 070158).

2.3.4 Vadose Zone Hydrology

The vadose zone is the zone between the land surface and the regional water table within which the hydraulic pressure is less than atmospheric. The pores within the vadose zone are unsaturated (i.e., they contain both air and water) beneath MDA H. Mesita del Buey is one of the drier mesas at the Laboratory and on the Pajarito Plateau. Infiltration occurs into the shallow subsurface mostly during snowmelt or following intense summer thunderstorms. Moisture from the shallow subsurface of the mesa is removed by evapotranspiration (ET). Figure 2.3-2 presents data showing that average potential ET rates exceed precipitation rates throughout the year at TA-54, that is, little to no water is available for infiltration at the site. Percolation into the deeper subsurface of the mesa appears to be very low. Newman et al. (2005, 099163) estimated percolation rates and vadose zone travel times in undisturbed, disturbed, and paved areas across TA-54 using moisture, chloride, and stable isotope data from shallow (1- to 2-m deep) cores. The study looked at vegetated and unvegetated areas. Under undisturbed and vegetated conditions, percolation rates on Mesita del Buey are estimated to be approximately 0.2 mm/yr; under disturbed conditions and beneath pavement, less ET occurs and percolation rates can range up to 10 mm/yr (Newman et al. 2005, 099163). Similar average percolation rates are confirmed by several independent studies (Birdsell et al. 2005, 092048; Kwicklis et al. 2005, 090069). If these conditions are maintained over long time frames, average travel times for conservative water-phase contaminants (those that do not react, adsorb, precipitate, or partition into the gas phase) from the surface to the regional aquifer of several hundred years to several thousand years are predicted under disturbed and undisturbed conditions, respectively (LANL 2005, 089332; Stauffer et al. 2005, 097432). Conservative vapor-phase contaminants migrate through vapor diffusion and may migrate more quickly than water-phase contaminants; non-conservative water-phase constituents (those that do react, adsorb, or precipitate) will migrate more slowly. The CSM for contaminant migration through the unsaturated zone at TA-54 is summarized in section 4 of this report.

At MDA H, neutron logging was used to determine volumetric moisture content in three boreholes in 2005 through 2007, 54-01023, 54-15461, and 54-15452 (Figures 2.3-3 and 2.3-4) (LANL 2007, 099140). The moisture content in the upper 140 ft below ground surface (bgs) is generally between 3% and 15% by volume. At approximately 150 ft bgs, the moisture content increases to approximately 20% to 40% by volume. This occurs at the base of Unit 1v-c; an increase in moisture content at the base of Unit 1 v-c is observed in core samples collected across the Laboratory and is thought to be related to the fine-grained nature of this unit. Moisture contents below this unit to depths of approximately 250 ft decrease to 10% to 25%. These moisture content values are low given that the porosity of the tuffs are in the 40% to 50% range; for fully saturated conditions, the volumetric moisture content is equivalent to the porosity. At these moisture contents, the fractures beneath MDA H are expected to be dry, and pore water is located in the tuff matrix.

No significant perched-intermediate groundwater has been observed directly beneath MDA H. Boreholes 54-609985 and 54-15462 (Figure 2.3-3), the deepest boreholes near MDA H, were drilled to depths of 300 ft through the mesa top and completed in the Otowi Member ash-flow tuffs. These did not encounter perched groundwater (LANL 2009, 108298). However, a small spatially limited saturated zone just beneath the canyon alluvium is observed below Cañada del Buey at wells CDBO-6 and CDBO-7

(Figure 2.3-5) within the colonnade portion of unit 1v (Qbt 1v-c) of the Tshirege Member of the Bandelier Tuff (Qbt 1v) (LANL 2009, 105754). Water is continuously present at CDBO-6, but is often absent at CDBO-7; its source is believed to be recharge of surface water. The downcanyon extent of the perched zone at CDBO-7 may be limited by rising of unit Qbt 1v-c above the canyon floor just east of well CDBO-7. The base of the unit is thought to be a hydrostratigraphic perching horizon (LANL 1999, 064617). This shallow perched zone does not appear to extend beneath MDA H to the south, as evidenced by neutron-log data measured in boreholes 54-01023, 54-15461, and 54-15452 discussed above, but it may be related to higher (although not saturated) moisture content seen in that unit beneath MDA H (Figure 2.3-4). In addition, during drilling at wells R-37 and R-52, located just to the southeast of CDBO-6 and CDBO-7, perched water was not observed within unit Qbt 1v-c.

In addition, deep perched-intermediate groundwater occurs beneath Pajarito Canyon to the south (wells R-40 screen 1, R-40i, R-51, and Seismic Hazards Borehole- (SHB)4, and beneath Cañada del Buey to the north of MDA H (R-37 screen 1 and R-52) (Figure 2.3-5). The perched groundwater at R-40 screen 1 and R-40i occurs in fractured lavas of the Cerros del Rio basalt between depths of approximately 584 and 784 ft bgs (Appendix D, Figure D-2.1-2). Screen 1 of well R-40 was completed from 751.6 to 785 ft bgs in the lower part of the perched-intermediate groundwater, and screen 2 was completed from 849.3 to 870.0 ft bgs in the regional aquifer. In addition, a 3-in. polyvinyl chloride (PVC) well (R-40i) was installed in the annulus between the R-40 well casing and the borehole wall to provide groundwater samples in a productive zone in the upper part of the perched zone; the PVC well screen was placed from 649.7 to 669 ft bgs. At R-40, the vertical distance between the base of the perched-intermediate zone and the regional water table is approximately 70 ft; the small vertical separation suggests that there may be limited hydraulic separation between the two zones. At well R-51, perched groundwater was encountered in two zones during drilling (Appendix D, Figure D-2.1-2). The upper perched zone is located at a depth of approximately 161 ft bgs in sedimentary deposits of the Cerro Toledo interval and the lower perched zone is located between depths of 502 and 568 ft bgs in the stratigraphic sequence that includes the Guaje Pumice Bed, Puye Formation, and uppermost part of Cerros del Rio basalt (LANL 2010, 109949). The upper perched zone at well R-51 is similar to another possible perched interval that was noted when core hole SHB-4 was drilled for the LANL Seismic Hazards Program (Gardner et al. 1993, 012582). During drilling of SHB-4, wet core samples were returned from depths of ~125–145 ft bgs within the lower part of the Cerro Toledo interval or upper Otowi Member (Gardner et al. 1993, 012582). The perched-intermediate zones beneath Pajarito Canyon probably result from local infiltration along the canyon floor that supports perennial, perched alluvial groundwater in this area. There may also be a component caused by lateral propagation of large-scale, mountain-front aquifer recharge occurring to the west of MDA H.

Perched-intermediate water was also encountered at wells R-37 and R-52 located on a narrow mesa between the north and south forks of Cañada del Buey (Appendix D, Figure D-2.1-2). Well R-37, located 0.5 km east-northeast of MDA H, was originally intended as a regional aquifer monitoring well for MDA H and J. Because perched groundwater was encountered during drilling at this location, well R-37 was built with two well screens (Appendix D): screen 1 was completed in perched-intermediate groundwater and screen 2 was completed in the regional aquifer (LANL 2009, 107116). During drilling at R-37, perched groundwater was first noted in basaltic gravels underlying the Cerros del Rio basalt. Water levels for this perched zone stabilized at approximately 912 ft bgs in the lower part of the basalt. R-37, screen 1 targets the basaltic gravels. Underlying silts and fine sands do not appear to be as productive and, together with the deeper claystone deposits (956–991 ft bgs), may represent the perching horizons. At R-37, the vertical distance between the perched-intermediate zone and the regional aquifer is approximately 70 ft (similar to the distance at R-40; see above and Appendix D); the small vertical separation suggests that there may be limited hydraulic separation between the two zones. A similar perched groundwater zone was encountered when regional aquifer monitoring well R-52 was drilled 0.3 km northeast of MDA H

(LANL 2010, 110533). The perched-intermediate zones encountered at wells R-37 and R-52 may result from local infiltration along Pajarito Canyon, Cañada del Buey, or even Mortandad Canyon to the north. In addition, there may be a component caused by lateral propagation of large-scale mountain-front aquifer recharge occurring to the west of MDA H.

It is uncertain whether the perched-intermediate zones observed at R-40 screen 1, R-51, R-37 screen 1, and R-52 are connected and extend beneath MDA H (Figure D-2.1-2). Such a connection is considered possible given the substantial thickness of the perched zones and their relative high groundwater capacity. However, differences in water chemistry between the different perched-intermediate zones indicate some separation between these groundwater zones, as supported by evidence presented in Appendix E. The perched-intermediate zone groundwater at R-37 screen 1 has different major ion chemistry and trace metal chemistry from perched-intermediate zone groundwaters at R-40i and R-40 screen 1. In addition, 1,4-dioxane and tritium are detected at R-37 screen 1, but these constituents are not detected at R-40i and R-40 screen 1. However, other constituents indicate potential mixing of waters at R-37 screen 1 and R-40 screen 1.

Wells R-37 screen 1, R-40 screen 1, and R-40i are well-positioned to provide adequate monitoring of perched-intermediate groundwater in the vicinity of MDA H. These wells monitor the potential early arrival of contaminants above the regional water table. The perched-intermediate zones may discharge into the regional aquifer downgradient of MDA H and could locally impact the water-level contours (see section 2.3.5).

2.3.5 Regional Aquifer Hydrology and Groundwater Monitoring Network

The regional aquifer beneath the Pajarito Plateau occurs at depths between 1200 ft (366 m) along the western edge of the Pajarito Plateau and approximately 600 ft (183 m) along the eastern edge. Beneath MDA H, the regional water-table elevation is approximately 5810 ft amsl or approximately 900 ft (300 m) bgs. The regional water table is observed within the Puye Formation beneath MDA H (Figures D-2.1-2 and D-2.1-8, Appendix D). The regional water-table map is shown in Figure D-3.2-2 of Appendix D and reflects new data collected at recently installed regional wells in the vicinity of MDA H.

The groundwater flow in the regional aquifer beneath MDA H is predominantly to the northeast. The upper portions of the regional aquifer are under phreatic (unconfined) conditions. The direction of the potential contaminant transport in the regional aquifer is expected to follow the hydraulic gradients along the regional water table, although the heterogeneity and stratification of the Puye Formation may cause permeability anisotropy that could lead to deviations from the predominant flow direction. In the area downgradient of MDA H, the direction of the regional aquifer flow is believed to be dominantly toward the northeast, based on regional water-table maps. However, there is some uncertainty about the flow regime related to (1) eastward thinning of the Puye Formation at the top of the regional aquifer, and (2) decreased depth of the Santa Fe Group sediments below the regional water table in the area between wells R-37 and R-34 (Figures D-2.1-2 through D-2.1-4). The regional structure of the groundwater flow in the aquifer in the area near MDA H may also be impacted by (1) water-supply pumping, (2) the local-scale infiltration recharge along Pajarito Canyon and, to a far lesser extent, Cañada del Buey, (3) the lateral propagation of large-scale mountain-front aquifer recharge occurring to the west of MDA H, and (4) the presence of Cerros del Rio lavas within the regional aquifer east of MDA H (Figures D-2.1-2, D-2.1-3, D-2.1-4, and Figure D-2.1-8; Appendix D). Hydrogeologic factors affecting groundwater flow directions and their uncertainties are further discussed in Appendix D.

The deeper portions of the regional aquifer beneath TA-54 are predominantly within stratified sedimentary deposits of the Chamita Formation (Figures D-2.1-3 and D-2.1-4, Appendix D). Hydrodynamically, the deeper portion of the aquifer is under confined conditions, and it is stressed by Pajarito Plateau water-supply pumping; the deep section pumped by the water-supply wells is approximately 120 ft beneath the regional water table. The intensive pumping causes small water-level fluctuations in the shallow phreatic zone. Based on the existing hydrogeological information, it has either already been observed or is expected that all the monitoring wells located in the vicinity of MDA H (R-51, R-52, R-37, and R-40) respond to the water-supply pumping at PM-2 and PM-4 (Table D-3.1-1). Currently, the largest pumping-induced seasonal fluctuations in the shallow phreatic zone near MDA H occur at R-20 screen 1, which varies up to 0.6 ft (0.2 m) (LANL 2009, 106939, Appendix M). Well R-20 is located 0.25 mi east-southeast of well PM-2 (Figure 2.3-5). These low-magnitude responses in the phreatic zone from municipal well pumping are in sharp contrast to the larger responses (up to 10 to 20 ft) at monitoring well screens completed in deeper parts of the aquifer (e.g., R-20 screen 3 [now plugged and abandoned]; see LANL 2009, 106939, Appendix M), indicating that the hydraulic communication between the phreatic zone and deeper parts of the aquifer is poor. Regardless of the poor hydraulic communication between the deep and shallow section of the aquifer, it is plausible that the shape of regional water table is influenced by the water-supply pumping at PM-2 in the area southeast of MDA H (near wells R-40, R-20, and R-54) (Figure D-3.2-2, Appendix D). The poor hydraulic communication between the two zones suggests that the dominant transport of potential contaminants would occur within the phreatic zone, but it does not preclude the possibility that lesser migration of potential contaminants would occur between the shallow and deep zones. Between the two zones, the hydraulic gradient has a downward vertical component because of water supply pumping in the deep zone, creating the possibility that downward contaminant migration may occur along highly permeable aquifer features, which create hydraulic connection between the deep and shallow regional aquifer zones (also called “hydraulic windows”). However, such aquifer features and downward contaminant migration have not been directly observed.

There is an effective regional groundwater monitoring network around MDA H. Two monitoring wells are located downgradient of MDA H (R-52 and R-37) and one well is located upgradient (R-51). R-40 may also be considered a potential downgradient well because it is located between MDA H and PM-2, and it provides the ability to detect contaminants that may be drawn toward PM-2 by water-supply pumping. All the monitoring wells are screened near the top of the regional aquifer in relatively permeable sedimentary deposits. Hydrogeologic data suggest that the screened regional-aquifer zones at the monitoring wells near MDA H are either unconfined or partially confined. This suggests that the upper regional well screens and the regional water table are hydraulically connected and that the screens are well placed to monitor for the arrival of contaminants at the water table.

2.4 Summary of Previous Investigations

MDA H has been the subject of numerous investigation activities. Phase I RFI activities were initially conducted in 1994 and 1995. Additional RFI activities were conducted in 2001 and 2002, and ongoing pore-gas monitoring activities continue at the site. Investigation activities are summarized in the following sections.

2.4.1 Summary of Phase I RFI

Initial Phase I RFI activities were conducted at MDA H in 1994 and 1995 (LANL 2001, 070158). Additional RFI activities were conducted in 2001 and 2002 to address data gaps identified by NMED during review of the RFI report (LANL 2001, 070158). The 1994–1995 investigation activities included sediment sampling in the drainage between the mesa-top outfall and Pajarito Canyon and the installation and sampling of four boreholes near MDA H. The 2001–2002 investigation activities included additional sediment sampling, installation of an ambient air-monitoring station adjacent to MDA H, installation of two additional boreholes, and sampling of the two new boreholes and one existing borehole. The results of the initial Phase I RFI activities are documented in the RFI report for channel sediment pathways from MDAs G, H, J, and L (LANL 1996, 054462), and the RFI Report for MDA H (LANL 2001, 070158). Results of the 2001–2002 investigation activities are documented in the addendum to the RFI report for MDA H (LANL 2002, 073270).

During the 1994–1995 RFI, four surface soil/sediment samples were collected from the mesa-top outfall drainage that carries surface runoff into Pajarito Canyon. The surface soil/sediment samples were analyzed for metals, cyanide, polychlorinated biphenyls (PCBs), pesticides, tritium, and radionuclides. The chemicals of potential concern (COPCs) detected in two of the five surface soil/sediment samples included methoxychlor at 0.036 mg/kg and 0.04 mg/kg, concentrations that are approximately twice the estimated quantitation limit. Other sediment COPCs included tritium, cadmium, and selenium. Of these, cadmium and selenium were identified as COPCs based on detection limits above a background value rather than positive detections. In the subsequent channel sediment sample, collected during the 2001–2002 RFI, selenium was the only COPC detected at 50% greater than the background value (Tables 2.4-1 and 2.4-2) (LANL 2002, 073270).

Thirty-three subsurface tuff samples were also collected during the 1994–1995 RFI from four vertical boreholes around the nine disposal shafts. These tuff samples were analyzed for metals, cyanide, VOCs, semivolatile organic compounds (SVOCs), PCBs, pesticides, tritium, and radionuclides. COPCs detected in the subsurface tuff samples included copper, cyanide, selenium, tritium, endosulfan sulfate, SVOCs, and VOCs.

In 2001 and 2002, additional sampling activities were conducted to address data gaps identified from the 1994–1995 sample results (LANL 2002, 073270). These sampling episodes consisted of:

- collecting additional subsurface samples from two new boreholes (54-15461 and 54-15462) and one existing borehole (54-1023) to better define the lateral and vertical extent of contaminants in pore gas,
- collecting a drainage channel sediment sample at a sediment accumulation location near a 1994–1995 sediment sampling location, and
- installing an ambient air-monitoring station for tritium adjacent to MDA H.

The subsurface samples were analyzed for tritium and VOCs, and the channel sediment sample was analyzed for metals, cyanide, PCBs, dioxins, furans, nitrates, HE, perchlorate, tritium, and radionuclides. A summary of the 1994–1995 and 2001–2002 investigation sampling results is provided in Tables 2.4-1 through 2.4-6.

Pore-gas samples collected from new boreholes 54-15461 and 54-15462, and from existing borehole 54-01023 indicated that concentrations of tritium decreased as depths exceeded 50 ft bgs in each borehole (Table 2.4-7). Several VOCs were also detected between 17 and 72 parts per billion by volume (ppbv) in samples from the new pore-gas boreholes. Toluene was detected in 31 of the 37 samples collected from borehole 54-01023 at a high concentration 2300 parts per million by volume (ppmv) (Table 2.4-8).

Ambient air tritium data were continuously collected on a biweekly basis for a 1-yr period (March 2001 to March 2002) from the ambient air-monitoring station. The annual average ambient air tritium concentration for the 1-yr monitoring period at this location was 25.5 pCi/m^3 (Table 2.4-9).

Constituents were further evaluated during the 2001–2002 RFI to identify the COPCs present. These COPCs are presented in Table 2.4-10.

For the risk-screening assessments performed in the RFI, residential land use was considered to be most restrictive, and therefore, the potential present-day risks were evaluated using this scenario (LANL 2001, 070158, p. 43). Human health- and ecological-risk screening assessments performed as part of the RFI report (LANL 2001, 070158) concluded that MDA H poses no unacceptable present-day risk to human health and the environment.

Table 4.1-1 of the RFI shows a comparison of carcinogenic COPCs to their respective screening action levels (SALs, named soil screening levels [SSLs] in current risk screening assessments), and includes site maximum concentrations that were detected from 17 ft to 78 ft bgs. All the carcinogenic COPCs were detected below their respective SALs, and the total potential cancer risk was calculated to be $1x10^{-7}$, which is below NMED's target risk level of $1 \text{ x}10^{-5}$ (LANL 2001, 070158, p. 43).

Table 4.2-2 of the RFI shows a comparison of noncarcinogenic COPCs to their respective SALs, and includes maximum concentrations that were detected from 0 to 72.8 ft bgs. All of the non-carcinogenic COPCs were detected below 10% of their respective SALs, indicating that exposure to either one or all of these COPCs do not present an unacceptable risk. The hazard index (HI) for noncarcinogenic COPCs was calculated to be 0.04, well below the NMED's target HI level of 1.0 (LANL 2001, 070158, p. 44).

The RFI addendum (LANL 2002, 073270) concluded that the additional data were sufficient to address the data gaps relating to tritium in the air and tuff as well as the nature and extent of contaminants in the sediments. The additional data did not change the conclusions of the earlier RFI with respect to potential human health or ecological risks. The RFI addendum also proposed collecting ambient air VOC data to confirm the conclusion, based on pore-gas data, that subsurface ambient air VOC concentrations were negligible. Acetone, detected in two samples from 5.1 to 6 ppb, was the only analyte identified during the 2003 ambient air sampling data.

2.4.2 Summary of Transport Modeling Performed for 2005 MDA H Corrective Measures Study

A system-level transport model for MDA H was developed using the GoldSim computer code and presented in the Corrective Measures Study (CMS) Report for MDA H (LANL 2005, 089332). The GoldSim model was used to simulate biotic transport, soil erosion, and aqueous-phase and gas-phase (radon and tritium) subsurface migration over time for chemicals present in the waste shafts at MDA H (LANL 2005, 089332; Appendix H). The GoldSim model incorporated input from more detailed, process-level models. Figure 2.4-1 shows the process-level models that supported the GoldSim system-level model, which combined:

- shallow infiltration and leakage through the top of the waste (represented using the code HELP),
- vadose zone flow and transport (using the code FEHM),
- biointrusion (using internal functionally within GoldSim),
- migration to groundwater (GoldSim), and
- erosion (GoldSim).

The model evaluated the combined effects of these environmental processes on contaminant concentrations over 1000 yr in possible exposure media.

For the model, the waste inventory of the nine disposal shafts at MDA H is represented as a single shaft divided into an upper and lower waste cell. The upper waste cell was considered to be the upper 17 ft of the waste in all nine shafts, which is considered to be available to biota (e.g., plant rooting or animal burrowing). It was assumed that all contaminants in the disposed wastes except uranium were immediately available for release and transport regardless of their physical form or packaging. The MDA H area was assumed to be covered with 1 cm of a gravel mulch cap, which was estimated to last 50 yr. The upper-bound concentrations of chemicals in surface soil over time as a result of erosion and biointrusion processes were estimated and found to be lower than background levels over the 1000-yr modeling period (LANL 2005, 089332, Table H-3.0-1). Over the course of 1000 yr, cumulative soil erosion is calculated to be approximately 8.5 cm. In addition, contaminants are not predicted to reach groundwater at measurable concentrations within the 1000-yr modeling period (LANL 2005, 089332, p. F-15). Long-term impacts to human health from site exposure are calculated to be below levels of concern for the entire 1000-yr period (LANL 2005, 089332, pp. H-36 through H-39).

2.4.3 Fracture Flow Study

An alternate groundwater-pathway risk assessment for fracture-facilitated contaminant transport was conducted to determine whether an alternate conceptual model of fracture-facilitated transport would result in different risks than those calculated using the original matrix-dominated conceptual model that was presented in the original CMS Report for MDA H (LANL 2005, 089332; Appendix O). The results indicated that the addition of fracture flow to the matrix-flow evaluation decreases the time required for contaminants to be transported through the upper fractured tuff units. Even with the addition of fracture-facilitated transport, however, contaminants would not reach, and therefore not impact, the regional aquifer for several hundred to several thousand years.

2.4.4 Summary of Pore-Gas Monitoring

Quarterly pore-gas monitoring activities have been conducted at MDA H since the second quarter of FY05 to characterize VOC and tritium concentrations present in the vadose zone beneath MDA H. Currently, pore-gas monitoring activities are implemented quarterly as directed by NMED in a June 23, 2009 letter to the Laboratory (NMED 2009, 106234).

Pore-gas monitoring activities at MDA H currently include screening 28 sampling ports in 4 vapor-monitoring boreholes. VOC and tritium samples are collected from each of the 28 sampling ports within each stratigraphic unit. Vapor-monitoring boreholes, port depths, and corresponding sampling intervals that were field screened and sampled during the most recently reported monitoring event (third quarter fiscal year 2010, from June 7 to June 23, 2010) (LANL 2010, 111123) are presented in Table 2.4-11. Pore-gas monitoring borehole locations are shown on Figure 2.4-2.

Results of long-term pore-gas monitoring activities at MDA H have concluded that tritium is the primary constituent in the subsurface at MDA H. VOCs are present at low concentrations in subsurface vapor. The screening method presented in the PMRs (shown in Table 2.4-12) uses Henry’s law to identify the vapor-phase VOC concentration threshold that would have to be exceeded for a given VOC to potentially impact the groundwater at concentrations exceeding applicable groundwater standards. No VOCs detected in pore gas exceed the groundwater screening comparison. The VOCs measured at MDA H monitoring locations pose no potential threat to groundwater. The nature and extent of VOCs detected in pore gas is discussed in section 3.2.3 and in Appendix E.

2.4.5 Summary of Pajarito Canyon Investigation

Sediment, surface water, and groundwater data are collected as part of the Canyons Investigations. These data are very useful in determining whether SWMUs (particularly those with outfall/mesa slope aspects) have contamination or release histories that manifest in the canyon floor, and whether they are at levels that represent unacceptable human-health risk or adverse ecological affects. These data are presented in Canyons Investigation Reports. For MDA H, potential releases are discussed within this and previous documents (LANL 2001, 070158; LANL 2002, 073270) that address nature and extent from the subsurface units that constitute MDA H.

For this section, the data from Pajarito Canyon, located south of MDA H, are used to address potential impacts from MDA H on shallow surface media including sediment, surface water, alluvial groundwater, and biota. The possible impact of releases from MDA H on sediment in Pajarito Canyon was evaluated using data collected from a sediment investigation at reach PA-3 East, which is downcanyon from MDA H (LANL 2009, 106939). These sediment data indicate no recognizable impacts from MDA H in canyon-bottom sediments. The spatial distribution of COPCs indicates that TA-09, TA-18, and possibly TA-16 are the main sources of mobile contaminants in surface water and groundwater in Pajarito Canyon. Groundwater data from alluvial wells located upgradient and downgradient of MDA H also indicate no recognizable impacts from MDA H in alluvial groundwater. Biota investigations for the segment of Pajarito Canyon adjacent to MDA H also indicate no adverse effects.

2.5 Status of Groundwater Monitoring

Groundwater monitoring at the Laboratory is currently conducted in accordance with the 2010 Interim Facility-Wide Groundwater Monitoring Plan (IFGMP) (LANL 2010, 109830). The monitoring at TA-54 provides the basis for accurately describing the groundwater conditions beneath TA-54, including MDA H. The groundwater monitoring network for TA-54 includes both perched-intermediate and regional wells (Figure 2.3-5). The monitoring well network at MDA H includes one new regional well, R-52, drilled in 2010 that is part of the overall effort to further characterize the groundwater conditions.

Groundwater characterization for TA-54 is conducted with perched-intermediate well screens at R-40i, R-40 screen-1, R-23i, and R-37 screen 1, and 18 regional wells: R-20, R-21, R-22, R-23, R-32, R-37, R-38, R-39, R-40, R-41, R-49, R-51, R-52, R-53, R-54, R-55, R-56, and R-57 (Figure 2.3-5). R-22 is not currently sampled because the sampling system was pulled for redevelopment. Final disposition of the well is being determined. The actively sampled wells have one or two screens, all of which are equipped with purgeable sampling systems. Table 2.5-1 shows the monitoring frequency and analyte suites specified for the active screens in these wells in the 2010 IFGMP (LANL 2010, 109830). Each screen is also equipped with a dedicated pressure transducer for continuous monitoring of groundwater levels.

Data from the groundwater monitoring network around TA-54 show sporadic detections of a variety of potential contaminants, including several VOCs, general inorganic chemicals, trace metals, and tritium (Appendix E). The temporal and spatial nature of the occurrences do not, however, clearly indicate the presence of a discernable plume or a source related to MDA H or other sources at TA-54 (LANL 2009, 106939). Further evaluation of existing groundwater data in the MDA H area is included in section 3.2.4 of this report.

3.0 SITE CONDITIONS

The following subsections summarize the current nature and extent of contamination in surface and subsurface media at MDA H.

3.1 Surface Conditions

The disposal shafts were drilled into the native tuff. Currently, MDA H has a vegetated surface that has been contoured to direct surface runoff away from the shafts and off-site. Shaft 9 has a concrete plug that is exposed at the surface.

MDA H is posted as a NES and is surrounded by an 8-ft-high chainlink fence. MDA H is under the control of the DOE and the Laboratory, which plan, control, and restrict all land use at TA-54. Access is gained through a locked gate only. No on-site activity may be conducted without prior review and approval of the activity by the facility manager. Access to Pajarito Road is also restricted to Laboratory employees.

3.2 Subsurface Conditions

3.2.1 Subsurface Utilities

There are no subsurface utilities within the MDA H fence line. Subsurface utilities adjacent to MDA H are shown on Figure 2.3-3.

3.2.2 Disposal Shafts

The MDA H disposal shafts are 6 ft in diameter and 60-ft deep. The shafts are unlined and filled with waste to 6 ft bgs. In eight of the nine disposal shafts, the upper 6 ft contain 3 ft of concrete beneath 3 ft of crushed tuff, while the upper 6 ft of one shaft (Shaft 9) contains only concrete. The 6ft-diameter concrete plug provides protection against erosion and intrusion by deep-rooting plants, burrowing animals, and humans.

3.2.3 Nature and Extent of Vadose Zone Contaminants

Subsurface VOC vapors are present in the vadose zone within the mesa at MDA H and are monitored at four pore-gas monitoring boreholes (Figure 2.3-3). The source of VOC vapors in the subsurface at MDA H is thought to be residual contamination (Omicron 2003, 075940). Volatilization of VOCs is probably responsible for very low soil-vapor concentrations currently present. The concentrations are low enough that they do not pose a risk to groundwater, based on screening values presented in the PMRs for vapor sampling at MDA H (e.g., LANL 2010, 111123) (Table 2.4-11).

Appendix E provides a present-day mass estimate for the total mass of VOCs found at MDA H. The estimated mass, based on vapor-monitoring results from June 2010 (LANL 2010, 111123), is 2.1 kg (4.6 lb). The results from the June 2010 monitoring showed 26 VOCs detected in samples. Most of the estimated mass is associated with alcohols (approximately 69%) and ketones (approximately 24%). Less than 5% of the total estimated mass, approximately 0.1 kg (0.22 lb), is associated with halogenated VOCs, which are generally of most concern with respect to groundwater contamination. Most VOCs were detected in only a few of the 28 sampling ports being monitored. For the VOCs detected most frequently, the highest concentrations were detected in the sampling ports in units Qbt 1v and Qbt 1g (60 to 205 ft bgs), with concentrations decreasing with depth in the lower units (Qct and Qbo).

Inorganic chemicals were disposed of at MDA H, but few have been observed above the background value (BV) in core samples collected at the site. These constituents migrate as waterborne constituents and their transport is controlled by vadose-zone water percolation rates, which are low in the unsaturated zone beneath MDA H, generally estimated to be less than 1 mm/yr (Newman et al. 2005, 099163). Copper was detected at concentrations above BVs in the uppermost core samples from each of the four boreholes sampled during RFI activities (LANL 2001, 070158, p. 39). However, the extent of copper’s presence was defined by concentrations decreasing with depth. Cyanide and selenium had detection limits (DLs) above BVs, but were not detected in the vadose zone. These results indicate little, if any, migration of metals and other inorganic chemicals from the disposal units.

3.2.4 Nature and Extent of Groundwater Contaminants

A screening protocol was implemented in Appendix E to evaluate the presence of contaminants in groundwater from wells downgradient of MDA H. Deep groundwater monitoring wells R-20, R-37, R-40i, R-40, and R-52 constitute the downgradient well network specific to MDA H. The screening was conducted using a tiered approach. The first tier compared analytical data with detection status (for organics) and with groundwater BVs (for naturally-occurring constituents, including trace metals). The second tier compared analytical data with the lowest applicable regulatory standards or other published risk-based screening levels. The evaluation of the outcome of this screening protocol also considered factors such as frequency of detection, data for corresponding quality assurance/quality control (QA/QC) samples such as field duplicates and blanks, persistence, trends, and relationship to field activities at a well such as redevelopment or installation of a sampling system.

The screening protocol was applied to validated water-quality data available as of December 10, 2010. Results from at least six sampling rounds are available for most wells, with the exception of new regional well R-52. This well was completed on April 5, 2010, and validated data are available for only three characterization events.

Based on the analysis in Appendix E, there is no compelling evidence that contaminants sourced at MDA H are present at any MDA H groundwater monitoring wells. Although VOCs are detected in regional groundwater at R-20 screen 2, hydrologic analysis presented in Appendix D indicates that groundwater flows toward the northeast beneath MDA H, and therefore, well R-20 is not downgradient of MDA H. Tritium and 1,4-dioxane may be local contaminants in the perched-intermediate groundwater at R-37 screen 1, but sources other than MDA H are more likely.

TA-54 monitoring-network wells, including those specific to MDA H, will continue to be sampled on a quarterly basis, consistent with the 2010 IFGMP (LANL 2010, 109830) and as summarized previously in Table 2.5-1.

4.0 CONCEPTUAL SITE MODEL FOR MDA H

A CSM is a representation of site conditions that conveys what is known or suspected about the sources, releases and release mechanisms, contaminant fate and transport, exposure pathways, potential receptors, and risks. Conceptual site models are developed based on analyses and interpretation of existing site knowledge, observations, and data. They describe potential contaminant sources, release mechanisms (transport pathways), exposure media that may become contaminated, and potential receptors (EPA 1989, 008021, pp. 4-10). The sources, pathways, and receptors applicable to MDA H are shown pictorially in Figure 4.0-1. A schematic diagram of the CSM that displays the release mechanisms from the sources (the disposal shafts) to potential receptors and the potential risks is shown in Figure 4.0-2.

The CSM diagram describes whether the exposure pathways are complete under current and future site conditions. For the future scenario, an assumption is made that institutional controls are not maintained and no remedy is implemented. Current and future risks are qualitatively evaluated for the purpose of the CME.

4.1 Primary Source of Contamination

The primary source is buried waste in the nine disposal shafts. MDA H was used as the Laboratory's site for disposal of security-classified, solid-form waste from 1960 to 1986. Radioactive materials and hazardous wastes were disposed of in the shafts at MDA H (see sections 2.1 and 2.2). The hazardous constituents disposed of at MDA H included metals, inorganic chemicals, graphite, plastic, HE, and residual quantities of VOCs. For the purposes of this CME report, the CSM is concerned with the transport and risks associated with the hazardous constituents.

4.2 Primary Release Mechanisms

Six primary release mechanisms for the waste from the shafts were identified (Figure 4.0-2). These are (1) release of waste into subsurface soils by biointrusion and leaching, (2) volatilization of VOCs to become soil vapor, (3) excavation into the waste, (4) biointrusion and surface erosion into the waste, (5) cliff retreat and seismic events that expose waste, and (6) disruption and dispersal of the waste due to physical impacts or exposure to moisture.

Biointrusion into the waste has the potential to spread contaminants into subsurface soils or to the surface through adsorption of soluble chemicals by plant roots or movement of wastes by burrowing animals. For plants common to Mesita del Buey, roots are most abundant in the upper 6.5 ft (2 m) but may extend deeper for some bushes and trees (Tierney and Foxx 1987, 006669). Burrow depths for ants and small mammals are generally less than 1 m, although a small fraction of burrows extend to depths of 6.5 ft (2 m) (Tierney and Foxx 1987, 006669). The rooting and burrow depths cited are similar to the estimated shaft cap thicknesses with concrete extending from 3 to 6 ft (0.9 to 1.8 m) bgs for eight of the shafts and from 0 to 6 ft (0 to 1.8 m) bgs for the other shaft. Shallow-rooting plants and animal burrows are present at MDA H and some intrusion into the waste is possible, although the concrete covering the shafts will limit intrusion. The site is periodically mowed to reduce combustible loading when needed, but plants are generally left in place to limit erosion. Under the future conditions assumed in the CSM, which includes further loss of cover maintenance, deeper-rooted plant communities and larger animal populations may be established.

Leaching of waste constituents into the subsurface soils beneath and adjacent to the shafts potentially occurs at the site. Leach rates are expected to be controlled by infiltration rates, which are estimated to be less than 1 mm/yr because MDA H is vegetated (section 2.3.4). Investigation data indicate little, if any, migration of metals and other inorganic chemicals due to leaching from the disposal units (section 3.2.4 and LANL 2001, 070158, p. 39).

The source of VOC vapors in the subsurface at MDA H is thought to be residual contamination from cleaning solvents on machined parts and minimal amounts of waste oil (potentially mixed with solvents) (Omicron 2003, 075940). Volatilization of VOCs is probably responsible for very low soil-vapor concentrations currently present. The concentrations are low enough that they do not pose a risk to groundwater based on screening values presented in the PMRs for vapor-sampling at MDA H (e.g., LANL 2010, 111123). In addition, a VOC mass balance presented in Appendix E indicates very small amounts of VOCs currently present at the site; a total VOC mass of 2.1 kg is estimated with 0.1 kg due to chlorinated VOCs. The source is not considered to be ongoing.

The third primary release mechanism is inadvertent excavation into the shafts. The concrete covers above the shafts may inhibit excavation. Exposure by excavation is a function of the volume and depth of waste excavated and will depend largely upon site access. Excavation into wastes is currently prohibited by site controls, but lack of these controls in the future may increase the potential for this release mechanism.

Erosion is another primary release mechanism that can expose waste. For the most part, surface erosion will result in a gradual thinning of the crushed tuff covering the shafts and of the mesa itself over extended periods of time, and eroded sediments will be transported into the adjacent canyons. However, the quantities and intensities of precipitation falling on the site will have strong impacts on the generation of surface runoff and, hence, rates and patterns of erosion (Wilson et al. 2005, 092034).

Exposure of the waste by cliff retreat is not currently observed because the shafts are set back from the mesa edge (Appendix D). Cliff retreat and seismic events are potential release mechanisms that may expose wastes over time (Appendix D).

Disruption and dispersal of the waste is a potential primary release mechanism that could be caused by sparks, friction, heat, physical impacts, waste pinching, air, and/or moisture interacting with the waste over time (i.e., HE). However, explosives-containing wastes left undisturbed in the shafts at MDA H are expected to be stable (Appendix C).

4.3 Secondary Sources of Contamination

Two secondary sources, subsurface soils and soil vapor, are generated directly from primary release mechanisms (Figure 4.0-2). Surface soils are included as a secondary source because migration of contaminants from subsurface soils to surface soils can occur through biotic intrusion, volatilization, excavation, erosion, and subsidence.

4.4 Secondary Release Mechanisms

Several secondary release mechanisms can further spread contaminants from secondary sources toward potential receptors (Figure 4.0-2). For surface soils, these mechanisms are (1) stormwater runoff and erosion, (2) volatilization and vapor diffusion of VOCs, (3) inadvertent excavation, (4) biointrusion, and (5) wind. For subsurface soils, the secondary release mechanisms are (1) leaching by percolating water, (2) volatilization and vapor diffusion of VOCs, (3) inadvertent excavation, and (4) biointrusion. For soil vapor, the secondary release mechanism is diffusion. Erosion, excavation, and biointrusion affect migration for contaminants mixed with surface and subsurface soils, much like the secondary release mechanism for waste (described above) because much of the waste material is surrounded by crushed tuff.

Currently, limited contaminant transport by stormwater runoff and erosion of surface soils occurs at MDA H. No surface release or residual contamination is evident or documented for MDA H (LANL 2001, 070158, p. 38). Past sampling of drainage channels surrounding MDA H indicates that lead was the only inorganic chemical detected above the sediment BV in the drainage channel, but was not different from the range of values in the background dataset (LANL 2001, 070158, p. 38). These pathways will become slightly more viable if cover maintenance is stopped.

Volatilization and vapor diffusion of VOCs can occur from both surface soils and subsurface soils with subsequent migration in soil vapor. VOCs in waste or in pore water volatilize to form soil vapor as determined by Henry’s law partitioning and these vapors can diffuse upward to the surface or downward toward groundwater. However, surface flux measurements showed near zero releases of volatile contaminants to the surface at MDA H (Trujillo et al. 1998, 058242); soil-vapor concentrations are low enough so that they do not pose a risk to groundwater based on screening values presented in vapor PMRs for MDA H (LANL 2010, 111123).

Leaching of contaminants from the disposal units and downward migration by percolating water will occur at a slow rate because of infiltrating water at the site, as discussed in section 4.2. Travel times of nonsorbing species from the source areas to the regional aquifer in excess of several hundred years are predicted under this scenario, assuming uniform groundwater flow in the subsurface (LANL 2005, 089332). Adsorbing constituents, like metals, have longer travel times than adsorbing constituents. In addition, most of the waste at the site (>57% and potentially up to 80%) is in solid metal form and therefore would not readily be leached by infiltrating water (Figure 2.2-1). Both vadose zone and regional groundwater data indicate that this release mechanism to groundwater is currently incomplete for both inorganic and organic chemicals.

4.5 Exposure Media

Contact with contaminated environmental media creates pathways for both human and ecological receptors (Figure 4.0-2). Seven potential exposure media are identified for the site: (1) sediment, (2) surface water, (3) air, (4) soil, (5) dust, (6) groundwater, and (7) waste.

4.6 Receptors and Risk

Three potential receptors are identified: (1) humans, (2) ecological receptors, and (3) groundwater. Groundwater is considered as both an exposure medium and a receptor; human and ecological receptors may be exposed to groundwater, but it is also a natural resource. Human and ecological receptors may be exposed if pathways are complete through exposure routes such as inhalation of volatile emissions in air or of dust, ingestion of contaminated media (sediment, groundwater, surface water), or dermal contact. Risks to human health and the environment may occur if elevated concentrations of contaminants are present in the exposure media. Both current and future risks are qualitatively evaluated below (Figure 4.0-2). The future risk scenario assumes loss of institutional controls. Assessment of future risk is informed in part by predictions made for the 2005 MDA H CMS (LANL 2005, 089332), as summarized in section 2.4.2.

Under current conditions, few transport pathways are considered to be potentially complete.

- Based on field data, the sediment and surface-water pathways are potentially complete. The risk from exposure is very low because current surface and subsurface contaminant levels do not pose an unacceptable risk to human health (LANL 2001, 070158, p. 54).
- The biointrusion pathway is considered to be complete for surface soils and for subsurface soils, and potentially complete for wastes. The completeness of the biointrusion pathway differs with depth because density of plant roots and animal burrows decreases with depth (section 4.2). Because the waste form consists predominantly of metal pieces, which are not bioavailable, the risk from exposure is very low. The concrete covers on the shafts also help to minimize exposure.
- All other pathways (vapor diffusion, wind, excavation, leaching and diffusion/volatilization to groundwater, disruption/dispersal, and cliff retreat/seismic events) are currently considered to be incomplete.

Under future conditions, the transport processes have longer to develop and pathways may become complete. For the CSM, institutional controls are assumed to cease. These changes impact the following pathways and exposure scenarios. Most risks are for human health and ecological receptors unless groundwater is specified.

- Stormwater runoff and erosion of surface soils may result in complete pathways for exposure to sediment and surface water. The future risk of these pathways is considered to be very low because surface soil concentrations would likely be low (LANL 2005, 089332, p. H-21).

- The air pathway remains incomplete for VOCs because of the low vapor concentrations (LANL 2010, 111123), and the small estimated mass of chlorinated VOCs (Appendix E).
- Wind may result in a complete pathway for exposure to dust. The future risk of this pathway is considered to be very low because surface soil concentrations would be low (LANL 2005, 089332, p. H-21).
- The potential for excavation into surface soils, subsurface soils, and waste increases in the future if people inadvertently enter the site. Exposure risks are very low from surface soils, low from subsurface soils, and medium from waste. Soil concentrations are assumed to increase with depth because of a greater chance of mixing with waste. The assumed future medium exposure risk that would result from excavation of waste is due to the potential for the pyrophoricity and shock sensitivity of the material disposed of in the shafts (Appendix C).
- The completeness of the biointrusion pathway differs with depth under future conditions because of the decreasing density of plant roots and animal burrows with depth. However, without maintenance, the surface soil will degrade and erode with time. Under the future scenario, the pathway is considered to be complete for surface soils and subsurface soils, and potentially complete for wastes. Exposure risks are assumed to be low because of the nature of the metal waste forms, which are largely low-solubility, solid material parts that would very slowly release contaminants in transportable/bioavailable form (LANL 2005, 089332, p. H-2).
- Leaching is considered to be a potentially complete pathway. However, the time period over which contaminants are predicted to reach groundwater is very long (e.g., several hundred to several thousand years), and contaminants are not predicted to exceed a regulatory limit, resulting in a very low risk to the groundwater resource.
- Diffusion of vapor-phase contaminants to groundwater is considered to be an incomplete pathway because of the low vapor concentrations (LANL 2010, 111123) and the small estimated mass of chlorinated VOCs (Appendix E).
- Erosion may result in a potentially complete pathway to the waste. However, modeling of erosion predicted cumulative soil erosion of approximately 0.3 ft over a 1000-yr period at MDA H (LANL 2005, 089332). The waste is currently at least 6 ft bgs. The assumed future low-exposure risk is based on uncertainty related to the erosion rate, waste inventory, and concentrations of hazardous constituents in the waste.
- Exposure of waste from cliff retreat and seismic activities may result in a potentially complete pathway. However, cliff retreat occurs over a long timeframe. The disposal units are located a minimum of 50 ft from the mesa edge and are not expected to be impacted by cliff retreat for more than 10,000 yr (Broxton and Eller 1995, 058207; Reneau and Raymond 1995, 054709); resulting in a very low future risk of exposure.
- Wastes left undisturbed in the shafts at MDA H are expected to remain stable and are subject to slow degradation and mineralization. Disruption and dispersal of waste may result in a potentially-complete exposure pathway with a high future risk to receptors. Sparks, friction, heat, physical impacts, waste pinching, air, and/or moisture may potentially cause detonation or other unwanted chemical reactions due to the nature of the waste (Appendix C).

4.7 Remedial Action Objectives

The remedial action objectives (RAOs) address exposure pathways with the potential for medium and high risk of exposure. Based on the CSM, the RAOs for MDA H are as follows:

- prevent future human health and ecological exposure to waste through excavation, and
- prevent future disruption and dispersal of waste by physical disruption or infiltration of moisture.

5.0 CORRECTIVE ACTIONS AND CLOSURE REQUIREMENTS

MDA H is subject to a CME as outlined in Section VII.D of the Consent Order. The regulated unit is subject to corrective action under the Consent Order pursuant to the alternative closure requirements in 40 CFR 264.110(c). The radioactive material in the shafts is subject to radiological protection requirements under DOE Order 5400.5. The closure requirements for the disposal units are discussed below.

5.1 Regulated Unit and SWMU

One of the nine shafts at MDA H (Shaft 9) received hazardous waste after July 26, 1982, and is considered a “regulated unit” under RCRA and subject to closure requirements specified in section 20.4.1.500 of the NMAC. As discussed in section 1.0 above, the regulated unit will be closed under alternative closure requirements established under the Consent Order rather than the closure requirements of 40 CFR 264 Subparts G and N. The alternative closure requirements will be established using the CME process for MDA H contained in Section VII.D of the Consent Order. Upon NMED’s selection of the remedy for MDA H, the Laboratory will prepare and submit a corrective measures implementation (CMI) plan. The CMI plan will fulfill the requirements for a closure plan and post-closure plan for the regulated unit, as specified in 40 CFR Part 264, Subparts G and N.

The cleanup and screening levels described in Section VIII of the Consent Order (Table 5.1-1) were followed in this CME to determine the recommended corrective measure alternative. The cleanup levels are based on the New Mexico Water Quality Control Commission’s (NMWQCC’s) groundwater and surface water standards, and NMED’s cleanup levels for protection of human health, which are consistent with the EPA’s National Oil and Hazardous Substance Pollution Contingency Plan, 40 CFR section 300.430(e)(2)(i)(A)(*2*).

NMED selected a carcinogenic human-health target risk level of 10^{-5} or a noncarcinogenic HI of 1.0 for site-specific cleanup levels of one or more contaminants for which toxicological data are published. NMED and the EPA have established SSLs and maximum contaminant levels (MCLs), and the NMWQCC has adopted groundwater and surface water standards that are described below.

5.1.1 Soil

NMED specified SSLs that are based on a target total excess cancer risk of 10^{-5} and, for noncarcinogenic contaminants, a target HI of 1.0 for residential and industrial land use. Residential and industrial SSLs are from NMED’s “Technical Background Document for Development of Soil Screening Levels, Revision 5.0” (NMED 2009, 108070). If an NMED SSL has not been established for a contaminant for which toxicological information is published (NMED 2009, 108070), the Laboratory uses the most recent version of the EPA Region 6 human health medium-specific screening level for residential and industrial soil.

If an excavation alternative is selected, these SSLs will be used as cleanup levels, as specified in the section VIII.B.1 of the Consent Order.

5.1.2 Groundwater

The selected corrective-measure alternative will be required to meet the groundwater-quality standards given in section VIII.A of the Consent Order. These standards incorporate the NMWQCC groundwater standards, including alternative abatement standards (20.6.2.4103 NMAC, and the drinking water MCLs adopted by EPA under the federal Safe Drinking Water Act (42 U.S. Code sections 300f to 300j-26) or the Environmental Improvement Board (20.7.10 NMAC). If both an NMWQCC standard and an MCL have been established for an individual substance, then the lower of the two levels is considered the cleanup level for that substance.

If there is not an MCL or NMWQCC standard, the Laboratory will use the NMED tap water screening levels (NMED 2009, 106420). If there is no NMED tap water screening level, the Laboratory will use EPA regional tap water screening levels (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm) adjusted to a 10^{-5} risk for carcinogens. If no NMWQCC groundwater standard or MCL has been established for a contaminant that has published toxicological information, then the Laboratory will use a target excess cancer risk level of 10^{-5} and/or an HI of 1.0 as the basis for proposing a cleanup level for the contaminant. If the naturally occurring (background) concentration of a contaminant exceeds the standard, then the cleanup goal defaults to the background concentration for that specific contaminant.

5.1.3 Surface Water

No permanent surface water is present at MDA H and MDA H does not have discharges of pollutants to surface water subject to a permit under section 402 of the federal Clean Water Act. Therefore, the surface water cleanup levels contained in section VIII.C of the Consent Order are not applicable to corrective measures at MDA H.

5.2 DOE Closure Requirements

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, specifies that the radiological protection requirements for the public, contained in the Order, must be met for as long as DOE maintains control over the property. The Order further notes that DOE cannot release the property from its control unless the DOE Order 5400.5 requirements for unrestricted release are met. Therefore, DOE Order 5400.5 effectively establishes requirements for DOE to maintain MDA H indefinitely in a manner that is protective of the public. In accordance with DOE Policy 454.1, *Use of Institutional Controls,* DOE will implement and maintain institutional controls as long as necessary to protect human health and the environment.

In 2003, the NNSA agreed with the Laboratory's initial hazard characterization of MDA H as a Hazard Category 3 NES, based upon the radioactive content of materials disposed. The site is defined in accordance with Title 10 of the Code of Federal Regulations, Part 830, Nuclear Safety Management (CFR 2001). Specific hazards and controls are allowed under the approved DSA following DOE Standard 1120-2005, Integration of Environment, Safety, and Health into Facility Disposition Activities, Volume 1 of 2: Technical Standard.

The DOE sets specific inactive-site surveillance, maintenance, and characterization requirements for allowed nuclear environmental sites a under a DSA. Corrective action activities would require the following modification to the existing DSA and NNSA/DOE approval prior to implementation:

- the basic description of the proposed activity and its operations, including safety structures, systems, and components;
- a hazards analysis of the activities and/or safety structures, systems, and components; and
- the hazard controls and their bases.

5.3 Consent Order CME Requirements

Consent Order-specified evaluation criteria were used in this report to select the recommended corrective measures alternative for MDA H. Sections VII.D.4.a and VII.D.4.b of the Consent Order provide threshold and balancing criteria for screening and evaluation of prospective corrective measures. These criteria are listed below in sections 5.3.1 and 5.3.2. Figure 5.3-1 presents a flow chart of the selection process used to determine the recommended corrective measures alternative. A final set of criteria described in section XI.F.11 of the Consent Order provides guidelines for describing the corrective measures alternatives in this CME. These criteria are listed in section 5.3.3.

5.3.1 Threshold Criteria

All technologies were screened based on the threshold criteria described in section VII.D.4.a of the Consent Order. To be selected, the technology must meet these criteria:

- be protective of human health and the environment;
- attain media cleanup standards;
- control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment; and
- comply with applicable standards for management of waste.

5.3.2 Balancing Criteria

The five balancing criteria against which each technology was evaluated are identified in section VII.D.4.b of the Consent Order. In proposing a recommended alternative, the balancing criteria are used to evaluate each technology. The criteria are as follows:

- long-term reliability and effectiveness;
- reduction of toxicity, mobility, or volume;
- short-term effectiveness;
- implementability; and
- cost.

5.3.3 Selection Criteria

Based on the evaluation of the technologies and combining the highest ranking technologies by source area, a recommended alternative was proposed. This alternative must comply with a final set of criteria described in section XI.F.11 of the Consent Order, and is detailed in section 9 of this CME report. The criteria used in the description of the final selection are as follows:

- achieve cleanup objectives in a timely manner,
- protect human and ecological receptors,
- control or eliminate the sources of contamination,
- control migration of released contaminants, and
- manage remediation waste in accordance with state and federal regulations.

The justification for the recommended corrective measures alternative includes the supporting rationale for the remedy selection based on the factors listed in sections 7 and 8, a discussion of short- and long-term objectives for the site, and the benefits and possible hazards of the alternative.

6.0 IDENTIFICATION OF TREATMENT TECHNOLOGIES

Section 6.1 describes the process used to identify treatment technologies, and section 6.2 screens treatment technologies for MDA H. The technologies retained for further evaluation in the process described in section 6.2 are summarized in section 6.3 and carried forward to section 7 for screening against the threshold criteria.

6.1 Evaluation of Treatment Technologies

General types of corrective measures technologies applicable to MDA H site conditions and waste types were selected from the comprehensive technology list developed by the Federal Remediation Technologies Roundtable (Table B-1, also available at http://www.frtr.gov/matrix2/section1/list-of-tables.html).

Technologies from each of the four general categories listed below have been developed and discussion has been provided to clearly identify the potential applicability of the technology. Technologies evaluated include the following:

- containment,
- in situ treatment,
- excavation/retrieval, and
- ex situ treatment.

Within the containment technology category, the subcategories evaluated consist of vertical barriers, deep and near-subsurface horizontal barriers, and surface barriers. Within the in situ treatment technology category, subcategories include biological, chemical, physical, and thermal treatment. The excavation/retrieval technology would require complete removal of the waste in the shafts, and either on-site or off-site waste treatment and/or disposal. Ex situ treatment may include oxidation, thermal treatment, stabilization, or various debris treatments under RCRA.

Of the wastes disposed of in the shafts at MDA H, approximately 80% consisted of metals in various forms (solid mass to finely-milled shavings). Approximately 24% of the total metals content consisted of uranium, much of which is DU (24%). Up to 13% of the waste in the shafts is HE-associated material. Based upon the potentially reactive nature of some of the waste, as summarized in Appendix C, many available technologies normally considered for remediation of similar shafts fail to adequately meet the remedial action objectives as defined in section 4.7. Furthermore, while very low concentrations of VOCs have been identified in area soil pore gas, records indicate that organic compounds were present only in minor amounts as residuals on solid waste placed in the shafts (Omicron 2003, 075940). Evaluation of measured VOC concentrations and a mass estimate presented in Appendix E indicate that VOCs do not pose a current or future risk to groundwater (LANL 2010, 111123).

6.2 Screening of Technologies

Corrective action guidance from EPA (1994, 095975, p. 58) and DOE (1993, 073487, pp. 4-51 and 4-52) requires that potential corrective measure technologies be screened to eliminate those that prove infeasible to implement, that rely on technologies unlikely to perform satisfactorily or reliably, or that do not achieve the corrective action objectives within a reasonable time frame.

For the MDA H CME, the screening of technologies included the following:

- a review of site setting, waste characteristics, and technology implementation to identify conditions that may limit or promote the use of certain technologies, such as potential hazards associated with impact to the waste material (Appendix C); and
- a determination of the level of technology development, performance record and inherent construction, and operations and maintenance (O&M) challenges for each technology considered.

6.2.1 Containment Technologies

Containment technologies are intended to limit migration of contaminants from the buried waste or limit infiltration of surface water into the vadose zone or waste. Such technologies may include surface and subsurface barriers, and various orientations and compositions of barriers may be used. Barriers may be used to contain or limit the lateral and/or vertical migration of contaminants. The general functionality, potential applicability, and/or limitations of each containment technology considered for MDA H are discussed below.

6.2.1.1 Vertical Barriers

Vertical barrier technologies are intended to minimize lateral migration of contaminant releases. The vertical barrier technologies considered below are of limited benefit at MDA H, primarily because the waste is not highly mobile. Soil data do not indicate contaminant concentrations above action levels. Based upon measured soil vapor levels at MDA H, the total mass of VOCs is estimated to be 2.1 kg (Appendix E), well below concentrations that pose current or future adverse impact to groundwater. VOCs are not considered a potential current or future impact to groundwater at MDA H (Appendix E).

Based upon the nature of the waste in the MDA H shafts, consideration of how each technology is implemented and potential impact to the waste is provided below.

Slurry Wall/Grout Curtain

Slurry walls are formed using slurried bentonite clays, cement grout, or other barrier materials placed in narrow, deep trenches, in a series of adjacent open boreholes on the perimeter, or at the migrating edge of a disposal site. Slurry walls are commonly used to intercept contaminants that migrate laterally. The arid to semiarid environment of MDA H is not compatible with the use of bentonite clays, which become cracked and permeable when desiccated. Likewise, the lack of vadose zone contaminants and the minimal potential for undisturbed waste contaminant migration negates the need for vertical barriers.

Implementation of slurry walls/grout curtains results in heat generation from curing grout, vibration, and increased air and/or moisture infiltration. Given the significant potential adverse effects that could result from slurry wall/grout curtain implementation, the slurry wall/grout curtain technology was not retained.

Rock-Grout Mixing

Rock-grout barriers are formed by drilling adjacent deep shafts on the perimeter of a disposal site and then mixing the cuttings with the injected grout in the shaft. Like slurry walls, rock-grout mixing is used to intercept contaminants that migrate laterally. Given the lack of vadose zone contaminants and the minimal potential for undisturbed waste contaminant migration, vertical barriers are unnecessary.

Implementation of rock-grout mixing results in heat generation from curing grout, vibration, and increased air and/or moisture infiltration. Given the significant potential adverse effects that could result from rock-grout mixing field implementation, the rock-grout mixing technology was not retained.

Synthetic Membrane

A synthetic membrane, such as a geosynthetic liner, can be placed in a vertical trench. The membrane forms a barrier that restricts the lateral migration of contaminants. This technology is typically used to impede lateral migration of vapor-phase contaminants. Given the lack of vadose zone contaminants and the minimal potential for undisturbed waste contaminant migration, vertical barriers are unnecessary.

Installation of a synthetic membrane would result in vibration and increased air and/or moisture infiltration. Given the significant potential adverse effects that could result from these conditions, the synthetic membrane technology was not retained.

Reactive Barrier

A chemically-active material can be placed in a vertical orientation around a typical waste disposal area, or the reactive materials can be incorporated into another barrier technology. A reactive chemical, such as zero-valence iron or activated carbon, may be chosen for the capability to adsorb or chemically degrade VOCs. Given the lack of vadose zone contaminants and the minimal potential for undisturbed waste contaminant migration, a reactive barrier is unnecessary. Likewise, reactive barriers have only been demonstrated with liquid-phase contaminants and not the vapor-phase, and therefore their applicability at MDA H is uncertain.

Installation of a reactive barrier would likely result in vibration and increased air and/or moisture infiltration. Given the significant potential adverse effects that could result from these conditions and its limited reliability, the reactive barrier technology was not retained.

6.2.1.2 Deep Subsurface Horizontal Barriers

The purpose of a deep subsurface horizontal barrier is to contain downward aqueous-phase contaminant transport and is generally suitable for sites with known aqueous-phase releases and/or climates with significant surface infiltration. Bottom barriers are horizontal subsurface barriers (i.e., underground barriers that run parallel to the surface) that prevent vertical migration by providing a floor of impermeable materials beneath the waste.

The deep subsurface barrier technologies are of limited benefit for MDA H application, because the waste disposed is primarily solid in form and not highly mobile. Soil data do not indicate contaminant concentrations above action levels. Based upon measured soil-vapor levels at MDA H, the total mass of VOCs at MDA H is estimated to be 2.1 kg (Appendix E), well below concentrations that pose current or future adverse impact to groundwater. VOCs are not considered a potential current or future impact to groundwater at MDA H.

Forced Grout Injection

The installation of a grout barrier under the shafts involves directional drilling with forced grout injection. Implementation of this technology is highly dependent on the physical properties of the soil under the waste. The implementation of forced grout injection results in heat generation from curing grout, vibration, and increased air and/or moisture infiltration. Because of the characteristics of the waste in the shafts and the significant potential adverse effects that could result from disruption/dispersal of the waste, the forced grout injection technology was not retained.

6.2.1.3 Near-Subsurface Horizontal Barriers

Near-subsurface horizontal barriers, created by a soil-grout mixture or by means of vitrification, potentially provide protection from exposure to contaminants by controlling intrusion into the waste by plants, animals, or people. Additionally, these barriers could limit disruption/dispersal of the waste by reducing surface water infiltration. The following horizontal barrier technologies within this category were considered.

Soil-Grout Mix

A concrete/grout mixture containing soil or crushed tuff was considered as an alternative cover material over the MDA H shafts. Although this barrier has the potential to decrease water infiltration by lowering permeability and/or penetrability by plants and animals, this type of barrier does not provide water storage for ET. Rainfall that does not infiltrate the soil-grout mix will migrate to the edges of the treated area where it will infiltrate, creating focused recharge and increased infiltration in that area.

The implementation of a soil-grout mixture containing soil or crushed tuff results in heat generation from curing grout and potential increased moisture infiltration. Because of the characteristics of the waste in the shafts and the significant potential adverse effects that could result from these conditions, the concrete/grout mixture containing soil or crushed tuff as an alternative cover material was not retained.

Vitrification

Vitrification is the process of using electrical resistance to heat soil or rock in situ to temperatures high enough to melt them. Soil temperatures during this process range from 2900°F to 3650°F (1600°C to 2000°C). When the melted materials cool, a glass-like material forms. In situ vitrification produces an impermeable, impenetrable horizontal barrier and has been demonstrated to a depth of 30 ft (9.1 m) at TA-21. Current operational cover soils at MDA H are 6 ft in thickness over the shafts. Although this barrier has the potential to decrease water infiltration by lowering permeability and/or penetrability by plants and animals, this type of barrier does not provide water storage for ET. Rainfall does not infiltrate the vitrified material and will migrate to the edges of the treated area where it will infiltrate, creating focused recharge and increased infiltration in that area.

The implementation of vitrification as a near-surface horizontal barrier will generate significant heat, introduce spark, and result in potential increased moisture infiltration. Because of the characteristics of the waste in the shafts and the significant potential adverse effects that could result from these conditions, the vitrification technology was not retained.

6.2.1.4 Surface Barriers

Barriers placed on the surface of disposal sites provide protection against surface-water infiltration, offer resistance to water and wind erosion, prevent or minimize intrusion into wastes by plants or animals, and act as a deterrent to inadvertent disturbance by humans. Cover system design guidance has also been developed that provides requirements and considerations for implementation at the Laboratory (Dwyer et al. 2007, 096232) and would be applied to the following as appropriate.

Asphalt Cover

Asphalt provides a substantial barrier to surface erosion processes and is typically used during operational phases of the facility to provide a secure and stable ground surface. It is, however, prone to cracking and degradation, and allows moisture in under the edges of the cover. It has been shown at another Laboratory site, MDA AB Area 2 at TA-49 (LANL 1999, 063918, p. 22), to trap moisture that would otherwise evaporate or transpire from the subsurface. The asphalt cover has the potential for failure due to the potential for moisture collecting under the asphalt and infiltrating the shafts, which could lead to disruption/dispersal of waste and may lead to enhanced leaching. Because maintaining low subsurface moisture content is a desirable feature for MDA H, the asphalt cover technology was not retained.

Compacted Clay Cover

Compacted clay covers have successfully controlled excess surface water infiltration at RCRA-regulated landfills located in humid environments. However, clay liners are far less effective in arid to semiarid climates (i.e., Los Alamos) because the clay tends to dry out and crack, allowing moisture to flow directly into disposal units (Mulder and Haven 1995, 071297, p. 7). Because of the characteristics of the waste in the shafts and the significant potential adverse effects that could result from these conditions, the compacted clay cover technology was not retained.

Multilayer Cover (RCRA Cover)

The multilayer cover, or RCRA cover, consists of different geologic and synthetic materials layered in a specific order to control various potentially detrimental processes and conditions (e.g., infiltration, erosion, and biointrusion) at a site. The RCRA Subtitle C covers fit within this category. Multilayer covers can be compromised if differential settlement occurs or if any of the components are not appropriate for the site. At sites with the potential for differential settlement, application of conventional multilayer caps is problematic. In addition, sites where clay components become desiccated and cracked can negatively impact cover performance.

The arid to semiarid climate in Los Alamos is also considered incompatible with the typical clay-component layers of the RCRA Subtitle C multilayer cover due to desiccation and cracking of clays. Based upon these concerns and the potential for moisture infiltration, the multilayer cover technology has significant limitations. Because of the characteristics of the waste in the shafts and the significant potential adverse effects that could result from these conditions, the multilayer cover (RCRA cover) technology was not retained.

Vegetative Cover

A vegetative cover consists of a soil cap supporting native vegetation. The vegetative cover is constructed over the disposal unit to protect it from erosion and to reduce the amount of surface water that may infiltrate. The vegetative cover typically has two different soil-type layers. The lower layer, directly above the waste, is finer-grained, has higher density, and has lower permeability than the soil above. The purpose of this layer is to inhibit surface water from seeping into the waste zone. The upper soil layer consists of coarser materials, has lower density, and higher permeability than the soil below. The purpose of this layer is to encourage plant growth. This two-layered soil cap would be seeded with native vegetation once in place. Vegetation is often used in combination with other best management practices (BMPs) such as protecting the soil from erosion along diversion ditches and on areas that have been regraded. The vegetative cover’s ET capacity is limited due to the design thickness of the cover. The vegetative cover technology was retained.

Evapotranspiration Cover

The ET cover is designed to provide protection from surface water infiltration in arid to semiarid environments where materials such as clays and synthetic/geosynthetic membranes are less reliable. ET covers may consist of multiple layers of geologic materials. Appropriate vegetation is a significant component for most ET covers to aid in the dewatering of the cover materials. The vegetated ET cover was developed specifically for landfills located in arid to semiarid environments such as Los Alamos (Barnes et al. 1990, 070209, pp. 1201–1202). The earliest research in this area was conducted at Los Alamos, at a test site within 2 mi of MDA H (Nyhan et al. 1984, 008797; Nyhan 1989, 006876; Nyhan et al. 1989, 006874). Because ET covers are designed for use in arid to semiarid environments, these covers do not incur subsidence and desiccation.

The demand for water or potential loss due to ET far exceeds the actual supply of water (i.e., precipitation) (Figure 2.3-2) in the arid to semiarid Los Alamos climate. The ET cover provides for a deeper rooting medium, thus offering the native vegetation the opportunity to survive lengthy periods of drought because the water storage of the ET cover is greater than that of a prescriptive RCRA cover. The ET cover technology was retained.

Biotic Barriers

Various materials have been used to control plant and/or animal intrusion into hazardous waste landfills. Installation of horizontal barriers constructed of cobble-sized rocks or pea gravel inhibits deep-rooting plants and discourages burrowing animals. Chainlink fencing laid on the surface has been successfully used at a Laboratory site to discourage burrowing animals although having no visible impact on beneficial vegetation (LANL 1999, 063919). Either of these biobarriers (i.e., rock/gravel or chainlink fencing) could be used as a stand-alone technology or could be incorporated into the enhanced cover designs considered for MDA H. The biotic barrier technology was retained.

Flexible Membrane Liner

Flexible membrane liners (FML) or geomembranes are thin, flexible, impermeable liners that are combined with base soil to reduce seepage. The geomembrane is a synthetic material that has very little structural function. A properly constructed subgrade and careful installation are required to provide optimal results, which would be difficult to implement with inherent potential for long-term settling of the site. A soil layer covers the geomembrane to protect it from physical abrasion as well as to prevent photo-degradation. This technology is typically used to impede vertical migration of vapor-phase contaminants, but is prone to trapping moisture beneath the FML. Given the lack of vadose zone contaminants and significant potential adverse effects that could result from these conditions, the FML technology was not retained.

Concrete Cap

A concrete cap acts as a biotic barrier and provides long-term security. A concrete cap consists of a thick layer of concrete placed on the ground surface over the shafts. The cap would restrict human as well as plant and/or animal intrusion into the shafts, and prevent removal of or human interference with the waste. This technology has been used in the nuclear industry to isolate waste. It would be used in a similar fashion for the waste contained in the MDA H shafts. However, the concrete cap has the potential for failure due to moisture collection under the concrete and subsequent infiltration into the shafts, which could lead to disruption/dispersal of waste. The concrete cap technology is not suitable for use at MDA H and was not retained.

6.2.2 In situ Treatment Technologies

In situ waste treatment technologies are used to reduce the mobility and/or toxicity of wastes, or to increase the stability of wastes without removal. In situ treatment generally requires longer time periods, affords less certainty about the uniformity of treatment due to soil variability, and it is more difficult to verify the effectiveness of the process. The benefit derived from most in situ treatment over ex situ treatment options is the reduction in exposure potential for workers. The decision to use in situ treatment at MDA H must be based upon the characteristics of the waste. The benefits of the different in situ methods (i.e., biological, chemical, and physical) at MDA H are weighed against the potential risks associated with the implementation of these technologies.

6.2.2.1 Monitored Natural Attenuation

Monitored natural attenuation (MNA) uses natural subsurface processes to reduce contaminant concentrations to acceptable levels. The natural attenuation processes include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil, soil vapor, or groundwater. These in situ processes include adsorption, biodegradation, dispersion, dilution, sorption, volatilization, radioactive decay, chemical reactions with subsurface materials, and chemical or biological stabilization. Based upon the nature of the wastes at MDA H, MNA is not likely to achieve the goals generally associated with the technology.

Consideration of the MNA technology requires evaluation of contaminant degradation rates and products as well as predicting contaminant concentration at downgradient receptor points. The primary objective is to demonstrate that natural processes of contaminant degradation will reduce contaminant concentrations below regulatory standards or risk-based levels before potential exposure pathways are completed. In addition, long-term monitoring is conducted to measure degradation rates to evaluate compliance with cleanup objectives. Commonly targeted contaminants for MNA include VOCs, SVOCs, and fuel hydrocarbons. Based upon measured soil-vapor levels at MDA H, the total mass of VOCs is estimated to be 2.1 kg (Appendix E), well below concentrations that could pose future adverse impact to groundwater. VOCs are not considered a potential current or future impact to groundwater at MDA H. Likewise, soil data do not indicate contaminant concentrations above action levels. The waste disposed of at MDA H is primarily solid in form and expected to remain stable in its current undisturbed state. Because of the low levels of VOCs present at the site, the MNA technology was not retained.

6.2.2.2 Biological Treatment Technologies

Biological methods, using various microorganisms and vegetation, have been effective in metabolizing a variety of organic contaminants and also in changing the solubility of certain inorganic chemical and radioactive species in low concentrations during the wastewater treatment processes. These technologies are not effective in treating halogenated SVOCs, including PCBs. Based upon soil-vapor levels at MDA H, the total mass of VOCs is estimated to be 2.1 kg (Appendix D), well below concentrations that could pose future adverse impact to groundwater. VOCs are not considered a potential current or future impact to groundwater at MDA H. The waste disposed of at MDA H is primarily solid in form and expected to remain stable in its current undisturbed state. In situ biological treatment technologies are discussed below.

Bioventing

Bioventing is an in situ remediation technology that uses indigenous microorganisms to biodegrade organic constituents adsorbed on soil particles in the vadose zone. Typically, aromatic hydrocarbons are most amenable to this technology. Air flow is introduced into the soil, and if necessary, nutrients are added, thereby enhancing the activity of the native bacteria and simulating the natural in situ biodegradation of hydrocarbons in the soil. During bioventing, oxygen may be supplied through direct air injection into the residual soil contamination. However, uniform delivery of the supplements (i.e., nutrients) into the contaminated soil can pose significant challenges.

Based upon the low levels of organic contaminants in the vadose zone, the increased air and/or moisture infiltration, and the significant potential adverse effects that could result from implementation, the bioventing technology was not retained.

Enhanced Bioremediation

Enhanced bioremediation is a process by which microorganisms (e.g., fungi, bacteria, and other microbes) found either indigenous to or inoculated into the soil and/or groundwater degrade (i.e., metabolize) organic contaminants, thereby converting the contaminants to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance conversion or desorption of contaminants from subsurface materials. Based upon the low levels of organic contaminants in the vadose zone, the increased air and/or moisture infiltration, and the significant potential adverse effects that could result from implementation, the enhanced bioremediation technology was not retained.

Phytoremediation

Phytoremediation is a bioremediation process that uses various types of vegetation to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. Contaminants are often transferred to the plant tissue from the soil and/or groundwater. Generally, the use of phytoremediation is limited to sites with lower contaminant concentrations and contamination in shallow soils, streams, and groundwater. The success of remediation depends on establishing a selected plant community. However, introducing new plant species can have widespread ecological ramifications that should be considered in advance. It is important to note that mobilization of contaminants in the soil may occur during the start-up period. Additionally, the establishment of the plants may require several seasons of irrigation. It is also undesirable for plants to translocate radionuclides to the surface through stems and leaves.

Based upon the low levels of organic contaminants, the irrigation requirements, the increased air and/or moisture infiltration, and the significant potential adverse effects that could result from implementation, the phytoremediation technology was not retained.

6.2.2.3 Chemical Treatment Technologies

During chemical treatment, the physical properties of the contaminants or the contaminated medium are used to destroy (i.e., chemically convert), separate, or contain the contamination. Two chemical treatment technologies are evaluated below.

Chemical Oxidation

Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. Managing, storing, and delivering large quantities of hazardous oxidizing materials typically pose additional concerns for workers and the environment. This technology was not considered applicable to the MDA H site based upon the waste sensitivity to oxidation and the significant potential adverse effects that could result from implementation. The chemical oxidation technology was not retained.

Soil Flushing

Soil flushing is the in situ extraction of contaminants from the soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through in situ soils using an injection or infiltration process. Extraction fluids must be recovered from the underlying strata and, when possible, recycled. Adding extraction fluids to the vadose zone that would have to be removed from groundwater is contrary to the intent of this CME. Based upon the waste sensitivity to moisture and the significant potential adverse effects that could result from implementation, the soil flushing technology was not retained.

6.2.2.4 Physical Treatment Technologies

In situ physical treatment technologies are a diverse group of technologies that include methods to remove mobile contaminants, increase the mobility of contaminants, further stabilize contaminants, and/or destroy contaminants in their places. Several in situ physical treatment technologies are presented below.

Soil-Gas Venting

Soil-gas venting consists of drilling open boreholes into the contaminated matrix to allow the release of subsurface vapors and gases to the atmosphere. Soil-gas venting uses ambient meteorological conditions to extract vapor-phase contaminants, primarily VOCs and methane, from the vadose zone. Because of the difference in barometric pressures between the atmosphere and the vadose zone, pore gas naturally moves toward equilibrium. No wellhead control device is used for this technology. Based upon the low levels of organic contaminants in the vadose zone, the increased air flow, and the significant potential adverse effects that could result from implementation, the soil-gas venting technology was not retained.

Soil Vapor Extraction

Active soil vapor extraction (SVE) uses vacuum blowers to accelerate the removal of subsurface gases or vapors. The blowers create a negative pressure or vacuum in one or more of the pore-gas boreholes. The gases or vapors are removed from the boreholes by advective transport. This technology commonly requires a treatment system for the contaminated subsurface vapor. At low contaminant concentrations, passive SVE may be more effective. Passive SVE is a pore-gas remediation technology that uses ambient meteorological conditions to extract vapor-phase contaminants, primarily VOCs and methane, from the vadose zone. As with soil venting, due to the difference in barometric pressures between the atmosphere and the vadose zone, pore gas naturally moves toward equilibrium. Passive SVE can be enhanced with a wellhead control device that restricts the inward flow of ambient air to the subsurface under high atmospheric barometric conditions, although only allowing the outward flow of air. Based upon the low levels of organic contaminants in the vadose zone, the increased air flow, and the significant potential adverse effects that could result from implementation, SVE technology was not retained.

Pneumatic Fracturing

Pneumatic fracturing uses the injection of a fluid under pressure to create open fractures in the area where a contaminant plume exists. Opening subsurface flow paths allows access to the contaminated media for removal or treatment. Because pneumatic fracturing has the potential to introduce large amounts of water into a formation that has optimal low-moisture content, it is not desirable. Based upon the waste's sensitivity to vibration, increased moisture, and the significant potential adverse effects that could result from implementation, the pneumatic fracturing technology was not retained.

Electrokinetic Soil Treatment

Electrokinetic soil treatment is an in situ process for the continuous removal of ionic or charged species from soils, including heavy metals, radionuclides, and ionized organic compounds. The technology is implemented by passing a direct current through the soil. Electrokinetics is most applicable in low permeability soils. Low permeability soils are typically saturated to partially saturated clay and silt-clay mixtures that are not readily drained. The effectiveness of this technology is dramatically reduced in low soil-moisture applications such as at MDA H, and the use of direct current in the vicinity of the waste would introduce significant potential adverse effects. Therefore, the electrokinetic soil technology was not retained.

Electroacoustic Treatment

In situ electroacoustic treatment is an emerging technology used to decontaminate soils containing organic compounds. As with electrokinetic soil treatment, this technology is most applicable in low-permeability soils, is less effective in low soil-moisture applications, and is less effective when the vapor-phase concentration of organic contaminants in the vadose zone is low. Based upon the low levels of organic contaminants in the vadose zone, the introduction of vibration, and the significant potential adverse effects that could result from implementation, the electroacoustic technology was not retained.

Dynamic Compaction

Dynamic compaction consolidates waste in its place to reduce the potential for settling over time. The technology has been successfully demonstrated on landfills where subsidence (i.e., settling) over large areas is likely, and where waste is near the surface and in a homogenous waste form. Based upon the shock sensitivity of the waste at MDA H and the significant potential adverse effects that could result from implementation, the dynamic compaction technology was not retained.

Jet Grouting Stabilization

Jet grouting employs high pressure injection of a cementitious grout slurry into a soil strata to hydraulically mix the soil, waste, and grout in situ. The grout slurry is injected into and/or around the waste to fill void spaces and to reduce the porosity within and between buried objects. The objective is stabilization of the waste form, reduction of the surface-water infiltration and movement through the waste, and overburden subsidence. In one method, grout is injected into holes drilled through the waste simultaneously pulverizing the waste and mixing it with the grout. This approach is only applicable for bulk-managed soil-like wastes.

A second waste stabilization method involves the direct injection of grout into void spaces surrounding waste. A pipe or auger is drilled into the subsurface and slowly rotated and pressurized. The high pressure (4000–13,000 psi) forces the grout out laterally through special ports in the sides of the pipe or auger. The slurry exits the jet port at very high velocity, penetrating the soil several inches to several feet from the injection piping. The rotating jets destroy soft soil formations and mix the native soil with cement. Finally, the rotating pipe/auger is drawn slowly upward at a controlled rate to create a nearly cylindrical column of treated soil.

Based upon the potential for introducing air and moisture under high pressure and the shock sensitivity of the waste at MDA H, significant potential adverse effects could result from implementation. Therefore, the jet-grouting stabilization technology was not retained.

6.2.2.5 Thermal Treatment Technologies

Thermal treatment technologies have been developed and implemented to decompose heat-sensitive contaminants into less toxic or less mobile forms, or to enhance the extractability of a contaminant by heating it into a vapor-phase. Heat is generated or delivered using several types of radiation (i.e., microwave, radio frequency, or thermal), or using direct conductance of electricity or injection of already heated materials (e.g., steam). Because of the thermal sensitivity of the waste materials in the shafts, the thermal treatment technologies were not retained.

6.2.3 Excavation/Removal Technologies

A review was conducted by subject matter experts of the characteristics of the complex mixture of waste disposed of in the shafts (Appendix C). It was determined that the waste is sensitive to sparks, friction, heat, physical impact, pinching, air, and/or moisture. Potential risks associated with excavation include:

- sparks from excavation equipment, abrading uranium components, or handling and adverse interactions of HE or pyrophoric metals;
- friction from excavation equipment or handling;
- impact/crush from equipment or dropping; and
- pinching from equipment or handling.

Such processes could also result in inadvertent pinching of residual amounts of HE remaining in crevices, cracks, and machinery components.

Excavation/removal of the waste materials in the shafts at MDA H would require extensive excavation of the surrounding soils as well as the waste in the shafts themselves. The implementation of the excavation technologies has the potential to introduce unwanted and uncontrolled energy sources into the interred waste materials. Potential risks associated with excavation include vibration, friction, heat generation, sparks, impact, or crushing of waste. Because of the shock sensitivity and the thermal sensitivity of the waste materials in the shafts, the excavation/removal technologies were not retained.

6.2.4 Ex Situ Treatment Technologies

General ex situ treatment technologies include neutralization, extraction, thermal treatment, stabilization, and the various debris treatments specified under RCRA. Because these technologies require excavation/removal technologies that were not retained, the ex situ treatment technologies were also not retained.

6.3 Summary of Technologies Suitable for MDA H

Candidate corrective measure technologies were evaluated in section 6.2 based on site conditions, waste characteristics, and technology limitations. The technologies considered applicable for MDA H, and retained for further consideration in developing corrective measure alternatives in section 7 are summarized below.

6.3.1 Containment Technologies

The following technologies are suitable to contain the waste in the shafts at MDA H (Table 6.3-1):

- surface barriers—vegetative cover,
- surface barriers—ET cover, and
- surface barriers—biotic barriers.

6.3.2 In Situ Treatment Technologies

The waste in the shafts is sensitive to sparks, friction, heat, physical impact, pinching, air, and/or moisture, and there are low concentrations of VOCs in the vadose zone. Therefore, in situ treatment technologies are ruled out at MDA H.

6.3.3 Excavation and Disposal Technologies

The waste in the shafts is sensitive to sparks, friction, heat, physical impact, pinching, air, and/or moisture, and there are low concentrations of VOCs in the vadose zone. Therefore, excavation and disposal technologies are ruled out at MDA H.

6.3.4 Ex Situ Treatment Technologies

The waste in the shafts is sensitive to sparks, friction, heat, physical impact, pinching, air, and/or moisture, and there are low concentrations of VOCs in the vadose zone. Therefore, ex situ treatment technologies are ruled out at MDA H.

7.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

Table 7.0-1 summarizes the potential corrective measures technologies that were carried forward from section 6. Table 7.0-1 also presents the numbering system used to identify the technologies evaluated in this section and in section 8.

The use of institutional controls is also evaluated as part of the identification and screening of corrective measures alternatives. Section III.W.3b of the Consent Order anticipates that institutional controls may be a component of the chosen corrective measure (e.g., fencing, control of site access, and Laboratory administrative controls).

Section 7.1 addresses the activities completed prior to beginning the corrective measure. The threshold screening criteria listed in section VII.D.4.a of the Consent Order (Figure 5.4-1) are detailed in section 7.2. Section 7.3 presents the screening of technologies against the threshold criteria. Those technologies that satisfy all four of the threshold criteria are carried forward into section 8.0 where the technologies and the alternatives they form are evaluated against the remedial alternative evaluation criteria (also referred to as balancing criteria) defined in section VII.D.4.b of the Consent Order (Figure 5.4-1).

7.1 Activities Undertaken Before Implementation of Corrective Measures

DOE sets forth specific inactive site surveillance, maintenance, and characterization requirements for designated nuclear environmental sites. Corrective action activities would require the following modification to the existing DSA and NNSA/DOE approval before implementation:

- the basic description of the proposed activity and its operations, including safety structures, systems, and components;
- a hazards analysis of the activities and/or safety structures, systems, and components; and
- the hazard controls and their basis for these controls.

The specific activities, structures, systems, and components associated with the selected remedy will be described and evaluated in accordance with Title 10 CFR 830 Nuclear Safety Management requirements, and the proposed activities must be authorized by DOE before implementation.

7.2 Corrective Measures Threshold Screening Criteria

Section VII.D.4.a of the Consent Order states, “The Respondents shall evaluate each of the remedy alternatives for the following threshold criteria.” To be selected the remedy alternative must:

1. *Be protective of human health and the environment.*

   Protection of human health and the environment should be evaluated based on reasonably anticipated land use, both now and in the future. It should take into consideration the potential exposure pathways identified in the CSM.

2. *Attain media cleanup standards.*

   The applicable cleanup standards developed in accordance with section VIII of the Consent Order are presented in section 5.1. EPA guidance (61 Federal Register 19432, May 1, 1996) states, “Media cleanup standards should reflect the potential risks of the facility and media in question by considering the toxicity of the constituents of concern, exposure pathways, and fate and transport characteristics." EPA guidance further explains, "Attaining media cleanup standards does not necessarily entail removal or treatment of all contaminated material above specific constituent concentrations. Depending on the site-specific circumstances, remedies may attain media cleanup standards through various combinations of removal, treatment, engineering and institutional controls." Affected media at MDA H is the soil surrounding the shafts.

3. *Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment.*

   Source control measures evaluated may include a combination of treatment, containment, removal, and institutional controls.

4. *Comply with applicable standards for management of wastes*.

   A remedy must be able to comply with all applicable regulatory requirements for management of any wastes removed or generated during corrective action as well as closure requirements for any waste or contamination remaining following implementation of the remedial alternative.

In accordance with 40 CFR section 264.110(c), the CME process is being used to establish alternative closure requirements for the RCRA-regulated unit pursuant to the Consent Order. Compliance with these closure performance standards is considered a threshold criterion and is evaluated as part of criterion 4 of section VII.D.4.a of the Consent Order.

7.3 Description and Screening of Technologies Retained

This section describes the potential corrective measures technologies and presents a qualitative evaluation of these technologies against the threshold criteria contained in section VII.D.4.a of the Consent Order. Table 7.3-1 summarizes this evaluation.

Because the MDA H RFI report (LANL 2001, 070158) identifies no unacceptable present-day risks to human health or the environment, the potential need for corrective action at MDA H is based on future potential for releases that might create unacceptable risks to human health or the environment.

7.3.1 Technology S-1: No Action

Technology S-1 represents a true no-action technology for the shafts. Under this technology, no action will be taken. The site will not be regraded and revegetated, nor shall maintenance of the surface soil be performed. The concrete/crushed-tuff plugs remain over the waste in the shafts. Institutional controls will not be maintained. In summary, this technology includes:

- no maintenance or monitoring, and
- no institutional controls.

7.3.1.1 Protection of Human Health and the Environment

Because there are no institutional controls, the potential remains for exposure through excavation. This technology does not prevent infiltration of moisture and subsequent disruption/dispersal of waste. This technology is not protective of human health and the environment.

7.3.1.2 Attainment of Media Cleanup Standards

This technology complies with NMED SSLs (NMED 2009, 108070) for soil surrounding the shafts. The MDA H RFI report identifies no unacceptable present-day risks to human health or the environment (LANL 2001, 070158).

7.3.1.3 Control of Sources and Releases

Because there are no institutional controls, this technology does not prevent releases of buried waste due to excavation. This technology does not provide protection against infiltration of moisture and subsequent disruption/ dispersal of waste. This technology will not adequately control sources and releases.

7.3.1.4 Compliance with Applicable Waste Management Standards

No waste will be generated under the no-action technology. Therefore, the waste management standards are not applicable.

7.3.1.5 Summary

Although the no-action technology does not meet all of the threshold criteria, it is carried forward for comparison in evaluating the other technologies.

7.3.2 Technology S-2: Maintenance and Monitoring

This technology represents implementation of institutional controls, monitoring and maintenance of the surface for hazardous waste constituents in the shafts, and includes the following:

- leaving existing concrete/crushed-tuff plugs on shafts;
- active monitoring and maintenance of the existing soil surface and existing concrete/crushed-tuff plugs on shafts for 30 yr; and
- institutional controls for 100 yr.

Active monitoring and maintenance of the cover will be performed for 30 yr to address erosion and animal burrowing, and manage vegetation (remove trees and invasive species) to limit the potential for biotic intrusion into buried waste. Additional active institutional controls (fencing, control of site access, and Laboratory administrative controls) are assumed to remain in place for 100 yr. DOE Order 5400.5 requirements for monitoring, maintenance, and institutional controls are not addressed in this CME.

7.3.2.1 Protection of Human Health and the Environment

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology does not prevent infiltration of moisture and subsequent disruption/dispersal of waste. This technology is not protective of human health and the environment.

7.3.2.2 Attainment of Media Cleanup Standards

This technology complies with NMED SSLs (NMED 2009, 108070) for soil surrounding the shafts. The MDA H RFI report identifies no unacceptable present-day risks to human health or the environment (LANL 2001, 070158).

7.3.2.3 Control of Sources and Releases

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology does not provide protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology will not adequately control sources and releases.

7.3.2.4 Compliance with Applicable Waste Management Standards

No wastes will be generated under the maintenance and monitoring technology. Therefore, the waste management standards are not applicable.

7.3.2.5 Summary

Maintenance and monitoring does not prevent infiltration of moisture and subsequent disruption/dispersal of waste. Therefore, maintenance and monitoring is not protective of human health and the environment and does not control sources and releases. This technology was not retained for further consideration.

7.3.3 Technology S-3a: Vegetative Cover

Under this technology, the site will be regraded and a vegetative cover will be installed over approximately 0.4 acres at the site (Figure 7.3-1). This technology includes the following:

- regrading of the existing soil surface, leaving existing concrete/crushed-tuff plugs on shafts;
- construction of a vegetative cover consisting of 1 ft of soil-gravel fill and 6 in. of topsoil, native vegetation, and a moisture-monitoring system;
- actively monitoring and maintaining the vegetative cover for 30 yr; and
- implementing institutional controls for 100 yr.

The vegetative cover will be designed to meet the requirements for an alternative cover for a hazardous waste landfill as specified in 40 CFR Part 264, Subpart G, Closure and Post-Closure. Moisture-monitoring probes will be installed in the cover during the 30 yr active monitoring and maintenance period. The vegetative cover will be designed with slopes sufficient to encourage precipitation runoff and at the same time reducing potential for erosion. A preliminary design includes a 1-ft soil-gravel admixture subsoil layer and a 6-in. vegetated topsoil layer. A soil-gravel admixture placed on the surface weathers to create desert paving and protects the cover from high-intensity rainfall, thereby reducing erosion potential. The vegetative cover provides limited ET capacity due to the design thickness of the cover. The proposed layout is presented in Figure 7.3-1.

Active maintenance and monitoring of the vegetative cover will be performed for 30 yr to control erosion and manage vegetation (i.e., remove trees, other deep-rooting plants, and invasive species) to limit the potential for biotic intrusion (e.g., animal burrowing) into buried waste. Monitoring of moisture levels will be conducted. Additional active institutional controls (e.g., fencing, control of site access, and Laboratory administrative controls) are assumed to remain in place for 100 yr. DOE Order 5400.5 requirements for monitoring, maintenance, and institutional controls are not addressed in this CME, but will be included in the CMI plan.

7.3.3.1 Protection of Human Health and the Environment

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. A properly designed vegetative cover will provide protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology is protective of human health and the environment.

7.3.3.2 Attainment of Media Cleanup Standards

This technology complies with NMED SSLs (NMED 2009, 108070) for soil surrounding the shafts and imported materials for the vegetative cover. The MDA H RFI report identifies no unacceptable present-day risks to human health or the environment (LANL 2001, 070158).

7.3.3.3 Control of Sources and Releases

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology provides protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology will adequately control sources and releases.

7.3.3.4 Compliance with Applicable Waste Management Standards

Any waste generated under this technology will comply with all applicable regulatory requirements.

7.3.3.5 Summary

Technology S-3a, the vegetative cover, meets the threshold screening criteria and is retained for further evaluation.

7.3.4 Technology S-3b: Evapotranspiration Cover

Under this technology, the site will be regraded and an ET cover will be installed over approximately 0.4 acres at the site (Figure 7.3-1). This technology includes the following:

- regrading of the existing soil surface, leaving existing concrete/crushed-tuff plugs on shafts;
- construction of an ET cover consisting of 3.5 ft of infiltration layer, 1.5 ft of gravel admixture and vegetated topsoil, and a moisture-monitoring system;
- actively monitoring and maintaining the cover for 30 yr; and
- implementing institutional controls for 100 yr.

The ET cover takes advantage of the arid to semiarid site conditions by evaporating and transpiring water from the cover. Engineered ET covers have demonstrated effectiveness in reducing infiltration in semiarid regions (Davenport et al. 1998, 069674, p. 1; Dwyer et al. 2000, 069673, pp. 23–26). ET covers can be adapted for the following:

- increased erosion resistance by adding gravel surface amendments;
- enhancing or limiting types of plants and plant growth for transpiration by varying depths of enriched soil;

- modifying the size of the ET reservoir layer above the waste layer by varying the depths of the primary crushed-tuff ET layer; and
- prevention of biointrusion by using barriers such as cobble, chainlink fencing, or pea-size gravel.

The ET cover will be designed to meet the requirements for an alternative cover for a hazardous waste landfill as specified in 40 CFR Part 264, Subpart G, Closure and Post-Closure. Moisture-monitoring equipment will be installed in the ET cover during the 30 yr active maintenance and monitoring period. A conceptual design (Dwyer 2007, 098276) includes a 1.5-ft vegetated topsoil-gravel admixture at the surface and a lower, 3.5-ft infiltration layer composed of crushed tuff mixed with soil and amendments to provide water storage and minimize infiltration. The cover will be designed with slopes sufficient to encourage precipitation runoff and at the same time limiting the potential for erosion. A soil-gravel admixture placed on the surface weathers to create desert paving and protects the cover from high-intensity rainfall, thereby reducing erosion potential. The proposed layout is presented in Figure 7.3-1.

Active monitoring and maintenance of the cover will be performed for 30 yr to control erosion and manage vegetation (i.e., remove trees, other deep-rooting plants, and invasive species) to limit the potential for biotic intrusion (e.g., animal burrowing) into buried waste. Monitoring of moisture levels will be conducted. Additional active institutional controls (e.g., fencing, control of site access, and Laboratory administrative controls) are assumed to remain in place for 100 yr. DOE Order 5400.5 requirements for monitoring, maintenance, and institutional controls are not addressed in this CME, but will be included in the CMI plan.

7.3.4.1 Protection of Human Health and the Environment

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. A properly designed ET cover will provide protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology is protective of human health and the environment.

7.3.4.2 Attainment of Media Cleanup Standards

This technology complies with NMED SSLs (NMED 2009, 108070) for soil surrounding the shafts and imported materials for the vegetative cover. The MDA H RFI report identifies no unacceptable present-day risks to human health or the environment (LANL 2001, 070158).

7.3.4.3 Control of Sourced and Releases

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology provides protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology will adequately control sources and releases.

7.3.4.4 Compliance with Applicable Waste Management Standards

Any waste generated under this technology will comply with all applicable regulatory requirements.

7.3.4.5 Summary

Technology S-3b, the ET cover, meets the threshold screening criteria and is retained for further evaluation.

7.3.5 Technology S-3c: Biotic Barrier

Under this technology, the site will be regraded and a biotic barrier cover will be installed over approximately 0.4 acres at the site (Figure 7.3-1). This technology includes the following:

- regrading of the existing soil surface, leaving existing concrete/crushed-tuff plugs on shafts,
- construction of a biotic barrier consisting of a 1-ft layer of cobbles with a minimum diameter of 6 in.,
- actively monitoring and maintaining the barrier for 30 yr, and
- implementing institutional controls for 100 yr.

The biotic barrier is intended to provide a restrictive barrier for preventing burrowing animals from tunneling into the waste. Active monitoring and maintenance of the biotic barrier will be performed for 30 yr to control erosion and manage vegetation (i.e., remove trees and other deep-rooting plants) to limit the potential for biotic intrusion (e.g., animal burrowing) into buried waste. Additional active institutional controls (e.g., fencing, control of site access, and Laboratory administrative controls) are assumed to remain in place for 100 yr. DOE Order 5400.5 requirements for monitoring, maintenance, and institutional controls are not addressed in this CME, but will be included in the CMI plan.

7.3.5.1 Protection of Human Health and the Environment

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology does not prevent infiltration of moisture and subsequent disruption/dispersal of waste. This technology is not protective of human health and the environment.

7.3.5.2 Attainment of Media Cleanup Standards

This technology complies with NMED SSLs (NMED 2009, 108070) for soil surrounding the shafts and imported materials for the biotic barrier. The MDA H RFI report identifies no unacceptable present-day risks to human health or the environment (LANL 2001, 070158).

7.3.5.3 Control of Sources and Releases

Institutional controls will be implemented to provide access controls, thereby restricting human exposure through excavation. This technology does not provide protection against infiltration of moisture and subsequent disruption/dispersal of waste. This technology will not adequately control sources and releases.

7.3.5.4 Compliance with Applicable Waste Management Standards

Any waste generated under this technology will comply with all applicable regulatory requirements.

7.3.5.5 Summary

Technology S-3c, the biotic barrier, does not prevent infiltration of moisture and subsequent disruption/dispersal of waste. Therefore, the biotic barrier is not protective of human health and the environment, and does not control sources and releases. This technology was not retained for further consideration.

7.4 Technologies Meeting Threshold Criteria and Retained for Further Evaluation

Table 7.4-1 presents a summary of the technologies that meet the threshold criteria. These technologies are retained and brought forward to section 8 for assessment against the remedial alternative evaluation criteria described in section VII.D.4.b of the Consent Order.

8.0 EVALUATION OF TECHNOLOGIES AGAINST REMEDIAL ALTERNATIVE EVALUATION CRITERIA

Corrective measures technologies identified in section 6 as appropriate for MDA H were screened against the Consent Order threshold criteria discussed in section 7. Corrective measures technologies determined to meet the Consent Order threshold criteria were brought forward for further evaluation, along with the no-action technology. These technologies were evaluated against the remedial alternative evaluation criteria (also known as the balancing criteria) from section VII.D.4.b of the Consent Order. The balancing criteria are discussed below.

8.1 Remedial Alternative Evaluation Criteria (Consent Order Section VII.D.4.b)

Section VII.D.4.b of the Consent Order requires that each remedial alternative be evaluated against the balancing criteria before proposing a recommended alternative.

8.1.1 Long-Term Reliability and Effectiveness (Consent Order Section VII.D.4.b.i)

This factor includes consideration of the magnitude of risks that will remain after implementation of the remedy, the extent of long-term monitoring or other management that will be required after implementation of the remedy, the uncertainties associated with leaving contaminants in place, and the potential for failure of the remedy. Preference is given to a remedy that reduces risks with little long-term management, and that has proved effective under similar conditions.

8.1.2 Reduction of Toxicity, Mobility, or Volume (Consent Order Section VII.D.4.b.ii)

This factor includes consideration of the reduction in the toxicity, mobility, and volume of contaminants. Preference is given to a remedy that uses treatment to more completely and permanently reduce the toxicity, mobility, and volume of contaminants.

8.1.3 Short-Term Effectiveness (Consent Order Section VII.D.4.b.iii)

This factor includes consideration of the short-term reduction in existing risks that the remedy would achieve; the time needed to achieve that reduction; and the short-term risks that might be posed to the community, workers, and the environment during implementation of the remedy. Preference is given to a remedy that quickly reduces short-term risks without creating significant additional risks.

8.1.4 Implementability (Consent Order Section VII.D.4.b.iv)

This factor includes consideration of installation and construction difficulties; O&M difficulties; difficulties with cleanup technology; permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. Permitting includes NMED and DOE requirements. Preference is given to a remedy that can be implemented quickly and easily, and poses fewer difficulties.

8.1.5 Cost (Consent Order Section VII.D.4.b.v)

This factor includes consideration of both capital costs and O&M costs. Capital costs shall include, without limitation, construction and installation costs; equipment costs; land development costs; and indirect costs, including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. O&M costs shall include, without limitation, operating labor and materials costs; maintenance labor and materials costs; replacement costs; utilities; monitoring and reporting costs; administrative costs; indirect costs; and contingency allowances. All costs shall be calculated based on their net present value (PV). Preference is given to a remedy that is less costly, but does not sacrifice protection of human health and the environment.

8.2 Criteria for Evaluation of Corrective Measures Options (Consent Order Section XI.F.10)

In addition to these five remedial alternative evaluation criteria, section XI.F.10 of the Consent Order identifies six criteria that must be included in the evaluation of the corrective measures options. These include applicability, technical practicability, effectiveness, implementability, human health and ecological protectiveness, and cost. These criteria listed in section XI.F.10 are listed below.

8.2.1 Applicability (Consent Order Section XI.F.10.a)

Applicability addresses the overall suitability for the corrective action option for containment or remediation of the contaminants in the subject medium and for protection of human health and the environment. Potential remedial action technologies were evaluated for their applicability to address the specific contaminants and media for protection of human health and the environment. Furthermore, the threshold screening process in section 7 specifically evaluated each technology for its ability to protect human health and the environment. Therefore, only technologies that are protective of human health and the environment were carried forward for evaluation in section 8.

8.2.2 Technical Practicability (Consent Order Section XI.F.10.b)

Technical practicability describes the uncertainty in designing, constructing, and operating a specific remedial alternative. The description includes an evaluation of historical applications of the remedial alternative, including performance, reliability, and minimization of hazards. The elements of technical practicability are all included within the definition of implementability provided in section VII.D.4.b.iv of the Consent Order. Each of the technologies is evaluated for implementability in this section.

8.2.3 Effectiveness (Consent Order Section XI.F.10.c)

Effectiveness assesses the ability of the corrective measure to mitigate the measured or potential impact of contamination in a medium under the current and projected site conditions. The assessment also includes the anticipated duration for the technology to attain regulatory compliance. In general, all corrective measures described above will have the ability to mitigate the impacts of contamination at the site, but not all remedial options will be equally effective at achieving the desired cleanup goals to the degree and within the same time frame as other options. Each remedy will be evaluated for both short-term and long-term effectiveness.

Both long-term reliability and effectiveness and short-term reliability and effectiveness are included in the remedial alternative evaluation criteria used to evaluate each technology in this section.

8.2.4 Implementability (Consent Order Section XI.F.10.d)

Implementability characterizes the degree of difficulty during the installation, construction, and operation of the corrective measure. O&M of the alternative shall be addressed in this section. Implementability is also one of the remedial alternative evaluation criteria in section VII.D.4.b of the Consent Order. Each technology is evaluated for its implementability in this section.

8.2.5 Human Health and Ecological Protectiveness (Consent Order Section XI.F.10.e)

This category evaluates the short-term (remedy installation-related) and long-term (remedy operation-related) hazards to human health and the environment of implementing the corrective measure. The assessment shall include an analysis of whether the technology will create a hazard or increase existing hazards and the possible methods of hazard reduction.

Protection of human health and the environment is one of the threshold criteria used to screen potential technologies in section 7. Only technologies determined to be protective of human health and the environment were carried forward from section 7 into section 8. To weigh the relative effectiveness of each technology for protecting human health and the environment, these factors are addressed further in this section. Long-term human health and ecological protection are included in the evaluation of long-term reliability and effectiveness for each technology. Likewise, short-term human health and ecological protection are included in the evaluation of short-term reliability and effectiveness for each technology.

8.2.6 Cost (Consent Order Section XI.F.10.f)

This section shall discuss the anticipated cost of implementing the corrective measures. The costs are divided into (1) capital costs associated with construction, installation, pilot testing, evaluation, permitting, and reporting the effectiveness of the alternative; and (2) continuing costs associated with operating, maintaining, monitoring, testing, and reporting on the use and effectiveness of the technology. Cost is also one of the remedial alternative evaluation criteria addressed in this section.

8.3 Screening of Technologies

The technologies carried forward in Table 7.4-1 are screened in the section below.

8.3.1 Technology S-1: No Action

This technology has been described in section 7.3.1.

8.3.1.1 Long-Term Reliability and Effectiveness

An increase in risk is associated with implementation of the no-action technology because it removes institutional controls. No long-term monitoring or other management will be conducted after the remedy is implemented. Uncertainty is associated with future exposure to waste remaining in place due to the lack of institutional controls and the potential for excavation and/or infiltration of moisture leading to disruption/dispersal of waste. The no-action technology does not provide long-term reliability and effectiveness.

8.3.1.2 Reduction of Toxicity, Mobility, or Volume

Because no action is taken, there is no reduction in toxicity, mobility, or volume of contaminants.

8.3.1.3 Short-Term Effectiveness

No short-term risk is associated with implementation of the no-action technology because no action is taken.

8.3.1.4 Implementability

There is no action to implement with this technology. The no-action technology does not require permitting or approval.

8.3.1.5 Cost

No costs are associated with the no-action technology.

8.3.2 Technology S-3a: Vegetative Cover

This technology has been described in section 7.3.3.

8.3.2.1 Long-Term Reliability and Effectiveness

Installation of a vegetative cover will reduce moisture infiltration. Institutional controls will reduce the potential for exposure through excavation. The vegetative cover exhibits medium reliability over the long term due to the limited thickness of the cover (approximately 18 in.). Moderate uncertainty and long-term risk will be associated with waste that remains in place. The uncertainty with performance is managed through institutional controls, maintenance, and monitoring.

8.3.2.2 Reduction of Toxicity, Mobility, or Volume

The vegetative cover technology does not reduce toxicity, mobility, or volume of contaminants.

8.3.2.3 Short-Term Effectiveness

Risk reduction is achieved with this technology because of the implementation of institutional controls. A vegetative cover can be constructed in a short time frame (i.e., approximately 12–24 mo). The vegetative cover poses relatively low risk to the community, workers, and the environment during construction because this activity does not involve any waste excavation or management. The vegetative cover technology can be implemented quickly without creating significant additional risk.

The greatest impacts to human health from installing the cover are associated with the physical hazards of construction activities and traffic risks associated with the transportation of raw materials for the cover to the site. Workers will not be exposed to the buried waste during cover construction activities because excavation of the waste disposal sites is not required for installing the cover.

8.3.2.4 Implementability

The vegetative cover shall be installed using standard construction techniques and shall present minimal installation and construction difficulties. Following installation, low to moderate maintenance is required.

No permits or permit modifications, other than DSA approval, would be required for the vegetative cover technology.

8.3.2.5 Cost

Total capital costs are estimated to be $1,044,883. The O&M costs are estimated to be $1,277,583. The PV cost is estimated to be $2,322,466. These costs are presented in Table 8.3-1.

8.3.3 Technology S-3b: ET Cover

The ET cover technology has been described in section 7.3.4.

8.3.3.1 Long-Term Reliability and Effectiveness

Installation of an ET cover will reduce moisture infiltration. Institutional controls will reduce the potential for future exposure through excavation. The cover exhibits medium to high long-term reliability due to the increased thickness of the cover (approximately 60 in.) and ET capacity. Medium to low long-term risk and low uncertainty will be associated with waste that remains in place. The uncertainty with performance is managed through institutional controls, maintenance, and monitoring.

8.3.3.2 Reduction of Toxicity, Mobility, or Volume

The ET cover technology does not reduce toxicity, mobility, or volume of contaminants.

8.3.3.3 Short-Term Effectiveness

Risk reduction is achieved with this technology because of the implementation of institutional controls. An ET cover can be constructed in a short time frame (i.e., approximately 12–24 mo).The ET cover poses relatively low risk to community, workers, and the environment during construction because it does not involve any waste excavation or management. The ET technology can be quickly implemented without creating any significant additional risk.

The greatest impacts to human health from installing the cover are associated with the physical hazards of construction activities and traffic risks associated with the transportation of raw materials to the site for the construction of the ET cover. Workers will not be exposed to the buried waste during ET cover construction activities because waste excavation is not required for installing the cover.

8.3.3.4 Implementability

The ET cover is installed using standard construction techniques and presents minimal installation and construction difficulties. Following installation, low to moderate maintenance is required. No permits or permit modifications, other than DSA approval, would be required for the ET cover technology.

8.3.3.5 Cost

Total capital costs are estimated to be $1,543,542. The O&M costs are estimated to be $1,277,583. The PV cost is estimated to be $2,821,125. These costs are presented in Table 8.3-1.

8.3.4 Screening Summary

After the technologies were evaluated with the Consent Order criteria listed above, they were ranked against each other with the relative rating system explained in Table 8.3-2. Based on this rating system, the technologies were scored as shown in Table 8.3-3.

8.4 Development and Evaluation of Alternatives

The highest ranked technology, as scored in Table 8.3-3, is the alternative evaluated as most effective for addressing the MDA H RAOs and is carried forward to section 9 for selection evaluation.

9.0 SELECTION OF THE RECOMMENDED CORRECTIVE MEASURES ALTERNATIVE

Selection of the recommended alternative is based on the rankings shown in Table 8.3-3. This table provides the screening results of the corrective measure alternatives based on selection criteria defined in section VII.D.4 and section XI.F.10 of the Consent Order and discussed in section 8.1 of this report.

Alternative S-3b (ET cover) is cumulatively superior to the other technologies. Alternative S-3b is superior to alternative S-3a, vegetative cover, in terms of the following balancing criteria: long-term reliability and effectiveness. The long-term reliability and effectiveness of the ET cover is superior to the vegetative cover due to the thickness of the cover and the ET capacity.

Alternative S-3b (ET cover) was selected as the recommended corrective measure.

The ET cover would be placed over the shafts and the entire MDA H NES limits, as shown in Figure 7.3-1. Institutional controls will be implemented to provide access control to prevent human intrusion. In addition, monitoring and maintenance of the cover will be performed.

The selected alternative meets the RAOs developed for the CSM for the source area:

- prevent future human health and ecological exposure to waste through excavation, and
- prevent future disruption and dispersal of waste by physical disruption or infiltration of moisture.

The recommended alternative also meets the five selection criteria. The remedy selected was based on the ability of the recommended alternative to (1) achieve cleanup objectives in a timely manner; (2) protect human and ecological receptors; (3) control or eliminate the sources of contaminants; (4) control migration of released contaminants; and (5) manage remediation waste in accordance with state and federal regulations.

The CSM has been refined to illustrate the impact of the recommended alternative on the release mechanisms and the reduction in exposure potential (incomplete pathways) and future risk reduction. The refined CSM is presented for the shafts in Figure 9.0-1.

10.0 DESIGN CRITERIA TO MEET CLEANUP OBJECTIVES

As required in section XI.F.12 of the Consent Order, this section presents a preliminary plan and key specifications for design of the ET cover and its anticipated implementation.

10.1 Design Approach

Selection of the recommended corrective action alternative requires designing an ET cover during the CMI phase for MDA H. The CMI plan will include DOE Order 5400.5 design requirements. The design process will include the following actions.

- Identify critical infiltration events, including identification of the design precipitation event (maximum precipitation event that the design can endure) or series of events.
- Determine the minimum required water-storage capacity of MDA H soil based on the design precipitation events identified above.
- Determine the minimum required thickness and contours required to ensure the ET cover has adequate thickness and slopes to control erosion and infiltration during the 30-yr maintenance period based on the design precipitation events identified above. Also, determine the minimum topsoil thickness required to establish and maintain vegetation. The surface area of the ET cover is a total of approximately 0.4 acres. The preliminary cover design includes 3.5 ft of fill and 1.5 ft of a topsoil/soil gravel admixture.
- Determine whether a biointrusion barrier is required.
- Determine peak flow rates for the diversion channel on the uphill side of the ET cover and determine armoring requirements for the diversion channel based on the calculated shear stresses.
- Identify the native seed mixture to be used, the surface treatment to be employed before seeding, and the frequency of watering necessary to establish vegetation on the cover.
- Plan for long-term maintenance requirements for the ET cover that includes annual inspection and repair for erosion and subsidence, removal of debris and large woody plants, removal of burrowing animals, and fertilization and mowing as needed to maintain the ET cover.

10.2 Preliminary Design Criteria and Rationale

Preparation of the CMI plan includes a schedule for design, including development of design calculations and documentation that will be submitted to NMED according to the CMI schedule. Design calculations will include, but will not be limited, to the following.

- The cover will have sufficient thickness and will be contoured to control erosion resulting from the 100 yr precipitation event.
- The cover will have sufficient capacity to store the “maximum” infiltration quantity resulting from the 100 yr precipitation event until it can be removed through ET.
- The proposed native seed mixture used to stabilize the cover with vegetation will closely emulate the local plant community, will ensure the vegetative cover remains viable, and will have no detrimental effect on neighboring Pueblo lands.
- The surface treatment method will encourage native vegetation establishment and growth as well as reduce erosion.

- Preliminary specifications, sufficient for evaluating the approximate cost of the alternative, are included for
    - cover vegetation;
    - surface treatment (gravel admixture, typical soil-gravel admixture, gravel size); and
    - cover soil (water-storage medium thickness, unsaturated hydraulic conductivity, erodibility).

10.2.1 Surface Treatment

Surface treatments, such as soil nutrients, a gravel layer, or a soil-gravel admixture, may be warranted in the semiarid climate at the Laboratory to help establish native vegetation and reduce erosion. During the CMI design phase, a seed mix will be specified to stabilize the cover with vegetation consisting of plant communities that closely resemble the undisturbed and well-established plant communities inhabiting Mesita del Buey.

The addition of a layer of gravel-soil admixture on the surface of the cover provides erosion protection for the design precipitation event and promotes ET from vegetation composed mostly of native species of grasses. Erosion and water-balance studies at the Laboratory indicate moderate amounts of gravel mixed into the cover topsoil will control both water and wind erosion with little effect on the vegetation or the soil-water balance. As wind and water flow over the cover surface, some winnowing of fines from the admixture is expected, creating a vegetated, erosion-resistant surface.

The design of a soil-gravel admixture layer is based primarily on the need to protect the soil cover from erosion. A soil-gravel admixture protects a cover from long-term wind erosion. The protection from water erosion depends on the depth, velocity, and duration of stormwater flowing across the MDA H cover. Flow values can be established from the physical properties of the cover (slope, convex or concave grading, slope uniformity, and length of flow paths) and the intensity of the precipitation (precipitation rates, infiltration in contrast to runoff relationships, snowmelt, and off-site flows).

An ET cover is intended to function under unsaturated conditions; consequently, obtaining very low saturated hydraulic conductivity is not essential to a successful cover. The cover soil moisture characteristics and cover compaction density are crucial parameters. Compaction density requirements will be based on the design criteria used but generally will achieve a density in the upper soil layer that approximates that of the surrounding undisturbed soil. Uniformity of compaction is critical to avoid creating preferential infiltration pathways.

The recommendation on surface treatment is based on review of site-specific conditions at nearby MDA G and Laboratory data from cover experiments at TA-51 (Nyhan et al. 1996, 063111). The best surface layer will be chosen during the CMI design phase.

10.2.2 Cover Soil

The performance of the ET cover relies on its thickness, materials, and placement. The ET cover for MDA H will be of sufficient thickness to prevent erosion resulting from the design precipitation event.

10.3 General Operation and Maintenance Requirements

Irrigation is needed during the year following construction to aid in the germination and establishment of the vegetative cover. Vegetation establishment will be offset by keeping infiltration below the storage capacity of the cover.

The Laboratory will inspect the cover on a regular basis and after significant precipitation events to identify erosion indicators on the cover. Any eroded areas will be repaired. After the cover is established, it will be inspected annually in the fall after the monsoon season has ended, and any cover erosion will be repaired.

10.3.1 Long-Term Monitoring Requirements

After implementation of the selected alternative, groundwater monitoring of the regional aquifer beneath MDA H will be conducted in accordance with requirements in the Laboratory's Hazardous Waste Facility Permit and section III.W.1 of the Consent Order.

10.4 Additional Engineering Data Required

Before the CMI design is completed, additional data are required, including:

- verifying the locations and existing depths to the top of waste in the shafts using ground-penetrating radar to properly determine the operational cover thickness,
- testing the geotechnical properties of all materials used for the soil-gravel admixture,
- verifying the locations of buried utilities to determine any potential conflicts, and
- reviewing existing plans and specifications for the water lines that parallel MDA H along Mesita del Buey Road to determine the existing condition of the lines and the best method for installing pressure sensors and automatic shut-off valves should a water line break occur.

These upgrades will be completed before the start of cover construction.

10.5 Additional Requirements

10.5.1 Permits and Regulatory Requirements

NMED will select a final remedy, issue a Statement of Basis for the selected remedy, and designate a period of time for public comment (section 11). DSA approval will be obtained for working within the NES boundary.

10.5.2 Access, Easements, Right-of-Way Agreements

Access, easements, and right-of-way agreements are internal to the Laboratory and will be developed as required once the corrective measure is selected.

10.5.3 Health and Safety Requirements

A site-specific health and safety plan will be prepared to describe the health and safety requirements to be followed during construction of the MDA H cover, O&M activities, and monitoring activities.

10.5.4 Community-Relations Activities

A community-relations program will be developed in accordance with section VII.E.4 to keep northern New Mexico stakeholders and other interested parties involved in project activities and progress.

11.0 SCHEDULE FOR COMPLETION OF ACTIVITIES

The Consent Order requires that a schedule for completion of activities be submitted in the CME report. Activities leading to completion of the remedy include planning, design, and construction of the ET cover. Several milestones for completion of the corrective measure at MDA H are presented in the Consent Order, along with schedule updates. In addition to these milestones, the Consent Order requires the CME report to include a proposed schedule for implementation of the preferred remedy. The schedule identifies the duration of corrective action operations, the frequency of monitoring and sampling activities, and the dates for submitting inspection and monitoring reports to NMED, including all status reports and preliminary data.

Proposed milestones include the following.

- NMED shall prepare a Statement of Basis for remedy selection and issue the statement for public comment.
- NMED shall receive public comments on the Statement of Basis for at least 60 d following public notice. NMED shall provide an opportunity for a public hearing that may extend the public comment period.
- Based upon the Laboratory’s preferred remedy in the CME, the Laboratory requests to submit a CMI plan within 18 mo after NMED selects a final remedy. The plan will contain detailed engineering design drawings and system specifications for all elements of the remedy and a schedule for implementation of the corrective action.
- DSA approval for activities to be performed within a NES will be obtained.
- Closure of Shaft 9 in accordance with RCRA closure requirements under 40 CFR 264 Subparts F and G. As directed by NMED (2000, 068569), closure of Shaft 9 will be incorporated into the corrective action of Shafts 1 through 8 in accordance with the alternate closure requirements of 20.4.1 NMAC 264.110(c).
- The corrective measure will be implemented and a remedy completion report submitted in accordance with the schedule in the CMI plan. Following approval of the CMI plan, construction of the Laboratory’s preferred remedy is expected to take 12–24 mo.
- Monitoring and maintenance, including reporting requirements, will be completed according to the CMI plan.
- Following completion of the remedy, groundwater monitoring will be conducted and reported as required by the Laboratory’s Hazardous Waste Facility Permit.

12.0 REFERENCES AND MAP DATA SOURCES

12.1 References

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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12.2 Map Data Sources

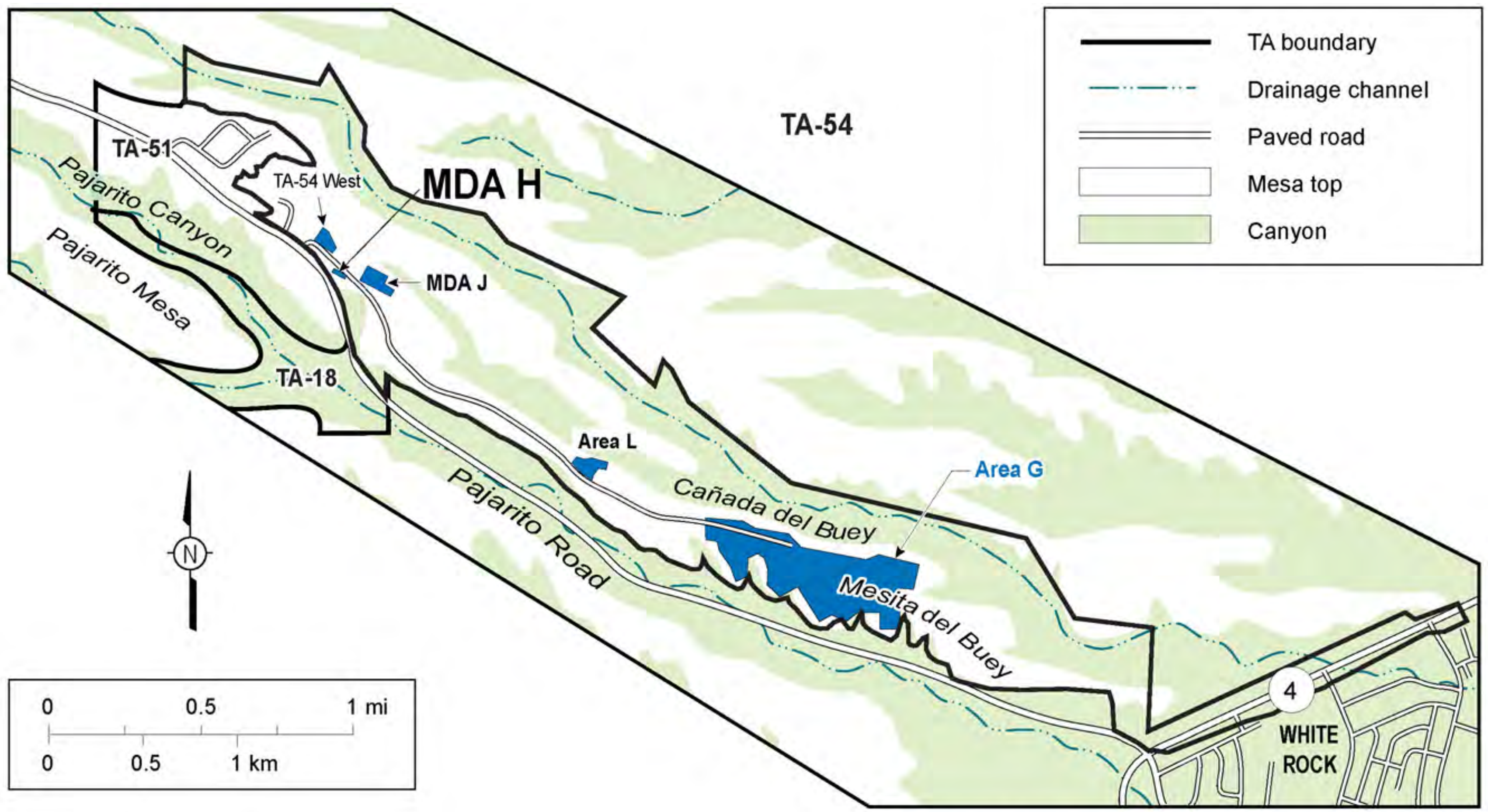
Hypsography, 20- and 100-ft Contour Intervals; Los Alamos National Laboratory, ENV-Environmental Remediation and Surveillance Program; 1991

LANL DOE Boundary; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 05 January 2005

LANL Technical Areas; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 05 January 2005

Materials Disposal Areas; Los Alamos National Laboratory, ENV-Environmental Remediation and Surveillance Program; ER2004-0221; 1:2,500 Scale Data; 23 April 2004

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Development Edition of 17 January 2006



Source: A. Kron_MDA L RFI Rpt., 120302, modified for F2.1-1, MDAG IR, 082605, ptm
graphic modified ALM, North Wind, Inc. 11102010

Figure 1.0-1 Location of MDA H in TA-54

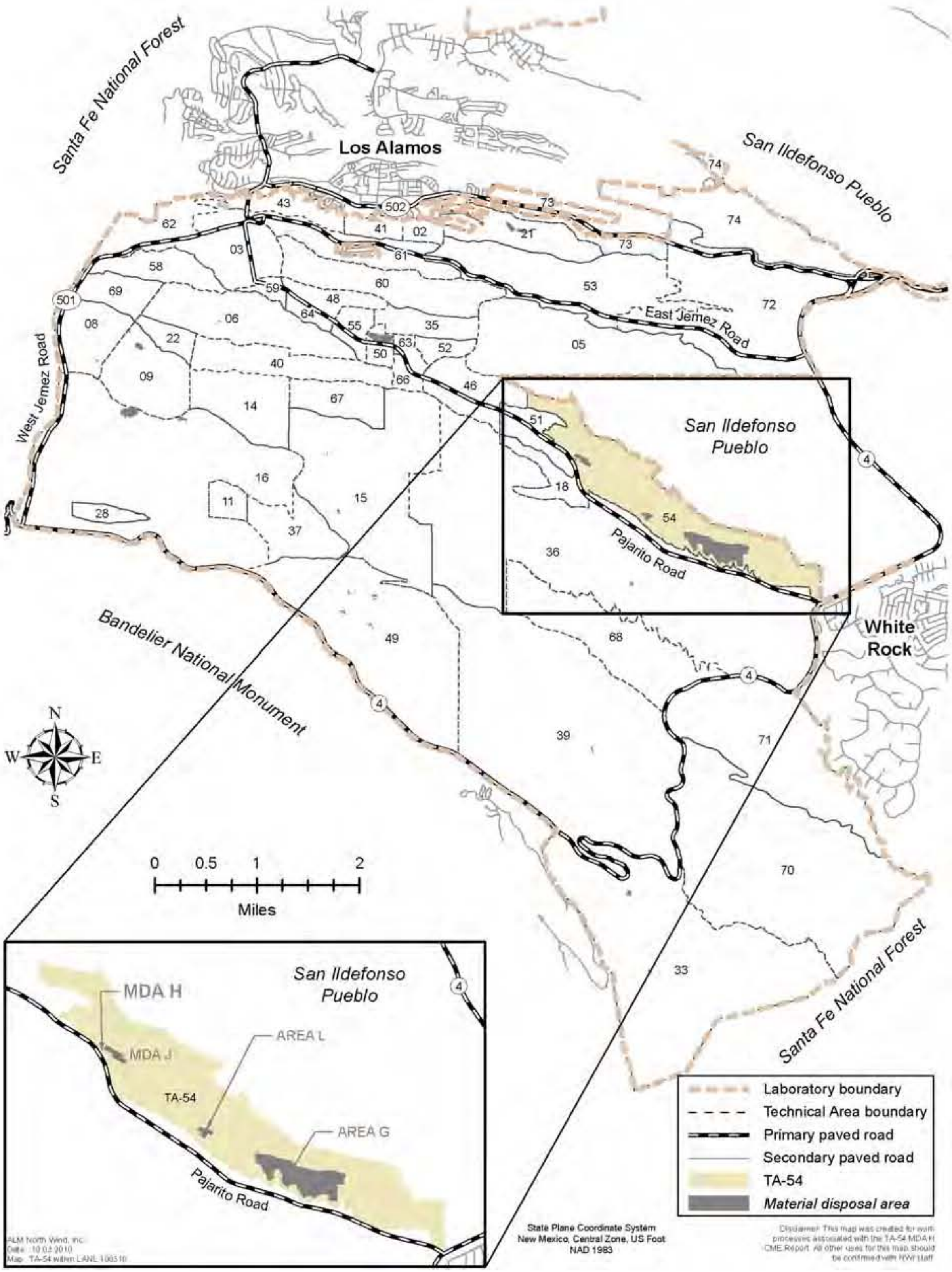


Figure 1.0-2 Location of MDA H in TA-54 with respect to Laboratory technical areas and surrounding landholdings

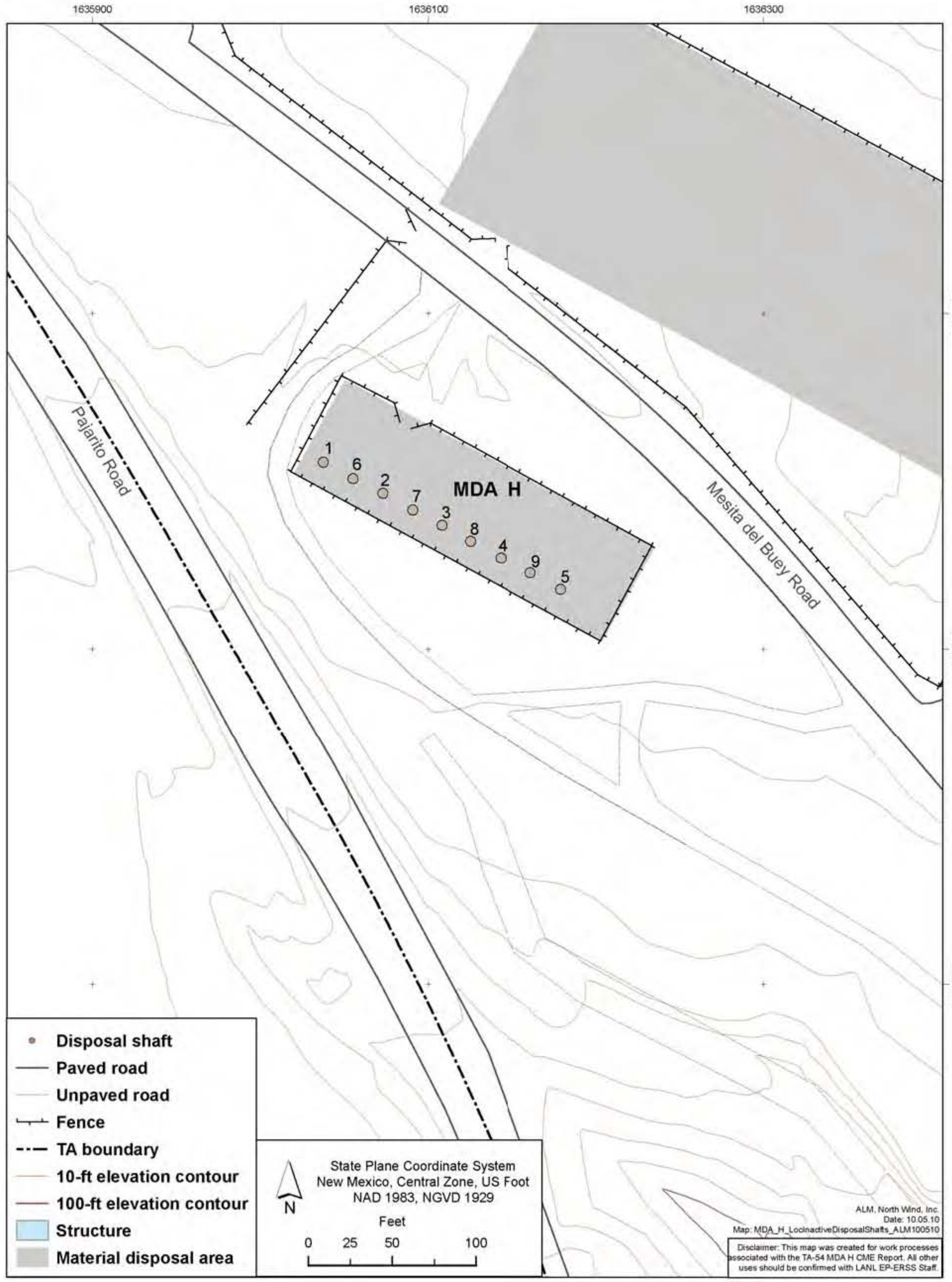


Figure 2.0-1 Location of inactive disposal shafts at MDA H

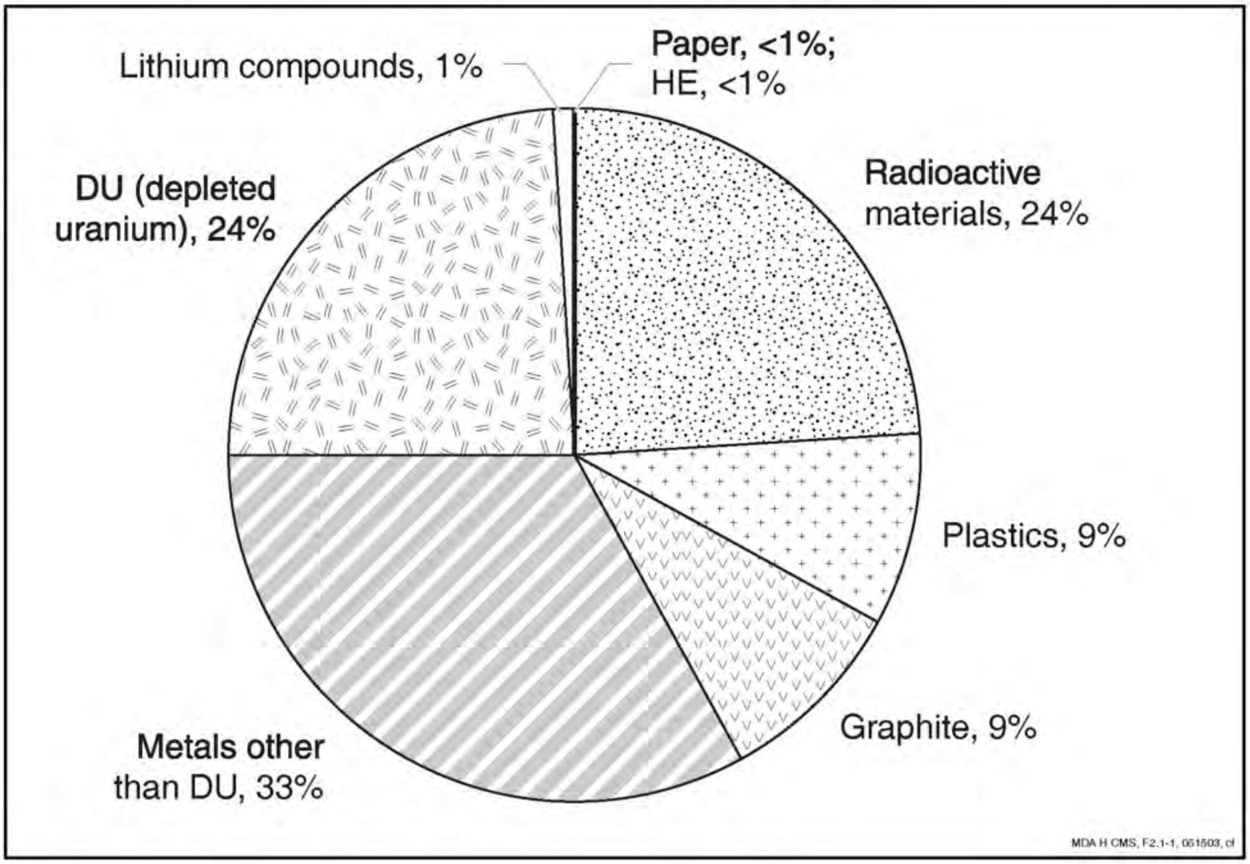


Figure 2.2-1 **Breakdown of logbook entries of identified waste materials disposed of in shafts (percentages by weight)**

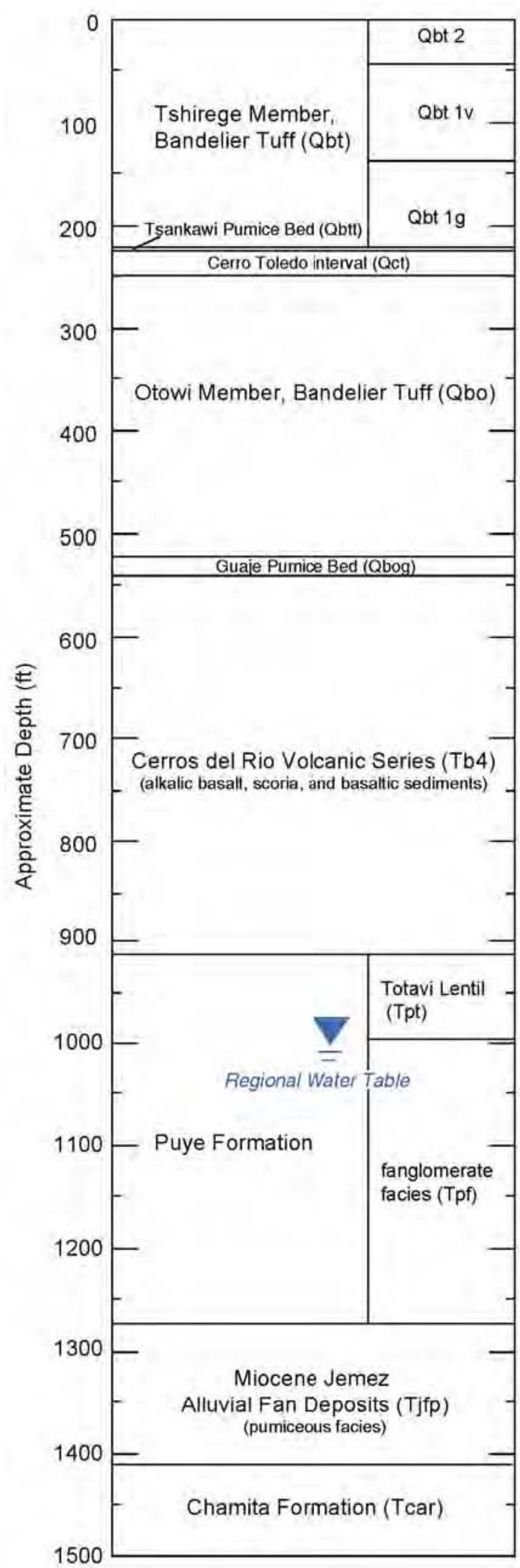


Figure 2.3-1 Generalized stratigraphic column for MDA H

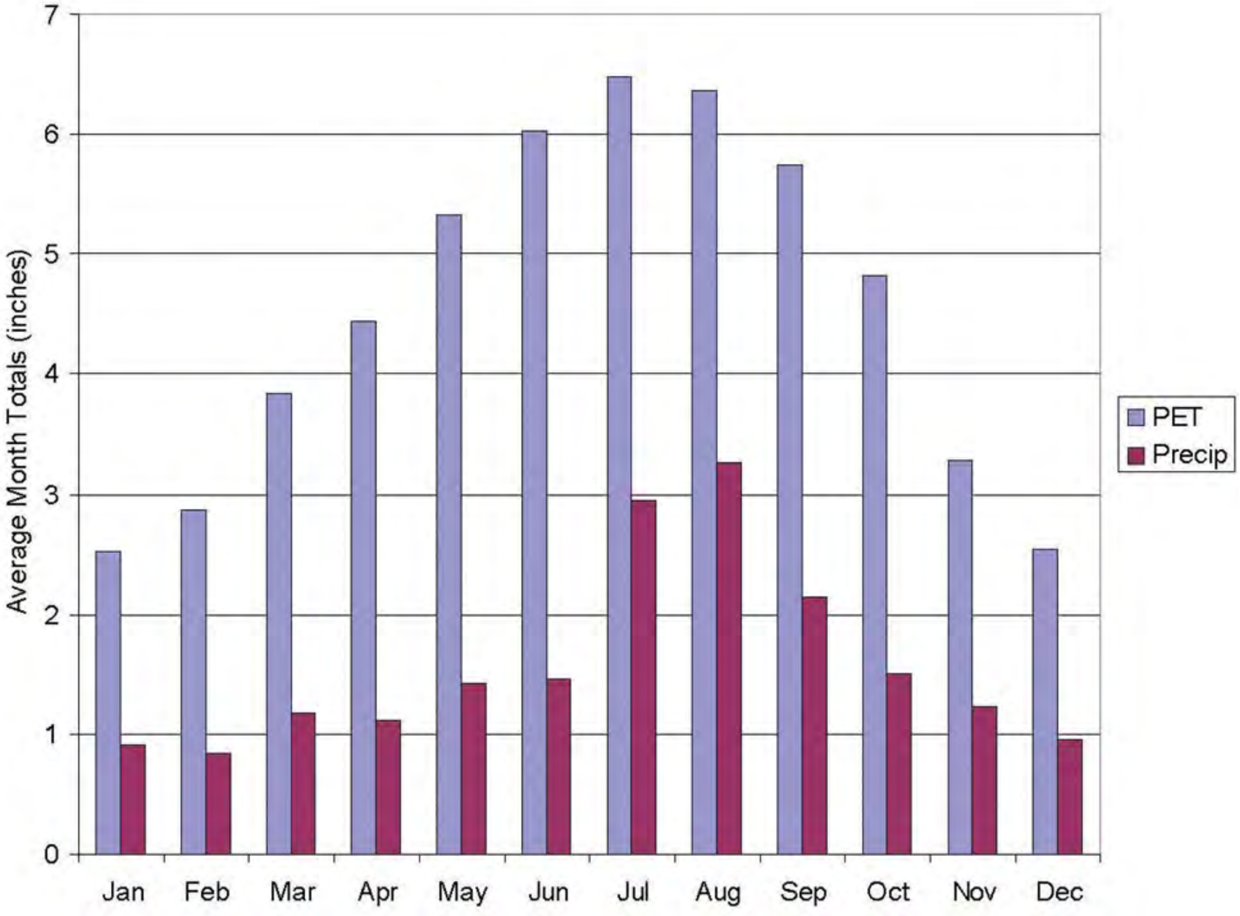


Figure 2.3-2 **Climate's demand for water (potential ET) compared with supply of water (precipitation) for Los Alamos, New Mexico**

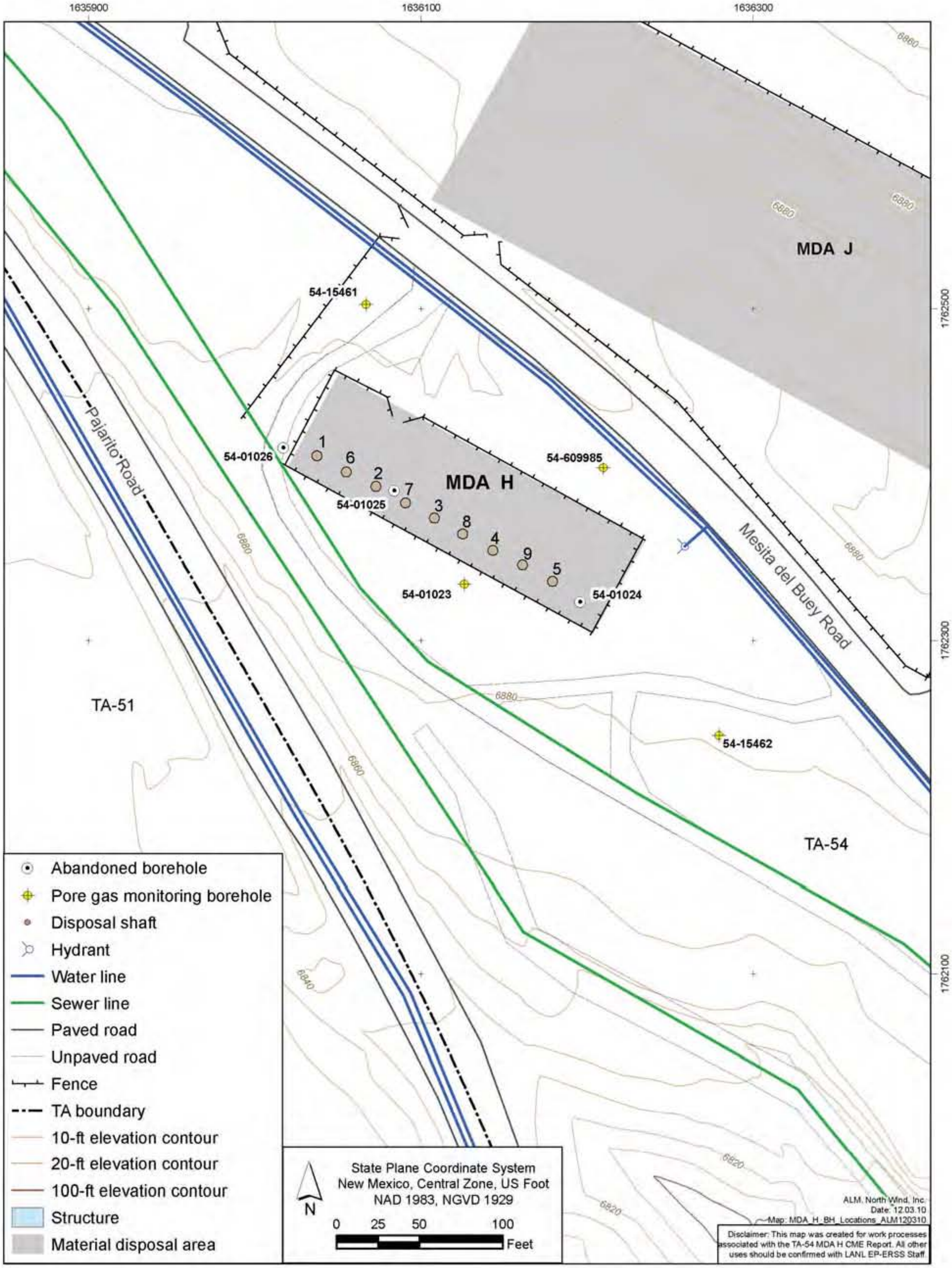
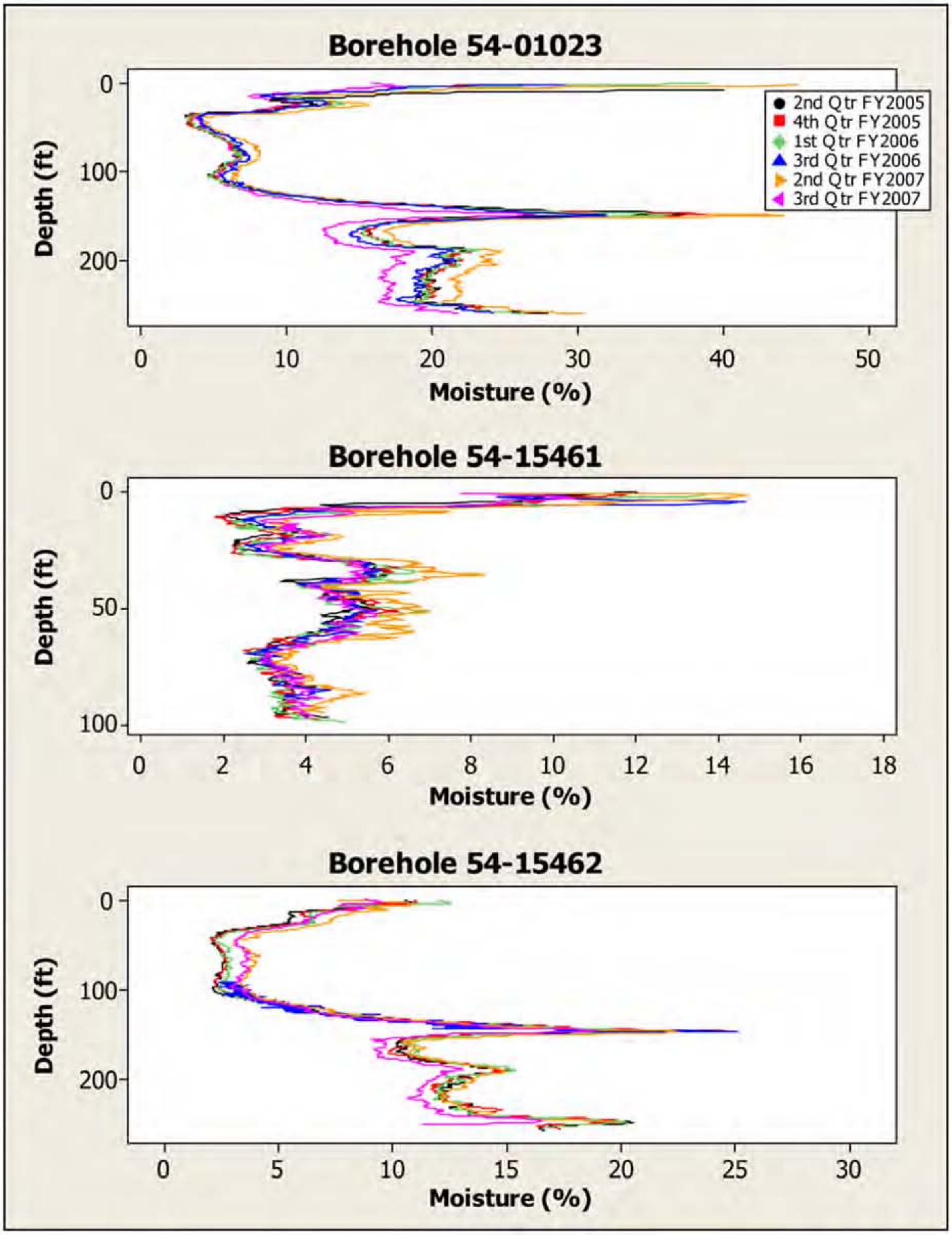
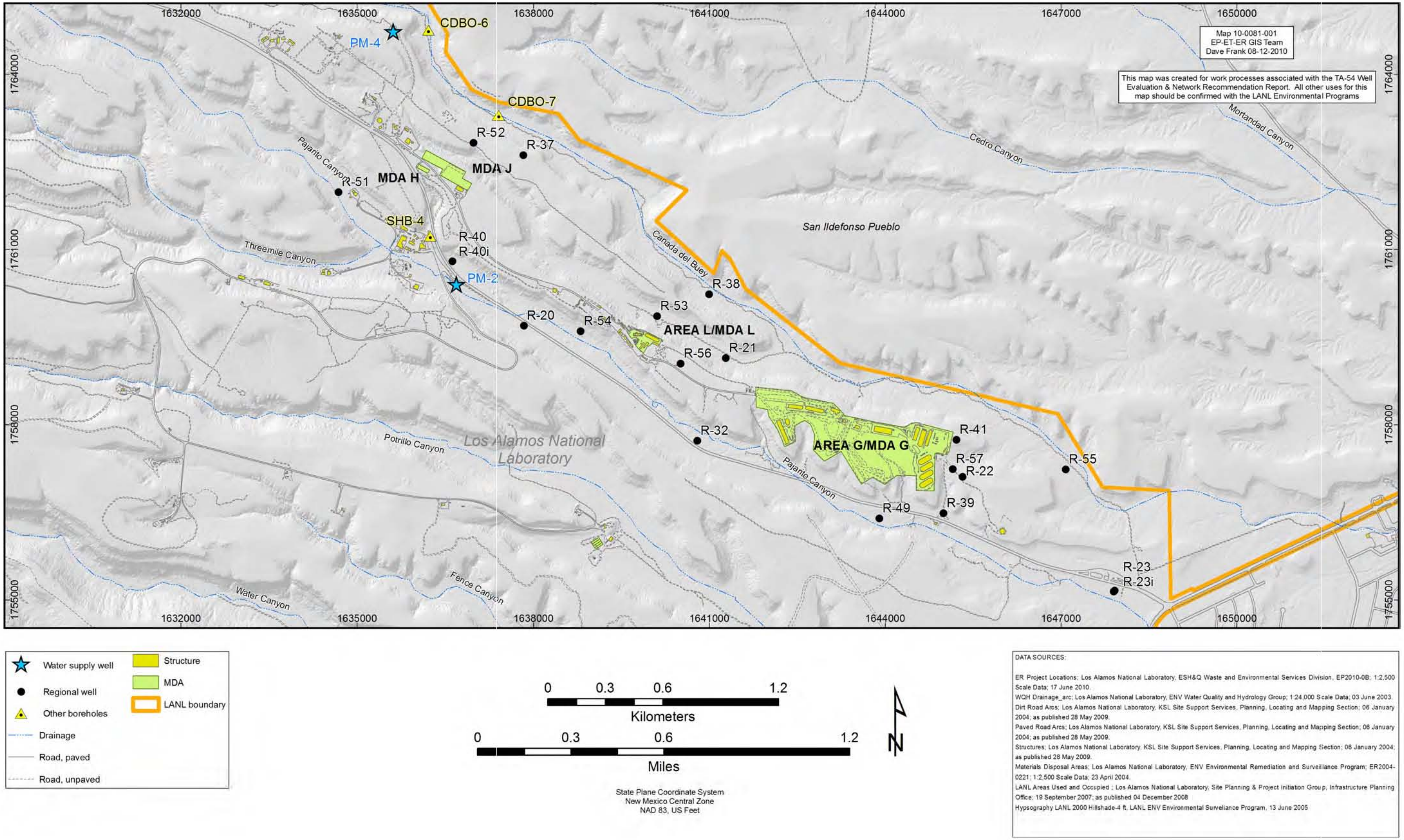


Figure 2.3-3 Location of pore gas-monitoring boreholes and abandoned RFI boreholes



Source: LANL (2007, 099140).

Figure 2.3-4 Moisture monitoring results for MDA H (% by volume)



DATA SOURCES:

ER Project Locations; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division, EP2010-0B; 1:2,500 Scale Data; 17 June 2010.

WQH Drainage_arc; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; 1:24,000 Scale Data; 03 June 2003.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Materials Disposal Areas; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; ER2004-0221; 1:2,500 Scale Data; 23 April 2004.

LANL Areas Used and Occupied ; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 04 December 2008

Hypsography LANL 2000 Hillshade-4 ft, LANL ENV Environmental Surveliance Program, 13 June 2005

Figure 2.3-5 TA-54 groundwater-monitoring network, also showing water-supply wells and shallow monitoring wells, CDBO-6 and CDBO-7

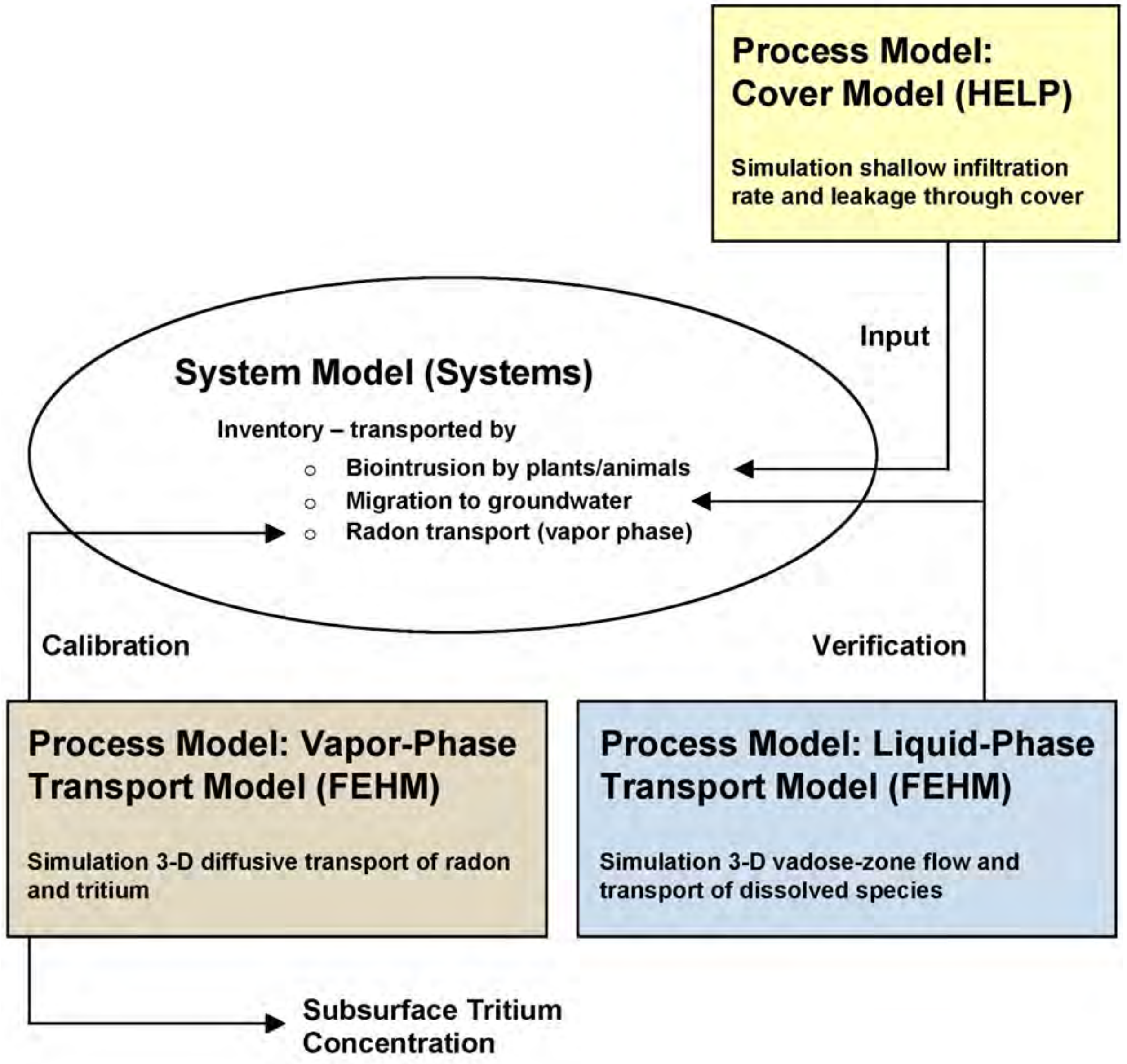
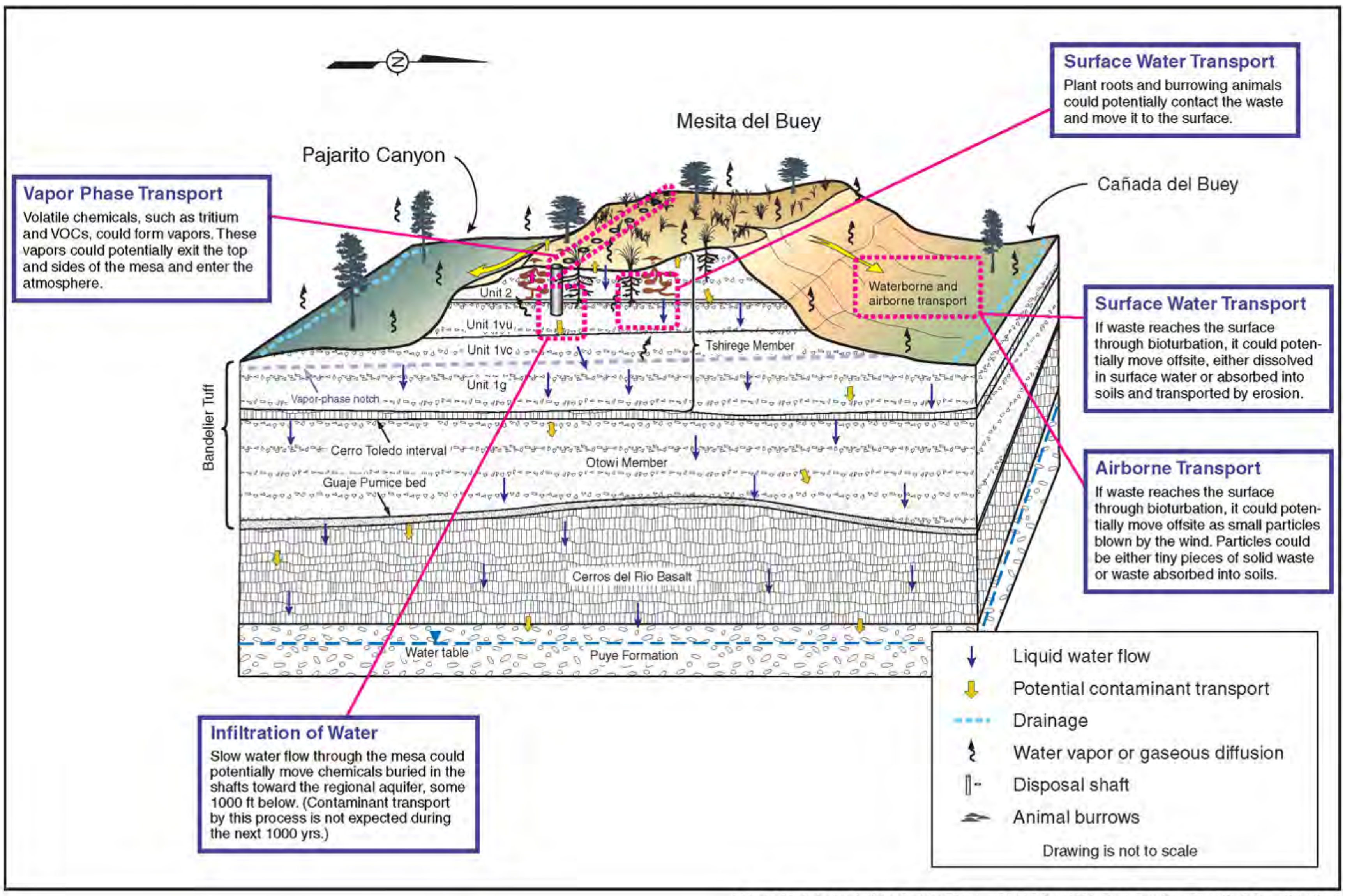


Figure 2.4-1 Links between the system model and the three process models



Surface Water Transport
Plant roots and burrowing animals could potentially contact the waste and move it to the surface.

Vapor Phase Transport
Volatile chemicals, such as tritium and VOCs, could form vapors. These vapors could potentially exit the top and sides of the mesa and enter the atmosphere.

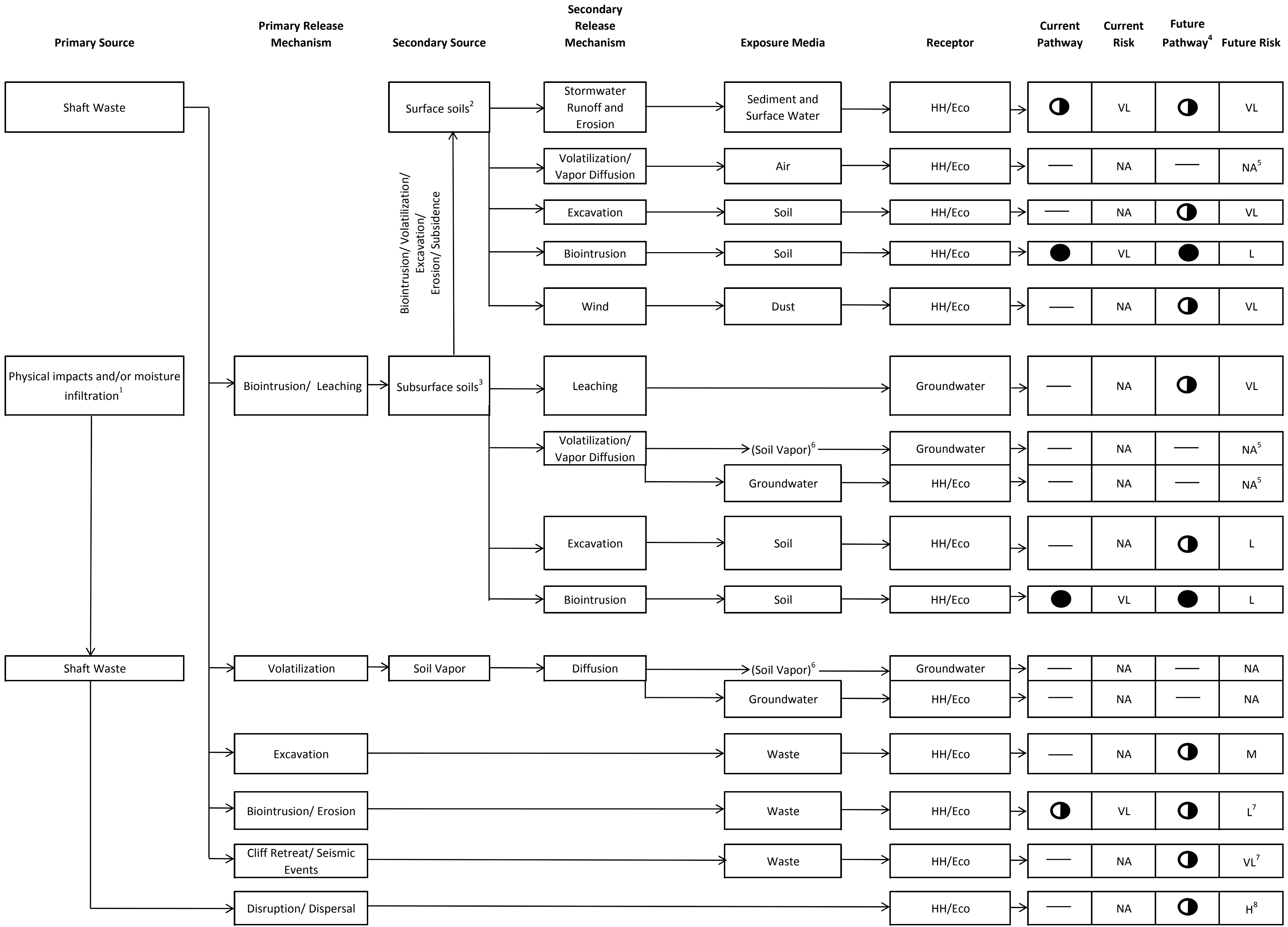
Surface Water Transport
If waste reaches the surface through bioturbation, it could potentially move offsite, either dissolved in surface water or absorbed into soils and transported by erosion.

Airborne Transport
If waste reaches the surface through bioturbation, it could potentially move offsite as small particles blown by the wind. Particles could be either tiny pieces of solid waste or waste absorbed into soils.

Infiltration of Water
Slow water flow through the mesa could potentially move chemicals buried in the shafts toward the regional aquifer, some 1000 ft below. (Contaminant transport by this process is not expected during the next 1000 yrs.)

J. Tauxe. 062101 after A. Kron_Rev. for F2.3-1, MDA H RS, 122001, RLM_Rev. for MDA H CMS Rpt., 051403, cf

Figure 4.0-1 Hydrogeologic conceptual site model for MDA H at TA-54



Exposure Pathways

● = Complete pathway

◐ = Potentially complete pathway

— = Incomplete pathway

Notes:

HH = Human Health

Eco = Ecological

Risks of Exposure

VL = Very Low

L = Low

M = Medium

H = High

NA = Not Applicable

Footnotes:

[1] = Physical impacts include sparks, friction, heat, and waste pinching as defined in Appendix C. This is not a primary source of contamination but impacts the primary source.

[2] = Surface soil is defined as 0 to 1 ft bgs.

[3] = Subsurface soil is defined as deeper than 1 ft bgs.

[4] = Future scenario assumes no remedy implemented and no institutional controls.

[5] = There is no VOC source.

[6] = This is not an exposure media but a potential source to groundwater.

[7] = The risk associated with this pathway is quantified as low or very low due to the low potential of this pathway becoming complete.

[8] = The risk associated with this pathway is potentially high based on information contained in Appendix C.

Figure 4.0-2 Conceptual site model

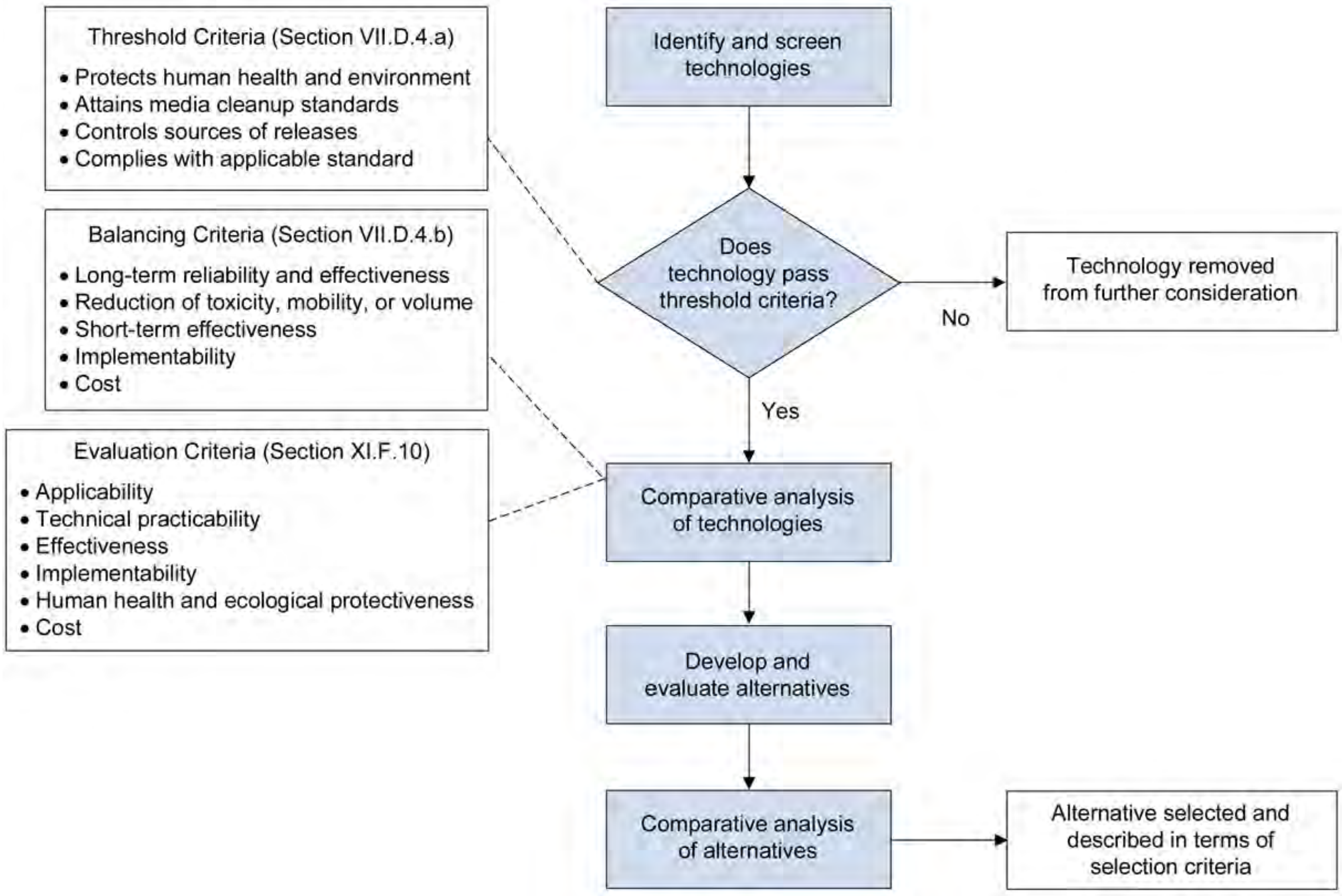
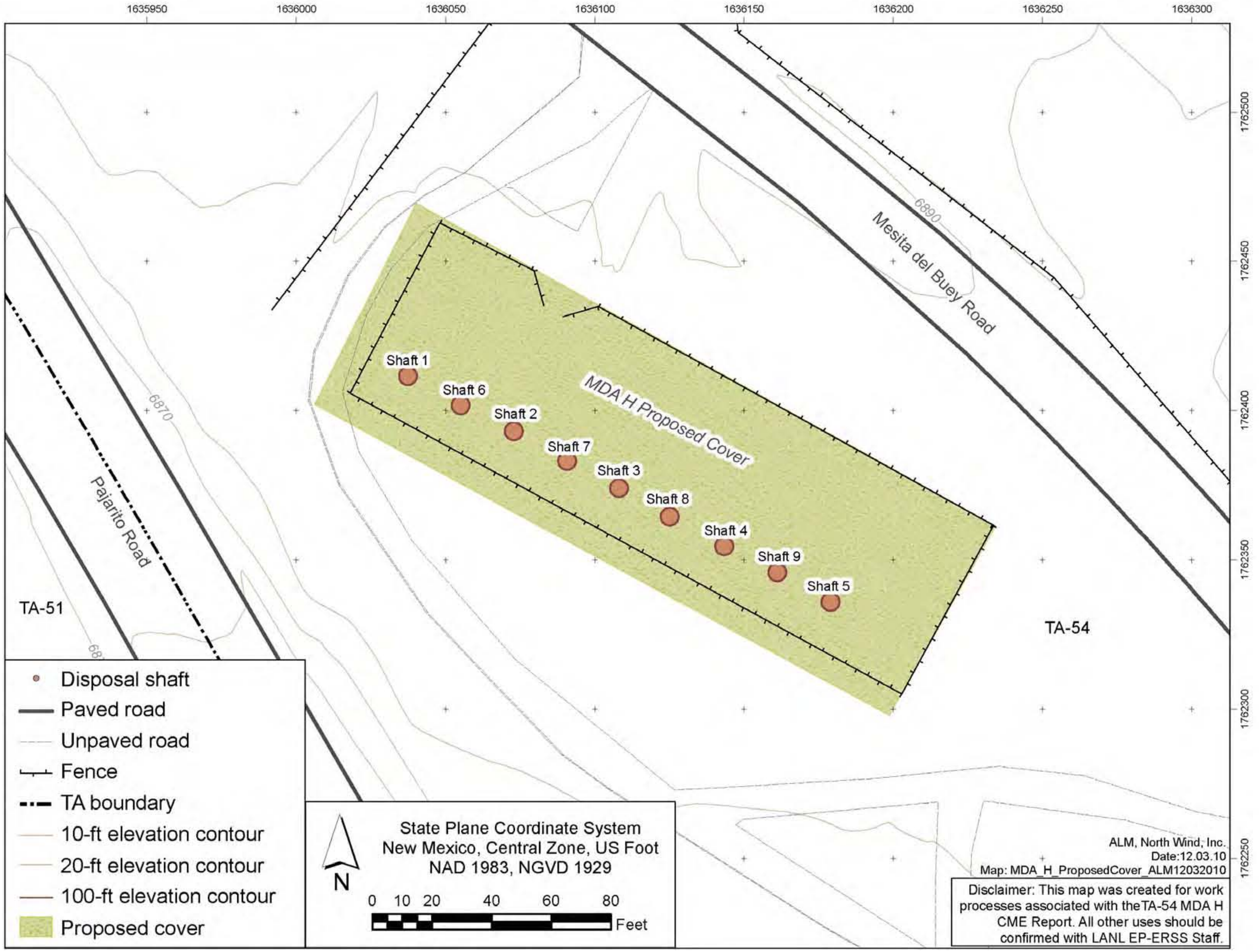
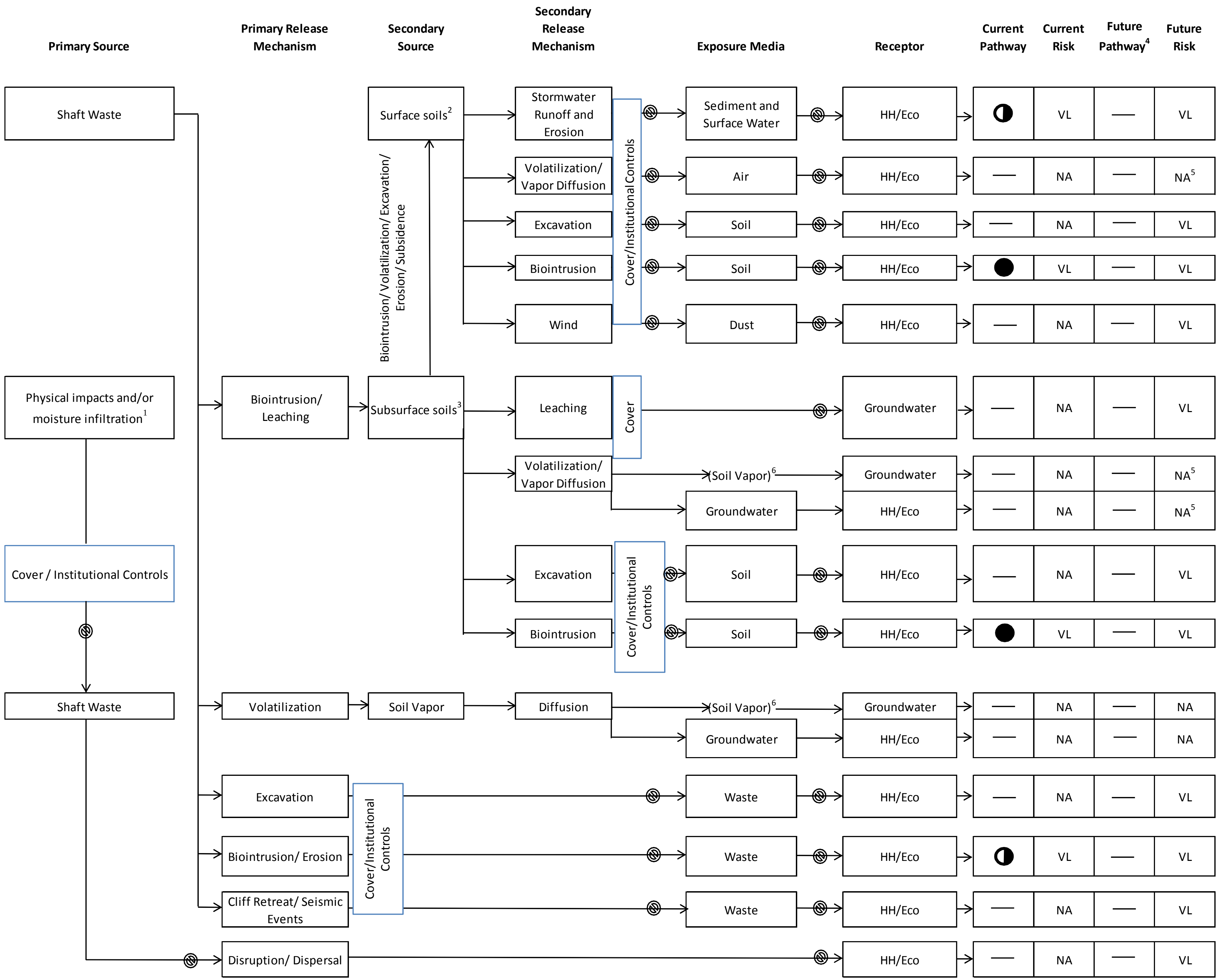


Figure 5.3-1 The selection process for the preferred corrective measures alternative



Disclaimer: This map was created for work processes associated with theTA-54 MDA H CME Report. All other uses should be confirmed with LANL EP-ERSS Staff.

Figure 7.3-1 **Location of vegetative, ET, or biotic cover**



Exposure Pathways

● = Complete pathway

◑ = Potentially complete pathway

— = Incomplete pathway

⊘ = Pathway broken by corrective measure remedy

Notes: HH = Human health, Eco = ecological.

Risks of Exposure

VL = Very Low

NA = Not Applicable

Footnotes:

[1] = Physical impacts include sparks, friction, heat, and waste pinching as defined in Appendix C. This is not a primary source of contamination but impacts the primary source.

[2] = Surface soil is defined as 0 to 1 ft bgs.

[3] = Subsurface soil is defined as deeper than 1 ft bgs.

[4] = Future scenario is defined as after the remedy is implemented.

[5] = There is no VOC source.

[6] = This is not an exposure media but a potential source to groundwater.

Figure 9.0-1 Refined conceptual site model

Table 1.0-1
Consent Order Requirement Crosswalk

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
1	The Respondents shall follow the Corrective Measures Evaluation Report format outlined in Section XI.F of this Consent Order.	VII.D.2	Table of contents
2	The corrective measures evaluation shall evaluate potential remedial alternatives and shall recommend a preferred remedy that will be protective of human health and the environment and attain the appropriate cleanup goals.	VII.D.2	Sections 5–9
3	1. A description of the location, status, and current use of the site.	VII.D.2	Sections 1 and 2
4	2. A description of the history of site operations and the history of releases of contaminants.	VII.D.2	Section 2
5	3. A description of site surface conditions.	VII.D.2	Sections 2 and 3
6	4. A description of site subsurface conditions.	VII.D.2	Sections 2 and 3
7	5. A description of on- and off-site contamination in all affected media.	VII.D.2	Sections 2 and 4
8	6. An identification and description of all sources of contaminants.	VII.D.2	Sections 2 and 4
9	7. An identification and description of contaminant migration pathways.	VII.D.2	Section 4
10	8. An identification and description of potential receptors.	VII.D.2	Section 4
11	9. A description of cleanup standards or other applicable regulatory criteria.	VII.D.2	Section 5
12	10. An identification and description of a range of remedy alternatives.	VII.D.2	Section 7
13	11. Remedial alternative pilot or bench scale testing results.	VII.D.2	None
14	12. A detailed evaluation and rating of each of the remedy alternatives, applying the criteria set forth in Section VII.D.4.	VII.D.2	Section 8
15	13. An identification of a proposed preferred remedy or remedies.	VII.D.2	Section 9
16	14. Design criteria of the selected remedy or remedies.	VII.D.2	Section 10
17	15. A proposed schedule for implementation of the preferred remedy.	VII.D.2	Section 11
18	The Respondents shall select corrective measures that are capable of achieving the cleanup standards and goals outlined in Section VIII of this Consent Order including, as applicable, approved alternate cleanup goals established by a risk assessment.	VII.D.3	Section 5 discusses goals but none were exceeded in the investigation report risk assessment

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
19	The Respondents shall evaluate each of the remedy alternatives for the following threshold criteria. To be selected, the remedy alternative must: 1. Be protective of human health and the environment. 2. Attain media cleanup standards. 3. Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment. 4. Comply with applicable standards for management of wastes.	VII.D.4.a	Section 7
20	The remedy shall be evaluated for long-term reliability and effectiveness. This factor includes consideration of the magnitude of risks that will remain after implementation of the remedy; the extent of long-term monitoring, or other management that will be required after implementation of the remedy; the uncertainties associated with leaving contaminants in place; and the potential for failure of the remedy. Respondents shall give preference to a remedy that reduces risks with little long-term management, and that has proven effective under similar conditions.	VII.D.4.b.i	Section 8
21	The remedy shall be evaluated for its reduction in the toxicity, mobility, and volume of contaminants. Respondents shall give preference to a remedy that uses treatment to more completely and permanently reduce the toxicity, mobility, and volume of contaminants.	VII.D.4.b.ii	Section 8
22	The remedy shall be evaluated for its short-term effectiveness. This factor includes consideration of the short-term reduction in existing risks that the remedy would achieve; the time needed to achieve that reduction; and the short-term risks that might be posed to the community, workers, and the environment during implementation of the remedy. Respondents shall give preference to a remedy that quickly reduces short-term risks, without creating significant additional risks.	VII.D.4.b.iii	Section 8
23	The remedy shall be evaluated for its implementability or the difficulty of implementing the remedy. This factor includes consideration of installation and construction difficulties; operation and maintenance difficulties; difficulties with cleanup technology; permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. Respondents shall give preference to a remedy that can be implemented quickly and easily, and poses fewer and lesser difficulties.	VII.D.4.b.iv	Section 8

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
24	The remedy shall be evaluated for its cost. This factor includes a consideration of both capital costs, and operation and maintenance costs. Capital costs shall include, without limitation, construction and installation costs; equipment costs; land development costs; and indirect costs including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. Operation and maintenance costs shall include, without limitation, operating labor and materials costs; maintenance labor and materials costs; replacement costs; utilities; monitoring and reporting costs; administrative costs; indirect costs; and contingency allowances. All costs shall be calculated based on their net present value. Respondents shall give preference to a remedy that is less costly, but does not sacrifice protection of health and the environment.	VII.D.4.b.v	Section 8
25	All investigation summaries, site condition descriptions, corrective action goals, corrective action options, remedial options selection criteria, and schedules shall be included in the corrective measures evaluations.	XI.F	Sections 2, 4, 5, 7, and 11
26	In general, interpretation of historical investigation data and discussions of prior interim activities shall be presented only in the background sections of the corrective measures evaluations.	XI.F	Section 2
27	At a minimum, detections of contaminants encountered during previous site investigations shall be presented in the corrective measures evaluations in table format with an accompanying site plan showing sample locations.	XI.F	Section 2
28	The other text sections of the corrective measures evaluations shall be reserved for presentation of corrective action-related information regarding anticipated or potential site-specific corrective action options and methods relevant to the project.	XI.F	Section 8
29	The title page shall include the type of document; Facility name; TA designation; SWMU or AOC name, site, and any other unit name; and the submittal date. A signature block providing spaces for the name and title of the responsible DOE and University of California (or co-operator) representative shall be provided on the title page in accordance with 20.4.1.900 NMAC incorporating 40 C.F.R. 270.11(d)(1).	XI.F.1	Title Page
30	This executive summary or abstract shall provide a brief summary of the purpose and scope of the corrective measures evaluation to be conducted at the subject site. The executive summary or abstract shall also briefly summarize the conclusions of the evaluation. The SWMU, AOC, and site names, location, and TA designation shall be included in the executive summary.	XI.F.2	Executive Summary

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
31	The table of contents shall list all text sections, subsections, tables, figures, and appendices or attachments included in the corrective measures evaluation. The corresponding page numbers for the titles of each section of the report shall be included in the table of contents.	XI.F.3	Table of contents
32	The Introduction section shall include the Facility name, TA designation, site location, and site status (e.g., closed corrective action). General information on the current site usage and status shall be included in this section. A brief description of the purpose of the corrective measures evaluation and the corrective action objectives for the project also shall be provided in this section.	XI.F.4	Section 1
33	The Background section shall describe the relevant background information. This section shall briefly summarize historical site uses by the U.S. Government and any other entity since the 1940s, including the locations of current and former site structures and features. A labeled figure shall be included in the document showing the locations of current and former site structures and features. The locations of any subsurface features such as pipelines, underground tanks, utility lines, and other subsurface structures shall be included in this section and labeled on the site plan, as appropriate.	XI.F.5	Section 2, Figure 2.0-1. There are no underground pipelines, structures, or utilities
34	This section shall include contaminant and waste characteristics, a brief summary of the history of contaminant releases, known and possible sources of contamination, and the vertical and lateral extent of contamination present in each medium. This section shall include brief summaries of results of previous investigations, including references to pertinent figures, data summary tables, and text in previous reports. References to previous reports shall include page, table, and figure numbers for referenced information. Summary tables and site plans showing relevant investigation locations shall be referenced and included in the Tables and Figures sections of the document, respectively.	XI.F.5	Sections 2, 3, and 4
35	A section on surface conditions shall describe current and historic site topography, features, and structures, including a description of topographic drainages, man-made drainages, vegetation, and erosional features. It shall also include a description of current uses of the site and any current operations at the site. This section shall also include a description of those features that could potentially influence corrective action option selection or implementation such as archeological sites, wetlands, or other features that may affect remedial activities. In addition, descriptions of features located in surrounding sites that may have an effect on the subject site regarding sediment transport, surface water runoff or contaminant transport shall be included in this section. A site plan displaying the locations of all pertinent surface features and structures shall be included in the Figures section of the corrective measures evaluation.	XI.F.6a	Sections 2 and 3

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
36	A section on subsurface conditions shall describe the site conditions observed during previous subsurface investigations. It shall include relevant soil horizon and stratigraphic information, groundwater conditions, fracture data, and subsurface vapor information. A site plan displaying the locations of all borings and excavations advanced during previous investigations shall be included in the Figures section of the corrective measures evaluation. A brief description of the stratigraphic units anticipated to be present beneath the site may be included in this section if stratigraphic information is not available from previous investigations conducted at the site.	XI.F.6b	Sections 2 and 3 Appendix D Figure 2.4-1
37	A section shall provide a list of all sources of contamination at the subject site where corrective measures are to be considered or required. Sources that are no longer considered to be releasing contaminants at the site, but may be the point of origination for contaminants transported to other locations, shall be included in this section.	XI.F.7a	Section 4
38	A section shall describe potential migration pathways that could result in either acute or chronic exposures to contaminants. It shall include such pathways as utility trenches, paleochannels, surface exposures, surface drainages, stratigraphic units, fractures, structures, and other features. The migration pathways for each contaminant and each relevant medium should be tied to the potential receptors for each pathway. A discussion of contaminant characteristics relating to fate and transport of contaminants through each pathway shall also be included in this section.	XI.F.7b	Section 4
39	A section shall provide a listing and description of all anticipated potential receptors that could possibly be affected by the contamination present at the site. Potential receptors shall include human and ecological receptors, groundwater, and other features such as pathways that could divert or accelerate the transport of contamination to human receptors, ecological receptors, and groundwater.	XI.F.7c	Section 4
40	A section shall set forth the applicable cleanup standards, risk-based screening levels, and risk-based cleanup goals for each pertinent medium at the subject site. The appropriate cleanup levels for each site shall be included, if site-specific levels have been established at separate sites or units. A table summarizing the applicable cleanup standards or levels, or inclusion of applicable cleanup standards or levels in the summary data tables shall be included in the Tables section of the document. The risk assessment shall be presented in a separate document or in an appendix to this report. If cleanup or screening levels calculated in a risk evaluation are employed, the risk evaluation document shall be referenced including pertinent page numbers for referenced information.	XI.F.8	Section 5, Table 5.0-1; Risk Assessment: in the MDA H RFI Report (LANL 2002, 073270)

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
41	A section shall identify and describe potential corrective measures for source, pathway, and receptor controls. Corrective measures options shall include the range of available options including, but not limited to, a no action alternative, institutional controls, engineering controls, in-situ and on-site remediation alternatives, complete removal, and any combination of alternatives that would potentially achieve cleanup goals.	XI.F.9	Sections 7 and 8
42	A section shall provide an evaluation of the corrective measures options identified in Section XI.F.9 above. The evaluation shall be based on the applicability, technical feasibility, effectiveness, implementability, impacts to human health and the environment, and cost of each option. A table summarizing the corrective measures alternatives and the criteria listed below shall be included in the Tables section of this document.	XI.F.10	Section 8 and associated tables
43	The assessment also shall include the anticipated duration for the technology to attain regulatory compliance. In general, all corrective measures described above will have the ability to mitigate the impacts of contamination at the site, but not all remedial options will be equally effective at achieving the desired cleanup goals to the degree and within the same time frame as other options. Each remedy shall be evaluated for both short-term and long-term effectiveness.	XI.F.10.c	Section 8
44	Implementability characterizes the degree of difficulty involved during the installation, construction, and operation of the corrective measure. Operation and maintenance of the alternative shall be addressed in this section.	XI.F.10.d	Section 8
45	This category evaluates the short-term (remedy installation-related) and long-term (remedy operation-related) hazards to human health and the environment of implementing the corrective measure. The assessment shall include whether the technology will create a hazard or increase existing hazards and the possible methods of hazard reduction.	XI.F.10.e	Section 8
46	This section shall discuss the anticipated cost of implementing the corrective measure. The costs shall be divided into: 1) capital costs associated with construction, installation, pilot testing, evaluation, permitting, and reporting of the effectiveness of the alternative; and 2) continuing costs associated with operating, maintaining, monitoring, testing, and reporting on the use and effectiveness of the technology.	XI.F.10.f	Section 8

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
47	The Respondents shall propose the preferred corrective measure(s) at the site and provide a justification for the selection in this section. The proposal shall be based upon the ability of the remedial alternative to (1) achieve cleanup objectives in a timely manner, (2) protect human and ecological receptors, (3) control or eliminate the sources of contamination, (4) control migration of released contaminants, and 5) manage remediation waste in accordance with State and Federal regulations. The justification shall include the supporting rationale for the remedy selection, based on the factors listed in Section XI.F.10 and a discussion of short- and long-term objectives for the site. The benefits and possible hazards of each potential corrective measure alternative shall be included in this section.	XI.F.11	Sections 8 and 9
48	The Respondents shall present descriptions of the preliminary design for the selected corrective measures in this section. The description shall include appropriate preliminary plans and specifications to effectively illustrate the technology and the anticipated implementation of the remedial option at the subject area. The preliminary design shall include a discussion of the design life of the alternative and provide engineering calculations for proposed remediation systems.	XI.F.12	Section 10
49	A section shall set forth a proposed schedule for completion of remedy-related activities such as bench tests, pilot tests, construction, installation, remedial excavation, cap construction, installation of monitoring points, and other remedial actions. The anticipated duration of corrective action operations and the schedule for conducting monitoring and sampling activities shall also be presented. In addition, this section shall provide a schedule for submittal of reports and data to the Department, including a schedule for submitting all status reports and preliminary data.	XI.F.13	Section 11
50	1. A table summarizing regulatory criteria, background, and/or the applicable cleanup standards.	XI.F.14	Table 5.2-1
51	2. A table summarizing historical field survey location data.	XI.F.14	Not needed; see Figures 2.0-1 and 2.4-1
52	3. Tables summarizing historical field screening and field parameter measurements of soil, rock, sediments, groundwater, surface water, and air quality data.	XI.F.14	LANL 2002, 073270
53	4. Tables summarizing historical soil, rock, or sediment laboratory analytical data. The summary tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Tables 2.4-1–2.4-6
54	5. A table summarizing historical groundwater elevation and depth to groundwater data. The table shall include the monitoring well depths and the screened intervals in each well.	XI.F.14	Table 2.5-1, Appendixes D and E

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
55	6. Tables summarizing historical groundwater laboratory analytical data. The analytical data tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Section 2, Table 3.3-1, Appendixes D and E
56	7. Tables summarizing historical surface water laboratory analytical data. The analytical data tables shall include the analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Not applicable; no surface water at site
57	8. Tables summarizing historical air sample screening and analytical data. The data tables shall include the screening instruments used, laboratory analytical methods, detection limits, and significant data quality exceptions that would influence interpretation of the data.	XI.F.14	Section 2 and Table 2.4-9
58	9. Tables summarizing historical pilot or other test data, if applicable, including units of measurement and types of instruments used to obtain measurements.	XI.F.14	None
59	10. A table summarizing the corrective measures alternatives and evaluation criteria.	XI.F.14	Tables 8.2-2–8.3-1
60	11. A table presenting the schedule for installation, construction, implementation, and reporting of selected corrective measures.	XI.F.14	Text of section 11 gives general schedule
61	A section shall present the following figures for each site, as appropriate. All figures must include an accurate bar scale and a north arrow. An explanation shall be provided on each figure for all abbreviations, symbols, acronyms, and qualifiers. All figures shall have a date.	XI.F.15	See below
62	1. A vicinity map showing topography and the general location of the subject site relative to surrounding features or properties.	XI.F.15	Figures 1.0-1 and 1.0-2
63	2. A unit site plan that presents pertinent site features and structures, underground utilities, well locations, and remediation system locations and details. Off-site well locations and other relevant features shall be included on the site plan if practical. Additional site plans may be required to present the locations of relevant off-site well locations, structures, and features.	XI.F.15	Figure 2.0-1
64	3. Figures showing historical soil boring or excavation locations and sampling locations.	XI.F.15	Figure 2.4-1
65	4. Figures presenting historical soil sample field screening and laboratory analytical data, if appropriate.	XI.F.15	Description in LANL 2002, 073270
66	5. Figures showing all existing wells including vapor monitoring wells and piezometers. The figures shall present historical groundwater elevation data and indicate groundwater flow directions.	XI.F.15	Section 2, Table 3.3-1, Appendixes D and E

Table 1.0-1 (continued)

No.	Consent Order Requirement	Consent Order Section Reference	CME Report Section
67	6. Figures presenting historical groundwater laboratory analytical data including past data, if applicable. The analytical data corresponding to each sampling location may be presented as individual concentrations, in table form on the figure or as an isoconcentration map.	XI.F.15	Section 2, Table 3.3-1, Appendixes D and E
68	7. Figures presenting historical surface water sample locations and analytical data including past data, if applicable. The laboratory analytical data corresponding to each sampling location may be presented as individual concentrations or in table form on the figure.	XI.F.15	Not applicable, no surface water exists at site
69	8. Figures presenting historical air sampling locations and presenting air quality data. The field screening or laboratory analytical data corresponding to each sampling location may be presented as individual concentrations, in table form on the figure or as an isoconcentration map.	XI.F.15	Section 2 and Table 2.4-9
70	9. Figures presenting historical pilot or other test locations and data, where applicable, including site plans or graphic data presentation.	XI.F.15	None
71	10. Figures presenting geologic cross-sections based on outcrop and borehole data, if applicable.	XI.F.15	Appendix D
72	11. Figures presenting the locations of existing and proposed remediation systems.	XI.F.15	Figures 7.3-1–7.3-3
73	12. Figures presenting existing remedial system design and construction details.	XI.F.15	Not applicable
74	13. Figures presenting preliminary design and construction details for preferred corrective measures.	XI.F.15	Figure 7.3-1
75	Each corrective measures evaluation shall include, as appropriate, as an appendix, the management plan for waste, including investigation derived waste, generated as a result of construction, installation, or operation of remedial systems or activities conducted.	XI.F.16	To be developed as part of CMI plan
76	Each corrective measures evaluation shall include additional appendices presenting relevant additional data, such as pilot or other test or investigation data, remediation system design specifications, system performance data, or cost analyses as necessary.	XI.F.16	Appendix F

Table 2.2-1
Summary of Wastes in MDA H Disposal Shafts

Inventory Waste Description	Mass (wt) of Material Reported in Logbook	Estimated Weight or Activity of Waste	Assumptions/Comments
Metals			
Aluminum (Al)	4976	58,700[a]	Not applicable
Barium (Ba)	Not reported	5300 lb	Estimated to be 40% of mock/inert HE.
Beryllium (Be)	238 lb	6534 lb	In solid form as part of shapes and weapon components. Material considered strategic and recycled when possible. Additional quantity of Be added based on process knowledge of Laboratory operations.
Cadmium (Cd)	Not reported	20 lb[a]	In solid form as part of shapes and weapon components.
Chromium (Cr)	Not reported	1960 lb	In chrome-plated parts. The available Cr in the environment only from non-stainless steel Cr. Cr estimate based on process knowledge of Laboratory operations.
Copper (Cu)	230 lb	2350 lb[a]	In solid form as part of shapes and weapon components.
Lead (Pb)	Not reported	78,250 lb[a]	In solid form as part of shapes and weapon components. Material recycled when possible.
Lithium (Li) and lithium compounds: Lithium Lithium hydride (LiH) Lithium fluoride (LiF) Lithium boride	4959 lb (total) 75 lb 466 lb 4408 lb 10 lb	4341 lb (total) 75 lb 466 lb 3790 lb 10 lb	Solid form and potentially reactive/toxic. 4408 lb LiF PBX[b] contains 86% LiF (3790 lb). Lithium samples assumed to be in the form of LiH.
Mercury (Hg)	Not reported	1300 lb[a]	Part of electrical components.
Silver (Ag): Silver in developed film Nonfilm silver	(Listed under plastic) Not reported	1310 lb[c] 39 lb[a]	Processed film disposed at MDA H containing Ag that is unavailable for biological uptake and not included in the total available Ag. Ag in film based on a maximum of 45 troy ounces per 100 lb of waste processed industrial x-ray film (0.0686 lb per troy ounce). Non-film Ag assumed to be present either as plating or electrical parts.
Steels	Steel listed as one of many materials (not broken out)	156,490 lb[a]	In solid form as part of shapes and weapon components. Includes stainless steels.
Tungsten (W)	11,500 lb	11,500 lb	Not applicable

Table 2.2-1 (continued)

Inventory Waste Description	Mass (wt) of Material Reported in Logbook	Estimated Weight or Activity of Waste	Assumptions/Comments
Specific Types of Waste			
Graphite	47,162 lb	47,162 lb	Not applicable
High explosives (HE):	51,958 lb (total)	1275 lb (total)	Unless otherwise specified, HE assumed to be RDX based on mobility and toxicity; 4408 lb LiF PBX[b] contains 14% RDX (617 lb) +375 lb = 992 lb. HE-contaminated assumes invisible surface contamination, ≤0.6% of the total waste mass (47,175 x 0.006 = 283 lb).
HE (RDX)[d]	4783 lb	992 lb	
HE contaminated (RDX)	47,175 lb	283 lb	
Mock/inert HE	13,260 lb	13,260 lb	Cyanuric acid estimated to be 40% of mock/inert HE.
Paper	755 lb	755 lb	Not applicable
Plastics:	54,461 lb (total)	53,151 lb (total)	Film weight less silver weight (54,461–1310 = 53,151 lb).
Film	42,346 lb	41,036 lb	
Magnetic media	4337 lb	4337 lb	
Plastic (nonspecific)	6555 lb	6555 lb	
Slides	1223 lb	1223 lb	
Radioactive Wastes			
Uranium	67,055 lb (total)	265,300/(104,800)[e] lb (total) 284.5/(94.2) Ci	Standard ratios apply for converting depleted uranium, “units”, and fuel elements[f] (enriched uranium and highly enriched uranium) masses to isotopic abundances.
Depleted uranium		233,000/(93,000) lb	
Enriched uranium		14,600/(1100) lb	
Fuel elements		17,700/(10,700) lb	
Plutonium	300 lb (total)	300 lb (total)/0.014 Ci	Plutonium surface contamination. For bounding purposes, assumed maximum concentration of 100 nCi/g; assumed volume contamination is “Pu-52” based on process knowledge.
Tritium	80 lb	3.5-106 Ci	Residual radioactivity in stainless-steel canisters of known mass; estimated activity based on fiscal year 1995 and 2002 measured tritium values (Appendix I).
Shapes and Parts Without Material Description[f]	134,295 lb	Not applicable	
Total	391,229 lb	709,297/(548,797)[e] lb	

[a] Waste metal estimates were calculated after review of waste generated from a similar operation at SNL, and then adjusted for operational and programmatic differences.

[b] PBX = Plastic-bonded explosives.

[c] Silver is not leachable based on knowledge of the waste form.

[d] RDX = 1,3,5-trinitro-1,3,5-triazacyclohexane (cyclotrimethylenetrinitramine).

[e] The first number represents the maximum (upper-bound) amount of material present in the waste. The number in parentheses is the best estimate of material present in the shafts.

[f] Based on the classified nature of these objects, specific information is not recorded in the logbooks.

Table 2.4-1
Frequency of Detected Inorganic Chemicals in Channel Sediment Samples

Analyte	Media	Number of Analyses	Number of Detects	Concentration Range[a] (mg/kg)	BV (mg/kg)	Frequency of Detects above BV	Frequency of Nondetects above BV
Aluminum	Sediment	4	4	1140–4800	15,400	0/4	0/4
Antimony	Sediment	4	0	[0.2–0.2]	0.83	0/4	0/4
Arsenic	Sediment	4	0	[0.91–1.7]	3.98	0/4	0/4
Barium	Sediment	4	3	[32.4]–71	127	0/4	0/4
Beryllium	Sediment	4	0	[0.2–0.39]	1.31	0/4	0/4
Boron	Sediment	4	0	[1.6–1.6]	na[b]	0/4	NA[c]
Cadmium	Sediment	4	0	[0.26–0.68]	0.4	0/4	3/4
Calcium	Sediment	4	2	[912]–1590	4420	0/4	0/4
Chromium	Sediment	4	4	2.4–4.8	10.5	0/4	0/4
Cobalt	Sediment	4	0	[1.7–4.6]	4.73	0/4	0/4
Copper	Sediment	4	0	[2.1–4.1]	11.2	0/4	0/4
Iron	Sediment	4	4	3690–5890	13800	0/4	0/4
Lead	Sediment	4	4	13.1–21.3	19.7	2/4	0/4
Magnesium	Sediment	4	0	[513–948]	2370	0/4	0/4
Manganese	Sediment	4	4	116–300	543	0/4	0/4
Molybdenum	Sediment	4	0	[5.2–5.3]	na	0/4	NA
Nickel	Sediment	4	0	[1.2–2.9]	9.38	0/4	0/4
Potassium	Sediment	4	0	[195–723]	2690	0/4	0/4
Silver	Sediment	4	0	[0.6–0.61]	1	0/4	0/4
Sodium	Sediment	4	0	[28.7–67.5]	1470	0/4	0/4
Thallium	Sediment	4	0	[0.2–0.2]	0.73	0/4	0/4
Vanadium	Sediment	4	1	[6.7]–11.2	19.7	0/4	0/4
Zinc	Sediment	4	4	0.2–35.3	60.2	0/4	0/4

[a] Values in square brackets indicate nondetects.

[b] na = Not available.

[c] NA = Not analyzed.

Table 2.4-2
Frequency of Detected Radionuclides in Channel Sediment Samples

Analyte	Media	Number of Analyses	Number of Detects	Concentration Range[a] (pCi/g)	BV (pCi/g)	Frequency of Detects above BV
Americium-241	Sediment	5	2	[0.003–0.00842]	0.04	0/5
Cesium-134	Sediment	1	0	[0.00608–0.00608]	na[b]	0/1
Cesium-137	Sediment	3	3	0.054–0.48	0.9	0/3
Cobalt-60	Sediment	1	0	[-0.00384–0.00384]	na	0/1
Europium-152	Sediment	1	0	[-0.00905–0.00905]	na	0/1
Plutonium-238	Sediment	4	0	[0.001–0.003]	0.006	0/4
Plutonium-239	Sediment	4	1	[0.001]–0.017	0.068	0/4
Polonium-210	Sediment	4	4	0.61–2.16	na	4/4
Ruthenium-106	Sediment	1	0	[-0.0147–0.0147]	na	0/1
Sodium-22	Sediment	1	0	[-0.00356–0.00356]	na	0/1
Strontium-90	Sediment	5	0	[-0.02–0.14]	1.04	0/5
Thorium-228	Sediment	5	5	0.84–1.22	2.28	0/5
Thorium-230	Sediment	5	5	0.587–1.21	2.29	0/5
Thorium-232	Sediment	5	5	0.87–1.3	2.33	0/5
Tritium	Sediment	5	4	[-0.448]–0.111001	0.093	1/5
Uranium-234	Sediment	4	4	0.71–1.34	2.59	0/4
Uranium-235	Sediment	4	0	[0.05–0.08]	0.2	0/4
Uranium-238	Sediment	4	4	0.77–1.36	2.29	0/4

[a] Values in square brackets indicate nondetects.

[b] na = Not available.

Table 2.4-3
Frequency of Detected Inorganic Chemicals in Tuff Samples

Analyte	Media	Number of Analyses	Number of Detects	Concentration Range[a] (mg/kg)	BV (mg/kg)[b]	Frequency of Detects above BV
Aluminum	Qbt 2	13	13	187–3140	7340	0/13
	Qbt 1v	20	20	167–2570	8170	0/20
Antimony	Qbt 2	13	2	[0.1]–[4.9]	0.5	1/13 2/13 DLs[c] > BV
	Qbt 1v	20	0	[0.1]–[5.0]	0.5	4/20 DLs > BV
Arsenic	Qbt 2	13	4	[0.2]–2.1	2.79	0/13
	Qbt 1v	20	8	[0.2]–1.8	1.81	0/20
Barium	Qbt 2	13	13	2.8–18	46	0/13
	Qbt 1v	20	20	1.7–10.7	26.5	0/20
Beryllium	Qbt 2	13	9	[0.08]–[0.49]	1.21	0/13
	Qbt 1v	20	16	0.1–[0.5]	1.7	0/20
Cadmium	Qbt 2	13	1	[0.02]–[0.49]	1.73	0/13
	Qbt 1v	20	2	[0.02]–0.52	0.4	1/20 4/20 DLs > BV
Calcium	Qbt 2	13	13	155–776	2200	0/13
	Qbt 1v	20	20	202–754	3700	0/20
Chromium	Qbt 2	13	9	[0.3]–7.0	7.14	0/13
	Qbt 1v	20	12	[0.3]–3.0	2.24	1/20
Cobalt	Qbt 2	13	8	0.14–1.8	3.14	0/13
	Qbt 1v	20	5	0.14–[1.01]	1.78	0/20
Copper	Qbt 2	13	9	[0.5]–35.4	4.66	4/13
	Qbt 1v	20	15	0.37–1.7	3.26	0/20
Cyanide	Qbt 2	11	0	[0.15–1.01]	0.5	2/11 DLs > BV
	Qbt 1v	15	0	[0.15–1.02]	0.5	4/15 DLs > BV
Iron	Qbt 2	13	13	685–4650	14500	0/13
	Qbt 1v	20	20	250–5330	9900	0/20
Lead	Qbt 2	13	13	1.3–16.2	11.2	1/13
	Qbt 1v	20	20	1.02–27.2	18.4	1/20
Magnesium	Qbt 2	13	13	27.8–400	1690	0/13
	Qbt 1v	20	20	27.6–321	780	0/20
Manganese	Qbt 2	13	13	49.6–212	482	0/13
	Qbt 1v	20	20	44.8–238	408	0/20
Mercury	Qbt 2	13	0	[0.02–0.1]	0.1	0/13
	Qbt 1v	20	3	[0.02]–0.07	0.1	0/20
Nickel	Qbt 2	13	8	[0.6]–6.0	6.58	0/13
	Qbt 1v	20	5	[0.6]–1.9	2.0	0/20

Table 2.4-3 (continued)

Analyte	Media	Number of Analyses	Number of Detects	Concentration Range[a] (mg/kg)	BV (mg/kg)[b]	Frequency of Detects above BV
Potassium	Qbt 2	13	12	90–871	3500	0/13
	Qbt 1v	20	15	[89.9]–271	6670	0/20
Selenium	Qbt 2	13	1	[0.2]–[0.95]	0.3	5/13 DLs > BV
	Qbt 1v	20	1	[0.2]–[0.46]	0.3	1/20 5/20 DLs > BV
Silver	Qbt 2	13	0	[0.1]–[1.3]	1.0	1/13 DL > BV
	Qbt 1v	20	1	[0.1]–0.71	1.0	0/20
Sodium	Qbt 2	13	13	64.9–771	2770	0/13
	Qbt 1v	20	20	78.9–382	6330	0/20
Thallium	Qbt 2	13	1	[0.1]–1.7	1.1	1/13
	Qbt 1v	20	0	[0.1]–[0.5]	1.24	0/20
Vanadium	Qbt 2	13	12	0.94–3.8	17	0/13
	Qbt 1v	20	16	0.7–3.3	4.38	0/20
Zinc	Qbt 2	13	13	8.4–32.5	63.5	0/13
	Qbt 1v	20	20	7.0–45	84.6	0/20

[a] Values in square brackets indicate nondetects.

[b] Tuff BVs obtained from LANL (1998, 059730).

[c] DLs = Detection limits.

Table 2.4-4
Frequency of Detected Radionuclides in Tuff Samples

Analyte	Media	Number of Analyses	Number of Detects	Concentration Range[a] (pCi/g)	Sediment BV or Fallout Value[b] (pCi/g)	Frequency of Detects or Detects above BV or Fallout Value
Americium-241	Tuff	33	0	[-0.11–0.37]	—[c]	0/33
Cesium-134	Tuff	17	0	[0.05–0.14]	No value	0/17
Cesium-137	Tuff	33	0	[-0.032–0.1]	No value	0/33
Cobalt-60	Tuff	33	0	[-0.03–0.09]	No value	0/33
Europium-152	Tuff	16	0	[-0.07–0.23]	No value	0/16
Ruthenium-106	Tuff	33	0	[-0.44–0.67]	No value	0/33
Sodium-22	Tuff	33	0	[-0.52–0.08]	No value	0/33
Tritium[d]	Tuff	33	22	[1.3]–777,000	No value	22/33
Uranium-235	Qbt 2	6	0	[0.11–0.13]	0.09	0/6
	Qbt 1v	11	0	[0.11–0.13]	0.14	0/11

[a] Values in square brackets indicate nondetects.

[b] Tuff background and fallout values obtained from LANL (1998, 059730).

[c] — = No value.

[d] Tritium values are in pCi/mL.

Table 2.4-5
Frequency of Detected Organic Chemicals in Tuff Samples

Suite or Analyte	Number of Analyses	Number of Detects	Concentration Range* (mg/kg)	Estimated Quantitation Limit (mg/kg)	Frequency of Detects
SVOCs					
Benzoic acid	33	1	0.49–[3.5]	0.81–3.5	1/33
Bis(2-ethylhexyl)phthalate	33	5	[0.038]–3.8	0.04–0.34	5/33
Di-n-butylphthalate	33	6	0.043–[0.35]	0.33–0.35	6/33
Diethylphthalate	33	1	0.28–[0.35]	0.33–0.35	1/33
Dimethylphthalate	33	1	0.042–[0.35]	0.33–0.35	1/33
Naphthalene	33	1	0.001–[0.35]	0.005–0.35	1/33
Pesticide/PCB					
Endosulfan sulfate	33	1	[0.000671]–[0.00351]	0.000671–0.00351	1/33
VOCs					
Acetone	33	2	[0.002]–[0.025]	0.002–0.021	2/33
Benzene	33	1	0.003–[0.0052]	0.005–0.0052	1/33
Butanone [2-]	33	2	0.002–[0.021]	0.01–0.021	2/33
Butylbenzene [n-]	33	1	0.0013–[0.0052]	0.005–0.0052	1/33
Butylbenzene [sec-]	33	2	0.0011–[0.0052]	0.005–0.0052	2/33
Hexachlorobutadiene	33	1	0.002–[0.005]	0.005–0.35	1/33
Methylene chloride	33	3	0.002–[0.011]	0.003–0.011	3/33
Toluene	33	3	0.001–[0.0052]	0.005–0.0052	3/33
Trichlorobenzene[1,2,3-]	9	2	0.001–[0.005]	0.005	2/9
Trichlorobenzene[1,2,4-]	33	1	0.001–[0.005]	0.005–0.35	1/33
Trichlorofluoromethane	33	6	0.002–0.007	0.005–0.0052	6/33

*Values in square brackets indicate nondetects.

Table 2.4-6
Detected Organic Chemicals in Tuff Samples

Analyte	Location ID	Sample ID	Sample Concentration (mg/kg)	Media	Depth (ft)
Acetone	54-1024	0554-95-0321	0.016	Qbt 2	9–9.2
	54-1026	0554-95-0312	0.011	Qbt 1v	76.5–78
Benzene	54-1026	0554-95-0312	0.003(J)	Qbt 1v	76.5–78
Benzoic acid	54-1026	0554-95-0300	0.49(J)	Qbt 2	16.5–18.1
Bis(2-ethylhexyl)phthalate	54-1024	0554-95-0323	1.3	Qbt 2	18.5–20
	54-1025	0554-95-0339	0.083(J)	Qbt 2	9–9.2
	54-1025	0554-95-0341	3.8	Qbt 2	17–18.8
	54-1025	0554-95-0347	0.085(J)	Qbt 1v	51–52.7
	54-1025	0554-95-0355	0.19(J)	Qbt 1v	86–90
2-Butanone	54-1023	0554-95-0284	0.002(J)	Qbt 2	15.5–17
	54-1023	0554-95-0288	0.007(J)	Qbt 1v	37–38.5
n-Butylbenzene	54-1025	0554-95-0349	0.0013(J)	Qbt 1v	61–62.8
sec-Butylbenzene	54-1025	0554-95-0347	0.011(J)	Qbt 1v	51–52.7
	54-1025	0554-95-0349	0.012(J)	Qbt 1v	61–62.8
Diethylphthalate	54-1024	0554-95-0325	0.28(J)	Qbt 2	26–27.8
Dimethylphthalate	54-1024	0554-95-0325	0.042(J)	Qbt 2	26–27.8
Di-n-butylphthalate	54-1023	0554-95-0286	0.057(J)	Qbt 2	27–28.5
	54-1023	0554-95-0288	0.05(J)	Qbt 1v	37–38.5
	54-1023	0554-95-0290	0.051(J)	Qbt 1v	47–48.5
	54-1023	0554-95-0292	0.047(J)	Qbt 1v	57–58.5
	54-1024	0554-95-0337	0.046(J)	Qbt 1v	86–87.8
	54-1026	0554-95-0302	0.047(J)	Qbt 2	26.5–28
Endosulfan sulfate	54-1024	0554-95-0327	0.000674	Qbt 2	36–37.8
Hexachlorobutadiene	54-1025	0554-95-0349	0.002(J)	Qbt 1v	61–62.8
Methylene chloride	54-1024	0554-95-0327	0.002(J)	Qbt 2	36–37.8
	54-1024	0554-95-0331	0.002(J)	Qbt 1v	61–62.5
	54-1024	0554-95-0333	0.002(J)	Qbt 1v	71–72.8
Naphthalene	54-1025	0554-95-0349	0.001(J)	Qbt 1v	61–62.8
Toluene	54-1026	0554-95-0308	0.002(J)	Qbt 1v	58–60
	54-1026	0554-95-0310	0.001(J)	Qbt 1v	66.5–68
	54-1026	0554-95-0312	0.001(J)	Qbt 1v	76.5–78
1,2,3-Trichlorobenzene	54-1025	0554-95-0347	0.001(J)	Qbt 1v	51–52.7
	54-1025	0554-95-0349	0.002(J)	Qbt 1v	61–62.8
1,2,4-Trichlorobenzene	54-1025	0554-95-0349	0.001(J)	Qbt 1v	61–62.8

Table 2.4-6 (continued)

Analyte	Location ID	Sample ID	Sample Concentration (mg/kg)	Media	Depth (ft)
Trichlorofluoromethane	54-1024	0554-95-0325	0.004(J)	Qbt 2	26–27.8
	54-1024	0554-95-0327	0.007	Qbt 2	36–37.8
	54-1024	0554-95-0329	0.002(J)	Qbt 1v	51–52.5
	54-1024	0554-95-0331	0.006	Qbt 1v	61–62.5
	54-1024	0554-95-0333	0.006	Qbt 1v	71–72.8
	54-1024	0554-95-0337	0.007	Qbt 1v	86–87.8

Note: Data qualifiers are defined in Appendix A.

Table 2.4-7
Frequency of Detects for Tritium in Pore Gas

Analyte	Analyte Code	Number of Analyses	Number of Detects	Number of Detected Locations	Concentration Range (pCi/L)	Location of Minimum Detected	Location of Maximum Detected
Tritium	H-3	33	32	3	[480]–3080000	54-15462 (50 ft)	54-15462 (100 ft)

Table 2.4-8
Frequency of Detects for VOCs in Pore Gas

Analyte	Analyte Code	Number of Analyses	Number of Detects	Number of Detected Locations	Concentration Range (ppbv)	Location of Minimum Detected	Location of Maximum Detected
Ethylbenzene	100-41-4	37	8	3	[0.68–10]	54-15462 (100 ft)	54-15461 (50 ft)
Styrene	100-42-5	37	1	1	[0.68–10]	54-15462 (100 ft)	54-15461 (50 ft)
Butadiene[1,3-]	106-99-0	37	1	1	[2.7–41]	54-15462 (100 ft)	54-15461 (50 ft)
Methyl-2-pentanone[4-]	108-10-1	37	1	1	[0.68–41]	54-15462 (100 ft)	54-15461 (50 ft)
Trimethylbenzene[1,3,5-]	108-67-8	37	3	2	[0.68–10]	54-15462 (100 ft)	54-15461 (50 ft)
Toluene	108-88-3	37	31	3	[0.8]–2300	54-01023 (100 ft)	54-15461 (95 ft)
Hexane	110-54-3	37	2	2	[2.7]–72	54-15462 (100 ft)	54-15461 (50 ft)
Cyclohexane	110-82-7	37	8	3	[2.7–41]	54-15462 (100 ft)	54-15461 (50 ft)
Propylene	115-07-1	37	1	1	[2.7–41]	54-15462 (100 ft)	54-15461 (50 ft)
Tetrachloroethene	127-18-4	37	6	2	[0.67]–19	54-15461 (50 ft)	54-15462 (100 ft)
Xylene (total)	1330-20-7	4	4	2	1.4–25	54-15462 (50 ft)	54-15461 (50 ft)
n-Heptane	142-82-5	37	1	1	[2.7–41]	54-15462 (100 ft)	54-15461 (50 ft)
Carbon tetrachloride	56-23-5	37	18	3	[0.67–10]	54-15461 (50 ft)	54-15461 (50 ft)
Ethyltoluene[4-]	622-96-8	33	12	3	0.7–[41]	54-15462 (100 ft)	54-15461 (50 ft)
Ethanol	64-17-5	37	14	3	[3.2]–48	54-15462 (50 ft)	54-15461 (50 ft)
Methanol	67-56-1	37	2	2	[68–1000]	54-15462 (100 ft)	54-15461 (50 ft)
Propanol[2-]	67-63-0	37	5	3	[3.2–41]	54-15462 (200 ft)	54-15461 (50 ft)
Acetone	67-64-1	37	22	5	[3.2]–51	54-15462 (50 ft)	54-15462 (233 ft)
Butanol[1-]	71-36-3	37	1	1	[6.7–100]	54-15461 (50 ft)	54-15461 (50 ft)
Benzene	71-43-2	37	6	2	[0.68]–34	54-15462 (100 ft)	54-15461 (50 ft)
Trichloroethane[1,1,1-]	71-55-6	37	25	3	[0.67]–26	54-15461 (50 ft)	54-15462 (50 ft)
Chloromethane	74-87-3	37	1	1	[0.67–10]	54-15461 (50 ft)	54-15461 (50 ft)
Methylene chloride	75-09-2	37	8	2	[0.79]–17	54-15462 (50 ft)	54-15461 (50 ft)
Carbon disulfide	75-15-0	37	9	3	[0.8–41]	54-15461 (100 ft)	54-15461 (50 ft)
Trichlorofluoromethane	75-69-4	33	20	3	[0.8–10]	54-15461 (100 ft)	54-15461 (50 ft)
Dichlorodifluoromethane	75-71-8	33	18	3	[0.8–10]	54-15461 (100 ft)	54-15461 (50 ft)
Trichloro-1,2,2-trifluoroethane[1,1,2-]	76-13-1	37	16	2	[0.67–10]	54-15461 (50 ft)	54-15461 (50 ft)
Dichloropropane[1,2-]	78-87-5	37	2	1	[0.67–10]	54-15461 (50 ft)	54-15461 (50 ft)
Butanone[2-]	78-93-3	37	6	2	[0.68–41]	54-15462 (100 ft)	54-15461 (50 ft)
Trichloroethene	79-01-6	37	7	3	[0.67–10]	54-15461 (50 ft)	54-15461 (50 ft)
Xylene[1,2-]	95-47-6	37	10	3	[0.68–10]	54-15462 (100 ft)	54-15461 (50 ft)
Trimethylbenzene[1,2,4-]	95-63-6	37	19	3	[0.79–10]	54-15462 (50 ft)	54-15461 (50 ft)
Xylene[1,3-]+xylene[1,4-]	Xylene[1,3 and 1,4]	33	19	3	[0.8–10]	54-01023 (250 ft)	54-15461 (50 ft)

Table 2.4-9
Monitoring of Tritium in Air

Start Time	End Time	Ambient Air Concentration (pCi/m^3)
3/26/01 9:37	4/9/01 9:19	4.0
4/9/01 9:19	4/23/01 9:00	3.1
4/23/01 9:00	5/7/01 9:08	5.9
5/7/01 9:08	5/21/01 9:26	3.1
5/21/01 9:26	6/4/01 8:46	14.2
6/4/01 8:46	6/18/01 8:12	15.5
6/18/01 8:12	7/2/01 9:56	26.0
7/2/01 9:56	7/16/01 8:47	27.1
7/16/01 8:47	7/31/01 9:45	29.8
7/31/01 9:45	8/14/01 8:03	42.4
8/14/01 8:03	8/28/01 9:44	38.1
8/28/01 9:44	9/13/01 7:52	9.8
9/10/01 7:52	9/25/01 8:57	53.7
9/25/01 8:57	10/9/01 9:34	70.1
10/9/01 9:34	10/24/01 10:27	51.9
11/5/01 13:44	11/20/01 11:45	68.6
10/24/01 10:27	11/5/01 13:44	40.3
11/20/01 11:45	12/3/01 9:45	19.0
12/3/01 9:45	12/17/01 9:35	10.2
12/17/01 9:35	1/7/02 9:53	12.0
1/7/02 9:53	1/22/02 10:09	17.0
1/22/02 10:09	2/4/02 8:38	13.7
2/4/02 8:38	2/19/02 11:52	15.3
2/19/02 11:52	3/4/02 9:30	22.7
3/4/02 9:30	3/18/02 10:56	25.1
3/18/02 10:56	4/2/02 8:28	24.1

Table 2.4-10
Summary of RFI Sampling Results for COPCs

Analyte	Medium	COPC (y/n?)	Rationale
Summary of 2001 RFI Data Review for COPCs			
Copper	Sediment	No	Not detected above sediment background value (BV)
	Tuff	Yes	Statistical tests found copper to be different from Qbt 2 background.
Cadmium	Sediment	Yes	Detection limits (DLs) above the sediment BV and sediment background data set
	Tuff	No	Not statistically different from tuff backgrounds
Cyanide	Sediment	No	Not detected above the sediment BV
	Tuff	Yes	DLs above the tuff BV
Selenium	Sediment	Yes	DLs above the sediment BV
	Tuff	Yes	DLs above the tuff BVs
Tritium	Sediment	Yes	Detected at a concentration above the fallout value in one sample
	Tuff	Yes	Detected in the majority of tuff samples
Methoxychlor	Sediment	Yes	Detected at low concentrations in two samples
	Tuff	No	Not detected in any tuff samples
Endosulfan sulfate	Tuff	Yes	Detected in one tuff sample below the estimated quantitation limit
	Sediment	No	Not detected in any sediment samples
Benzoic acid, bis(2-ethylhexyl)phthalate, diethylphthalate, dimethylphthalate, di-n-butylphthlalate, napthalene	Tuff	Yes	Detected in one to six tuff samples
	Sediment	NA*	Not analyzed for in sediment samples
Summary of 2001 RFI Data Review for COPCs			
Acetone, benzene, 2-butanone, n-butylbenzene, sec-butylbenzene, hexachlorobutadiene, methylene chloride, toluene, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, trichlorofluoromethane	Tuff	Yes	Detected in one to six tuff samples
	Sediment	NA	Not analyzed for in sediment samples

Table 2.4-10 (continued)

Analyte	Medium	COPC (y/n?)	Rationale
Summary of 2002 RFI Addendum Data Review for COPCs			
Selenium	Sediment	Yes	Detected at 0.41 mg/kg; above the sediment BV of 0.3 mg/kg
Tritium	Pore gas	Yes	Concentrations ranging from 1.4–6400 pCi/mL of water vapor collected on silica gel
	Ambient air	No	Concentrations below EPA dose standard of 10 mrem/yr
VOCs (primarily acetone, toluene, 1,1,1-trichloroethane, and trichloroethylene)	Pore gas	Yes	Thirty-three detected VOCs. Concentrations <0.1 parts per million by volume (ppmv) with the exception of toluene. Toluene concentrations up to 2.3 ppmv.
	Ambient air	No	Only acetone detected in 2003 sampling. The 6 parts per million (ppm) detected is below the Occupational Safety and Health Administration 8-hr time-weighted average permissible exposure limit of 1000 ppm.

*NA = Not analyzed.

Table 2.4-11
NMED-Approved MDA H Subsurface Vapor-Monitoring Locations, Port Depths, and Corresponding Sampling Intervals

Borehole ID	VOC and Tritium Sampling Port Depth Intervals (ft bgs)
54-01023[a]	12.5 (10–15), 62.5 (60–65), 102.5 (100–105), 152.5 (150–155), 202.5 (200–205), 247.5 (245–250), 260.5 (258–263)
54-15461	11 (10–12), 61 (60–62), 96 (95–97)
54-15462[a]	12.5 (10–15), 62.5 (60–65), 102.5 (100–105), 152.5 (150–155), 202.5 (200–205), 247.5 (245–250), 260.5 (258–263), 282.5 (280–285), 297.5 (295–300)
54-609985[b]	6.5 (4–9), 62.5 (60–65), 102.5 (100–105), 152.5 (150–155), 202.5 (200–205), 247.5 (245–250), 260.5 (258–263), 282.5 (280–285), 297.5 (295–300)

Note: Depths denote locations where VOC and tritium samples will be collected. Sampling intervals are given in parentheses.

[a] Borehole was redrilled November 2009; depths reflect new ports and intervals.

[b] New borehole was drilled in November 2009.

Table 2.4-12
Screening of VOCs Detected in Pore Gas at MDA H during Third Quarter Fiscal Year 2010

VOCs	Maximum Pore Gas Concentration (µg/m^3)	Calculated Concentrations in Pore Gas Corresponding to Groundwater Standard (µg/m^3)	Screening Value (unitless)	Potential for Groundwater Impact[a]
Acetone	25	35,200	0.00071	No
Benzene	10	1140	0.0088	No
Butanol[1-]	13	1332	0.0098	No
Butanone[2-]	9.6	16,330	0.00059	No
Carbon disulfide	7.7	590,000	0.000013	No
Carbon tetrachloride	17	5500	0.0031	No
Chlorodifluoromethane	20	170,000,000	0.00000012	No
Chloroform	100	12,000	0.0083	No
Cyclohexane	85	79,300,000	0.0000011	No
Dichlorodifluoromethane	71	5,460,000	0.000013	No
Dichloroethane[1,1-]	4.8	5750	0.00083	No
Dichloroethane[1,2-]	5.9	240	0.025	No
Dichloroethene[1,1-]	4.4	5500	0.0008	No
Dichloropropane[1,2-]	5.2	600	0.0087	No
Ethanol	32	na[b]	na	No
Ethylbenzene	6.7	226,100	0.00003	No
Hexane	29	65,120,000	0.00000045	No
Methylene chloride	3.2	650	0.0049	No
Propanol[2-]	25	na	na	No
Tetrachloroethene	7.7	3600	0.0021	No
Toluene	33	204,000	0.00016	No
Trichloro-1,2,2-trifluoroethane[1,1,2-]	41	1,298,000,000	0.000000032	No
Trichloroethane[1,1,1-]	170	42,300	0.004	No
Trichloroethene	13	2000	0.0065	No
Trichlorofluoromethane	77	5,200,000	0.000015	No
Xylene[1,2-]	4.1	132,000	0.000031	No
Xylene[1,3-]+xylene[1,4-]	15	167,000	0.000090	No

Note: Calculated concentrations in pore gas corresponding to groundwater screening levels derived from denominator of Equation 3.0-3 of the MDA H PMR (LANL 2010, 111123). Screening value derived from Equation 3.0-3 of the MDA H PMR (LANL 2010, 111123).

[a] If the screening value is less than 1, the concentration of the VOC in pore gas does not have the potential to exceed the groundwater SL.

[b] na = Not available.

Table 2.5-1
Interim Monitoring Plan for Wells in the TA-54 Monitoring Group, MDAs G, H, and L

Well	Rationale	Number of VOC Sampling Rounds through October 2010	TAL Metals[a]	VOCs + TICs[b]	SVOCs + TICs[b]	Pesticides	PCBs[c]	HEXP[d]	Dioxins/Furans	RAD[e]	Low-Level Tritium[f]	General Inorganics[g]	Perchlorate	Stable Isotopes[h]	Field Parameters[i]
Wells Downgradient of MDA G															
R-22 screen 1	Monitors TA-54 and potential sources in Pajarito Watershed. Rehabilitated Westbay well; final configuration to be determined.	1 (PR[j])	TBD[k]	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
R-22 screens 2 through 5	Monitors TA-54 and potential sources in Pajarito Watershed. Rehabilitated Westbay well; final configuration to be determined.	0	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
R-23i[l] piezometer (port 1)	Downgradient monitoring location for TA-54. Monitors potential sources in Pajarito Watershed and potential sources in canyons to the north.	12	Q	Q	S	—[m]	—	S	—	A	S	Q	S	A	Q
R-23i[l] screen 1 (port 2)	Downgradient monitoring location for TA-54. Also monitors potential sources in Pajarito Watershed and potential sources in canyons to the north.	17	Q	Q	S	—	—	S	—	A	S	Q	S	A	Q
R-23i[l] screen 2 (port 3)	Downgradient monitoring location for TA-54. Monitors potential sources in Pajarito Watershed and potential sources in canyons to the north.	15	Q	Q	S	—	—	S	—	A	S	Q	S	A	Q
R-23[l]	Downgradient monitoring location for TA-54. Also monitors potential sources in Pajarito Watershed and possible sources from canyons to the north.	24	Q	Q	Q	A	A	A	A	A	Q	Q	Q	A	Q
R-39	Monitors TA-54 and potential sources in Pajarito Watershed.	9	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q

Table 2.5-1 (continued)

Well	Rationale	Number of VOC Sampling Rounds through October 2010	TAL Metals[a]	VOC + TICs[b]	SVOC + TICs[b]	Pesticides	PCB[c]	HEXP[d]	Dioxins/Furans	RAD[e]	Low-Level Tritium[f]	General Inorganics[g]	Perchlorate	Stable Isotopes[h]	Field Parameters[i]
R-41 screen 1	Monitors perched intermediate groundwater near northeast corner of MDA G. Screen has been dry since installation.	0	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-41 screen 2	Monitors groundwater near northeast corner of MDA G.	7	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-49 screen 1	Monitors groundwater south of Area G in Pajarito Canyon.	7	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-49 screen 2	Monitors groundwater south of Area G in Pajarito Canyon.	7	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-55 screen 1	New well downgradient of MDA G to monitor for potential contaminant releases from MDA G and other sources in Pajarito Canyon. Completed on August 25, 2010.[n]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-55 screen 2	New well downgradient of MDA G to monitor for potential contaminant releases from MDA G and other sources in Pajarito Canyon. Completed on August 25, 2010.[l]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-57 screen 1	New well downgradient of MDA G at eastern end of TA-54; monitors for potential releases from MDA G. Completed on June 8, 2010.[n]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-57 screen 2	New well downgradient of MDA G at eastern end of TA-54; monitors for potential releases from MDA G. Completed on June 8, 2010.[n]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
Wells Downgradient of MDA H															
R-20 screen 1[o]	Monitors TA-54 and potential sources in Pajarito Watershed.	11 (PR[o])	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-20 screen 2[o]	Monitors TA-54 and potential sources in Pajarito Watershed.	11 (PR[o])	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q

Table 2.5-1 (continued)

Well	Rationale	Number of VOC Sampling Rounds through October 2010	TAL Metals[a]	VOC + TICs[b]	SVOC + TICs[b]	Pesticides	PCB[c]	HEXP[d]	Dioxins/Furans	RAD[e]	Low-Level Tritium[f]	General Inorganics[g]	Perchlorate	Stable Isotopes[h]	Field Parameters[i]
R-37 screen 1	Monitors perched-intermediate groundwater downgradient of MDA H.	8	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-37 screen 2	Monitors regional groundwater downgradient of MDA H.	7	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-40i[p]	Monitors TA-54 and potential sources in Pajarito Watershed. Screen impacted by drilling fluids.	8	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-40 screen 1[p]	Monitors TA-54 and potential sources in Pajarito Watershed.	7	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-40 screen 2[o]	Monitors TA-54 and potential sources in Pajarito Watershed.	7	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-52 screen 1	New well north-northeast of MDAs H and J, on mesa south of Cañada del Buey. Monitors for potential releases of contaminants from MDAs H and J. Completed on April 5, 2010.[n]	3	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-52 screen 2	New well north-northeast of MDAs H and J, on mesa south of Cañada del Buey. Monitors for potential releases of contaminants from MDAs H and J. Completed on April 5, 2010.[n]	3	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
Wells Downgradient of MDA L															
R-21	Monitors regional groundwater in Mortandad Canyon.	20	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-32	Monitors TA-54 and potential sources in Pajarito Watershed.	13 (PR)	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q
R-38	Monitors groundwater downgradient of MDA L in the north fork of Cañada del Buey, in the Mortandad Watershed.	8	Q	Q	Q	A	A	A	A	A	Q	Q	Q	S	Q

Table 2.5-1 (continued)

Well	Rationale	Number of VOC Sampling Rounds through October 2010	TAL Metals[a]	VOC + TICs[b]	SVOC + TICs[b]	Pesticides	PCB[c]	HEXP[d]	Dioxins/Furans	RAD[e]	Low-Level Tritium[f]	General Inorganics[g]	Perchlorate	Stable Isotopes[h]	Field Parameters[i]
R-53 screen 1	New well located north of MDA L in Cañada del Buey; monitors for potential releases from MDA L. Completed March 29, 2010.[l]	3	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-53 screen 2	New well located north of MDA L in Cañada del Buey; monitors for potential releases from MDA L. Completed March 29, 2010.[l]	3	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-54 screen 1[o]	New well located immediately west of MDA L in Pajarito Canyon; monitors for potential releases from MDA L. Completed on January 29, 2010.[n]	4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-54 screen 2[o]	New well located immediately west of MDA L in Pajarito Canyon; monitors for potential releases from MDA L. Completed on January 29, 2010.[n]	4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-56 screen 1	Located on Mesita del Buey between MDA G and MDA L. Monitors for potential contaminant releases from MDAs G and L, and other sources in Pajarito Canyon. Completed on July 19, 2010.[n]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
R-56 screen 2	Located on Mesita del Buey between MDA G and MDA L. Monitors for potential contaminant releases from MDAs G and L, and other sources in Pajarito Canyon. Completed on July 19, 2010.[n]	1	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q
Wells Upgradient of MDAs G, H, and L															
R-51 screen 1	New well west of MDAs H and J, and northwest of TA-18. Monitors other potential contaminant sources in Pajarito Canyon. Completed February 8, 2010.[n]	4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q

Table 2.5-1 (continued)

Well	Rationale	Number of VOC Sampling Rounds through October 2010	TAL Metals[a]	VOC + TICs[b]	SVOC + TICs[b]	Pesticides	PCB[c]	HEXP[d]	Dioxins/Furans	RAD[e]	Low-Level Tritium[f]	General Inorganics[g]	Perchlorate	Stable Isotopes[h]	Field Parameters[i]
R-51 screen 2	New well west of MDAs H and J, and northwest of TA-18. Monitors other potential contaminant sources in Pajarito Canyon. Completed February 8, 2010.[n]	4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	S	Q

Source: Table 5.4-1 of the 2010 IFGMP (LANL 2010, 109830).

Notes: Sampling suites and frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); Nonfiltered and filtered samples will be collected for general inorganics (excluding anions) and metals. Anions and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media. Stable isotope samples for nitrogen isotopes are filtered; stable isotope samples for deuterium and oxygen isotopes are not filtered.

[a] Metals analysis includes the 23 target analyte list (TAL) metals, plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[b] VOC = Volatile organic compound; SVOC = semivolatile organic compound; TIC = tentatively-identified compound.

[c] PCB = Polychlorinated biphenyl (compound).

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide (RAD) suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for stable nitrogen, deuterium, and oxygen isotopes.

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used. Alkalinity (ALK) will be measured for all samples either in the field or at the on-site EES-14 laboratory.

[j] PR = Post-rehabilitation sampling events.

[k] TBD = To be determined.

[l] In the 2010 IFGMP (LANL 2010, 109830, Table 5.4-1), wells R-23 and R-23i are assigned to "General Surveillance Monitoring Locations." These wells are included in Table 2.5-1 above because they are relevant downgradient wells.

[m] — = This analytical suite is not scheduled to be collected at this location.

[n] Characterization suites and frequencies apply to new intermediate perched or regional groundwater wells. “New” wells are defined as those which are completed, rehabilitated, or converted after July 1, 2009. After completion of four rounds of characterization sampling, a new well is reassigned automatically to the routine analytical suites and frequencies of the appropriate area-specific monitoring group or general surveillance monitoring plan unless specified otherwise.

[o] Wells R-20 and R-54 are generally upgradient of MDA L. However, these wells potentially could be downgradient of MDA L if pumping at water-supply well PM-2 affects the local gradient. Similarly, well R-40 screen 2 is generally upgradient of MDA H but could potentially be downgradient of this MDA if pumping at PM-2 affects the local gradient.

[p] The gradient in the perched intermediate zone is not known with sufficient accuracy to determine whether or not wells R-40i and R-40 screen 1 are downgradient of MDA H.

Table 5.1-1
Summary of Regulatory Criteria and Cleanup Levels

Media	Regulatory Criteria and Cleanup Level Source
Groundwater	Water Quality Control Commission standards
	Safe Drinking Water Act standards
Soil	NMED's "Technical Background Document for Development of Soil Screening Levels"
	EPA Region VI Human Health Medium Specific Screening Levels

Table 6.3-1
Summary of Technologies
Retained for Further Evaluation at MDA H

Retained Containment Technologies
Surface barriers—vegetative cover
Surface barriers—ET cover
Surface barriers—biotic barriers

Table 7.0-1
Summary of Potential Remedial Action Technologies

Shafts	No Action	Maintenance and Monitoring	Containment
Exposure pathways of concern include • direct exposure to waste by means of excavation and • disruption/dispersal of waste.	S-1 No action	S-2 Maintenance and monitoring	S-3a—Vegetative cover S-3b—ET cover S-3c—Biotic barrier

Table 7.3-1
Screening of Technologies against the Threshold Screening Criteria

		Threshold Screening Criteria				
Technology	Description	Protective of HH&E	Attains Media Cleanup Standards	Controls Source and Releases	Complies with Waste Management Standards	Retained
Technology S-1 No action	This technology includes no monitoring, maintenance, or institutional controls.	**No** Potential remains for exposure through excavation. Does not prevent disruption or infiltration.	**Yes** Complies with NMED SSLs for soil surrounding the shafts.	**No** Does not control releases from buried waste due to excavation. Does not provide protection against infiltration and disruption or dispersal.	**Yes** No waste will be generated.	**Yes** For comparison purposes only.
Technology S-2 Maintenance and monitoring	Site will be monitored for signs of erosion and maintained as needed for 30 yr. Institutional controls will be implemented for 100 yr.	**No** Does not prevent infiltration and thus disruption or dispersal.	**Yes** Complies with NMED SSLs for soil surrounding the shafts.	**No** Does not provide protection against infiltration and disruption or dispersal.	**Yes** No waste will be generated.	**No**
Technology S-3a Vegetative cover	The existing surface soil will be regraded and a vegetative cover will be constructed, maintained, and monitored for 30 yr. Institutional controls will be implemented for 100 yr.	**Yes** Provides protection against exposure through excavation, infiltration, disruption, and dispersal.	**Yes** Complies with NMED SSLs for cover materials and soil surrounding shafts.	**Yes** Provides protection against excavation, infiltration, disruption, or dispersal.	**Yes** Any waste generated under this technology will comply with all applicable regulatory requirements.	**Yes**

Table 7.3-1 (continued)

Technology	Description	Threshold Screening Criteria				Retained
		Protective of HH&E	Attains Media Cleanup Standards	Controls Source and Releases	Complies with Waste Management Standards	
Technology S-3b ET cover	The existing surface soil will be regraded and an ET cover will be constructed, maintained, and monitored for 30 yr. Institutional controls will be implemented for 100 yr.	**Yes** Provides protection against exposure through excavation, infiltration, disruption, and dispersal.	**Yes** Complies with NMED SSLs for cover materials and soil surrounding shafts.	**Yes** Provides protection against excavation, infiltration, disruption, or dispersal.	**Yes** Any waste generated under this technology will comply with all applicable regulatory requirements.	**Yes**
Technology S-3c Biotic barrier	The existing surface soil will be regraded and a biotic barrier will be constructed, maintained, and monitored for 30 yr. Institutional controls will be implemented for 100 yr.	**No** Does not prevent infiltration and thus disruption or dispersal.	**Yes** Complies with NMED SSLs for biotic barrier materials and soil surrounding shafts.	**No** Does not provide protection against infiltration and disruption or dispersal.	**Yes** Any waste generated under this technology will comply with all applicable regulatory requirements.	**No**

Table 7.4-1
Technologies That Meet the Threshold Criteria and Are Retained for Further Evaluation

Technologies Retained
Technology S-1 No action
Technology S-3a Vegetative cover
Technology S-3b ET cover

Table 8.3-1
Cost Estimates

Item Description	Labor Hours	Labor Total – Gross ($)	Materials Total – Gross ($)	Subcontractors Total – Gross ($)	Equipment Total – Gross ($)	Other Total – Gross ($)	Gross Total Costs ($)
Project WBS: 1 - MDA G CME							
Project WBS: 1.PS3a - Vegetative Cover							
Project WBS: 1.PS3a.1 - Vegetative Cover - Direct Costs							
Vegetative Cover - Direct Costs Total	1,438.90	121,646.83	104,936.71	33,099.54	105,720.45	1,189.10	366,593
Project WBS: 1.PS3a.2 - Vegetative Cover - Indirect Costs							
Vegetative Cover - Indirect Costs Total	1,117.00	245,212.66		84,782.61		348,294.50	678,290
Project WBS: 1.PS3a.3 - Vegetative Cover - Direct Operations & Maintenance							
Vegetative Cover - Direct Operations & Maintenance Total	4,684.90	555,732.34	64,284.38		6,685.53		626,702
Project WBS: 1.PS3a.4 - Vegetative Cover - Indirect Operations & Maintenance							
Vegetative Cover - Indirect Operations & Maintenance Total	1,025.00	225,020.36				425,861.00	650,881
Vegetative Cover Total	**8,265.70**	**1,147,612.19**	**169,221.09**	**117,882.15**	**112,405.98**	**775,344.60**	**2,322,466**
Project WBS: 1.PS3b - ET Cover							
Project WBS: 1.PS3b.1 - ET Cover - Direct Cost							
ET Cover - Direct Cost Total	1,638.40	140,812.63	175,523.20	46,370.80	186,944.95	1,189.10	550,841
Project WBS: 1.PS3b.2 - ET Cover - Indirect Cost							
ET Cover - Indirect Cost Total	1,597.90	350,802.14		127,385.29		514,513.60	992,701
Project WBS: 1.PS3b.3 - ET Cover - Direct Operations & Maintenance							
ET Cover - Direct Operations & Maintenance Total	4,684.90	555,732.34	64,284.38		6,685.53		626,702
Project WBS: 1.PS3b.4 - ET Cover - Indirect Operations & Maintenance							
ET Cover - Indirect Operations & Maintenance Total	1,025.00	225,020.36				425,861.00	650,881
ET Cover Total	8,946.20	1,272,367.47	239,807.58	173,756.09	193,630.48	941,563.70	2,821,125

Table 8.3-2
Explanation of Ranking System Used for Evaluating Remedial Technology Evaluation Criteria

	Remedial Technology Balancing Criteria				
Relative Rating	Long-Term Reliability and Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implementability	Cost
1 Very low benefit	Low long-term reliability and effectiveness, high long-term risk, and high uncertainty associated with leaving waste in place.	No reduction in toxicity, mobility, or volume of contaminants.	Long time to achieve risk reduction and adds short-term risk.	Difficult to obtain DSA approval and technically difficult to construct.	High cost to implement and maintain.
2 Low benefit	Low to medium long-term reliability and effectiveness, and high to medium long-term risk and uncertainty in leaving waste in place.	No reduction in toxicity and volume, minor reduction in mobility.	Moderate to long time to achieve risk reduction with moderate short-term risk.	Requires DSA approval and difficult to construct.	Moderate cost to implement, higher cost to maintain.
3 Medium benefit	Medium long-term reliability, effectiveness, risk, and uncertainty in leaving waste in place.	No reduction in toxicity and volume, moderate reduction in mobility.	Moderate time to achieve risk reduction with moderate short-term risk.	Requires DSA approval and average difficulty to construct.	Moderate cost to implement and maintain.
4 High benefit	Medium to high long-term reliability and effectiveness, medium to low long-term risk and low uncertainty associated with leaving waste in place.	Little or no reduction in toxicity and volume, significant reduction in mobility.	Moderate to short time to achieve risk reduction with limited short-term risk.	Requires DSA approval, but easy to construct.	Lower cost to implement, moderate cost to maintain.
5 Very high benefit	High long-term reliability and effectiveness, low long-term risk, and low uncertainty associated with leaving waste in place.	Toxicity, mobility and volume of contaminants are reduced.	Short time to achieve risk reduction with little to no short term risk.	Does not require DSA approval and easy to construct.	Low cost to implement and maintain.

Table 8.3-3
Screening of Technologies against the Balancing Criteria

Technology	Description	Balancing Criteria					Score
		Long-Term Reliability and Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Implement-ability	Cost	
Technology S-1 No action	No action is taken. This technology includes no monitoring, maintenance, or institutional controls.	1	1	1	5	5	13
Technology S-3a Vegetative cover	The vegetative cover will be constructed, maintained, and monitored for 30 yr. Institutional controls will be implemented for 100 yr.	3	1	4	4	4	16
Technology S-3b ET cover	The ET cover will be constructed, maintained, and monitored for 30 yr. Institutional controls will be implemented for 100 yr.	4	1	4	4	4	17

Appendix A

Acronyms and Abbreviations, Metric Conversion Table, and Data Qualifier Definitions

A-1.0 ACRONYMS AND ABBREVIATIONS

AB	authorization basis
AOC	area of concern
amsl	above mean sea level
bgs	below ground surface
BMP	best management practice
BV	background value
CFR	Code of Federal Regulations
CME	corrective measures evaluation
CMI	corrective measures implementation
CMS	corrective measures study
Consent Order	Compliance Order on Consent
COPC	chemical of potential concern
CSM	conceptual site model
DL	detection limit
DOE	Department of Energy (U.S.)
DSA	document safety analysis
DU	depleted uranium
EPA	Environmental Protection Agency (U.S.)
EQL	estimated quantitation limit
ER	environmental restoration
ET	evapotranspiration
EU	enriched uranium
FML	flexible membrane line
FOD	Facility Operation Director
gpm	gallons per minute
HE	high explosives
HELP	Hydrologic Evaluation of Landfill Performance
HEU	highly enriched uranium
HI	hazard index
HWB	Hazardous Waste Bureau (NMED)
IFGMP	Interim Facility-Wide Groundwater Monitoring Plan
IIS	Inventory Isolation System
Laboratory	Los Alamos National Laboratory

LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory (Laboratory's name before January 1, 1981)
LiH	lithium hydride
LiF	lithium fluoride
Ma	million year(s) ago
MCL	maximum contaminant level
MDA	material disposal area
MNA	monitored natural attenuation
NES	nuclear environmental site
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
NMHWA	New Mexico Hazardous Waste Act
NNSA	National Nuclear Security Administration
O&M	operations and maintenance
OMB	Office of Budget and Management
PA/CA	performance assessment/composite analysis
PBX	plastic-bonded explosives
PCB	polychlorinated biphenyl
PETN	pentaerythritol tetranitrate
PMR	periodic monitoring report
PV	present value
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RFI	RCRA facility investigation
SNL	Sandia National Laboratories (New Mexico)
SAL	screening action level
SHB	seismic hazards borehole
SNL	Sandia National Laboratories
SSL	soil screening level
SVE	soil vapor extraction

SVOC	semivolatile organic compound
SWMU	solid waste management unit
TA	technical area
TPRA	technical programmatic risk assessment
VOC	volatile organic compound

A-2.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	By	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

A-3.0 DATA QUALIFIER DEFINITIONS

Data Qualifier	Definition
U	The analyte was analyzed for but not detected.
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the result is likely to be biased high.
J-	The analyte was positively identified, and the result is likely to be biased low.
UJ	The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
R	The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

Appendix B

Waste Inventory for Material Disposal Area H

B-1.0 INTRODUCTION

Waste was disposed of in the Material Disposal Area (MDA) H shafts over approximately 26 yr from May 1960 until August 1986. During this period, disposal events were recorded in a single Los Alamos Scientific Laboratory (LASL) logbook that contains brief, unclassified descriptions of the waste, including approximate weights. Information from the logbook is summarized in Table B-1.0-1. Logbook descriptions include sufficient information to identify many of the potential hazardous wastes, constituents, and radionuclides in the inventory (LASL 1960–1986, 070034). However, the quantities of the materials disposed of can only be estimated because the details in the logbook are insufficient, and some descriptions of the materials disposed of at MDA H are still classified. Therefore, the documented logbook information was supplemented by a review of waste disposal records, process knowledge of current and former site operations, and best professional and engineering judgment from subject matter experts. In addition, the quantities and metal composition of components excavated and recovered from the Classified Waste Landfill at Sandia National Laboratories (SNL), a site with similar disposal materials, were reviewed to support the estimates of the MDA H metals inventory. These efforts resulted in the refined estimate of the waste inventory at MDA H that is discussed in this section (Omicron 2003, 075940).

The percentages by weight of material disposed of in the shafts at MDA H as recorded in the logbook are shown in Figure 2.2-1 of the report. The largest component of the MDA H waste inventory, 57%, is metal, both radioactive and nonradioactive (24% depleted uranium [DU] and 33% other metals). Potentially reactive materials, such as lithium compounds, represent approximately 1% of the inventory. Graphite represents approximately 9% of the inventory, and radioactive materials other than DU account for approximately 24% of the inventory. Plastics account for approximately 9% of the inventory, and paper and high explosives (HE) each constitute less than 1% of the inventory (LASL 1960–1986, 070034).

Logbook entries include waste that potentially meets the Resource and Conservation and Recovery Act definition of characteristic hazardous waste such as lithium hydride and HE. Additional potentially hazardous wastes or constituents not listed in logbook entries are expected to be present based on process knowledge. These materials, including barium, cadmium, chromium, lead, mercury, and silver, were used as shielding, solders, parts, or coatings. Other hazardous constituents, such as beryllium and copper, are listed in logbook entries. Volatile organic compounds (VOCs) are not listed in the logbook entries, but are detected in trace amounts in vapor-phase sampling at MDA H (e.g., LANL 2010, 111123). Radionuclides listed in or identified from the logbook entries include tritium, uranium-234, uranium-235/236, uranium-238, plutonium-238, plutonium-239/240, plutonium-241, and plutonium-242.

Much of the inventory at MDA H includes design-phase materials in the form of shapes, molds, modules, and mockups (Table B-1.0-1). One of the assumptions made and used to estimate the inventory is that strategic materials (e.g., beryllium) would have been used only in the final design stages of the research and development process. In initial design phases, the parts would have been constructed of cardboard or wood; in the second phase, they would have been constructed of metals, such as aluminum or steel; and in the final phase, the parts would have been constructed of DU or other strategic materials. The wood or cardboard would have been destroyed (i.e., burned), and the nonradioactive materials would have been recycled, leaving only the materials that were not easily recycled.

The total amount of uranium disposed of at MDA H is uncertain because descriptions of the individual isotopes are classified and because disposed of items listed as “shapes and parts” may be DU. Therefore, both upper-bound and best-estimate values were developed for the uranium inventory. The upper-bound value is the maximum quantity of uranium that could have been disposed of at MDA H, and the best-estimate value is the quantity of uranium that is believed to have been disposed of at MDA H.

The results of the inventory analysis for the corrective measures evaluation are summarized in Table 2.2-1.

B-1.1 Metals

The estimated amounts of metals disposed of at MDA H are based on (1) logbook entries, (2) interviews with site workers from MDA H and the facilities generating the wastes disposed of at MDA H, and (3) information about material excavated from the Classified Waste Landfill at SNL. The logbook information indicates that the classified objects disposed of at MDA H contained specific types of metals, but the logbook information does not list the actual quantities of metals or the composition of the objects. Therefore, metal quantities and the composition of metal-containing components excavated and recovered from the Classified Waste Landfill at SNL were reviewed to estimate metal quantities for aluminum, beryllium, cadmium, chromium, copper, lead, mercury, silver, and steel (Galloway 2001, 071343; Omicron 2003, 075940). The total mass of waste recorded at MDA H is 391,229 lb. A percentage of the total mass of waste disposed of in the shafts (based on programmatic differences between the two laboratories) was used to estimate a reasonable maximum mass of these specific metals disposed of at MDA H. Mass estimates are described below.

- Aluminum is listed in the MDA H inventory. It was used in large quantities for Los Alamos National Laboratory (LANL or the Laboratory) operations based on weight, cost, and ease of casting/machining. These same properties made aluminum easy to declassify and recycle. Most classified aluminum parts would not have been disposed of at MDA H, with the exception of parts that were contaminated. The mass of aluminum was increased to 15% of the total MDA H inventory (58,700 lb) based on the SNL inventory.
- Barium is not listed in the MDA H inventory. Based on process knowledge of Laboratory operations, barium is estimated to be present as 40% (5300 lb) of the mock/inert HE listed in the logbook.
- Beryllium is listed in the MDA H inventory. Beryllium was used in some classified shapes, although it is not listed as a component of the shapes in the MDA H inventory. Beryllium or beryllium alloys were recycled whenever possible; thus, limited quantities were estimated to have been disposed of at MDA H. The mass of beryllium was increased to 1.7% of the total inventory (6534 lb) based on process knowledge of Laboratory operations.
- Cadmium is not listed in the MDA H inventory. Based on process knowledge of Laboratory operations, cadmium was used in the form of coatings. Based on programmatic differences between the Laboratory and SNL operations, the mass of cadmium in the MDA H inventory is estimated to be 0.005% (20 lb) (Myers 2002, 073709).
- Chromium is not listed in the MDA H inventory. Based on process knowledge of Laboratory operations, chromium was used during plating of certain parts. The chromium/nickel mass in stainless steel was not included in the inventory because it is unavailable for environmental transport. The mass of chromium is estimated to be 0.5% (1960 lb) of the total MDA H inventory based on process knowledge of Laboratory operations.
- Copper is listed in the MDA H inventory. Copper was present in shapes, electrical components, and batteries based on process knowledge of Laboratory operations. Based on programmatic differences between the Laboratory and SNL operations, the estimated mass of copper was increased to 0.6% (2350 lb) of the MDA H inventory (Myers 2002, 073709).
- Lithium and lithium compounds are listed in the MDA H inventory. The mass of lithium and lithium compounds identified in logbook entries is 1.3% (4959 lb) of the total MDA H inventory. Lithium

compounds identified include lithium hydride (LiH), lithium fluoride (LiF), and lithium boride. The bulk of the lithium compounds are from a disposal of 4408 lb of "Lithium fluoride (LiF) [plastic-bonded explosive] PBX containing 86% LiF" (Omicron 2003, 075940). Based on process knowledge of Laboratory operations, lithium and lithium compounds could have been present in some of the parts as well as in samples. An additional 15 lb of LiH was added to the disposal made on December 18, 1981, according to a memorandum dated March 6, 1986 (Omicron 2003, 075940).

- Steel is listed in the MDA H inventory. Steel in all forms, such as alloys, was used in large quantities for Laboratory operations based on cost, availability, and ease of machining. These properties also made non-contaminated steel parts easy to declassify and recycle. Most classified steel parts, except those that were contaminated, would have been disposed of off-site. The mass of steel is estimated to be 40% (156,490 lb) of the total MDA H inventory based on the SNL inventory.
- Lead is not listed in the MDA H inventory. Based on process knowledge of Laboratory operations, lead was used in solders as well as in models to give density without adding a radioactive component. Lead would have also been used for shielding of high-energy particles. Non-contaminated classified lead parts would have been recycled whenever possible. The mass of lead is estimated to be 20% (78,250 lb) of the total MDA H inventory based on the SNL inventory.
- Mercury is not listed in the MDA H inventory. Based on process knowledge of Laboratory operations, mercury would have been present in electrical components and batteries. Based on programmatic differences between Laboratory and SNL operations, the mass of mercury is estimated to be 0.33% (1300 lb) of the total MDA H inventory (Myers 2002, 073709).
- Silver is not listed in the MDA H inventory; however, developed film is listed. Based on process knowledge of Laboratory operations, silver would have also been present in electrical or plated waste items disposed of at MDA H and is estimated to be 0.01% (39 lb) of the total MDA H inventory. Silver present in developed film is not readily available for release and environmental transport and would represent up to 3.1 wt% (1310 lb) of the film weight based on the assumption that industrial-type x-ray films were used.
- Tungsten is listed in the MDA H inventory. The mass of tungsten is identified in the logbook entries as 11,500 lb. Based on process knowledge of Laboratory operations, tungsten was used for tools and high-strength applications and is included in the steel estimate above.

B-1.2 High Explosives

The estimate of HE is based entirely on logbook entries. It was assumed that any HE-contaminated material in the logbook entries is residual contamination, representing no more than 1 wt% of the discarded HE-contaminated object before "flashing" (i.e., burning) of the object (LANL 2001, 071344). The common Laboratory practice (then and now) is to flash objects to remove unreacted explosives before disposal (LASL 1961, 030561). All HE-contaminated material recorded in the logbook was assumed to be contaminated with residual RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) because RDX was the most commonly used explosive during MDA H operations. In addition, the assumption that all HE is RDX is protective based on the relative mobility, persistence, and toxicity of this explosive compared with other conventional HE. The quantity of RDX estimated to exist from HE-contaminated material in the MDA H inventory is approximately 283 lb.

Only two logbook disposal entries (Table B-1.0-1) record the disposal of large quantities of HE at MDA H. Both disposals occurred in Shaft 3. The first logbook entry recorded is the disposal of 4408 lb of "lithium fluoride PBX … containing 14% RDX (powder form)" (LASL 1963, 073218). The second logbook entry reported 375 lb of "1 lot H.E. classif[ied] mat'l" waste was disposed of in Shaft 3. The second disposal is assumed to be 100% RDX. The total RDX for these two disposals is 992 lb. Thus, an estimated total of 1275 lb of RDX was disposed of in the MDA H shafts.

B-1.3 Plutonium

Three logbook entries (Table B-1.0-1) describe disposal of "shapes" (weapon molds/components) contained in drums contaminated with residual amounts of plutonium. A total of 300 lb of waste is listed in the MDA H logbook as "Pu contaminated." Inventory estimates of the amount and isotopic composition of the residual plutonium were based on the assumptions that (1) the plutonium contamination existed in the form of plutonium oxide (because plutonium readily oxidizes), (2) the amount of plutonium contamination was detectable by instruments in use at the time of disposal (with an assumed detection limit of 100 nCi/g), and (3) the isotopic ratio (plutonium-52) was that of the most common plutonium-contaminated waste disposed of at MDA G. (MDA G and MDA H received waste from the same technical areas [TAs], and this was the most prevalent plutonium material disposed of at MDA G for which accurate records exist.) Based on these assumptions, the maximum calculated total activity of plutonium at MDA H is approximately 0.014 Ci in the 300 lb of plutonium-contaminated waste disposed of in the shafts.

B-1.4 Tritium

The information in the logbook entries is not sufficient to accurately estimate the tritium inventory. Tritium disposed of at MDA H was most likely not disposed of as a gas, based on knowledge of its uses at the Laboratory and site operators' knowledge that tritiated wastewater at the Laboratory was adsorbed onto a solid matrix and disposed of at MDA G (Dickason 1960, 011514; LASL 1961, 030561). It is not anticipated that tritium is present as a solid (such as lithium tritide) at MDA H because it was both valuable and easily recoverable in its solid form. Therefore, the inventory is estimated to range between 3.5 and 167 Ci based on field data for tritium (LANL 2005, 089332, Appendix I) and not corrected for decay.

B-1.5 Uranium

Logbook entries describe DU in the form of shapes, molds, modules, mockups, and scrap. Most entries do not specify uranium mass or composition. Based on process knowledge of Laboratory operations, uranium-contaminated waste in the MDA H inventory includes the following isotopes: uranium-234, uranium-235/236, and uranium-238. Each radioisotope has different characteristics that are important in the context of potential long-term impacts. Most important is uranium-234, which decays over very long periods into radium, radon gas, and uranium-235. Naturally occurring uranium is mostly uranium-238 (>99%) with small amounts of uranium-235 (<1%) and even smaller amounts of uranium-234 (<0.01%). Enriched uranium (EU) has more uranium-235 than naturally occurring uranium; DU has less uranium-235 than naturally occurring uranium. EU is used in nuclear applications (e.g., fuel elements); DU (<0.72% uranium-235) is used for nonnuclear applications (e.g., weapon mockups).

Logbook entries list 93,000 lb of DU present in the MDA H inventory (24% of the total mass recorded at MDA H). Based on past disposal practices and engineering judgment, an upper-bound estimate was developed for DU because many of the entries for shapes and parts in the logbook could have been made from DU; however, material was not always specified in the logbook entry. Therefore, the estimated mass of DU was increased to 233,000 lb as an upper-bound estimate (80% of the mass associated with shapes, molds, modules, mockups, and scrap).

Logbook entries are not specific about the mass or composition of EU disposed of at MDA H. The three categories of EU that may have been disposed of at MDA H include EU, highly enriched uranium (HEU), and fuel elements. Based on process knowledge of Laboratory operations and the total mass listed in the logbook entries that may have contained EU/HEU, the best estimate for the quantity of EU/HEU was restricted to a maximum of 44 lb per disposal. The estimate of EU/HEU was also based on the pre-1964 quantities of HEU used per test in Appendix D of the Nuclear Weapons Databook (Cochran et al. 1987, 075921). This assumption is reasonable because criticality would have become a major concern at higher masses. The best estimate of EU/HEU is 1100 lb.

An upper-bound mass of EU/HEU was calculated to be 14,600 lb, based on the total mass of logbook entries that may have contained EU/HEU. The documented mass of these categories of waste was converted directly into activity of constituent uranium isotopes, using standard mass ratios for the different uranium material types. EU isotopic activity percentages were calculated to be 91.1% uranium-238, 8.7% uranium-235, 0.075% uranium-234, and 0.09% uranium-236 using mass percentage conversions from Taggart (1992, 070212). HEU isotopic activity percentages were found to represent a maximum of 93.3% uranium-235, 1.1% uranium-234, 0.2% uranium-236, and 5.4% uranium-238 (Haskin 1995, 070214). For the EU and HEU, a ratio of 95:5 EU to HEU was used to determine isotopic properties. This ratio is considered to be bounding because accountable HEU was significantly more valuable than EU and was easily recoverable.

Based on logbook entries, the upper-bound mass of fuel elements was estimated to be 17,700 lb, with the entire mass in the logbook entries assumed to be uranium. The composition of the fuel elements was assumed to be the same as EU for the upper-bound value. The best estimate of uranium mass in the fuel elements was based on the following assumptions.

- Fuel elements listed as “unloaded” were considered to have been emptied of uranium, thereby reducing the mass of fuel elements by 3400 lb.
- Cladding and associated hardware were 25% of the mass, thereby reducing the mass of the fuel elements by an additional 3600 lb.

The resulting best estimate of uranium mass of fuel elements is 10,700 lb. The best estimate and upper-bound values for the uranium inventory are listed in Table 2.2-1.

Based on the information provided in the MDA H disposal logbook (LASL 1960–1986, 070034), uranium fuel elements may have been irradiated in a neutron flux. However, because of the restrictions placed on the MDA H operations by the Laboratory’s SP-2 Group Office (the Laboratory security group responsible for MDA H at the time), the rules for accepting these materials at MDA H prohibited gram quantities of fissile materials. SP-2 worked with the Health Physics Group, H-1, to ensure that this requirement was met. Based on this restriction, only short-term irradiation could have been conducted without allowing the fuel elements to generate gram quantities of fissile material within the fuel elements.

B-1.6 Other Types of Waste

B-1.6.1 Graphite

Logbook entries (Table B-1.0-1) describe disposal of “graphite” shapes and scrap material. A total of 47,162 lb of waste containing graphite is listed in the MDA H logbook.

B-1.6.2 Mock/Inert HE

Logbook entries (Table B-1.0-1) describe disposal of “inert” (mock) shapes and scrap material. A total of 13,260 lb of mock/inert HE waste is listed in the MDA H logbook.

B-1.6.3 Paper

Logbook entries (Table B-1.0-1) describe disposal of “documents” because of either classification or their contamination by radioactive materials. A total of 755 lb of documents or paper waste is listed in the MDA H logbook.

B-1.6.4 Plastic

Logbook entries describe plastic in the form of shapes and scrap. Most entries do not specify mass or composition of the plastics. Plastics include materials such as film, magnetic media, slides, and other nonspecific plastic (such as polymers, foams, glues, epoxy resins, elastomers, rubber, etc.). A total of 54,461 lb of waste as plastic, including film (42,346 lb), magnetic media (4337 lb), slides (1223 lb), and other nonspecific plastic (6555 lb) is listed in the MDA H logbook.

B-1.6.5 Volatile Organic Compounds

VOCs are not listed in the logbook entries but are detected in trace amounts in vapor-phase sampling at MDA H (e.g., LANL 2010, 111123). The source of VOC vapors in the subsurface at MDA H is thought to be residual contamination from lubricants or cleaning solvents used on machined parts and minimal amounts of waste oil that potentially mixed with solvents (Omicron 2003, 075940). An estimate for the current-day mass of VOCs in the subsurface at MDA H, based on July 2010 vapor-sampling data, is presented in Appendix E. The estimated total mass of VOCs includes both liquid and vapor phases and is 4.6 lb. Most is associated with alcohols (approximately 69%) and ketones (approximately 24%). Less than 5% of the total estimated mass (approximately 0.22 lb) is associated with halogenated VOCs.

B-2.0 REFERENCES

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Table B-1.0-1
Disposal Records by Shaft

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
1	5-3-60	1344	Tungsten carbide	Tungsten carbide			1	1 ft × 1 ft × 1 ft	100	60.0	From storage in CMB-6
1	5-4-60	1345	SM		2	Truckload	1024	16 ft × 8 ft × 4 ft	12,575	58.8	From storage in Ice House
1	5-9-60	1346	Sleeve				1	1 ft × 1 ft × 1 ft	10	58.8	
1	5-23-60	1347	SM				1	1 ft × 1 ft × 1 ft	100	58.8	
1	5-27-60	1348	1 case, 2 carriers		1	Case	18	3 ft × 2 ft × 3 ft	300	58.1	
1	5-27-60	1348	1 case, 2 carriers		2	Carriers	18	3 ft × 2 ft × 3 ft	300		
1	6-14-60	1578	SP				0.125	6 in. × 6 in. × 6 in.	50	58.1	
1	6-21-60	None	S	Contamination (unknown type)			Negligible		Negligible	58.1	
1	6-22-60	1579	SM	Aluminum, graphite, plaster, phenolic, rubber			56	2 ft × 2 ft × 14 ft	1875	56.1	
1	7-7-60	1580	Scrap	Tungsten carbide and tungsten alloy	8	Boxes	21.875	12 1/2 in. × 10 1/2 in. × 36 in.	11,400	55.0	8 each boxes large size from SM-38 carpenter shop
1	7-7-60	1580	Scrap	Tungsten carbide and tungsten alloy	1	Box	12.7	21 1/2 in. × 20 in. × 7 ft1 in.	11,400		8 each boxes large size from SM-38 carpenter shop
1	8-1-60	1582	Film, x-ray	Film			60	5 ft × 4 ft × 3 ft	300	54.8	
1	8-2-60	1583	Film, x-ray	Film	33	Boxes	33 (2.625)	18 in. × 18 in. × 14 in.	6900	49.8	
1	8-2-60	1583	Film, x-ray	Film	33	Boxes	86.6	18 in. × 18 in. × 14 in.	6900		
1	8-2-60	1584	SM	Aluminum and steel			4.4	20 in. × 16 in. × 24 in.	100	49.7	
1	8-3-60		Alpha sources		2	Each				50.0	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
1	8-8-60	1590	Inert objects		26	Boxes	26 (1.7778)	16 in. × 12 in. × 16 in.	700	48.4	
1	8-8-60	1590	Inert objects		26	Boxes	46.2	16 in. × 12 in. × 16 in.	700		
1	8-16-60	1592	SM						20	48.3	
1	8-17-60	1594	Cones						100	48.2	
1	8-17-60	1594	SM						100		
1	8-17-60	1594	SM						100		
1	8-17-60	1595	SP		300	Grams			0.7	48.2	
1	8-29-60	1596	SM	Copper					5	48.2	
1	9-9-60	1586	SM				27		1000	47.2	
1	9-27-60	1352	SM		27	Pieces			975	45.9	
1	10-7-60	1354B	Cones						1	45.8	
1	10-7-60	1354B	Cylinders						1		
1	10-7-60	1354B	SM						1		
1	10-26-60	1361B	Film, radiographic	Film			25		1000	45.0	
1	12-15-60	1372B	SM						100	44.8	
1	1-16-61	1375B	Scrap pieces	D-38					69	44.7	
1	1-20-61	1375B	Scrap pieces	D-38					69		
1	1-23-61	1606B	Scrap	D-38					50	44.7	
1	1-24-61	1608B	SM						250	44.3	
1	2-21-61	1617B	Scrap pieces	D-38					50	44.2	
1	2-24-61	1619B	Scrap pieces	D-38					150	44.0	
1	2-24-61	1620B	Scrap pieces	D-38					75	43.9	
1	3-10-61	1876B	SP							43.9	
1	3-15-61	1878B	Cable harness assemblies						251	43.6	
1	3-17-61	1877B	SP						200	43.3	
1	3-20-61	1879B	Inert objects						350	42.8	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
1	3-21-61	None	Film	Film					2000	39.9	
1	3-29-61	1628B	Unit						1016	38.5	
1	4-4-61	1629B	SP				27		1000	37.5	
1	6-14-61	1708B	Film, x-ray	Film			8		325	37.3	
1	6-19-61	1709B	SP						5	37.3	
1	6-28-61	1891B	SP		19	Units			190	36.0	
1	7-25-61	2036B	Radioactive solid waste	Radioactive solid waste	7	Drums			638	35.4	
1	8-2-61		S	Film			1		35	35.4	
1	8-17-61	1893B	Radioactive solid waste, (from Silas Mason on RR-36734, 8/22/61)	Radioactive solid waste	2	Drums			90	35.3	
1	9-19-61	1894B	Film, x-Ray	Film			20		900	34.4	
1	9-27-61	2061B	SM						29,580	6.0	
2	10-17-61	2068B	SM						2655	55.8	
2	11-1-61	2040B	SM	D-38					240	55.5	
2	11-7-61	2041B	Scrap pieces	D-38					100	55.3	
2	11-17-61	2044B	Container	SS					20	55.3	
2	11-28-61	2076B	SM						10	55.3	
2	11-28-61	2080B	SM						25	55.2	
2	12-21-61	2081B	Assorted plastic parts	Plastic					4500	48.2	
2	2-20-62	2091B	Scrap pieces	D-38					300	47.7	
2	2-21-62	2095B	SM						200	47.4	
2	3-2-62	2100B	SM	D-38					100	47.3	
2	3-26-62	1856B	SM						50	47.2	
2	3-28-62	1861B	SM		1	Lot			3725	45.0	
2	3-28-62	1861B	X-ray film	Film	14	Boxes	35		1400	39.2	
2	3-28-62	1865B	Film, 16 mm	Film					10	39.2	
2	5-31-62	3078B	SM	D-38					400	38.5	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
2	6-6-62	3082B	Module, support blocks						15	38.5	
2	6-8-62	3083B	Scrap pieces	D-38					100	38.3	
2	6-27-62	3088B	SM						500	37.6	
2	6-27-62	3089B	Various components	Graphite					1000	36.0	
2	7-5-62	3094B	SM	D-38			4		175	35.8	
2	7-17-62	3097B	SM		1	Lot	160		3075	33.0	
2	7-17-62	3097B	X-ray film	Film	10	Box	160		3075		
2	8-3-62	3030B	SM	D-38	3	Barrels	6		225	32.8	
2	8-9-62	3033B	SM		5	Boxes			280	32.5	
2	8-17-62	3035B	X-ray film	Film	21	Boxes			2100	30.6	
2	8-22-62	3037B	Air masks, oxygen, not classified		4	Each				30.6	
2	9-4-62	3038B	SM	Graphite	1	Package			100	30.5	
2	9-5-62	3040B	SM		2	Pieces			1000	29.6	
2	9-12-62	3053B	SM		2	Pieces			150	29.5	
2	9-13-62	3054B	SM	Graphite	5	Barrels, packing			400	29.1	
2	9-20-62	3055B	Reflector cylinder	Graphite	1	Each			500	28.6	
2	9-25-62	3056B	Support disc		1	Each			1500	27.3	
2	9-28-62	3058B	SM		18	Each			200	27.1	TA-16-27
2	9-28-62	3058B	SM		4	Each			200	27.1	TA-16-10
2	10-12-62	3046B	SM		1	Box			100	27.0	
2	10-25-62	3061B	SM	D-38	3	Barrels, packing			400	26.6	
2	10-31-62	3063	SM	D-38	6	Barrels, packing			600	26.1	
2	11-16-62	3047B	Various components	Graphite	60	Pieces			3074	23.2	
2	11-16-62	3047B	Various components	Graphite	3	Boxes			3074	0.0	
2	11-29-62	3050B	SM		8	Drums			2099	21.3	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
2	11-29-62	3050B	SM		3	Boxes			2099	0.0	
2	12-4-62	3067B	Carriers		1	Lot			1575	19.9	TA-16, S-Site
2	12-4-62	3067B	SM		1	Lot			1575		TA-16, S-Site
2	12-4-62	3067B	Molds		1	Lot			1575		TA-16, S-Site
2	1-2-63	3068B	Carrying case		1	Each			1	19.8	
2	1-4-63	3069B	Film, x-ray	Film			50		1080	18.9	
2	1-22-63	2705B	SM	D-38 and scrap	2	Boxes			50	18.8	
2	2-5-63	2715B	Foils and prints		4	Boxes			200	18.6	
2	2-8-63	2718B	SM	Graphite	1	Box			5	18.6	
2	2-14-63	2720B	SM	Styrofoam	5	Boxes			20	18.6	
2	2-19-63	2780B	SM	D-38	6	Barrels, packing			400	18.2	
2	3-6-63	2777B	SP	Rubber	1	Each			5	18.2	
2	3-14-63	2779B	SM		1	Lot			7950	10.9	
2	3-22-63	2781B	SM	Cold and D-38	4	Boxes			150	10.8	
2	3-29-63	2784B	SM	D-38	2	Boxes			80	10.7	
2	3-29-63	2785B	SM	D-38	4	Drums			250	10.5	
2	3-29-63	2785B	SM	Aluminum	1	Drums			250		
2	4-2-63	2786B	Tubes	Aluminum	6	Tubes	0.153	56 in. × 1 in.	5	10.5	
2	4-2-63	2786B	SM	Graphite					5		
2	4-4-63	2787B	SP		1	Lot			15	10.5	
2	4-5-63	2789B	SM	D-38	4	Drums			225	10.2	
2	4-16-63	2792B	SP	Graphite	5	Boxes			200	10.1	
2	5-9-63	2151B	X-ray film	Film	1	Lot			4350	6.1	
2	5-9-63	2151B	SM		1	Lot			4350		
2	5-15-63	2155B	D-38 and cold stock	D-38 and cold stock	2	Boxes			68	6.0	
3	6-4-63	2156B	1 unit		1	Drums			250	59.7	55 gal
3	6-5-63	2157B	Lithium fluoride PBX	Lithium fluoride PBX					4408	53.6	
3	6-10-63	2158B	D-38	D-38	4	Package			185	53.3	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
3	6-24-63	2162B	S/N Units		13	Each			100	53.2	
3	7-1-63	2164B	SM	D-38 graphite					400	52.6	
3	7-1-63	2165B	SM	D-38 graphite	3	Boxes			100	52.5	
3	7-3-63	2166B	SM	D-38	18	Barrels, packing			2125	49.6	
3	7-16-63	2816B	SM		1	Box			25	49.5	
3	7-16-63	2817B	SM		38	Each			1475	47.5	
3	7-17-63	2712B	Tank, "Cambridge Corp.", Model A S/N-B-30116		1	Each			2500	44.1	
3	7-24-63	2102B	Slides	Glass	92 (total)	Each			10	44.1	
3	7-24-63	2102B	Slides	Glass	67	Each		3 1/4 × 4 in.	10		
3	7-24-63	2102B	Slides	Glass	25	Each		4 in. × 5 in.	10		
3	7-31-63	2819B	SM		2	Cans			250	43.7	
3	8-1-63	2103B	Film, x-ray (60 each cartons)	Film	2	Lots			3300	39.2	
3	8-23-63	2105B	Film, x-ray (56 each cartons)	Film	2	Lots			2800	35.3	
3	8-23-63	2821B	SM						400	34.8	
3	8-23-63	2822B	SM						35	34.7	
3	8-27-63	2107B	SM	Aluminum and SS	1	Unit			1200	33.1	
3	8-27-63	2107B	SM	D-38	1	Unit			1200		
3	8-28-63	2823B	SM	D-38	2	Boxes			95	32.9	
3	9-6-63	2824B	SM	Beryllium	1	Box			13	32.9	
3	9-16-63	2108B	Modules, unfinished, tie rod	D-38					195	32.7	
3	9-17-63	2825B	S/N units		6	Each			100	32.5	
3	9-17-63	2825B	SP		1	Box			100		
3	9-18-63	2177B	SP	Graphite	1	Lot			150	32.3	
3	9-20-63	2110B	SM	Beryllium	1	Lot			25	32.3	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
3	9-20-63	2178B	SM	Graphite and metal	1	Box			10	32.3	
3	9-26-63	2126B	SM		2	Boxes			25	32.2	
3	9-27-63	2179B	SM	Metal	1				350	31.8	
3	9-30-63	2180B	SP	HE	1	Lot			375	31.2	
3	10-1-63	2181	SP		14	Each			1	31.2	
3	10-2-63	2127B	Film x-ray	Film	31	Box			1500	29.2	
3	10-17-63	2128	SM		41	Each			250	28.8	
3	11-13-63	2184	SM		1	Box			150	28.6	
3	11-13-63	2187	SM		1	Package			125	28.4	
3	11-13-63	2187	SM		2	Boxes			125		
3	12-4-63	2190	SM	Metal	1	Lot			900	27.2	
3	12-4-63	2190	SP	Film	6	Boxes			900		
3	1-10-64	2194	SM		3	Boxes			207	26.9	
3	1-16-64	2197	SM		2	Each			7	26.9	
3	1-29-64	2129	SP	Film	9	Cartons			300	26.5	
3	2-11-64	2143	SM	D-38	15	Drums			1400	24.6	
3	2-11-64	2182	Y tubes		1	Lot			75	24.5	
3	2-11-64	2182	Serial numbered items		19				75		
3	2-14-64	2146	SM	D-38	6	Drums			342	24.0	
3	3-6-64	2150	SM	D-38	41	Each			2000	21.2	
3	3-23-64	2119	SM	Titanium and steel	10	Each			25	21.2	
3	3-24-64	2120	SP	Graphite	3	Boxes			200	20.9	
3	5-7-64	2135	SP	HE contaminated	1	Lot			600	20.1	
3	5-14-64	2476	SM	D-38 and cold stock	2	Package			200	19.8	
3	5-14-64	2476	SM	D-38 and cold stock	2	Boxes			200		
3	5-15-64	2174	SP	Graphite	3	Boxes			75	19.7	
3	5-21-64	2478	SP		1	Box			25	19.7	
3	5-27-64	2479	SP	Graphite	13	Boxes			400	19.1	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
3	6-11-64	2352	SP	Aluminum	1	Lot			150	18.9	
3	6-15-64	2353	SP	Graphite	l	Lot			1000	17.6	
3	6-23-64	2134	SM		7	Each			465	16.9	
3	7-13-64	2482	SM		1	Package			10	16.9	
3	7-21-64	2483	SM		2	Boxes			400	16.4	
3	7-24-64	2487	SM	Steel and aluminum	6	Boxes			300	15.9	
3	7-27-64	2357	SP	Film	6	Boxes			700	15.0	
3	7-27-64	2488	SP		4	Drums			300	14.6	
3	8-4-64	2490	SP		2	Drums			200	14.3	
3	8-4-64	2491	SP		1	Lot			250	13.9	
3	10-14-64	2533	Fuel elements	Fuel elements	2	Package			75	13.8	
3	10-23-64	2537	Unloaded fuel elements	Fuel elements, unloaded	1	Box			30	13.8	
3	10-30-64	2538	Scrap	Graphite	l	Lot			200	13.5	
3	11-5-64	2542	SP	Graphite	1	Package			5	13.5	
3	11-6-64	2541	SP		1	Each			400	13.0	
3	11-11-64 and 11-12-64	2545	SP	Graphite					3500	8.2	
3	11-12-64	2544	SM	D-38					200	7.9	
3	11-16-64	2547	SP	HE contaminated					1200	6.2	
3	11-19-64	2550	Fuel elements	Fuel elements					150	6.0	
4	12-23-64	2557	SP		1	Box			15	60.0	
4	1-6-65	2560	SP		2	Lots			350	59.4	
4	1-19-65	2563	SP	Graphite	9	Drums			1000	57.9	
4	1-20-65	2564	Cold stock and D-38	Cold stock and D-38	5	Containers			250	57.6	
4	1-27-65	2567	SP	D-38, lithium, etc.	1	Lot			75	57.4	
4	2-18-65	2367	X-ray film, 15 cartons	Film	1	Lot			500	56.7	
4	3-1-65	2583	SP		1	Lot			10	56.7	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
4	3-5-65	2587	Hedgehog train units and detonators	Detonators	1	Lot			600	55.8	
4	3-23-65	2593	SP		1	Lot			350	55.2	
4	4-6-65	2597	SP	Graphite	4	Drums			350	54.7	
4	4-6-65	2599	Cold stock and D-38	Cold stock and D-38	1	Lot			400	54.1	
4	4-16-65	3352	SP		1	Box			75	54.0	
4	5-4-65	3362	SP		1	Lot			250	53.6	
4	5-5-65	3364	Fuel elements	Fuel elements	8	Bundles			100	53.4	
4	5-20-65	3356	X-ray film	Film	31	Boxes			1700	50.9	
4	5-29-65	3357	SP	Graphite	1	Lot			200	50.6	
4	7-14-65	3372	SP	Graphite	3	Boxes	6		120	50.4	Trash boxes
4	7-14-65	3375	SP		5	Drums			380	49.8	
4	7-15-65	3374	Ring and slug assemblies		1	Drums	7.35		750	48.7	55-gal. drum
4	7-20-65	3377	SP		1	Lot			2000	45.6	
4	7-21-65	3359	Graph and D-38	Graph and D-38	8	Boxes			50	45.6	
4	8-10-65	3378	SP	Contains U-235	2	Boxes	1		250	45.2	
4	8-18-65	3382	Tritium cont	Tritium cont	1	Unit	0.5		15	45.2	
4	8-25-65	3360	SP		6	Units			50	45.1	
4	9-3-65	3384	Cold scrap and D-38	Cold scrap and D-38	6	Boxes			250	44.7	
4	9-20-65	3386	Photos	Film	5	Boxes			100	44.6	
4	9-20-65	3386	Fuel elements	Fuel elements	5	Boxes			100		
4	9-23-65	3388	SP		1	Lot			150	44.3	
4	9-30-65	3391	SP	Tritium cont	2		0.5		20	44.3	
4	10-1-65	3392	SP		11	Boxes			175	44.0	
4	10-14-65	3393	SP	HE contaminated	1	Load			3850	38.2	
4	10-25-65	3394	Fuel elements (unloaded and D-38)	Fuel elements (unloaded and D-38)	1	Lot			850	36.9	
4	10-26-65	3502	SM	SS- Be	2	Drums	7.35		100	36.8	25-gal. drums

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
4	11-4-65	3395	SP		1	Truckload			2500	33.0	
4	11-17-65	3397	SP	Magnesium	2	Each			3	33.0	
4	11-23-65	3398	Unload fuel elements (scrap)	Fuel elements, unload	9	Containers			100	32.8	
4	11-23-65	3399	SP		4	Boxes			250	32.5	
4	11-23-65	3503	SM	D-38	2	Drums			175	32.2	
4	1-5-66	3504	SM		2	Drums			100	32.0	
4	1-5-66	3504	SM		1	Box			100		
4	1-28-66	3426	Cold stock and D-38	Cold stock and D-38	4	Boxes			150	31.8	
4	1-28-66	3427	Fuel elements	Fuel elements	5	Boxes			250	31.4	
4	1-28-66	3428	S	Contaminated	3	Boxes	1.5		75	31.3	
4	1-28-66	3430	SM	Tritium	2 1	Boxes box			30	31.3	From TA-41
4	2-4-66	3433	Unloaded fuel elements	Fuel elements, unloaded	3	Boxes			100	31.1	
4	2-18-66	3435	SP	HE cont	1	Truckload			2900	26.7	
4	2-25-66	3436	Fuel elements (unloaded) and scrap	Fuel elements, unloaded	5	Boxes			225	26.4	
4	2-25-66	3437	SP		2	Boxes			75	26.3	
4	3-1-66	3438	SP	Graphite	4	Drums			400	25.7	
4	3-10-66	3441	Fuel elements - unloaded	Fuel elements, unloaded	9	Each			20	25.6	
4	4-4-66	3509	Keys		1	Box			100	25.5	
4	4-6-66	3446	S	Paper	5	Plastic bag					
4	4-12-66	3448	SP		15	Boxes			450	24.8	
4	4-13-66	3508	Radiographic film	Film	12	Cartons	96		3000	20.3	
4	4-21-66	3447	SP	Graphite	15	Drums			1500	18.0	
4	5-2-66	3449	Fuel elements - scrap	Fuel elements	9	Boxes			750	16.9	
4	5-4-66	3450	SM		2	Drums			75	16.7	
4	5-5-66	3451	Miscellaneous scrap		5	Boxes			250	16.4	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
4	5-31-66	3453	SM	Tritium cont	1	Each	0.1		15	16.3	
4	5-31-66	3455	SM		10	Drums			500	15.6	
4	6-2-66	3454	SM		2	Drums			100	15.4	
4	6-15-66	3510	Scrap	D-38	9	Bundles			250	15.0	
4	6-15-66	3510	Scrap	D-38	4	Boxes			250		
4	6-22-66	3457	Radiographic film	Film	118	Boxes			4120	8.8	
4	6-22-66	3458	SM	Aluminum and D-38	1	Drums			25	8.8	
4	6-24-66	3459	SM		2	Boxes			650	7.8	
4	7-28-66	3513	Module clamps		1	Box			75	7.7	
4	8-9-66	3462	SM	Lithium hydride	8	Boxes			400	7.1	
4	8-16-66	3463	Cold stock and D-38	Cold stock and D-38	3	Boxes			200	6.8	
4	8-16-66	3464	SM		7	Boxes			250	6.4	
4	8-29-66	3407	SM		11	Boxes			255	6.0	
5	10-7-66	3467	SM	Graphite	6	Drums			620	59.4	
5	10-13-66	3468	Unloaded fuel elements	Fuel elements, unloaded	5	Boxes			200	59.2	
5	10-13-66	3470	SM	D-38, SS, and aluminum	3	Drums			80	59.1	
5	10-13-66	3869	Unloaded fuel elements and scrap	Fuel elements, unloaded	14	Boxes			525	58.6	
5	11/66	3533	Glass-mounted slides		1	Lot			700	57.9	
5	11-9-66	3473	SP		1	Lot			600	57.3	
5	12-1-66	3497	SP	Graphite					1000	56.3	Conf. R.D.
5	12-2-66	3474	SM	D-38					25,925	30.7	
5	12-6-66	3521	SM						350	30.3	
5	12-14-66	2499	SM						75	30.2	
5	12-14-66	3500	SM	D-38					10	30.2	
5	12-15-66	3527	SM						360	29.9	
5	12-19-66	3475	SM		1	Box			175	29.7	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
5	12-19-66	3528	D-38 impregnated fuel elements	Fuel elements, D-38 impregnated	10	Boxes			200	29.5	
5	12-19-66	3529	Unloaded fuel elements	Fuel elements, unloaded	3	Boxes			150	29.4	
5	1-12-67	3532	Fuel elements	Fuel elements	1	Box			30	29.3	
5	1-16-67	3585	Unloaded fuel elements	Fuel elements, unloaded	3	Each			5	29.3	
5	1-26-67	3524	SM	HE contaminated					400	28.9	
5	1-27-67	3587	SM	Graphite					3	28.9	
5	1-30-67	3538	SM						15	28.9	
5	2-3-67	3540	SM	S/Ns					174	28.7	
5	2-27-67	3525	SM	Graphite					3300	25.5	
5	2-28-67	3544	Records	Pu contaminated					25	25.5	
5	4-12-67	3547	Cold scrap and D-38	Cold scrap and D-38	9	Boxes			325	25.1	
5	4-19-67	3551	SM	Aluminum, SS, titanium	1	Lot			400	24.7	
5	4-24-67	3552	Fuel elements, unloaded and 38	Fuel elements	6	Each			10	24.7	
5	4-28-67	3591	Scrap fuel elements	Fuel elements	13	Cartons			410	24.3	
5	5-5-67	3592	Unloaded fuel elements	Fuel elements, unloaded	4	Cartons			160	24.2	
5	5-10-67	3553	SM		1	Lot			150	24.0	
5	5-15-67	3554	SM	D-38	4	Drums			180	23.8	
5	5-19-67 thru 6-8-67	3566	Obsolete reactor parts and hardware						10,655	13.3	
5	6-15-67	3560	SM	Fuel elements	7	Boxes			225	13.1	
5	7-18-67	3562	SM		1	Lot			600	12.5	
5	9-6-67	3567	SM	Graphite	8	Boxes			400	12.1	
5	9-7-67	3568	SM	Depleted uranium	1	Lot			250	11.8	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
5	9-20-67	3570	Unloaded fuel elements	Fuel elements, unloaded	11	Boxes			660	11.2	
5	9-27-67	3572	SM	HE contaminated	1	Lot			5200	6.0	
5	11-11-67	3531	Fuel elements and modules, unloaded and D-38	Fuel elements, unloaded and D-38	1	Lot			35	6.0	
6	7-12-67	6550B	SM		1	Lot			2575	56.2	
6	10-9-67	6478	SM	HE cont	2	Loads			18,425	28.6	
6	10-17-67	6477	Mounted slides	Glass	4	Boxes			50	28.5	
6	10-26-67	3573	SM		2	Drums			250	28.2	
6	11-10-67	6481	SM		8	Boxes			175	27.9	
6	11-10-67	6482	SM		1	Lot			150	27.7	
6	11-16-67	3574	Scrap	Graphite	4	Drums			400	27.1	
6	12-1-67	3575	Graphite fuel elements	Fuel elements, graphite	6	Boxes			275	26.7	
6	1-16-68	2524	Cold scrap and D-38	Cold scrap and D-38	9	Bundles			600	25.8	
6	1-16-68	2524	Cold scrap and D-38	Cold scrap and D-38	5	Boxes			600		
6	1-16-68	6530	Scrap	D-38 graphite	6	Drums			450	25.1	
6	1-18-68	6582	SM		1	Garbage can			100	25.0	
6	2-7-68	None	SM		3	Boxes			80	24.8	
6	2-20-68	6535	SM		12	Drums			1500	22.6	
6	2-20-68	6536	SM		13	Boxes			550	21.8	
6	2-27-68	6537	SM	HE cont	1	Box			25	21.7	
6	2-27-68	6538	SM	HE cont	1	Truckload			2425	18.1	
6	3-8-68	6542	SM		6	Drums			200	17.8	
6	4-17-68	6545	SM		3	Boxes			125	17.6	
6	5-7-68	6492	Fuel elements, 500 each	Fuel elements	18	Boxes			1000	16.1	
6	5-8-68	6546	SM	D-38	4	Drums			75	16.0	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
6	5-8-68	6546	SM	D-38	2	Cans			75		
6	5-23-68	6495	Shells - expended - mortar		4	Each			20	16.0	
6	5-24-68	6551	SM	Aluminum	42				225	15.7	
6	7-10-68	6549	Unloaded fuel elements	Fuel elements, unloaded	9	Boxes			475	14.9	
6	7-16-68	6301	SM						40	14.9	
6	7-22-68	2525	Cold scrap and D-38	Cold scrap and D-38	12	Bundles			1000	13.4	
6	7-22-68	2525	Cold scrap and D-38	Cold scrap and D-38	6	Boxes			1000		
6	8-1-68	6554	Depleted uranium	Depleted uranium	11	Drums			513	12.6	
6	8-1-68	6551A	SP		1	Box			30	12.6	
6	8-8-68	6555B	SP		1	Box			30	12.5	
6	8-29-68	6304	SP	Containing D-38	4	Drums			500	11.8	
6	9-23-68	6305	SP		1	Lot			100	11.6	
6	12-3-68	6307	SM	Metal	2	Each			500	10.9	
6	12-17-68	6308	SM	Aluminum, SS, Tuballoy					225	10.6	
6	12-17-68	6309	SM	SS, copper, beryllium					75	10.4	
6	1-13-69	6564	Fuel elements	Fuel elements	15	Boxes			900	9.1	
6	1-31-69	6566B	Documents		1	Box			35	9.0	
6	2-5-69	6567B	SM		3	Drums			750	7.9	
6	2-12-69	6311	SM	HE cont					1000	6.4	
6	2-25-69	6312	Scrap fuel elements	Fuel elements	1	Lot			75	6.3	
6	2-25-69	6313	SM						200	6.0	
6	3-6-69	6314	S	Glass					10	6.0	
7	3-20-69	6316	SM	D-38					10	60.0	
7	3-21-69	6317	SM	D-38 and cold stock and D-38					325	59.5	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
7	3-21-69	6318	Obsolete parts						200	59.3	Part of GMX-7 material disposed of in Hot Dump
7	3-27-69	6319	Cold stock and D-38	Cold stock and D-38		Can			500	58.6	
7	4-4-69	6320	Miscellaneous scrap	60 kg D-38					250	58.2	
7	4-7-69	6321	SM						150	58.0	
7	4-29-69	6570	Fuel elements	Fuel elements					500	57.3	
7	6-13-69	6876	S	Film	8	ft				57.3	
7	6-18-69	6322	Scrap	D-38					750	56.3	
7	7-3-69	None	Obsolete, damaged, etc., seals (government security)						125	56.1	
7	8-5-69	6881	SP						6575	46.9	
7	8-19-69	None	Obsolete, damaged, etc., seals (government security)						25	46.9	
7	8-29-69	6325	SM		3	Drums			150	46.7	
7	9-19-69	6885	SP	Fuel elements, graphite	7	Boxes			500	46.0	
7	9-19-69	6886	SP	Fuel elements, graphite	1	Package			35	45.9	
7	9-25-69	6887	Machine gun, spare barrels, and other components						25	45.9	
7	9-30-69	6858	S						20	45.9	
7	10-1-69	6883	SM	Beryllium					25	45.8	
7	10-3-69	6889	SP	Plastic	3	Boxes			150	45.6	
7	10-9-69	6888	Samples	D-38 etc.					1753	43.2	
7	10-23-69	6891	SM		1	Lot			1000	41.8	
7	10-26-69	6894	SM	Pu contaminated	4	Drums			100	41.7	
7	11-14-69	6895	GBV		8	Units			5	41.7	
7	11-26-69	6897	SM	Pu contaminated	7	Drums			175	41.4	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
7	12-18-69	6899	SM	Graphite D-38	1	Lot			400	40.9	
7	12-24-69	6900B	Slides - #635262, 65, 68, and 70		1	Box			5	40.9	
7	1-9-70	6926B	Data processing sheets		1	Box			20	40.8	
7	1-9-70	6927B	SP	Graphite	2	Boxes			200	40.5	
7	1-9-70	6928B	S		1	Box			20	40.5	
7	1-9-70	6929B	SM	D-38 and other	5	Drums			200	40.2	
7	1-19-70	6930B	Shredded drawings		1	Lot			150	40.0	
7	1-19-70	6931B	SP		1	Each			150	39.8	
7	1-19-70	6932B	Tubes		8	Each			5	39.8	
7	2-3-70	6862B	SP	Graphite					1000	38.4	
7	2-10-70	ó	SP		2	Boxes			40	38.4	
7	2-18-70	6936B	SP	Steel and copper	4	Boxes			150	38.2	
7	2-18-70	6936B	SP		4	Boxes			150		
7	2-19-70	6454	SP		1	Lot			3000	34.0	
7	2-19-70	6454	Vessels		13	Each			3000		
7	3-6-70	6942	SP	Fuel elements, graphite	3	Lots			7675	23.3	
7	3-12-70	6865	SP	HE contaminated					500	22.6	
7	3-16-70	6939	SM	D-35	6	Boxes			150	22.4	
7	3-19-70	6941	Slides, mounted	Glass	5	Each			5	22.4	
7	3-19-70	6943	SP		1	Lot			600	21.6	
7	4-6-70	6945	Lantern slides		35	Each			5	21.5	
7	4-7-70	6946	SP	Fuel elements, graphite	20	Boxes			800	20.4	
7	4-7-70	6947	SP		3	Drums			150	20.2	
7	4-7-70	6947	SP		1	Box			150		
7	4-15-70		Mounted slides, etc.	Glass					25	20.2	
7	4-20-70	6948	SP						350	19.7	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
7	5-8-70	6820	SP		1	Each				19.7	
7	5-8-70	6869	SP		2	Barrels			1000	18.3	
7	5-11-70	6870	Keys and cores	Keys and cores	1	Lot			275	17.9	
7	5-20-70	6906	SP		1	Each			1377	16.0	
7	5-25-70	6457	SP		5	Each			35	16.0	
7	7-8-70	6907	SP		1	Each			10	15.9	
7	7-22-70	6909	SP	Lithium hydride	2	Containers			1	15.9	
7	8-4-70	6954	Magnetic tape recordings		8	C/B boxes			200	15.7	
7	8-5-70	6913	SP	HE contaminated	1	Lot			2075	12.8	
7	9-17-70	6957	X-units with load coil assemblies		86	Each			2150	9.8	
7	9-29-70	6458	SP		3	Boxes			100	9.6	
7	10-23-70	6459	Transmitters, receivers, covers, and miscellaneous items						150	9.4	
7	11-10-70	6917	Klystrons		3	Each			5	9.4	
7	12-11-70	6964	SP		1	Garbage can			100	9.3	
7	1-29-71	6965B	Slides and signs		1	Lot			5	9.3	
7	1-29-71	6966B	Slides and negatives		1	Lot			25	9.3	
7	2-17-71	3183B	SP						25	9.2	
7	2-19-71	6976B	Scrap fuel elements (unloaded)	Fuel elements, (unloaded)					50	9.1	
7	2-19-71	6976B	Radiographic plates						50		
7	4-1-71	3412B	SP	Inert HE	1	Lot			1600	6.9	
7	5-10-71	3414B	SP		1	Box			75	6.8	
7	5-11-71	3413B	Test sets		18	Each			25	6.8	
7	6-4-71	3418B	Slides (Jane Hall collection)		1	Lot			40	6.7	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
7	8-24-71	6464B	Squibs and miscellaneous items		1	Lot			500	6.0	
7	9-8-71	5804B	SP		1	Lot			20	6.0	
8	10-4-71	5810B	SM	Steel	1	Box			40	59.9	
8	11-22-71	6467	SM		7	Each			100	59.8	
8	11-22-71	5814B	Source, dummy neutron		3	Each				59.8	
8	12-3-71	5816	SP	HE contaminated	1	Load			5475	52.1	
8	12-6-71	5815	SP		2	Garbage can			75	52.0	
8	3-22-72	5857	SP		1	Box			20	52.0	
8	3-24-72	5858	S	Paper	1	Box			50	51.9	
8	4-7-72	5859	Recorder charts and paper		3	Boxes			50	51.9	
8	5-12-72	5864	SP		3	Garbage can			200	51.6	
8	5-31-72	5865	S		1	Box			50	51.5	Contaminated by association with U-235
8	7-13-72	5875	S		36	Each			3	51.5	
8	8-7-72	5655	SP		1	Lot			75	51.4	
8	8-15-72	5656	SP		1	Lot			2060	48.5	Possible declassified
8	8-15-72	5656	Load rings and components		1	Lot			2060		Possible declassified
8	8-30-72	5657	Mylar tape	Mylar	1	Box			10	48.5	
8	8-30-72	5658	SP		2	Boxes			15	48.5	
8	9-25-72	5662	SP		5	Boxes			150	48.3	
8	11-9-72	5666	SM		3	Cans	14.0		400	47.7	35 gal.
8	11-15-72	5670	Voice tapes (recordings)		64	Rolls			75	47.6	
8	1-29-73	6256	Slides (negatives)	Film	11	Each		4 in. × 3 1/4 in.	1	47.6	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
8	2-21-73	3189	Miscellaneous metal parts		1	Lot			500	46.9	
8	3-2-73	6992	Analogue computer tapes	Computer tape	1	Lot			1200	45.2	
8	3-6-73	7260	SP		11	Boxes			300	44.8	
8	3-14-73	7264	SP		1	Lot			150	44.6	
8	3-28-73	7265	SP.		1	Lot			150	44.4	
8	4-13-73	3190	Silos, remnants of silo program		16	Each			15	44.4	
8	4-13-73	7267	S		1	Lot			60	44.3	
8	4-24-73	3191	SP		9	Each			300	43.8	
8	4-24-73	3191	Silo parts display		1	Each			300		
8	4-24-73	3191	SP		1	Container			300		
8	7-20-73	7357	SP		1	Lot			150	43.6	
8	7-26-73	7355	SP		1	Lot			50	43.6	
8	8-10-73	7358	Classified neg. slides (S-RD) per CD #61		8	Each			1	43.6	
8	10-18-73	7366	S		22	Each				43.6	
8	11-2-73	7362	Lithium boride material	Lithium boride	3	Cans	0.40		10	43.6	1 gal., metal
8	11-14-73	7367	Dies, pressing, LASL drawing # Y-4187-D		2	Units			80	43.4	
8	2-28-74	6473	1A and 1J valves (uncl.)		63	Each			300	43.0	
8	2-28-74	6473	SP		16	Each			300		
8	3-26-74	7372	SP		1	Lot			250	42.7	
8	5-10-74	7375	SP	Metal	1	Lot			20	42.6	
8	6-27-74	7333	SP		1	Lot			4175	36.8	
8	7-12-74	7331	S		3	Each			1	36.8	
8	7-16-74	7335	S		1	Lot			15	36.8	
8	7-16-74	7335	S		1	Lot			15		

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
8	8-8-74	6580	SP		1	Each			50	36.7	
8	9-11-74	6584	Part S/N 874A13-002		1	Each			5	36.7	
8	9-11-74	6584	Miscellaneous parts		1	Box			5		
8	9-24-74	7000	SP		3	Each			25	36.7	
8	9-30-74	7341	SP		1	Lot			10	36.6	
8	2-7-75	7285	SP	Lithium samples	74	Each			50	36.6	
8	4-24-75	7287	SP		6	Boxes			430	36.0	
8	5-16-75	7293	SP		56	Each			15	35.9	
8	9-23-75	8130	SP		1	Load			3000	31.7	
8	8-3-76	8149	SP		1	Lot			30	31.7	
8	8-23-76	7307	SP		1	Lot			1500	29.6	
8	10-1-76	7310	SP		1	Lot			5800	21.5	
8	11-16-76	7308	SP		1	Lot			2600	17.8	
8	11-16-76	7309	SP		1	Lot			3700	12.6	
8	11-16-76	7309	File safe, CL, 04D Legal, (LASL P/N 139515)	File safe	1	Each			3700		
8	12-14-76	7314	SP		2	Boxes			65	12.6	
8	9-29-77	8989	SP		1	Lot			2575	8.9	
8	7-10-79	9305	SP		5 ea.	Drums, metal			2000	6.1	
8	7-10-79	9305	SP		5 ea.	Drums, metal			2000		
8	7-16-79	9306	Part No. 422212		5	Each			100	6.0	
8	7-16-79	9306	Part No: 422213		5	Each			100		
9	7-23-80	9310	SP						70	59.9	
9	7-23-80	9311	SP						150	59.7	
9	7-23-80	9314	SP						300	59.2	
9	7-21-81	9036	SP						200	58.9	
9	12-8-81	9309B	SP						100	58.8	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
9	12-8-81	9318B	SP	LiH- 10g (+), Be – unknown amount, D-38 – unknown amount					15	58.7	From C&D information, 15 lb of LiH added based on Memorandum HSE7-86-78
9	12-8-81	9321B	SP	File system cartridges						58.7	From C&D information
9	1-19-82	9051B	SP						200	58.5	
9	1-21-82	9322B	SP						1000	56.9	
9	1-25-82	9052	SP						5810	48.1	
9	4-13-82	9023	SP								
9	4-13-82	9324B	SP						4000	42.1	
9	4-13-82	9325B	SP						4000	36.0	
9	8-17-82	9056B	SP						250	35.6	
9	1-5-83	9337B	SP	From C&D information –unknown from TA-41 - #W30					500	34.8	
9	6-8-83	9341B	SP	From C&D information Be					Unknown	0.0	
9	6-17-83	9343B	SP	From C&D information Be sample					Unknown	0.0	
9	10-16-84	12532	SP						5000	27.3	
9	1-8-85	12378	Computer tape—degaussed [3]	Computer tape			60		300	26.8	
9	1-31-85		6-drawer file with combo locks	File safe	1	Box			250	26.4	
9	1-31-85		Combination locks		1	Box			250		
9	2-28-85		Keys and cores	Keys/cores			2	~1 or 2 ft^3	75	26.3	
9	3-18-85	11707, 13290	Computer tape degaussed – 3 tapes/sack (50 lb per sack)	Computer tape	21	Sacks		15 in. × 7 in.	1000	24.8	

Table B-1.0-1 (continued)

Shaft No.	Date	Form 252-R	Nomenclature and/or Description	Materials	Quantity	Unit of Measure	Volume (ft^3)	Dimensions	Weight (lb)	Depth in Shaft*	Remarks
9	3-20-85	11882	Al_20_3 and SS parts - in sack	Al_20_3 and SS			1.337		40	24.7	10-gal. drum
9	9-24-85	9170B	S		7	Envelopes			141	24.5	
9	10-17-85	13375B	Computer disk packs—digital RPO6	Computer disk pack	16				80	24.4	
9	12-24-85		Keys, cores, locks	Keys and cores			6		400	23.8	
9	1-15-86		3 drawers (file) with boxes of combo locks	File and locks			10		200	23.5	~ 8–10 ft^3
9	3-25-86	12383B	Graphite w/motor oil	Graphite with motor oil	3	Drums	1.47		40	23.4	11 gal.
9	4-7-86	13310	Computer disk packs, disk pack platters	Computer disk pack						21.9	
9	4-7-86	13311	Computer disk packs, disk pack platters	Computer disk pack					1000		
9	5-8-86	12382	Computer disk pack	Computer disk pack			1		7	21.9	
9	7-22-86	10087	Computer disks pack, disk pack platters	Computer disk pack			90		200	21.6	
9	8-29-86	10088	Computer disk pack	Computer disk pack	4	Bags	8		200	21.3	

Notes: Blank cells indicate not recorded. S = scrap, SM = scrap metal, SP = scrap pieces, SS = stainless steel, D-38 = depleted uranium, cold stock = nonradioactive materials, S/N = serial number or part number.

*Depth is based on average densities. Location within shafts is approximate based on mass except when known (measured) depths have been included for shafts 1 and 2.

Appendix C

Characteristics of Disposed Waste and Their Effect on Remediation Alternatives

SME Review and Assessment of MDA H Waste Characteristics on Site Closure

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Background

The question of uranium metal and/or high explosive (HE) instability (e.g. pyrophoricity[1] and deflagration/detonation[2], respectively) has been raised regarding potential risks during environmental remediation activities at the MDA-H disposal site. Such remediation activities could include jet grouting, in situ vitrification, in situ thermal treatment, excavation, and/or surface work using heavy equipment. The purpose of this document is to summarize factors influencing uranium metal pyrophoricity and high explosives instability, and whether remedial action poses a risk for disruption and dispersal event(s). In addition, the general extent to which uranium is pyrophoric and HE is unstable in its present state in disposal shafts at MDA-H is discussed. The possibility of a uranium fire is a serious matter, first in terms of dispersal of hazardous materials within and beyond the MDA, and second in terms of subsequent required decontamination. Since uranium and plutonium metal have been known to ignite spontaneously, concern about the pyrophoricity is decidedly justified.[3]

Summary of Findings and Recommendations

Subject matter experts (SMEs) in high explosives, materials science, actinides and geoscience were assembled from Los Alamos National Laboratory, and a technical assessment of information available on wastes emplaced into shafts at MDA-H has been performed. The SMEs evaluated waste disposed in shafts that can result in problems for remedial actions due to long-term stability, chemical reactions, mixing, releases or other issues. This document summarizes key bounding aspects of waste in the shafts identified, particularly as it may impact stabilization, protection and/or remediation actions for the site.

Key issues initially identified for review include waste characteristics, combinations, and stability. Particular components of interest are actinide materials, high explosive materials, and other chemical components. Remedial action alternatives, including especially jet grouting, are under evaluation for the site and the impacts and risks of such approaches are the focus of the assessment.

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[1] Pyrophoric definition: igniting spontaneously, from Latin pyrophorus, from Greek fire-bearing

[2] Deflagration and detonation definitions – deflagrate: a rapid chemical reaction proceeding along the surface at subsonic velocity; detonate: a violent chemical reaction proceeding through the reacted material toward the unreacted material at supersonic velocity. *"DoD Ammunition and Explosives Safety Standards"*, **1992**, DOD 6055.9-STD

[3] D. E. Patterson, "The Rocky Flats Fire," *Fire Journal*, **64**, 5-7, 15 (January, **1970**)

High Explosives or Mock High Explosives

Documented estimates of MDA-H inventory place 1275 lbs of RDX explosive in MDA-H disposal shafts. A wide variety of explosives were in use for weapons programs during the period from 1960 through 1985.[4]

Mechanisms that may cause unwanted reactions in explosives include spark, friction, heat, impact and pinch.[5] Spark may cause localized hot spots on HE surfaces and lead to deflagration. Friction may cause localized heating and lead to deflagration. Heat may lead directly to deflagration. Impacts may cause localized compression-heating leading to violent deflagration, or if of sufficient strength, detonation. Pinching may cause compression-heating and lead to violent deflagration or detonation.

All of the explosives used during the time the shafts were being filled have the potential to transition from deflagration to detonation.[6,7] The dangers of a detonation are well known. Less well appreciated are the effects of deflagration. For instance, black powder does not detonate, but deflagrates, and has been used as a propellant or blasting agent for hundreds of years. Violent deflagration may also cause huge amounts (100 times the explosive volume) of rapidly expanding gas to be produced, as is the case of a carbide cannon. Energy sources, such as sparks, may also act indirectly on explosives through an intermediary, such as a flammable/detonable gas, to cause a reaction in explosives. Combinations, such as water on uranium or lithium, may lead to formation of hydrogen-gas intermediaries and heat, or directly to flame-producing reactions.

The MDA-H inventory includes both materials that were flashed[8] and materials that include major amounts of HE. In general, items that are flashed are suspected to have HE on or in them (gears, cracks, joints, springs, threads, etc.). Molds, HE machining tools and fixtures, melt cast equipment and HE mixing/blending equipment are other examples of items that have usually been flashed. These items are almost always non combustible (metal, glass, etc.). Sealed containers are not flashed, nor are items with HE bonded to certain metals. Parts that contain HE that could make a solid fuel rocket-like device if ignited or large consolidated pieces that could deflagrate or detonate are not flashed. However, pieces that are flashed may still contain explosives. Low melt temperature HE

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[4] Those explosives include RDX (Royal Demolition Explosive or Research Department Explosive, an explosive nitramine compound, hexahydro-1,3,5-trinitro-1,3,5 triazine), TNT (trinitrotoluene, a solid nitroaromatic compound), HMX (high melting explosive, an explosive polynitramine, octahydro-1,3,5,7-tetranitro-1,3,5,7 tetrazocine), PETN (Pentaerythritol tetranitrate, used as the primary ingredient in detonating fuses and as a component mixed with hexahydro-1,2,5-trinitro-1,3,4-triazine in “plastic” explosives such as Semtex), Picric acid, azides, styphnates, and various mixtures of mock explosives such as Comp B (explosives are made from TNT, RDX, and wax, such as 59.5 percent RDX, 39.5 percent TNT and 1 percent wax with desensitizing agents added).

[5] L. C. Smith and B. G. Craig, *Primer on SDT, DDT, XDT, Pickup and Sympathetic Detonation*, **1979**, LA-UR-79-3106, LASL

[6] J. M. McAfee, B. W. Asay, A. W. Campbell, and J. B. Ramsay, Deflagration to Detonation in Granular HMX. - Ninth Symposium (International) on Detonation, **1989**, pp 265-279

[7] J.M. McAfee, B.W. Asay, and J.B. Bdzil, Deflagration-To-Detonation in Granular HMX: Ignition, Kinetics, and Shock Formation. - Tenth International Detonation Symposium, **1993**, pp 716-723, LA-UR-93-1754

[8] Flashing of materials with small amounts of explosive contamination involves rapid heating of the item (e.g. a metal part, pipe or piece of ductwork) that results in reaction of explosive. At LANL, this has been accomplished using high temperature, forced-air propane torches at Open Burn facilities.

can partially burn, melt and run into all kinds of nooks and crannies, thereby remaining a risk for deflagration or detonation if inappropriately disturbed.

Explosive containing wastes left undisturbed in the shafts at MDA-H are expected to be stable and only subject to slow natural degradation and mineralization.[9] However, local disruption by processes that can introduce sparking, friction, impact, heating and/or pinching would be expected to greatly increase risks of deflagration and possibly detonation.

Inorganic Materials, specifically depleted uranium and other actinides

Current estimates of MDA-H inventory place 93,000 lbs of depleted uranium (DU), 1100 lbs of enriched uranium (EU), and 10,700 lbs of uranium fuel elements in MDA-H disposal shafts. Minor amounts (300 lbs) of plutonium-contaminated wastes were also disposed in the shafts.

In the case of actinides, uranium and plutonium metals are highly reactive substances that can react with practically every element in the periodic table except the noble gases.[10] Oxides formed on uranium metal surfaces are not adherent and spall[11] off after a certain thickness is reached.[12,13,14] As with most metal oxides, the free energy of formation of uranium and plutonium oxides is negative (heat is given off when oxides form from metallic materials). Most metal oxides have a free energy of formation that is on the order of kilocalories per mole, while actinide metal oxides have a free energy of formation on the order of hundreds of kilocalories per mole.[15] As a consequence, the actinide metals are thermodynamically unstable in air, and in principle, one would expect complete conversion of actinide metal into the oxide that is most air stable. In practice this does not occur due to the kinetics of the oxidation process in air.

When an object experiences combustion, or catches fire, it is undergoing oxidation, and chemically, all elemental materials not in their highest stable oxidation state in air can burn. Consequently, all metallic objects that form stable oxides can oxidize in air, under appropriate conditions. Many metals oxidize so slowly that the heat generated during oxidation is dissipated and ignition temperature is never reached. However, under proper conditions, some metals oxidize rapidly in the presence of air or moisture, generating

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[9] J. C. Pennington, D. Gunnison, D. W. Harrelson, J. M. Brannon, M. Zakikhani, T. F. Jenkins, J. U. Clarke, C. A. Hayes, T. Myers, E. Perkins, D. Ringelberg, D. Townsend, H. Fredrickson, J. H. May, “Natural attenuation of explosives in soil and water systems at Department of Defense sites: Interim report,” Technical Report EL-99-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. **1999.**

[10] *The Chemistry of the Actinide and Transactinide Elements*, L.R. Morss, N.M. Edelstein, and J. Fuger, Eds, **2006**, Springer.

[11] Spall (v): to break off chips, scales, or slabs

[12] C. A. Colmenares, "The Oxidation of Thorium, Uranium and Plutonium," *Prog. Solid State Chem.*, **9**, 139, **1975**.

[13] I. Grenthe, J. Drożdżyński, T. Fujino, E. C. Buck, T. E. Albrecht-Schmitt, S. F. Wolf, “Chapter 5, Uranium” in *The Chemistry of the Actinides and Transactinides*, 3rd Edition, Lester R. Morss, Norman M. Edelstein, Jean Fuger, Eds. **2006**, Springer, New York, 813-1264.

[14] D. L. Clark, D. W. Keogh, M. P. Neu, W. Runde, "*Uranium and Uranium Compounds*," *Kirk-Othmer Encylopedia of Chemical Technology*, 5th Ed., Wiley Interscience, **2006**, Vol 25, 391-454.

[15] F. L. Oetting, M.H. Rand, and R.J. Ackermann, *The Chemical Thermodynamics of Actinide Elements and Compounds, Part 1, The Actinide Elements.* **1976**: IAEA, Vienna, STI/PUB/424/1.

sufficient heat to reach their ignition temperature and undergo autoignition. Generally, autoignition can occur anytime that a reaction or reactions are strongly exothermic, have negative free energies of reaction at the ignition temperature, and have a greater rate of heat production than rate of heat transfer away from the reaction zone. In such instances, the surface oxidation becomes vigorous enough to make the reaction self-sustaining. While such reactions are generally less likely to be vigorous underground due to limitations on oxygen and moisture supply to dispersed waste materials, they are possible in complex and concentrated waste accumulations, with similarities to processes exhibited by coal seam and peat fires.

C. R. Schmitt has reviewed the parameters that induce the pyrophoricity of various materials and points out that they are numerous and often interrelated.[16] The variables cited by Schmitt as affecting pyrophoricity include (1) particle size and activity; (2) moisture content; (3) hydrogen content; (4) stress; (5) purity and composition; (6) amount of surface oxide; and (7) mass of material.

Pyrophoricity of uranium is well-known, and DOE has issued several reports and handbooks on safe handling of metallic uranium.[17,18] Most metallic uranium is handled in massive forms (e.g. multi-gram sized items or larger) that do not present a significant fire risk unless exposed to a severe and prolonged external fire. Once ignited, massive metal burns very slowly. Unless covered with oil, massive uranium burns with virtually no visible flame. Alternatively, uranium can be stabilized against pyrophoricity by encasing it with another metal and for power reactor purposes, uranium fuel elements are always encased in a metal cladding (usually zirconium or stainless steel).

Disposal of actinide waste materials has included a wide range of forms, from physical parts to finely divided shavings or dusts. In general, plutonium has been of sufficient value that it was recovered for reuse, if at all possible. Similarly, enriched uranium was usually recovered. In contrast, depleted uranium was in relatively great supply and so was often disposed, as is documented for MDA-H. Uranium in finely divided form is readily ignitable, and uranium scrap from machining operations is subject to spontaneous ignition. Uranium metal turnings will form a protective coating of oxide on the surface. As turnings are pulled apart, they often throw sparks as the oxide coated is scraped away to reveal a fresh metal surface. This reaction can usually be avoided by initial storage under dry oil. Grinding dust has been known to ignite even under water, and fires have occurred spontaneously in drums of coarser scrap after prolonged exposure to moist air. Uranium surfaces treated with concentrated nitric acid are subject to explosion or spontaneous ignition in air. Moist dust, turnings, and chips react slowly with water to form hydrogen, which would be expected to be occurring even in buried materials. Because of uranium's thermal conductivity, larger pieces generally have to be heated entirely to their ignition temperature before igniting.

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[16] C. R. Schmitt, "Pyrophoric Materials--A Literature Review," *J. Fire and Flammability*, **2**, 157, April **1971**.

[17] *DOE Handbook. Primer on Spontaneous Heating and Pyrophoricity***,** DOE-HDBK-1081-94 December **1994,** U.S. Department of Energy, Washington, D.C. 20585. Available at http://www.hss.energy.gov/NuclearSafety/ns/techstds/standard/hdbk1081/hbk1081e.html

[18] *Assessment of Uranium Storage Safety Issues at Department of Energy Facilities,* Draft, November **1993**, Oak Ridge Y-12 Plant, Y/ES-014

Recommendations

Based on the discussion above specifically regarding uranium and high explosives in the MDA-H shafts, the SME group is of the opinion that any remedial action that results in excavation, drilling, in situ vitrification, thermal treatment, or jet grouting poses substantial hazards of reactions that could be uncontrollable. In this case, it is our combined opinion that options for leaving the material in place, with an appropriate cap that limits infiltration of water should be considered.

Drilling introduces energy sources near, or into, the shafts. Local activities that introduce spark, friction, heat and pinching are possible detrimental impacts to system stability. Water could enter the shafts and interact with waste materials in various ways, including as a component of grout or drilling mud if either are employed. Jet grouting is a particular concern as both a source of water that may intrude into wastes in shafts, and as a mechanism that introduces high pressures that could impact and mix waste materials, or serve to remove the protective oxide coating from uranium metal scraps. Curing grout/concrete produces heat and, while the level of heat would not necessarily be a major concern by itself, it may accelerate other unwanted chemical reactions. Water in the injected grout or drilling mud could cause some leaching of Barium from the HE and increase reactions of metal components.

Excavation of the shafts would introduce many unwanted energy sources into the interred materials. Reasonable scenarios associated with excavation include: sparks, from excavation equipment, sparks from abrading uranium components, or handling and adverse interactions of HE or pyrophoric metals; friction from excavation equipment or handling; impact/crush from equipment, or dropping; and pinching from equipment or handling. Such processes could also result in inadvertent pinching of residual amounts of HE remaining in crevices, cracks and machinery components (gears, threads, etc.), even those that have been treated by flashing.

The least intrusive remedial actions for the MDA-H shafts containing complex mixtures of waste materials, would involve emplacement of a surface cap system to limit intrusion and water infiltration. The present stability of the overall system would be maintained, and care can be taken to avoid compressing materials within the shafts.

Documents Reviewed

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LANL MDA-H description 2001.pdf

Map – Locations of inactive disposal shafts and RFI boreholes at MDA H
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fig2.1-3_MDAH_CMS_inactive dispsl shaftsBHs.pdf

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DOE-EA1464-Corrective Measures.pdf

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ERID-075940_Omicron_2003.pdf

Appendix B MDA H Disposal Inventory ER2005-0020, pages B-1 – B-22 (June 2005)
AppB_MDA_H_CMS_Rev1_MDAH-Disposal_Inv.pdf

Appendix H Borehole Logs ER2000-0669, pages H-1 – H-13 (May 2001)
ERID-070158_RFI_MDA-H-AppM_2001.pdf

Appendix M Uranium Corrosion ER2005-0020, pages M-1 – M-4 (June 2005)
ERID-089332_CMSR_MDA-H-AppM_2005.pdf

Appendix O An Alternate Groundwater-Pathway Risk Assessment for Material Disposal Area H: Fracture-Facilitated Contaminant Transport EP2004-0395 (LAUR-04-4956) 26p. (September 2004)
AppO_MDA_H_CMS_Rev1_FINAL.pdf

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Review of the Periodic Monitoring Report for Vapor Sampling Activities at Material Disposal Area-H…, Official Correspondence (May 2010)
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Contributors Biographical Data

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Dr. David L. Clark received a B.S. in chemistry in 1982 from the University of Washington and a Ph.D. in inorganic chemistry in 1986 from Indiana University. His thesis work was recognized by the American Chemical Society with the Nobel Laureate Signature Award for the best chemistry Ph.D. thesis in the United States. Clark was a postdoctoral fellow at the University of Oxford before joining Los Alamos National Laboratory as a J. Robert Oppenheimer Fellow in 1988. He became a Technical Staff Member in the Isotope and Nuclear Chemistry Division in 1989. Since then he has held various leadership positions at the Laboratory, including program management for nuclear weapons and Office of Science programs, and Director of the Glenn T. Seaborg Institute for Transactinium Science between 1997-2009. He was a lead member of the Actinide Migration Evaluation external advisory team at Rocky Flats Environmental Technology Site from 1996-2006. He is currently a Fellow of the American Association for the Advancement of Science, a Laboratory Fellow, and Leader of the Plutonium Science Strategy for Los Alamos National Laboratory. His research interests are in the structure and bonding of actinide materials, applications of synchrotron radiation to actinide science, behavior of actinides in the environment, and in the aging effects of nuclear weapons materials. He has published 150 peer-reviewed publications.

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Paul Dunn is the Group Leader for the Materials Science and Technology: Metallurgy(MST-6) at Los Alamos National Laboratory. He earned his duel B.S. degrees in Physical Metallurgy and Extractive Metallurgy in 1983 and M.S. in Welding Metallurgy in 1985 from the Colorado School of Mines. Since joining Los Alamos, he has worked extensively in the Nuclear Weapons Program, developing new processes for casting and melting of uranium and uranium alloys. As the Group Leader for MST-6, he oversees programs in every element of the Nuclear Weapons portfolio and provides the Los Alamos prototyping capability for all uranium components used at the Laboratory.

Appendix D

Technical Area 54 Geology and Hydrology

D-1.0 INTRODUCTION

This appendix discusses the sitewide geology and hydrology of Technical Area 54 (TA-54). Section D-2.0 discusses the site geology and includes TA-54 stratigraphy (section D-2.1), seismic hazards (section D-2.2), and cliff retreat (section D-2.3). Section D-3.0 discusses the regional aquifer hydrology of the area. It includes information on the regional aquifer monitoring wells near Material Disposal Area (MDA) H (section D-3.1) and presents interpretations of regional aquifer water-table maps (section D-3.2).

D-2.0 GEOLOGY

The following discussion describes the sitewide geology for TA-54 at Los Alamos National Laboratory (LANL or the Laboratory). More localized descriptions of geology are presented in the approved work plans for MDAs G and L (LANL 2004, 087624; LANL 2004, 087833; LANL 2006, 094673) and in the corrective measures study for MDA H (LANL 2005, 089332). The geology of the upper vadose-zone in the vicinity of the MDAs was characterized through borehole logging discussed in various investigation reports (LANL 2005, 090513; LANL 2006, 091888; LANL 2007, 096409). Additional information about vadose-zone and regional-aquifer geology around TA-54 was collected during the installation of deep wells to monitor perched-intermediate and regional groundwater. These monitoring wells screened in the regional aquifer include R-20, R-21, R-22, R-23, R-32, R-37, R-38, R-39, R-40, R-41, R-49, R-51, R-52, R-53, R-54, R-55, R-56, and R-57. Collectively, the investigations described above confirm that the sitewide geology for TA-54 is consistent with the regional geology described by Broxton and Vaniman (Broxton and Vaniman 2005, 090038).

D-2.1 TA-54 Stratigraphy

The stratigraphy in the vicinity of TA-54 includes Quaternary Bandelier Tuff (including Cerro Toledo deposits); Pliocene Cerros del Rio volcanic series; and Puye Formation (fanglomerate, Totavi Lentil, and lacustrine facies); Miocene Jemez alluvial fan deposits (fanglomerate and pumiceous facies); and Chamita Formation. The Bandelier Tuff and the Cerros del Rio volcanic series are the primary units making up the vadose zone. Cerros del Rio volcanic rocks in the vicinity of MDA G, the Puye Formation (including the Totavi Lentil), Miocene Jemez alluvial fan deposits, and the Chamita Formation are part of the regional aquifer. Figure D-2.1-1 shows the locations of intermediate and regional monitoring wells in the vicinity of TA-54. Figures D-2.1-2, D-2.1-3, and D-2.1-4 show north-to-south geologic cross-sections for TA-54 based on boreholes in the vicinity. The Bandelier Tuff forms the upper vadose at TA-54.

D-2.1-1 Bandelier Tuff

The Bandelier Tuff has two members, each consisting of a basal pumice fall overlain by a petrologically related succession of ash-flow tuffs (Bailey et al. 1969, 021498). The lower Bandelier Tuff includes the Otowi Member and its basal pumice fall deposit, the Guaje Pumice Bed. The upper Bandelier Tuff is made up of the Tshirege Member and its basal pumice fall, the Tsankawi Pumice Bed. The Cerro Toledo interval is an informal name given to stratified volcaniclastic sediments and tephra deposited between the Otowi and Tshirege Members.

The following description of Bandelier Tuff uses the term “welding” to distinguish between tuff that is less compacted (or noncompacted) and porous (nonwelded) and that which is more compacted and dense (welded). In the field, the degree of welding in tuff is quantified by the degree of flattening of pumice fragments (a higher degree of flattening and elongation equals a higher degree of welding).

Petrographically, welded tuff shows adhesion (welding) of pumice and ash, but nonwelded tuff does not. The term “devitrified” is applied to tuff whose volcanic glass has crystallized to a fine-grained mineral assemblage of alkali feldspar and silica polymorphs (cristobalite and tridymite).

Tshirege Member (Qbt)

The Tshirege Member of the Bandelier Tuff is a compound cooling unit that resulted from several successive ash-flow deposits separated by periods of inactivity, which allowed for partial cooling of each unit (Smith and Bailey 1966, 021584; Broxton and Reneau 1995, 049726). The properties related to groundwater flow and contaminant migration (e.g., density, porosity, degree of welding, fracture content, and mineralogy) vary both vertically and laterally as a result of localized emplacement temperature, thickness, gas content, and composition. As a result, the groundwater flow and contaminant transport occurring through these units are expected to be impacted by their heterogeneities. The Tshirege Member thins eastward across TA-54, ranging in thickness from 235 ft (72 m) near MDA H to 128 ft (39 m) on the east side of MDA G.

Tshirege Member Unit 2 (Qbt 2)

Unit 2 of the Tshirege Member of the Bandelier Tuff is a competent unit that forms the caprock of Mesita del Buey. It is the host unit for most disposal pits and shafts at TA-54. The thickness of unit 2 varies from 36 to 65 ft (11 to 19.8 m). Where exposed, unit 2 forms a medium brown vertical cliff that stands out in marked contrast to the slope-forming, lighter-colored tuffs below. It is a moderately welded ash-flow tuff composed of crystal-rich, devitrified pumice fragments in a matrix of ash, shards, and phenocrysts (primarily sanidine and quartz). Vapor-phase crystallization of flattened shards and pumices is extensive in this unit.

Unit 2 is extensively fractured as a result of contraction during postdepositional cooling. Cooling-joint fractures are visible on mesa edges and on the walls of pits. In general, the fractures dissipate at the bottom of unit 2. On average, fractures in unit 2 are nearly vertical. At MDA G, Purtymun et al. (1978, 005728) measured an average fracture spacing of 3 to 5.6 ft (0.9 to 1.7 m), and Purtymun and Kennedy (1971, 004798) cite a maximum aperture of 2 in. (51 mm). Reneau and Vaniman (1998, 063135) mapped the walls of Pit 39 at MDA G and measured average fracture spacing of 3.2 to 4.2 ft (1.0 to 1.3 m) and average apertures of 0.12 to 0.21 in (3.1 to 5.3 mm) (with a maximum of 3.9 in. [10 cm]). The fractures are often filled with clays, calcite, and fine detritus to a depth of about 10 ft (3 m); smectites are the dominant clay minerals present. Smectites are known for their tendency to swell when water is present and for their ability to strongly bind certain elements, properties that have implications for the transport of metals and radionuclides in fractures. Opal and calcite may be found throughout the fractured length, usually in the presence of tree and plant roots (live and decomposed); the presence of both the minerals and the roots indicates moisture at depth in fractures (Reneau and Vaniman 1998, 063135).

The base of unit 2 is marked by a series of thin (less than 3.9-in.- [10-cm-] thick) discontinuous, stratified, crystal-rich, and fines-depleted sandy surge deposits. Cross beds and planar bedding structures are often observed in these deposits.

Tshirege Member Unit 1v (Qbt 1v)

Tshirege Member unit 1v is a light-colored vapor-phase-altered cooling unit underlying unit 2. This unit forms generally sloping outcrops, which contrast with the near-vertical cliffs of unit 2. Unit 1v is further subdivided into units 1v(u) and 1v(c).

Unit 1v(u). The uppermost portion of unit 1v is devitrified and vapor-phase-altered ash-fall and ash-flow tuff; it is designated unit 1v(u), where *u* signifies upper. This unit thins eastward across TA-54, ranging in thickness from 100 ft (30 m) near MDA H to 25 ft (8 m) on the east side of MDA G. Unit 1v(u) is nonwelded at its base and becomes partly welded in its interior. Only the more prominent cooling fractures originating in unit 2 continue into the more welded upper section of unit 1v(u), but these die out in the lower, less consolidated section. More typically, fractures in unit 2 do not extend into unit 1v(u).

Unit 1v(c). Beneath unit 1v(u) is unit 1v(c), where *c* stands for colonnade, named for the columnar jointing visible in cliffs formed in this unit. Unit 1v(c) is an orangish-brown nonwelded devitrified ash-flow tuff at its base and top; it becomes more welded in its interior. Unit 1v(c) varies in thickness from 6 to 15 ft (1.8 to 3 m) at TA-54. The basal contact of unit 1 v(c) is marked by a rapid vertical change (within 0.7 ft [0.2 m]) from devitrified (crystallized) matrix in unit 1 v(c) to vitric (glassy) matrix in the underlying unit 1g. In many outcrops, the transition from devitrified to vitric rock matrix forms a prominent erosional recess called the vapor-phase notch; at other locations this transition is marked by a prominent bench. No depositional break is associated with the vapor-phase notch, indicating this mineralogic transition developed within the interior of the cooling ash-flow sheet after the tuffs were deposited.

Tshirege Member Unit 1g (Qbt 1g)

Unit 1g is a white to tan vitric, pumiceous, nonwelded ash-flow tuff. This unit thins eastward across TA-54, ranging in thickness from 100 ft (30 m) near MDA H to 50 ft (16 m) on the east side of MDA G. Few fractures are observed in the outcrops of this unit where exposed in nearby areas, and the weathered cliff faces have a distinctive Swiss-cheese appearance because of the softness of the tuff. The uppermost 5 to 20 ft (1.5 to 6.1 m) of unit 1g are discolored by oxidation, possibly by development of ferric oxyhydroxides. This portion of unit 1g is resistant to erosion, helping to preserve the vapor-phase notch in the outcrops. A pumice-poor surge deposit forms the base of unit 1g locally.

Tsankawi Pumice Bed (Qbtt)

The Tsankawi Pumice Bed is the basal fall deposit of the Tshirege Member of the Bandelier Tuff. It is a crudely stratified deposit of gravel-sized vitric pumice and quartz and sanidine crystals. The maximum thickness of the Tsankawi Pumice Bed is 2 ft (0.6 m). Despite being thin, this pumice-fall unit was uniformly deposited throughout the area and is expected to be laterally continuous.

Cerro Toledo Interval (Qct)

The Cerro Toledo interval represents channelized fluvial deposits that consist of thin beds of tuffaceous sandstone, siltstone, and ash- and pumice-falls that were deposited between the Tshirege and Otowi Members of the Bandelier Tuff. The Cerro Toledo interval also includes localized gravel- and cobble-rich fluvial deposits eroded from Tschicoma Formation dacite lavas in the eastern Jemez Mountains. This unit reaches a maximum thickness of 55 ft (17 m) at well R-56, but because it fills channels eroded into the top of the Otowi Member, its thickness is variable and these deposits are absent in many areas of TA-54.

Otowi Member (Qbo)

The Otowi Member is a white to tan, vitric, pumiceous, nonwelded ash-flow tuff. The pumice is fully inflated, supporting tubular structures, which have not collapsed as a result of welding. The matrix is an unsorted mix of glass shards, phenocrysts, perlite clasts, volcanic lithics, and minute, broken pumice fragments. Otowi ash-flow tuffs thin eastward against a paleotopographic high formed by Cerros del Rio volcanics near White Rock. These tuffs are continuous under TA-54, but unit thicknesses decrease eastwards, ranging between 250 ft (76 m) near MDA H to 45 ft (14 m) on the east side of MDA G.

Guaje Pumice Bed (Qbog)

The Guaje Pumice Bed (Qbog) is the basal fall deposit of the Otowi Member. It is a stratified, fines-depleted deposit of gravel- to pea-sized vitric pumice and quartz and sanidine crystals. Borehole data indicate the maximum thickness of this unit at TA-54 ranges between 5 ft (1.5 m) and 19 ft (5.8 m). This pumice-fall unit was deposited throughout the area and is expected to be laterally continuous. It is potentially important for the vadose zone flow and transport because higher moisture content and zones of saturations occur within this unit at other areas of the Laboratory beneath wet canyons (e.g., Los Alamos Canyon). Site investigations indicate that saturated conditions do not occur in the Guaje Pumice Bed at TA-54.

D-2.1.2 Cerros del Rio Volcanic Series (Tb 4)

Basaltic rocks of the Cerros del Rio volcanic field crop out primarily in White Rock Canyon and east of the Rio Grande in the Caja del Rio (Griggs and Hem 1964, 092516; Smith et al. 1970, 009752; Kelley 1978, 011659; Sawyer et al. 2007, 106130). The northwest part of the volcanic field extends beneath the Pajarito Plateau where it is covered by thick deposits of Bandelier Tuff (Dransfield and Gardner 1985, 006612; Broxton and Reneau 1996, 055429). Cerros del Rio volcanic rocks interfinger with the upper Puye Formation west of the Rio Grande and unconformably overlie the Tesuque Formation east of the river. Discontinuous thin beds of fine-grained cemented sandstone and siltstone (possible paleosols or eolian deposits) and coarse-grained volcanic colluvium occur at the top of the Cerros del Rio volcanics. Sediments directly beneath individual lava flows show varying degrees of cementation and mineralogic alteration from thermal contact metamorphism.

The Cerros del Rio volcanic series is a thick sequence of stacked lava flows that are separated by interflow breccias, cinder or scoria zones, volcaniclastic and riverine sediments, phreatomagmatic deposits, and lake-bed deposits. The lava flows generally have massive interiors made up of dense, variably fractured impermeable rock. Cuttings samples of lavas and related deposits were analyzed by x-ray fluorescence for major and trace elements to correlate lavas from borehole to borehole in the vicinity of TA-54 (Figures D-2.1-2, D-2.1-3, and D-2.1-4). The lava flows range in composition from basalt to dacite, with the more silicic rock types (dacites) occurring at the base of the volcanic pile and less evolved flows (tholeiites and alkali basalts) at the top (Figure D-2.1-5). The volcanic sequence thickens eastward, ranging from about 300 ft (91 m) thick near MDA H to about 775 ft (236 m) near the east end of MDA G. The thickest deposits generally coincide with a south-southwest-draining paleovalley that is defined by structure contours at the base of the unit shown in Figure D-2.1-6). An isolated occurrence of anomalously thick (983 ft [300 m]) Cerros del Rio volcanic deposits occurs at well R-22 and is discussed further below.

The Cerros del Rio volcanic series was erupted primarily between 2.8 and 2.3 million years ago (Ma) (WoldeGabriel et al. 1996, 054427; WoldeGabriel et al. 2001, 092523; Sawyer et al. 2007, 106130). Overlapping ^{40}Ar/^{39}Ar ages of 2.40±0.09 and 2.50±0.33 were obtained for dacite and overlying tholeiite lavas, respectively, at well R-22.

Rapid lateral facies variations of the volcanic rocks and their intercalated deposits are common at TA-54 (Figures D-2.1-2, D-2.1-3, and D-2.1-4). These variations reflect dynamic landscape processes associated with the rapid growth of overlapping volcanoes and associated lava flows in a basin floor environment that included the ancestral Rio Grande floodplain and the western alluvial slope of the

Española basin. The thickest volcanic deposits overlie thick, laterally continuous Totavi Lentil (Tpt) riverine deposits in the vicinity of MDA G and to the east. The presence of phreatomagmatic deposits within the volcanic sequence indicates that erupting magmas frequently interacted explosively with the ancestral Rio Grande and its saturated flood plain sediments. Lavas flowing into low-lying areas periodically blocked the ancestral Rio Grande, causing lake sediment (lacustrine) deposits to form behind temporary lava dams. Riverine deposits intercalated within the volcanic sequence mark the changing course of the ancestral Rio Grande in response to the continuously evolving basin-floor topography. These intercalated riverine deposits are associated with temporary river channels, and the deposits are probably not laterally continuous.

The presence of volcanic vents in the vicinity of TA-54 is inferred from the presence of thick cinder and phreatomagmatic deposits that commonly accumulate near their source vents. Cinder deposits more than 50 ft (16 m) thick occur in wells R-20, R-21, R-22, R-34, R-39, R-41, R-49, R-53, R-54, R-55, and R-56. These cinder deposits range in composition from basalt to dacite, indicating that there are multiple vents in the vicinity. Thick (>25 ft [>7.6 m]) basaltic phreatomagmatic deposits occur in wells R-38, R-41, R-49, R-55, and R-57, suggesting maar volcanoes are located near the east end of MDA G. Additionally, structure contours for the top of the Cerros del Rio volcanics show that a broad north-trending paleotopographic high area also occurs near the east end of MDA G (Figure D-2.1-7). This paleotopographic probably represents a volcanic constructional highland formed by coalesced volcanic vents. Structure contours for the top of the dacite lava indicate a small dome and flow complex may have been buried by subsequent Cerros del Rio lavas near the east end of MDA G.

Well R-22 may have intersected a volcanic vent conduit of unknown morphology that fed the upper tholeiitic lavas at the east end of TA-54. All the wells at the east end of TA-54 (e.g., R-23, R-39, R-41, R-55, R-49, and R-57) show a consistent volcanic stratigraphy of basaltic lavas (tholeiite and alkali basalt) overlying more evolved lava types (trachyandesite and dacite). However, well R-22 is the only location where tholeiites are found beneath dacite lavas. The lowermost tholeiites at R-22 occur 213 ft (65 m) deeper than the base of the volcanic pile (dacite lava) and 785 ft (239 m) deeper than tholeiites at R-57, located only 215 ft (66 m) to the west.

It is possible the deep tholeiites at R-22 represent older lavas filling a very deep and narrow south-draining paleocanyon, but such a canyon would have been cut into poorly consolidated riverine sediments that were not likely to support such a steep-walled feature. Moreover, closely spaced boreholes in the vicinity do not intersect any igneous lithologies this deep, as would be expected if there were a lava-filled canyon with lateral extent. The alternative interpretation offered here is that R-22 was drilled through an obliquely oriented vent conduit related to the upper tholeiitic lavas. Chemical compositions of the shallow and deep tholeiites at R-22 are similar; these similarities suggest, but do not prove, a relationship between the two.

The Cerros del Rio volcanic series is largely in the vadose zone at TA-54. However, the base of these volcanic deposits extends more than 150 ft beneath the regional water table in the vicinity of MDA G where lavas pooled in the south-southwest-draining paleovalley described above (Figure D-2.1-8). Under unsaturated and saturated conditions, groundwater flow in lava interiors is impacted by the fractures, with properties of groundwater flow and contaminant transport (direction, magnitude, etc.) influenced by fracture aperture, fracture density, fracture orientation, fracture connectivity, and fracture-filling materials. Groundwater flow and contaminant transport are also impacted by the interflow zones made up of highly porous and highly-permeable breccias, cinder and scoria deposits, and sedimentary deposits. The nonfractured volcanic rocks and clay-filled fractured zones are expected to have low saturated permeability. Zones with significant connected open fractures, lava tubes, and interflow zones are expected to have higher saturated permeability and low matrix porosity, a combination of properties that can lead to fast travel times. Over short distances (meters to tens of meters), the direction and magnitude of the groundwater flow and contaminant transport within these volcanic rocks are highly uncertain because of the complex internal stratigraphy of these rocks. However, it is likely the combined fracture- and porous-flow paths form an integrated flow network over a scale of tens to hundreds of meters and more predictable flow directions and magnitudes can be determined when the water-table hydraulic gradients are applied to flow paths averaged over longer distances. Poorly connected or isolated groundwater pockets may occur in this setting, but these zones are stagnant and do not pose a risk for contaminant transport.

D-2.1.3 Puye Formation (Tpf, Tpt, and Tpl)

The Puye Formation is generally subdivided into three interfingering facies: fanglomerate (Tpf), Totavi Lentil riverine deposits (Tpt), and lacustrine beds (Tpl). At TA-54, the dominant facies are fanglomerate and riverine deposits. Lacustrine beds of the Puye Formation are minor at TA-54, and they (and thin riverine deposits) are included within the Cerros del Rio volcanic series where these strata are interbedded within the thick stacks of lava flows.

The fanglomerate facies of the Puye Formation was deposited as broad, coalescing alluvial fans shed eastward from the Jemez volcanic field into the western Española basin (Griggs and Hem 1964, 092516; Bailey et al. 1969, 021498). The sources for these alluvial-fan deposits were large overlapping dacite to low-silica rhyolite dome complexes of the Tschicoma Formation located in the eastern part of the Jemez Mountains. The dome complexes erupted between about 3 and 5 Ma (Broxton et al. 2007, 106121). The fanglomerate deposits are a heterogeneous assemblage of clast- to matrix-supported conglomerates, with associated gravels and lithic sandstones. Clasts in the coarsest deposits consist of subangular to subrounded cobbles and boulders of lava and tuff in a poorly sorted matrix of ash, silts, and sands. Debris flow deposits are common throughout the unit. Primary and reworked ash- and pumice-fall deposits of dacitic to rhyolitic composition are interbedded with the conglomerates and gravels. At TA-54, the fanglomerate facies thins eastward; it is >263 ft (>80 m) thick at well R-52 and is absent on the east side of MDA G.

During the early Pliocene, before the development of the Cerros del Rio volcanic field, the distal parts of Puye alluvial fans merged with ancestral Rio Grande axial river sediments (Totavi Lentil) that were being deposited over a basin floor that was at least 3 to 6 km wide. As a result, fanglomerate and riverine deposits are interbedded in the vicinity of MDA G and eastwards. The riverine deposits consist of poorly consolidated conglomerate containing well-rounded cobbles and gravels of Precambrian quartzite, granite, and pegmatite with subrounded to subangular cobbles and boulders of silicic to intermediate and rarer basaltic volcanic rocks. Precambrian clasts commonly make up >80% of the clasts in the deposits. These deposits also contain subordinate subangular to subrounded clasts of volcanic rocks from the Jemez volcanic field in some horizons. Loose, well-sorted, fine to coarse quartz and microcline sands occur as lenses within the conglomerate. The early Pliocene Totavi deposits are up to 203 ft (62 m) thick and formed laterally continuous deposits beneath MDA G and to the east; these deposits probably reflect basin-floor sediments. The ancestral Rio Grande flowed north to south so it is expected that Totavi deposits contain stacked channel sands and gravels with the same orientation with length-to-width dimensions, on the order of 0.5 to 3 km and 50 m, respectively. This may cause large-scale anisotropy of flow and transport properties of the aquifer medium, with preferential flow along permeable channel deposits. Totavi deposits west of MDA G are much thinner (<40 ft [12 m]) or they are highly mixed with Puye fanglomerate; the deposits in this area probably represent an area of overlap between the western alluvial slope and the basin floor.

During the late Plicocene, the eastern Jemez Mountains remained structurally high and continued to supply sediment to Puye alluvial fans in the western Española basin. However, the onset of Cerros del Rio volcanism had three major effects on the Puye depositional patterns: (1) concurrent sedimentation and volcanism led to interfingering of Puye and Cerros del Rio deposits, (2) growth of a constructional volcanic highlands on the basin floor provided an eastern source of volcaniclastic sediments that became incorporated into the Puye Formation, and (3) areas of Totavi Lentil deposition became more restricted in areal distribution and frequently shifted laterally as lavas dammed and diverted the Rio Grande.

D-2.1.4 Miocene Jemez Alluvial Fan Deposits (Tjfp)

Miocene Jemez alluvial fan deposits generally include a lower fanglomerate part and an upper subunit of pumiceous sands and gravels (Broxton and Vaniman 2005, 090038). Only the upper pumiceous subunit was encountered in boreholes at TA-54. These deposits share similarities with the overlying Puye Formation in terms of source region and depositional setting, and they are interpreted as alluvial fans shed eastward from the Jemez volcanic field into the western Española basin during the Miocene. However, there appears to be a 2-Ma hiatus in deposition between these two fan deposits throughout the Pajarito Plateau. Core samples collected from well SCI-2 in Sandia Canyon, located 1.4 mi (2.3 km) north of TA-54, showed a poorly developed oxidized paleosol occurs at the top of the Miocene Jemez alluvial fan deposits at this location. However, the lateral extent and the continuity of the paleosol are not known. Additionally, Formation Microimager geophysical logs collected at R-20 (LANL 2003, 079600) indicate the bedding in these pumiceous sediments dips toward the south-southwest, possibly indicating postdepositional tilting of the Miocene units before the Puye Formation was deposited. The pumiceous sediments are 115 ft (35 m) thick at well R-20, and pinch out eastward, probably in the vicinity of MDA L.

The pumiceous sediments consist of well-bedded horizons of light-colored reworked pumiceous sands and subordinate gravels of rhyolite and dacite. Deposits typically contain up to 30% subangular to rounded vitric rhyolite pumice admixed with 70% to 90% ash and lithic sands. Some intervals contain as much as 90% subangular to angular pumice that represent primary fall deposits or reworked deposits that underwent minimal transport. Pumice clasts are characterized by sparse phenocrysts of quartz, sanidine, and plagioclase. Seven pumice samples collected from boreholes across the Pajarito Plateau yielded $^{40}Ar/^{39}Ar$ feldspar ages ranging between 6.44 ± 0.46 and 7.50 ± 0.30 Ma. The ages overlap the 6.01 ± 0.05 to 7.1 ± 0.2 Ma ages reported for the Bearhead Rhyolite in outcrops southwest of the Pajarito Plateau (Justet and Spell 2001, 093391). Microprobe analyses of glass and whole rock analyses of pumices closely match the chemistry of the Bearhead Rhyolite.

These pumiceous deposits are entirely within the regional aquifer and should have relatively high permeability based on their sandy lithology. The material deposited within individual beds is relatively uniform, and their heterogeneity is primarily associated with bedding. The south-southwest dip of these deposits may cause some preferential groundwater flow toward the east-southeast along the strike of bedding. However, beneath TA-54, these beds are too deep in the regional aquifer for preferential flow to be a concern at MDA H, and these beds are thin to absent beneath MDAs L and G.

D-2.1.5 Chamita Formation (Tcar)

The Chamita Formation of the Santa Fe Group is made up of basin-floor axial river deposits consisting of the Hernandez and Vallito Members. The Hernandez Member represents ancestral Rio Chama deposits, and the Vallito Member represents ancestral Rio Grande deposits. These south-flowing river systems merged in the vicinity of Buckman Mesa (Koning et al. 2007, 106122), and the separate members are grouped at the formation level in the vicinity of TA-54. The Chamita Formation is >1285 ft (391 m) below ground surface (bgs) at well PM-2 and >559 ft (170 m) thick at well R-16. Most water-supply wells on the

Pajarito Plateau are completed in this formation. The Chamita Formation ranges in age between 6 and 13 Ma. The upper part of the formation overlaps in age with Miocene Jemez alluvial fan deposits, and it is likely the alluvial fans interfinger with axial river sediments in the western part of the basin floor. The Chamita Formation is overlain by Miocene pumiceous alluvial fan deposits at well R-20 and by riverine deposits of the Totavi Lentil at well R-57.

The Chamita Formation consists of fine- to coarse-grained quartz sands and silty sands with minor microcline and felsic to intermediate volcanic, fine- to coarse-grained volcanic lithic sands, and sandy and silty gravels dominated by well-rounded felsic to intermediate volcanics and 1% to 3% Precambrian quartzite. Some gravel deposits also contain subangular to subrounded intermediate volcanic clasts that probably represent input of sediment from tributary streams draining the Miocene Jemez volcanic field. These stratified deposits are variably cemented by calcite with poorly to noncemented sands and gravels intercalated with cemented sandstones.

The Chamita Formation is entirely within the regional aquifer at TA-54. These rocks should have relatively good permeability characteristics because they contain relatively abundant, sorted, coarse-grained channel fills. However, intercalated silt-rich sands and gravels are likely to be less transmissive than clean channel sands and gravels, providing vertical stratification and hydraulic compartmentalization. Because of their accumulation as axial deposits in a north-to-south-flowing river, these sediments probably contain north-to-south oriented stacked channel sands and gravels with long length to width dimensions similar to the Totavi Lentil. This may cause large-scale anisotropy of flow and transport properties of the aquifer medium with preferential north-to-south orientation.

Basaltic lava flows are intercalated within the Chamita Formation at wells PM-2 and R-22. These basalts are deep within the regional aquifer and show varying degrees of alteration of groundmass minerals and phenocrysts with fractures that appear to be at least partly sealed by smectite. Alteration minerals typically include smectite; calcite may also occur. At well PM-2, upper and lower basalt flows are 52 ft (16 m) and 94 ft (29 m) thick, respectively. At well R-22, the basalt sequence is 68 ft (21 m) thick. The basalt at R-22 yielded a ^{40}Ar/^{39}Ar age of 8.97±0.11 Ma. The basalts at PM-2 occur at greater depths than the R-22 basalt. Assuming they are correlative, these basalts appear to have a westward component of dip.

D-2.2 Seismic Hazards

A seismic hazard evaluation was conducted at several sites around the Laboratory to estimate ground motion from possible earthquakes (tectonics) (Wong et al. 1995, 070097). The objective was to determine the seismic hazard criteria for designing new nuclear facilities. The evaluation led to the conclusion that within 100 yr an earthquake with a magnitude of 6 or greater is considered likely to occur in the Pajarito fault system.

While TA-54, including MDA H, was not incorporated in the study, its geology is similar to two of the sites evaluated in the study (TA-18 and TA-46). Results of the study were applied in the safety analysis report for MDA G, which includes the Laboratory’s radioactive waste disposal facility (Benchmark Environmental Corporation 1995, 063300). A magnitude 6 or greater earthquake was determined not to pose a hazard from waste buried below the surface at MDA G. Therefore, it is assumed that an earthquake would not cause a surface rupture at either MDAs H or G, which are located on the same mesa.

Small-scale faults have been documented in the disposal pits and in cliff outcrops at MDA G (Schultz and Kelley 2009, 111231). However, these faults have small displacements (less than a foot of offset on Tshirege subunits), they lack lateral continuity (they cannot be traced across mesas or to other canyon exposures), they do not show movement in Holocene time, and they do not have clear connections to other major regional faults. Therefore, these small faults are not considered a seismic hazard to MDA G or neighboring facilities. Based on the data from published geologic studies at and around TA-54, aerial reconnaissance of the area within a 5-mi radius of MDA G, an analysis of aerial photographs, and field reconnaissance of lineaments and contact elevations,(Schultz and Kelley 2009, 111231), no faults with Holocene displacement are present at MDA G.

D-2.3 Cliff Retreat

The MDAs at TA-54 are located on Mesita del Buey next to Pajarito Canyon and Cañada del Buey, and cliff retreat is a primary process by which the canyon walls erode. No site-specific cliff retreat studies are available for MDA H, but its setting is similar to that of other areas of the Laboratory, including MDA G, where such studies have been conducted. Siting of disposal pits at MDA G included a 50-ft setback from the mesa edges to avoid the possibility of exposure of waste by cliff retreat (Purtymun and Kennedy 1971, 004798; Rogers 1977, 005707). Geomorphic studies at DP and Pajarito Mesas indicate mass wasting and cliff retreat on the Pajarito Plateau occurs by detachment of fracture-bounded blocks in relatively small rockfalls along shallow canyons similar to those bordering Mesita del Buey at MDA G (Broxton and Eller 1995, 058207; Reneau and Raymond 1995, 054709). Larger-scale mass wasting involving landsliding along canyon walls occurs only where canyons are deeper, including Los Alamos Canyon next to DP Mesa and Pajarito Canyon next to Pajarito Mesa. Using various lines of evidence, including the size of fracture-bounded blocks and long-term evolution of the canyons, and assuming a 10,000-yr period of interest, the studies at DP and Pajarito Mesas supported the use of a 50-ft setback from mesa edges for shallow canyons as exist next to MDA G (Broxton and Eller 1995, 058207; Reneau and Raymond 1995, 054709). Larger setbacks were recommended next to deeper canyons where larger-scale mass wasting occurs.

D-3.0 HYDROLOGY

D-3.1 Regional Aquifer Wells Near MDA H

Information about the hydrogeological properties of the regional aquifer can be obtained by analyzing the ambient water-level transients and pumping drawdowns observed at the monitoring wells near MDA H. The aquifer properties are important to evaluate groundwater flow and contaminant transport in the regional aquifer. The hydrogeological conditions at the monitoring wells are important to take into account in evaluating monitoring-well capabilities for characterizing regional groundwater flow and to detect potential contaminants originating from MDA H. Drawdown data are collected during the pumping tests (up to 24 h long) conducted at each of the monitoring wells. Drawdown data are also obtained as a result of the water-supply pumping at the municipal wells on the Pajarito Plateau; the transient analysis of water-supply pumping effects is computationally intensive but allows for a cost-effective estimation of the effective large-scale properties of the aquifer (Harp and Vesselinov 2010, 111220). The analysis of the water-table drawdowns caused by water-supply pumping also allows for the evaluation of the impact of the water-supply pumping on the regional groundwater flow directions. This is important because MDA H is located in close proximity to two of the water-supply wells on the Pajarito Plateau: PM-4 (~2250 ft to the north-northwest) and PM-2 (~1750 ft to the south) (Figure D-2.1-1).

Hydrogeologic information obtained from the regional water-supply and monitoring wells next to MDA H (PM-2, PM-4, R-51, R-52, R-37, R-40 and R-20; Figure D-2.1-1) is summarized below.

D-3.1.1 Water-Supply Wells

PM-2

PM-2 was completed in 1965 within the Puye Formation and Santa Fe Group (Figure D-2.1-1). The screen is placed about 130 ft beneath the regional water table. During pumping, the drawdown at the well is about 70 ft. The existing water-level data suggest PM-2 pumps a deep confined section of the regional aquifer, and the intensive pumping does not cause long-term decline of the aquifer hydraulic pressures. In contrast, the water levels at PM-2 seem to be recovering since 2004, from ~5840 ft in 2004 to ~5855 ft in 2008. The regional water table at R-40 screen 2 is ~5864 ft, about 10 ft higher than the PM-2 water level. The head difference suggests a degree of hydraulic separation between the deep and shallow aquifer sections tapped by PM-2 and R-40 screen 2, respectively. Currently, no definitive information is available, but it is expected that R-40 screen 2 will respond to PM-2 pumping. The PM-2 spinner test (LANL 2009, 106939, Appendix J) demonstrated that water is extracted from the upper section of the louvers. PM-2 pumping is detected in many monitoring wells. Thus far, the highest drawdowns have been observed at R-20 screen 3. The zone of influence for PM-2 seems to extend preferentially to the north; R-28 and other wells near Sandia Canyon are impacted by PM-2 pumping (LANL 2009, 107453) potentially because of structures or heterogeneities in the regional aquifer. For example, highly permeable channels with north-south orientation observed within the Puye Formation may cause permeability anisotropy that could impact the predominant direction of drawdown propagation. PM-2 has not operated since 2008 because of maintenance and repairs, and currently no water-level information is available.

PM-4

PM-4 is located on Mesita del Buey about midway between supply wells PM-2 and PM-5 (Figure D-2.1-1). PM-4 was completed in 1981 within the Puye Formation and Santa Fe Group. The screen is placed about 120 ft beneath the regional water table. During pumping, the drawdown at the well is about 70 ft. The existing water-level data suggest PM-4 pumps a deep confined section of the regional aquifer that is hydraulically connected with the aquifer zone pumped at PM-2; hydraulic cross-communication occurs between the two wells during pumping. The water-level elevation was steady at ~5840 ft from 2004 to 2008. However, in 2009, water levels declined steadily in PM-4, reaching ~5828 ft because of active pumping of PM-4 since use of PM-2 ceased in 2008. It is expected that the PM-4 water levels will recover when the pumping is reduced. PM-4 pumping is detected in many monitoring wells. There are no observations of the elevation of the regional water table in monitoring wells near PM-4. It is expected that the elevation of the regional water table is higher than the water level observed in the water-supply well because of vertical hydraulic disconnection and head differences between the deep and shallow aquifer zones observed elsewhere. The analyses of the regional water table (section D-3.3) suggest its elevation is about ~5860 ft at PM-4 or 20 to 30 ft higher than the water level observed at PM-4.

D-3.1.2 Monitoring Wells

R-51 is screened within sands and gravels of the Puye Formation. Screen 1 is 10 ft long (from 915 to 925 ft bgs). Screen 2 is also 10 ft long (from 1031 to 1041 ft bgs). The zone above screen 1 from 905 to 915 ft is clay-rich and presumably low in hydraulic conductivity. As such, this zone is expected to provide hydraulic confinement of the screen 1 zone. The composite static water level is 890.62 ft bgs (5869.38 ft above mean sea level [amsl]). When the screen zones were isolated, the water level in screen 1 rose 0.80 ft (889.82 ft bgs; 5870.18 ft amsl), and the head in screen 2 declined 0.83 ft (891.45 ft bgs; 5868.55 ft amsl). The vertical component of the hydraulic gradient at R-51 is on the order of 0.016.

The clay-rich sediments above screen 1 suggest locally confined conditions based on borehole logs. However, screen 1 has a high barometric efficiency of around 94%. Screen 2, on the other hand, has a barometric efficiency of about 58%, suggesting unconfined or partially confined conditions at both screens. It is somewhat surprising that the lower screen has higher barometric efficiency than the upper screen.

Screen 1 produced 4.1 gallons per minute (gpm) for 60 min, with 4.56 ft of drawdown for a short-term specific capacity of 0.9 gpm/ft. Analysis of the screen 1 pumping tests suggests a hydraulic conductivity of 16 ft/d. Screen 2 produced 21.1 gpm for 1440 min with 77.7 ft of drawdown for a specific capacity of 0.27 gpm/ft. Analysis of the screen 2 pumping tests suggests a hydraulic conductivity of 3.5 ft/d. Pumping screen 1 had no discernable effect on water levels in screen 2, whereas pumping screen 2 caused about 0.08 ft of drawdown in screen 1. Both screen zones showed evidence of pumping influence from water supply well PM-4. Response to PM-2 pumping is expected as well, but PM-2 has been offline since R-51 was installed.

Perched groundwater was encountered in two zones during R-51 drilling. The upper perched zone is located at a depth of approximately 161 ft bgs in sedimentary deposits of the Cerro Toledo interval, and the lower perched zone is located between depths of 502 and 568 ft bgs in the stratigraphic sequence that includes the Guaje Pumice Bed, the Puye Formation, and the uppermost part of Cerros del Rio basalt (LANL 2010, 110533).

R-52

Both screens in R-52 lie within sands and gravels of the Puye Formation. Screen 1 is 20.5 ft long (from 1035.2 to 1055.7 ft bgs), and screen 2 is 10 ft long (from 1107 to 1127 ft bgs). The composite static water level is 1017.96 ft bgs (5865.08 ft amsl). After the screen zones were isolated by packers, the water level in screen 1 rose 0.60 ft (1017.36 ft bgs; 5865.68 ft amsl), and the water level in screen 2 declined 1.18 ft (1019.14 ft bgs; 5863.90 ft amsl). The vertical component of the hydraulic gradient at R-52 is on the order of 0.03. The barometric efficiency is about 100% for both well screens, suggesting both screens are either confined or unconfined. Drilling data and drawdown responses during the pumping test suggest the screens are unconfined or partially confined.

Screen 1 produced 3.6 gpm for 885 min, with 1.4 ft of drawdown for a specific capacity of 2.6 gpm/ft. Analysis of the screen 1 pumping tests estimates an average hydraulic conductivity value of 18.9 ft/d. Screen 2 produced 7.9 gpm for 1440 min with 7.64 ft of drawdown for a specific capacity of 1.03 gpm/ft. Analysis of the screen 2 pumping tests suggests a near-well hydraulic conductivity of 26.2 ft/d and a hydraulic conductivity over a broader area of 19.3 ft/d. Pumping screen 1 at 4.2 gpm for 1440 min caused about 0.1 ft of drawdown in screen 2. Pumping screen 2 at 10.8 gpm caused more than 0.2 ft of drawdown in screen 1. No discernable effect was observed on R-37 screen 2, located just over 1100 ft away, to pumping of either of the R-52 screens, Both screens are expected to show the influence of pumping from water-supply wells PM-2 and PM-4.

Aerated groundwater was produced from both screens 1 and 2 during the pumping tests, which complicated the execution and interpretation of the pumping test.

A perched zone was encountered during drilling of R-52 (LANL 2010, 110533). Perched water was first observed while drilling at 916.0 ft bgs within Cerros del Rio volcanic rocks. The water level of this perched zone was measured at about 700 to 710 ft bgs during drilling. The perched zone is expected to have properties similar to the perched zone detected at R-37 (see discussion of R-37 below).

R-37

R-37 is a dual-screen well with screen 1 placed in a perched-intermediate zone and screen 2 placed in the regional aquifer. Screen 1 is 20.7 ft long and straddles the base of Cerros del Rio lavas and volcaniclastic sediments of the Puye Formation derived from local Cerros del Rio volcanics (from 929.3 to 950 ft bgs). The contact between the lava and sediment is 933 ft bgs. The static water level in screen 1 is 906.9 ft bgs (5963 ft amsl). Screen 2 is within dacitic gravels of the Puye Formation about 15 ft below the regional water table. It has a length of 20.68 ft (from 1025.96 to 1046.64 ft bgs). The static water level is 1009.6 ft bgs (5860 ft amsl), about 103 ft deeper than the perched groundwater level in screen 1; the vertical distance between the two screens is 75 ft.

Screen 1 shows a barometric efficiency lower than most deep wells on the Pajarito Plateau (62%), but the lower efficiency is expected for a screen completed in perched groundwater. Screen 2 showed a barometric efficiency of near 100%, typical of most regional aquifer wells on the Pajarito Plateau so it can be either confined or unconfined. Drilling data and drawdown responses during the pumping test suggest that screen 2 is unconfined or partially confined.

The screen 1 response during a pumping test was complex and difficult to interpret. Much of the data are thought to be affected by wellbore storage. Late-time data indicated the possibility the pumping water level had fallen below the contributing zones. Linear recovery response suggests the possibility that much of the production to screen 1 may come from lavas above the top of the screen. The base of lava flows are commonly fractured and brecciated, possibly providing good zones for water storage. Screen 1 produced 0.81 gpm with 34.5 ft of drawdown after 1 d of pumping for a specific capacity of 0.0235 gpm/ft.

Screen 2 produced 12.5 gpm with 4.0 ft of drawdown after 1 d of pumping for a specific capacity of 3.13 gpm/ft. Drawdown and recovery data analyses of the pumping test data produced consistent results, indicating an average hydraulic conductivity value for screen 2 of 21.4 ft/d. Late pumping and recovery data from screen 2 show steady flattening over time, which is consistent with continued vertical growth of the cone of depression into deeper aquifer sediments.

Transients in the water-level data demonstrate that screen 2 has a small response to water-supply pumping at PM-4, but more water-level data are needed to confirm this response. Response to PM-2 pumping is also expected, but PM-2 has been offline since R-37 was installed.

R-40/R-40i

R-40/R-40i is a multiple-well completion that includes screens 1 and 2 in well R-40, and R-40i is a 3-in. slotted schedule 80 polyvinyl chloride well installed in the annulus outside the R-40 well casing. R-40 screen 1 is completed in a perched zone in Cerros del Rio basalt, and screen 2 is completed in the regional aquifer in the Puye Formation. Screen 1 is 33.5 ft long (751.6 to 785.1 ft bgs), and the static water level is ~761 ft bgs or 5957 ft amsl. Screen 2 is 20.8 ft long (849.2 to 870 ft bgs), and the static water level is 853.9 ft bgs or 5864.1 ft amsl. The top of the screen 2 lies within a transition zone separating overlying basalt-rich sediments from underlying basalt-free sediments, with the bottom of the screen extending into the basalt-free sediments. Well R-40i is set in an upper perched zone within Cerros del Rio basalt and consists of 19.3-ft slotted pipe (649.7 to 669 ft bgs). At the time of aquifer testing, the static water level for screen R-40i was 9.4 ft above the top of the screen at 640.3 ft bgs or 6077.7 ft amsl.

The difference in the water levels between screens 1 and 2 is ~93 ft. The difference in the water levels between screen 1 and R-40i is ~121 ft. The three screens at R-40 are within distinct zones of saturation with different water levels. None of the pumping tests affected water levels in any of the other R-40/R-40i well screens or at nearby monitoring well R-20. Nevertheless, R-40i and R-40 screen 1 are considered to be in a single relatively thick zone of saturation (Figure D-2.1-2). The vertical distance between R-40i and R-40 screen 1 is 80 ft; the vertical distance between screens 1 and 2 is 65 ft.

During the aquifer pump test, groundwater flow into R-40 screen 1 was on the order of only 12 gal./d, suggesting extremely low permeability of the screened interval (less than 0.1 ft/d).

The water level data in R-40 screen 2 responds to atmospheric pressure changes with a barometric efficiency of 75%, suggesting the screened saturated zone is unconfined. Hydraulic conductivity is estimated to be 4.4 ft/d.

The water levels in screen R-40i responded to atmospheric pressure changes with a barometric efficiency of 33% and an average lag time of 5 h. Hydraulic conductivity is estimated to be 118 ft/d. The pumping test data also suggest the effective average hydraulic conductivity is lower ~22 ft/d at an unknown distance from the well. Late drawdown and recovery data showed boundary effects potentially because of the limited lateral extent of the perched zone.

R-20

R-20 was drilled in 2002 and had three regional aquifer screens. Screen 1 is within cinder beds of the Cerros del Rio lavas, and the screen length is 7.6 ft from 5782 to 5789 ft amsl. Screen 2 is within Miocene Jemez pumiceous alluvial fan deposits, and the screen length is 7.6 ft from 5540 to 5547 ft amsl. Screen 3 is within Chamita Formation sediments, and the screen length is 7.7 ft from 5358 to 5366 ft amsl. Hydraulic conductivity of the screens was estimated using single-hole pumping tests. The apparent hydraulic conductivity of all the screens was evaluated to be about 1 ft/d.

Screen 1 is placed about 77 ft beneath the regional water table. The screened saturated zones appears to be either unconfined or under partly confined conditions. The deeper two screens appear to be confined. The vertical component of the hydraulic gradient between screens 1 and 2 is on the order of 0.2. The vertical component of the hydraulic gradient between screens 1 and 3 is on the order of 0.1. It is important to note that even though screen 3 is substantially impacted by the water-supply pumping, the vertical component of the hydraulic gradient is higher between screens 1 and 2 than between screens 1 and 3. This finding suggests the spatial and temporal distribution of the vertical component of the hydraulic gradient in the regional aquifer is not only controlled by the water-supply pumping but also by (1) hydrogeological processes occurring in the shallower section of the regional aquifer (e.g., aquifer recharge), and (2) vertical distribution of aquifer properties (hydrostratigraphy, heterogeneities).

R-20 was rehabilitated in 2007, and screen 3 was plugged and abandoned. Screens 1 and 2 were redeveloped. The specific capacity of screen 1 substantially improved, from 0.01 to 0.02 gpm/ft, as a result of the redevelopment. The specific capacity of screen 2 did not improve; the low specific capacity (0.01 gpm/ft) is a result of low permeability of the screened aquifer sediments. The postdevelopment hydraulic conductivity of screens 1 and 2 is about 2 and 1 ft/d, respectively.

Transients in the water level data demonstrate that all R-20 screens are impacted by the water-supply pumping at PM-2 and PM-4. Screen 3 drawdown was on the order of 20 ft because of water-supply pumping. Screen 1 and 2 drawdowns are much smaller, on the order of 0.5 and 2 ft, respectively. The analysis of water-level transients also allowed for estimating the effective large-scale properties of the regional aquifer between the water-supply wells and R-20 (Table D-3.1-1).

D-3.1.3 Summary of Regional Monitoring Wells

Table D-3.1-1 presents information about the regional monitoring wells near MDA H related to estimated hydraulic conductivity based on conducted pumping test, hydrodynamic conditions at the screens (unconfined, partially confined or confined), and the submergence of the uppermost screen below the regional water table.

Table D-3.1-2 summarizes the information regarding the water-level transients observed in the regional monitoring wells near TA-54 and whether these transients are related to the water-supply pumping. When a sufficient amount of data is available, the water-level transients are analyzed to evaluate the large-scale aquifer properties (transmissivity and specific storage, Table D-3.1-2). For many of the newer regional wells in the TA-54 monitoring network, the period of record for water levels is not sufficient to analyze the transients.

Table D-3.1-3 summarizes the estimated vertical component of the hydraulic gradient at the monitoring wells with more than one screen near TA-54. The highest values for the vertical component of the hydraulic gradient are observed at R-20, R-49, R-57, and R-22. Well R-20 is located close to PM-2, and its water levels have been strongly impacted by the water-supply pumping (Table D-3.1-1); therefore, the high value is probably caused by the water-supply pumping.

Hydrogeologic data suggest that the screened regional-aquifer zones at the monitoring wells near MDA H are either unconfined or partially confined. This finding suggests that the upper well screens and the regional water table are potentially hydraulically connected, and they are good monitoring locations.

The perched zones near MDA H probably result from local infiltration along the canyon floors along Pajarito Canyon, Cañada del Buey, or even Mortandad Canyon to the north. There may also be a component caused by the lateral propagation of large-scale mountain-front aquifer recharge occurring to the west of MDA H. It is not known if the perched-intermediate zones observed at R-40 screen 1, R-51, R-37 screen 1, and R-52 are connected and extend beneath MDA H, as illustrated in Figure D-2.1-2. Such a connection is considered possible given the substantial thickness of the perched zones and their relative high groundwater capacity. The direction of the groundwater flow in the perched zones is not known; it is potentially to the northwest based on the observed perched water levels in R-41 (~6077 ft) and R-37 (~5963 ft). These perched zones are expected to discharge into the regional aquifer somewhere downgradient from MDA H. The perched zones at R-40 and R-52 have substantially higher water levels than the regional water table (~120 ft). Nevertheless, the small vertical distance between the perched and regional zones (~80 ft) brings into question the level of saturation of the subsurface media between the zones. The perched zones are expected to discharge into the regional aquifer somewhere downgradient of R-40 and R-52. This discharge may affect the shape of the regional water table.

D-3.2 Regional Aquifer Water-Table Maps

Groundwater flow directions and fluxes that control contaminant transport in the aquifer are generally dictated by the shape of the regional water table (Freeze and Cherry 1979, 088742, Chapter 5; Vesselinov 2005, 090040). The general shape of the regional water table beneath the Laboratory is predominantly controlled by the areas of regional recharge to the west (the flanks of Sierra de los Valles and the Pajarito fault zone) and discharge to the east (the Rio Grande and the White Rock Canyon Springs). The structure of the regional phreatic flow is also expected to be impacted by (1) local infiltration zones (e.g., beneath wet canyons); (2) heterogeneity and anisotropy in the aquifer properties; and (3) discharge zones (water-supply wells and springs).

Information about the elevation of the regional water table is provided by existing data from monitoring wells (water levels) and selected springs (for example, the White Rock Canyon Springs; discharge elevations of the springs are applied as an estimate of the local elevation of the regional water table). Well data are predominantly applied to map the elevation of the regional water table; spring discharge elevations are used in the vicinity of White Rock Canyon to provide additional constraints on the water-table elevation. The analyses do not include the water levels observed at the water-supply wells (such as PM-2 and PM-4 near MDA H). Existing hydrogeological information suggests the elevation of the regional water table is higher than the water level observed in the water-supply well because of vertical hydraulic disconnection and head differences between the deep and shallow aquifer zones observed elsewhere.

Water-table elevations under the Pajarito Plateau vary in time because of transient effects that include pumping of the water-supply wells and large- and small-scale variability in aquifer recharge. In general, water-level maps are representative of specific periods of time. The interpretation of water-level data not representative of the same time period is a source of uncertainty in the mapping process. Differences in the depths of screen placements and local hydrogeologic conditions also complicate the interpretation of the water-level data. In addition, up to a month (depending on the local hydrogeological conditions) is required for the water levels in the recently drilled wells to equilibrate after they are disturbed by drilling, development, and pump testing.

The process of water-table contouring is theoretically constrained by conformity rules (Freeze and Cherry 1979, 088742): (1) the contour lines should be perpendicular to the flow paths; (2) the length and the width of the flownet cells formed by the contour lines between two adjacent flow paths should have the same ratios. These rules are theoretically valid only for the case of two-dimensional (lateral) groundwater flow in a uniform, isotropic aquifer with no recharge/discharge sources within flownet cells. Deviations from the conformity rules are caused by three-dimensional flow effects, aquifer heterogeneity and anisotropy as well as recharge/discharge sources within flownet cells. Here, the regional water table maps are contoured by attempting to satisfy four goals simultaneously: (1) to match the water-level data at the monitoring wells, (2) to account for issues of data representativeness (confined versus unconfined hydrodynamic conditions at the screens, submergence of the screen below the regional water table, water-level transients, etc.), (3) to preserve flownet conformity, and (4) to account for conceptual models of groundwater flow in the regional aquifer. Because of the existing uncertainties in the data and knowledge about the site, a series of alternative conceptual-model assumptions pertaining to the regional groundwater flow have been evaluated. The actual contouring is performed using a combination of manual and automated techniques; the automated contouring is performed using the minimum curvature method.

D-3.2.1 Water-Table Map Based on March 2009 Data

A Laboratory-wide water-table map based on monthly averaged regional-aquifer water-level data from March 2009 is presented in Figure D-3.2-1. The development of this water-table map is discussed in detail in the 2010 General Facility Information (GFI) report (LANL 2010, 109084). This version of the map does not include water-level data from the recently drilled monitoring wells near MDA H (R-51, R-52, R-53, R-54, and R-56).

The distribution of hydrostratigraphic units at the regional water table and the estimated thickness of the Cerros del Rio lavas beneath the regional water table are presented in Figure D-2.1-8. The thickness of the lavas is evaluated using the March 2009 version of the water-table map (LANL 2010 109084) and an updated version of the 2009 geologic framework model (Cole et al. 2010, 106101) based on the new geologic data collected at the recently drilled wells at TA-54. The hydrogeological properties and thickness of Cerros del Rio lavas below the water table are thought to affect flow directions in the regional aquifer to the east of MDA H (Figure D-2.1-8).

D-3.2.2 Preliminary Water-Table Map Based on July–September 2010 Data

An updated water-table map for the MDA H area at TA-54 is also constructed based on monthly-averaged water-level data from July to September 2010 (Figure D-3.2-2). The analysis is preliminary, and the mapping process follows the procedures discussed in the 2010 GFI report (LANL 2010, 109084). The analysis of the water-table contours in the updated map includes preliminary water-level data from the new wells in the area near MDA H (including R-51 and R-52).

A visual comparison of both water-table maps (Figures D-3.2-1 and D-3.2-2) demonstrates some similarities in the predicted groundwater flow directions in the regional aquifer beneath MDA H. In the area directly beneath MDA H, the regional water table is located within the Puye Formation (Figure D-2.1-2). The regional groundwater flow is to the northeast. The measured water levels at the regional monitoring wells around MDA H represent unconfined or partially confined hydrogeologic conditions (Table D-3.1-2).

The northeastward direction of the regional groundwater flow beneath MDA H (Figures D-3.2-1 and D-3.2-2) may indicate a complex three-dimensional flow structure in the aquifer that is potentially influenced by hydrostratigraphy, aquifer recharge, and/or water-supply pumping in the deep sections of the regional aquifer. Local infiltration and aquifer recharge along Pajarito Canyon south of MDA H, and/or the lateral propagation of large-scale mountain-front aquifer recharge occurring to the west of MDA H, may cause the northeastern groundwater flow in the regional aquifer beneath MDA H. This conceptual model is supported by the existing perched zones in the area near MDA H. It is also plausible the shape of regional water table near wells R-40, R-20, and R-54 is influenced by the water-supply pumping in PM-2. Preliminary water-level data suggest the water-level elevation at R-54 is higher than at R-20 (Figure D-3.2-2). The presence of the low permeability Cerros del Rio lavas (Tb 4) below the regional water table in the area to the east of MDA H, beneath MDA G, may act as a hydrogeologic barrier that diverts flow northeastward in the R-40 area (Figures D-3.2-1 and D-3.2-2). The impact of this hydrogeologic barrier on the groundwater flow may have been observed during the pumping tests conducted in R-53, R-56, and R-38: the drawdowns observed during the pumping tests conducted at these wells are impacted by boundary effects. The distribution of hydrostratigraphic units at the regional water table and the estimated thickness of the Cerros del Rio lavas beneath the regional water table are presented in Figure D-2.1-8. The relatively lower water levels and flat hydraulic gradients in the area north of R-38 are potentially caused by flow through highly permeable Puye Formation sediments (as indicated by the pumping test results from wells at R-28, R-11, R-13, R-44, and R-45). The three-dimensional structure of the groundwater flow may also be influenced by the general trends of (1) decreased thickness of the Puye Formation at the top of the regional aquifer and (2) decreased depth of the Santa Fe Group sediments below the regional water table in the area between R-37 and R-34 (LANL 2009, 106939, Figure O-4.0-1).

In summary, an effective regional groundwater monitoring network exists around MDA H. Two monitoring wells are located downgradient of MDA H (R-52 and R-37), and one well is located upgradient (R-51). Well R-40 may also be considered a potential downgradient well because it is located between MDA H and PM-2, and it provides the ability to detect contaminants that may be drawn toward PM-2 by water-supply pumping. All the monitoring wells are screened near the top of the regional aquifer in relatively permeable sedimentary deposits. Hydrogeologic data suggest the screened regional-aquifer zones at the monitoring wells near MDA H are either unconfined or partially confined, indicating the upper regional well screens and the regional water table are hydraulically connected and the screens are well placed to monitor for the arrival of contaminants at the water table.

D-4.0 REFERENCES

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Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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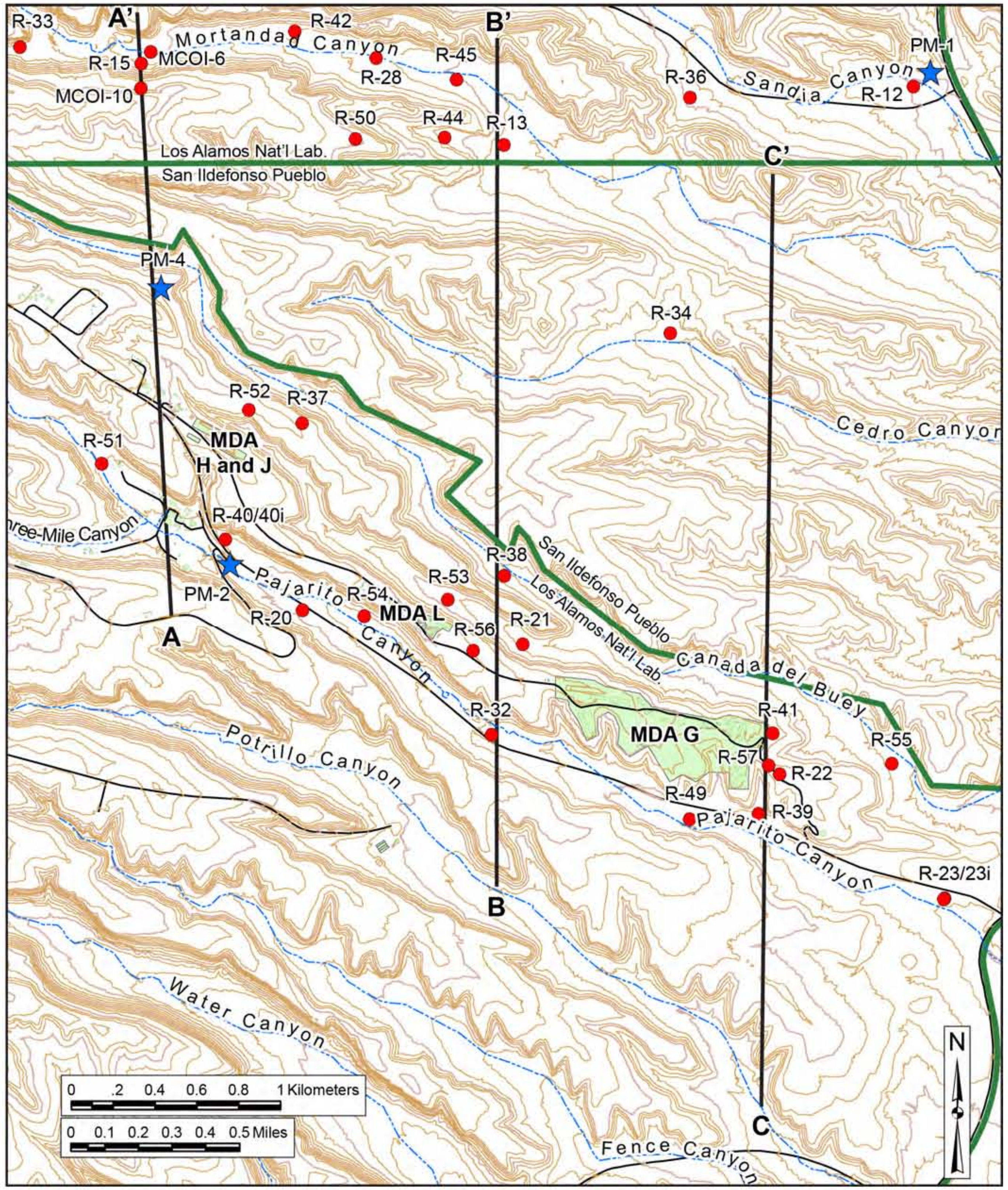
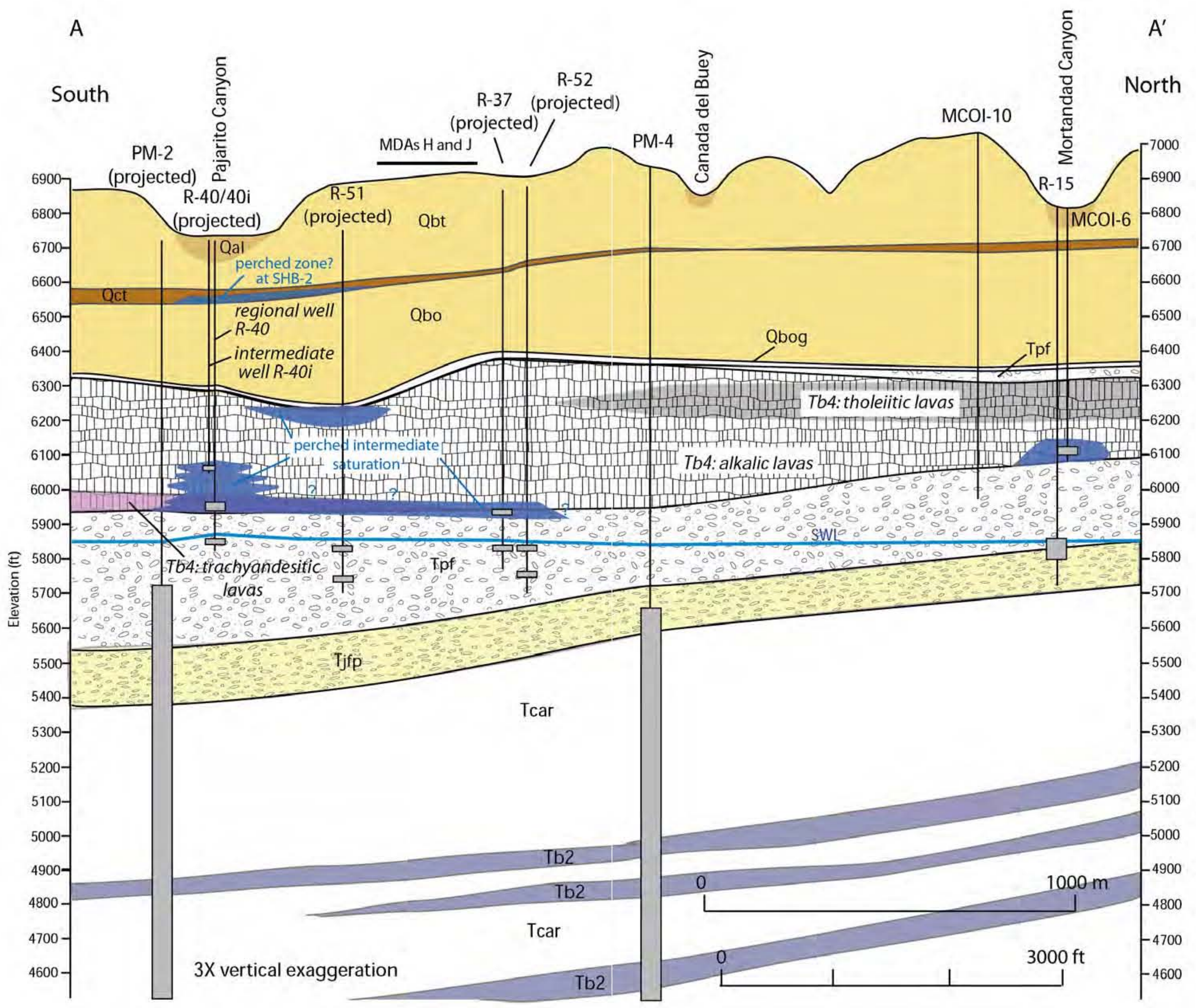


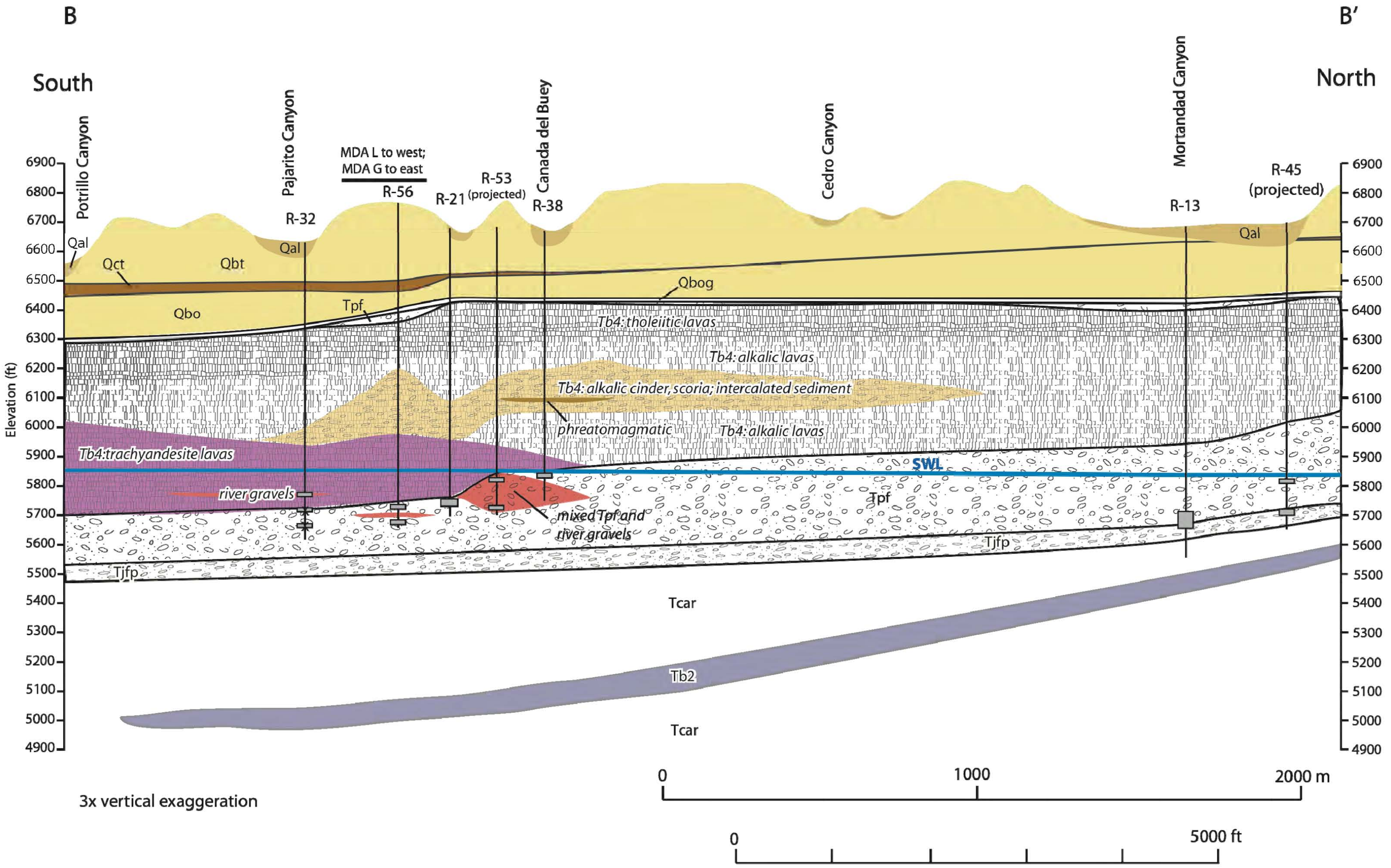
Notes: The locations of north-south cross-sections shown in Figures D-2.1-2 (A–A′), D-2.1-3 (B–B′), and D-2.1-4 (C–C′) are indicated by solid lines. Municipal supply wells are shown as blue stars.

Figure D-2.1-1 Locations of perched-intermediate and regional wells (red circles) in the vicinity of TA-54



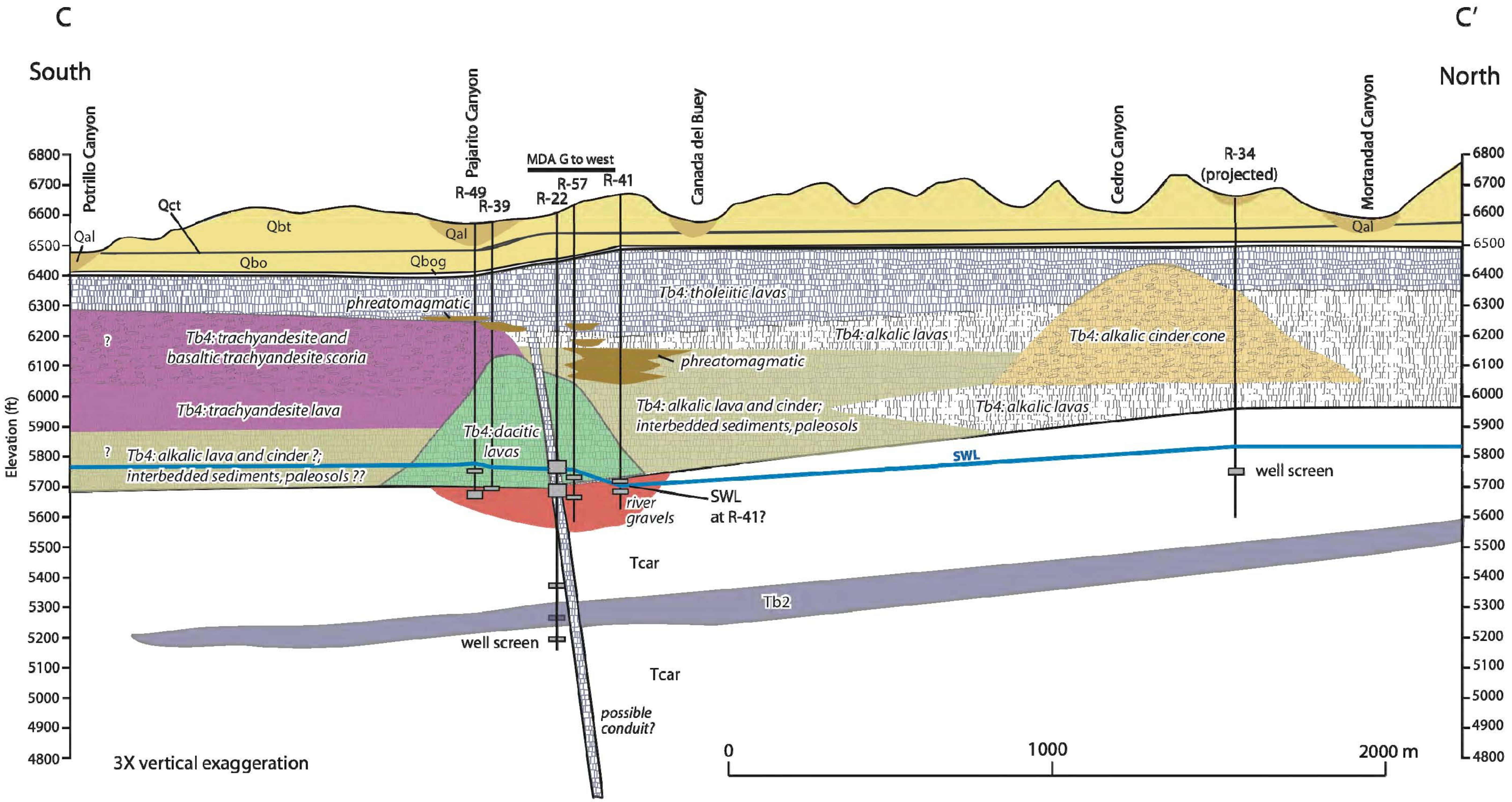
Note: See Figure D-2.1-1 for location of cross-section.

Figure D-2.1-2 North-south cross-section A–A′ near MDA H



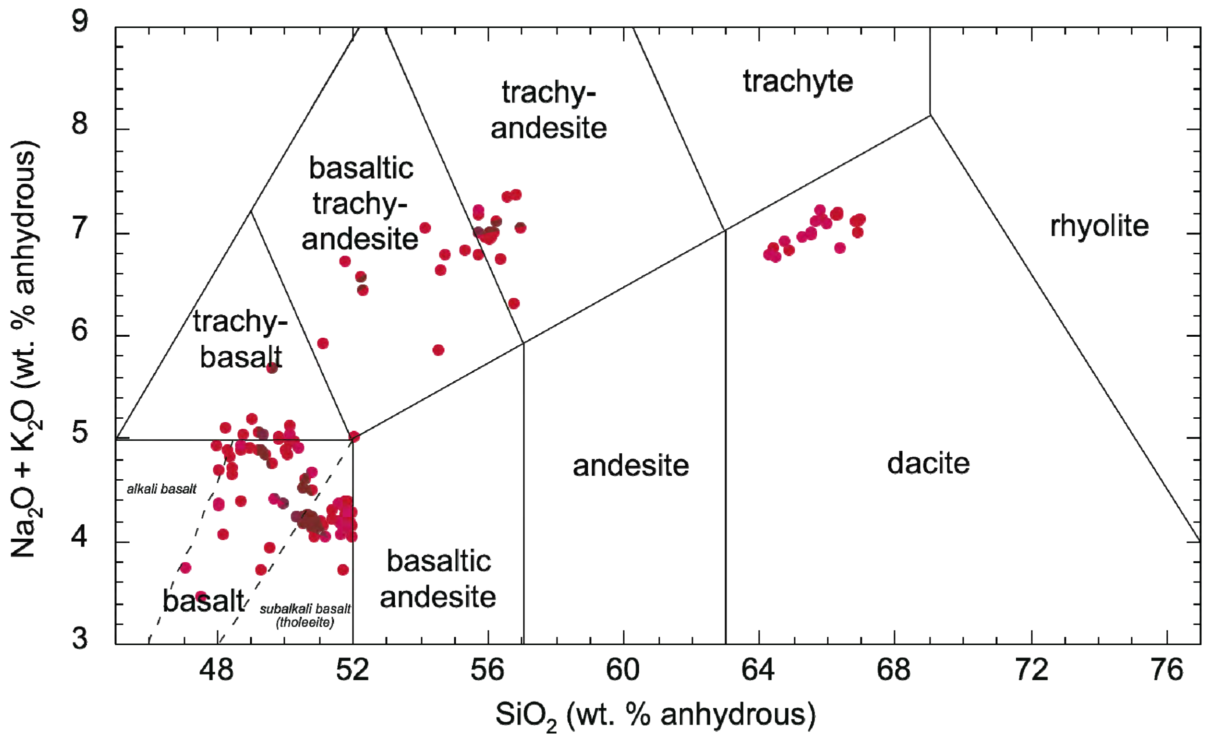
Note: See Figure D-2.1-1 for location of cross-section.

Figure D-2.1-3 North-south cross-section B–B′ east of MDA L and west of MDA G



Note: See Figure D-2.1-1 for location of cross-section.

Figure D-2.1-4 North-south cross-section C–C′ near east end of MDA G



Note: Gray arrow shows the eruption sequence from oldest to youngest rocks.

Figure D-2.1-5 Alkali-silica diagram showing chemical classification of Cerros del Rio volcanic rocks in the vicinity of TA-54

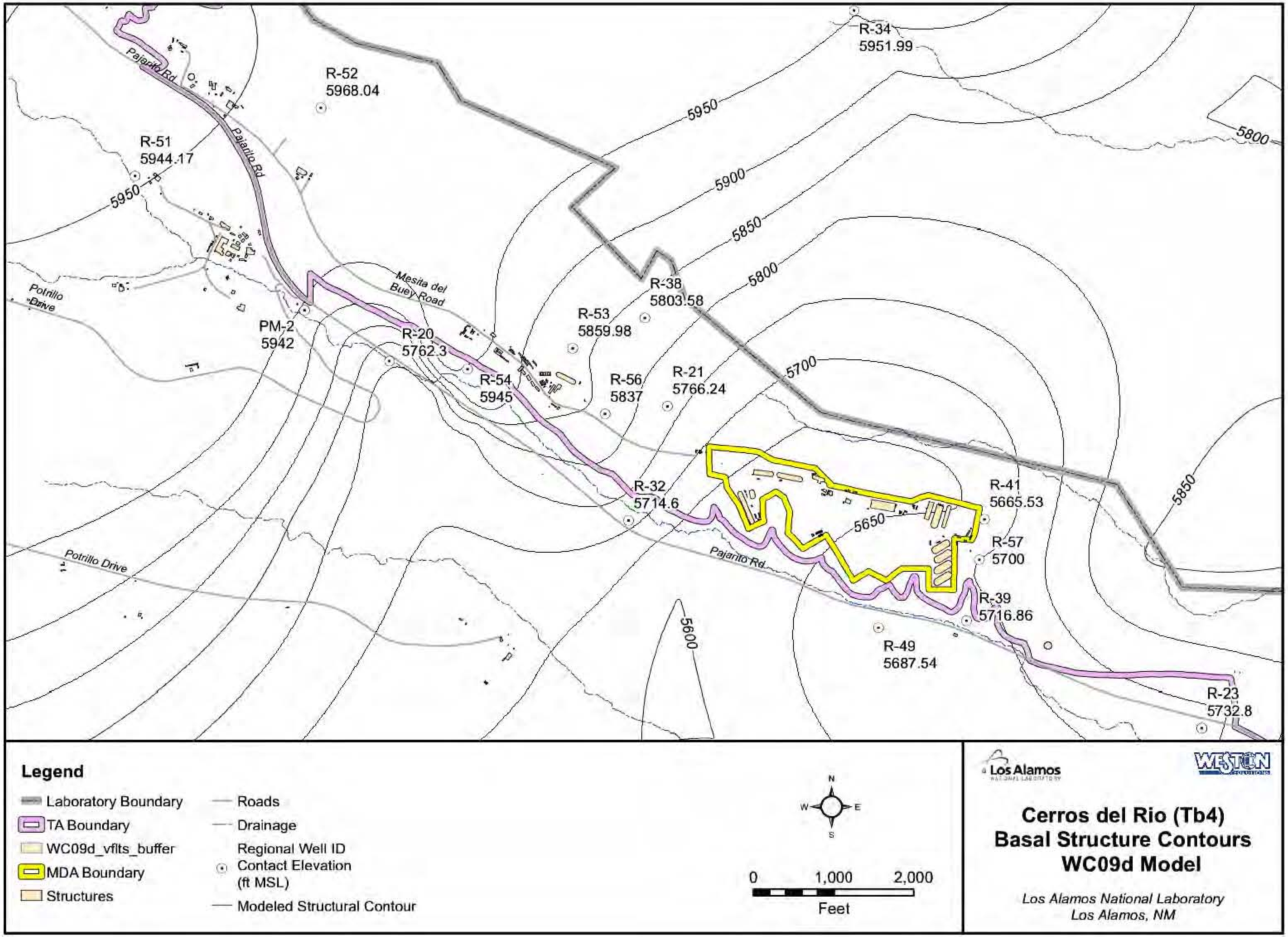


Figure D-2.1-6 Structure contour map for the base of Cerros del Rio volcanic rocks in the vicinity of TA-54

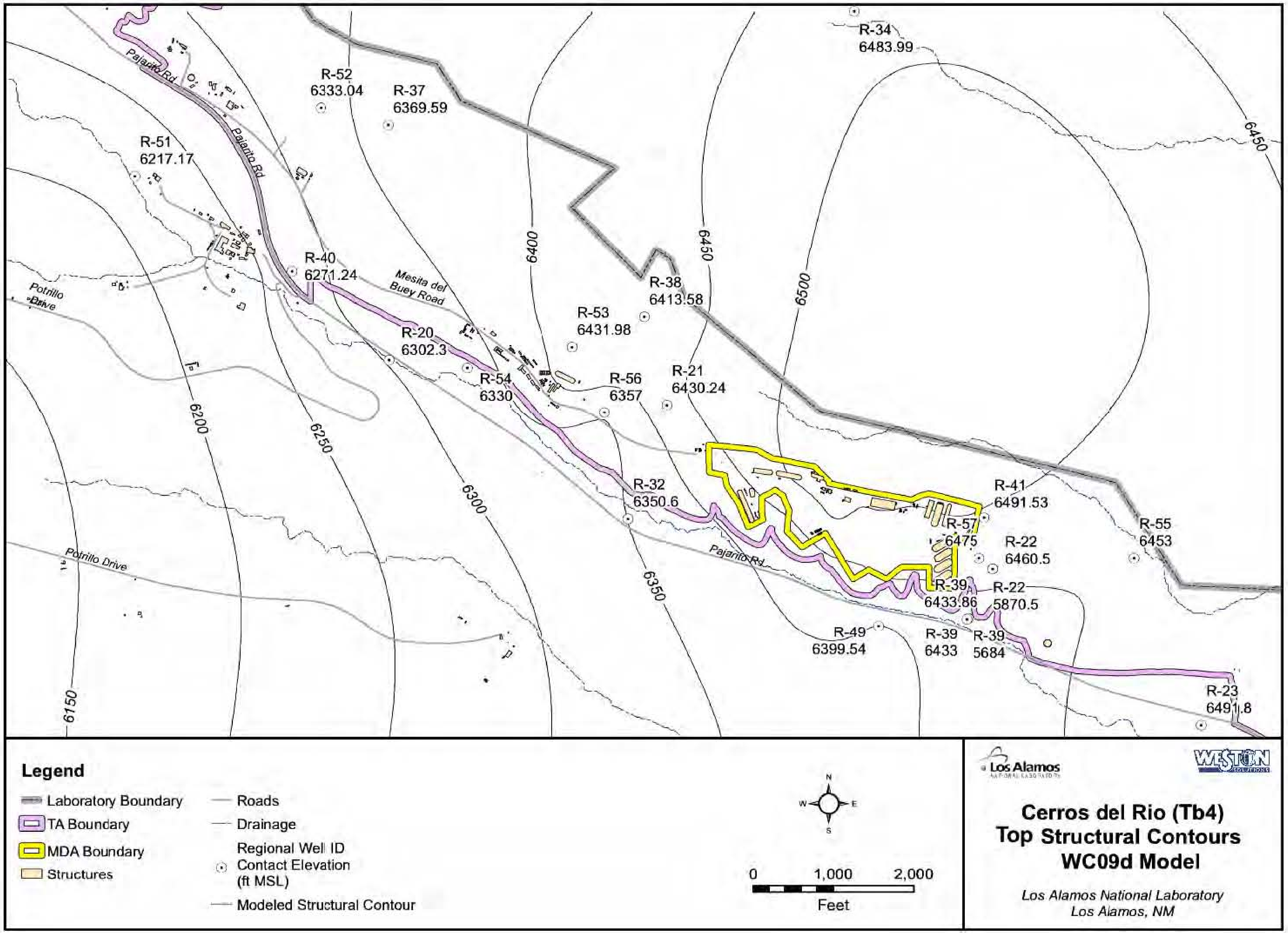
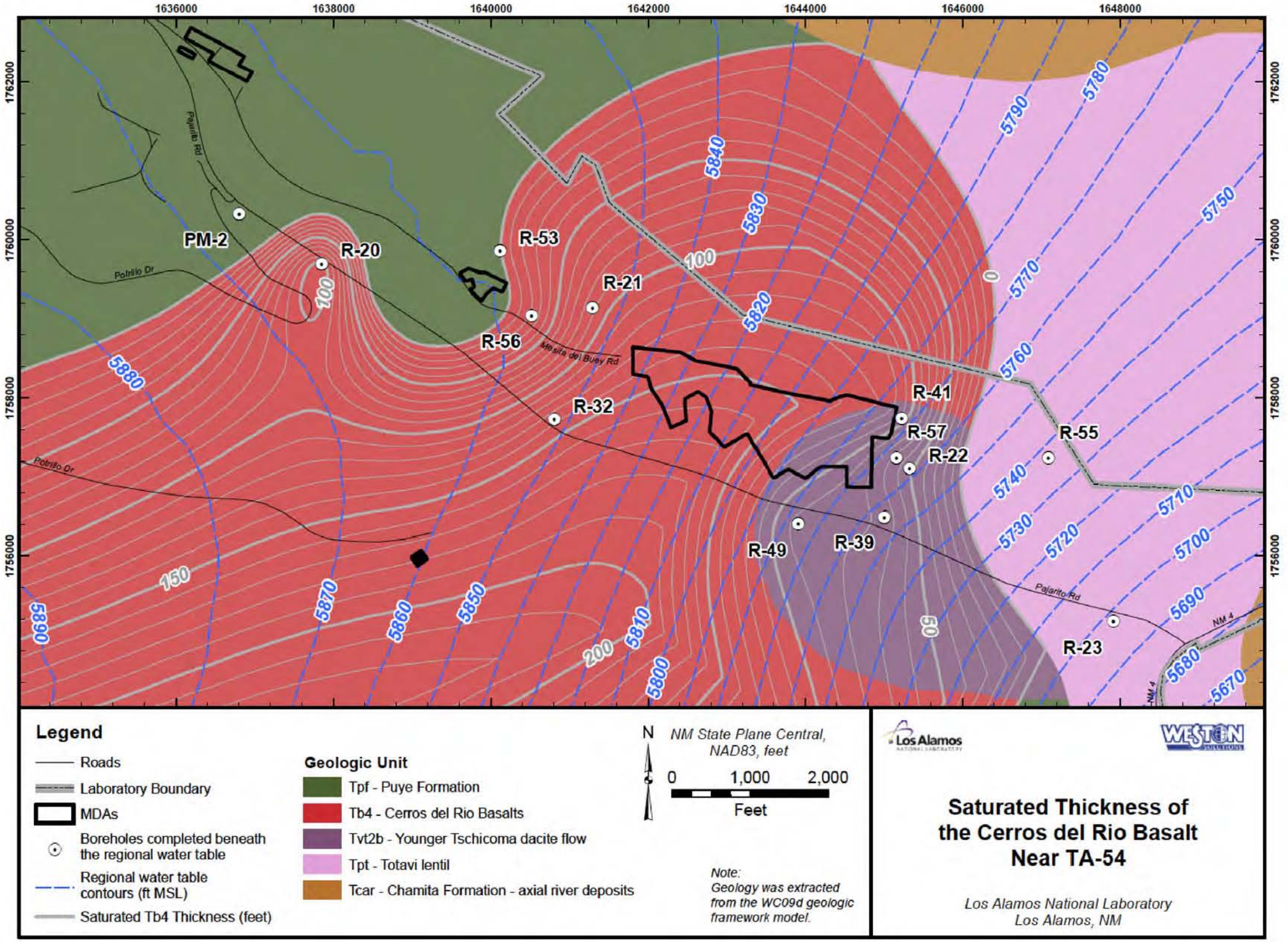
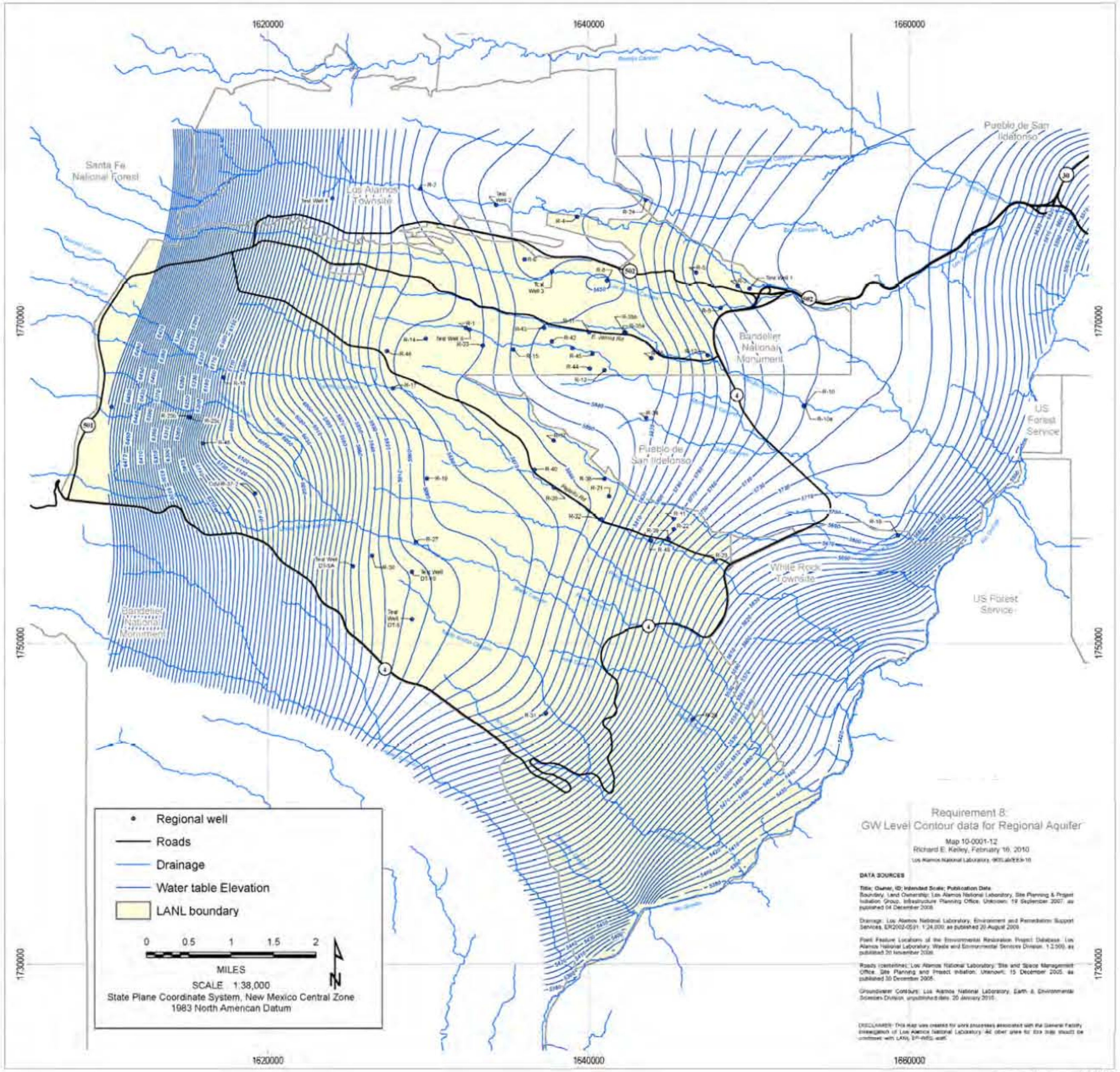


Figure D-2.1-7 Structure contour map for the top of Cerros del Rio volcanic rocks in the vicinity of TA-54



Notes: Groundwater-level contour map is based on average data representative for March 2009 (LANL 2010, 109084) The water table contours (blue dashed contours) do not include wells installed after March 2009. Recently acquired data show the base of the lavas at R-41 is above the water table.

Figure D-2.1-8 Hydrostratigraphy at the regional water table and estimated thickness of Cerros del Rio lavas beneath the regional water table (gray contours)



Requirement 8:
GW Level Contour data for Regional Aquifer

Map 10-0001-12
Richard E. Kelley, February 16, 2010
Los Alamos National Laboratory, WES-EES-10

DATA SOURCES

Title; Owner, ID; Intended Scale; Publication Date
Boundary, Land Ownership: Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; Unknown; 19 September 2007; as published 04 December 2008.

Drainage: Los Alamos National Laboratory, Environment and Remediation Support Services, ER2002-0591; 1:24,000; as published 20 August 2009.

Point Feature Locations of the Environmental Restoration Project Database: Los Alamos National Laboratory, Waste and Environmental Services Division; 1:2,500; as published 20 November 2008.

Roads (centerline): Los Alamos National Laboratory, Site and Space Management Office, Site Planning and Project Initiation; Unknown; 15 December 2005; as published 30 December 2005.

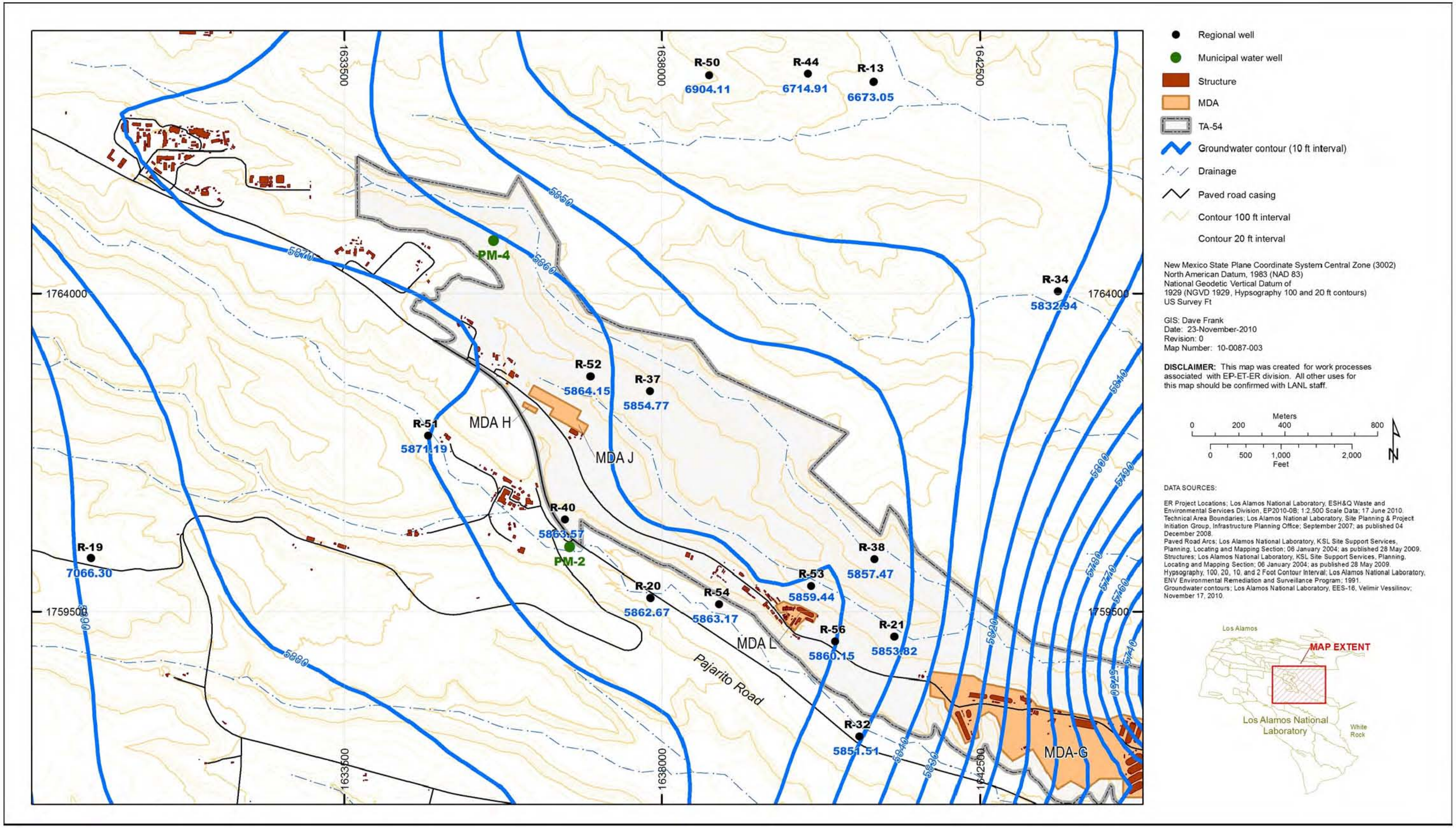
Groundwater Contours: Los Alamos National Laboratory, Earth & Environmental Sciences Division, unpublished data; 20 January 2010.

DISCLAIMER: This map was created for work processes associated with the General Facility Information of Los Alamos National Laboratory. All other uses for this map should be confirmed with LANL EP-WES staff.

2010 General Facility Information, MONTH 2010
LA-UR-10-1563

Source: LANL (2010, 109084).

Figure D-3.2-1 Groundwater level contour map based on average data representative for March 2009



New Mexico State Plane Coordinate System Central Zone (3002)
North American Datum, 1983 (NAD 83)
National Geodetic Vertical Datum of
1929 (NGVD 1929, Hypsography 100 and 20 ft contours)
US Survey Ft

GIS: Dave Frank
Date: 23-November-2010
Revision: 0
Map Number: 10-0087-003

DISCLAIMER: This map was created for work processes associated with EP-ET-ER division. All other uses for this map should be confirmed with LANL staff.

DATA SOURCES:

ER Project Locations; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division, EP2010-0B; 1:2,500 Scale Data; 17 June 2010.
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Figure D-3.2-2 Preliminary water-table map based on data representative for July–September 2010 regional water levels in the area near MDA G

Table D-3.1-1
Estimates of Effective Aquifer Hydraulic Properties in the Area Near TA-54

Well Screen	PM-2		PM-4		Comment
	T (m^2/d)	S (-)	T (m^2/d)	S (-)	
R-51#1	ND[a]	ND	ND	ND	Small response to PM-4; more data needed
R-51#2	ND	ND	ND	ND	Responses to PM-4; PM-2 also expected
R-52#1	ND	ND	ND	ND	Small response to PM-4; more data needed
R-52#2	ND	ND	ND	ND	Small response to PM-4; more data needed
R-40#2	ND	ND	ND	ND	Responses to PM-4; PM-2 also expected
R-37#2	ND	ND	ND	ND	Small response to PM-4; more data needed
R-20#1	4.2E+03	3.9D-02	8.5E+03	1.5D-02	Responses to PM-2 and PM-4 only
R-20#2	1.9E+03	6.2D-03	3.2E+03	8.9D-04	Responses to PM-2 and PM-4 only
R-20#3	4.5E+02	9.1D-04	7.9E+02	2.2D-05	Responses to PM-2 and PM-4 only
R-54#1	ND	ND	ND	ND	Potentially small response to PM-4; more data needed
R-54#2	ND	ND	ND	ND	Responses to PM-4; PM-2 also expected
R-53#1	—[b]	—	—	—	No apparent water-supply pumping response
R-53#2	ND	ND	ND	ND	Responses to PM-4; PM-2 also expected
R-56#1	ND	ND	ND	ND	Water-supply responses expected; more data needed
R-56#2	ND	ND	ND	ND	Water-supply responses expected; more data needed
R-38	—	—	—	—	No apparent water-supply pumping response
R-21	1.7E+03	2.9D-02	1.1E+03	9.3D-03	Responses to PM-2 and PM-4 only
R-32#1	—	—	—	—	No apparent water-supply pumping response
R-32#2	3.1E+03	6.0D-03	3.8E+03	2.5D-03	Responses to PM-2 and PM-4 only
R-32#3	3.1E+03	2.9D-03	4.0E+03	1.5D-03	Responses to PM-2 and PM-4 only
R-49#1	—	—	—	—	No apparent water-supply pumping response
R-49#2	—	—	—	—	No apparent water-supply pumping response
R-41#2	—	—	—	—	No apparent water-supply pumping response
R-57#1	ND	ND	ND	ND	More data needed; water-supply responses not expected
R-57#2	ND	ND	ND	ND	More data needed; water-supply responses not expected
R-39	—	—	—	—	No apparent water-supply pumping response
R-55#1	ND	ND	ND	ND	More data needed; water-supply responses not expected
R-55#2	ND	ND	ND	ND	More data needed; water-supply responses not expected
R-23	—	—	—	—	No apparent water-supply pumping response

Notes: Wells are ordered from west to east, approximately following the general groundwater flow directions of the regional aquifer. Estimates are based on analysis of the water-level transients observed at the monitoring wells caused by water-supply pumping.

[a] ND = Currently data to estimate aquifer properties are not sufficient.

[b] — = No estimate for aquifer properties is available because no apparent pumping drawdowns were observed.

Table D-3.1-2
Hydrogeologic Characteristics of the Monitoring Wells in the Area Near MDA H

Well Screen	k (ft/d)	Unit	Submergence below the Water Table	Hydrodynamic Conditions	Comments Based on the Pumping Tests Conducted at the Screens
R-51#1	16	Tpf	25	Unconfined or partly confined	Clay-rich materials 10 ft thick above screen 1; pumping test complicated because of gases in the aquifer
R-51#2	4	Tpf	140	Unconfined or partly confined	Pumping test complicated because of gases in the aquifer
R-52#1	19	Tpf	18	Unconfined or partly confined	Pumping test complicated because of gases in the aquifer
R-52#2	26	Tpf	90	Unconfined or partly confined	Pumping test complicated because of gases in the aquifer
R-40#2	4	Tpf mixed with Tpt	-4	Unconfined	Hydraulic connection between the regional aquifer and the overlying perched zone (screened at R-40 screen 1 and R-40i) is unknown.
R-37#2	21	Tpf	14	Unconfined	Drawdown equilibration at late pumping times
R-20#1	1	Tb 4 (cinders)	77	Unconfined or partly confined	—*
R-20#2	1	Tjfp	317	Confined	—
R-20#3	1	Tcar	407	Confined	Plugged and abandoned

Note: Wells are ordered from west to east, approximately following the general groundwater flow directions of the regional aquifer.

* — = No comment.

Table D-3.1-3
Vertical Component of the Hydraulic Gradient at the Monitoring Wells Near TA-54

Well	Value
R-51	0.02
R-52	0.03
R-20	0.2
R-54	–0.03
R-53	0.09
R-56	0.05
R-32	0.02
R-49	0.4
R-57	0.2
R-22	0.2
R-55	0.03

Note: Wells are ordered from west to east, approximately following the general groundwater flow directions of the regional aquifer.

Appendix E

Contaminants Detected in Vapor Phase and Deep Groundwater Samples from Monitoring Wells Near Material Disposal Area H

E-1.0 INTRODUCTION

This appendix discusses contaminants detected during monitoring below and downgradient of Material Disposal Area (MDA) H. Volatile organic compounds (VOCs) were not listed in the waste logbook entries, but were detected in trace amounts in vapor-phase sampling in the MDA H Resource Conservation and Recovery Act Facility Investigation boreholes; section E-2.0 provides an estimate of the inventory of VOCs present in the vadose zone beneath MDA H based on vapor-monitoring data gathered at the site. Section E-3.0 summarizes chemicals detected in deep (perched-intermediate and regional) groundwater wells specific to MDA H (R-20, R-37, R-40i, R-40, and R-52). Section E-4.0 compares the list of chemicals of potential concern (COPCs) detections in groundwater with those known or potentially expected to be present in the vadose zone below MDA H and evaluates the hypothesis that MDA H is a source of COPCs detected in the groundwater. Based on these analyses, section E-5.0 provides conclusions concerning the transport of COPCs through the vadose zone below MDA H to deep groundwater downgradient of MDA H.

E-2.0 ESTIMATED INVENTORY OF VOLATILE ORGANIC COMPOUNDS IN THE VADOSE ZONE AT MATERIAL DISPOSAL AREA H

E-2.1 Purpose

Quarterly pore-gas monitoring activities have been conducted at MDA H since the second quarter of fiscal year 2005 to characterize VOC and tritium concentrations present in the vadose zone beneath MDA H. Currently, pore gas samples are collected at 28 ports in 4 vapor-monitoring boreholes. Monitoring activities are implemented quarterly as directed by the New Mexico Environment Department (NMED) in a June 23, 2009, letter to the Laboratory.(NMED 2009, 106234). These data are used here to estimate the mass of VOCs in the vadose zone at MDA H.

Based on available information, the source of VOCs is expected to be incidental contamination of the wastes disposed at MDA H. The inventory of VOCs associated with this type of source would be small compared with sources such as disposal of bulk solvent wastes. To determine whether the results of pore-gas monitoring at MDA H were consistent with such a source, these data were used to estimate the inventory of VOCs in the subsurface at MDA H.

The inventory of VOCs present in the subsurface is estimated based on the concentrations of VOCs measured in pore gas and equilibrium partitioning relations. This estimate was used to quantify the mass in the vapor phase, dissolved phase, and when adsorbed to solids. For the purpose of this evaluation, only a rough order of magnitude inventory estimate was needed. Therefore, simplifying assumptions were made for some of the data. When assumptions were necessary, they were made to yield more conservative results (e.g., a higher estimate of the inventory). The approach used for estimating the VOC inventory and the results of the evaluation are described below.

E-2.2 Approach

VOCs present in subsurface media will be in pore gas as vapors, dissolved into pore water, and adsorbed onto solid media. Detected concentrations of VOCs in pore gas are orders of magnitude less than the vapor pressures of these chemicals, which is evidence that VOCs are not present as a separate, nonaqueous liquid phase. Several equilibrium partitioning constants describe the relationship between the concentrations of chemicals in these various phases. These constants were used to develop an expression for the overall concentration of a VOC in the bulk medium (i.e., tuff) as a function of the concentration in the vapor phase. Measured vapor phase concentrations were then used to calculate the bulk concentration in tuff, which was used to estimate the overall mass of the inventory based on an assumed volume of affected media.

The first partitioning constant used is Henry's law coefficient. The dimensionless form of Henry's law coefficient describes the equilibrium relationship between the volumetric concentrations of chemicals in air and in water.

$$H' = C_{air} / C_{water}$$ **Equation E-1**

Where H' = the dimensionless form of Henry's law coefficient,

C_{air} = the volumetric concentration of chemical in air (M/L^3), and

C_{water} = the volumetric concentration of chemical in water (M/L^3).

Rearranging Equation E-1 gives

$$C_{water} = C_{air} / H'$$ **Equation E-2**

The second partitioning constant used is the distribution coefficient. The distribution coefficient describes the equilibrium relationship between the concentrations of chemicals dissolved in water and adsorbed on solids.

$$K_d = C_{solid} / C_{water}$$ **Equation E-3**

Where K_d = the distribution coefficient (L^3/M) and

C_{solid} = the mass concentration of contaminant in soil or tuff (M/M).

For organic chemicals, the adsorption of chemicals onto the solid phase is strongly influenced by the amount of organic carbon present in the solid. The distribution coefficient can be estimated from the organic carbon distribution coefficient and the fraction of organic carbon in tuff.

$$K_d = K_{oc} \; f_{oc}$$ **Equation E-4**

Where K_{oc} is the organic carbon distribution coefficient (L^3/M) and

f_{oc} is the fraction of organic carbon in tuff (M/M).

Rearranging Equation E-3 and substituting Equation E-2 and Equation E-4 give

$$C_{solid} = K_{oc} \; f_{oc} \; C_{air} / H'$$ **Equation E-5**

The bulk concentration of chemical in tuff is equal to the total mass of chemical in all three phases per unit mass of tuff.

$$C_{bulk} = \frac{M_{air} + M_{water} + M_{solid}}{M_{soil}}$$ **Equation E-6**

Where C_{bulk} = the bulk concentration of chemical in tuff (M/M),

M_{air} = the mass of chemical present in the vapor phase in pore gas (M),

M_{water} = the mass of chemical present in the liquid phase in pore water (M),

M_{solid} = the mass of chemical present in the solid phase in tuff (M), and

M_{soil} = the mass of the soil or tuff.

The mass of chemical present in the vapor phase in pore gas is equal to the product of the concentration in air and the volume of air. The latter is equal to the product of the air-filled porosity and the volume of tuff. The mass of contaminant present in the liquid phase in pore water is equal to the product of the concentration in water and the volume of water. The latter is equal to the product of the water-filled porosity and the volume of tuff. The mass of contaminant present in the solid phase in tuff is equal to the product of the concentration in the solid phase and the mass of tuff. The latter is equal to the product of the volume of tuff and the bulk density of tuff.

Using the relationships described above, Equation E-6 can be rewritten as

$$C_{bulk} = \frac{\left(C_{air}\, V_{soil}\, \theta_{air}\right) + \left(C_{air}\, V_{soil}\, \theta_{water} \big/ H'\right) + \left(C_{air}\, K_{oc}\, f_{oc}\, V_{soil}\, \rho_{soil} \big/ H'\right)}{V_{soil}\, \rho_{soil}}$$ **Equation E-7**

where V_{soil} = the volume of tuff (L^3),

θ_{air} = the air-filled porosity (L^3/L^3),

θ_{water} = the water-filled porosity or volumetric water content (L^3/L^3), and

ρ_{soil} = the bulk density of tuff (M/L^3).

Equation E-7 can be simplified to:

$$C_{bulk} = \frac{C_{air}\left(\theta_{air} + \theta_{water} \big/ H' + \left(K_{oc}\, f_{oc}\, \rho_{soil}\right) \big/ H'\right)}{\rho_{soil}}$$ **Equation E-8**

Equation E-8 gives the bulk concentration of VOC in tuff as a function of the pore gas concentration and properties of the chemical and tuff. The sources of the data used in Equation E-8 and any associated assumptions are described below.

- C_{air}– The pore-gas monitoring results provide the concentration of a particular VOC measured at each sampling point. To simplify the analysis, a uniform pore gas concentration was assumed for the entire affected volume. This concentration was calculated as the average of the detected values from the sample results collected during June 2010. Using only the detected values in the calculation overestimates the average concentration, particularly for VOCs having a high frequency of non-detects. Most of the VOCs detected at MDA H were detected in less than half the samples.

- θ_{air}– The air-filled porosity will depend on the total porosity and moisture content of the tuff, both of which will vary depending on geologic unit and depth. To simplify the analysis, a single value of 0.4 was assumed for the entire affected volume. This value was selected as being representative of tuff at Los Alamos National Laboratory (LANL) beneath dry mesas, such as Mesita del Buey where MDA H is located.
- θ_{water}– The volumetric water content will vary depending on the physical properties of the geologic unit. To simplify the analysis, a single value of 0.05 was assumed for the entire affected volume. This value was selected as being representative of tuff at LANL beneath dry mesas.
- H' and K_{oc}– Henry's law coefficient and organic carbon distribution coefficient are physical properties of the VOC, and H' is a function of temperature. The values for these two coefficients were obtained from the NMED soil screening-level technical background document (NMED 2009, 108070). If values were not available from this source, they were obtained from the U.S. Environmental Protection Agency regional screening level database (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm). The values of H' and K_{oc} used are presented in Table E-2.2-1.
- f_{oc}– The fraction of organic carbon depends on the amount of organic matter present in the tuff and varies depending on the amount of weathering and biological activity. A single value of 0.0005 (0.05%) was assumed to be representative of tuff in the subsurface beneath MDA H. This value is a factor of 3 less than the representative value for soil presented by NMED (2009, 108070) and reflects the lower organic content of tuff.
- ρ_{soil}– The bulk density depends on the total porosity of the tuff and the density of the solids comprising the tuff, and will vary depending on geologic unit. A single value of 1.46 kg/L was used based on the total porosity of 0.45 and an assumed solids density of 2.65. This single value is assumed to be representative of tuff in the subsurface beneath MDA H.

E-2.3 Results

Equation E-8 was used with the data described above to calculate a bulk concentration for each detected VOC (Table E-2.3-1). To calculate a mass inventory, concentrations of each VOC were multiplied by the mass of affected tuff. The latter was calculated from the estimated dimensions of the plume and the bulk density of tuff. Based on the available monitoring data, the VOC plume was assumed to have dimensions of 450-ft long x 200-ft wide x 300-ft deep, resulting in a volume of 2.7×10^{7} ft^{3}, or 7.65×10^{8} L. The mass of tuff was calculated as this volume multiplied by the dry bulk density of tuff (1.46 kg/L). This mass (1.12×10^{9} kg) was multiplied by the bulk concentration of each VOC to obtain the chemical inventory. These results are presented in Table E-2.3-1 and summarized by chemical class in Table E-2.3-2.

Table E-2.3-3 provides the average concentration calculated for each analyte that was used as input to the mass estimates provided in Tables E-2.3-1 and E-2.3-2. As the definition of C_{air} notes above, these averages use only detected values and neglect nondetects; this yields a considerably higher estimated average concentration than would be calculated if the nondetects were included. Table E-2.3-3 shows the detected values used to calculate the averages. It is clear that most constituents are not detected in all 28 ports. These average concentrations were assumed to be present in the entire volume calculated above, which includes areas where many of the constituents are not detected. The combination of the overestimated concentration and volume yields a high predicted mass, especially for constituents that are detected at only a few sampling ports.

E-2.4 Discussion

The estimated VOC inventory in the subsurface at MDA H is on the order of 2 kg. This estimate is considered to be high (conservative) based on the assumptions used in the calculation (section E-2.3). This order of magnitude estimate is consistent with the expected source of VOCs (i.e., incidental contamination of the wastes disposed at MDA H rather than disposal of bulk chemical wastes). This result is also consistent with operational history at Technical Area 54 (TA-54). Specifically, MDA H was established for disposal of classified solid-form wastes, which would likely not include bulk solvent wastes.

Ninety-two percent of the estimated inventory at MDA H is associated with alcohols and ketones (e.g., butanol and acetone). These classes of chemicals are soluble in water and have low Henry's law coefficients (i.e., they partition more strongly into the aqueous phase than into the vapor phase). Thus, most of the inventory of these compounds is dissolved into the pore water. In contrast, halogenated VOCs (e.g., tetrachloroethene), which are generally the most toxic and of the most concern with respect to potential groundwater contamination, are not soluble in water (high Henry's law coefficient) and partition strongly into the vapor phase (air-filled pore space). These comprise less than 5% of the total estimated inventory (approximately 0.1 kg).

E-3.0 DEEP GROUNDWATER MONITORING WELLS NEAR MATERIAL DISPOSAL AREA H

E-3.1 Purpose

Groundwater monitoring at Los Alamos National Laboratory (LANL or the Laboratory) is currently conducted in accordance with the 2010 Interim Facility-Wide Groundwater Monitoring Plan (hereafter, the 2010 IFGMP) (LANL 2010, 109830). Wells potentially downgradient of MDA H include deep (perched-intermediate and regional) groundwater wells R-20, R-37, R-40, R-40i, and R-52. Monitoring well R-51 is located upgradient of MDA H. Additional wells assigned to the TA-54 monitoring network include those specific to MDA G (R-22, R-39, R-41, R-49, R-55, and R-57) and MDA L (R-21, R-38, R-53, R-54, and R-56). In addition, two deep groundwater monitoring wells (R-23 and R-23i) are located further downgradient of TA-54 in Pajarito Canyon. Table E-3.1-1 summarizes relevant information about the screened intervals and sampling systems installed in each of the 17 deep groundwater monitoring wells in the TA-54 monitoring well network. This section focuses on the five monitoring wells immediately downgradient of MDA H, although it is recognized that all of the TA-54 monitoring network wells contribute in an integrated fashion to monitor for different potential sources of contaminants.

Section E-3.2 reviews the geochemical performance of each screened interval in the wells specific to MDA H, focusing on the ability of each screen to provide reliable data for COPCs specific to MDA H. The largest component of the MDA H waste inventory is metal (24% depleted uranium and 33% other metals) (Figure 2.2-1). Key RCRA metals present at MDA H include barium, cadmium, chromium, lead, mercury, and silver (Table 2.2-1; Appendix B). Radioactive materials other than depleted uranium account for approximately 24% of the inventory and include tritium, uranium isotopes, and plutonium isotopes. Other materials present include graphite, plastics, paper, and high explosives (HE). VOCs were not listed in the waste logbook entries, but are detected in trace amounts in vapor-phase sampling; these data were used to estimate the VOC inventory at MDA H in Table E-2.3-1.

Section E-3.3 outlines the protocol used to compare water-quality data with applicable regulatory or other risk-based screening levels, and with groundwater background concentrations for naturally-occurring constituents. Results of the screening protocol are presented in section E-3.4 (for organic compounds and HE) and in section E-3.5 (for inorganic constituents). Section E-3.6 summarizes tritium data for the wells; the presence or absence of tritium at a location provides a useful tracer of flow and transport pathways because it travels conservatively in groundwater.

E-3.2 Geochemical Performance of Monitoring Wells

Evaluations of the geochemical performances of four of the wells specific to MDA H (R-20, R-37, R-40i, and R-40) were previously reported in the “TA-54 Well Evaluation and Network Recommendations, Revision 1” (hereafter the TA-54 Network Evaluation, Rev. 1) (LANL 2007, 098548, Appendix B) and in the 2010 “Interim Facility-Wide Groundwater Monitoring Plan” (LANL 2010, 109830, Table F-2.0-1). These evaluations focus on the capability of each screened interval to provide water-quality data that are reliable and representative of predrilling conditions for COPCs sourced at MDA H. These earlier evaluations are updated in this section based on the most recent water-quality samples, and the protocol is extended to include samples from newly completed well R-52. The evaluation protocol is the same as that used in the TA-54 Network Evaluation, Rev. 1, and the 2010 IFGMP, which is based on the approach described in the “Well Screen Analysis Report, Revision 2” (LANL 2007, 096330).

Key observations based on the evaluations are summarized below, focusing on the implications for reliable and representative detections of COPCs sourced at MDA H, particularly tritium, uranium and other trace metals, high explosive compounds, and VOCs.

- R-20 screen 1 meets geochemical-monitoring objectives unconditionally. The geochemical performance of R-20 screen 1 through August 3, 2010 was evaluated in the Corrective Measures Evaluation report for MDA L (LANL 2010, 110852). That report concluded that water quality in this screened interval has mostly—if not completely—reequilibrated to predrilling conditions following well rehabilitation and conversion activities in late 2007 and installation of the Baski sampling system on May 22, 2008. Based on updated groundwater background values (BVs), discussed in section E-3.3, and the presence of detectable background levels of nitrate, perchlorate, and redox-sensitive trace metals, conditions appear to be oxidizing, as is typical for local regional groundwater. Barium concentrations are stable although slightly elevated relative to the upper tolerance limit (UTL) for regional background groundwater (section E-3.5). The stability of inorganic geochemical indicators extending over the past six or more groundwater sampling events suggests that they may be representative of predrilling conditions. This well screen is capable of providing representative data for all MDA H COPCs.
- R-20 screen 2 meets geochemical-monitoring objectives conditionally. The geochemical performance of R-20 screen 2 through June 1, 2010, was evaluated in the CME report for MDA L (LANL 2010, 110852, Appendix D-3.0). That report concluded that geochemical conditions in the screened interval had improved relative to those that existed before rehabilitation activities were conducted in 2007 but did not appear to have recovered to the same extent as in the upper screen. This conclusion was based in part on the observation that the concentrations for a few parameters consistently fall outside the range of natural background variability and had not attained stable concentrations. For example, post-rehabilitation barium concentrations are approximately twice the UTL, which could indicate incomplete recovery of groundwater from the sulfate-reducing conditions that persisted in this screened interval until its rehabilitation in 2007. However, this screen may also show the presence of local contaminants, which affects the applicability of some of the geochemical evaluation criteria. Based on the longer postconversion data record now available, this screen is capable of providing representative data for most MDA H COPCs, including uranium and tritium, but excluding barium, iron, and manganese.
- R-37 screen 1 meets geochemical-monitoring objectives unconditionally. This well screen is capable of providing representative data for all MDA H COPCs.

- R-37 screen 2 meets geochemical-monitoring objectives unconditionally. Geochemical parameters appear to have reequilibrated to predrilling conditions approximately six months following the installation of the dedicated Baski sampling system on December 16, 2009. This well screen is capable of providing representative data for all MDA H COPCs.
- R-40i meets geochemical-monitoring objectives conditionally. Evaluation of water-quality samples collected in 2010 indicates the continued presence of residual constituents from products and materials introduced downhole during drilling and well construction, evidenced by elevated total organic carbon (TOC) and ammonia, and reducing conditions. This well screen is currently capable of providing representative data for most MDA H COPCs, including barium, uranium, and tritium. The geochemical performance of this screen will continue to be reassessed as additional data become available.
- R-40 screen 1 meets geochemical-monitoring objectives conditionally. Evaluation of water-quality samples collected in 2010 indicates the continued presence of residual constituents from products and materials introduced downhole during drilling and well construction, although not to the same extent as in R-40i. This well screen is capable of providing representative data for most MDA H COPCs, including barium, uranium, and tritium. The geochemical performance of this screen will continue to be reassessed as additional data become available.
- R-40 screen 2 meets geochemical-monitoring objectives unconditionally. There is no evidence of the presence of residual effects of drilling or construction. This well screen is capable of providing representative data for all MDA H COPCs.
- R-52 screen 1 meets geochemical-monitoring objectives unconditionally. There is no evidence of the presence of residual effects of drilling or construction in the characterization samples collected in 2010. This well screen is capable of providing representative data for all MDA H COPCs.
- R-52 screen 2 meets geochemical-monitoring objectives unconditionally. There is no evidence of the presence of residual effects of drilling or construction in the characterization samples collected in 2010. This well screen is capable of providing representative data for all MDA H COPCs.

E-3.3 Screening Protocol for Groundwater Data

A two-tier screening protocol is used to evaluate water-quality data from approximately 60 sampling events at the MDA H monitoring network wells.

1. The first tier compares COPC data with groundwater background concentrations.
    - Naturally occurring inorganic COPCs are compared with groundwater BVs determined in the Groundwater Background Investigation Report, Revision 4 (hereafter GBIR R4) (LANL 2010, 110535) (Table E-3.3-1). Groundwater BVs consist of UTLs for those constituents detected at a sufficiently high detection rate (≥25%) and for a sufficient number of sample results (≥10); if these statistical criteria were not met, then the BV is set at the maximum method detection limit (MDL) reported by the analytical laboratory (GBIR R4, section 3.7).
    - Because organic COPCs are not present in uncontaminated groundwater, the first-tier screening results in the identification of all organic COPCs detected at each monitored location.

2. The second-tier screening compares COPC data with the lowest applicable regulatory standard or other risk-based screening level based on the most current guidance documents from NMED and the EPA.

    - Groundwater perchlorate data are compared with the screening level of 4 µg/L established in section VIII.A.1.a of the Compliance Order on Consent (the Consent Order).
    - Regulated COPCs are compared with the lowest applicable regulatory standard: the New Mexico Water Quality Control Commission (NMWQCC) groundwater standards, standards for toxic chemicals calculated in accordance with 20.6.2.7.WW New Mexico Administrative Code, and the drinking water maximum contaminant levels (MCLs) adopted by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act. WQCC groundwater standards generally apply only to the dissolved (filtered) portion of specified contaminants, with the exception of the standards for mercury, organic compounds, and organic constituents, which apply to the total (unfiltered) concentrations of the contaminants. As a conservative screening measure, EPA MCLs are considered appropriate screening values for both filtered as well as unfiltered concentrations.
    - For constituents that have no other regulatory standard but for which toxicological information is published, concentrations are compared with the lowest risk-based screening level for tap water reported in the most current versions of NMED and EPA guidance documents: NMED’s Tap Water Screening Levels listed in Table A-1 of the *Technical Background Document for Development of Soil Screening Levels*, or the EPA *Regional Screening Levels for Chemical Contaminants at Superfund Sites* (RSLs) for tap water. For these screening levels, the tables indicate whether the value listed for a particular substance is a risk type of C (cancer) or N (noncancer). For the cancer-risk type, the EPA RSL table shows risk levels calculated for 10^{-6} excess cancer risk, and the NMED table shows risk levels calculated for 10^{-5} excess cancer risk. For noncancer-risk types, both tables list values calculated for a hazard index (HI) of 1.0. The Consent Order specifies screening at a risk level of 10^{-5} (rather than 10^{-6}) excess cancer risk. For these constituents, the EPA 10^{-6} risk-level values have been multiplied by a factor of 10 to adjust them to the 10^{-5} risk level. As a conservative screening measure, the NMED soil screening level (SSL) values and EPA RSL values are considered appropriate screening values for both filtered and unfiltered concentrations.
    - The values used to screen detected organic constituents and HE compounds in this appendix are the same as those listed in the 2010 IFGMP (LANL 2010, 109830, Appendix C), with the exception of three compounds listed in Table E-3.3-2.
    - The outcome of the screening protocol is summarized in a set of frequency-of-detection tables that summarize all detected organic compounds as well as all inorganic constituents detected above groundwater background concentrations. The detection status for an analytical result is established using the combined set of laboratory-assigned validation qualifiers and reason codes assigned during data validation. For detected constituents, the screening tables include summary information such as the total number of samples collected for each analyte at the location where it was detected; the numbers of detections; the mean and maximum detected values; the number of detections exceeding groundwater BVs (for inorganic constituents); and the number of detections exceeding the lowest applicable regulatory or risk-based screening levels. For

this report, analytical data for field duplicates are also included in the statistical analysis as one indication of the reproducibility of detected and nondetected results.

- In the discussion that follows, data collected from well R-20 before installation of a permanent Baski sampling system on May 22, 2008, have been excluded from the frequency of detection tables. Exclusion of these data is justified because the bulk of the analytical data from well R-20 before its rehabilitation have been identified as nonrepresentative because of potential residual effects from drilling products (LANL 2008, 103100). Furthermore, the water-level map (Figure D-3.2-2) indicates that R-20 is not downgradient of MDA H because regional flow beneath MDA H is toward the northeast.

E-3.4 Screening Results for Organic COPCs

Among organic COPCs, 32 organic compounds have been detected in samples collected at wells R-20, R-37, R-40i, R-40, and R-52 (Table E-3.4-1). Table E-3.4-2 summarizes the number of events in which each compound was detected at each well screen. The list of detected organic compounds includes 15 VOCs, 4 semivolatile organic compounds (SVOCs), 4 pesticides, 7 dioxin/furans, and 2 HE compounds. The vast majority of these cases are sporadic detections at low concentrations at or below the practical quantitation limit (PQL) of the analytical method.

- Of the 60 cases in which an organic compound has been detected at least once at a particular screen, 40 of those cases have been one-time occurrences, and 10 cases involved analytes detected twice at a location. Two of the 10 latter cases reflected the detection of the analyte in a field duplicate for the same sampling event (Table E-3.4-1).
- In 11 cases, an organic compound was detected in more than two samples from the same location: 1,4-dioxane (R-37 screen 1); acetone (R-20 screen 1 and R-52 screen 1); ethylbenzene, trichloroethene (TCE), xylene[1,2-], and xylene[1,3-]+xylene[1,4-] (R-20 screen 2); and toluene (R-20 screen 1, R-20 screen 2, R-40i, and R-40 screen 2). Seven of the 11 cases occurred at R-20 (which is not downgradient of MDA H, as noted above).
- Of the 32 organic compounds detected, only 8 analytes have been detected above the PQL: acetone (R-20 screen 1, R-37 screen 1 and R-52 screen 1); 1,4-dioxane (R-20 screen 2, by the less sensitive VOC method only); toluene (R-20 screen 1, R-37 screen 1, R-40i), TCE and xylene[1,3-]+xylene[1,4-] (R-20 screen 2); diethylphthalate (R-20 screen 1); and DDE[4,4'-] and DDT[4,4'-] (R-37 screen 2). During the most recent sampling event at each well in October 2010, diethylphthalate at R-20 screen 1 was the only organic compound detected above its PQL.
- One organic compound (1,4-dioxane at R-20 screen 2) was detected above its risk-based screening level, but this analyte was not detected when the sample was reanalyzed using the more sensitive SVOC analytical method (Table E-3.4-1). This compound is persistently detected below its PQL, but above one-half of its screening level (updated by the EPA in November 2010) at R-37 screen 1. Potential sources for this 1,4-dioxane are evaluated in section E-4.0.
- Bis(2-ethylhexyl)phthalate has been detected (below its PQL) once each above one-half of its screening level at three locations: R-37 screen 1, R-40i, and R-40 screen 1 (Table E-3.4-1).
- At R-20 screen 2, three VOCs continue to be detected at low (below PQLs) but persistent concentrations: toluene, TCE, and xylene[1,3-]+xylene[1,4-] (Table E-3.4-1).

E-3.5 Screening Results for Inorganic COPCs

Among inorganic COPCs, 22 constituents have been detected above groundwater BVs in samples collected at wells R-20, R-37, R-40i, R-40, and R-52 (Table E-3.5-1). Table E-3.5-2 summarizes the number of events in which each constituent was detected above its BV at each well screen. The list includes 7 general inorganic constituents and 15 trace metals. Of these, 3 trace metals (antimony, manganese, and zinc) and 1 general inorganic constituent (nitrate-nitrite) have been detected at concentrations above the lowest applicable standards.

- General inorganic constituents detected above UTLs established in GBIR R4 (LANL 2010, 110535) for at least half of the sampling events at the same location include chloride (R-37 screen 1), magnesium (R-37 screen 1, R-40i, and R-40 screen 1), nitrate-nitrite (R-37 screen 2 and R-52 screen 1), and perchlorate (R-37 screen 1). Some of these exceedances may reflect the presence of local contaminants, but in other cases they may indicate natural variability in local groundwater geochemistry that is not captured in the background statistics in GBIR R4 (section E-4.0). For example, average nitrate-nitrite concentrations in two screens at the top of the regional aquifer in the Puye Formation slightly north of MDA H (R-37 screen 2 and R-52 screen 1) fall within a narrow range of 0.54 to 0.77 mg/L compared with the UTL of 0.58 mg/L in GBIR R4 (LANL 2010, 110535). The UTL in the previous version, GBIR R3, was 0.89 mg/L, and the slightly higher concentrations could well be representative of background in this part of the regional aquifer.
- Filtered concentrations of trace metals detected above background screening levels (MDLs or UTLs) established in GBIR R4 (LANL 2010, 110535) for at least half of the sampling events at the same location include barium (R-20 screen 1, R-20 screen 2), iron and manganese (R-20 screen 2 and R-40i), molybdenum (R-40i, R-40 screen 1 and R-40 screen 2), strontium (R-20 screen 2), and zinc (R-37 screen 1, R-40 screen 1) (Table E-3.5-2). Barium concentrations are consistently above the UTL at R-20 screen 1. Molybdenum is elevated in intermediate groundwater at R-40i and R-40 screen 1, but has been below its UTL at R-40 screen 2 for the last 4 events. Most of these occurrences (barium, iron, manganese, and strontium) are associated with reducing conditions in two screens: R-20 screen 2 and R-40i (Table E-3.5-1).
- Total (unfiltered) concentrations of trace metals detected above background screening levels (MDLs or UTLs) established in GBIR R4 (LANL 2010, 110535) for at least half of the sampling events at the same location include aluminum (R-37 screen 2, R-40 screen 2, and R-52 screen 1); barium (R-20 screens 1 and 2); copper (R-40 screen 1); manganese (R-20 screen 2 and R-40i); molybdenum (R-37 screen 1, R-40i, R-40 screen 1, and R-40 screen 2); and strontium (R-20 screen 2).
- Concentrations of total aluminum that exceed BVs and reach peak values during the first few sampling events following well completion or installation of a sampling system (e.g., regional screens in wells R-40 and R-52) are most likely due to suspended particulates or colloidal material associated with the formation. The persistence of total aluminum concentrations observed at R-37 screen 2 may be related to the location of the pump intake in the sump, approximately 9 ft below the bottom of the screen rather than within the screen interval itself.
- Molybdenum is consistently elevated in intermediate groundwater at R-37 screen 1, R-40i, and R-40 screen 1, but decreased to concentrations below the UTL in regional groundwater at R-40 screen 2 for the last four events.
- Most of the cases involving barium, manganese, and strontium concentrations above UTLs are associated with two screens (R-20 screen 2 and R-40i, Table E-3.5-1) and may be related to reducing conditions present at these locations.

- One general inorganic constituent (nitrate-nitrite) was reported at a concentration above the MCL (10 mg/L as N). However, this particular result (748 mg/L at R-20 screen 1) is attributed to sample contamination (Table E-3.5-1).
- Three trace metals (antimony, manganese, and zinc) have been detected at concentrations above their respective lowest applicable standards or risk-based screening levels. All occurrences are for perched-intermediate groundwater at wells R-40i and R-40 screen 1.
    - At R-40 screen 1, antimony was detected in five of seven samples, and exceeded its BV in samples collected from 2 of 7 sampling events. Concentrations are variable and do not show a clear trend. In contrast, manganese and zinc concentrations at this same location reached peak concentrations on December 4, 2009, but have steadily declined since then and have been below their respective BVs or only slightly above their MDLs in samples collected during the most recent events.
    - At R-40i, manganese concentrations consistently exceed UTLs and are attributed to reducing conditions at this location. For zinc, the maximum concentration at R-40i occurred in the first sample (January 28, 2009). All subsequent samples have been nondetects, detected below its PQL (10 µg/L) in filtered samples, or below its UTL (34.4 µg/L) in unfiltered samples.

E-3.6 Tritium Detections

Tritium activities in the monitoring wells are all far below the EPA MCL of 20,000 pCi/L; the majority of water samples are below detection. Nonetheless, the presence or absence of tritium at a location provides a useful tracer of flow and transport pathways because it travels conservatively in groundwater and can indicate a vapor-phase pathway. Tritium has been detected above natural BVs in perched-intermediate and regional groundwater at R-37 screens 1 and 2, respectively (Table E-3.6-1). Perched-intermediate groundwater in well R-37 screen 1 is the only location that shows evidence of persistent, elevated tritium activity, averaging 37 pCi/L ±7 pCi/L for the most recent 5 events. This activity is only slightly less than those in the most recent samples collected at two nearby shallow wells upgradient of R-37 in the same watershed: CDBO-6 (57 pCi/L on August 2, 2010) and CDBO-7 (49 pCi/L on May 6, 2009). Tritium has not been detected above its BV in regional groundwater at R-37 screen 2 in the latest 3 sampling events (Table E-3.6-1).

MDA H is one potential source of the tritium detected at R-37. However, other likely sources consistent with the low activities observed include local fallout from TA-16 air emissions, global-fallout tritium in precipitation during the mid-1960s, which had activities as high as 6200 pCi/L at that time, and releases from the TA-50 Radioactive Liquid Waste Treatment facility in the Mortandad Watershed.

E-4.0 COPC SOURCES

This section identifies possible sources for detected constituents. Based on the analyses presented in sections E-3.4, E-3.5, and E-3.6, there is compelling evidence that the following constituents are present in groundwater in one or more of the wells in the MDA H monitoring network because they are detected (organics) or detected above BVs (inorganics and tritium) in at least half the samples collected at a given location and including at least one of the last three sampling events in 2010:

- 1,4-dioxane, chloride, perchlorate, and tritium (R-37 screen 1)
- toluene, TCE, and xylene[1,3-]+xylene[1,4-] (R-20 screen 2)

- magnesium (R-37 screen 1, R-40i, and R-40 screen 1)
- barium (R-20 screen 1 and R-20 screen 2)
- iron and manganese (R-20 screen 2 and R-40i)
- molybdenum (R-37 screen 1 (unfiltered only), R-40i, and R-40 screen 1)
- strontium (R-20 screen 2)
- zinc (R-40 screen 1)

Based on the analysis of the groundwater flow beneath MDA H (Appendix D), R-20 is not downgradient of MDA H; therefore, contaminants detected at R-20 are not likely to be from the site. R-20 is located within Pajarito Canyon downgradient of TA-18 and other potential sources within the Pajarito Watershed. The well is within a segment of Pajarito Canyon that may be a focus for infiltration (LANL 2009, 106939, section 7.2.1 and Appendix H). In addition, borehole samples and alluvial groundwater samples have indicated the presence of inorganic, organic, and radionuclide COPCs in the subsurface beneath the canyon bottom (LANL 2009, 106939). Solid waste management units (SWMUs) or areas of concern (AOCs) within the Pajarito watershed are considered to be more likely potential sources of contaminants at R-20 than is MDA H. If the R-20 detections are excluded from the list above, the constituents remaining become:

- 1,4-dioxane, chloride, perchlorate, and tritium (R-37 screen 1)
- magnesium and molybdenum (R-37 screen 1, R-40i, and R-40 screen 1)
- iron and manganese (R-40i)
- zinc (R-40 screen 1)

These nine constituents are all associated with perched-intermediate groundwater at two locations: R-37, northeast of MDA H; and R-40i/R-40, southeast of MDA H. Potential sources for these constituents have not been determined with certainty, complicated by an insufficient length of record to establish representative groundwater conditions at these wells following installation of a dedicated sampling system. Possible sources and/or causes for the persistent detections of these constituents are discussed here.

- *MDA H.* Tritium is present in the vadose zone at MDA H as evidenced through vapor monitoring (LANL 2010, 111123). Therefore, MDA H is considered to be a potential source for the tritium detected in R-37 screen 1. Although it is conceivable that 1,4-dioxane is present in the vapor-phase beneath MDA H because this chemical is sometimes used as a stabilizer for chlorinated solvents, such as 1,1,1-trichloroethane, this source is unlikely given the extremely low VOC concentrations in the vapor-phase beneath MDA H (Table E-2.3-1). Other sources of tritium and 1,4-dioxane discussed below are more likely. There is no evidence that MDA H is likely to be a source for the other constituents listed above.
- *Canyons sources in the Pajarito and Mortandad Watersheds.* Infiltration of surface water and alluvial groundwater occurs along wet canyon floors, and evidence of contaminant transport to perched-intermediate zones has been observed in both Pajarito and Mortandad Canyons (LANL 2006, 094161). Lateral flow along perching horizons may transport contaminants from nearby wet canyon sources such that they are detected in wells near MDA H. For example, elevated concentrations of 1,4-dioxane, chloride, perchlorate, and tritium are present at intermediate well MCOI-6 in Mortandad Canyon (LANL 2006, 094161); these constituents could potentially be transported southward toward R-37 (Figure D-2.1-2). Similarly, chloride, 1,4-dioxane, and tritium

are observed at elevated concentrations in upcanyon sources in Pajarito Canyon (e.g., at shallow wells 03-B-10 and 03-B-13). These contaminants may be transported toward R-37 by means of infiltration in the canyon floor of Pajarito Canyon and by lateral flow along perching horizons in the vadose zone. Even if not present in the source term, concentrations of many major ions as well as trace metals are likely to be altered from natural conditions as a result of water–rock interactions along the flow path if contaminants are present in the groundwater. This mechanism could account for slightly elevated concentrations of chloride, magnesium, iron, manganese, and molybdenum observed in perched-intermediate groundwater.

- *Residual effects of drilling and well construction activities.* Elevated iron and manganese concentrations at R-40i are thought to be related to reducing conditions caused by the presence of residual organic drilling products remaining at this well screen (section E-3.2). Temporarily elevated concentrations of constituents are also commonly observed during the first few sampling events following well completion or installation of a sampling system due to suspended particulates or colloidal material from the formation, or due to residual mixing of groundwater from higher saturated zones. With time, these constituents gradually approach predrilling concentrations as the interval is flushed by ambient groundwater flow. However, this natural return to equilibrium conditions is quite prolonged at some screens, such as R-40 screen 1, because of the extremely low permeability of the screened interval (Appendix D), and may account for the continued presence of zinc in groundwater at R-40 screen 1. Drilling products or materials used downhole also cannot be ruled out as sources of trace metals due to their presence in lubricants and greases, and 1,4-dioxane may be present in products that contain diethylene glycol.
- *Background values.* Some constituents are consistently detected slightly above the UTLs developed in GBIR R4 at locations where contamination is not expected and is unlikely. It is possible that some of the wells have unique conditions that are not reflected in the background data set, as proposed for nitrate at R-37 screen 2 and R-52 screen 1 (section E-3.5). This may also be the case for the slightly elevated concentrations of chloride, magnesium, and perchlorate at R-37 screen 1.
- *Sporadic low-level detections or analytical errors.* Some of the sporadic low-level detections may be the result of field or laboratory contamination or analytical errors. For example, acetone, 2-butanone, chloromethane, and toluene are among the VOCs detected with the greatest frequency in equipment blanks, field blanks, and field trip blanks collected during groundwater sampling events. Laboratory contamination is the likely cause for the improbably high nitrate-nitrite concentration reported for R-20 screen 1 (748 mg/L as nitrogen for a sample collected on August 3, 2010; Table E-3.5-1) and may also be the case for the single detection of 1,4-dioxane reported for R-20 screen 2 (61 µg/L for a sample collected on September 8, 2008) obtained as part of the VOC analytical suite EPA Method 8260. This analytical method is prone to false detections of 1,4-dioxane, which is now analyzed as part of the SVOC analytical suite using the more sensitive EPA Method 8270. Dioxane(1,4-) has not been detected in R-20 screen 2 samples analyzed using the more sensitive method.

E-5.0 CONCLUSIONS

Based on the preceding analysis, there is no compelling evidence that contaminants sourced at MDA H are present at any MDA H groundwater monitoring wells. Although tritium and 1,4-dioxane may be local contaminants in the perched-intermediate groundwater at R-37 screen 1, sources other than MDA H are more likely. A longer period of record for MDA H monitoring wells as well as for other wells in the TA-54 groundwater monitoring network will help in an integrated fashion to distinguish potential sources of contaminants.

Groundwater characterization and monitoring is ongoing at TA-54 in accordance with annual revisions to the IFGMP. Monitoring frequency and analyte suites are specified in annual updates to the IFGMP (LANL 2010, 109830).

E-6.0 REFERENCES

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

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Table E-2.2-1
Henry's Law Coefficients and Distribution Coefficients

Chemical	H' (dimensionless)	K_{oc} (L/kg)
Acetone	0.0016	1.98
Benzene	0.228	166
Butanol[1-]	0.00036[a]	2.44[a]
Butanone[2-]	0.0023	3.83
Carbon disulfide	0.59	1.00
Carbon tetrachloride	1.1	48.6
Chlorodifluoromethane	1.7	35
Chloroform	0.15	35
Cyclohexane	6.1[a]	166[a]
Dichlorodifluoromethane	14.0	48.6
Dichloroethane[1,1-]	0.23	35
Dichloroethene[1,1-]	1.1	35
Dichloropropene[1,2-]	0.12	67.7
Ethanol	na[b]	na
Ethylbenzene	0.323	518
Hexane	74	149
Methylene chloride	0.13	23.7
Propanol[2-]	na	na
Tetrachloroethene	0.72	107
Toluene	0.272	268
Trichloro-1,2,2-trifluoroethane[1,1,2-]	22.0	225
Trichloroethane[1,1,1-]	0.705	48.6
Trichloroethene	0.4	67.7
Trichlorofluoromethane	4.0	48.6
Xylene[1,2-]	0.213	443
Xylene[1,3-]+xylene[1,4-]	0.27	443

Note: Values from NMED 2009 (108070) unless otherwise noted.

[a] Value from Environmental Protection Agency regional screening level database (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[b] na = Not available (parameters for this constituent are not included in the EPA regional screening database because this constituent does not have a groundwater cleanup level).

Table E-2.3-1
Results of VOC Mass Inventory Estimate for MDA H

Chemical	Average Pore Gas Concentration (µg/m^3)	Calculated Bulk Concentration (µg/kg)	Mass Inventory (g)
Acetone	17.14	3.82E-01	4.27E+02
Benzene	6.55	5.16E-03	5.76E+00
Butanol[1-]	13.00	1.30E+00	1.45E+03
Butanone[2-]	4.20	6.72E-02	7.50E+01
Carbon disulfide	7.23	2.41E-03	2.69E+00
Carbon tetrachloride	10.55	3.45E-03	3.85E+00
Chlorodifluoromethane	19.00	5.78E-03	6.46E+00
Chloroform	36.57	2.26E-02	2.53E+01
Cyclohexane	28.89	8.42E-03	9.40E+00
Dichlorodifluoromethane	38.94	1.08E-02	1.21E+01
Dichloroethane[1,1-]	4.50	2.25E-03	2.51E+00
Dichloroethene[1,1-]	4.00	1.28E-03	1.43E+00
Dichloropropene[1,2-]	4.83	4.06E-03	4.54E+00
Ethanol	23.40	na*	na
Ethylbenzene	6.70	7.92E-03	8.84E+00
Hexane	15.55	4.28E-03	4.78E+00
Methylene chloride	4.60	2.89E-03	3.23E+00
Propanol[2-]	19.50	na	na
Tetrachloroethene	6.55	2.59E-03	2.89E+00
Toluene	14.01	1.25E-02	1.40E+01
Trichloro-1,2,2-trifluoroethane[1,1,2-]	18.95	5.32E-03	5.94E+00
Trichloroethane[1,1,1-]	43.03	1.54E-02	1.71E+01
Trichloroethene	6.89	3.06E-03	3.42E+00
Trichlorofluoromethane	37.13	1.07E-02	1.20E+01
Xylene[1,2-]	4.10	6.05E-03	6.75E+00
Xylene[1,3-]+xylene[1,4-]	7.47	9.12E-03	1.02E+01
Total			2.12E+03

Note: Values from NMED 2009 (108070) unless otherwise noted.

* na = Henry's law coefficient and/or partition coefficient were not available and concentration and inventory could not be calculated.

Table E-2.3-2
Calculated Bulk Concentrations and Mass Inventories by Chemical Class

Chemical	Bulk Concentration (µg/kg)	Mass Inventory (g)	Percent of Total Inventory*
Alcohols			
Butanol[1-]	1.30E+00	1.45E+03	69%
Halogenated Aliphatics			
Carbon tetrachloride	3.45E-03	3.85E+00	
Chlorodifluoromethane	5.78E-03	6.46E+00	
Chloroform	2.26E-02	2.53E+01	
Dichlorodifluoromethane	1.08E-02	1.21E+01	
Dichloroethane[1,1-]	2.25E-03	2.51E+00	
Dichloroethene[1,1-]	1.28E-03	1.43E+00	
Dichloropropene[1,2-]	4.06E-03	4.54E+00	
Methylene chloride	2.89E-03	3.23E+00	
Tetrachloroethene	2.59E-03	2.89E+00	
Trichloro-1,2,2-trifluoroethane[1,1,2-]	5.32E-03	5.94E+00	
Trichloroethane[1,1,1-]	1.54E-02	1.71E+01	
Trichloroethene	3.06E-03	3.42E+00	
Trichlorofluoromethane	1.07E-02	1.20E+01	
Subtotal	3.2E-02	1.01E+02	4.8%
Ketones			
Acetone	3.82E-01	4.72E+02	
Butanone[2-]	6.72E-02	7.50E+01	
Subtotal	2.7E+00	5.02E+02	24%
Nonhalogenated Aliphatics			
Carbon disulfide	2.41E-03	2.69E+00	
Cyclohexane	8.42E-03	9.40E+00	
Hexane	4.28E-03	4.78E+00	
Subtotal	9.4E-03	1.69 E+01	0.8%
Nonhalogenated Aromatic			
Benzene	5.16E-03	5.76E+00	
Ethylbenzene	7.92E-03	8.84E+00	
Toluene	1.25E-02	1.40E+01	
Xylene[1,2-]	6.05E-03	6.75E+00	
Xylene[1,3]+xylene[1,4-]	9.13E-03	1.02E+01	
Subtotal	2.4E-01	4.55E+01	2.2%
Total	1.0E+01	2.12E+03	100%

* Percentages are not calculated for individual chemicals.

Table E-2.3-3
Average Calculations by Analyte

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-01023	10–15	6/8/2010	MD54-10-14362	Acetone	12	µg/m^3	—*
54-01023	150–155	6/8/2010	MD54-10-14365	Acetone	19	µg/m^3	—
54-01023	245–250	6/8/2010	MD54-10-14367	Acetone	15	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Acetone	17	µg/m^3	—
54-15461	10–12	6/7/2010	MD54-10-14350	Acetone	25	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Acetone	20	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Acetone	11	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Acetone	15	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Acetone	17	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Acetone	14	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Acetone	14	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Acetone	18	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Acetone	22	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14389	Acetone	21	µg/m^3	—
				Average	**17.14**		
54-01023	150–155	6/8/2010	MD54-10-14365	Benzene	3.1	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Benzene	10	µg/m^3	—
				Average	**6.55**		
54-15462	60–65	6/7/2010	MD54-10-14354	Butanol[1-]	13	µg/m^3	—
				Average	13		
54-01023	10–15	6/8/2010	MD54-10-14362	Butanone[2-]	2.7	µg/m^3	—
54-01023	150–155	6/8/2010	MD54-10-14365	Butanone[2-]	9.6	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Butanone[2-]	2.6	µg/m^3	—
54-15461	10–12	6/7/2010	MD54-10-14350	Butanone[2-]	3.4	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Butanone[2-]	4.9	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Butanone[2-]	6.2	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Butanone[2-]	2.7	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Butanone[2-]	3	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Butanone[2-]	2.5	µg/m^3	—
				Average	**4.178**		
54-15462	200–205	6/7/2010	MD54-10-14357	Carbon disulfide	7.7	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Carbon disulfide	6.4	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Carbon disulfide	7.6	µg/m^3	—
				Average	**7.233**		
54-01023	200–205	6/8/2010	MD54-10-14366	Carbon tetrachloride	7	µg/m^3	—
54-01023	245–250	6/8/2010	MD54-10-14367	Carbon tetrachloride	6.4	µg/m^3	J+

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-01023	258–263	6/8/2010	MD54-10-14368	Carbon tetrachloride	7.9	µg/m^3	J+
54-15462	280–285	6/7/2010	MD54-10-14360	Carbon tetrachloride	6	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Carbon tetrachloride	6.3	µg/m^3	J
54-15462	295–300	6/7/2010	MD54-10-14361	Carbon tetrachloride	6	µg/m^3	J
54-609985	150–155	6/8/2010	MD54-10-14381	Carbon tetrachloride	7.5	µg/m^3	J+
54-609985	200–205	6/8/2010	MD54-10-14382	Carbon tetrachloride	14	µg/m^3	J+
54-609985	245–250	6/8/2010	MD54-10-14383	Carbon tetrachloride	17	µg/m^3	J+
54-609985	258–263	6/8/2010	MD54-10-14384	Carbon tetrachloride	14	µg/m^3	J+
54-609985	280–285	6/8/2010	MD54-10-14385	Carbon tetrachloride	16	µg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14389	Carbon tetrachloride	13	µg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14386	Carbon tetrachloride	16	µg/m^3	J+
				Average	**10.55**		
54-609985	200–205	6/8/2010	MD54-10-14382	Chlorodifluoromethane	18	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Chlorodifluoromethane	20	µg/m^3	—
				Average	**19**		
54-01023	10–15	6/8/2010	MD54-10-14362	Chloroform	13	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Chloroform	22	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Chloroform	36	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Chloroform	100	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Chloroform	77	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Chloroform	28	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Chloroform	43	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Chloroform	58	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Chloroform	48	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Chloroform	47	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Chloroform	49	µg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Chloroform	20	µg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Chloroform	5.3	µg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Chloroform	56	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Chloroform	27	µg/m^3	—
54-609985	258–263	6/8/2010	MD54-10-14384	Chloroform	20	µg/m^3	—
54-609985	280–285	6/8/2010	MD54-10-14385	Chloroform	25	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14386	Chloroform	20	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14389	Chloroform	16	µg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Chloroform	21	µg/m^3	—
				Average	**36.57**		
54-01023	150–155	6/8/2010	MD54-10-14365	Cyclohexane	4.3	µg/m^3	—
54-01023	200–205	6/8/2010	MD54-10-14366	Cyclohexane	10	µg/m^3	—

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-01023	245–250	6/8/2010	MD54-10-14367	Cyclohexane	14	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Cyclohexane	5.2	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Cyclohexane	6.7	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Cyclohexane	7.9	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Cyclohexane	11	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Cyclohexane	11	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Cyclohexane	5.5	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Cyclohexane	19	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Cyclohexane	33	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Cyclohexane	33	µg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Cyclohexane	8.3	µg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Cyclohexane	37	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Cyclohexane	56	µg/m^3	—
54-609985	258–263	6/8/2010	MD54-10-14384	Cyclohexane	55	µg/m^3	—
54-609985	280–285	6/8/2010	MD54-10-14385	Cyclohexane	80	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14386	Cyclohexane	85	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14389	Cyclohexane	67	µg/m^3	—
				Average	**28.89**		
54-01023	10–15	6/8/2010	MD54-10-14362	Dichlorodifluoromethane	29	µg/m^3	J+
54-01023	100–105	6/8/2010	MD54-10-14364	Dichlorodifluoromethane	30	µg/m^3	J+
54-01023	150–155	6/8/2010	MD54-10-14365	Dichlorodifluoromethane	28	µg/m^3	J+
54-01023	200–205	6/8/2010	MD54-10-14366	Dichlorodifluoromethane	30	µg/m^3	J+
54-01023	245–250	6/8/2010	MD54-10-14367	Dichlorodifluoromethane	21	µg/m^3	J
54-01023	258–263	6/8/2010	MD54-10-14388	Dichlorodifluoromethane	24	µg/m^3	J
54-01023	258–263	6/8/2010	MD54-10-14368	Dichlorodifluoromethane	24	µg/m^3	J
54-01023	60–65	6/8/2010	MD54-10-14363	Dichlorodifluoromethane	39	µg/m^3	J+
54-15461	10–12	6/7/2010	MD54-10-14350	Dichlorodifluoromethane	14	µg/m^3	—
54-15461	60–62	6/7/2010	MD54-10-14351	Dichlorodifluoromethane	19	µg/m^3	—
54-15461	95–97	6/7/2010	MD54-10-14352	Dichlorodifluoromethane	20	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Dichlorodifluoromethane	32	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Dichlorodifluoromethane	41	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Dichlorodifluoromethane	71	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Dichlorodifluoromethane	58	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Dichlorodifluoromethane	39	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Dichlorodifluoromethane	56	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Dichlorodifluoromethane	48	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Dichlorodifluoromethane	42	µg/m^3	J
54-15462	295–300	6/7/2010	MD54-10-14387	Dichlorodifluoromethane	42	µg/m^3	J

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-15462	60–65	6/7/2010	MD54-10-14354	Dichlorodifluoromethane	48	μg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Dichlorodifluoromethane	60	μg/m^3	J
54-609985	150–155	6/8/2010	MD54-10-14381	Dichlorodifluoromethane	63	μg/m^3	J
54-609985	200–205	6/8/2010	MD54-10-14382	Dichlorodifluoromethane	58	μg/m^3	J
54-609985	245–250	6/8/2010	MD54-10-14383	Dichlorodifluoromethane	49	μg/m^3	J
54-609985	258–263	6/8/2010	MD54-10-14384	Dichlorodifluoromethane	41	μg/m^3	J
54-609985	280–285	6/8/2010	MD54-10-14385	Dichlorodifluoromethane	44	μg/m^3	J
54-609985	295–300	6/8/2010	MD54-10-14386	Dichlorodifluoromethane	40	μg/m^3	J
54-609985	295–300	6/8/2010	MD54-10-14389	Dichlorodifluoromethane	33	μg/m^3	J
54-609985	4–9	6/8/2010	MD54-10-14378	Dichlorodifluoromethane	15	μg/m^3	J
54-609985	60–65	6/8/2010	MD54-10-14379	Dichlorodifluoromethane	49	μg/m^3	J
				Average	**38.94**		
54-15462	100–105	6/7/2010	MD54-10-14355	Dichloroethane[1,1-]	3.5	μg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Dichloroethane[1,1-]	4.8	μg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Dichloroethane[1,1-]	3.8	μg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Dichloroethane[1,2-]	5.9	μg/m^3	—
				Average	**4.5**		
54-15462	150–155	6/7/2010	MD54-10-14356	Dichloroethene[1,1-]	3.6	μg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Dichloroethene[1,1-]	4.4	μg/m^3	—
				Average	**4**		
54-01023	200–205	6/8/2010	MD54-10-14366	Dichloropropane[1,2-]	5.2	μg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Dichloropropane[1,2-]	4.9	μg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Dichloropropane[1,2-]	4.4	μg/m^3	—
				Average	**4.833**		
54-01023	150–155	6/8/2010	MD54-10-14365	Ethanol	12	μg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14388	Ethanol	38	μg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Ethanol	22	μg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Ethanol	32	μg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14389	Ethanol	13	μg/m^3	—
				Average	**23.4**		
54-15462	245–250	6/7/2010	MD54-10-14358	Ethylbenzene	6.7	μg/m^3	—
				Average	**6.7**		
54-01023	150–155	6/8/2010	MD54-10-14365	Hexane	3.6	μg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Hexane	23	μg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Hexane	29	μg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Hexane	6.6	μg/m^3	—
				Average	**15.55**		
54-609985	245–250	6/8/2010	MD54-10-14383	Methylene chloride	3.2	μg/m^3	—

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-609985	295–300	6/8/2010	MD54-10-14389	Methylene chloride	6	µg/m^3	—
				Average	**4.6**		
54-15462	100–105	6/7/2010	MD54-10-14355	Propanol[2-]	25	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Propanol[2-]	14	µg/m^3	—
				Average	**19.5**		
54-01023	10–15	6/8/2010	MD54-10-14362	Tetrachloroethene	6.2	µg/m^3	—
54-15461	60–62	6/7/2010	MD54-10-14351	Tetrachloroethene	6.8	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Tetrachloroethene	7.7	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Tetrachloroethene	5.2	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Tetrachloroethene	6.2	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Tetrachloroethene	7.2	µg/m^3	—
				Average	**6.55**		
54-01023	150–155	6/8/2010	MD54-10-14365	Toluene	9.9	µg/m^3	—
54-15461	95–97	6/7/2010	MD54-10-14352	Toluene	6.2	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Toluene	15	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Toluene	33	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Toluene	9.3	µg/m^3	—
54-609985	295–300	6/8/2010	MD54-10-14389	Toluene	9.7	µg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Toluene	15	µg/m^3	—
				Average	**14.01**		
54-01023	100–105	6/8/2010	MD54-10-14364	Trichloro-1,2,2-trifluoroethane[1,1,2-]	12	µg/m^3	—
54-01023	150–155	6/8/2010	MD54-10-14365	Trichloro-1,2,2-trifluoroethane[1,1,2-]	13	µg/m^3	—
54-01023	200–205	6/8/2010	MD54-10-14366	Trichloro-1,2,2-trifluoroethane[1,1,2-]	15	µg/m^3	—
54-01023	245–250	6/8/2010	MD54-10-14367	Trichloro-1,2,2-trifluoroethane[1,1,2-]	8.9	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Trichloro-1,2,2-trifluoroethane[1,1,2-]	11	µg/m^3	—
54-01023	60–65	6/8/2010	MD54-10-14363	Trichloro-1,2,2-trifluoroethane[1,1,2-]	10	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Trichloro-1,2,2-trifluoroethane[1,1,2-]	20	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Trichloro-1,2,2-trifluoroethane[1,1,2-]	21	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Trichloro-1,2,2-trifluoroethane[1,1,2-]	41	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Trichloro-1,2,2-trifluoroethane[1,1,2-]	30	µg/m^3	—

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-15462	245–250	6/7/2010	MD54-10-14358	Trichloro-1,2,2-trifluoroethane[1,1,2-]	17	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Trichloro-1,2,2-trifluoroethane[1,1,2-]	26	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Trichloro-1,2,2-trifluoroethane[1,1,2-]	22	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Trichloro-1,2,2-trifluoroethane[1,1,2-]	19	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Trichloro-1,2,2-trifluoroethane[1,1,2-]	20	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Trichloro-1,2,2-trifluoroethane[1,1,2-]	29	µg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Trichloro-1,2,2-trifluoroethane[1,1,2-]	18	µg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Trichloro-1,2,2-trifluoroethane[1,1,2-]	20	µg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Trichloro-1,2,2-trifluoroethane[1,1,2-]	22	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Trichloro-1,2,2-trifluoroethane[1,1,2-]	17	µg/m^3	—
54-609985	258–263	6/8/2010	MD54-10-14384	Trichloro-1,2,2-trifluoroethane[1,1,2-]	15	µg/m^3	—
54-609985	280–285	6/8/2010	MD54-10-14385	Trichloro-1,2,2-trifluoroethane[1,1,2-]	14	µg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Trichloro-1,2,2-trifluoroethane[1,1,2-]	15	µg/m^3	—
				Average	**18.95**		
54-01023	10–15	6/8/2010	MD54-10-14362	Trichloroethane[1,1,1-]	7.9	µg/m^3	—
54-01023	100–105	6/8/2010	MD54-10-14364	Trichloroethane[1,1,1-]	29	µg/m^3	—
54-01023	150–155	6/8/2010	MD54-10-14365	Trichloroethane[1,1,1-]	35	µg/m^3	—
54-01023	200–205	6/8/2010	MD54-10-14366	Trichloroethane[1,1,1-]	30	µg/m^3	—
54-01023	245–250	6/8/2010	MD54-10-14367	Trichloroethane[1,1,1-]	11	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Trichloroethane[1,1,1-]	11	µg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14388	Trichloroethane[1,1,1-]	11	µg/m^3	J+
54-01023	60–65	6/8/2010	MD54-10-14363	Trichloroethane[1,1,1-]	17	µg/m^3	—
54-15461	10–12	6/7/2010	MD54-10-14350	Trichloroethane[1,1,1-]	12	µg/m^3	—
54-15461	60–62	6/7/2010	MD54-10-14351	Trichloroethane[1,1,1-]	12	µg/m^3	—
54-15461	95–97	6/7/2010	MD54-10-14352	Trichloroethane[1,1,1-]	12	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Trichloroethane[1,1,1-]	93	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Trichloroethane[1,1,1-]	110	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Trichloroethane[1,1,1-]	170	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Trichloroethane[1,1,1-]	100	µg/m^3	—

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-15462	245–250	6/7/2010	MD54-10-14358	Trichloroethane[1,1,1-]	36	μg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Trichloroethane[1,1,1-]	47	μg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Trichloroethane[1,1,1-]	33	μg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Trichloroethane[1,1,1-]	28	μg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Trichloroethane[1,1,1-]	26	μg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Trichloroethane[1,1,1-]	140	μg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Trichloroethane[1,1,1-]	66	μg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Trichloroethane[1,1,1-]	76	μg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Trichloroethane[1,1,1-]	53	μg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Trichloroethane[1,1,1-]	27	μg/m^3	—
54-609985	258–263	6/8/2010	MD54-10-14384	Trichloroethane[1,1,1-]	20	μg/m^3	J+
54-609985	280–285	6/8/2010	MD54-10-14385	Trichloroethane[1,1,1-]	16	μg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14386	Trichloroethane[1,1,1-]	14	μg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14389	Trichloroethane[1,1,1-]	10	μg/m^3	J+
54-609985	4–9	6/8/2010	MD54-10-14378	Trichloroethane[1,1,1-]	23	μg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Trichloroethane[1,1,1-]	58	μg/m^3	—
				Average	**43.03**		
54-01023	100–105	6/8/2010	MD54-10-14364	Trichloroethene	6.1	μg/m^3	—
54-01023	150–155	6/8/2010	MD54-10-14365	Trichloroethene	4.9	μg/m^3	—
54-01023	200–205	6/8/2010	MD54-10-14366	Trichloroethene	5	μg/m^3	—
54-01023	60–65	6/8/2010	MD54-10-14363	Trichloroethene	4.9	μg/m^3	—
54-15461	60–62	6/7/2010	MD54-10-14351	Trichloroethene	5.2	μg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Trichloroethene	5.7	μg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Trichloroethene	8	μg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Trichloroethene	9.5	μg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Trichloroethene	13	μg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Trichloroethene	9.2	μg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Trichloroethene	6.3	μg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Trichloroethene	7.4	μg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Trichloroethene	5.8	μg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Trichloroethene	5.5	μg/m^3	—
				Average	**6.893**		
54-01023	10–15	6/8/2010	MD54-10-14362	Trichlorofluoromethane	36	μg/m^3	J+
54-01023	100–105	6/8/2010	MD54-10-14364	Trichlorofluoromethane	61	μg/m^3	J+
54-01023	150–155	6/8/2010	MD54-10-14365	Trichlorofluoromethane	35	μg/m^3	J+
54-01023	200–205	6/8/2010	MD54-10-14366	Trichlorofluoromethane	34	μg/m^3	J+
54-01023	245–250	6/8/2010	MD54-10-14367	Trichlorofluoromethane	21	μg/m^3	—
54-01023	258–263	6/8/2010	MD54-10-14368	Trichlorofluoromethane	24	μg/m^3	—

Table E-2.3-3 (continued)

Location	Depth (ft)	Date	Sample	Analyte	Result	Unit	2nd Qual
54-01023	258–263	6/8/2010	MD54-10-14388	Trichlorofluoromethane	24	µg/m^3	J+
54-01023	60–65	6/8/2010	MD54-10-14363	Trichlorofluoromethane	77	µg/m^3	J+
54-15461	10–12	6/7/2010	MD54-10-14350	Trichlorofluoromethane	11	µg/m^3	—
54-15461	60–62	6/7/2010	MD54-10-14351	Trichlorofluoromethane	16	µg/m^3	—
54-15461	95–97	6/7/2010	MD54-10-14352	Trichlorofluoromethane	18	µg/m^3	—
54-15462	10–15	6/7/2010	MD54-10-14353	Trichlorofluoromethane	36	µg/m^3	—
54-15462	100–105	6/7/2010	MD54-10-14355	Trichlorofluoromethane	42	µg/m^3	—
54-15462	150–155	6/7/2010	MD54-10-14356	Trichlorofluoromethane	73	µg/m^3	—
54-15462	200–205	6/7/2010	MD54-10-14357	Trichlorofluoromethane	46	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Trichlorofluoromethane	27	µg/m^3	—
54-15462	258–263	6/7/2010	MD54-10-14359	Trichlorofluoromethane	38	µg/m^3	—
54-15462	280–285	6/7/2010	MD54-10-14360	Trichlorofluoromethane	34	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14361	Trichlorofluoromethane	27	µg/m^3	—
54-15462	295–300	6/7/2010	MD54-10-14387	Trichlorofluoromethane	29	µg/m^3	—
54-15462	60–65	6/7/2010	MD54-10-14354	Trichlorofluoromethane	54	µg/m^3	—
54-609985	100–105	6/8/2010	MD54-10-14380	Trichlorofluoromethane	60	µg/m^3	—
54-609985	150–155	6/8/2010	MD54-10-14381	Trichlorofluoromethane	60	µg/m^3	—
54-609985	200–205	6/8/2010	MD54-10-14382	Trichlorofluoromethane	48	µg/m^3	—
54-609985	245–250	6/8/2010	MD54-10-14383	Trichlorofluoromethane	37	µg/m^3	—
54-609985	258–263	6/8/2010	MD54-10-14384	Trichlorofluoromethane	30	µg/m^3	J+
54-609985	280–285	6/8/2010	MD54-10-14385	Trichlorofluoromethane	31	µg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14389	Trichlorofluoromethane	23	µg/m^3	J+
54-609985	295–300	6/8/2010	MD54-10-14386	Trichlorofluoromethane	29	µg/m^3	J+
54-609985	4–9	6/8/2010	MD54-10-14378	Trichlorofluoromethane	14	µg/m^3	—
54-609985	60–65	6/8/2010	MD54-10-14379	Trichlorofluoromethane	56	µg/m^3	—
				Average	**37.13**		
54-15462	245–250	6/7/2010	MD54-10-14358	Xylene[1,2-]	4.1	µg/m^3	—
				Average	**4.1**		
54-01023	150–155	6/8/2010	MD54-10-14365	Xylene[1,3-]+xylene[1,4-]	3.8	µg/m^3	J
54-15462	100–105	6/7/2010	MD54-10-14355	Xylene[1,3-]+xylene[1,4-]	3.6	µg/m^3	—
54-15462	245–250	6/7/2010	MD54-10-14358	Xylene[1,3-]+xylene[1,4-]	15	µg/m^3	—
				Average	**7.467**		

Note: Data qualifiers are defined in Appendix A.

*— = Data require no secondary qualifier.

Table E-3.1-1
Information for Wells in the TA-54 Monitoring Well Network

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
Wells Immediately Downgradient of MDA H								
R-20	Screen 1	905	Cerros del Rio basalt (cinder deposits)	6	11-Mar-04	6-Jun-06	Westbay	• Well completed on 15-Sep-02. Multiple completion with three screens in the regional aquifer. Westbay multiport sampling system installed on 18-Jan-03. • Westbay system removed 28-Jun-06; screens 1, 2, and 3 isolated by temporary packers. • Packers removed on 12-Nov-07 for redevelopment, abandonment of screen 3, and testing activities. Single packer installed between screens 1 and 2 on 5-Dec-07. • Screen 3 plugged and abandoned on 18-Nov-07 due to unfavorable geochemical conditions resulting from residual drilling, construction, and development products. Data from this screen are not included in the statistical summaries. • Baski dual-pump sampling system installed on 22-May-08, with a Baski k-packer positioned below screen 2 (LANL 2008, 103100). Pump intake for Bennett pump in screen 1 is positioned ~4 ft above the bottom of screen 1. Pump intake for Grundfos submersible pump in screen 2 is positioned ~5 ft above the top of screen 2. • Samples collected from screens 1 and 2 after installation of the Baski sampling system on 22-May-09 are included in the statistical summaries of analyte detections (section E-3.0). Data for earlier samples are discussed in the text, but are not included in the statistical summaries. • Potential cross flow between screened intervals in 2009 because of underinflated packer; water-quality samples not affected (LANL 2010, 108783).
				4	6-Jul-06	30-Nov-07	Temporary	
				11	21-Jun-08	20-Oct-10	Baski dual-pump (RSP)[b]	
	Screen 2	1147	Pumiceous fanglomerates	6	10-Mar-04	7-Jun-06	Westbay	
				3	8-Jul-06	4-Dec-07	Temporary	
				11	23-Jun-08	11-Oct-10	Baski dual-pump (GSP)	
	Screen 3	1330	Santa Fe Group sediments	6	9-Mar-04	8-Jun-06	Westbay	
				4	7-Jul-06	19-Jan-07	Temporary	

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
R-37	Screen 1	929	Puye Formation basaltic gravels	2	13-Jul-09	20-Aug-09	Temporary	• First two attempts to drill R-37 unsuccessful due to problems encountered within highly fractured and loose zone within lower portion of Cerros Del Rio basalt. • Third borehole drilled using dual-rotary casing advance drilling method. AQF-2 foaming agent was added to the drilling fluid used from below the surface casing to the bottom of the basalt at 933 ft bgs; no foam was added from 933 ft bgs to TD. Drilling completed on 27-May-09. • During placement of the annular fill around screen 2, more than 2 times the calculated volume of sand filter pack was required to fill borehole annulus in the Puye Formation. The volume required to fill fractures and voids in the basalt around screen 1 was almost 3 times the calculated volume. • Well completed on 6-Jun-09. Dual completion in a perched-intermediate zone and in the top of the regional aquifer. • Development of screen 2 completed on 17-Jun-09; aquifer test of screen 2 completed on 22-Jun-09. • TAM packer installed above screen 2 to isolate screen 1 on 29-Jun-09 in preparation for development. Depth to perched water = 909.6 ft bgs; depth to regional water table = 1009.6 ft bgs (composite depths of perched and regional groundwater measured 29-Jun-09,16 hr after installation of TAM packer). • Development of screen 1 started on 30-Jun-09. Aquifer test of screen 1 completed 13-Jul-09. Development of screen 1 continued from 21-Aug-09 to 1-Sep-09. • TAM packer removed when Baski dual-pump system installed on 11-Nov-09 (LANL 2010, 108926), with a Bennett pump in screen 1 and Grundfos submersible pump in screen 2. Pump intake in screen 1 is positioned ~1 ft above the bottom of the screen. Pump intake for screen 2 is positioned in the sump, ~9 ft below the bottom of the screen. • Because of a problem with the Bennett pump, Baski system was removed on 14-Dec-09 and reinstalled on 16-Dec-09.
				6	18-Nov-09	12-Oct-10	Baski dual-pump (RSP)	
	Screen 2	1026	Puye Formation dacite clastics	1	22-Jun-09	22-Jun-09	Temporary	
				6	18-Nov-09	14-Oct-10	Baski dual-pump (GSP)	

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
R-40	Screen 1	752	Cerros del Rio basalt	1	21-Apr-09	21-Apr-09	Temporary (GSP)	• Well completed on 5-Jan-09. Upper screen (length = 33.5 ft) in intermediate zone; lower screen (length = 20.7 ft) straddles the top of the regional water table. • During placement of the annular fill around screen 2, more than 3 times the calculated volume of sand filter pack was required to fill fractures and voids in the basalt. • Development of screen 2 initiated on 6-Jan-09; aquifer test of screen 2 completed on 15-Jan-09. • TAM detachable packer installed between upper and lower screens on 16-Jan-09 in preparation for development of screen 1. Water in screen 1 bailed dry and indicated a meager recovery rate of ~7 gallons per day (gpd). Development of screen 1 continued between 6-Mar-09 and 10-Apr-09. End-of-development sample collected from screen 1 on 21-Apr-09, after which the TAM packer was removed to resume development of screen 2 from 21-Apr-09 to 28-Apr-09. • TAM packer removed when Baski dual-pump system installed (11-Jun-09), with a Bennett pump in screen 1 and Grundfos submersible pump in screen 2. Pump intake for screen 1 positioned at bottom of screen. Pump intake for screen 2 positioned in the sump, approximately 1 ft below the bottom of screen.
				6	4-Sep-09	20-Oct-10	Baski dual-pump (RSP)	
	Screen 2	849	Puye fanglomerates	1	15-Jan-09	15-Jan-09	Temporary (GSP)	
				6	3-Sep-09	19-Oct-10	Baski dual-pump (GSP)	
R-40i	Single	650	Cerros del Rio basalt	1	28-Jan-09	28-Jan-09	Portable pump (GSP)	• 3-in-I.D. polyvinyl chloride (PVC) well installed in annulus of well R-40, in an intermediate perched zone. Screen length = 19.3 ft. • Wells R-40i and R-40 completed on 5-Jan-09. Depth to water in R-40i measured at 640.45 ft bgs (8-Jan-09), ~9 ft above screen slots. • Development methods for R-40i limited to bailing, or bailing and swabbing. Development started on 25-Jan-09 and was halted for a 24-hr aquifer test ending on 28-Jan-09. Development pumping resumed between 5-Mar-09 and 28-Apr-09. • Dedicated Bennett electric pump installed on 10-Jun-09. Pump intake is positioned at the bottom of the screen.
				7	10-Jun-09	20-Oct-10	Dedicated pump (RSP)	
R-52	Screen 1	1035	Puye Formation	3	2-May-10	12-Oct-10	Baski dual-APV (GSP)	• Fluid-assisted air-rotary and dual-rotary drilling using AQF-2 foaming agent from surface to 915 ft bgs; no foam was added from 915 ft bgs to TD. • Drilling completed on 6-Feb-10. Regional water table at 1021 ft bgs (composite depth, 7-Feb-10). • Well completed on 5-Apr-10. • Baski dual-APV sampling system installed by 19-Jul-10.
	Screen 2	1107	Puye Formation	3	23-Apr-10	12-Oct-10	Baski dual-APV (GSP)	

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
Wells Immediately Downgradient of MDA G								
R-22	Screen 1	907	Cerros del Rio basalt	19	13-Mar-01	26-Feb-09	Westbay	• Well completed on 19-Oct-00. Portland cement was used in the annular space above screens 1 and 2, between screens 2 and 3, and between screens 3 and 4. • Screens 1 and 2 did not produce sufficient water for pump development before installation of the sampling system. • Westbay multiport sampling system installed on 8-Dec-00 (Ball et al. 2002, 071471). • Westbay system removed between 19-Apr-09 and 3-May-09 for redevelopment focused on screens 1 and 5. • Several specific-capacity tests, purging, and sampling events were conducted between 13-May-09 and 2-Jul-09 in configurations that included a single packer and double packers as well as open hole (no packers). Analytical samples were collected from screen 1 during the extended purging activity conducted from 23-Jun-09 to 2-Jul-09, using a pneumatic Bennett pump and inflatable packer. Analytical samples were collected from screen 5 during the extended hydraulic testing and purging activity conducted from 17-May-09 to 27-May-09 using a 10-hp pump and single inflatable packer above the pump. • Four temporary inflatable packers were installed on 28-May-09 and 30-May-09 to isolate the five screens from one another. • Well R-22 was removed from sampling under the 2010 IFGMP until a decision has been made concerning its final post-conversion configuration.
				15 (4)[b]	24-Jun-09	2-Jul-09	Temporary (RSP)	
	Screen 2	963	Cerros del Rio basalt	19	12-Mar-01	26-Feb-09	Westbay	
	Screen 3	1274	Upper Puye fanglomerates	19	8-Mar-01	27-Feb-09	Westbay	
	Screen 4	1378	Older basalt (clay-altered)	19	7-Mar-01	26-Feb-09	Westbay	
	Screen 5	1448	Lower Puye fanglomerates	20	6-Mar-01	26-Feb-09	Westbay	
				29 (8)[b]	18-May-09	26-May-09	Temporary (GSP, single inflatable packer)	
R-39	Single	859	Cerros del Rio dacite	8	19-Feb-09	8-Oct-10	Dedicated pump (GSP)	• Fluid-assisted air-rotary drilling in an open borehole using AQF-2 foaming agent from surface to 717 ft bgs; no foam was added from 717 ft bgs to TD. • Drilling completed on 12-Nov-08. Regional water table at 824 ft bgs (13-Nov-08). • Well completed by 1-Dec-08. Single completion at the top of the regional aquifer. Top of screen is approximately 30 ft below regional water table. • Well development and aquifer testing completed on 22-Dec-08. • Dedicated Grundfos submersible pump installed on 19-Feb-09. Pump intake is positioned at top of screen.

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
R-41	Screen 1	~935	Unassigned quartzo-feldspathic gravels	0	na[b]	na	na	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 775 ft bgs; no foam was added from 775 ft bgs to TD. • Drilling completed on 21-Feb-09. • Well completed on 19-Mar-09. Dual completion in a dry intermediate zone and at the top of the regional aquifer. Regional water table at 960 ft bgs (22-Mar-09). • Only the lower screen interval (screen 2) produced water and was able to be developed. • Screen 1 has been dry since installation. • Dedicated Grundfos submersible pump installed in screen 2 on 6-Jul-09, with a Baski inflatable packer installed between screens 1 and 2. Top of screen 2 is ~4 ft below the regional water table. Pump intake for screen 2 is positioned in the sump, approximately 3.5 ft below bottom of screen.
	Screen 2	965	Unassigned quartzo-feldspathic gravels	6	2-Apr-09	8-Oct-10	Dedicated pump (PP)	
R-49	Screen 1	845	Dacitic lavas and breccias with minor intercalated sediments	6	23-Jun-09	7-Oct-10	Baski dual-APV (GSP)	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 577 ft bgs; no foam was added from 577 ft bgs to TD. • Drilling completed on 30-Apr-09. • Well completed on 1-Jun-09. Dual completion with both screens in the regional aquifer. Regional water table at 832 ft bgs (composite depth, 9-Jun-09). Upper screen is located ~35 ft below the water table. • Well development and aquifer testing completed on 23-Jun-09. • Baski dual-APV sampling system with Grundofs submersible pump installed on 20-Aug-09. APV for screen 1 is positioned in the sump, almost 20 ft below the bottom of the screen. APV for screen 2 is positioned near the top of screen 2.
	Screen 2	906	Unassigned Totavi-like fluvial clastics	6	18-Jun-09	7-Oct-10	Baski dual-APV (GSP)	
R-55	Screen 1	~870	Puye Formation	1	9-Sep-10	9-Sep-10	Portable pump	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 682 ft bgs; no foam was added from 682 ft bgs to TD. • Drilling completed on 29-Jun-10. Regional water table at 843.5 ft bgs (composite depth, 30-Jun-10). • Well completed on 25-Aug-10. • Baski system scheduled to be installed in late 2010.
	Screen 2	~1000	Chamita Formation	1	14-Sep-10	14-Sep-10	Portable pump	
R-57	Screen 1	910	Cerros del Rio dacitic lava flow(s)	1	1-Jul-10	1-Jul-10	Portable 5-hp pump	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 786 ft bgs; no foam was added from 786 ft bgs to TD.

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
	Screen 2	972	Totavi Lentil Puye Formation	1	25-Jun-10	25-Jun-10	Portable 10-hp pump	• Drilling completed on 24-Apr-10. Regional water table at 879 ft bgs (composite depth, 27-Apr-10). • Well completed on 8-Jun-10. • Baski dual-APV system scheduled to be installed in Nov-10.
Wells Immediately Downgradient of MDA L								
R-21	Single	889	Puye Formation	22	31-Mar-04	11-Oct-10	Dedicated pump (GSP)	• Drillling completed 1-Nov-02. • Well completed on 26-Nov-02. Single completion at the top of the regional aquifer. • Regional water table 799 ft bgs (3-Dec-02). Development completed 5-Dec-02. Aquifer test completed 17-Jan-03. • Dedicated Grundfos submersible pump installed on 14-Feb-03.
R-32	Screen 1	871	Cerros del Rio basalt and river gravels	9	1-Mar-04	7-Jul-07	Westbay	• Well completed on 12-Aug-02. • Westbay multiport sampling system installed on 17-Nov-02. Screen 2 never used for water-quality sampling. • Westbay system removed 18-Sep-07 for well rehabilitation and conversion to single completion well at screen 1 (LANL 2007, 100572). • Screens 2 and 3 plugged and abandoned on 20-Sep-07 due to unfavorable geochemical conditions resulting from residual drilling, construction, and development products (LANL 2007, 100572). • Baski k-packer and dedicated submersible pump installed on 7-Nov-07 (LANL 2007, 100572).
	Screen 3	976	Puye Formation	10	3-Mar-04	6-Jul-07	Westbay	
	Single	868	Cerros del Rio basalt and river gravels	12	14-Dec-07	14-Oct-10	Dedicated pump (GSP)	
R-38	Single	821	Cerros del Rio basalt	6	6-Feb-09	11-Oct-10	Dedicated pump	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 515 ft bgs; no foam was added from 515 ft bgs to TD. • Drilling completed on 6-Nov-08. Regional water table at 810 ft bgs (7-Nov-08). • Well completed on 7-Dec-08. Single completion at the top of the regional aquifer. • Development completed 10-Dec-08. Aquifer tests completed 17-Dec-08. • Dedicated Grundfos submersible pump installed 12-Jan-09. Top of screen is ~10 ft below the regional water table. Pump intake is positioned ~3.7 ft above the top of the screen.

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
R-53	Screen 1	849	Puye Formation	2	19-Apr-10	12-Oct-10	Baski dual-APV (GSP)	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 725 ft bgs; no foam was added from 725 ft bgs to TD. • Drilling completed on 7-Mar-10. Regional water table at 840 ft bgs (composite depth, 9-Mar-10). • Well completed on 29-Mar-10. • Baski dual-APV sampling system installed by 7-Jul-10.
	Screen 2	960	Puye Formation	2	14-Apr-10	12-Oct-10	Baski dual-APV (GSP)	
R-54	Screen 1	830	Cerros del Rio basaltic sediments	4	15-Feb-10	13-Oct-10	Baski dual-APV (GSP)	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 705 ft bgs; no foam was added from 705 ft bgs to TD. • Drilling completed on 6-Jan-10. • Well completed on 29-Jan-10. Regional water table at 815 ft bgs (9-Feb-10). • Baski dual-APV sampling system and pump installed on 17-May-10 (LANL 2010, 109828).
	Screen 2	915	Puye Formation	4	21-Feb-10	13-Oct-10	Baski dual-APV (GSP)	
R-56	Screen 1	945	Puye Formation dacitic lavas and silty gravels	1	19-Aug-10	19-Aug-10	Portable submersible pump (GSP)	• Dual-rotary fluid-assisted drilling using AQF-2 foaming agent from surface to 819 ft bgs; no foam was added from 819 ft bgs to TD. • Drilling completed on 13-Jun-10. Regional water table at 925 ft bgs (composite depth, 15-Jun-10). • Well completed on 19-Jul-10 (LANL 2010, 110482). • Baski dual-APV system scheduled to be installed in late 2010.
	Screen 2	1047	Puye Formation dacitic lavas and silty gravels	1	13-Aug-10	13-Aug-10	Portable submersible pump (GSP)	
Wells Downgradient of MDAs G, H, and L								
R-23i	Piezometer (Port 1)	400	Cerros del Rio basalt	12	6-Sep-07	21-Oct-10	Portable pump (RSP)	• Well completed on 10-Nov-05. • Sampling system installed in well on 15-Dec-06. • Piezometer installed in well annulus. Development methods were limited to bailing, or bailing and swabbing. Geochemistry appears to be affected by seasonal water-level changes (LANL 2010, 109830, Table F-4.0-1). Sampled using portable Bennett pump. • Some samples from screen 2 in 2009 potentially affected by cross flow (LANL 2010, 109830, Table F-4.0-1). Sampling system removed for repairs in Dec-09. • Well was redeveloped in Jan-10 before reinstallation of the Baski sampling system.
	Screen 1 (Port 2)	470	Cerros del Rio basalt	22	3-Oct-06	18-Oct-10	Baski dual-pump (RSP)	
	Screen 2 (Port 3)	524	Cerros del Rio basalt (interflow sediments)	16	11-Oct-06	18-Oct-10	Baski dual-pump (GSP)	

Table E-3.1-1 (continued)

Well	Screen	Depth (ft bgs)	Screen Lithology	Sampling Events[a]			Sampling System (Pump Type)	Chronology of Key Events Relevant to Water-Quality Evaluation
				Total N	Earliest	Most Recent		
R-23	Single	816	Santa Fe Group sediments	24	17-Dec-03	12-Aug-10	Dedicated pump (GSP)	• Well completed on 2-Oct-02. • Dedicated submersible pump installed on 14-Feb-03.
Wells Upgradient of MDAs G, H, and L								
R-51	Screen 1	915	Puye Formation	4	8-Mar-10	19-Oct-10	Baski dual-APV (GSP)	• Fluid-assisted air-rotary and dual-rotary drilling using AQF-2 foaming agent from surface to 776 ft bgs; no foam was added from 776 ft bgs to TD. • Drilling completed on 14-Jan-10. • Well completed on 8-Feb-10. Regional water table at 891 ft bgs (composite depth, 17-Feb-10). • Well development completed on 8-Mar-10 (upper screen) and 22-Feb-10 (lower screen). Baski dual-APV sampling system installed on 7-May-10.
	Screen 2	1031	Puye Formation	4	22-Feb-10	19-Oct-10	Baski dual-APV (GSP)	

Sources: Well completion reports for R-20 (LANL 2003, 079600); R-21 (Kleinfelder 2003, 090047); R-22 (Ball et al. 2002, 071471); R-23 (LANL 2003, 079601); R-23i (Kleinfelder 2006, 092495); R-32 (LANL 2003, 079602); R-37 (LANL 2010, 110510); R-38 (LANL 2009, 105298); R-39 (LANL 2009, 105620); R-40 (LANL 2009, 106432); R-41 (LANL 2009, 106453); R-49 (LANL 2009, 107450); R-51 (LANL 2010, 109949); R-52 (LANL 2010, 110533); R-53 (LANL 2010, 110516); R-54 (LANL 2010, 109828). Fact sheets for R-55 (LANL 2010, 110717); R-56 (LANL 2010, 110482), and R-57 (LANL 2010, 109836). Well rehabilitation and conversion reports for R-20 (LANL 2008, 100473) and R-32 (LANL 2007, 100572). Well redevelopment report for R-22 (LANL 2009, 106796). Assessment of cross flow in monitoring wells with inflatable packers (LANL 2010, 108783). Groundwater Level Status Report for 2009 (LANL 2010, 108926).

Notes: APV = Access port valve; ft bgs = feet below ground surface; hp = horsepower; N = number; TD = total depth.

[a] Sampling events for analyses by off-site laboratories.

[b] Pump Types: BP = bladder pump; GSP = gear-driven submersible pump; PP = peristaltic pump; RSP = reciprocating piston-type submersible pump. Westbay sampling systems do not use a pump.

Table E-3.3-1
Background Values and Screening Values for Inorganic COPCs

Analyte	Units	Field Prep[a]	Intermediate Groundwater		Regional Groundwater		Lowest Applicable Standard or Risk-Based Screening Level[c]	
			BV[b]	BV Type[b]	BV[b]	BV Type[b]	Value	Type of Standard
General Inorganics								
Calcium	mg/L	F	42.8	UTL	21.4	UTL	—[d]	—
Calcium	mg/L	UF	38.8	UTL	21.1	UTL	—	—
Chloride	mg/L	F	4.26	UTL	7.27	UTL	250	NM GW Std
Chloride	mg/L	UF	—	—	3.22	UTL	250	EPA Secondary MCL
Cyanide (total)	mg/L	F	—	—	—	—	0.2	EPA Primary MCL
Fluoride	mg/L	F	0.705	UTL	0.54	UTL	1.6	NM GW Std
Fluoride	mg/L	UF	—	—	0.517	UTL	4	EPA Primary MCL
Magnesium	mg/L	F	4.78	UTL	4.48	UTL	—	—
Magnesium	mg/L	UF	4.302	UTL	4.5	UTL	—	—
Nitrate-nitrite as N	mg/L	F	0.658	UTL	0.58	UTL	10	EPA Primary MCL
Nitrate-nitrite as N	mg/L	UF	—	—	0.58	UTL	10	EPA Primary MCL
Perchlorate	mg/L	F	0.483	UTL	0.519	UTL	4	NMED Consent Order
Potassium	mg/L	F	8.74	UTL	3.074	UTL	—	—
Potassium	mg/L	UF	22.7	UTL	2.997	UTL	—	—
Sodium	mg/L	F	32.9	UTL	26.8	UTL	—	—
Sodium	mg/L	UF	31.1	UTL	27.9	UTL	—	—
Sulfate	mg/L	F	9.83	UTL	7.89	UTL	600	NM GW Std
Sulfate	mg/L	UF	—	—	5.151	UTL	600	NM GW Std
Total dissolved solids	mg/L	F	220	UTL	188	UTL	1000	NM GW Std
Metals								
Aluminum	µg/L	F	1462	UTL	68	MDL	5000	NM GW Std
Aluminum	µg/L	UF	5524	UTL	68	MDL	37000	EPA TapWtr RSL
Antimony	µg/L	F	1	MDL	0.5	MDL	6	EPA Primary MCL
Antimony	µg/L	UF	1	MDL	0.5	MDL	6	EPA Primary MCL
Arsenic	µg/L	F	3.43	UTL	3.72	UTL	10	EPA Primary MCL
Arsenic	µg/L	UF	6	MDL	5.47	UTL	10	EPA Primary MCL
Barium	µg/L	F	127.1	UTL	75.3	UTL	1000	NM GW Std
Barium	µg/L	UF	105	UTL	72.6	UTL	2000	EPA Primary MCL
Beryllium	µg/L	F	1	MDL	1	MDL	4	EPA Primary MCL
Beryllium	µg/L	UF	1	MDL	1	MDL	4	EPA Primary MCL
Boron	µg/L	F	42.42	UTL	35.42	UTL	750	NM GW Std
Boron	µg/L	UF	42.22	UTL	37.6	UTL	7300	EPA Primary MCL

Table E-3.3-1 (continued)

Analyte	Units	Field Prep[a]	Intermediate Groundwater		Regional Groundwater		Lowest Applicable Standard or Risk-Based Screening Level[c]	
			BV[b]	BV Type[b]	BV[b]	BV Type[b]	Value	Type of Standard
Cadmium	µg/L	F	1	MDL	0.63	MDL	5	EPA Primary MCL
Cadmium	µg/L	UF	1	MDL	0.63	MDL	5	EPA Primary MCL
Chromium	µg/L	F	4.74	UTL	10.63	UTL	50	NM GW Std
Chromium	µg/L	UF	11.24	UTL	10.27	UTL	100	EPA Primary MCL
Cobalt	µg/L	F	1	MDL	1	MDL	50	NM GW Std
Cobalt	µg/L	UF	1	MDL	1	MDL	11	EPA Tap RSL
Copper	µg/L	F	3	MDL	3	MDL	1000	NM GW Std
Copper	µg/L	UF	3	MDL	3	MDL	1500	EPA Tap RSL
Iron	µg/L	F	616	UTL	30	MDL	1000	NM GW Std
Iron	µg/L	UF	2265	UTL	748	UTL	26000	EPA Tap RSL
Lead	µg/L	F	0.5	MDL	1.8	MDL	15	EPA Primary MCL
Lead	µg/L	UF	4.822	UTL	1.8	MDL	15	EPA Primary MCL
Manganese	µg/L	F	102.2	UTL	35.98	UTL	200	NM GW Std
Manganese	µg/L	UF	143.3	UTL	40.62	UTL	880	EPA Tap RSL
Mercury	µg/L	F	0.07	MDL	0.07	MDL	2	EPA Primary MCL
Mercury	µg/L	UF	0.07	MDL	0.07	MDL	2	EPA Primary MCL
Molybdenum	µg/L	F	5.33	UTL	3.4	UTL	1000	NM GW Std
Molybdenum	µg/L	UF	2.88	UTL	3.625	UTL	180	EPA Tap RSL
Nickel	µg/L	F	2.98	UTL	3.45	UTL	200	NM GW Std
Nickel	µg/L	UF	4.775	UTL	4.477	UTL	730	EPA Tap RSL
Selenium	µg/L	F	2.5	MDL	6	MDL	50	NM GW Std
Selenium	µg/L	UF	6	MDL	6	MDL	50	EPA Primary MCL
Silver	µg/L	F	1	MDL	1	MDL	180	EPA Tap RSL
Silver	µg/L	UF	1	MDL	1	MDL	180	EPA Tap RSL
Strontium	µg/L	F	477	UTL	192	UTL	22000	EPA Tap RSL
Strontium	µg/L	UF	480	UTL	191	UTL	22000	EPA Tap RSL
Thallium	µg/L	F	1	MDL	0.4	MDL	2	EPA Primary MCL
Thallium	µg/L	UF	1	MDL	0.4	MDL	2	EPA Primary MCL
Uranium	µg/L	F	2.226	UTL	1.708	UTL	30	EPA Primary MCL
Uranium	µg/L	UF	4.984	UTL	1.085	UTL	30	EPA Primary MCL
Vanadium	µg/L	F	21.55	UTL	15.21	UTL	180	EPA Tap RSL
Vanadium	µg/L	UF	30.01	UTL	24.45	UTL	180	EPA Tap RSL

Table E-3.3-1 (continued)

Analyte	Units	Field Prep[a]	Intermediate Groundwater		Regional Groundwater		Lowest Applicable Standard or Risk-Based Screening Level[c]	
			BV[b]	BV Type[b]	BV[b]	BV Type[b]	Value	Type of Standard
Zinc	µg/L	F	3.3	MDL	24.68	UTL	180	EPA Tap RSL
Zinc	µg/L	UF	34.38	UTL	43.14	UTL	180	EPA Tap RSL

[a] Field Prep = field preparation (of sample). F = filtered, UF = unfiltered.

[b] BV = groundwater background value, from GBIR Rev 4 (LANL 2010, 110535). BV Type = type of background value. MDL = minimum detection limit; UTL = upper tolerance level; See discussion in section E-3.3.

[c] Screening level = lowest applicable regulatory standard or other risk-based screening level. See discussion in section E-3.3.

- EPA Primary MCL = EPA maximum contaminant level (primary standard for drinking water) (40 Code of Federal Regulations Part 141).
- EPA Tap RSL = EPA regional screening level for tapwater (available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Most recent version is dated November 2010.
- NM GW Std = New Mexico Water Quality Control Commission Standards for Groundwater (New Mexico Administrative Code 20.6.2.3103).

[d] — = None.

Table E-3.3-2
Screening Values for Selected Organic COPCs

Analytical Suite	Analyte	Screening Level in 2010 IFGMP[a] (µg/L)	Screening Level Used in this Appendix (µg/L)	Screening Level Source	Comment
PEST/PCB	Chlordane[gamma-]	None	1.9	EPA TAP RSL[b]	The screening level of 1.9 µg/L for total chlordane (also known as technical-grade chlordane) is adopted as an appropriate screening level for gamma-chlordane in this appendix because there are no available screening values specific for chlordane isomers, and the analytical laboratory does not report a "total chlordane" concentration (which is the total of the alpha- plus gamma- isomers).
SVOC	Dioxane[1,4-]	61	6.7	EPA TAP RSL	The 10^{-6} excess cancer risk for 1,4-dioxane is 0.67 µg/L in the most recent version of the EPA RSL table (November 2010), compared with the previous value of 6.1 µg/L. The updated value corresponds to 6.7 µg/L for a 10^{-5} excess cancer risk level.
VOC	Xylene[1,3]+xylene[1,4-]	None	1200	EPA TAP RSL	The EPA RSL table does not provide a screening level specifically for xylene[1,3-] + xylene [1,4-] as a combined analysis. However, the three individual xylene isomers (1,2-xylene, 1,3-xylene, and 1,4-xylene) all have the same screening level of 1200 µg/L. This value is adopted as an appropriate screening level in this appendix for xylene[1,3-] + xylene [1,4-].

Note: Except for the analytes listed in this table, the values used to screen detected organic consitutents and high-explosive compounds in this appendix are the same as those listed in the 2010 IFGMP (LANL 2010, 109830, section C-4.1).

[a] 2010 IFGMP (LANL 2010, 109830, section C-4.1)

[b] EPA Tap RSL = EPA regional screening level for tapwater (available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Most recent version is dated November 2010.

Table E-3.4-1
Statistical Summary of Organic Analytes and High Explosives Detected in Groundwater Samples Collected from Wells R-20, R-37, R-40i, R-40, and R-52 through November 30, 2010

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL[b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
VOC Detections													
Acetone	R-20	905	17	5	25.1	85.7	5	22000	EPA TAP RSL	—[d]	11000	—	—
	R-37	929	11	2	21.2	21.5	5	22000	EPA TAP RSL	—	11000	—	Detected in one event (18-Dec-09), when Baski system was reinstalled. Not detected before or after this event.
	R-52	1035	5	3	5.7	6.5	5	22000	EPA TAP RSL	—	11000	—	Detected in two events (5-Aug-10 and 12-Oct-10) after installation of Baski system. Result was below PQL for sample from most recent event.
Acetonitrile	R-40	752	2	1	7.5	7.5	25	130	EPA TAP RSL	—	75	—	Detected once below PQL in first sample (21-Apr-09) prior to installation of dedicated sampling system.
Butanol[1-]	R-20	905	3	1	16	16	50	3700	EPA TAP RSL	—	1850	—	—
	R-40i	650	7	1	16	16	50	3700	EPA TAP RSL	—	1850	—	Detected below PQL in first sample (28-Jan-09), collected using portable pump. Not detected in subsequent samples (collected using dedicated pump).
	R-40	752	6	1	25	25	50	3700	EPA TAP RSL	—	1850	—	Detected once below PQL in first sample (21-Apr-09)before installation of dedicated sampling system.
Butanone[2-]	R-40	752	6	1	1.87	1.87	5	7100	EPA TAP RSL	—	3550	—	Detected below PQL in most recent sample (20-Oct-10)

Table E-3.4-1 (continued)

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL[b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
Chloromethane	R-20	905	17	1	0.46	0.46	1	190	EPA TAP RSL	—	95	—	—
	R-37	1026	11	1	0.34	0.34	1	190	EPA TAP RSL	—	95	—	Detected below PQL in first sampling event (22-Jun-09). Not detected in samples collected after Baski installed.
	R-40i	650	9	2	0.35	0.35	1	190	EPA TAP RSL	—	95	—	Detected twice below PQL (10-Jun-09 and 31-Aug-09). Detected in field duplicates; not detected in corresponding routine samples.
	R-52	1035	5	1	0.33	0.33	1	190	EPA TAP RSL	—	95	—	Detected once below PQL (2-May-10). Detected in field duplicate; not detected in corresponding routine sample.
Dichloroethene[cis-1,2-]	R-20	1147	17	1	0.31	0.31	1	70	EPA Primary MCL	—	35	—	Detected once below PQL (24-Feb-10).
Dioxane[1,4-]	R-20	1147	1	1	61.4	61.4	50	6.7[e]	EPA TAP RSL	1	3.35	1	Single detection in a sample collected following well rehabilitation and conversion, analyzed by EPA Method 8260 (for VOCs). Analyte was below the method detection limit in this same sample analyzed using the more sensitive EPA Method 8270 (for SVOCs).
Ethylbenzene	R-20	1147	17	4	0.27	0.28	1	700	EPA Primary MCL	—	350	—	—
Isopropylbenzene	R-20	1147	17	1	0.25	0.25	1	680	EPA TAP RSL	—	340	—	—
Naphthalene	R-40	752	6	1	0.75	0.75	1	30	NM GW STD	—	15	—	Detected once below PQL in first sample (21-Apr-09), prior to installation of dedicated sampling system.

Table E-3.4-1 (continued)

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL[b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
Toluene	R-20	905	17	7	1.36	2.95	1	750	NM GW STD	—	375	—	Not detected since 10-Mar-09
	R-20	1147	17	11	0.40	0.64	1	750	NM GW STD	—	375	—	Consistently detected below PQL.
	R-37	929	11	1	1.33	1.33	1	750	NM GW STD	—	375	—	Detected above PQL in first sample (13-Jul-09), collected before installation of dedicated sampling system. Not detected in subsequent samples.
	R-37	1026	11	1	0.42	0.42	1	750	NM GW STD	—	375	—	Detected below PQL in first sample (22-Jun-09) collected before installation of dedicated sampling system. Not detected in subsequent samples.
	R-40i	650	9	6	9.0	24.2	1	750	NM GW STD	—	375	—	Detected in six samples from four events in 2009 (28-Jan-09, 10-Jun-09, 31-Aug-10, 4-Dec-09). Not detected in subsequent three events.
	R-40	752	6	2	0.81	0.84	1	750	NM GW STD	—	375	—	Detected below PQL in two samples (21-Apr-10 and 20-Oct-10).
	R-40	849	10	3	0.28	0.29	1	750	NM GW STD	—	375	—	Detected below PQL in three samples from two events (15-Jan-09 and 23-Feb-10).
Trichlorobenzene[1,2,3-]	R-40	752	6	1	0.62	0.62	1	29	EPA TAP RSL	—	14	—	Detected once below PQL in first sample (21-Apr-09) before installation of dedicated sampling system.
Trichlorobenzene[1,2,4-]	R-40	752	6	1	0.50	0.50	1	70	EPA Primary MCL	—	35	—	Detected once below PQL in first sample (21-Apr-09) before installation of dedicated sampling system.
Trichloroethene (TCE)	R-20	1147	17	15	1.35	3.04	1	5	EPA Primary MCL	—	2.5	—	Max concentration in 2-Dec-09, decreasing steadily since then; detected below PQL in last 3 samples.
	R-40	752	6	2	0.64	0.81	1	5	EPA Primary MCL	—	2.5	—	Detected twice below PQL (4-Jun-10 and 20-Oct-10)
Xylene[1,2-]	R-20	1147	17	4	0.38	0.42	1	1200	EPA TAP RSL	—	600	—	—
Xylene[1,3-]+xylene[1,4-]	R-20	1147	17	13	1.73	3.51	2	1200[e]	EPA TAP RSL	—	600	—	Max concentration in 2-Dec-09, decreasing since then; detected below PQL in last 3 samples.
SVOC Detections													
Benzoic acid	R-20	1147	15	2	15.7	15.7	20	150000	EPA TAP RSL	—	75000	—	—

Table E-3.4-1 (continued)

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL[b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
Bis(2-ethylhexyl)phthalate	R-37	929	11	2	3.5	4.7	10	6	EPA Primary MCL	—	3	1	Detected below PQL in first two events (22-Jun-09 and 20-Aug-09). Not detected in corresponding field duplicate (FD) for Aug-09 event, nor in samples collected after Baski installed.
	R-40i	650	10	1	4.8	4.8	10	6	EPA Primary MCL	—	3	1	—
	R-40	752	6	1	3.1	3.1	10	6	EPA Primary MCL	—	3	1	—
Diethylphthalate	R-20	905	13	2	19.6	28.5	10	29000	EPA TAP RSL	—	14500	—	Detected above PQL in last two events (8-Aug-10 and 20-Oct-10)
	R-40i	650	10	1	3.0	3.0	10	29000	EPA TAP RSL	—	14500	—	—
	R-40	752	6	1	5.8	5.8	10	29000	EPA TAP RSL	—	14500	—	—
Dioxane[1,4-]	R-37	929	11	8	4.0	5.0	10	6.7[e]	EPA TAP RSL	—	3.35	7	Consistently detected below PQL.
	R-37	1026	11	2	2.2	2.3	10	6.7[e]	EPA TAP RSL	—	3.35	—	Detected below PQL in one event (18-Dec-09), when Baski system was reinstalled. Not detected before or after this event.
Pesticide Detections													
Chlordane[gamma-]	R-40	752	3	1	0.01	0.01	0.02	1.90[e]	EPA TAP RSL	—	0.95	—	Detected once below PQL (4-Dec-09)
DDE[4,4'-]	R-37	1026	6	1	0.09	0.09	0.04	2	EPA TAP RSL	—	1	—	Detected once above PQL (18-Nov-09). when Baski system was first installed. Not detected before or after this event.
DDT[4,4'-]	R-37	1026	6	1	0.05	0.05	0.04	2	EPA TAP RSL	—	1	—	Detected once above PQL (18-Nov-09). when Baski system was first installed. Not detected before or after this event.
Heptachlor	R-20	1147	6	1	0.01	0.01	0.05	0.4	EPA Primary MCL	—	0.2	—	Detected once below PQL (29-May-09)
	R-40	752	3	1	0.02	0.02	0.02	0.4	EPA Primary MCL	—	0.2	—	Detected once below PQL (4-Dec-09)

Table E-3.4-1 (continued)

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL[b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
Dioxin and Furan Detections													
Heptachlorodibenzo-dioxin[1,2,3,4,6,7,8-]	R-37	929	7	1	9.E-7	9.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (20-Aug-09). Not detected after Baski was installed.
	R-40i	650	6	1	9.E-7	9.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (31-Aug-09)
	R-40	849	7	1	5.E-7	5.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (23-Feb-10)
Heptachlorodibenzo-dioxins(total)	R-37	929	7	1	2.E-6	2.E-6	5.E-5	—	—	—	—	—	Detected once below PQL (20-Aug-09). Not detected after Baski was installed.
	R-37	1026	6	2	1.E-6	1.E-6	5.E-5	—	—	—	—	—	Detected twice below PQL (22-Jun-09 and 18-Nov-09) before and just after Baski was installed. Not detected in subsequent samples.
	R-40i	650	6	1	2.E-6	2.E-6	5.E-5	—	—	—	—	—	Detected once below PQL (31-Aug-09)
	R-40	849	7	1	5.E-7	5.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (23-Feb-10)
Heptachlorodibenzo-furan[1,2,3,4,6,7,8-]	R-40	849	7	1	4.E-7	4.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (23-Feb-10)
Heptachlorodibenzo-furans(total)	R-40	849	7	1	4.E-7	4.E-7	5.E-5	—	—	—	—	—	Detected once below PQL (25-Feb-09)
Octachlorodibenzo-dioxin[1,2,3,4,6,7,8,9-]	R-20	905	4	1	3.E-6	3.E-6	5.E-5	—	—	—	—	—	
	R-37	929	7	1	4.E-6	4.E-6	1.E-4	—	—	—	—	—	Detected once below PQL (18-Nov-09) when Baski was first installed. Not detected in samples collected before or after this event.
	R-37	1026	6	1	2.E-6	2.E-6	1.E-4	—	—	—	—	—	Detected once below PQL (18-Nov-09) when Baski was first installed. Not detected in samples collected before or after this event.
	R-40i	650	6	2	3.E-6	3.E-6	1.E-4	—	—	—	—	—	Detected twice below PQL (28-Jan-09 and 10-Jun-09)
	R-40	752	3	1	2.E-6	2.E-6	1.E-4	—	—	—	—	—	Detected once below PQL (21-Apr-09)

Table E-3.4-1 (continued)

Analyte	Well	Port Depth (ft bgs)	No. of Analyses[a]	No. of Detects[a]	Average Detect (µg/L)	Maximum Detect (µg/L)	PQL [b] (µg/L)	Screening Level[c] (µg/L)	Screening Level Source[c]	No. > Screening Level	1/2 Screening Level (µg/L)	No. > 1/2 Screening Level	Comments
Octachlorodibenzo-furan[1,2,3,4,6,7,8,9-]	R-37	929	5	1	3.E-6	3.E-6	1.E-4	—	—	—	—	—	Detected once below PQL (18-Dec-09) when Baski was reinstalled. Not detected in samples collected before or after this event.
High Explosives Compound Detections													
Nitrobenzene	R-20	1147	9	1	0.15	0.15	0.32	1.2	EPA TAP RSL	—	0.6	—	—
RDX	R-40	849	7	1	0.20	0.20	0.32	6.1	EPA TAP RSL	—	3.0	—	—

[a] Detection statistics are shown for a screen only for those analytes detected at least once. The tabulated statistics exclude data rejected during validation. Data for field duplicates are included; thus, two detections of a given analyte do not necessarily imply the analyte was detected in two different sampling events.

[b] PQL values from the 2010 IFGMP (LANL 2010, 109830, section C-4.1). The 2010 IFGMP provides an explanation for each analyte with a target PQL above the applicable background or screening level.

[c] Screening level = lowest applicable regulatory standard (if one exists), or risk-based screening level (if no regulatory standard exists, and if toxicological information is available), as prescribed by the Consent Order and implemented as documented in Appendix B of the 2010 IFGMP (LANL 2010, 109830).

- EPA Primary MCL = EPA maximum contaminant level (primary standard for drinking water) (40 Code of Federal Regulations Part 141).
- EPA Tap RSL = EPA regional screening level for tapwater (available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Most recent version is dated November 2010.
- NMED Tap SL = NMED screening level for tap water, Table A-1. Most recent version of Table A-1 is dated December 2009.
- NM GW Std = New Mexico Water Quality Control Commission Standards for Groundwater (New Mexico Administrative Code 20.6.2.3103).

[d] — = None.

[e] The technical basis for this screening value, which differs from that listed for this compound in the 2010 IFGMP (109830, section C-4.1), is provided in Table E-3.3-2.

Table E-3.4-2
Number of Sampling Events in which an Organic COPC Was Detected at Wells R-20, R-37, R-40i, R-40, and R-52 through November 30, 2010

Analyte	R-20		R-37		R-40i	R-40		R-52	
	Scr 1	Scr 2	Scr 1	Scr 2		Scr 1	Scr 2	Scr 1	Scr 2
Port Depth (ft bgs)	905	1147	929	1026	650	752	849	1035	1107
Dioxins/Furans									
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	—[a]	—	1	—	1	—	1	—	—
Heptachlorodibenzodioxins (Total)	—	—	1	2	1	—	1	—	—
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	—	—	—	—	—	—	1	—	—
Heptachlorodibenzofurans (Total)	—	—	—	—	—	—	1	—	—
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1	—	1	1	2	1	—	—	—
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	—	—	1	—	—	—	—	—	—
High Explosives Compounds									
Nitrobenzene	—	1	—	—	—	—	—	—	—
RDX	—	—	—	—	—	—	1	—	—
Pesticides									
Chlordane[gamma]	—	—	—	—	—	1	—	—	—
DDE[4,4'-]	—	—	—	1	—	—	—	—	—
DDT[4,4'-]	—	—	—	1	—	—	—	—	—
Heptachlor	—	1	—	—	—	1	—	—	—
SVOCs									
Benzoic acid	—	1	—	—	—	—	—	—	—
Bis(2-ethylhexyl)phthalate	—	—	2[c]	—	1[c]	1[c]	—	—	—
Diethylphthalate	2[b]	—	—	—	1	1	—	—	—
Dioxane[1,4-]	—	—	6[c]	1	—	—	—	—	—
VOCs									
Acetone	4[b]	—	1[b]	—	—	—	—	1[b]	—
Acetonitrile	—	—	—	—	—	1	—	—	—
Butanol[1-]	1	—	—	—	1	1	—	—	—
Butanone[2-]	—	—	—	—	—	1	—	—	—
Chloromethane	1	—	—	1	2	—	—	1	—
Dichloroethene[cis-1,2-]	—	1	—	—	—	—	—	—	—
Dioxane[1,4-]	—	1[b,c]	—	—	—	—	—	—	—
Ethylbenzene	—	3	—	—	—	—	—	—	—
Isopropylbenzene	—	1	—	—	—	—	—	—	—
Naphthalene	—	—	—	—	—	1	—	—	—
Toluene	4	7	1[b]	1	3[b]	1	2	—	—
Trichlorobenzene[1,2,3-]	—	—	—	—	—	1	—	—	—
Trichlorobenzene[1,2,4-]	—	—	—	—	—	1	—	—	—

Table E-3.4-2 (continued)

Analyte	R-20		R-37		R-40i	R-40		R-52	
	Scr 1	Scr 2	Scr 1	Scr 2		Scr 1	Scr 2	Scr 1	Scr 2
Port Depth (ft bgs)	905	1147	929	1026	650	752	849	1035	1107
Trichloroethene (TCE)	—	8[b]	—	—	—	2	—	—	—
Xylene[1,2-]	—	2	—	—	—	—	—	—	—
Xylene[1,3-]+xylene[1,4-]	—	7[b]	—	—	—	—	—	—	—

[a] — = Not detected.

[b] Detected at least once above PQL.

[c] Detected at least once above 1/2 of the lowest applicable screening level.

Table E-3.5-1
Statistical Summary of Inorganic COPCs Detected above Groundwater BVs in Samples Collected from Wells R-20, R-37, R-40i, R-40, and R-52 through November 30, 2010

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl [b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
General Inorganics (F) Detected at Least Once above Groundwater BVs																	
Chloride	R-37	929	Intermediate	8	8	4.38	4.61	mg/L	4.26	UTL	6	250	NM GW Std	—[d]	125	—	Steady value slightly above UTL
	R-37	1026	Regional	8	8	3.79	8.49	mg/L	7.27	UTL	1	250	NM GW Std	—	125	—	Max value (18-Nov-09) associated with first installation of Baski sampling system.
Fluoride	R-37	929	Intermediate	8	8	0.59	0.74	mg/L	0.705	UTL	2	1.6	NM GW Std	—	0.8	—	Two highest values (18-Nov-09 and 18-Dec-09) are associated with removal & installation of sampling systems.
	R-37	1026	Regional	8	8	0.35	0.61	mg/L	0.54	UTL	2	1.6	NM GW Std	—	0.8	—	
	R-40i	650	Intermediate	7	7	0.42	1.12	mg/L	0.705	UTL	1	1.6	NM GW Std	—	0.8	1	Maximum value in first sample (28-Jan-09), collected before completion of development.
Magnesium	R-37	929	Intermediate	8	8	5.53	5.87	mg/L	4.78	UTL	8	—	—	—	—	—	Steady value slightly above UTL
	R-37	1026	Regional	8	8	3.33	4.67	mg/L	4.48	UTL	1	—	—	—	—	—	Two highest values (18-Nov-09 and 18-Dec-09) are associated with removal & installation of sampling systems.
	R-40i	650	Intermediate	7	7	7.66	8.59	mg/L	4.78	UTL	7	—	—	—	—	—	Steady value above UTL
	R-40	752	Intermediate	6	6	6.40	6.77	mg/L	4.78	UTL	6	—	—	—	—	—	Steady value above UTL
Nitrate-nitrite as N	R-20	905	Regional	11	7	107	748	mg/L	0.58	UTL	1	10	EPA Primary MCL	1	5	1	Max value (3-Aug-10) attributed to sample contamination. Excluding this sample, average = 0.16 mg/L, max = 0.27 mg/L.
	R-37	929	Intermediate	8	8	0.55	0.81	mg/L	0.66	UTL	2	10	EPA Primary MCL	—	5	—	Average value is below UTL
	R-37	1026	Regional	8	8	0.62	0.77	mg/L	0.58	UTL	3	10	EPA Primary MCL	—	5	—	Average value is slightly above UTL
	R-52	1035	Regional	3	3	0.65	0.70	mg/L	0.58	UTL	2	10	EPA Primary MCL	—	5	—	Values are slightly above UTL

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl [b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
Perchlorate	R-37	929	Intermediate	8	8	0.53	0.61	mg/L	0.48	UTL	7	4	NM CONS	—	2	—	Average value is slightly above UTL
Sulfate	R-37	929	Intermediate	8	8	9.42	10.3	mg/L	9.83	UTL	1	600	NM GW Std	—	300	—	—
General Inorganics (UF) Detected at Least Once above Groundwater BVs																	
Calcium	R-37	1026	Regional	8	8	14.3	21.4	mg/L	21.1	UTL	1	—	—	—	—	—	—
Magnesium	R-37	929	Intermediate	8	8	5.58	6.05	mg/L	4.30	UTL	8	—	—	—	—	—	Steady value above UTL
	R-37	1026	Regional	8	8	3.38	4.77	mg/L	4.50	UTL	1	—	—	—	—	—	Two highest values (18-Nov-09 and 18-Dec-09) are associated with removal & installation of sampling systems.
	R-40i	650	Intermediate	7	7	7.66	8.38	mg/L	4.30	UTL	7	—	—	—	—	—	Steady value above UTL
	R-40	752	Intermediate	7	7	6.42	6.89	mg/L	4.30	UTL	7	—	—	—	—	—	Steady value above UTL
Metals (F) Detected at Least Once Above Groundwater BVs																	
Antimony	R-40	752	Intermediate	7	5	5.36	9.26	µg/L	1	MDL	3	6	EPA Primary MCL	3	3	3	Highly variable values. Not detected in R-40i or R-40 screen 2.
Arsenic	R-40i	650	Intermediate	7	3	2.85	3.75	µg/L	3.43	UTL	1	10	EPA Primary MCL	—	5	—	—
Barium	R-20	905	Regional	11	11	75.6	92.7	µg/L	75.3	UTL	6	1000	NM GW Std	—	500	—	Consistently above UTL
	R-20	1147	Regional	14	14	159.6	202	µg/L	75.3	UTL	14	1000	NM GW Std	—	500	—	Elevated values attributed to ongoing recovery from reducing conditions (section E-3.2)
Cobalt	R-37	929	Intermediate	8	1	1.17	1.17	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—
	R-40i	650	Intermediate	7	1	1.01	1.01	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—
	R-40	752	Intermediate	6	1	2.69	2.69	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—
	R-40	849	Regional	8	1	1.01	1.01	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—
	R-52	1035	Regional	3	1	1.03	1.03	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—
	R-52	1107	Regional	3	1	1.62	1.62	µg/L	1	MDL	1	50	NM GW Std	—	25	—	—

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl[b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
Copper	R-37	929	Intermediate	8	1	8.28	8.28	µg/L	3	MDL	1	1000	NM GW Std	—	500	—	—
	R-40i	650	Intermediate	7	2	11.8	14	µg/L	3	MDL	2	1000	NM GW Std	—	500	—	—
	R-40	752	Intermediate	6	2	3.32	3.33	µg/L	3	MDL	2	1000	NM GW Std	—	500	—	—
Iron	R-20	905	Regional	11	3	74	120	µg/L	30	MDL	3	1000	NM GW Std	—	500	—	—
	R-20	1147	Regional	14	10	47	103	µg/L	30	MDL	10	1000	NM GW Std	—	500	—	Average value is slightly above MDL
	R-40i	650	Intermediate	7	7	1094	1420	µg/L	616	UTL	6	1000	NM GW Std	—	500	6	Steady value above UTL attributable to reducing conditions (section E-3.2)
	R-40	849	Regional	8	2	92	140	µg/L	30	MDL	2	1000	NM GW Std	—	500	—	—
	R-52	1107	Regional	3	1	68	68	µg/L	30	MDL	1	1000	NM GW Std	—	500	—	—
Lead	R-40	752	Intermediate	6	1	0.88	0.88	µg/L	0.5	MDL	1	15	EPA Primary MCL	—	7.5	—	—
Manganese	R-20	1147	Regional	14	14	66	78	µg/L	36	UTL	14	200	NM GW Std	—	100	—	Steady values above UTL are attributed to ongoing recovery from reducing conditions (section E-3.2)
	R-40i	650	Intermediate	7	7	301	398	µg/L	102	UTL	7	200	NM GW Std	6	100	7	Steady values above UTL are attributed to ongoing recovery from reducing conditions (section E-3.2)
	R-40	752	Intermediate	6	6	105	400	µg/L	102	UTL	2	200	NM GW Std	1	100	2	Max value on 4-Dec-09. Steadily decreasing since then; <UTL for last three events.
	R-40	849	Regional	8	4	29	104	µg/L	36	UTL	1	200	NM GW Std	—	100	1	Maximum value in first sample (15-Jan-09), All subsequent samples are < UTL.
Molybdenum	R-40i	650	Intermediate	7	7	17.3	22	µg/L	5.3	UTL	7	1000	NM GW Std	—	500	—	Steady value above UTL
	R-40	752	Intermediate	6	6	9.2	12.9	µg/L	5.3	UTL	6	1000	NM GW Std	—	500	—	Steadily decreasing since Baski installation (11-Jun-09) although still above UTL

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl[b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
	R-40	849	Regional	8	8	3.5	6.1	µg/L	3.4	UTL	4	1000	NM GW Std	—	500	—	Below UTL for most recent four events
Nickel	R-20	1147	Regional	14	13	2.8	3.7	µg/L	3.45	UTL	3	200	NM GW Std	—	100	—	—
	R-40	752	Intermediate	6	6	14.2	49.8	µg/L	2.98	UTL	3	200	NM GW Std	—	100	—	—
	R-40	849	Regional	8	7	1.7	3.8	µg/L	3.45	UTL	1	200	NM GW Std	—	100	—	—
Strontium	R-20	1147	Regional	14	14	211	232	µg/L	192	UTL	12	22000	EPA Tap RSL	—	11000	—	Steady value slightly above UTL
Thallium	R-20	905	Regional	11	3	0.43	0.5	µg/L	0.4	MDL	2	2	EPA Primary MCL	—	1	—	—
Uranium	R-37	1026	Regional	8	8	0.78	1.75	µg/L	1.71	UTL	1	30	EPA Primary MCL	—	15	—	—
Zinc	R-37	929	Intermediate	8	5	34	115	µg/L	3.3	MDL	5	180	EPA Tap RSL	—	90	1	Max value in first sampling event (13-Jul-09); steadily decreasing thereafter; not detected in last three events
	R-40i	650	Intermediate	7	3	117	343	µg/L	3.3	MDL	2	180	EPA Tap RSL	1	90	1	Max value in first sampling event (28-Jan-09). All subsequent samples are nondetects or detected <4 µg/L.
	R-40	752	Intermediate	6	6	166	909	µg/L	3.3	MDL	6	180	EPA Tap RSL	1	90	1	Steadily decreasing . Max value in first sampling event (3-Apr-09). Excluding this sample, average = 17 µg/L, max = 40 µg/L.; <6 µg/L in last two events.
	R-40	849	Regional	8	8	27	158	µg/L	24.7	UTL	1	180	EPA Tap RSL	—	90	1	Max value in first sampling event (15-Jan-09). All subsequent samples are <15 µg/L.
	R-52	1035	Regional	3	3	19	41	µg/L	24.7	UTL	1	180	EPA Tap RSL	—	90	—	—
Metals (UF) Detected at Least Once Above Groundwater BVs																	
Aluminum	R-20	1147	Regional	14	3	235	417	µg/L	68	MDL	3	37000	EPA Tap RSL	—	18500	—	—
	R-37	1026	Regional	8	8	180	267	µg/L	68	MDL	8	37000	EPA Tap RSL	—	18500	—	Persistent but variable values; not detected in filtered samples.

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl[b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
	R-40	849	Regional	8	5	282	901	µg/L	68	MDL	5	37000	EPA Tap RSL	—	18500	—	
	R-52	1035	Regional	3	2	1386	2690	µg/L	68	MDL	2	37000	EPA Tap RSL	—	18500	—	Max in first sample. Not detected most recent sample (Oct-10), nor in any filtered samples.
	R-52	1107	Regional	3	1	118	118	µg/L	68	MDL	1	37000	EPA Tap RSL	—	18500	—	
Antimony	R-40	752	Intermediate	8	5	5.0	8.9	µg/L	1	MDL	3	6	EPA Primary MCL	3	3	3	Highly variable values. Not detected in R-40i or R-40 screen 2.
Barium	R-20	905	Regional	11	11	76.4	90.5	µg/L	72.6	UTL	7	2000	EPA Primary MCL	—	1000	—	Consistently above UTL
	R-20	1147	Regional	14	14	159	190	µg/L	72.6	UTL	14	2000	EPA Primary MCL	—	1000	—	Elevated values attributed to ongoing recovery from reducing conditions (section E-3.2)
Cobalt	R-40	752	Intermediate	7	1	1.42	1.42	µg/L	1	MDL	1	11	EPA Tap RSL	—	5.5	—	—
Copper	R-37	929	Intermediate	8	1	15.4	15.4	µg/L	3	MDL	1	1500	EPA Tap RSL	—	750	—	—
	R-40	752	Intermediate	7	5	8.3	13.5	µg/L	3	MDL	5	1500	EPA Tap RSL	—	750	—	Variable but persistent values above MDL; not detected or detected near MDL in filtered samples.
Iron	R-52	1035	Regional	3	3	473	1320	µg/L	748	UTL	1	26000	EPA Tap RSL	—	13000	—	Above UTL only in first sample.
Lead	R-20	1147	Regional	14	3	4.1	10.8	µg/L	1.8	MDL	1	15	EPA Primary MCL	—	7.5	1	—
Manganese	R-20	1147	Regional	14	14	65	72	µg/L	40.6	UTL	14	880	EPA Tap RSL	—	440	—	Steady values above UTL are attributed to ongoing recovery from reducing conditions (section E-3.2)
	R-40i	650	Intermediate	7	7	303	392	µg/L	143	UTL	6	880	EPA Tap RSL	—	440	—	Steady values above UTL are attributed to ongoing recovery from reducing conditions (section E-3.2)
	R-40	752	Intermediate	7	7	97	383	µg/L	143	UTL	1	880	EPA Tap RSL	—	440	—	Max value on 4-Dec-09. Steadily decreasing since then; ≤10 µg/L for last four events.

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl [b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
	R-40	849	Regional	8	6	22	108	µg/L	40.6	UTL	1	880	EPA Tap RSL	—	440	—	—
Mercury	R-20	1147	Regional	14	1	0.29	0.29	µg/L	0.07	MDL	1	2	EPA Primary MCL	—	1	—	—
Molybdenum	R-37	929	Intermediate	8	8	3.7	4.2	µg/L	2.9	UTL	8	180	EPA Tap RSL	—	90	—	Steady value above UTL
	R-40i	650	Intermediate	7	7	17.5	21.8	µg/L	2.9	UTL	7	180	EPA Tap RSL	—	90	—	Steady value above UTL
	R-40	752	Intermediate	7	7	9.3	14.4	µg/L	2.9	UTL	7	180	EPA Tap RSL	—	90	—	Steadily decreasing since Dec-09 but still above UTL
	R-40	849	Regional	8	8	3.5	6.1	µg/L	3.6	UTL	4	180	EPA Tap RSL	—	90	—	Steadily decreasing; below UTL for most recent 4 events
Nickel	R-20	1147	Regional	14	13	3.0	4.5	µg/L	4.5	UTL	1	730	EPA Tap RSL	—	365	—	—
	R-37	1026	Regional	8	8	4.1	15.6	µg/L	4.5	UTL	2	730	EPA Tap RSL	—	365	—	—
	R-40	752	Intermediate	7	7	16.5	76.9	µg/L	4.8	UTL	3	730	EPA Tap RSL	—	365	—	—
Strontium	R-20	1147	Regional	14	14	210	230	µg/L	191	UTL	13	730	EPA Tap RSL	—	365	—	Steady value slightly above UTL
Thallium	R-20	905	Regional	11	2	0.405	0.41	µg/L	0.4	MDL	1	2	EPA Primary MCL	—	1	—	—
	R-20	1147	Regional	14	2	0.415	0.43	µg/L	0.4	MDL	1	2	EPA Primary MCL	—	1	—	—
Uranium	R-37	1026	Regional	8	8	0.80	1.8	µg/L	1.085	UTL	2	30	EPA Primary MCL	—	15	—	—
Zinc	R-37	929	Intermediate	8	6	40	154	µg/L	34.4	UTL	1	180	EPA Tap RSL	—	90	1	Max value in first sampling event (13-Jul-09); steadily decreasing thereafter; not detected in last two events
	R-40i	650	Intermediate	7	5	75	341	µg/L	34.4	UTL	1	180	EPA Tap RSL	1	90	1	Max value in first sampling event (28-Jan-09). All subsequent samples are nondetects or detected <20 µg/L.

Table E-3.5-1 (continued)

Analyte	Well	Port Depth (ft bgs)	Hydrologic Zone	No. of Analyses[a]	No. of Detects[a]	Average Detected Value	Max Detected Value	Units	BV[b]	Type of BV[b]	No. > BV	Scr Lvl[b,c]	Type of Scr Lvl[b,c]	No.> Scr Lvl	½ Scr Lvl	No. > ½ Scr Lvl	Comments
	R-40	752	Intermediate	7	7	168	978	µg/L	34.4	UTL	2	180	EPA Tap RSL	1	90	2	Max value in first sampling event (21-Apr-09); second highest value (125 µg/L) on 4-Dec-09. Detected <26 µg/L in last four events.
	R-40	849	Regional	8	8	44	171	µg/L	43.1	UTL	1	180	EPA Tap RSL	—	90	1	Max value in first sampling event (15-Jan-09). All subsequent samples are <42 µg/L.
Zinc	R-52	1035	Regional	3	3	25	47	µg/L	43.1	UTL	1	180	EPA Tap RSL	—	90	—	—

Notes: BV = Groundwater background value; F = filtered; UF = unfiltered.

[a] Detection statistics are shown for a screen only for those general inorganics and trace metals detected at least once above the groundwater BV. The tabulated statistics include data for field duplicates. Thus, two detections of a given analyte do not necessarily imply the analyte was detected in two different sampling events.

[b] Groundwater BVs used in this appendix are from the GBIR R4 (LANL 2010, 110535). The BVs are listed in Table E-3.3-1, along with the lowest applicable regulatory standards or other risk-based screening values adopted for use in this appendix.

[c] Screening level = lowest applicable regulatory standard (if one exists), or risk-based screening level (if no regulatory standard exists, and if toxicological information is available), as prescribed by the Consent Order and implemented as documented in Appendix B of the 2010 IFGMP (LANL 2010, 109830):

- EPA Primary MCL = EPA maximum contaminant level (primary standard for drinking water) (40 Code of Federal Regulations Part 141).
- EPA Tap RSL = EPA regional screening level for tapwater (available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Most recent version is dated November 2010.
- NMED Tap SL = NMED screening level for tap water, Table A-1. Most recent version of Table A-1 is dated December 2009.
- NM GW Std = New Mexico Water Quality Control Commission Standards for Groundwater (New Mexico Administrative Code 20.6.2.3103).

[d] — = None.

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Table E-3.5-2
Number of Sampling Events in which Inorganic COPCs Were Detected above Groundwater BVs at Wells R-20, R-37, R-40i, R-40, and R-52 through November 30, 2010

	R-20		R-37			R-40		R-52	
Analyte	Scr 1	Scr 2	Scr 1	Scr 2	R-40i	Scr 1	Scr 2	Scr 1	Scr 2
Port Depth (ft bgs)	905	1147	929	1026	650	752	849	1035	1107
Total Number of Sampling Events	11	11	8	7	8	7	7	3	3
General Inorganics (filtered)									
Chloride	—[a]	—	6	1	—	—	—	—	—
Fluoride	—	—	2	2	1	—	—	—	—
Magnesium	—	—	8	1	7	6	—	—	—
Nitrate-nitrite as nitrogen	1[b]	—	2	3	—	—	—	2	—
Perchlorate	—	—	7	—	—	—	—	—	—
Sulfate	—	—	1	—	—	—	—	—	—
General Inorganics (unfiltered)									
Calcium	—	—	1	—	—	—	—	—	—
Magnesium	—	—	8	1	7	7	—	—	—
Metals (filtered)									
Antimony	—	—	—	—	—	2[b]	—	—	—
Arsenic	—	—	—	—	1	—	—	—	—
Barium	6	11	—	—	—	—	—	—	—
Cobalt	1	—	1	—	1	1	1	1	1
Copper	—	—	1	—	2	2	—	—	—
Iron	3	8	—	—	6	—	2	—	1
Lead	—	—	—	—	—	1	—	—	—
Manganese	—	11	—	—	6[b]	2[b]	1	—	—
Molybdenum	—	—	—	—	6	6	3	—	—
Nickel	—	3	—	—	—	3	1	—	—
Strontium	—	9	—	—	—	—	—	—	—
Thallium	2	—	—	—	—	—	—	—	—
Uranium	—	—	—	1	—	—	—	—	—
Zinc	—	—	5	—	2[b]	6[b]	1	1	—
Metals (unfiltered)									
Aluminum	—	2	—	6	—	—	4	2	1
Antimony	—	—	—	—	—	2[b]	—	—	—
Barium	7	11	—	—	—	—	—	—	—
Cobalt	—	—	—	—	—	1	—	—	—
Copper	—	—	1	—	—	5	—	—	—
Iron	—	—	—	—	—	—	—	1	—

Table E-3.5-2 (continued)

Analyte	R-20		R-37		R-40i	R-40		R-52	
	Scr 1	Scr 2	Scr 1	Scr 2		Scr 1	Scr 2	Scr 1	Scr 2
Port Depth (ft bgs)	905	1147	929	1026	650	752	849	1035	1107
Total Number of Sampling Events	11	11	8	7	8	7	7	3	3
Lead	—	1	—	—	—	—	—	—	—
Manganese	—	11	—	—	6	1	1	—	—
Molybdenum	—	—	8	—	7	7	3	—	—
Nickel	—	1	—	1	—	3	—	—	—
Strontium	—	10	—	—	—	—	—	—	—
Thallium	1	1	—	—	—	—	—	—	—
Uranium	—	—	—	2	—	—	—	—	—
Zinc	—	—	1	—	1[b]	2[b]	1	1	—

[a] — = Not detected above groundwater BV or other screening level.

[b] Detected at least once above lowest applicable screening level.

Table E-3.6-1
Average and Maximum Tritium Activities in Groundwater Collected from Monitoring Network Wells Specific to MDA H through November 2010

Well	Port Depth (ft bg)	Lab Code[a]	No. of Analyses	No. of Detects	Average (pCi/L)	Max (pCi/L)	MDA[b] (pCi/L)	BV[c] (pCi/L)	No. > BV	Comments
Screens Completed in Perched-Intermediate Groundwater										
R-37	929	UMTL	4	4	24.4	44.7	0.3	36.08	2	Consistently detected ≥25 pCi/L since 18-Nov-09
		ARSL	3	3	34.2	42.1	2.6	36.08	1	
R-40i	650	UMTL	5	0	—[d]	—	0.3	36.08	—	—
		ARSL	2	1	4.6	4.6	2.0	36.08	—	Detected in most recent samples for which data are available (28-Jul-10)
R-40	752	UMTL	4	0	—	—	0.3	36.08	—	—
		ARSL	2	1	17.1	17.1	2.0	36.08	—	Detected in most recent samples for which data are available (28-Jul-10)
Screens Completed in Regional Aquifer										
R-20	905	UMTL	4	0	—	—	0.3	6.26	—	Before redevelopment
		UMTL	5	0	—	—	0.3	6.26	—	During redevelopment
		UMTL	7	0	—	—	0.3	6.26	—	After redevelopment and conversion
		ARSL	3	0	—	—	3.8	6.26	—	
	1147	UMTL	5	1	7.4	7.4	0.3	6.26	1	Before redevelopment. The analytical lab (UMTL) noted “detection was bad distillation”; tritium not detected in reanalyzed sample.
		UMTL	5	0	—	—	0.3	6.26	—	During redevelopment
		UMTL	8	0	—	—	0.3	6.26	—	After redevelopment and conversion
		ARSL	5	0	—	—	4.4	6.26	—	
R-37	1026	UMTL	3	2	9.0	13.5	0.3	6.26	1	Two highest values (18-Nov-09 and 18-Dec-09) are associated with removal & installation of sampling systems. Detected below BV in sample collected on 3-Mar-10; not detected in most recent two samples for which data are available (8-Jun-10 and 10-Aug-10).
		ARSL	3	1	24.4	24.4	1.6	6.26	1	
R-40	849	UMTL	5	0	—	—	0.3	6.26	—	—
		ARSL	2	0	—	—	2.1	6.26	—	—
R-52	1035	ARSL	2	0	—	—	2.9	6.26	—	—
	1107	ARSL	2	0	—	—	2.5	6.26	—	—

[a] Lab codes: ARSL = American Radiological Services Laboratory; UMTL = University of Miami Tritium Laboratory.

[b] Value listed is the maximum MDA associated with data reported for this location.

[c] Background value (BV) from GBIR R4 (LANL 2010, 110535).

[d] — = Not applicable (tritium not detected at this location or no comments concerning the results shown).

Appendix F

Supporting Information for Cost Estimates

F-1.0 INTRODUCTION

This appendix provides the basis for the cost estimates, summary cost information, assumptions, estimate details, and material and labor pricing data used in developing the cost estimates for corrective measures evaluation (CME) technologies for the Material Disposal Area (MDA) H at Technical Area 54 (TA-54) at Los Alamos National Laboratory (the Laboratory), detailed in section 8 of the CME report. The estimates are intended to be consistent with U.S. Environmental Protection Agency (EPA) guidance on developing and documenting costs estimated during feasibility studies (EPA 2000, 071540).Cost estimates are expected to be within the accepted standard accuracy range of +50% to –30% established by EPA for remedial alternative estimates at the alternatives screening stage (EPA 2000, 071540, pp. 2-4).

F-1.1 Compliance Order on Consent Requirements

The Compliance Order on Consent (Consent Order) requires that capital costs shall include, without limitation, construction and installation costs, equipment costs, land development costs, and indirect costs, including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. Operations and maintenance (O&M) costs shall include, without limitation, operating labor and materials costs, maintenance labor and materials costs, replacement costs, utilities, monitoring and reporting costs, administrative costs, indirect costs, and contingency allowances. All costs shall be calculated based on their net present value (PV).

As presented in guidance documents, confusion often exists with the terms “direct” and “indirect” costs. Therefore, in this report the term “capital” costs includes planning, design, construction, management-related activities, and both labor and professional services for installing the remedial alternative. Recurring operations, maintenance, and monitoring costs, including regular annual costs and periodic costs, are separated from capital costs. Periodic costs include 5-yr reviews, equipment replacement, and major repairs.

F-2.0 METHOD

This estimate has been developed based on a bottoms-up approach using WinEst software. The assumptions used in the calculations are discussed in section F-3.0. The construction pricing is based on the 2010 RS Means Database for equipment and materials, and the current Davis-Bacon Wage Rates for construction in Los Alamos. A labor factor was used to increase the project cost on labor because of the remote location of the site or for additional rigor for a site. The basic estimating units generally reflect a normal standard for construction costs. Many special work situations and job conditions may require additional material or labor work hours. The quantities used here are only for estimating purposes and vary slightly from quantities stated within the site history section. The actual design and operations will vary when the corrective measures implementation is completed.

F-2.1 Capital Costs

Capital costs consist of construction and installation costs, equipment costs, land development costs, and indirect costs, including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. Detailed estimates of capital cost in calendar year 2010 dollars are provided below and in section 8 tables of the CME report.

F-2.2 Operation and Maintenance Costs

O&M costs include operating labor and materials costs, maintenance labor and materials costs, replacement costs, utilities, monitoring and reporting costs, administrative costs, indirect costs, and contingency allowances. Detailed estimates of monitoring, inspection, and maintenance costs in 2010 dollars are provided below and in section 8 tables of the CME report.

F-2.3 PV Analysis

To compare one technology's costs with other technologies that spend money over different time periods, the costs were discounted to a 2010 net PV as recommended in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study" (EPA 2000, 071540). PV costs for a technology are the sum of all capital costs and continuing costs. Presentation of capital, operating, and maintenance costs as PV is consistent with the CME requirements contained in section VII.D.4.b.v of the Consent Order. The principle is also embraced for federal programs. The Office of Management and Budget (OMB) Circular A-94 states, "The standard criterion for deciding whether a government program can be justified on economic principles is net present value" (Office of Management and Budget 1992, 094804, p. 3). The OMB circular Appendix C (revised December 2009) recommends the use of a real discount rate of .9% for activities lasting 3 yr and 2.7% for activities between 20 to 30 yr. These assumptions have been used in the calculation of the net PV for the remedial alternatives presented in this CME.

Net PV was calculated according to the following formula:

$$PV_{total} = \sum_{t=1}^{t=n} \frac{1}{(1+i)^t} \cdot C_t$$

where PV_{total} = present single sum of money,

t = specific year,

n = final project year,

i = the discounted interest rate, and

C_t = cost in year t in base year dollars.

The discount factor, denoted as the $1/(1 + i)^t$ term within the PV equation, has been calculated for the interest rates listed above. The PV analyses are presented in the cost estimate tables in section 8.

F-2.4 General Assumptions

The estimate is based on an 8-h work day and a 5-d workweek. No overtime is included. On-site activities will be conducted under Hazardous Waste Operations and Emergency Response (HAZWOPER) requirements. Safety levels are based on the Occupational Safety and Health Administration regulations in 29 Code of Federal Regulations Part 1910. Most activities are set to safety level D.

Existing facilities will be used for radiological and site access control.

All appropriate site-related plans (e.g., general safety plan, quality assurance plan, waste management plan, work plan, hoisting and rigging plan, and health and safety plan) will be prepared and submitted by the subcontractor. All plans will be reviewed and approved by the Laboratory as necessary so as not to adversely impact the project schedule.

Attachment F-1 is the detailed cost assembly report for the estimates described below. All technologies, except the no-action technology, will include institutional controls (site control, fencing, signage, guards and access control, and reports) as well as monitoring and maintenance. Monitoring and maintenance includes maintenance of the cover and other controls. Moisture monitoring will occur for the vegetative and evapotranspiration (ET) cover.

F-3.0 TECHNOLOGIES

Two corrective measures technologies, plus the no-action technology, are included.

F-3.1 Technology S-1: No Action

For this technology, the site is left as-is. There is no cost.

F-3.2 Technology S-3a: Vegetative Cover

This technology includes the following tasks:

- Regrading of the existing soil surface and installing a vegetative cover over MDA H
- Site surveillance, monitoring, and maintenance of the cover for 30 yr
- Institutional controls for 100 yr

F-3.2.1 Assumptions

The following assumptions were used to develop the cost estimate for this technology:

- Area of .4 acres to be covered by the vegetative cover, as shown in Figure 7.3-1
- Approximately 700 ft of fencing to be installed around the site
- Construction of a vegetative cover consisting of 1 ft of fill (645 yd^3) and 6 in. of topsoil (323 yd^3), native vegetation, and a moisture monitoring system. Construction of a vegetative cover consisting of 1 ft of crushed tuff from TA-61 (a 23-m round trip) and 6 in. of topsoil from a location within a 50-mi radius (100-mi round trip), native vegetation, and a moisture-monitoring system.
- Up to 24 mo for completion of readiness reviews, obtaining document safety analysis (DSA) approval, and completion of construction
- Irrigation of cover for 1 yr to establish vegetation
- Moisture monitoring for 30 yr
- Cover maintenance, including visual inspection, removal of debris and large woody plants, and erosion control for a period of 30 yr
- Periodic revegetation of bare areas and mowing of the entire site every 5 yr for 30 yr
- Indirect O&M cost for professional management based on 26% of direct O&M costs
- Design costs calculated using the percentage method (16% of direct capital costs)

F-3.3 Technology S-3b: ET Cover

This technology includes the following tasks:

- Regrading of the existing soil surface and installation of an ET cover over MDA H
- Site surveillance, monitoring, and maintenance of the cover for 30 yr
- Institutional controls for 100 yr

F-3.3.1 Assumptions

The following assumptions were used to develop the cost estimate for this technology:

- area of 0.4 acres to be covered by the ET cover, as shown in Figure 7.3-1
- approximately 700 ft of fencing to be installed around the site
- construction of the ET cover consisting of a 1.5-ft-thick vegetated topsoil–gravel admixture (968 yd^3) at the surface, a 3.5-ft-thick infiltration layer composed of crushed tuff mixed with soil and amendments (2259 yd^3) below, and a moisture monitoring system
- construction of a vegetative cover consisting of 3.5 ft of crushed tuff from TA-61 (a 23-mi round trip) and 1.5 ft of topsoil from a location within a 50-mi radius (100-mi round trip), native vegetation, and a moisture-monitoring system
- up to 24 mo for completion of readiness reviews, obtaining DSA approval, and completion of construction
- irrigation of cover for 1 yr to establish vegetation
- cover maintenance, including visual inspection, removal of debris and large woody plants, and erosion control for a period of 30 yr
- moisture monitoring for 30 yr
- periodic revegetation of bare areas included and mowing of the entire site every 5 yr for 30 yr
- indirect O&M cost for professional management based on 26% of direct O&M costs
- design costs calculated using the percentage method (16% of direct capital costs)

F-4.0 REFERENCES

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

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

EPA (U.S. Environmental Protection Agency), July 2000. "A Guide to Developing and Documenting Cost Estimates during the Feasibility Study," EPA 540-R-00-002, prepared by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency Office of Emergency and Remedial Response, Washington, D.C. (EPA 2000, 071540)

Office of Management and Budget, October 29, 1992. "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," Circular No. A-94, Washington, D.C. (Office of Management and Budget 1992, 094804)

Attachment F-1

Detailed Cost Estimate Report

Item Description	Quantity	Unit	Gross Unit Price	Labor Hours	Labor Total - Gross	Mat Total - Gross	Subs Total - Gross	Equip Total - Gross	Other Total - Gross	Gross Total Costs
Project WBS: 1 - MDA G CME										
Project WBS: 1.PS3a - Vegetative Cover										
Project WBS: 1.PS3a.1 - Vegetative Cover - Direct Costs										
Fence Demo & Construction				231.5	18,355.49	56,687.13		3,683.54		78,726
Fence, chain link industrial, aluminized steel, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire	700	LF	92	132.7	10,518.40	52,320.57		1,640.96		64,480
Fence, chain link industrial, galvanized steel, add for corner post, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, 3" diameter, includes excavation, in concrete	4	EA	256	3.4	270.34	713.46		42.13		1,026
Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts & hardware in concrete	1	Opng	6,156	31.3	2,478.01	2,802.89		874.84		6,156
Signs, stock, aluminum, reflectorized, .080" aluminum, 24" x 24", excludes posts	7	EA	191	4.5	360.26	850.21		126.64		1,337
Demo Existing - Selective demolition, chain link fences & gates, fence,	700	LF	8	59.6	4,728.48			998.97		5,727
Veg Cover				1,207.40	103,291.35	48,249.58	33,099.54	102,036.91	1,189.10	287,866
Fine grading, for roadway, base or leveling course, large area, 6,000 S.Y. or more	1,936.00	SY	1	21.7	1,701.49			1,019.57		2,721
TUFF Material and Delivery	645.3	CY	35			22,472.82				22,473
Backfill, bulk, 6" to 12" lifts, dozer backfilling	645.3	CY	5	13.9	1,087.38			2,225.30		3,313
Compaction, 2 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	645.3	CY	1	4.6	362.46			570.06		933
Compaction, water for, 3000 gallon truck, 6 mile haul	645.3	CY	4	10.1	793.5	1,260.67		679.7		2,734
Backfill, bulk, 6" to 12" lifts, dozer backfilling	323	CY	5	6.9	544.25			1,113.81		1,658
Borrow, common earth, 3 C.Y. bucket, loading and/or spreading, front end loader, wheel-mounted	323	CY	1	3.5	272.13			153.65		426
Borrow, Topsoil, Retrieval and Drop	339.8	ton	19	52.2	4,098.30			2,416.16		6,514
Soils for earthwork, common borrow, spread with 200 H.P. dozer, includes load at pit and haul, 23 miles round trip, excludes compaction	404	CY	104	26.8	2,103.54	5,078.49		34,669.91		41,852
Fine grading, fine grade for small irregular areas, to 15,000 S.Y.	1,936.00	SY	4	65.9	5,172.57			3,354.56		8,527
Geotextile Subsurface Drainage Filtration, TRM , hand layed, ideal conditions	1,936.00	SY	9	18.3	1,433.42	16,443.61				17,877
Seeding, mechanical seeding, 215 lb/acre	0.4	acre	1,801	3	237.36	383.91		99.21		720
Rent water truck, off highway, 6000 gallon capacity - Rent per day	40	days	2,036	340.8	26,735.26			54,698.78		81,434

Item Description	Quantity	Unit	Gross Unit Price	Labor Hours	Labor Total - Gross	Mat Total - Gross	Subs Total - Gross	Equip Total - Gross	Other Total - Gross	Gross Total Costs
Mobilization or demobilization, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles	2	EA	816	7.6	594.79			1,036.22		1,631
Field Non-Manual - JHRS	175.6	hour	159	249.3	27,995.40					27,995
Craft Distributable - Labor	219.5	hour	112	311.7	24,530.36					24,530
Craft Distributable - Materials	219.5	hour	12			2,610.08				2,610
Excavation permit	1	ea	1,189						1,189.10	1,189
Storm water prevention	1	lsum	33,100				33,099.54			33,100
Traffic Control	50	hour	113	71	5,629.14					5,629
Vegetative Cover - Direct Costs Total				1,438.90	121,646.83	104,936.71	33,099.54	105,720.45	1,189.10	366,593
Project WBS: 1.PS3a.2 - Vegetative Cover - Indirect Costs										
Veg Cover				1,117.00	245,212.66		84,782.61		348,294.50	678,290
Vegetative Mat Design	1	lsum	84,783				84,782.61			84,783
Professional Management	1	lsum	210,087	957	210,087.19					210,087
Contingency - Cost 30%	1	lsum	208,977						208,976.70	208,977
Contingency - Schedule 10%	1	lsum	69,659						69,658.90	69,659
Contingency - TPRA 10%	1	lsum	69,659						69,658.90	69,659
DSA Administration	1	lsum	35,125	160	35,125.47					35,125
Vegetative Cover - Indirect Costs Total				1,117.00	245,212.66		84,782.61		348,294.50	678,290
Project WBS: 1.PS3a.3 - Vegetative Cover - Direct Operations & Maintenance										
Veg Cover				4,684.90	555,732.34	64,284.38		6,685.53		626,702
TDR Monitoring	1	EA	59,187	56.8	4,986.39	54,200.63				59,187
TDR Moisture Monitoring (30 years)	1	lsum	276,928	1,923.70	276,927.61					276,928
Site Maintenance for 30 years.	1	lsum	63,487	697.7	46,717.71	10,083.76		6,685.53		63,487
Annual Long Term Monitoring Report - 100 years	1	lsum	227,101	2,006.70	227,100.62					227,101
Vegetative Cover - Direct Operations & Maintenance Total				4,684.90	555,732.34	64,284.38		6,685.53		626,702
Project WBS: 1.PS3a.4 - Vegetative Cover - Indirect Operations & Maintenance										
Veg Cover				1,025.00	225,020.36				425,861.00	650,881
Professional Management (years 31-100)	1	lsum	36,781	167.5	36,780.80					36,781
Professional Management (years 1-30)	1	lsum	188,240	857.4	188,239.57					188,240
Contingency - Cost 30%	1	lsum	255,517						255,516.60	255,517
Contingency - Schedule 10%	1	lsum	85,172						85,172.20	85,172
Contingency - TPRA 10%	1	lsum	85,172						85,172.20	85,172
Vegetative Cover - Indirect Operations & Maintenance Total				1,025.00	225,020.36				425,861.00	650,881
Vegetative Cover Total				8,265.70	1,147,612.19	169,221.09	117,882.15	112,405.98	775,344.60	2,322,466
Project WBS: 1.PS3b - ET Cover										

Item Description	Quantity	Unit	Gross Unit Price	Labor Hours	Labor Total - Gross	Mat Total - Gross	Subs Total - Gross	Equip Total - Gross	Other Total - Gross	Gross Total Costs
Project WBS: 1.PS3b.1 - ET Cover - Direct Cost										
ET Cover				1,539.60	132,975.54	171,156.64	46,370.80	184,902.38	1,189.10	536,594
Fence, chain link industrial, aluminized steel, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire	700	LF	92	132.7	10,518.40	52,320.57		1,640.96		64,480
Fine grading, select gravel, 6" deep, hand grading, including compaction	1,936.00	SY	7	165.3	12,965.41			361.76		13,327
TUFF Material and Delivery	2,259.00	CY	35			78,666.87				78,667
Backfill, bulk, 6" to 12" lifts, dozer backfilling	2,259.00	CY	5	48.5	3,806.40			7,789.75		11,596
Compaction, 2 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	2,259.00	CY	1	16.2	1,268.80			1,995.52		3,264
Compaction, water for, 3000 gallon truck, 6 mile haul	2,259.00	CY	4	35.4	2,777.69	4,413.02		2,379.30		9,570
Borrow, common earth, 3 C.Y. bucket, loading and/or spreading, front end loader, wheel-mounted	968	CY	1	10.4	815.54			460.46		1,276
Borrow, Topsoil, Retrieval and Drop	1,019.30	ton	19	156.7	12,293.69			7,247.76		19,541
Soils for earthwork, common borrow, spread with 200 H.P. dozer, includes load at pit and haul, 23 miles round trip, excludes compaction	1,210.00	CY	104	80.3	6,300.21	15,210.34		103,838.10		125,349
Fine grading, fine grade for small irregular areas, to 15,000 S.Y.	1,936.00	SY	4	65.9	5,172.57			3,354.56		8,527
Geotextile Subsurface Drainage Filtration, TRM , hand layed, ideal conditions	1,936.00	SY	9	18.3	1,433.42	16,443.61				17,877
Seeding, mechanical seeding, 215 lb/acre	0.4	acre	1,801	3	237.36	383.91		99.21		720
Rent water truck, off highway, 6000 gallon capacity - Rent per day	40	days	2,036	340.8	26,735.26			54,698.78		81,434
Mobilization or demobilization, dozer, loader, backhoe or excavator, above 150 H.P., up to 50 miles	2	EA	816	7.6	594.79			1,036.22		1,631
Field Non-Manual - JHRS	250.2	hour	159	355.3	39,890.01					39,890
Craft Distributable - Labor	22.7	hour	112	32.2	2,536.85					2,537
Craft Distributable - Materials	312.7	hour	12			3,718.33				3,718
Excavation permit	1	ea	1,189						1,189.10	1,189
Storm water prevention	1	lsum	46,371				46,370.80			46,371
Traffic Control	50	hour	113	71	5,629.14					5,629
Fence Demo & Construction				98.8	7,837.09	4,366.56		2,042.57		14,246
Fence, chain link industrial, galvanized steel, add for corner post, 6 ga. wire, 2-1/2" posts @ 10' OC, 8' high, 3" diameter, includes excavation, in concrete	4	EA	256	3.4	270.34	713.46		42.13		1,026
Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts & hardware in concrete	1	Opng	6,156	31.3	2,478.01	2,802.89		874.84		6,156

Item Description	Quantity	Unit	Gross Unit Price	Labor Hours	Labor Total - Gross	Mat Total - Gross	Subs Total - Gross	Equip Total - Gross	Other Total - Gross	Gross Total Costs
Signs, stock, aluminum, reflectorized, .080" aluminum, 24" x 24", excludes posts	7	EA	191	4.5	360.26	850.21		126.64		1,337
Demo Existing - Selective demolition, chain link fences & gates, fence,	700	LF	8	59.6	4,728.48			998.97		5,727
ET Cover - Direct Cost Total				1,638.40	140,812.63	175,523.20	46,370.80	186,944.95	1,189.10	550,841
Project WBS: 1.PS3b.2 - ET Cover - Indirect Cost										
ET Cover				1,597.90	350,802.14		127,385.29		514,513.60	992,701
ET Mat Design	1	lsum	127,385				127,385.29			127,385
Professional Management	1	lsum	315,677	1,437.90	315,676.66					315,677
Contingency - Cost 30%	1	lsum	308,708						308,708.00	308,708
Contingency - Schedule 10%	1	lsum	102,903						102,902.80	102,903
Contingency - TPRA 10%	1	lsum	102,903						102,902.80	102,903
DSA Administration.	1	lsum	35,125	160	35,125.47					35,125
ET Cover - Indirect Cost Total				1,597.90	350,802.14		127,385.29		514,513.60	992,701
Project WBS: 1.PS3b.3 - ET Cover - Direct Operations & Maintenance										
ET Cover				4,684.90	555,732.34	64,284.38		6,685.53		626,702
TDR Monitoring of ET Cover	1	EA	59,187	56.8	4,986.39	54,200.63				59,187
TDR Moisture Monitoring (30 years)	1	lsum	276,928	1,923.70	276,927.61					276,928
Site Maintenance for 30 years.	1	lsum	63,487	697.7	46,717.71	10,083.76		6,685.53		63,487
Annual Long Term Monitoring Report - 100 years	1	lsum	227,101	2,006.70	227,100.62					227,101
ET Cover - Direct Operations & Maintenance Total				4,684.90	555,732.34	64,284.38		6,685.53		626,702
Project WBS: 1.PS3b.4 - ET Cover - Indirect Operations & Maintenance										
ET Cover				1,025.00	225,020.36				425,861.00	650,881
Professional Management (years 31-100)	1	lsum	36,781	167.5	36,780.80					36,781
Professional Management (years 1-30)	1	lsum	188,240	857.4	188,239.57					188,240
Contingency - Cost 30%	1	lsum	255,517						255,516.60	255,517
Contingency - Schedule 10%	1	lsum	85,172						85,172.20	85,172
Contingency - TPRA 10%	1	lsum	85,172						85,172.20	85,172
ET Cover - Indirect Operations & Maintenance Total				1,025.00	225,020.36				425,861.00	650,881
ET Cover Total				8,946.20	1,272,367.47	239,807.58	173,756.09	193,630.48	941,563.70	2,821,125

Acronyms and Abbreviations for Attachment F-1

CAMU	corrective action management unit
CF	cubic foot
CME	corrective measures evaluation
CMI	corrective measure implementation
CY	cubic yard
DC	direct capital (cost)
DOM	direct operations and maintenance
DSA	Document safety analysis
EA	each
EPA	Environmental Protection Agency (U.S.)
ET	evapotranspiration
HAZWOPER	Hazardous Waste Operations and Emergency Response
H.P.	horse power
IC	indirect capital (cost)
IOM	indirect operations and maintenance
LSUM	lump sum
JHRS	job hours
LDR	land disposal restriction
LF	linear foot
LLW	low-level waste
MDA	material disposal area
MNTH	month
MPH	mile per hour
MSF	thousands of square feet
O&M	operations and maintenance
OC	on center
OMB	Office of Management and Budget
opng	opening
PI	pit and impoundments
PV	present value
RCRA	Resource Conservation and Recovery Act
S	shaft

spec	specification
SVE	soil-vapor extraction
SY	square yard
TA	technical area
TN	ton
TPRA	technical programmatic risk assessment
TRM	turf-reinforcing mat
VOC	volatile organic compound
VZ	vadose zone
WBS	work breakdown structure
YR	year