LA-UR-10-2468
April 2010
EP2010-0197

Phase III Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

Los Alamos National Laboratory, operated by Los Alamos National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-06NA25396, has prepared this document pursuant to the Compliance Order on Consent, signed March 1, 2005. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.

LA-UR-10-2468
EP2010-0197

Phase III Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1

April 2010

Responsible project manager:

Printed Name	Signature	Title	Organization	Date
Stephani Fuller		Project Manager	Environmental Programs	4/26/10

Responsible LANS representative:

Printed Name	Signature	Title	Organization	Date
Michael J. Graham	M. J. Graham	Associate Director	Environmental Programs	26 April 10

Responsible DOE representative:

Printed Name	Signature	Title	Organization	Date
David R. Gregory	David R. Gregory	Project Director	DOE-LASO	27/April/2010

EXECUTIVE SUMMARY

This investigation work plan presents proposed Phase III investigation activities at Material Disposal Area (MDA) C at Los Alamos National Laboratory (the Laboratory) in Technical Area 50.

The objectives of the proposed investigation activities are to define the lateral and vertical extent of subsurface volatile organic compound vapor and tritium contamination at MDA C, install two downgradient regional groundwater monitoring wells, and characterize background concentrations of inorganic chemicals detected in dacite lava. The data collected during the Phase III investigation will be used to support future corrective action decisions for MDA C.

The specific investigation activities proposed are

- collecting pore-gas samples from 14 existing pore-gas monitoring wells to verify the results of the Phase II investigation;
- installing four new vapor-monitoring wells to the base of the Guaje Pumice Bed (approximately 650 ft below ground surface) and, if possible, at least 10 ft into the underlying Tschicoma Formation dacite;
- collecting pore-gas samples from the new vapor-monitoring wells;
- drilling and constructing two regional groundwater monitoring wells; and
- determining representative background concentrations for inorganic chemicals in Tschicoma Formation dacite.

CONTENTS

Figures

Tables

Appendixes

1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or 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 separated by deep canyons containing perennial and intermittent streams running from west to east. Mesa tops range in elevation from approximately 6200 to 7800 ft.

The Laboratory's Environmental Programs (EP) Directorate, formerly the Environmental Restoration Project, is participating in a national effort by DOE to clean up sites and facilities previously involved in weapons research and development. The goal of EP is to ensure that past operations do not threaten human health and safety or the environmental in and around Los Alamos County, New Mexico. To achieve this goal, the Directorate is currently investigating sites potentially contaminated by past Laboratory operations. The sites under investigation are designated as either solid waste management units (SWMUs) or areas of concern.

This investigation work plan addresses SWMU 50-009, also known as Material Disposal Area (MDA) C, which is potentially contaminated with both hazardous and radioactive chemicals. MDA C is located at Technical Area 50 (TA-50) at the Laboratory. Figure 1.0-1 shows the location of MDA C and the surrounding technical areas.

Corrective actions at the Laboratory are subject to the March 1, 2005, Compliance Order on Consent (the Consent Order). Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the New Mexico Environment Department (NMED) in accordance with DOE policy.

1.1 Work Plan Overview

This investigation work plan describes the proposed Phase III investigation activities for MDA C. The Laboratory submitted the revised MDA C Phase II Investigation Report to NMED on October 1, 2009, for review and approval (LANL 2009, 107389). The report was disapproved by NMED in a letter dated October 15, 2009 (NMED 2009, 107361). The notice of disapproval (NOD) for the revised investigation report required the Laboratory to submit a Phase III investigation work plan to install groundwater and vapor-monitoring wells. The Phase III investigation work plan was submitted to NMED on February 5, 2010 (LANL 2010, 108594), and NMED issued an NOD on March 29, 2010 (NMED 2010, 109018).

Section 2 of the work plan presents the general site information, operational history, the results of previous investigations, and the current conceptual site model of potential contaminant sources, transport mechanisms, pathways, and receptors for MDA C. General site conditions are discussed in section 3. Section 4 presents the scope of proposed investigation activities. Section 5 provides investigation methods for proposed field activities. Ongoing monitoring and sampling programs relevant to MDA C are presented in section 6. Section 7 is an overview of the anticipated schedule of the investigation and reporting activities. The references cited in this work plan and the map data sources are provided in section 8.

Appendix A of this work plan includes a list of acronyms and abbreviations, a metric conversion table, and a data qualifier definitions table. Appendix B describes the management of investigation-derived waste

(IDW). Appendix C presents the results of a monitoring well network analysis used to evaluate potential locations for the new regional wells at MDA C.

1.2 Investigation Objectives

The objectives of the Phase III investigation are to define the lateral and vertical extent of subsurface volatile organic compound (VOC) vapor and tritium contamination at MDA C, install two downgradient regional groundwater monitoring wells, and characterize background concentrations of inorganic chemicals detected in dacite lava. The data collected during the Phase III investigation will be used to support future corrective-action decisions for MDA C.

The Phase II investigation involved extending existing boreholes and installing new boreholes to characterize subsurface VOC vapor and tritium concentrations. The specific criteria established in the Phase II investigation work plan (LANL 2007, 098425) for defining vertical extent of VOC pore gas contamination were not met at several locations. The existing vapor-monitoring wells at MDA C will be resampled to determine whether these criteria have been met. If not, deeper boreholes will be installed at three locations to define vertical extent and a new borehole will be installed farther to the south of MDA C to determine lateral extent toward Twomile Canyon.

Regional groundwater monitoring well R-46 has been installed to the east of MDA C. The location of this well was determined by a specified probability of detecting releases migrating from MDA C to supply well PM-5 (NMED 2007, 098775). Two additional regional wells will be installed at locations selected to provide a higher probability of detecting all potential releases from MDA C. Data from these wells are needed to support selection of corrective measures at MDA C.

During the Phase II investigation, a rock sample was collected from the top of the dacite underlying the Guaje Pumice Bed below MDA C. Concentrations of inorganic chemicals in the dacite were elevated compared to those in the overlying tuff units, but there were no comparable background data currently available for dacite. Representative background concentrations for inorganic chemicals in dacite will be evaluated during the Phase III investigation.

2.0 BACKGROUND

2.1 General Site Information

MDA C is located in TA-50 at the head of Ten Site Canyon. TA-50 is bounded on the north by Effluent and Mortandad Canyons, on the east by the upper reaches of Ten Site Canyon, on the south by Twomile Canyon, and on the west by TA-55. Facilities at TA-50 include a radioactive liquid waste treatment facility (RLWTF), a waste reduction characterization facility, offices, several storage areas, other SWMUs, and MDA C.

MDA C is an inactive 11.8-acre landfill consisting of 6 disposal pits, a chemical disposal pit, and 108 shafts (Figure 2.1-1). Solid low-level radioactive wastes and chemical wastes were disposed of in the landfill between 1948 and 1974. The depths of the seven pits at MDA C range from 12 to 25 ft below the original ground surface. The depths of the 108 shafts range from 10 to 25 ft below the original ground surface. The original ground surface is defined as beneath the cover that was placed over the site in 1984. The pits and shafts are constructed in the Tshirege Member of the Bandelier Tuff. The regional aquifer is estimated to be approximately 1330 ft deep based on the water level in well R-46 (LANL 2009, 105592). The topography of MDA C is relatively flat, although the slope steepens to the north where the northeast corner of MDA C abuts the south wall of Ten Site Canyon.

2.2 Operational History

MDA C is a decommissioned material disposal area established to replace MDA B at TA-21 as a disposal area for Laboratory-derived waste. MDA C operated from May 1948 to April 1974 but received waste only intermittently from 1968 until it was decommissioned in 1974. Wastes disposed of at MDA C consisted of liquids, solids, and containerized gases generated from a broad range of nuclear research and development activities conducted at the Laboratory. These wastes include uncontaminated classified materials, metals, hazardous materials, and radioactively contaminated materials. A summary of the estimated waste inventory was included in Appendix J of the MDA C investigation report (LANL 2006, 094688). After closure, the pits and shafts were subsequently covered with varying amounts of fill material.

2.3 Previous Investigations

2.3.1 Summary of Previous Investigations

Previous Resource Conservation and Recovery Act facility investigation fieldwork was conducted at MDA C from 1993 to 2009. Fieldwork included the following activities:

- three geophysical surveys (1994, 2001, and 2002)
- biota screening and sampling (2003)
- surface investigations that included surface soil and fill sampling (1993) and VOC surface flux measurements (2000)
- subsurface investigations that included core sampling (1995), borehole air-flow velocity measurements (1995–1996), pore-gas sampling (2001), and tritium-probe sampling (2003)
- a geophysical survey to identify boundaries of waste disposal pits (2006)
- borehole drilling and sampling of subsurface tuff and pore gas, a radiological field survey, and surface soil sampling (2004–2009)

Figure 2.3-1 shows the locations of all boreholes drilled during previous investigation activities.

The most recent investigation at MDA C was the Phase II investigation completed in 2009. Field investigation activities during the Phase II investigation included drilling five new boreholes, extending the depth of eight existing boreholes, and drilling seven additional boreholes next to existing boreholes to install vapor-monitoring systems; core sampling; pore-gas sampling; collecting surface and near-surface samples to define the nature and extent of inorganic chemicals at the surface and allow completion of risk screening assessments; and evaluating the potential effect of subsurface fractures on contaminant concentrations and transport. The depths of the boreholes installed during the Phase II investigation ranged from 450 to 653 ft below ground surface (bgs). Core samples were analyzed for inorganic chemicals, organic chemicals, and radionuclides. Pore-gas samples were analyzed for VOCs and tritium. Fourteen of the Phase II investigation boreholes were completed as vapor-monitoring wells.

As part of related groundwater investigations in the Mortandad Canyon watershed, regional groundwater monitoring well R-46 was installed 880 ft downgradient (east-southeast) of MDA C in 2009 to detect potential groundwater contamination migrating from MDA C to supply well PM-5 and to provide groundwater monitoring data to support a corrective measures evaluation at MDA C (NMED 2007, 098775; LANL 2009, 105592). The borehole for well R-46 was advanced to a total depth (TD) of 1415 ft bgs. The well was completed with a single screen set at a depth interval of 1340 to 1360 ft bgs near the top of the regional aquifer in the Puye Formation.

2.3.2 Results of Previous Investigations

The results of previous investigations at MDA C were presented in the approved investigation work plan (LANL 2005, 091493), the investigation report (LANL 2006, 094688), and the Phase II investigation report (LANL 2009, 107389). The following sections summarize the results of the Phase I and earlier investigations, the Phase II investigation, and recent groundwater monitoring.

2.3.2.1 Phase I and Earlier Investigations

During the Phase I investigation, trichloroethene (TCE) and tetrachloroethene (PCE) were detected in all boreholes. The maximum detected concentration of TCE in pore-gas samples (77,000 $\mu g/m^3$) was at a depth of 150 ft bgs in borehole location 50-24771 between Pit 4 and Pit 5 (LANL 2006, 094688). Concentrations of TCE and PCE were highest in boreholes in the vicinity of Pits 1–5. Data from the single borehole location deeper than 300 ft bgs (borehole location 50-24818) indicated that the concentrations of VOCs in pore gas decrease substantially below a depth of 325 ft bgs, corresponding to changes in lithology from the Tshirege Member to the Otowi Member of the Bandelier Tuff. However, no other boreholes at other locations at MDA C were deep enough to confirm this decreasing vertical trend.

VOCs were detected in pore gas in all boreholes installed on or near the perimeter of MDA C. Therefore, additional data were needed to define the lateral extent of vapor-phase contamination. Data from the step-out boreholes installed during the Phase I investigation indicate the magnitude of reduction in VOC concentration with distance from the MDA boundary. Boreholes 50-24820 and 50-24821 were installed approximately 200 ft south of the MDA C boundary. Pore-gas samples from these boreholes showed TCE and PCE concentrations 30% to 85% lower than samples collected from equivalent depths in boreholes along the southern boundary of MDA C. Samples from borehole 50-25451, located approximately 400 ft from the southern MDA C boundary, had concentrations of TCE and PCE approximately 2 orders of magnitude less than samples collected from equivalent depths along the boundary.

Inorganic chemicals were generally detected at concentrations only slightly above background levels in a small percentage of subsurface tuff samples. Because only screening-level inorganic chemical data were available for surface soil samples, the nature and extent of potential inorganic chemical contamination at the surface were not defined. Additional surface soil samples were required to confirm the results of screening-level data and to define the nature and extent for inorganic chemicals at the surface (NMED 2007, 095437).

The results of the Phase I and earlier investigations at MDA C indicate the vertical extent of inorganic chemical contamination has been defined. During the 1995 and 2004–2007 investigations, inorganic chemical samples were collected from 40 boreholes. Of these, a total of 13 boreholes had one or more inorganic chemicals detected above the background value (BV) and the maximum concentration of the background data set in the sample collected at TD. A total of 13 inorganic chemicals (aluminum, arsenic, barium, beryllium, calcium, copper, chromium, iron, magnesium, manganese, lead, selenium, and zinc) were detected above BVs and the maximum concentration of the background data set, with each of these chemicals being detected above BV and the maximum concentration of the background data set in one to four boreholes. Thus, out of approximately 1000 TD sampling results, a total of 32 TD sampling results were above BVs and the maximum concentration of the background data set. The detections above background in TD samples were generally only slightly above background and were generally not accompanied by detections above background in shallower lithologic units. The results appear to indicate the detections above background in TD samples are associated with natural variability of the tuff rather than indicative of unbounded releases.

Several radionuclides were detected in subsurface tuff, and tritium was detected in numerous subsurface pore-gas samples.

2.3.2.2 Phase II Investigation

Cadmium, chromium, cobalt, manganese, selenium, and zinc were detected above BVs in surface and near-surface samples. These inorganic chemicals were generally detected infrequently and at concentrations less than twice the BVs. The vertical and lateral extent of contamination are defined for all inorganic chemicals in surface and near-surface at MDA C.

Inorganic chemicals identified as chemicals of potential concern (COPCs) in subsurface core are aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, nitrate, perchlorate, selenium, silver, vanadium, and zinc. With the exception of borehole 50-603470, which was advanced to a depth of 650 ft bgs to the top of the Tschicoma Formation, the Phase II data indicated that the nature and extent of subsurface inorganic chemical contamination were defined. At borehole 50-603470, the highest concentrations of inorganic chemicals were generally detected in the deepest sample, which was collected from dacite lava of the Tschicoma Formation. Concentrations of inorganic chemicals detected in this sample are presented in Table 2.3-1. Because there are no defined BVs for the Tschicoma Formation dacite, it was not possible to determine whether these results were above background.

Twenty-three organic chemicals were detected in subsurface core samples. Organic chemicals were detected infrequently and at low concentrations, generally near estimated quantitation limits (EQLs). The Phase II data indicated that nature and extent of subsurface organic chemical contamination were defined.

Thirty-eight VOCs and tritium were detected in pore-gas samples. Table 2.3-2 presents the results of the pore-gas VOC sampling from the Phase II boreholes. Data from the Phase II boreholes, which are the deepest boreholes at the site (450 ft bgs or deeper), showed that VOC concentrations increased with depth to a maximum generally in the range of 200 to 300 ft bgs, and then decreased with depth in successively deeper geologic units. For example, in the deepest borehole, which is at location 50-24769/50-603470, the TCE concentration decreased by more than 300 times from the highest concentration (60,000 $\mu g/m^3$) at 300 ft bgs to the deepest sample at 650 ft bgs (180 $\mu g/m^3$). Additionally, TCE concentrations decrease with depth from the maximum concentrations at the following locations.

- location 50-24771/50-603471: 91,000 $\mu g/m^3$ (250 ft bgs) to 34,000 $\mu g/m^3$ (450 ft bgs)
- location 50-24783/50-603472: 30,000 $\mu g/m^3$ (300 ft bgs) to 6500 $\mu g/m^3$ (450 ft bgs)
- location 50-24784: 1600 $\mu g/m^3$ (362 ft bgs) to 350 $\mu g/m^3$ (450 ft bgs)
- location 50-24813: 78,000 $\mu g/m^3$ (200 ft bgs) to 2400 $\mu g/m^3$ (600 ft bgs)
- location 50-603467: 21,000 $\mu g/m^3$ (287 ft bgs) to 6900 $\mu g/m^3$ (600 ft bgs)
- location 50-603061: 3400 $\mu g/m^3$ (228 ft bgs) to 230 $\mu g/m^3$ (450 ft bgs)
- location 50-603062: 5100 $\mu g/m^3$ (100 ft bgs) to 400 $\mu g/m^3$ (450 ft bgs)
- location 50-603063: 14,000 $\mu g/m^3$ (200 ft bgs) to 5000 $\mu g/m^3$ (450 ft bgs)
- location 50-603064: 24,000 $\mu g/m^3$ (176 ft bgs) to 6 $\mu g/m^3$ (500 ft bgs)

Concentrations of PCE also decreased with depth. The PCE concentrations were much lower overall (maximum concentration of 2500 µg/m^3 at location 50-24771). The Phase II data also showed that VOC concentrations decrease with increasing distance from the disposal units or the central portion of MDA C. The decreasing concentrations laterally from the central portion of MDA C are illustrated for PCE in Figures 2.3-2 and 2.3-3, and for TCE in Figures 2.3-4 and 2.3-5. The cross-section locations are shown in Figure 2.3-6.

The approved Phase II investigation work plan required defining the vertical extent of VOCs by extending the boreholes until pore-gas samples contained TCE and PCE less than screening levels based on groundwater protection (2100 µg/m^3 and 3800 µg/m^3, respectively). The Phase II pore-gas results showed this requirement for TCE had not been met in the following cases:

- 34,000 µg/m^3 at 450 ft bgs at location 50-24771/50-603471
- 6500 µg/m^3 at 450 ft bgs at location 50-24783/50-603472
- 2400 µg/m^3 at 600 ft bgs at location 50-24813
- 6900 µg/m^3 at 600 ft bgs at location 50-603467
- 18,000 µg/m^3 at 450 ft bgs at location 50-603468
- 7700 µg/m^3 at 450 ft bgs at location 50-24822
- 5000 µg/m^3 at 450 ft bgs at location 50-603063

Tritium was detected in most Phase II subsurface pore-gas samples. Table 2.3-3 presents the results of the pore-gas tritium sampling from the Phase II boreholes. Tritium decreased with depth in all but two of the Phase II boreholes. At location 50-603383, tritium activities were relatively constant for the four samples collected at depths of 286 ft, 359 ft, 408 ft, and 450 ft bgs. Tritium activities in these four samples ranged from 52,007 pCi/L to 70,989 pCi/L. At location 50-603064, the highest tritium activity (2078 pCi/L) was detected in the deepest sample (500 ft bgs). The decreasing concentrations of tritium laterally from the central portion of MDA C are shown in Figures 2.3-7 and 2.3-8.

Five radionuclides were detected or detected above BVs in subsurface core samples. Radionuclides were detected infrequently in subsurface samples, and the Phase II data indicated that nature and extent of subsurface radionuclide contamination was defined.

2.3.3 Groundwater Monitoring

Groundwater monitoring wells located near MDA C are well R-14, located in Ten Site Canyon; wells R-17 and PCI-2, located in Pajarito Canyon; and well R-46, located on Mesita del Buey. The well locations are shown in Figure 2.3-9, which also shows the location of water-supply well PM-5.

Regional well R-46 was installed to detect contaminants potentially migrating from MDA C toward water-supply well PM-5. Monitoring results for well R-46 are reported in the period monitoring reports for the Mortandad and Sandia watersheds. The most recent monitoring report was submitted to NMED in February 2010 and included results of monitoring conducted during the period from August 3, 2009, to August 19, 2009 (LANL 2010, 108756). This report included the results of sampling conducted at well R-46 in March, May, June, and August 2009. Contaminants detected in the samples from well R-46 above screening levels were antimony and bis(2-ethylhexyl)phthalate. Antimony was detected at 6.88 µg/L, slightly above the U.S. Environmental Protection Agency (EPA) drinking water maximum contaminant level (MCL) of 6 µg/L, in an unfiltered sample collected in May 2009. This analytical result was qualified as estimated because antimony was detected in a laboratory method blank at a concentration less than 5 times the sample concentration. Bis(2-ethylhexyl)phthalate was detected above the EPA MCL of 6 µg/L in samples collected in May 2009 (77.4 µg/L and 96.4 µg/L), June 2009 (30.8 µg/L), and August 2009 (26 µg/L). Bis(2-ethylhexyl)phthalate was not detected in the sample collected in March 2009. Two VOCs were detected in the four samples collected from well R-46 in May, June, and August 2009. Acetone was detected at concentrations ranging from 16.8 µg/L to 64.1 µg/L (below the screening level of 22,000 µg/L), and toluene was detected at concentrations ranging from 3.3 µg/L to 10.9 µg/L (below the screening level of 750 µg/L). Neither VOC was detected in the samples collected in March 2009.

2.4 Conceptual Model

This section describes the conceptual model of contaminant sources, transport, pathways, and receptors at MDA C. This conceptual model is used to guide development of an investigation approach that will meet the objectives of the investigation. This conceptual model is focused on subsurface VOC and tritium contamination rather than the other contaminants addressed in previous investigations.

2.4.1 Potential Contaminant Sources

The exact nature of the VOC and tritium sources is not known. Sources may have included concentrated sources, such as discarded liquid solvents, as well as dilute sources, such as solvent-contaminated rags. The sources may also have included containerized wastes, as well as uncontainerized wastes. Given the age of the site and the periods of disposal, it is likely that uncontainerized VOCs and tritium have already been released from the waste into the subsurface. The release of containerized VOCs and tritium requires failure or breaching of the waste container. VOCs and tritium will have been released from waste containers that have already failed. If intact containers are present, releases of contaminants may occur into the future.

The amount of tritium available for future release is affected by radioactive decay. The half-life of tritium is 12.3 yr. MDA C was decommissioned in 1974, meaning approximately three half-lives have elapsed since the last tritium could have been disposed of at MDA C. The amount of tritium potentially present at MDA C, therefore, has decreased by a factor of at least eight since disposal occurred.

2.4.2 Potential Contaminant Transport Mechanisms

Vapor-phase transport largely accounts for the observed migration to depth of VOCs and tritium in pore gas within the Bandelier Tuff below MDA C. Extensive analyses of the VOC contamination in pore gas beneath MDA L at TA-54 have shown that vapor-phase transport accounts for the migration of VOCs, for which vapor-phase concentrations are in equilibrium with water concentrations as determined by Henry's law partitioning. This conceptual model also applies for MDA C. Vapor migration of VOCs in the subsurface can be described by diffusive behavior that is unaffected by preferential air flow or barometric pumping within the mesa (Stauffer et al. 2005, 090537, p. 760). Diffusion ideally spreads contamination spherically along concentration gradients. However, topography plays an important role in vapor transport at TA-50. With low vapor concentrations at the top and sides of the mesas, the steepest concentration gradients are toward the surface. These steep gradients lead to enhanced vapor diffusion toward these external boundaries. However, continual downward vapor diffusion does occur; the steep concentration gradients from the source regions toward the surface simply act to skew the diffusive plume growth toward the external topographic boundaries at the expense of deeper transport.

Stratigraphic controls, such as dipping interfaces between units, have less impact on vapor-phase transport than for liquid-phase transport because of the tendency for the plume to spread in all directions rather than being gravity driven. The pore structure and moisture content of each stratigraphic unit, however, affect diffusion through the different geologic media. Tortuous pores in porous media lead to effective longer diffusive path lengths, which slow diffusion. For a given rock unit, as the moisture content increases, there are fewer dry pore spaces for vapor diffusion, causing the pore space to become effectively more tortuous, which decreases diffusion rates. Besides decreasing diffusion rates, pore water also acts as a reservoir for VOC vapors. As a vapor plume encounters pore water, VOCs will transfer into the pore water according to Henry's law partitioning. This partitioning further slows vapor plume growth and, again, higher moisture content decreases plume growth. Vapor diffusion will also occur along fractures in the direction of their orientation. Fractures are likely to be less tortuous than the matrix, and diffusion rates along open, dry fractures (like those that might be encountered in the fractured Tschicoma dacite) may be elevated relative to the porous matrix. These factors, along with the topographic controls discussed above, and distributed sources in the pits and shafts, lead to nonidealized plumes that are not spherical but are truncated by the topography and potentially flatten out in wetter strata. It is expected, however, that the maximum pore gas concentration at a given depth will be approximately centered below the maximum pore gas concentration observed at shallower depths rather than being strongly stratigraphically controlled. This is observed in the TCE and tritium plumes discussed in Appendix C.

If vapor-phase transport of VOCs were to reach the regional aquifer by diffusing through the fractured dacite and underlying Puye sediment, the Henry's law partitioning would result in extremely low maximum predicted groundwater concentrations based on current observed vapor concentrations in the Guaje Pumice Bed above the dacite (Table 2.3-2, borehole 50-603470; LANL 2009, 107389). In the event that VOC transport causes low concentrations to reach the regional aquifer, the maximum concentrations arriving in pore gas should be located below MDA C as described above. Pore gas would partition at the interface with the regional aquifer. Observed aquifer concentrations will likely be much less than the theoretical maximum predicted by Henry's law partitioning. Rather, the aquifer concentration is related to the relative magnitudes of the diffusive vapor flux arriving at the aquifer, the groundwater flow velocity, and the local mixing depth within the aquifer and can be substantially reduced through local aquifer dilution (Truex et al. 2009, 108331).

Tritium is transported in the subsurface at TA-50 through a multiphase coupled process. Primarily, it is transported by the diffusion of water vapor. However, as tritiated water vapor diffuses away from a source area, it readily equilibrates with tritium-free pore water. The relatively rapid process of vapor-phase diffusion (in the case of tritium, the vapor is water vapor) is effectively slowed down by the presence of pore water, which acts as a reservoir for tritium activity that partitions from the vapor. This interaction with pore water results in a lower effective water-vapor diffusion coefficient than would be observed if no liquid pore water were present. This conceptual model is based on observations of tritium in the subsurface at both MDA G at TA-54 and at TA-53 (Vold and Eklund 1996, 070156, p. 1; Stauffer 2003, 080930, p. 1). Data and modeling results indicate that the effective vapor-phase diffusion coefficient for tritium is 25 times lower than for the more volatile vapor-phase VOCs at TA-54, primarily because those VOCs do not partition as readily into pore water. Diffusion of tritium toward the surface occurs because concentration gradients toward the surface are steep, leading to some surface flux of tritium to the atmosphere in water vapor. In addition, radioactive decay of tritium (half-life of 12.3 yr) decreases tritium mass as it migrates through the unsaturated zone. If some tritium reaches the water table by water-vapor diffusion, it should be centered directly below the disposal site, as discussed above, and the tritium would then significantly partition into the groundwater.

VOCs and tritium reaching the surface of the regional aquifer will be advectively transported with the regional groundwater flow. Potential groundwater transport pathways from MDA C were evaluated to identify the proposed locations for new regional groundwater monitoring wells at MDA C. This evaluation is presented in Appendix C.

2.4.3 Potential Receptors and Pathways

The receptors of primary concern with respect to subsurface VOC and tritium contamination are potential consumers of contaminated groundwater. These receptors could be exposed to VOCs and/or tritium that migrate through the vadose zone to the regional aquifer. Municipal water supply well PM-5 is located approximately 1 mi east and downgradient of MDA C (Figure 2.3-9). It is currently not known whether VOCs and/or tritium have migrated from MDA C to the regional aquifer and whether this pathway is potentially complete. One of the objectives of the Phase III investigation is to collect additional data to evaluate this pathway and set up a monitoring network.

2.4.4 Cleanup Standards

The environmental media of concern with respect to the Phase III investigation are groundwater and pore gas. Cleanup levels for groundwater are specified in section VIII.A.1 of the Consent Order and consist of New Mexico Water Quality Control Commission (WQCC) groundwater standards and drinking water MCLs adopted by the EPA under the Safe Drinking Water Act. If both a WQCC standard and MCL exist for a contaminant, the lower of the two is the cleanup level. If neither a WQCC standard or MCL exists for a contaminant, the EPA regional screening level for tap water (adjusted to 10^{-5} risk for carcinogens) is the cleanup level.

The Consent Order does not contain any cleanup standards, risk-based screening levels, risk-based cleanup goals, or other regulatory criteria for pore gas. In the past, the Laboratory has used screening levels based on equilibrium partitioning with groundwater cleanup levels to screen pore-gas data. These screening levels are intended to provide a very conservative indication of the potential for contaminants in pore gas to result in groundwater concentrations above groundwater cleanup levels. Because of the high degree of conservatism with these screening levels, they are not appropriate for use as cleanup levels. If site-specific cleanup or action levels for pore gas are needed, they should be developed based on equilibrium partitioning with consideration for natural dilution and attenuation processes that occur during transport through the vadose zone and aquifer.

3.0 SITE CONDITIONS

This section summarizes site conditions at MDA C. This summary focuses on subsurface site conditions that are relevant to the Phase III investigation. General site conditions, including surface conditions, are summarized in the MDA C investigation work plan (LANL 2003, 087152).

3.1 Stratigraphic Units

The general stratigraphy of the bedrock beneath MDA C can be inferred from descriptions of the regional geology (Broxton and Vaniman 2005, 090038) and has been further defined using geologic logs from the boreholes drilled at the site as part of previous investigations. A generalized stratigraphic cross-section of the Bandelier Tuff units encountered below MDA C in previous investigations is shown in Figure 3.1-1. The thicknesses of the strata described below were reported in the Phase II investigation report for MDA C (LANL 2009, 107389) and the well completion report for well R-46 (LANL 2009, 105592).

The predominant tuff unit at the surface of MDA C is unit 3 (Qbt 3) of the Tshirege Member of the Bandelier Tuff. The upper part of Qbt 3 is a partly welded devitrified ash-flow tuff that forms the mesa caprock at MDA C. Welding decreases downsection, and the base of Qbt 3 is nonwelded and poorly indurated. Qbt 3 is approximately 100 ft thick at MDA C.

Below Qbt 3 is unit 2 of the Tshirege Member (Qbt 2), which is a competent, resistant unit that forms cliffs where it is exposed. Qbt 2 is a moderately welded ash-flow tuff composed of crystal-rich, devitrified pumice fragments in a matrix of ash, shards, and phenocrysts (primarily potassium feldspar and quartz). It is approximately 65 ft thick at MDA C.

Qbt 2 is extensively fractured as a consequence of contraction during postdepositional cooling. The cooling-joint fractures are visible on the mesa edges. In general, the fractures dissipate at the bottom of Qbt 2. On average, fractures in Qbt 2 are nearly vertical. Mean spacing between fractures ranges between 1.9 and 2.6 ft, and fracture width ranges between less than 0.03 in. and 0.51 in., with a median width of 0.12 in. (LANL 2003, 087152, p. 18). The fractures are typically filled with clays to a depth of about 9.9 ft; 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, both of which have implications for the transport of contaminants in fractures.

The base of Qbt 2 is marked by a series of thin (less than 3.9 in. thick) discontinuous, crystal-rich, fines-depleted surge deposits. Stratified planar and cross-bedded structures are characteristic in these deposits.

Below Qbt 2 is unit 1v of the Tshirege Member (Qbt 1v), which is comprised of vapor-phase-altered tuffs that form sloping outcrops, which contrast the near-vertical cliffs of Qbt 2. Qbt 1v is approximately 75 ft thick at MDA C and is subdivided into units 1vu (Qbt 1vu) and 1vc (Qbt 1vc).

Qbt 1vu is the upper part of Qbt 1v and is comprised of devitrified and vapor-phase-altered ash-flow tuff; it is designated Qbt 1vu, where u signifies upper. Qbt 1vu is unconsolidated at its base and becomes partly welded in its upper part. Relatively few of the cooling fractures originating in overlying Qbt 2 continue downward into Qbt 1vu, and those that do generally die out downsection.

Qbt 1vc is the lower part of Qbt 1v and is comprised poorly welded but generally indurated, devitrified ash-flow tuff. It is designated Qbt 1vc, where c stands for colonnade, named for the columnar jointing visible in cliffs formed from this unit. The basal contact of unit 1vc is marked by a rapid change (within 0.7 ft) from devitrified (crystallized) matrix in unit 1vc to vitric (glassy) matrix in the underlying unit 1g (Qbt 1g).

Qbt 1g of the Tshirege Member is comprised of nonwelded vitric ash-flow tuff. Qbt 1g is approximately 75 ft thick at MDA C. Few fractures occur in outcrops of Qbt 1g, and outcrops of this unit generally form slopes because the tuff is poorly indurated. The uppermost 5 to 20 ft of unit 1g are iron-stained and slightly welded. A distinctive pumice-poor surge deposit forms the base of unit 1g.

Below Qbt 1g is the Tsankawi Pumice Bed (Qbtt), the basal plinian fall deposit of the Tshirege Member of the Bandelier Tuff. It is a thin, crudely stratified deposit of clast-supported gravel-sized vitric pumice, crystals, and minor ash. It is approximately 2 ft thick at MDA C.

Below Qbtt is the Cerro Toledo interval (Qct), which consists of thin beds of tuffaceous sandstones, paleosols, siltstones, ash, and pumice falls separating the Tshirege and Otowi Members of the Bandelier Tuff. The Cerro Toledo interval also includes localized gravel- and cobble-rich fluvial deposits predominantly derived from intermediate composition lavas eroded from the Jemez Mountains west of the Pajarito Plateau. This interval is approximately 65 ft thick at MDA C.

Below the Cerro Toledo interval is the Otowi Member of the Bandelier Tuff (Qbo), The Otowi is comprised of massive, nonwelded, pumice-rich, vitric ash flow tuffs. The pumices are fully inflated, supporting tubular structures that have not collapsed as a result of welding. The matrix is an unsorted mix of glass shards, phenocrysts, perlite clasts, and minute, broken pumice fragments. The Otowi Member is approximately 230 ft thick at MDA C.

Below the Otowi Member lies the Guaje Pumice Bed (Qbog), which is the basal air-fall deposit of the Otowi Member of the Bandelier Tuff. The pumice bed is stratified deposit of sorted pumice, crystals, lithics, and minor ash. The Guaje Pumice Bed is approximately 35 ft thick at MDA C.

Dacite lava of the Tschicoma Formation was encountered in the deepest Phase II investigation borehole at MDA C (location 50-603470) and at regional well R-46. At location 50-603470, dacite was encountered at a depth of 650 ft bgs. The thickness of the dacite could not be determined because this borehole penetrated the dacite only approximately 2 ft. At well R-46, the Tschicoma dacite consisted of massive dacite lava(s) from depths of 697 to 921 ft bgs (LANL 2009, 105592, pp. 6–7). The upper 5 ft of the lava section is strongly vesicular to scoriaceous. Below this zone, the dacite rapidly becomes dark gray, is massive (nonvesicular), and phenocryst-poor with an aphantic groundmass. The massive nature of the dacite is consistent throughout the section. Intervals of strong fracturing and jointing were observed in drill cuttings and in a borehole video log.

Dacite scoria and breccia was encountered in the R-46 borehole at a depth interval of 921 to 955 ft bgs. This interval contains abundant reddish brown, ferruginous, altered dacite that is vesicular to scoriaceous and partly glassy, indicating a flow breccia forming the base of the overlying massive dacite lava.

The Puye Formation (Tpf) underlies the dacite lava, breccia, and scoria. In the R-46 borehole, Puye Formation volcaniclastic sediment was encountered from a depth of 955 to 1405 ft bgs. The regional water table occurs at a depth of 1326 ft at R-46. The Puye Formation is made up of stratified coarse-grained dacitic detritus, generally in the form of poorly cemented boulders, cobbles, and pebbles in a silty and sandy matrix. Despite their coarse-grained nature, these rocks contain ubiquitous silt to depths of about 1395 ft. Cuttings and geophysical logs indicate that rocks in the 1360- to 1375-ft interval are particularly silt rich. Intervals of silt-free gravels and sands occur in the 1335- to 1340-ft and 1395- to 1415-ft intervals.

3.2 Groundwater

Groundwater beneath the Laboratory occurs in the regional aquifer and in perched, intermediate, and shallow aquifers. With the exception of TA-16 and TA-53, perched groundwater is generally detected beneath relatively wet canyons (e.g., Los Alamos Canyon) as (1) shallow alluvial aquifers that occur in some wet canyons (generally at depths less than 100 ft), and (2) deeper “intermediate” perched aquifers that occur in zones separated from both alluvial and regional aquifers by unsaturated rock. Other than at Mesita de Los Alamos at TA-53, data indicate that dry mesas such as Mesita del Buey show no evidence of perched groundwater beneath the mesa. However, alluvial and intermediate perched aquifers in adjacent canyons may cause increased moisture content within the vadose zone at the base of the mesa. At TA-53, perched groundwater originating beneath Los Alamos Canyon appears to extend beneath adjacent Mesita de Los Alamos.

Groundwater was first encountered in well R-46 in the Puye Formation. After the borehole was advanced to a TD of 1415 ft bgs, the water level in the borehole was measured at approximately 1328 ft bgs.

4.0 SCOPE OF ACTIVITIES

The scope of the Phase III investigation involves collecting pore-gas samples from existing pore-gas monitoring wells, installing and sampling four new pore-gas monitoring wells, installing two new regional groundwater-monitoring wells, and characterizing background concentrations of metals in dacite lava. These activities and associated supporting activities (e.g., waste management) are described below.

4.1 Pore-Gas Sampling

The Laboratory is conducting quarterly sampling of the Phase II monitoring wells for VOCs and tritium before installation of additional vapor-monitoring wells and regional wells begins. The Phase II results represent sampling from a single point in time. The samples from the Phase II boreholes were collected shortly after drilling was completed and the effect of drilling activities (e.g., injection of air into the subsurface) is not known. Therefore, additional sampling and analysis is being conducted to verify the results of the Phase II investigation, including determining whether the criterion for defining vertical extent of TCE contamination has been met.

The first round of sampling began the week of January 25, 2010. An additional round of sampling is proposed for April 2010. The results of this sampling will be used to verify or, if necessary, update the conceptual model of subsurface contamination at MDA C, including the determination of vertical extent. Additional vapor-monitoring wells will be installed as described in section 4.2. If necessary, the number, locations, and/or configuration of these wells may be revised based on the results of the pore-gas sampling. If such changes are deemed necessary, they will be discussed with NMED and submitted to NMED for approval.

Once installation of new vapor-monitoring wells is complete, samples will be collected from these wells and from the 14 existing Phase II wells. One additional round of quarterly sampling from the new wells and existing Phase II wells will be performed 3 mo after the initial Phase III sampling. The results of this sampling will be used to verify or, if necessary, update the conceptual model of subsurface contamination at MDA C and evaluate the potential transport of VOCs and tritium from MDA C to the regional aquifer.

4.2 Installation of Vapor-Monitoring Wells

Based on the current understanding of subsurface pore-gas contamination at MDA C, the Laboratory is proposing to install four new deep vapor-monitoring wells. The NOD for the Phase II investigation report calls for advancing the new boreholes until pore gas samples collected during drilling are below target criteria of 2100 $\mu g/m^3$ for TCE and 3800 $\mu g/m^3$ for PCE (NMED 2009, 107361). Based on experience installing the Phase II investigation boreholes, pore-gas sampling during drilling appears to have limited utility for determining borehole depth. Specifically, there was poor agreement between the concentrations of TCE and PCE measured in samples collected during drilling and those measured in samples collected from the same depth intervals after the monitoring wells were constructed. Rather than use field sampling to determine borehole depth, the Laboratory proposes extending each new borehole to the bottom of the Guaje Pumice Bed (approximately 650 ft bgs) and, if possible, at least 10 ft into the Tschicoma Formation dacite without collecting pore-gas samples during drilling. These boreholes will be completed as vapor-monitoring wells as described in section 4.2.2.

The Phase II and previous investigations have defined lateral and vertical extent of nonvapor-phase contaminants in subsurface tuff. Therefore, core samples will not be collected for laboratory analysis during drilling.

4.2.1 Well Locations

As specified in the NOD for the Phase II investigation report (NMED 2009, 107361), the Laboratory currently proposes installing vapor-monitoring wells next to existing monitoring wells 50-603471, 50-603472, and 50-603468 and at a new location south of MDA C (Figure 4.2-1). The boreholes at the three existing locations will be used to determine the vertical extent of contamination as well as to verify the conceptual model of vapor-phase contaminant transport in the subsurface. The borehole at the new location will be used to characterize lateral extent of contamination to the south and to evaluate the effects of the canyon-wall boundary on the distribution of subsurface contaminants.

4.2.2 Well Configuration

The Laboratory proposes constructing vapor-monitoring wells in each of the new boreholes. The NOD for the Phase II investigation report states the boreholes should be left open for use in future investigations, monitoring-well installation, and/or remediation points (NMED 2009, 107361). Based on experience with the Phase II deep borehole drilling, casing-advance drilling methods will be used to install these boreholes. These boreholes are not expected to remain open in the deeper units penetrated without the casing. Therefore, rather than trying to maintain open boreholes, stainless-steel vapor-monitoring wells will be constructed using the same methods as used in the Phase II investigation.

There are existing vapor-monitoring wells at locations 50-603471, 50-603472, and 50-603468, each of which is completed with nine sampling ports. The depths of the ports and the geologic unit where each port is located are identified in Table 4.2-1. At each location, a new borehole will be advanced to the bottom of the Gauje Pumice Bed (approximately 650 ft bgs) within 25 ft of the existing vapor-monitoring wells. Four sampling ports will be installed at depths of 500, 550, and 600 ft and at the base of the Guaje Pumice Bed (approximately 650 ft bgs). The upper three screens will be installed in the Otowi Member. In addition, one screen will be installed at least 10 ft into the Tschicoma Formation dacite if this depth can be reached without use of drilling fluids. If the borehole cannot be advanced at least 10 ft into the dacite without using drilling fluids, it will be backfilled with bentonite to the base and the pumice bed and no screen will be placed in the dacite. The proposed configuration of these wells is shown in Figure 4.2-2. The existing vapor-monitoring wells will be used to monitor the upper geologic units.

At the new location south of MDA C, a borehole will be advanced to the bottom of the Guaje Pumice Bed (approximately 650 ft bgs) and, if possible, at least 10 ft into the Tschicoma Formation dacite. Based on the Phase II investigation and other experience constructing vapor-monitoring wells, 10 sampling ports are the maximum number than can be installed in this borehole. This well will be configured with sampling ports at the same depth intervals as the 10 deepest Phase II vapor-monitoring well at location 50-603470. The proposed port depths and corresponding geologic units are presented in Table 4.2-2. The proposed configuration of the well is shown in Figure 4.2-3.

4.3 Installation of Regional Wells

The Laboratory proposes installing two regional groundwater monitoring wells near MDA C. The NOD for the Phase II investigation report calls for installing one well near the southeast corner of MDA C and one well approximately 300 ft south of this location (NMED 2009, 107361). The NOD also specified a well configuration consisting of two screens, one just below the water table and one intersecting fast-pathway permeable strata no more than 100 ft below the water table. The Laboratory performed an evaluation of hydrogelogic data to optimize well locations and configurations in terms of meeting the investigation objectives. This evaluation is discussed in Appendix C.

The NOD calls for collecting pore-gas samples from the regional well boreholes during drilling. As described in section 4.2, experience from the Phase II investigations shows limited utility of data collected from boreholes using packers during drilling. The use of fluids during drilling of regional wells further complicates collection of representative vapor samples. Therefore, vapor samples will not be collected from the regional well boreholes.

4.3.1 Well Locations

A monitoring well network evaluation was performed to identify locations for the installation of new groundwater monitoring wells at MDA C. The goal of the evaluation was to identify locations that would provide a 95% probability of detecting contaminant releases from MDA C. As a result of this evaluation, two monitoring locations were identified. The network evaluation is presented in Appendix C. NMED concurred with one of the proposed locations but required moving the location of the other well to the south and east of the Laboratory's proposed location (NMED 2010, 109018). These locations are shown in Figure 4.2.1. NMED requires that the southern well be drilled first and that water-level data and any other pertinent information collected from this well be used to revise the location of the northern well, if necessary. Any proposed change to the well location will be submitted to NMED for review and approval.

4.3.2 Well Configuration

Near the eastern boundary of MDA C, the top of regional groundwater is expected to lie approximately 1340 ft bgs within the sedimentary rock of the Puye Formation. The two proposed regional wells will be drilled to a depth of approximately 1410 ft bgs, penetrating approximately 70 ft into the regional aquifer, which is approximately the same TD as regional well R-46. The boreholes for these wells will be drilled using fluid-assisted air-rotary drilling methods. Drilling fluids will include municipal water and AQF-2 foam to a depth of 1240 ft bgs; an attempt will be made to use only municipal water for circulation below 1240 ft to minimize the effects of drilling fluids on groundwater chemistry in the regional aquifer. Drill casing may be used to advance the boreholes through unstable rock formations or to seal off lost-circulation zones. To facilitate vadose zone characterization, an attempt will be made to drill an open borehole through the dacite lava so that potential zones of perched groundwater can be characterized by open-borehole video and geophysical logs.

Characterization of the two new regional boreholes will include a lithologic log prepared from drill cuttings, water-level measurements in the borehole during drilling and in the completed well, groundwater samples collected during drilling and in the completed well for selected chemical analyses, driller's observations about drilling conditions and water production, borehole video and geophysical logs, and aquifer tests conducted in conjunction with the pumping tests at the completed well. Groundwater screening samples will be analyzed for total organic carbon, anions, VOCs, trace metals, and tritium. Details of these characterization activities will be included in separate drilling work plans submitted for the two wells.

Both wells will be completed with one well screen, placed near the water table. Because of the close proximity of the two wells to MDA C and the location of the water table in the Puye Formation sediment, use of one screen near the water table is appropriate for detecting the first arrival of contaminants from MDA C. Final well designs will be based on hydrogeological conditions encountered during drilling and revised well design documents will be submitted to NMED for approval.

4.4 Dacite Background Study

A background study will be performed to establish background values for inorganic chemicals in dacite at MDA C. During the Phase II investigation, the deepest sample at location 50-603470 was collected from the top of a dacite lava flow of the Tschicoma Formation. This sample was analyzed for target analyte list (TAL) metals. Analytical results for this sample showed elevated concentrations for 12 inorganic chemicals (arsenic, barium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, and vanadium) compared to samples from the overlying Bandelier Tuff (LANL 2009, 107389, Table F-2.2-1 and Plate 5). The elevated concentrations detected in the deepest sample likely represent the natural chemistry of the Tschicoma Formation; however, there are no established background data for inorganic chemicals in this dacite.

The inorganic chemistry of the dacite beneath MDA C will be established by analyzing core and cuttings from boreholes penetrating dacite lava at locations considered representative of natural background conditions. The dacite beneath MDA C is a distinctive fine-grained unit that lacks coarse phenocrysts, unlike the more typical coarse-phenocryst Tschicoma dacites exposed in outcrop. For this reason the samples to be analyzed in this study will be selected from archived core and cuttings of this distinctive lithology in the vicinity of MDA C. A total of five samples from three locations are included in this investigation (Table 4.4-1). These background samples were collected from the same dacite lava flow that underlies MDA C. Three samples were selected from unaltered flow material, one was selected from the flow top, which may be weathered, and include overlying soil, and one was selected from a fracture-coated surface. The samples will be supplied as coarse material to an external laboratory for analysis of TAL metals, including extraction using EPA Method 3050.

The metal concentrations in the deep dacite sample at location 50-603470 will be compared to mean plus 2 standard deviation concentrations for the background samples collected. Results of the comparison will be evaluated and discussed in the investigation report.

4.5 Geophysical Logging

The NOD specifies video logging of the vapor-monitoring and regional well boreholes to identify fractures and stratigraphic and lithologic unit contacts for the purpose of collecting pore-gas samples (NMED 2009, 107361). Based on previous drilling experience at MDA C, it is not expected that boreholes will be open when drilling through the depth intervals of interest in the Phase III vapor-monitoring boreholes (i.e., depths below those previously characterized in the Phase II investigation, 450 ft and below). As a result, video logging of the vapor-monitoring boreholes will not be performed. Video logging of the regional well boreholes will be performed, if possible, in uncased intervals.

Moisture-content logging will be performed on each borehole prior to construction of the vapor or groundwater monitoring well.

For the regional wells, the suite and timing of geophysical logging will depend on borehole conditions. In the vadose zone, a borehole video camera, natural gamma, and induction tools will be used in the open borehole if conditions allow. In the regional aquifer, a full suite of geophysical logs will be run, if required, for proper placement of the screens. The logs will be collected by Schlumberger, Inc., and for open-hole conditions will include accelerator porosity sonde (neutron porosity), array induction, combined magnetic resonance, natural and spectral gamma, and formation micro-imager logs. In cased portions of the borehole, neutron porosity, triple lithodensity, elemental capture, natural gamma, and spectral gamma logs will be collected.

4.6 IDW

The IDW is waste generated as a result of field investigation activities and may include, but is not limited to, drill cuttings; drilling fluids and development water; potentially contaminated personal protective equipment (PPE); sampling supplies; fluids from the decontamination of sampling equipment; and all other waste potentially coming in contact with contaminants. The IDW generated during the Phase III investigation at MDA C will be managed to protect human health and the environment, comply with applicable EPA and NMED regulations, DOE orders, and Laboratory implementation requirements, and adhere to Laboratory waste-minimization goals. The management of IDW is described in Appendix B of this work plan.

5.0 INVESTIGATION METHODS

The following sections describe the primary field methods to be used in implementing this work plan. A list of applicable standard operating procedures (SOPs) for field activities is provided in Table 5.0-1. A summary of each of the investigation methods associated with these procedures is presented in Table 5.0-2.

5.1 Pore-Gas Sample Collection

Pore-gas samples will be collected from existing vapor-monitoring well ports (Table 5.1-1) and from the proposed new vapor-monitoring well ports. The samples from each borehole will be collected in accordance with EP-ERSS-SOP-5074, Sampling for Sub-Atmospheric Air. Subsurface pore-gas samples will be collected in SUMMA canisters and submitted to the Sample Management Office (SMO) for shipment to the analytical laboratory for VOC analysis by EPA Method TO-15. Pore-gas samples will also be collected in silica gel sample tubes for analysis of tritium by EPA Method 906.0.

Before samples are collected, the screened interval and sample collection system will be purged in accordance with EP-ERSS-SOP-5074. During the purge, measurements of percent oxygen, percent carbon dioxide, and percent methane will be collected from the sample train exhaust every several minutes to ensure that all ambient air is evacuated from the system. Static subsurface pressure will also be measured. Once these gas concentrations are stable, vapor sampling will proceed.

Initial vapor-monitoring samples in new wells will be collected within 30 d of completion of each vapor-monitoring well. After the initial samples are collected, one additional round of quarterly samples will be collected.

5.2 Borehole Drilling

Previous investigations at MDA C used a combination of hollow-stem auger (HSA) and air-rotary methods. HSA drilling facilitates collecting subsurface core samples, but the HSA method is limited in the drilling depth that can be achieved. HSA was generally used to drill to approximately 300 ft bgs, which is near the bottom of the Tshirege Member. Air-rotary drilling was then used to extend the boreholes to TD. Because core samples will not be collected during the Phase III investigation, there is no advantage to using HSA drilling. Therefore, air-rotary drilling will be used to drill the vapor-monitoring and regional groundwater boreholes.

The air-rotary method uses a drill pipe or drill stem coupled to a drill bit that rotates and cuts through soil and rock. The cuttings produced from the rotation of the drill bit are transported to the surface by compressed air, which is forced down the borehole through the drill pipe and returns to the surface through the annular space between the drill pipe and the borehole wall. The circulation of the compressed air not only removes the cuttings from the borehole but also helps to cool the drill bit. Air-rotary drilling is best suited for hard rock formations. During drilling, the air compressor will have an in-line organic filter system to filter the air coming from the compressor and to avoid possible contamination of the formation. The organic filter system will be inspected regularly to ensure the system is functioning properly. In addition, a cyclone-velocity dissipater or similar air-containment/dust-suppression system will be used to direct the cuttings to one location rather than allowing the cuttings to discharge uncontrolled from the borehole.

Casing will be advanced as the drill bit advances to prevent sloughing of any material from soft, unconsolidated intervals into the borehole during drilling and after drilling is completed. Because borehole stability will be maintained by the casing, the casing will be used to assist with installing a pore-gas monitoring well at each location. Casing may not be needed when advancing the regional groundwater boreholes through the Tschicoma Formation dacite.

The boreholes will be logged during drilling by the on-site geologist. Borehole logging will be performed in accordance with SOP-12.01, Field Logging, Handling, and Documentation of Borehole Materials.

5.3 Vapor-Monitoring Well Construction

Vapor-monitoring wells will be constructed by installing sample screens within filter packs at target depth intervals. The sample screens will be connected to stainless-steel tubes that will extend to the ground surface. The sample screens and tubes will be emplaced through the temporary well casing and the casing will be slowly withdrawn as backfill material (sand or bentonite) is added. This approach will be used to prevent slough from entering the borehole.

Vapor-monitoring well construction will consist of the following steps:

1. Measure and record the TD of the borehole after drilling to the target depth.
2. Add approximately 2.5 ft of 10/20 silica sand to support the stainless-steel screen and measure and record the depth. The maximum silica sand interval is approximately 5 ft.
3. Lower the sampling screen and enough stainless-steel tubing to reach top of silica sand and measure and record the depth.
4. Add another 2.5 ft of 10/20 silica sand and measure and record the depth.
5. Add enough bentonite pellets to reach the next screen location and measure and record the depth. Add water periodically to hydrate the pellets as they are being emplaced.
6. Label the top of each stainless-steel tube to identify each screen and the depth of the screen and install a cap over the end of the tube.
7. Repeat steps 3 through 6 until the ground surface is reached.
8. Install surface completion, including a concrete pad, steel-protective casing, and locking steel cap.

5.4 Regional Monitoring Well Construction

The wells will be constructed as 5-in.-inside diameter stainless-steel wells with one 20-slot, rod-based wire-wrapped well screen. The primary filter packs of 10/20 silica sand will extend 5 ft above and 5 ft below the screen. Two-foot secondary filter packs of 20/40 silica sand will be placed above and below the primary filter pack. The annular space above the upper secondary filter pack will be sealed with hydrated bentonite chips.

Actual well-screen lengths and positions will be based on data acquired during drilling, including information from lithological logs of cuttings, water-level measurements, video logs, geophysical logs, and driller's observations. Drilling work plans will be submitted to NMED for approval before drilling begins, and a well-design document will be submitted to NMED for approval before each well is constructed.

5.5 Geophysical Logging

All boreholes will be logged for moisture content after drilling to TD is completed. Moisture content will be determined using a neutron probe in accordance with SOP-5040, Subsurface Moisture Measurements Using a Neutron Probe.

As conditions allow, the regional well boreholes will be logged for neutron porosity, triple lithodensity, elemental capture, natural gamma, and spectral gamma. Geophysical logging will be performed by a subcontractor in accordance with EP-ERSS-SOP-5030, Contract Geophysical Logging.

5.6 Equipment Decontamination

Following drilling and sampling activities, all equipment used in drilling and sampling activities will be decontaminated. Residual material adhering to equipment will be removed using dry decontamination methods such as the use of wire brushes and scrapers (SOP-01.08, Field Decontamination of Drilling and Sampling Equipment). If equipment cannot be free-released using dry decontamination methods, wet decontamination methods will be used. If wet decontamination is required, the equipment will be pressure-washed on a temporary decontamination pad covered with a high-density polyethylene liner. Cleaning solutions and wash water will be collected and contained for proper disposal. Decontamination solutions will be sampled and analyzed to determine the final disposition of the wastewater and the effectiveness of the decontamination procedures. Equipment ready for demobilization will be surveyed by a Health and Safety Radiation Control Division technician before it is released from the site.

6.0 MONITORING PROGRAM

Pore-gas monitoring at existing Phase II monitoring wells is ongoing, as described in section 4.1, and additional monitoring will be performed during the Phase III investigation.

Regional wells R-14, R-17, R-46, and intermediate-well PCI-2 are being monitored on a quarterly basis as part of the Laboratory's Interim Facility-Wide Groundwater Monitoring Plan (LANL 2009, 106115). Monitoring data are reported quarterly in periodic monitoring reports for the Mortandad watershed (wells R-14 and R-46) and the Pajarito watershed (well R-17 and PCI-2). Monitoring data from these wells will be evaluated and presented in the Phase III investigation report.

7.0 SCHEDULE

Implementation of the Phase III MDA C field investigation and reporting activities proposed herein will be implemented in phases. The first phase of work consists of collecting two rounds of pore-gas samples from the 14 existing Phase II monitoring wells. Collection of the first round of samples began the week of January 25, 2010, and the second round of sampling will begin in May 2010. The second phase of work consists of installing the new vapor and regional groundwater monitoring wells. Drilling of the boreholes for these wells is expected to begin in October 2010, following review and assessment of the new vapor-monitoring data; review and approval of any changes to the proposed vapor-well configurations; preparation and approval of drilling work plans for the regional wells; procurement of drilling services; and field mobilization. Installation of the new vapor wells and the first regional monitoring well is expected to be completed in December 2010. Installation of the second regional monitoring well is expected to be completed in May 2011. Specific dates for completing the regional wells will be included in the drilling work plans, to be submitted by June 30, 2010, and December 31, 2010. The third phase of work will involve collecting and evaluating the data from new and existing vapor and groundwater monitoring wells. A minimum of two rounds of quarterly pore-gas and groundwater data will be collected from each new well and evaluated to provide an integrated assessment of the potential transport of contaminants beneath MDA C, including the vadose zone and regional aquifer. The results of this assessment, along with descriptions of investigation activities and sampling results, will be provided in the Phase III investigation report. The investigation report will be submitted to NMED by October 31, 2011.

8.0 REFERENCES AND MAP DATA SOURCES

8.1 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 number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

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

Broxton, D.E., and D.T. Vaniman, August 2005. "Geologic Framework of a Groundwater System on the Margin of a Rift Basin, Pajarito Plateau, North-Central New Mexico," *Vadose Zone Journal,* Vol. 4, No. 3, pp. 522–550. (Broxton and Vaniman 2005, 090038)

LANL (Los Alamos National Laboratory), November 2003. "Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1," Los Alamos National Laboratory document LA-UR-03-8201, Los Alamos, New Mexico. (LANL 2003, 087152)

LANL (Los Alamos National Laboratory), October 2005. "Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 2," Los Alamos National Laboratory document LA-UR-05-7363, Los Alamos, New Mexico. (LANL 2005, 091493)

LANL (Los Alamos National Laboratory), December 2006. "Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50," Los Alamos National Laboratory document LA-UR-06-8096, Los Alamos, New Mexico. (LANL 2006, 094688)

LANL (Los Alamos National Laboratory), July 2007. "Phase II Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1," Los Alamos National Laboratory document LA-UR-07-5083, Los Alamos, New Mexico. (LANL 2007, 098425)

LANL (Los Alamos National Laboratory), March 2009. "Completion Report for Regional Aquifer Well R-46," Los Alamos National Laboratory document LA-UR-09-1338, Los Alamos, New Mexico. (LANL 2009, 105592)

LANL (Los Alamos National Laboratory), May 2009. “2009 Interim Facility-Wide Groundwater Monitoring Plan,” Los Alamos National Laboratory document LA-UR-09-1340, Los Alamos, New Mexico. (LANL 2009, 106115)

LANL (Los Alamos National Laboratory), October 2009. “Phase II Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1,” Los Alamos National Laboratory document LA-UR-09-6266, Los Alamos, New Mexico. (LANL 2009, 107389)

LANL (Los Alamos National Laboratory), February 2010. “Phase III Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50,” Los Alamos National Laboratory document LA-UR-10-0613, Los Alamos, New Mexico. (LANL 2010, 108594)

LANL (Los Alamos National Laboratory), March 2010. “Periodic Monitoring Report for Mortandad and Sandia Watersheds, August 3–August 19, 2009,” Los Alamos National Laboratory document LA-UR-10-0939, Los Alamos, New Mexico. (LANL 2010, 108756)

NMED (New Mexico Environment Department), February 19, 2007. “Notice of Disapproval (NOD) for Material Disposal Area (MDA) C, Solid Waste Management Unit 50-009, at Technical Area 50,” New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2007, 095437)

NMED (New Mexico Environment Department), October 29, 2007. “Notice of Approval, Mortandard Canyon Groundwater Monitoring Well Network Evaluation, Revision 1,” New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2007, 098775)

NMED (New Mexico Environment Department), October 15, 2009. “Second Notice of Disapproval, Phase II Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50,” New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2009, 107361)

NMED (New Mexico Environment Department), March 29, 2010. “Notice of Disapproval, Phase III Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50,” New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M. Graham (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2010, 109018)

Stauffer, P.H., October 2003. “Summary of TA53 Borehole Tritium Analysis,” Los Alamos National Laboratory document LA-UR-07-5084, Los Alamos, New Mexico. (Stauffer 2003, 080930)

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

Truex, M.J., M. Oostrom, and M.L. Brusseau, 2009. “Estimating Persistent Mass Flux of Volatile Contaminants from the Vadose Zone to Ground Water,” *Ground Water Monitoring and Remediation,* Vol. 29, No. 2, pp. 63–72. (Truex et al. 2009, 108331)

Vold, E., and B. Eklund, 1996. “Determination of an In-Situ Vadose Zone Vapor Phase Diffusion Coefficient at a Mesa Top Waste Disposal Facility,” Los Alamos National Laboratory document LA-UR-96-1848, Los Alamos, New Mexico. (Vold and Eklund 1996, 070156)

8.2 Map Data Sources

Communication Lines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 08 August 2002; as published 15 January 2009.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Hypsography; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

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

Orthophotography, 2008 Los Alamos National Laboratory Aerial Photography, Site Planning and Project Initiation Group, February 2009.

Ownership Boundaries Around LANL Area; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 04 December 2008.

Paved Parking; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 12 August 2002; as published 15 January 2009.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Phase II Monitoring Well Locations; Los Alamos Technical Associates project file MDA C borehole locations, N. Plannerer; 13 March 2009.

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2009-0162; 13 March 2009.

Primary Electric Grid; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Primary Gas Distribution Lines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Primary Industrial Waste Lines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Primary Landscape Features; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Road Centerlines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 15 December 2005; as published 15 January 2009.

Security and Industrial Fences and Gates; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Sewer Line System; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

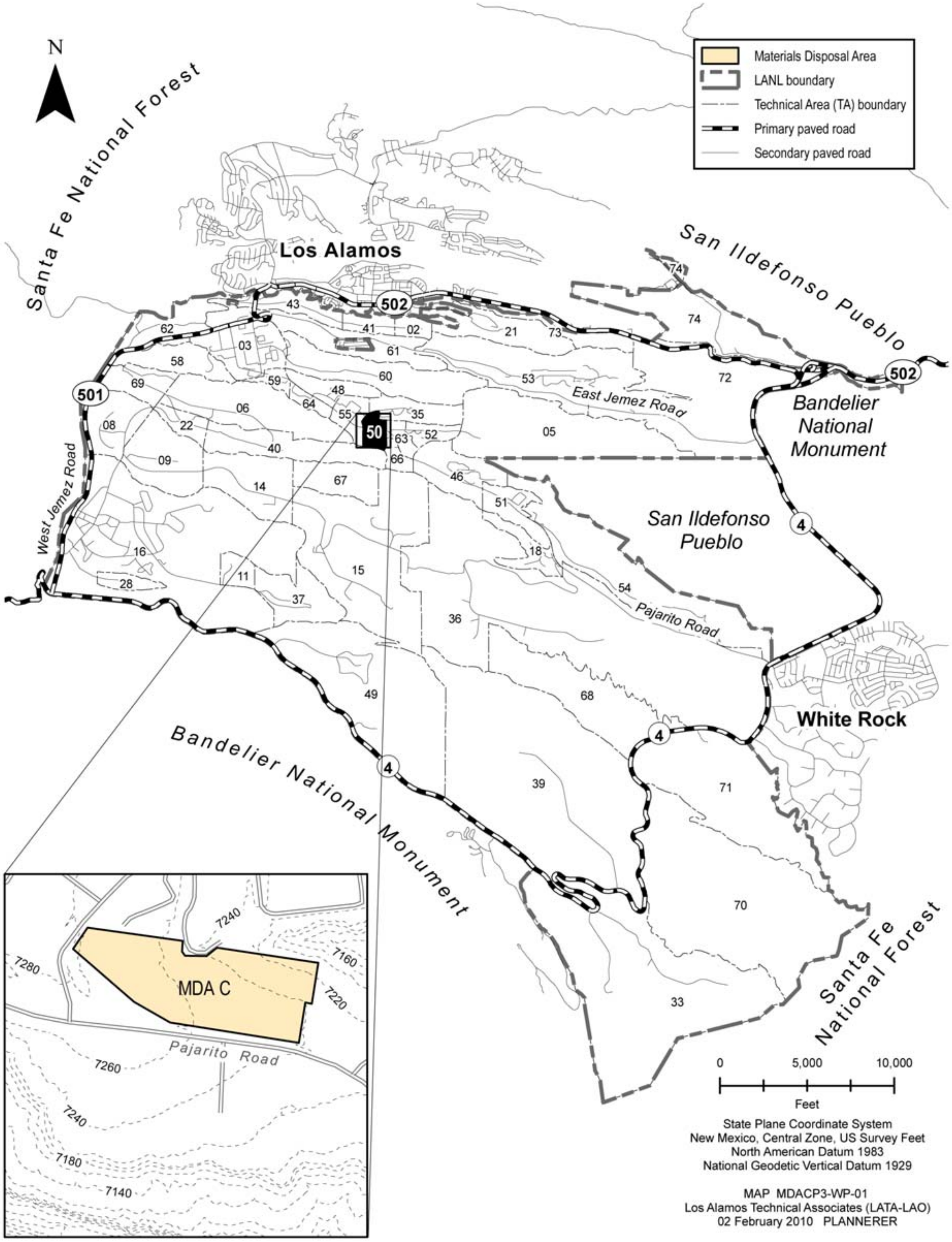
Storm Drain Line Distribution System; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 04 December 2008.

Waste Storage Features; Los Alamos National Laboratory, Environment and Remediation Support Services Division, GIS/Geotechnical Services Group, EP2007-0032; 1:2,500 Scale Data; 13 April 2007.

Water Lines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.



State Plane Coordinate System
New Mexico, Central Zone, US Survey Feet
North American Datum 1983
National Geodetic Vertical Datum 1929

MAP MDACP3-WP-01
Los Alamos Technical Associates (LATA-LAO)
02 February 2010 PLANNERER

Figure 1.0-1 Location of MDA C with respect to Laboratory TAs and surrounding land holdings

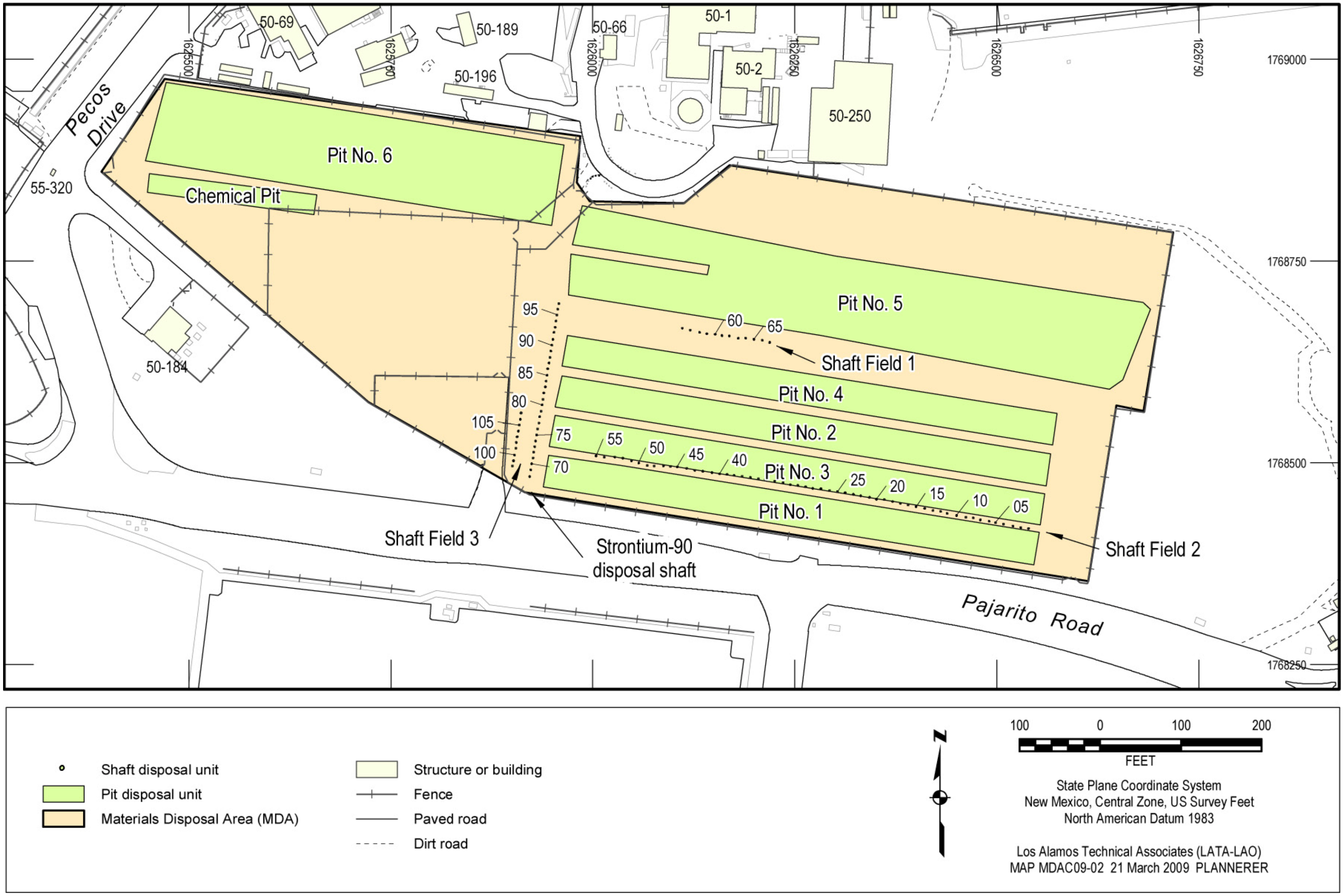


Figure 2.1-1 Location of pits and shafts at MDA C

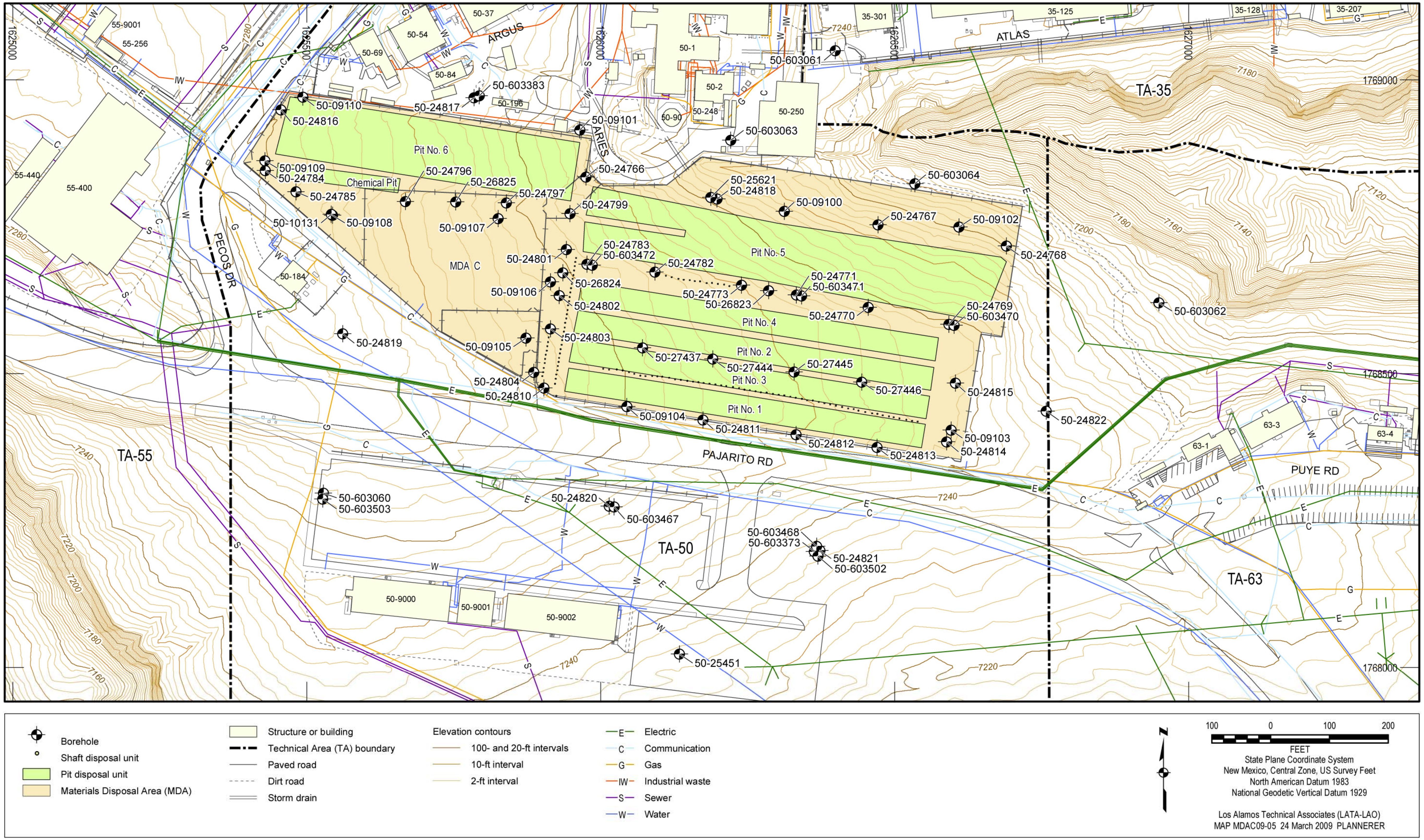
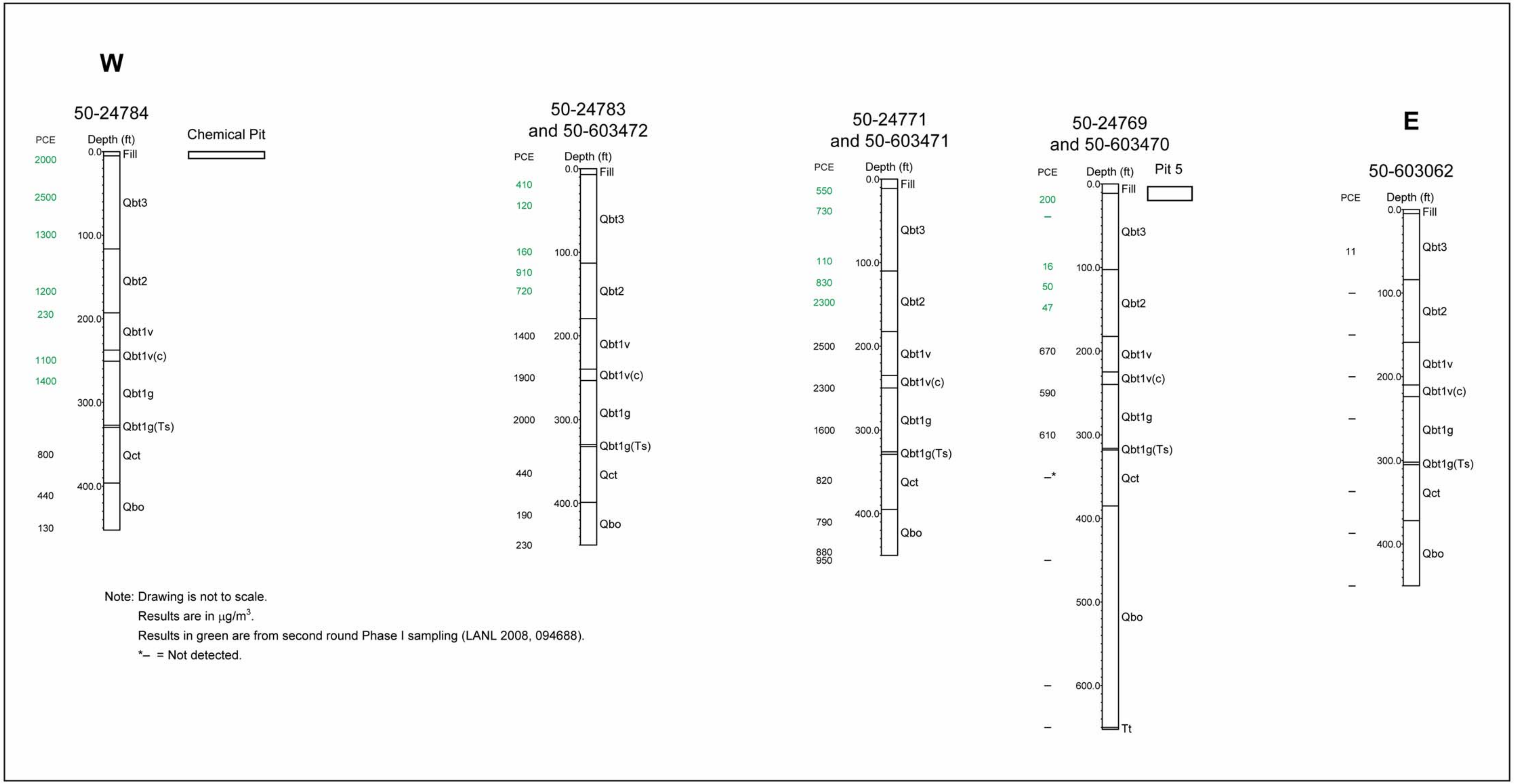


Figure 2.3-1 Locations of investigation boreholes at MDA C



Note: Drawing is not to scale.
Results are in $\mu g/m^3$.
Results in green are from second round Phase I sampling (LANL 2008, 094688).
*– = Not detected.

Figure 2.3-2 West-east transect across MDA C showing PCE concentrations in pore gas

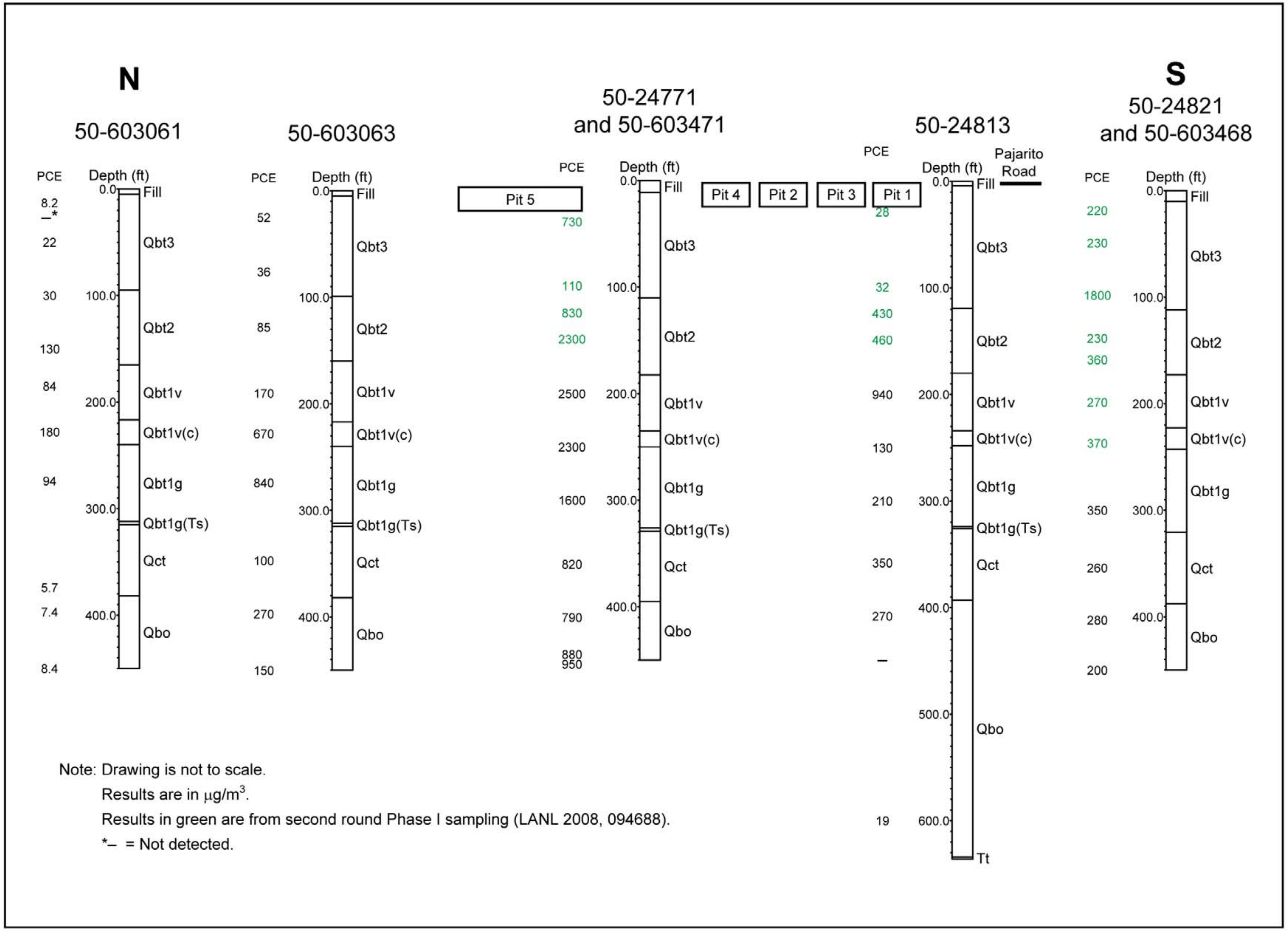
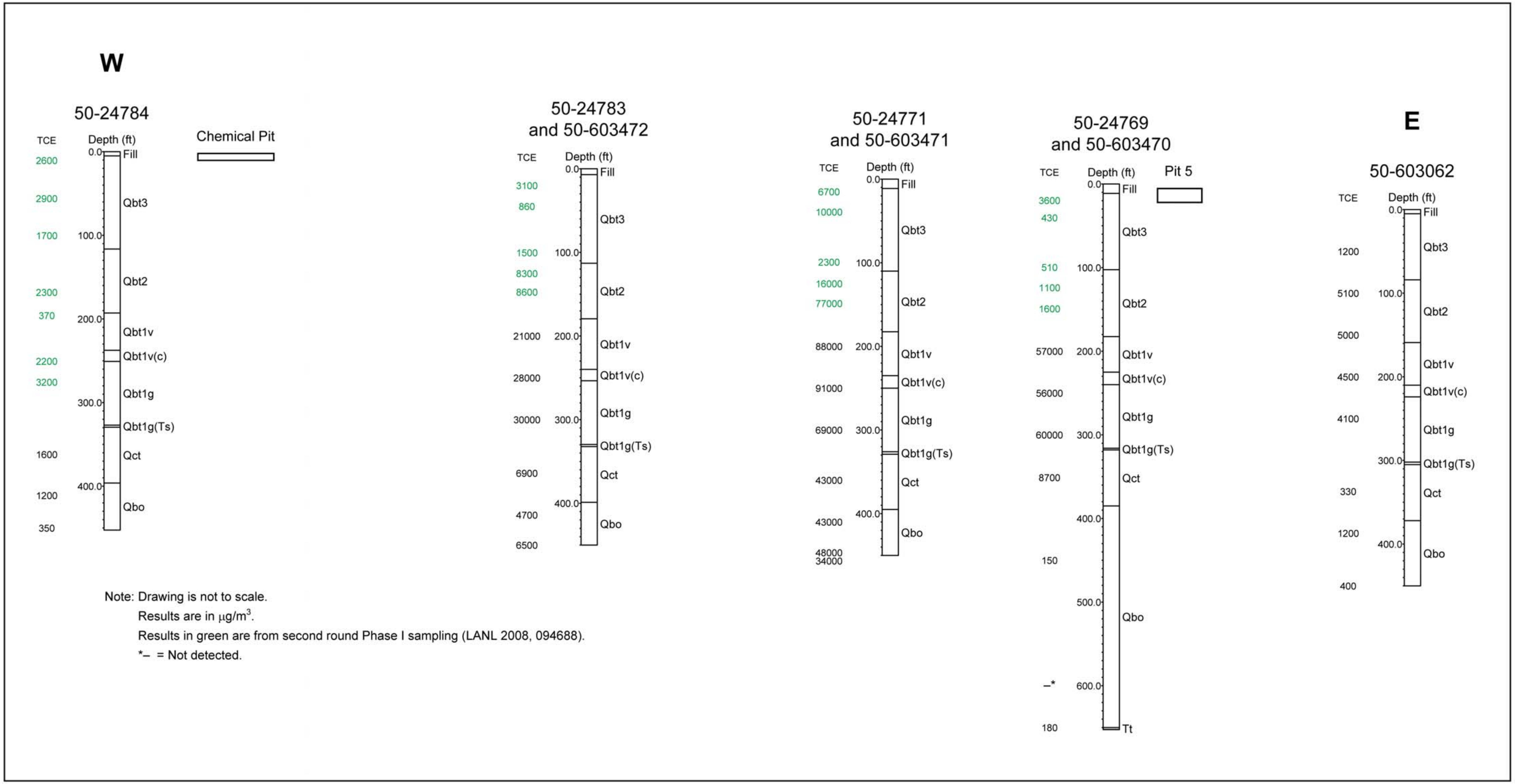
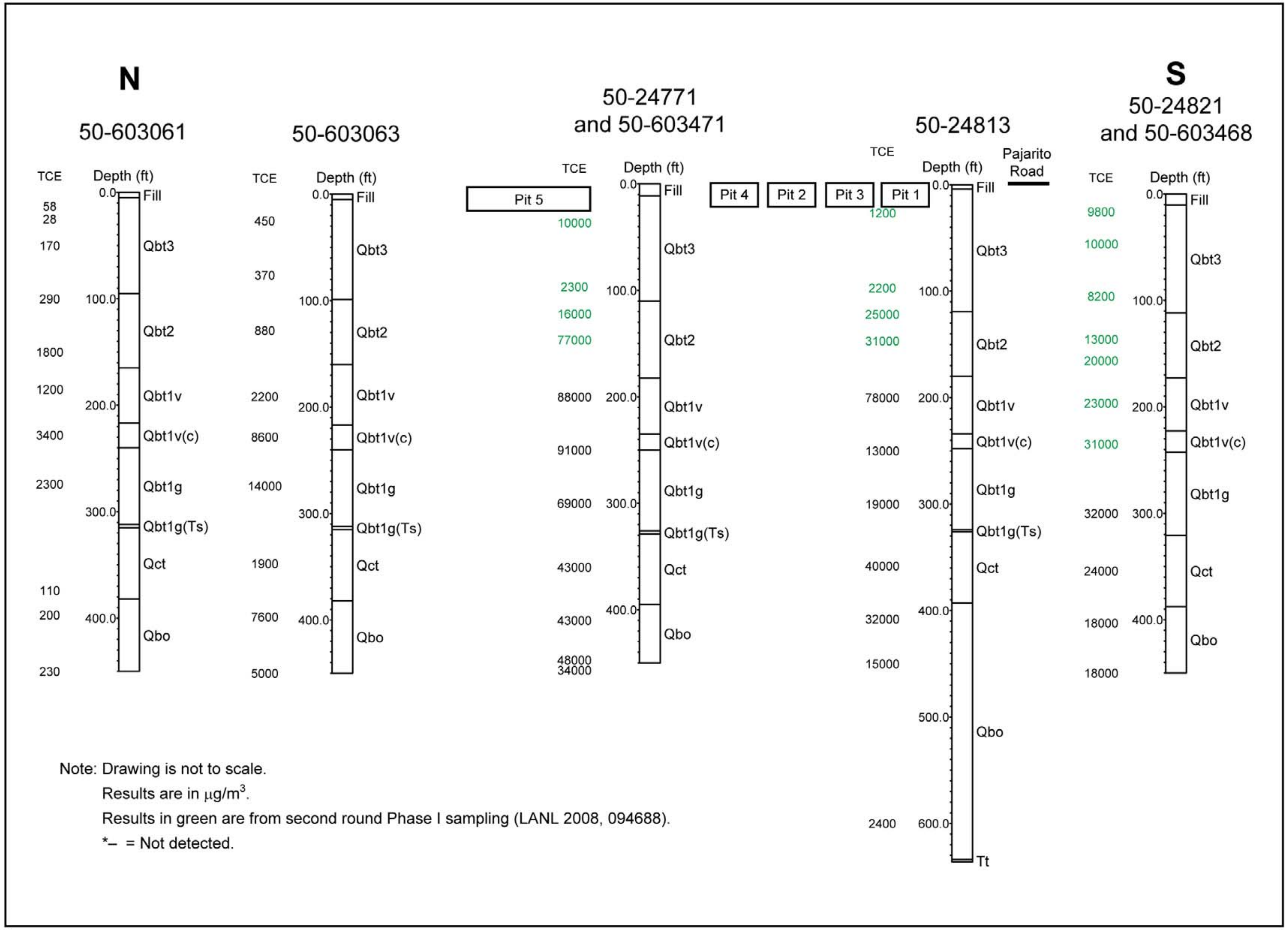


Figure 2.3-3 North-south transect across MDA C showing PCE concentrations in pore gas



Note: Drawing is not to scale.
Results are in $\mu g/m^3$.
Results in green are from second round Phase I sampling (LANL 2008, 094688).
*– = Not detected.

Figure 2.3-4 West-east transect across MDA C showing TCE concentrations in pore gas



Note: Drawing is not to scale.

Results are in $\mu g/m^3$.

Results in green are from second round Phase I sampling (LANL 2008, 094688).

*– = Not detected.

Figure 2.3-5 North-south transect across MDA C showing TCE concentrations in pore gas

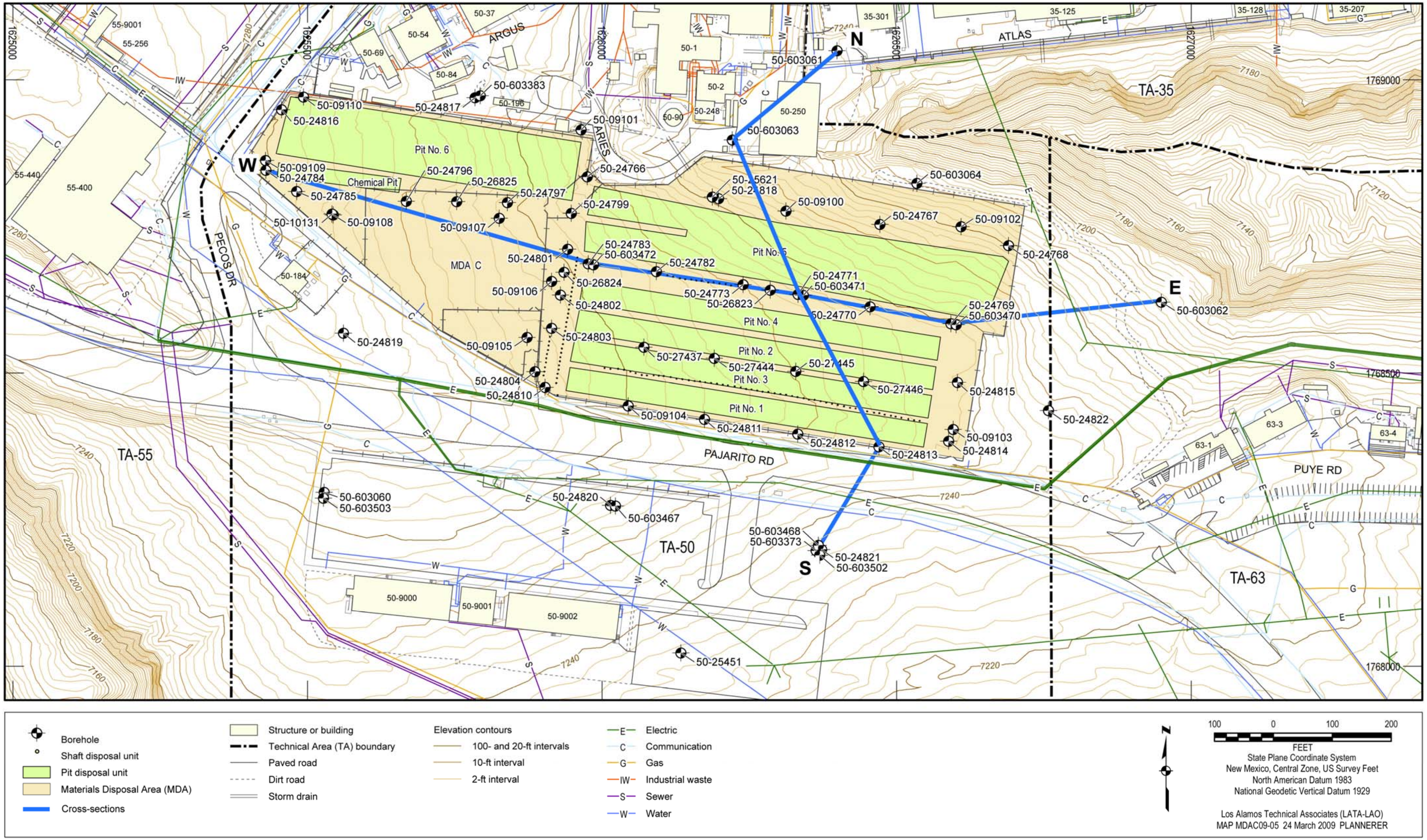
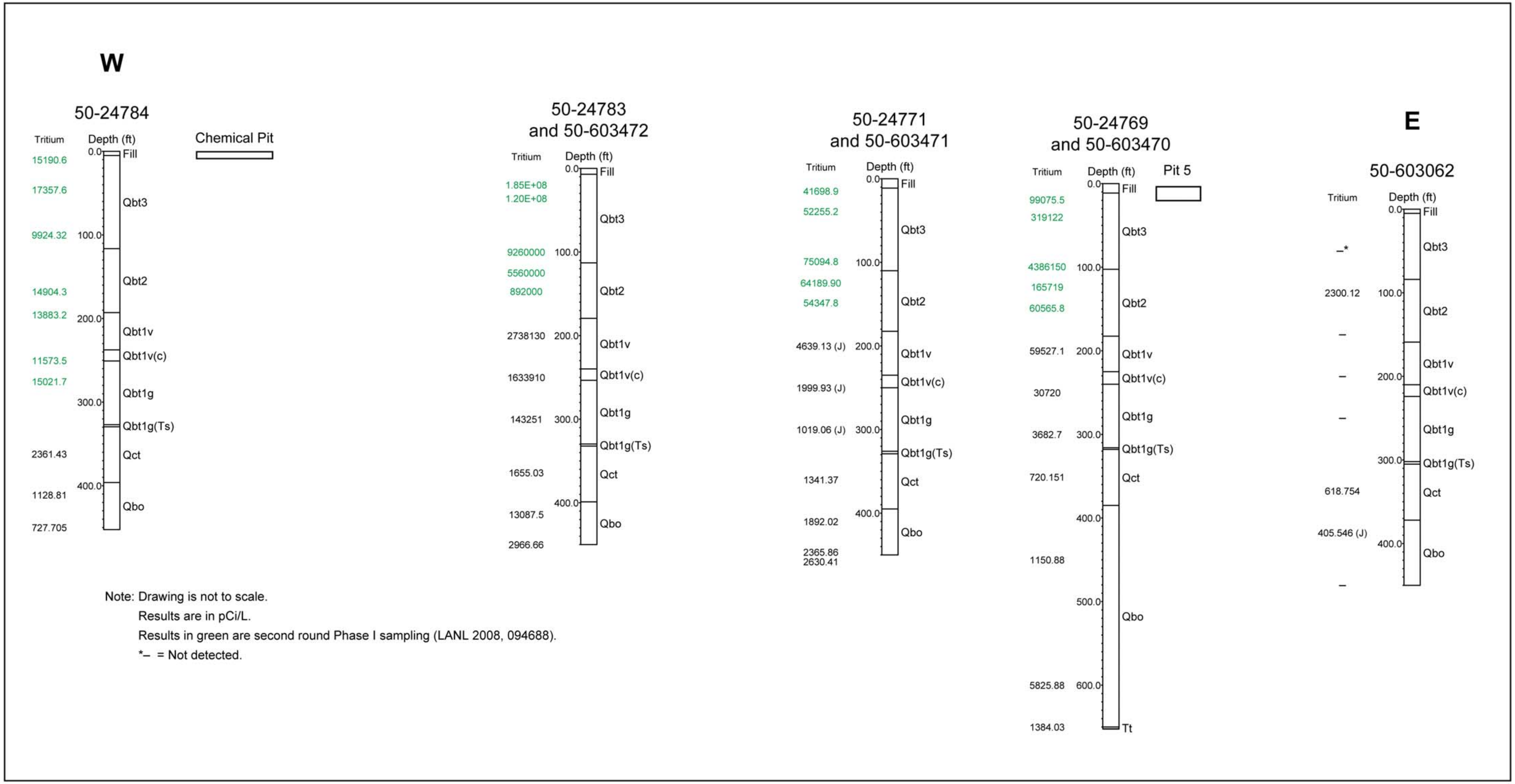
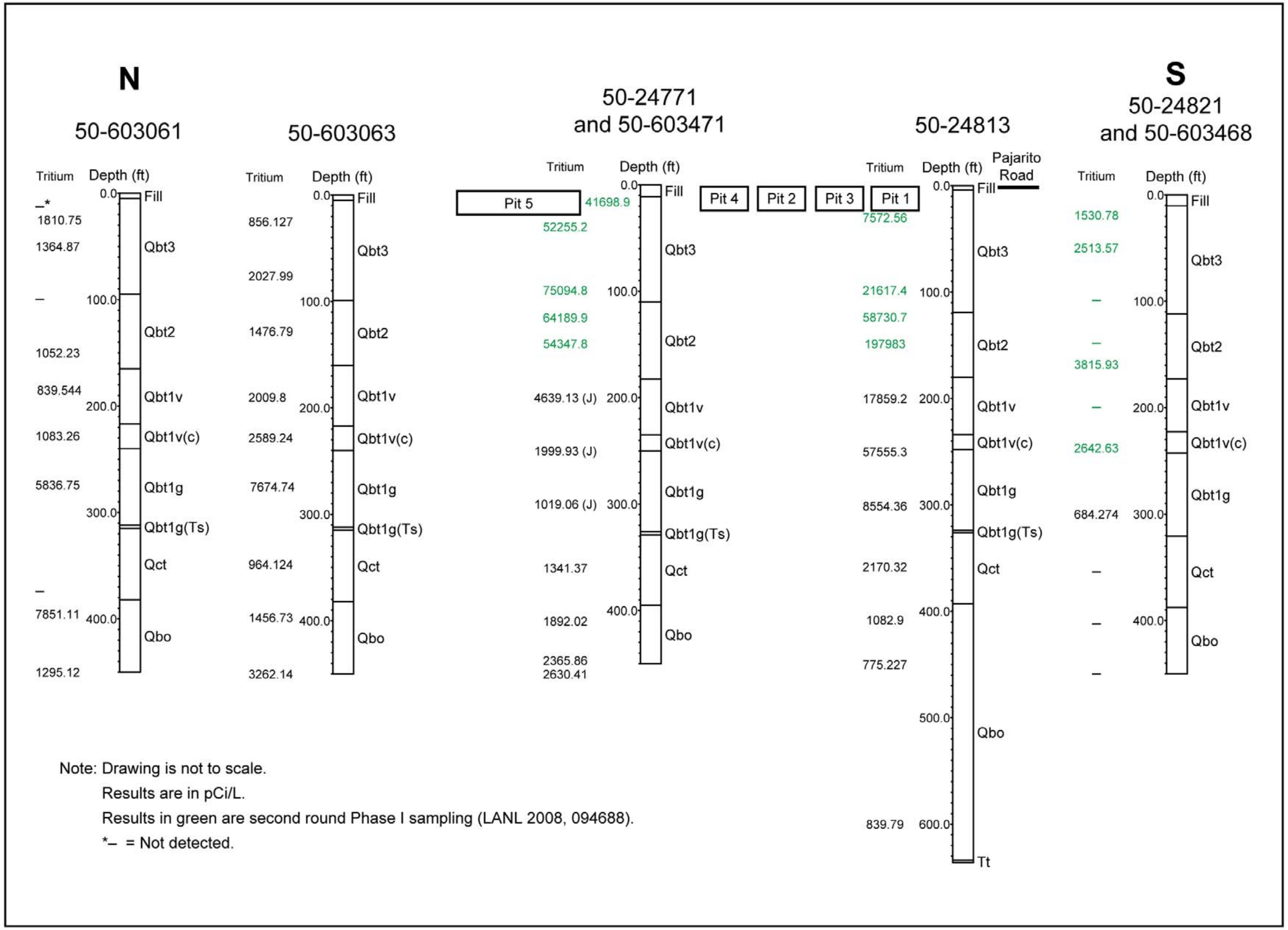


Figure 2.3-6 Locations of cross-sections across MDA C



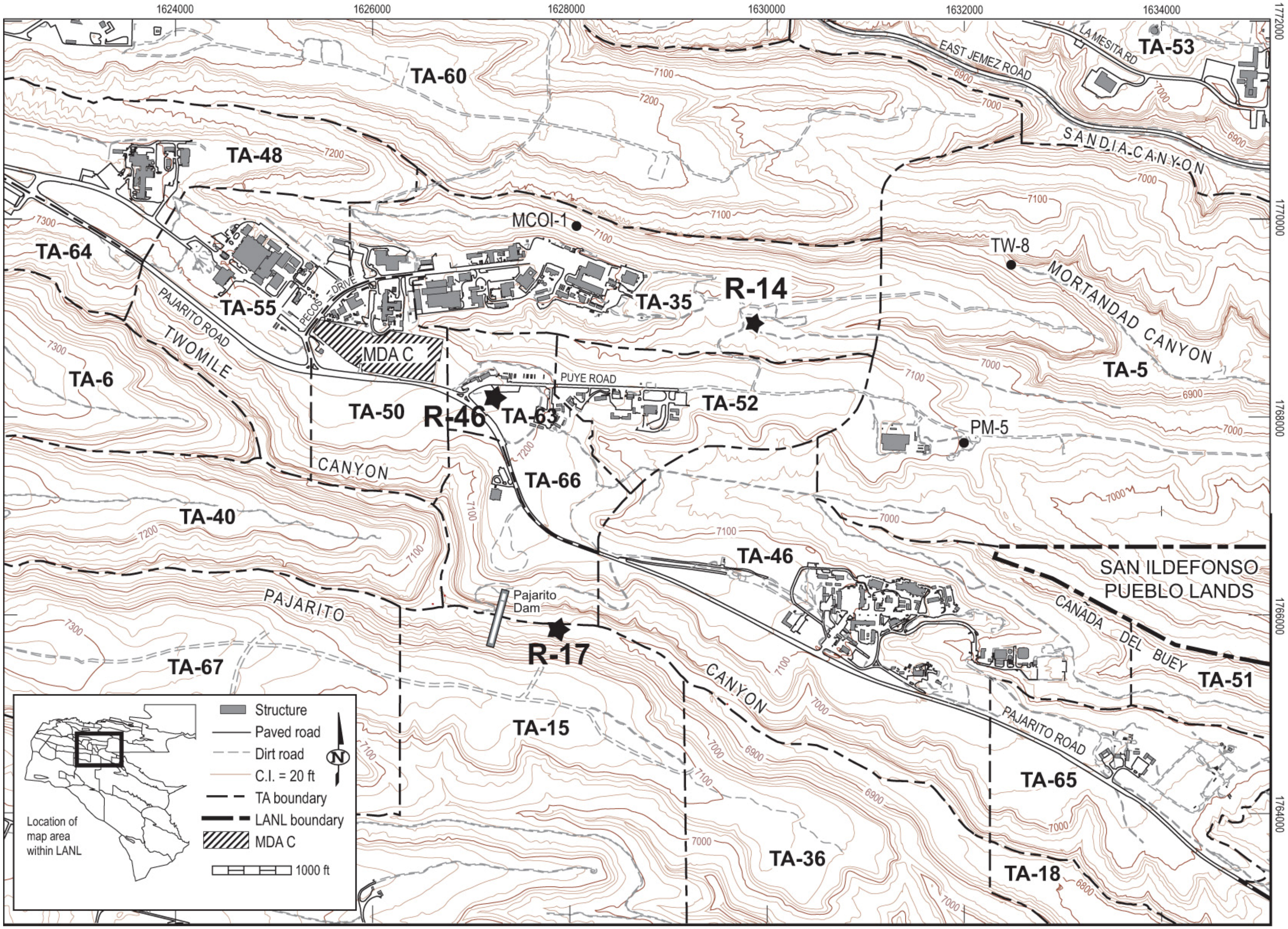
Note: Drawing is not to scale.
Results are in pCi/L.
Results in green are second round Phase I sampling (LANL 2008, 094688).
*– = Not detected.

Figure 2.3-7 West-east transect across MDA C showing tritium concentrations in pore gas



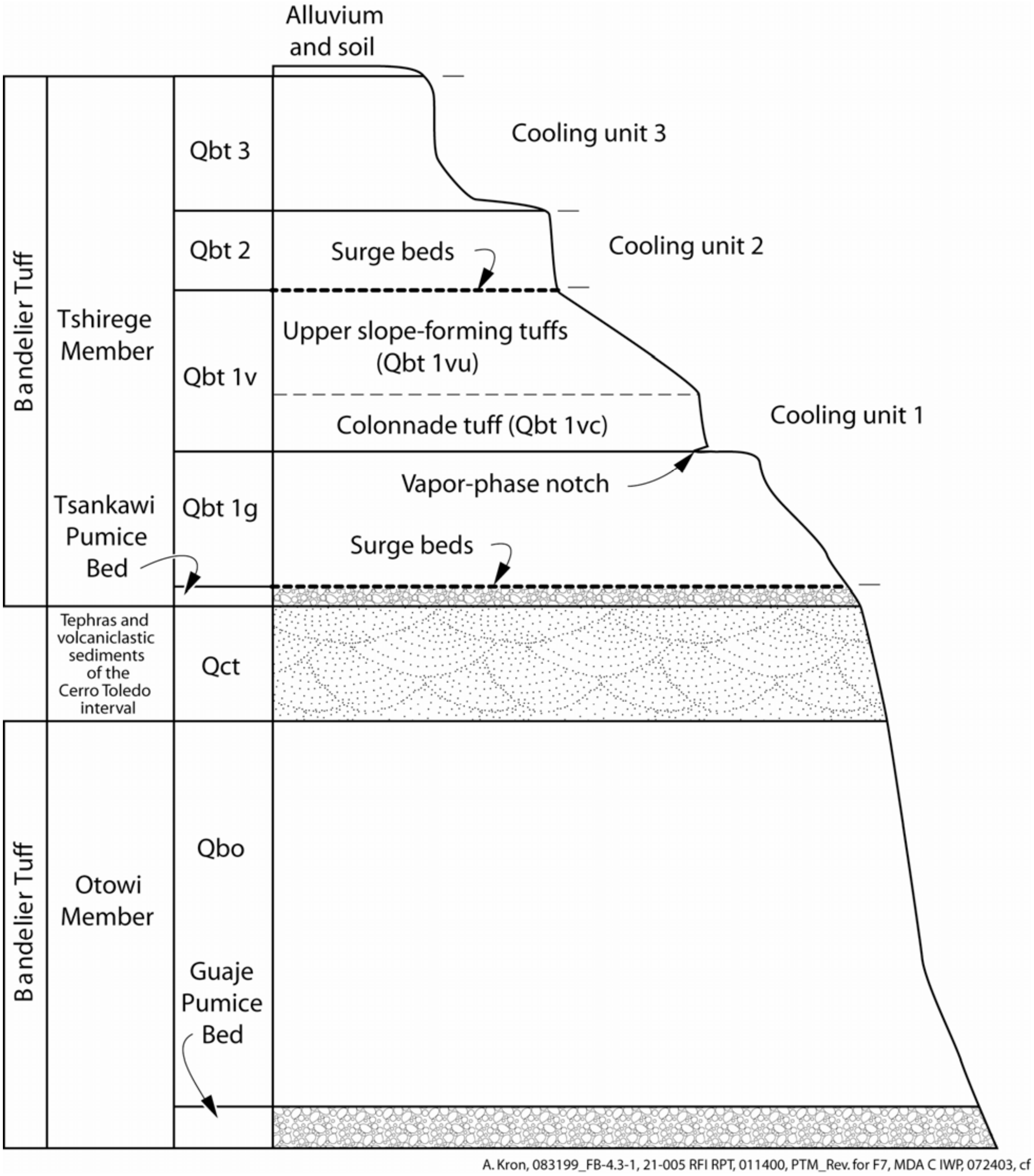
Note: Drawing is not to scale.
Results are in pCi/L.
Results in green are second round Phase I sampling (LANL 2008, 094688).
*– = Not detected.

Figure 2.3-8 North-south transect across MDA C showing tritium concentrations in pore gas



Sources: FIMAD G110278 121101 andGISLab m200396, 091102_Rev. for F4.1-1, MDA C Phase II IR, 042309, dwd

Figure 2.3-9 Location of regional groundwater monitoring wells near MDA C



A. Kron, 083199_FB-4.3-1, 21-005 RFI RPT, 011400, PTM_Rev. for F7, MDA C IWP, 072403, cf

Figure 3.1-1 Generalized stratigraphy of Bandelier Tuff in the vicinity of MDA C

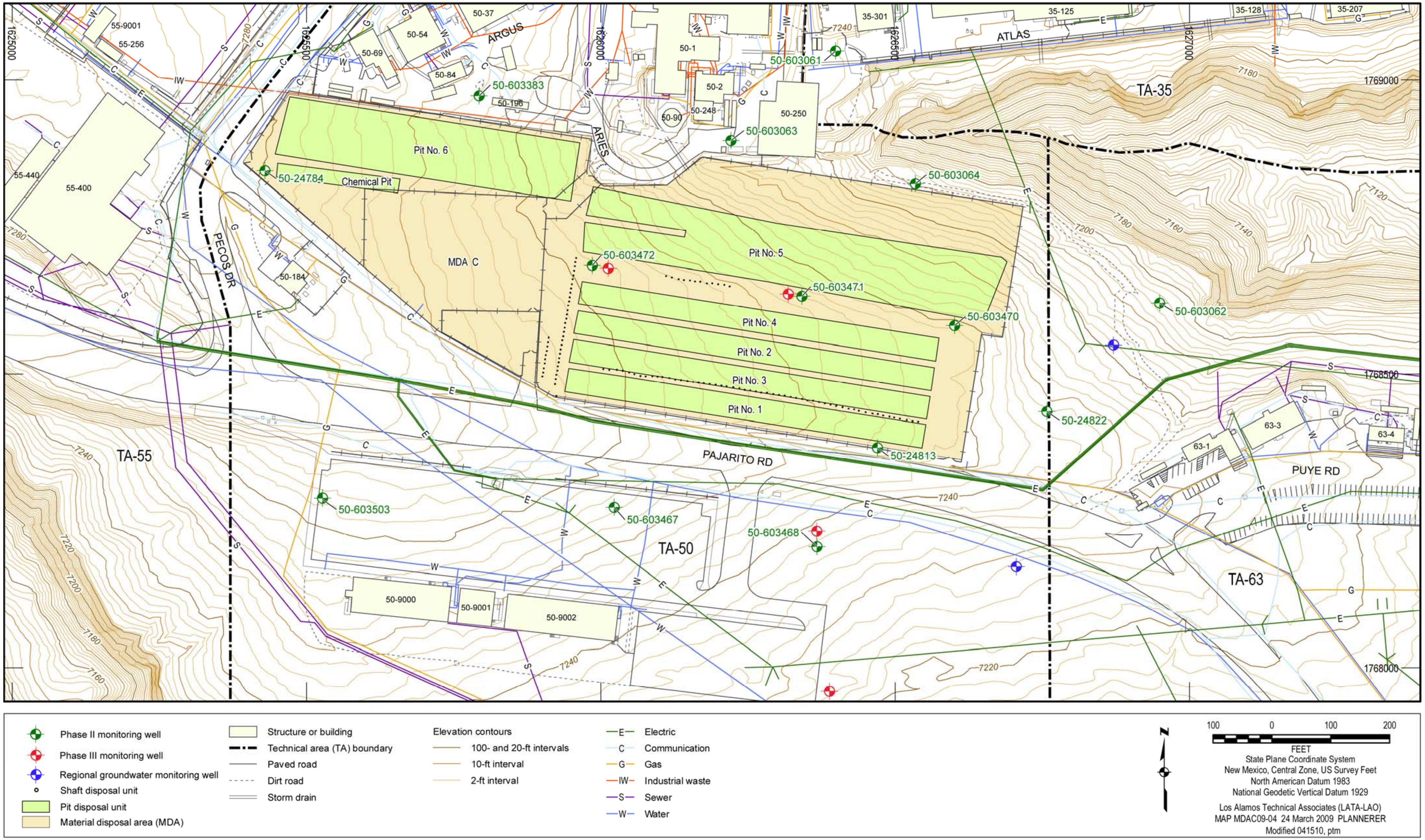
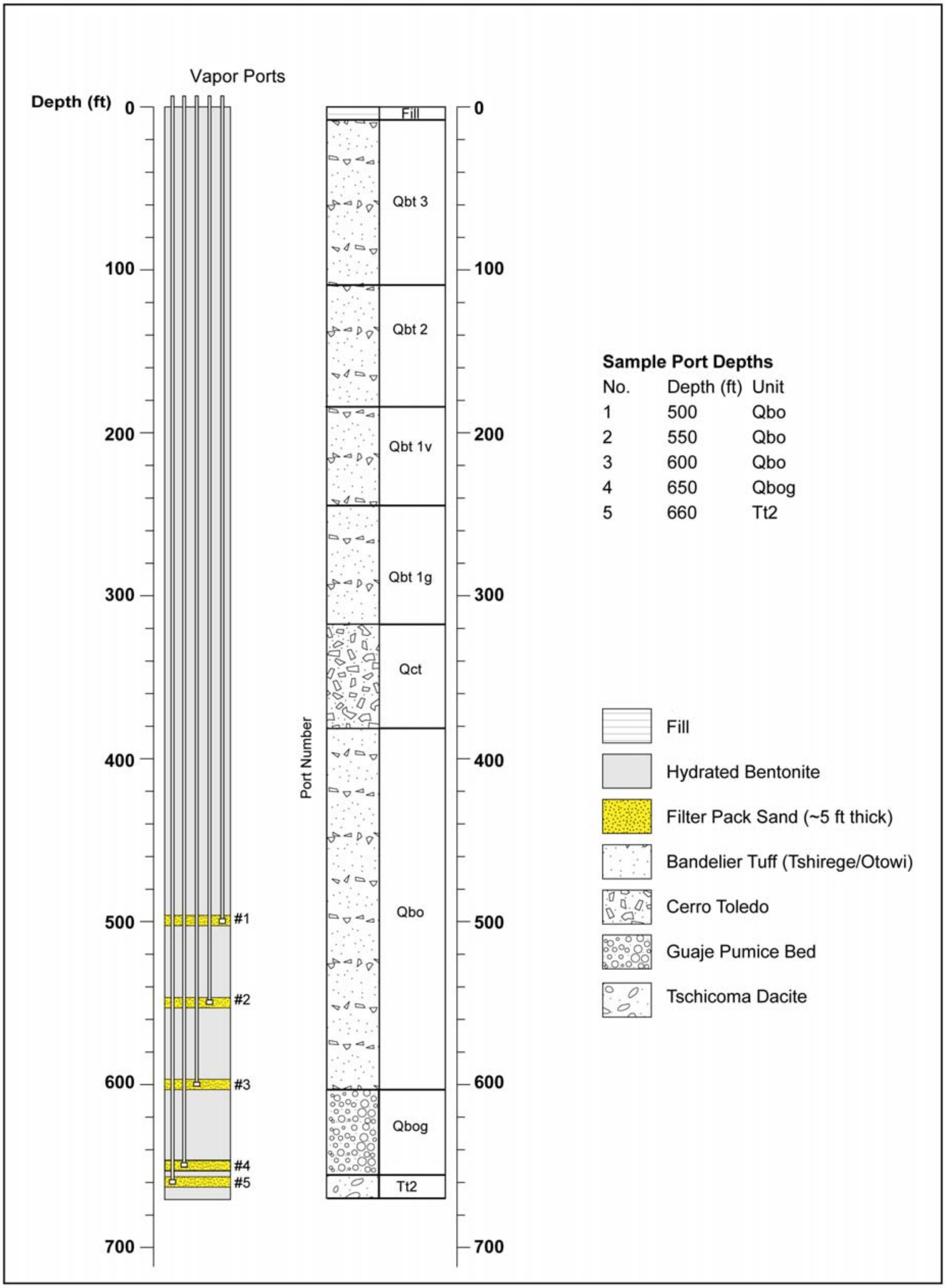


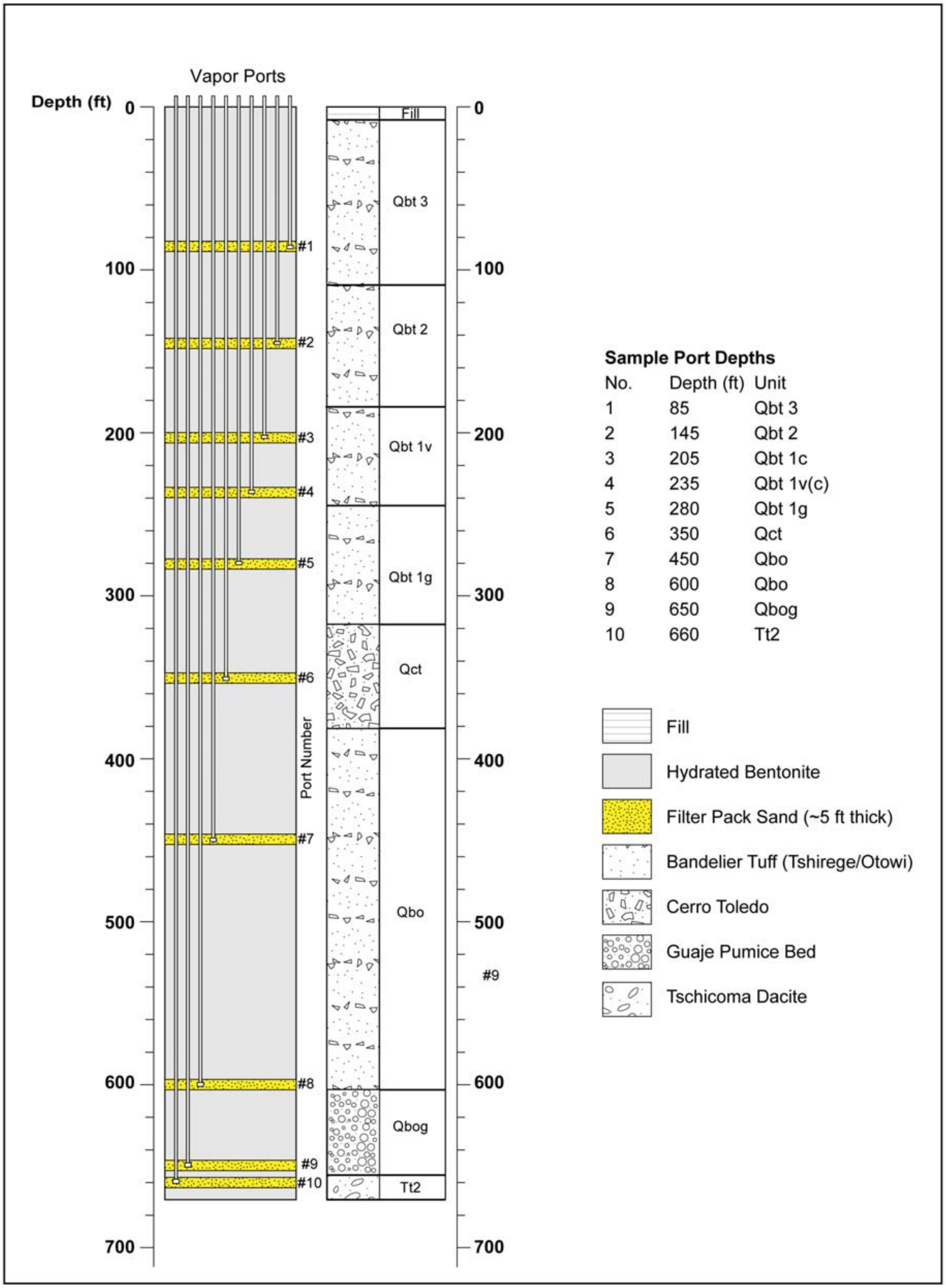
Figure 4.2-1 Locations of proposed vapor and regional groundwater monitoring wells at MDA C



Sample Port Depths

No.	Depth (ft)	Unit
1	500	Qbo
2	550	Qbo
3	600	Qbo
4	650	Qbog
5	660	Tt2

Figure 4.2-2 Proposed configuration of new vapor-monitoring wells adjacent to existing wells



Sample Port Depths

No.	Depth (ft)	Unit
1	85	Qbt 3
2	145	Qbt 2
3	205	Qbt 1c
4	235	Qbt 1v(c)
5	280	Qbt 1g
6	350	Qct
7	450	Qbo
8	600	Qbo
9	650	Qbog
10	660	Tt2

Figure 4.2-3 Proposed configuration of new vapor-monitoring well south of MDA C

Table 2.3-1
Concentrations of Inorganic Chemicals Detected in Dacite Sample

Inorganic Chemical	Concentration
Aluminum	17200
Arsenic	12.6
Barium	151 (J)
Beryllium	0.749
Cadmium	0.333 (J)
Calcium	22000
Chromium	25.4
Cobalt	9.13
Copper	14.7
Iron	19300
Lead	7.46
Magnesium	6590 (J)
Manganese	366 (J)
Nickel	40.2
Potassium	4250
Selenium	3.69
Silver	0.124 (J-)
Sodium	331
Vanadium	28.8
Zinc	34.8

Note: Results are in mg/kg. Data qualifiers are defined in Appendix A.

Table 2.3-2
VOCs Detected in Pore Gas in Phase II Boreholes at MDA C

Sample ID	Location ID	Depth (ft)	Media	Acetone	Benzene	Butadiene[1,3-]	Butanol[1-]	Butanone[2-]	Carbon Disulfide	Carbon Tetrachloride	Chlorobenzene	Chlorodifluoromethane	Chloroform	Cyclohexane	Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Dichlorodifluoromethane	Dichloroethane[1,1-]	Dichloroethane[1,2-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol
Boreholes 50-24769 and 50-603470																						
MD50-08-7459	50-24769	200.00–200.00	Pore gas	—*	—	—	—	—	—	550	—	—	1500	—	—	1700	—	—	—	490	—	—
MD50-08-7460	50-24769	250.00–250.00	Pore gas	—	—	—	—	—	—	570	—	—	1200	—	—	1600	—	—	—	410	—	—
MD50-08-7451	50-24769	300.00–300.00	Pore gas	—	—	—	—	—	—	630	—	—	980	—	—	1500	—	—	—	330	—	—
MD50-08-7465	50-603470	351.00–351.00	Pore gas	—	—	—	—	—	—	71	—	—	97	—	—	340	—	—	—	—	—	—
MD50-08-7464	50-603470	450.00–450.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MD50-08-7461	50-603470	650.00–650.00	Pore gas	—	—	—	—	—	27	—	—	—	—	—	—	140	—	—	—	—	—	—
Boreholes 50-24771 and 50-603471																						
MD50-08-7626	50-24771	200.00–200.00	Pore gas	—	—	—	—	—	—	2400	—	—	3400	—	—	1600	—	—	—	800	—	—
MD50-08-7627	50-24771	250.00–250.00	Pore gas	—	—	—	—	—	—	2100	—	—	2700	—	—	1600	—	—	—	700	—	—
MD50-08-7625	50-24771	300.00–300.00	Pore gas	—	—	—	—	—	—	1200	—	—	1500	—	—	1100	—	—	—	510	—	—
MD50-08-7628	50-603471	360.00–360.00	Pore gas	—	—	—	—	—	—	680	—	—	600	—	—	780	—	—	—	200	—	—
MD50-08-7629	50-603471	410.00–410.00	Pore gas	—	—	—	—	—	—	600	—	—	710	—	—	230	—	—	—	220	—	—
MD50-08-7630	50-603471	450.00–450.00	Pore gas	—	—	—	—	—	—	450	—	—	1100	—	—	—	—	—	—	290	—	—
MD50-09-3534	50-603471	450.00–450.00	Pore gas	—	—	—	—	—	—	210	—	—	960	—	—	—	—	—	—	200	—	—
Boreholes 50-24783 and 50-603472																						
MD50-08-7656	50-24783	200.00–200.00	Pore gas	—	—	—	—	—	—	350	—	—	720	—	—	320	—	—	—	190	110	—
MD50-08-7657	50-24783	250.00–250.00	Pore gas	—	—	—	—	—	—	490	—	—	710	—	—	400	—	—	—	210	93	—
MD50-08-7655	50-24783	300.00–300.00	Pore gas	—	—	—	—	—	—	570	—	250	640	—	—	480	—	—	—	190	—	—
MD50-08-7658	50-603472	364.00–364.00	Pore gas	—	—	—	—	—	—	170	—	50	140	—	—	170	—	—	—	32	16	—
MD50-08-7659	50-603472	414.00–414.00	Pore gas	86	—	—	—	—	—	130	—	—	38	—	—	130	—	—	—	—	—	—
MD50-08-7660	50-603472	450.00–450.00	Pore gas	56	—	—	—	—	38	240	—	—	42	—	—	260	—	—	—	—	—	—
Borehole 50-24784																						
MD50-08-7691	50-24784	362.00–362.00	Pore gas	18	—	—	—	4.8	17	330	—	—	16	—	—	170	—	—	5.4	3.5	—	—
MD50-08-7690	50-24784	411.00–411.00	Pore gas	—	—	—	—	—	22	370	—	—	7.3	—	—	210	—	—	4.4	—	—	—
MD50-08-7689	50-24784	450.00–450.00	Pore gas	—	—	—	—	—	14	120	—	—	—	—	—	83	—	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Acetone	Benzene	Butadiene[1,3-]	Butanol[1-]	Butanone[2-]	Carbon Disulfide	Carbon Tetrachloride	Chlorobenzene	Chlorodifluoromethane	Chloroform	Cyclohexane	Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Dichlorodifluoromethane	Dichloroethane[1,1-]	Dichloroethane[1,2-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol
Borehole 50-24813																						
MD50-08-7716	50-24813	200.00–200.00	Pore gas	—	—	—	—	—	—	2400	—	—	2300	—	—	2400	—	—	—	690	—	—
MD50-08-7717	50-24813	250.00–250.00	Pore gas	120	—	—	—	—	—	260	—	—	440	—	—	250	—	—	—	130	—	—
MD50-08-7715	50-24813	300.00–300.00	Pore gas	—	—	—	—	—	—	360	—	—	420	—	—	430	—	—	—	130	—	—
MD50-08-7721	50-24813	358.00–358.00	Pore gas	—	—	—	—	—	29	640	—	—	500	—	—	980	—	—	—	170	—	—
MD50-08-7720	50-24813	408.00–408.00	Pore gas	—	—	—	—	—	—	500	—	—	220	—	—	960	—	—	—	85	—	—
MD50-08-7719	50-24813	450.00–450.00	Pore gas	—	—	—	—	—	—	280	—	—	—	—	—	610	—	—	—	—	—	—
MD50-08-7718	50-24813	600.00–600.00	Pore gas	—	—	—	—	—	14	110	—	—	—	—	—	240	—	—	—	—	—	—
Borehole 50-603383																						
MD50-08-14863	50-603383	286.00–286.00	Pore gas	26	—	—	12	4.7	—	120	4.3	—	27	—	8.7	83	4	—	11	14	69	—
MD50-08-14864	50-603383	359.00–359.00	Pore gas	14	11	—	18	5.6	39	—	6.4	—	—	—	—	—	—	—	—	—	—	—
MD50-08-14865	50-603383	408.00–408.00	Pore gas	—	4.3	—	50	—	—	250	25	14 (J)	7.9	—	8.4	210	—	—	10	6.2	7	—
MD50-08-14866	50-603383	450.00–450.00	Pore gas	—	4.7	—	39	3.6	—	140	21	13 (J)	5.7	—	8.5	170	—	—	6.8	4.8	5.9	—
Borehole 50-603467																						
MD50-08-14858	50-603467	287.00–287.00	Pore gas	—	—	—	—	—	—	630	—	—	530	—	—	340	—	—	—	160	—	—
MD50-08-14860	50-603467	360.00–360.00	Pore gas	—	—	—	—	—	—	340	—	—	230	—	—	200	—	—	—	76	—	—
MD50-08-14859	50-603467	409.00–409.00	Pore gas	—	—	—	—	—	—	300 (J)	—	—	82 (J)	—	—	200 (J)	—	—	—	—	—	—
MD50-08-14857	50-603467	500.00–500.00	Pore gas	—	—	—	—	—	—	270	—	—	54	—	—	230	—	—	—	—	—	—
MD50-08-14856	50-603467	600.00–600.00	Pore gas	140	—	—	140	45	—	310	27	—	52	—	—	230	—	—	—	—	—	160
Borehole 50-603468																						
MD50-08-7894	50-603468	300.00–300.00	Pore gas	—	—	—	—	—	—	580	—	—	370	—	—	670	—	—	—	140	—	—
MD50-08-7895	50-603468	354.00–354.00	Pore gas	—	—	—	—	—	—	500	—	—	190	—	—	640	—	—	—	—	—	—
MD50-08-7896	50-603468	403.00–403.00	Pore gas	—	—	—	—	—	—	370	—	—	85	—	—	450	—	—	—	—	—	—
MD50-08-7897	50-603468	450.00–450.00	Pore gas	180	—	—	—	78	—	270	—	—	140	—	—	260	—	—	—	—	—	—
Borehole 50-24822																						
MD50-08-7949	50-24822	351.00–351.00	Pore gas	—	—	—	—	—	9.6	21	—	—	20	—	—	63	—	—	—	5.5	—	—
MD50-08-7948	50-24822	402.00–402.00	Pore gas	—	—	—	—	—	—	210	—	—	64	—	—	530	—	—	—	—	—	—
MD50-08-7947	50-24822	450.00–450.00	Pore gas	—	—	—	—	—	18	160	—	—	31	—	—	430	—	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Acetone	Benzene	Butadiene[1,3-]	Butanol[1-]	Butanone[2-]	Carbon Disulfide	Carbon Tetrachloride	Chlorobenzene	Chlorodifluoromethane	Chloroform	Cyclohexane	Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Dichlorodifluoromethane	Dichloroethane[1,1-]	Dichloroethane[1,2-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol
Boreholes 50-603060 and 50-603503																						
MD50-08-8161	50-603060	50.00–50.00	Pore gas	11	—	—	—	2.4	—	15	—	—	29	—	—	19	—	—	—	3.7	7.6	5.3
MD50-08-8160	50-603060	100.00–100.00	Pore gas	12	—	—	—	—	2.8	34	—	—	60	—	—	35	—	3.5	—	8.8	21	—
MD50-08-8159	50-603060	150.00–150.00	Pore gas	20	—	—	—	—	—	18	—	—	27	—	—	17	—	—	—	4.5	10	—
MD50-08-8158	50-603060	200.00–200.00	Pore gas	—	—	—	—	—	—	36	—	—	34	—	—	28	—	—	—	8.5	12	—
MD50-08-8157	50-603060	250.00–250.00	Pore gas	17	—	—	—	—	—	57	—	—	50	—	—	47	—	—	—	13	14	—
MD50-08-8162	50-603503	347.00–347.00	Pore gas	49	—	—	—	6.7	8	24	—	—	25	3.4	—	23	—	—	—	5.8	—	—
MD50-08-8163	50-603503	397.00–397.00	Pore gas	18	—	—	—	3.2	—	22	—	—	46	—	—	19	—	—	—	4.7	9.2	—
MD50-08-8164	50-603503	450.00–450.00	Pore gas	57	—	—	—	22	130	88	—	—	12	—	—	68	—	—	—	5.6	—	—
Borehole 50-603061																						
MD50-08-8206	50-603061	13.00–13.00	Pore gas	—	—	—	—	—	—	—	—	—	—	3.5	—	510	—	—	24	—	—	—
MD50-08-8205	50-603061	25.00–25.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	46	—	—	6.3	—	—	—
MD50-08-8204	50-603061	50.00–50.00	Pore gas	40	—	—	—	—	—	—	—	—	4.2	—	—	64	—	—	30	—	—	—
MD50-08-8203	50-603061	100.00–100.00	Pore gas	16	—	—	—	2.8	—	6	—	—	5.8	8.6	—	63	—	—	90	—	—	—
MD50-08-8202	50-603061	150.00–150.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	220	—	—	1200	—	—	—
MD50-08-8201	50-603061	185.00–185.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	200	—	—	500	—	—	—
MD50-08-8230	50-603061	228.00–228.00	Pore gas	—	—	—	—	—	—	130	—	—	—	—	—	340	—	—	1600	—	—	—
MD50-08-8231	50-603061	274.00–274.00	Pore gas	—	—	—	—	—	25	120	—	—	—	—	—	280	—	—	710	—	—	—
MD50-08-8209	50-603061	347.00–347.00	Pore gas	—	—	—	—	—	3.6	7.3	—	—	—	—	—	20	—	—	18	—	—	—
MD50-08-8208	50-603061	397.00–397.00	Pore gas	29	53	10	—	—	16	16	—	—	—	3.3	—	51	—	—	33	—	—	15
MD50-08-8207	50-603061	450.00–450.00	Pore gas	35	5.7	—	—	5.9	59	36	—	—	—	—	—	130	—	—	44	—	—	—
Borehole 50-603062																						
MD50-08-8251	50-603062	50.00–50.00	Pore gas	12	—	—	—	—	—	8.1	—	—	16	—	—	31	—	—	—	—	—	—
MD50-08-8250	50-603062	100.00–100.00	Pore gas	—	—	—	—	—	—	49	—	—	36	—	—	180	—	—	—	—	—	—
MD50-08-8249	50-603062	150.00–150.00	Pore gas	—	—	—	—	—	—	44	—	—	33	—	—	180	—	—	—	—	—	—
MD50-08-8248	50-603062	200.00–200.00	Pore gas	—	—	—	—	—	—	40	—	—	26	—	—	160	—	—	—	—	—	—
MD50-08-8247	50-603062	250.00–250.00	Pore gas	—	—	—	—	—	—	44	—	—	19	—	—	170	—	—	—	—	—	—
MD50-08-8252	50-603062	337.00–337.00	Pore gas	170	—	—	—	22	5.8	8.3	—	—	—	—	—	46	—	—	—	—	—	—
MD50-08-8253	50-603062	387.00–387.00	Pore gas	—	—	—	—	—	15	28	—	—	—	—	—	110	—	—	—	—	—	—
MD50-08-8254	50-603062	450.00–450.00	Pore gas	—	—	—	—	—	27	14	—	—	—	—	—	71	—	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Acetone	Benzene	Butadiene[1,3-]	Butanol[1-]	Butanone[2-]	Carbon Disulfide	Carbon Tetrachloride	Chlorobenzene	Chlorodifluoromethane	Chloroform	Cyclohexane	Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Dichlorodifluoromethane	Dichloroethane[1,1-]	Dichloroethane[1,2-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol
Borehole 50-603063																						
MD50-08-8296	50-603063	10.00–10.00	Pore gas	12	—	—	—	—	—	6.7	—	—	9.9	—	—	35	—	—	6.3	—	—	—
MD50-08-8295	50-603063	25.00–25.00	Pore gas	17	—	—	—	—	—	—	—	—	12	—	—	14	—	—	5.5	—	—	—
MD50-08-8294	50-603063	50.00–50.00	Pore gas	12	—	—	—	—	—	12	—	—	25	—	—	36	5.1	—	17	—	—	—
MD50-08-8291	50-603063	99.00–99.00	Pore gas	50	—	—	—	—	—	31	—	—	100	—	—	80	21	—	51	12	—	—
MD50-08-8292	50-603063	150.00–150.00	Pore gas	—	—	—	—	—	—	160	—	91	270	—	—	310	43	—	180	48	—	—
MD50-08-8293	50-603063	200.00–200.00	Pore gas	—	—	—	—	—	—	240	—	130	390	—	—	430	34	—	210	82	—	—
MD50-09-1668	50-603063	347.00–347.00	Pore gas	—	—	—	—	—	4.6	45	—	—	31	—	—	72	—	—	7	6.9	—	—
MD50-09-1667	50-603063	397.00–397.00	Pore gas	—	—	—	—	—	63	200	—	—	170	—	—	240	23	—	—	22	—	—
MD50-09-1666	50-603063	450.00–450.00	Pore gas	—	—	—	—	—	55	140	—	—	130	—	—	200	20	—	—	15	—	—
Borehole 50-603064																						
MD50-08-8343	50-603064	25.00–25.00	Pore gas	—	—	—	—	—	50	160	—	—	480	—	—	620	—	—	530	150	—	—
MD50-08-8342	50-603064	66.00–66.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9.3
MD50-08-8344	50-603064	113.00–113.00	Pore gas	—	—	—	—	—	—	—	—	—	170	—	—	120	—	—	100	—	—	—
MD50-08-8345	50-603064	176.00–176.00	Pore gas	—	—	—	—	—	—	230	—	—	480	—	—	720	—	—	540	190	—	—
MD50-08-8338	50-603064	200.00–200.00	Pore gas	—	—	—	—	—	—	56	—	—	140	—	—	170	—	—	100	47	—	—
MD50-08-8337	50-603064	250.00–250.00	Pore gas	16	20	—	—	—	—	11	—	—	43	6.3	—	34	—	—	23	18	—	—
MD50-08-8341	50-603064	332.00–332.00	Pore gas	50	6.8	—	—	12 (J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MD50-08-8340	50-603064	400.00–400.00	Pore gas	8.2	64	6.8	—	—	—	—	—	—	—	42	—	—	—	—	—	—	—	—
MD50-08-8339	50-603064	500.00–500.00	Pore gas	—	3.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Ethylbenzene	Ethyltoluene[4-]	Hexane	Methanol	Methylene Chloride	n-Heptane	Propylene	Styrene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane	Trimethylbenzene[1,2,4-]	Trimethylbenzene[1,3,5-]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Boreholes 50-24769 and 50-603470																						
MD50-08-7459	50-24769	200.00–200.00	Pore gas	—	—	—	—	780	—	—	—	670	—	—	940	—	57000	—	—	—	—	—
MD50-08-7460	50-24769	250.00–250.00	Pore gas	—	—	—	—	860	—	—	—	590	—	—	800	—	56000	—	—	—	—	—
MD50-08-7451	50-24769	300.00–300.00	Pore gas	—	—	—	—	970	—	—	—	610	—	—	680	—	60000	—	—	—	—	—
MD50-08-7465	50-603470	351.00–351.00	Pore gas	—	—	—	—	120	—	—	—	—	—	—	—	—	8700	—	—	—	—	—
MD50-08-7464	50-603470	450.00–450.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	—	150	—	—	—	—	—
MD50-08-7461	50-603470	650.00–650.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	—	—	180	—	—	—	—	—
Boreholes 50-24771 and 50-603471																						
MD50-08-7626	50-24771	200.00–200.00	Pore gas	—	—	—	—	2800	—	—	—	2500	—	—	780	—	88000	—	—	—	—	—
MD50-08-7627	50-24771	250.00–250.00	Pore gas	—	—	—	—	2900	—	—	—	2300	—	—	600	—	91000	—	—	—	—	—
MD50-08-7625	50-24771	300.00–300.00	Pore gas	—	—	—	—	2200	—	—	—	1600	—	—	—	—	69000	—	—	—	—	—
MD50-08-7628	50-603471	360.00–360.00	Pore gas	—	—	—	—	890	—	—	—	820	—	—	—	—	43000	—	—	—	—	—
MD50-08-7629	50-603471	410.00–410.00	Pore gas	—	—	—	—	900	—	—	—	790	—	—	—	—	43000	—	—	—	—	—
MD50-08-7630	50-603471	450.00–450.00	Pore gas	—	—	—	—	940	—	—	—	880	—	—	—	—	48000	—	—	—	—	—
MD50-09-3534	50-603471	450.00–450.00	Pore gas	—	—	—	—	680	—	—	—	950	—	—	—	—	34000	—	—	—	—	—
Boreholes 50-24783 and 50-603472																						
MD50-08-7656	50-24783	200.00–200.00	Pore gas	—	—	—	—	760	—	—	—	1400	—	—	140	—	21000	—	—	—	—	—
MD50-08-7657	50-24783	250.00–250.00	Pore gas	—	—	—	—	890	—	—	—	1900	—	—	140	—	28000	—	—	—	—	—
MD50-08-7655	50-24783	300.00–300.00	Pore gas	—	—	—	—	850	—	—	—	2000	—	—	—	—	30000	—	—	—	—	—
MD50-08-7658	50-603472	364.00–364.00	Pore gas	—	—	—	—	100	—	—	—	440	—	—	38	—	6900	—	—	—	—	—
MD50-08-7659	50-603472	414.00–414.00	Pore gas	—	—	—	—	47	—	—	—	190	—	—	—	—	4700	—	—	—	—	—
MD50-08-7660	50-603472	450.00–450.00	Pore gas	—	—	—	—	52	—	—	—	230	—	29	—	—	6500	—	—	—	—	—
Borehole 50-24784																						
MD50-08-7691	50-24784	362.00–362.00	Pore gas	—	—	—	—	4.5	—	—	—	800	—	—	36	14	1600	17	—	—	—	—
MD50-08-7690	50-24784	411.00–411.00	Pore gas	—	—	—	—	—	—	—	—	440	—	4.2	20	8.1	1200	18	—	—	—	—
MD50-08-7689	50-24784	450.00–450.00	Pore gas	—	—	—	—	—	—	—	—	130	—	3.3	—	—	350	7.4	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Ethylbenzene	Ethyltoluene[4-]	Hexane	Methanol	Methylene Chloride	n-Heptane	Propylene	Styrene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane	Trimethylbenzene[1,2,4-]	Trimethylbenzene[1,3,5-]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Borehole 50-24813																						
MD50-08-7716	50-24813	200.00–200.00	Pore gas	—	—	—	—	2300	—	—	—	940	—	—	—	—	78000	—	—	—	—	—
MD50-08-7717	50-24813	250.00–250.00	Pore gas	—	—	—	—	540	—	—	—	130	—	—	—	—	13000	53	—	—	—	—
MD50-08-7715	50-24813	300.00–300.00	Pore gas	—	—	—	—	500	—	—	—	210	—	—	—	—	19000	—	—	—	—	—
MD50-08-7721	50-24813	358.00–358.00	Pore gas	—	—	—	—	640	—	—	—	350	—	—	—	—	40000	—	—	—	—	—
MD50-08-7720	50-24813	408.00–408.00	Pore gas	—	—	—	—	310	—	—	—	270	—	—	—	—	32000	—	—	—	—	—
MD50-08-7719	50-24813	450.00–450.00	Pore gas	—	—	—	—	140	—	—	—	—	—	—	—	—	15000	—	—	—	—	—
MD50-08-7718	50-24813	600.00–600.00	Pore gas	—	—	—	—	—	—	14	—	19	—	—	—	—	2400	15	—	—	—	—
Borehole 50-603383																						
MD50-08-14863	50-603383	286.00–286.00	Pore gas	—	—	—	—	14	—	—	—	400	—	5.1	150	46	1700	10	—	—	—	—
MD50-08-14864	50-603383	359.00–359.00	Pore gas	4.4	—	6.7	—	—	—	7.5	—	—	—	27	—	—	16	—	—	—	4.7	12
MD50-08-14865	50-603383	408.00–408.00	Pore gas	—	—	—	—	4.4	—	—	—	320	—	16	89	19	1600	20	—	—	—	—
MD50-08-14866	50-603383	450.00–450.00	Pore gas	—	—	—	—	3.7	—	—	—	290	86	16	170	12	1400	14	—	—	—	—
Borehole 50-603467																						
MD50-08-14858	50-603467	287.00–287.00	Pore gas	—	—	—	—	580	—	—	—	980	—	—	—	—	21000	—	—	—	—	—
MD50-08-14860	50-603467	360.00–360.00	Pore gas	—	—	—	—	250	—	—	—	560	—	—	—	—	14000	—	—	—	—	—
MD50-08-14859	50-603467	409.00–409.00	Pore gas	—	—	—	—	78 (J)	—	—	—	450 (J)	—	—	—	—	11000 (J)	—	—	—	—	—
MD50-08-14857	50-603467	500.00–500.00	Pore gas	—	—	—	—	40	—	—	—	280	—	—	—	—	10000	—	—	—	—	—
MD50-08-14856	50-603467	600.00–600.00	Pore gas	—	—	160	—	32	630	58	—	200	35	—	—	—	6900	—	—	—	—	—
Borehole 50-603468																						
MD50-08-7894	50-603468	300.00–300.00	Pore gas	—	—	—	—	430	—	—	—	350	—	—	—	—	32000	—	—	—	—	—
MD50-08-7895	50-603468	354.00–354.00	Pore gas	—	—	—	—	230	—	—	—	260	—	—	—	—	24000	—	—	—	—	—
MD50-08-7896	50-603468	403.00–403.00	Pore gas	—	—	—	—	100	—	—	—	280	—	—	—	—	18000	—	—	—	—	—
MD50-08-7897	50-603468	450.00–450.00	Pore gas	—	—	—	—	120	—	—	—	200	340	—	—	—	18000	—	—	—	—	—
Borehole 50-24822																						
MD50-08-7949	50-24822	351.00–351.00	Pore gas	—	—	—	—	21	—	—	—	16	—	—	—	—	1900	—	—	—	—	—
MD50-08-7948	50-24822	402.00–402.00	Pore gas	—	—	—	—	51	—	—	—	46	—	—	—	—	12000	—	—	—	—	—
MD50-08-7947	50-24822	450.00–450.00	Pore gas	—	—	—	—	22	—	—	—	—	—	—	—	—	7700	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Ethylbenzene	Ethyltoluene[4-]	Hexane	Methanol	Methylene Chloride	n-Heptane	Propylene	Styrene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane	Trimethylbenzene[1,2,4-]	Trimethylbenzene[1,3,5-]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Boreholes 50-603060 and 50-603503																						
MD50-08-8161	50-603060	50.00–50.00	Pore gas	—	—	—	—	5.8	—	—	—	110	—	9.2	20	8.5	590	—	—	—	—	—
MD50-08-8160	50-603060	100.00–100.00	Pore gas	—	—	—	—	14	—	—	—	210	—	14	52	20	1200	—	—	—	—	—
MD50-08-8159	50-603060	150.00–150.00	Pore gas	—	—	—	—	9.2	—	—	—	93	—	5.2	29	10	620	—	—	—	—	—
MD50-08-8158	50-603060	200.00–200.00	Pore gas	—	—	—	—	24	—	—	—	160	—	13	21	9.7	1400	—	—	—	—	—
MD50-08-8157	50-603060	250.00–250.00	Pore gas	—	—	—	—	45	—	—	—	240	—	18	34	16	2200	—	—	—	—	—
MD50-08-8162	50-603503	347.00–347.00	Pore gas	—	—	—	—	28	—	—	—	72	—	—	24	7.7	970	—	—	—	—	—
MD50-08-8163	50-603503	397.00–397.00	Pore gas	—	—	—	—	9.8	—	—	—	190	—	—	21	9.7	990	—	—	—	—	—
MD50-08-8164	50-603503	450.00–450.00	Pore gas	—	—	—	—	13	—	—	—	120	—	—	—	—	2000	—	—	—	—	—
Borehole 50-603061																						
MD50-08-8206	50-603061	13.00–13.00	Pore gas	—	—	—	—	—	—	—	—	8.2	—	31	2400	260	58	5.6	—	—	—	—
MD50-08-8205	50-603061	25.00–25.00	Pore gas	—	—	—	—	—	—	—	—	—	—	56	240	55	28	—	—	—	—	—
MD50-08-8204	50-603061	50.00–50.00	Pore gas	—	—	—	—	—	—	—	—	22	—	260	640	320	170	—	—	—	—	—
MD50-08-8203	50-603061	100.00–100.00	Pore gas	—	—	—	—	—	—	—	—	30	—	49	2400	520	290	—	—	—	—	—
MD50-08-8202	50-603061	150.00–150.00	Pore gas	—	—	—	—	86	—	—	—	130	—	52	25000	4800	1800	—	—	—	—	—
MD50-08-8201	50-603061	185.00–185.00	Pore gas	—	—	—	—	27	—	—	—	84	—	670	13000	2600	1200	—	—	—	—	—
MD50-08-8230	50-603061	228.00–228.00	Pore gas	—	—	—	—	100	—	—	—	180	—	—	31000	4800	3400	—	—	—	—	—
MD50-08-8231	50-603061	274.00–274.00	Pore gas	—	—	—	—	—	—	—	—	94	—	—	16000	1900	2300	—	—	—	—	—
MD50-08-8209	50-603061	347.00–347.00	Pore gas	—	—	—	—	—	—	—	—	5.7	—	5.4	560	28	110	—	—	—	—	—
MD50-08-8208	50-603061	397.00–397.00	Pore gas	9.2	7.5 (J)	5.3	110	—	—	50	6.6	7.4	—	83	900	32	200	6.1	8.7	—	11	32
MD50-08-8207	50-603061	450.00–450.00	Pore gas	—	—	13	—	—	110	—	—	8.4	—	5.6	1400	30	230	12	—	—	—	—
Borehole 50-603062																						
MD50-08-8251	50-603062	50.00–50.00	Pore gas	—	—	—	—	—	—	—	—	11	—	59	40	13	1200	—	—	—	—	—
MD50-08-8250	50-603062	100.00–100.00	Pore gas	—	—	—	—	—	—	—	—	—	—	15	190	28	5100	—	—	—	—	—
MD50-08-8249	50-603062	150.00–150.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	200	27	5000	—	—	—	—	—
MD50-08-8248	50-603062	200.00–200.00	Pore gas	—	—	—	—	—	—	—	—	—	—	66	170	23	4500	—	—	—	—	—
MD50-08-8247	50-603062	250.00–250.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	150	—	4100	—	—	—	—	—
MD50-08-8252	50-603062	337.00–337.00	Pore gas	—	—	—	—	—	—	—	—	—	—	4.5	18	—	330	—	—	—	—	—
MD50-08-8253	50-603062	387.00–387.00	Pore gas	—	—	—	—	—	—	—	—	—	—	—	35	—	1200	7.1	—	—	—	—
MD50-08-8254	50-603062	450.00–450.00	Pore gas	—	—	—	—	—	—	—	—	—	—	4	9.5	—	400	—	—	—	—	—

Table 2.3-2 (continued)

Sample ID	Location ID	Depth (ft)	Media	Ethylbenzene	Ethyltoluene[4-]	Hexane	Methanol	Methylene Chloride	n-Heptane	Propylene	Styrene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane	Trimethylbenzene[1,2,4-]	Trimethylbenzene[1,3,5-]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Borehole 50-603063																						
MD50-08-8296	50-603063	10.00–10.00	Pore gas	—	—	—	—	—	—	—	—	52	—	94	390	65	450	—	—	—	—	—
MD50-08-8295	50-603063	25.00–25.00	Pore gas	—	—	—	—	—	—	—	—	36	—	190	100	33	370	—	—	—	—	—
MD50-08-8294	50-603063	50.00–50.00	Pore gas	—	—	—	—	—	—	—	—	85	—	90	320	85	880	—	—	—	—	—
MD50-08-8291	50-603063	99.00–99.00	Pore gas	—	—	—	—	7.5	—	—	—	170	—	920	920	250	2200	—	—	—	—	—
MD50-08-8292	50-603063	150.00–150.00	Pore gas	—	—	—	—	28	—	—	—	670	—	1000	3200	680	8600	33	—	—	—	—
MD50-08-8293	50-603063	200.00–200.00	Pore gas	—	—	—	—	84	—	—	—	840	—	130	3700	660	14000	—	—	—	—	—
MD50-09-1668	50-603063	347.00–347.00	Pore gas	—	—	—	—	23	—	—	—	100	—	—	230	7.7	1900	8	—	—	—	—
MD50-09-1667	50-603063	397.00–397.00	Pore gas	—	—	—	—	75	—	—	—	270	—	—	160	—	7600	—	—	—	—	—
MD50-09-1666	50-603063	450.00–450.00	Pore gas	—	—	—	—	56	—	—	—	150	—	—	77	—	5000	—	—	—	—	—
Borehole 50-603064																						
MD50-08-8343	50-603064	25.00–25.00	Pore gas	—	—	—	540	110	—	—	—	220	—	—	9800	2000	15000	—	—	—	—	—
MD50-08-8342	50-603064	66.00–66.00	Pore gas	—	—	—	—	—	—	—	—	—	—	7.9	11	—	15	—	—	—	—	5.9
MD50-08-8344	50-603064	113.00–113.00	Pore gas	—	—	—	—	—	—	—	—	110	—	—	2700	510	2500	—	—	—	—	—
MD50-08-8345	50-603064	176.00–176.00	Pore gas	—	—	—	—	290	—	—	—	400	—	—	9700	2000	24000	—	—	—	—	—
MD50-08-8338	50-603064	200.00–200.00	Pore gas	—	—	—	—	86	—	—	—	76	—	36	2300	530	6200	—	—	—	—	—
MD50-08-8337	50-603064	250.00–250.00	Pore gas	20	25	14	—	35	10	—	—	18	—	120	320	96	1600	—	29	8.5	30	79

Note: Results are in μg/m^3. Data qualifiers are defined in Appendix A.

* — = Not detected.

Table 2.3-3
Tritium Detected in Pore Gas in Phase II Boreholes at MDA C

Sample ID	Location ID	Depth (ft)	Tritium
Boreholes 50-24769 and 50-603470			
MD50-08-7459	50-24769	200.00–200.00	59527.1
MD50-08-7460	50-24769	250.00–250.00	30720
MD50-08-7451	50-24769	300.00–300.00	3682.7
MD50-08-7465	50-603470	351.00–351.00	720.151
MD50-08-7464	50-603470	450.00–450.00	1150.88
MD50-08-7462	50-603470	600.00–600.00	5825.88
MD50-08-7461	50-603470	650.00–650.00	1384.03
Boreholes 50-24771 and 50-603471			
MD50-08-7626	50-24771	200.00–200.00	4639.13 (J)
MD50-08-7627	50-24771	250.00–250.00	1999.93 (J)
MD50-08-7625	50-24771	300.00–300.00	1019.06 (J)
MD50-08-7628	50-603471	360.00–360.00	1341.37
MD50-08-7629	50-603471	410.00–410.00	1892.02
MD50-08-7630	50-603471	450.00–450.00	2365.86
MD50-09-3534	50-603471	450.00–450.00	2630.41
Boreholes 50-24783 and 50-603472			
MD50-08-7656	50-24783	200.00–200.00	2738130
MD50-08-7657	50-24783	250.00–250.00	1633910
MD50-08-7655	50-24783	300.00–300.00	143251
MD50-08-7658	50-603472	364.00–364.00	1655.03
MD50-08-7659	50-603472	414.00–414.00	13087.5
MD50-08-7660	50-603472	450.00–450.00	2966.66
Borehole 50-24784			
MD50-08-7691	50-24784	362.00–362.00	2361.43
MD50-08-7690	50-24784	411.00–411.00	1128.81
MD50-08-7689	50-24784	450.00–450.00	727.705
Borehole 50-24813			
MD50-08-7716	50-24813	200.00–200.00	17859.2
MD50-08-7717	50-24813	250.00–250.00	57555.3
MD50-08-7715	50-24813	300.00–300.00	8554.36
MD50-08-7721	50-24813	358.00–358.00	2170.32
MD50-08-7720	50-24813	408.00–408.00	1082.9
MD50-08-7719	50-24813	450.00–450.00	775.227
MD50-08-7718	50-24813	600.00–600.00	839.79

Table 2.3-3 (continued)

Sample ID	Location ID	Depth (ft)	Tritium
Borehole 50-603383			
MD50-08-14863	50-603383	286.00–286.00	59153.5
MD50-08-14864	50-603383	359.00–359.00	64216.3
MD50-08-14865	50-603383	408.00–408.00	70989
MD50-08-14866	50-603383	450.00–450.00	52007.3
Borehole 50-603467			
MD50-08-14858	50-603467	287.00–287.00	4199.1 (J)
MD50-08-14860	50-603467	360.00–360.00	419.125
MD50-08-14859	50-603467	409.00–409.00	—*
MD50-08-14857	50-603467	500.00–500.00	7512.63 (J)
MD50-08-14856	50-603467	600.00–600.00	—
Borehole 50-603468			
MD50-08-7894	50-603468	300.00–300.00	684.274
MD50-08-7895	50-603468	354.00–354.00	—
MD50-08-7896	50-603468	403.00–403.00	—
MD50-08-7897	50-603468	450.00–450.00	—
Borehole 50-24822			
MD50-08-7949	50-24822	351.00–351.00	4506.35
MD50-08-7948	50-24822	402.00–402.00	1135.58
MD50-08-7947	50-24822	450.00–450.00	808.382
Boreholes 50-603060 and 50-603503			
MD50-08-8161	50-603060	50.00–50.00	3405.46
MD50-08-8160	50-603060	100.00–100.00	2334.79
MD50-08-8159	50-603060	150.00–150.00	—
MD50-08-8158	50-603060	200.00–200.00	3310.42
MD50-08-8157	50-603060	250.00–250.00	2488.95
MD50-08-8162	50-603503	347.00–347.00	—
MD50-08-8163	50-603503	397.00–397.00	1152.98
MD50-08-8164	50-603503	450.00–450.00	—
Borehole 50-603061			
MD50-08-8206	50-603061	13.00–13.00	—
MD50-08-8205	50-603061	25.00–25.00	1810.75
MD50-08-8204	50-603061	50.00–50.00	1364.87
MD50-08-8203	50-603061	100.00–100.00	—
MD50-08-8202	50-603061	150.00–150.00	1052.23
MD50-08-8201	50-603061	185.00–185.00	839.544
MD50-08-8230	50-603061	228.00–228.00	1083.26
MD50-08-8231	50-603061	274.00–274.00	5836.75
MD50-08-8209	50-603061	347.00–347.00	—

Table 2.3-3 (continued)

Sample ID	Location ID	Depth (ft)	Tritium
MD50-08-8208	50-603061	397.00–397.00	7851.11
MD50-08-8207	50-603061	450.00–450.00	1295.12
Borehole 50-603062			
MD50-08-8251	50-603062	50.00–50.00	—
MD50-08-8250	50-603062	100.00–100.00	2300.12
MD50-08-8249	50-603062	150.00–150.00	—
MD50-08-8248	50-603062	200.00–200.00	—
MD50-08-8247	50-603062	250.00–250.00	—
MD50-08-8252	50-603062	337.00–337.00	618.754
MD50-08-8253	50-603062	387.00–387.00	405.546 (J)
MD50-08-8254	50-603062	450.00–450.00	—
Borehole 50-603063			
MD50-08-8296	50-603063	10.00–10.00	856.127
MD50-08-8295	50-603063	25.00–25.00	2027.99
MD50-08-8294	50-603063	50.00–50.00	1476.79
MD50-08-8291	50-603063	99.00–99.00	2009.8
MD50-08-8292	50-603063	150.00–150.00	2589.24
MD50-08-8293	50-603063	200.00–200.00	7674.74
MD50-09-1668	50-603063	347.00–347.00	964.124
MD50-09-1667	50-603063	397.00–397.00	1456.73
MD50-09-1666	50-603063	450.00–450.00	3262.14
Borehole 50-603064			
MD50-08-8343	50-603064	25.00–25.00	—
MD50-08-8342	50-603064	66.00–66.00	612.348
MD50-08-8344	50-603064	113.00–113.00	1476.51 (J)
MD50-08-8345	50-603064	176.00–176.00	1318.47 (J)
MD50-08-8338	50-603064	200.00–200.00	534.669
MD50-08-8337	50-603064	250.00–250.00	525.898
MD50-08-8341	50-603064	332.00–332.00	838.065
MD50-08-8340	50-603064	400.00–400.00	998.676
MD50-08-8339	50-603064	500.00–500.00	2077.88

Note: Results are in pCi/L. Data qualifiers are defined in Appendix A.

* — = Not detected.

Table 4.2-1
Sampling Port Depths of Existing Vapor-Monitoring Wells at Proposed Drilling Locations

	50-603471		50-603472		50-603468	
Sampling Port	Depth (ft bgs)	Screened Unit	Depth (ft bgs)	Screened Unit	Depth (ft bgs)	Screened Unit
1	30	Qbt 3	27	Qbt 3	30	Qbt 3
2	90	Qbt 3	93	Qbt 3	92	Qbt 3
3	146	Qbt 2	146	Qbt 2	142	Qbt 2
4	209	Qbt 1v	210	Qbt 1v	198	Qbt 1v
5	242	Qbt 1vc	247	Qbt 1vc	233	Qbt 1vc
6	288	Qbt 1g	292	Qbt 1g	282	Qbt 1g
7	360	Qct	364	Qct	354	Qct
8	410	Qbo	414	Qbo	403	Qbo
9	450	Qbo	450	Qbo	450	Qbo

Table 4.2-2
Sampling Port Depths of Proposed Vapor-Monitoring Well South of MDA C

Sampling Port	Depth (ft bgs)	Screened Unit
1	85	Qbt 3
2	145	Qbt 2
3	205	Qbt 1v
4	235	Qbt 1vc
5	280	Qbt 1g
6	350	Qct
7	450	Qbo
8	600	Qbo
9	650	Qbog
10	660	Tt 2*

* Note: Sampling port will be installed only if borehole can be advanced at least 10 ft into Tschicoma dacite without use of drilling fluids.

Table 4.4-1
Samples Selected for Dacite Background Study

Borehole	Depth (ft)	Location	Sample Type	Sample Description
SHB-1	657	Seismic Hazard Borehole on mesa 1700 ft NW of MDA C	Core	Unaltered dacite lava; near top of flow
SHB-1	657	Seismic Hazard Borehole on mesa 1700 ft NW of MDA C	Core	Dacite lava with fracture coating
R-46	697–700	Monitoring well on mesa 840 ft ESE of MDA C	Cuttings	Top of lava flow; dacite lava clasts with tan volcaniclastic siltstone
MCOI-1	531–531.3	Corehole on south bench of Mortandad Canyon 1800 ft NE of MDA C	Core	Unaltered dacite lava; near top of flow
MCOI-1	800–800.6	Corehole on south bench of Mortandad Canyon 1800 ft NE of MDA C	Core	Unaltered dacite lava; near bottom of flow

Table 5.0-1
Field-Investigation Procedures for Phase III Investigation Activities at MDA C

ENV-DO-206, Sample Containers and Preservation
ENV-DO-207, Handling, Packaging, and Transporting Field Samples
SOP-01.01, General Instructions for Field Investigations
SOP-01.04. Sample Control and Field Documentation
SOP-01.05, Field Quality Control Samples
SOP-01.06, Management of Environmental Restoration Project Waste
SOP-01.08, Field Decontamination of Drilling and Sampling Equipment
SOP-01.10, Waste Characterization
SOP-03.11, Coordinating and Evaluating Geodetic Surveys
EP-ERSS-SOP-5074, Sampling for Sub-Atmospheric Air
SOP-12.01, Field Logging, Handling, and Documentation of Borehole Materials

Note: These procedures are available at http://int.lanl.gov/environment/all/qa.shtml.

Table 5.0-2
Summary of Field Investigation Procedures for Phase III Investigation Activities at MDA C

Method	Summary
Sample Containers and Preservation	Specific requirements/processes for sample containers, preservation techniques, and holding times are based on EPA guidance for environmental sampling, preservation, and quality assurance. Specific requirements for each sample are printed on the sample collection logs provided by the SMO (size and type of container, i.e. glass, amber glass, polyethylene, preservative). All samples are preserved by placing in insulated containers with ice to maintain a temperature of 4°C. Other requirements, such as use of nitric acid or other preservatives, may apply to different media or analytical requests.
Handling, Packaging, and Shipping of Samples	Field team members seal and label samples before they are packed and ensure that the sampling and transport containers are free of external contamination. Field team members package all samples to minimize the possibility of breakage during transportation. After all environmental samples are collected, packaged, and preserved, a field team member transports them to the SMO. A split of each sample is sent to an SMO-approved radiation screening laboratory under chain of custody (COC). Once the radiation screening results are received, the SMO arranges for the corresponding analytical samples to be shipped to fixed laboratories for full analyses.
Sample Control and Field Documentation	The collection, screening, and transport of samples are documented on standard forms generated by the SMO. These forms include sample collection logs, COC forms, and sample container labels. The collection logs are completed at the time the samples are collected and are signed by the sampler and a reviewer who verifies the logs for completeness and accuracy. Corresponding labels are initialed and applied to each sample container, and custody seals are placed around container lids or openings. COC forms are completed and assigned to verify the samples are not left unattended.
Field Quality Control Samples	Field quality control samples are collected as follows: *Field Duplicate*: At a frequency 10%; collected at the same time as a regular sample and submitted for the same analyses. *Equipment Rinsate Blank*: At a frequency of 10%; collected by rinsing sampling equipment with deionized water, which is collected in a sample container and submitted for laboratory analysis. *Trip Blanks*: Required for all field events that include the collection of samples for VOC analysis. Trip blanks containers of certified clean sand that are opened and kept with the other sample containers during the sampling process.
Management, Characterization, and Storage of IDW	IDW will be managed, characterized, and stored in accordance with an approved waste characterization strategy form that documents site history, field activities, and the characterization approach for each waste stream managed. Waste characterization will comply with on-site or off-site waste acceptance criteria, as appropriate. All stored IDW will be marked with appropriate signage and labels. Drums containing IDW will be stored on pallets to prevent deterioration of containers. The means to store, control, and transport each potential waste type and classification will be determined before field operations begin. A waste storage area will be established before waste is generated. Each container of waste generated will be individually labeled with waste classification, item identification number, and radioactivity (if applicable), immediately following containerization. All waste will be segregated by classification and compatibility to prevent cross-contamination.
Field Decontamination of Drilling and Sampling Equipment	Dry decontamination is the preferred method to minimize the generating liquid waste. Dry decontamination may include the use of a wire brush or other tool to remove soil or other material adhering to the sampling equipment, followed by use of a commercial cleaning agent (nonacid, waxless cleaners) and paper wipes. Dry decontamination may be followed by wet decontamination if necessary. Wet decontamination may include washing with a nonphosphate detergent and water, followed by a water rinse and a second rinse with deionized water. Alternatively, steam cleaning may be used.

Table 5.0-2 (continued)

Method	Summary
Coordinating and Evaluating Geodetic Surveys	Geodetic surveys are focused on obtaining survey data of acceptable quality for use during project investigations. Geodetic surveys will be conducted with a Trimble 5700 differential global-positioning system. The survey data will conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA D802, “Geospatial Positioning Accuracy Standard for A/E/C/ and Facility Management.” All coordinates will be expressed as SPCS 83, NM Central, U.S. feet coordinates. All elevation data will be reported relative to the National Geodetic Vertical Datum of 1983.
Sampling of Subatmospheric Air	Subsurface pore-gas samples are collected from discrete zones within each borehole. Subsurface pore-gas samples are collected using a sample-train apparatus to pull subatmospheric air from the rock formation at desired sampling intervals. Leak checks on the sample train are required before every sampling or screening activity. The Teflon tubing used to connect the sample train to the vapor inlet is replaced for every borehole to prevent cross-contamination. The sampling system is connected to the stainless-steel tubing associated with the desired sampling port and the air pump is turned on. During the purge, percent oxygen, percent carbon dioxide, and percent methane readings from the sample train exhaust are collected every several minutes using a LANDTEC GEM-500 gas extraction meter to ensure all ambient air is evacuated from the system. At the end of every purge cycle, a photoionization detector VOC reading is collected from the air in the sample-train apparatus. Vapor samples are collected using a SUMMA canister and analyzed by EPA Method TO-15. Vapor samples can also be collected in silica gel samples tubes for tritium analysis using EPA Method 906.0. All instruments used during field screening are calibrated daily following the manufacturers’ specifications.
Field Logging, Handling, and Documentation of Borehole Materials	After they reach the surface, the core barrels are immediately opened for field screening, logging, and sampling. Logging of borehole materials includes noting the run number, core recovery in feet, depth interval (in 5-ft increments), field-screening results, and lithological and structural description and taking photographs. Once the core material is logged, selected samples are taken from discrete intervals of the core. All borehole material not sampled is then disposed of as waste. No material from the boreholes will be archived.

Table 5.1-1
Phase II Vapor-Monitoring Wells and Sampling Ports

Sampling Port	Depth (ft bgs)	Unit Screened
Well 50-603470 (stainless steel)		
1	30	Qbt 3
2	83	Qbt 3
3	143	Qbt 2
4	203	Qbt 1v
5	233	Qct
6	278	Qbt 1g
7	351	Qct
8	450	Qbo
9	600	Qbo
10	650	Qbog
Well 50-603471 (FLUTe)		
1	30	Qbt 3
2	90	Qbt 3
3	146	Qbt 2
4	209	Qbt 1v
5	242	Qct
6	288	Qbt 1g
7	360	Qct
8	410	Qbo
9	450	Qbo
Well 50-603472 (stainless steel)		
1	27	Qbt 3
2	93	Qbt 3
3	146	Qbt 2
4	210	Qbt 1v
5	247	Qbt 1vc
6	292	Qbt 1g
7	364	Qct
8	414	Qbo
9	450	Qbo
Well 50-24784 (stainless steel)		
1	25	Qbt 3
2	96	Qbt 3
3	155	Qbt 2
4	215	Qbt 1v
5	244	Qbt 1vc

Table 5.1-1 (continued)

Sampling Port	Depth (ft bgs)	Unit Screened
Well 50-24784 (stainless steel) (cont.)		
6	289	Qbt 1g
7	362	Qct
8	411	Qbo
9	450	Qbo
Well 50-24813 (stainless steel)		
1	25	Qbt 3
2	99	Qbt 3
3	150	Qbt 2
4	207	Qbt 1v
5	241	Qbt 1vc
6	286	Qbt 1g
7	358	Qct
8	408	Qbo
9	450	Qbo
10	600	Qbo
Well 50-603383 (FLUTe)		
1	26	Qbt 3
2	85	Qbt 3
3	139	Qbt 2
4	206	Qbt 1v
5	244	Qbt 1vc
6	286	Qbt 1g
7	359	Qct
8	408	Qbo
9	450	Qbo
Well 50-603467 (FLUTe)		
1	26	Qbt 3
2	91	Qbt 3
3	143	Qbt 2
4	206	Qbt 1v
5	244	Qbt 1vc
6	287	Qbt 1g
7	360	Qct
8	409	Qbo
9	500	Qbo
10	600	Qbo

Table 5.1-1 (continued)

Sampling Port	Depth (ft bgs)	Unit Screened
Well 50-603468 (FLUTe)		
1	30	Qbt 3
2	92	Qbt 3
3	142	Qbt 2
4	198	Qbt 1v
5	233	Qbt 1vc
6	282	Qbt 1g
7	354	Qct
8	403	Qbo
9	450	Qbo
Well 50-24822 (stainless steel)		
1	25	Qbt 3
2	81	Qbt 3
3	142	Qbt 2
4	204	Qbt 1v
5	235	Qbt 1vc
6	280	Qbt 1g
7	351	Qct
8	402	Qbo
9	450	Qbo
Well 50-603503 (stainless steel)		
1	25	Qbt 3
2	80	Qbt 3
3	133	Qbt 2
4	198	Qbt 1v
5	237	Qbt 1vc
6	278	Qbt 1g
7	347	Qct
8	397	Qbo
9	450	Qbo
Well 50-603061 (stainless steel)		
1	25	Qbt 3
2	76	Qbt 3
3	128	Qbt 2
4	190	Qbt 1v
5	228	Qbt 1vc
6	274	Qbt 1g
7	347	Qct

Table 5.1-1 (continued)

Sampling Port	Depth (ft bgs)	Unit Screened
Well 50-603061 (stainless steel) (cont.)		
8	397	Qbo
9	450	Qbo
Well 50-603062 (stainless steel)		
1	25	Qbt 3
2	64	Qbt 3
3	122	Qbt 2
4	184	Qbt 1v
5	217	Qbt 1vc
6	263	Qbt 1g
7	337	Qct
8	387	Qbo
9	450	Qbo
Well 50-603063 (stainless steel)		
1	25	Qbt 3
2	76	Qbt 3
3	128	Qbt 2
4	190	Qbt 1v
5	228	Qbt 1vc
6	274	Qbt 1g
7	347	Qct
8	397	Qbo
9	450	Qbo
Well 50-603064 (stainless steel)		
1	25	Qbt 3
2	66	Qbt 3
3	113	Qbt 2
4	176	Qbt 1v
5	214	Qbt 1vc
6	259	Qbt 1g
7	332	Qct
8	482	Qbo
9	500	Qbo

Appendix A

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

A-1.0 ACRONYMS

AK	acceptable knowledge
bgs	below ground surface
BV	background value
CME	corrective measures evaluation
COC	chain of custody
COPC	chemical of potential concern
DOE	Department of Energy (U.S.)
EP	Environmental Programs Directorate
EPA	Environmental Protection Agency (U.S.)
EQL	estimated quantitation limit
HSA	hollow-stem auger
IDW	investigation-derived waste
LANL	Los Alamos National Laboratory
LLW	low-level waste
MCL	maximum contaminant level
MDA	material disposal area
MLLW	mixed low-level waste
NMED	New Mexico Environment Department
NOD	notice of disapproval
NOI	notice of intent
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PPE	personal protective equipment
RLWTF	radioactive liquid waste treatment facility
RPF	Records Processing Facility
SMO	Sample Management Office
SOP	standard operating procedure
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TA	technical area
TAL	target analyte list
TCE	trichloroethene

TD	total depth
TPH	total petroleum hydrocarbons
VOC	volatile organic compound
WAC	waste acceptance criteria
WCSF	waste characterization strategy form
WQCC	Water Quality Control Commission (New Mexico)

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

Investigation-Derived Waste Management

B-1.0 INTRODUCTION

This appendix describes how investigation-derived waste (IDW) generated during the Phase III investigation of Material Disposal Area (MDA) C will be managed by Los Alamos National Laboratory (the Laboratory). IDW may include, but is not limited to, drill cuttings; drilling fluids and development water; contaminated personal protective equipment (PPE), sampling supplies, and plastic; fluids from the decontamination of PPE and sampling equipment; and all other wastes potentially coming into contact with contaminants.

B-2.0 IDW

All IDW generated during investigation activities will be managed in accordance with the current version of standard operating procedure (SOP)-5238, Characterization and Management of Environmental Program Waste. This SOP incorporates the requirements of applicable U.S. Environmental Protection Agency (EPA) and New Mexico Environment Department (NMED) regulations, U.S. Department of Energy (DOE) orders, and Laboratory requirements.

The most recent version of the Laboratory’s Hazardous Waste Minimization Report will be implemented during the investigation to minimize waste generation. The Hazardous Waste Minimization Report is updated annually as a requirement of Module VIII of the Laboratory’s Hazardous Waste Facility Permit.

A waste characterization strategy form (WCSF) will be prepared and approved per requirements of SOP-5238, Characterization and Management of Environmental Program Waste. The WCSF will provide detailed information on IDW characterization methods, management, containerization, and potential volumes. IDW characterization is completed through review of sampling data and/or documentation or by direct sampling of the IDW or the media investigated (e.g., surface soil, subsurface soil, etc.). Waste characterization may include a review of historical information and process knowledge to identify whether listed hazardous waste may be present (i.e., due diligence reviews). If low levels of listed hazardous waste are identified, a “contained in” determination may be submitted for approval to NMED.

Wastes will be containerized and placed in clearly marked and appropriately constructed waste accumulation areas. Waste accumulation area postings, regulated storage duration, and inspection requirements will be based on the type of IDW and its classification. Container and storage requirements will be detailed in the WCSF and approved before the waste is generated. Table B-2.0-1 summarizes how waste is expected to be managed.

The waste streams anticipated to be generated during work plan implementation are described below.

B-2.1 Drill Cuttings

This waste stream consists of soil and rock chips generated by the drilling of vapor-monitoring boreholes. Drill cuttings from vapor-monitoring boreholes will be containerized in 20-yd^3 rolloff containers, 55-gal. drums, B-12 containers, or other appropriate containers at the point of generation. Drill cuttings from regional groundwater boreholes will be collected along with drilling fluids in lined pits constructed at the drill site. The initial management of cuttings will rely on the data from previous investigations and/or process knowledge. They will be managed in secure, designated areas appropriate to the type of waste. If new analytical data changes the expected waste category, the waste will be managed appropriate to the final waste determination.

Cuttings will be land applied if they meet the criteria in the NMED-approved Notice of Intent (NOI) Decision Tree for Land Application of Investigation Derived Waste Solids from Construction of Wells and Boreholes. This waste stream will be characterized based on direct sampling of the waste. The following analyses will be performed: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), nitrate, perchlorate, radionuclides, total metals, and, if needed, toxicity characteristic metals. If process knowledge, odors, or staining indicates the cuttings may be contaminated with petroleum products, the materials will also be analyzed for total petroleum hydrocarbons (TPH) and polychlorinated biphenyls (PCBs). Other constituents may be analyzed as necessary to meet the waste acceptance criteria (WAC) for a receiving facility. The Laboratory expects most cuttings will be land applied or disposed of as a low-level waste (LLW); however, the waste may also be classified as hazardous or mixed low-level waste (MLLW). All cuttings not land-applied will be treated/disposed of at an authorized on-site or off-site facility appropriate for the waste classification.

B-2.2 Drilling Fluids and Development Water

This waste stream consists of fluids injected into the borehole during drilling and water purged from regional wells during well development. Drilling fluids will initially be accumulated on-site in lined pits with drill cuttings. Development water will be accumulated on site in tank trailers. The initial management of development water will rely on the data from previous investigations and/or process knowledge. If new analytical data changes the expected waste category, the waste will be managed appropriate to the final waste determination.

Drilling fluids and development water will be land applied if they meet the criteria in the NMED-approved NOI Decision Tree for Land Application of Drilling, Development, Rehabilitation, and Sampling Purge Water. This waste stream will be characterized based on direct sampling of the waste. The following analyses will be performed: VOCs, SVOCs, nitrate, perchlorate, radionuclides, total metals, and, if needed, toxicity characteristic metals. Other constituents may be analyzed as necessary to meet the land application NOI or the WAC for a receiving facility. The Laboratory expects purge water will be land applied; however, the waste may also be classified as hazardous, LLW, or MLLW. All purge water not land-applied will be treated/disposed of at an authorized on-site or off-site facility appropriate for the waste classification.

B-2.3 Contact Waste

The contact waste stream consists of potentially contaminated materials that “contacted” waste during investigation activities. This waste stream consists primarily of, but is not limited, to PPE such as gloves; decontamination wastes such as paper wipes; and disposable sampling supplies. Characterization of this waste stream will use acceptable knowledge (AK) of the waste materials, the methods of generation, and analysis of the material contacted (e.g., drill cuttings). The initial management of waste will rely on the data from previous investigations and/or process knowledge. Wastes will be managed in secure, designated areas appropriate to the type of the waste. If new analytical data changes the expected waste category, the waste will be managed in accumulation areas appropriate to the final waste determination. The Laboratory expects most of the contact waste to be designated industrial waste or LLW; however, the waste may also be classified as hazardous or MLLW waste. All wastes will be treated/disposed of at an authorized on-site or off-site facility appropriate for the waste classification.

B-2.4 Decontamination Fluids

The decontamination fluids waste stream will consist of liquid wastes from decontamination activities (i.e., decontamination solutions and rinse waters). Consistent with waste minimization practices, the

Laboratory employs dry equipment decontamination methods to the extent possible. If dry decontamination cannot be performed, liquid decontamination wastes will be collected in containers at the point of generation. The decontamination fluids will be characterized through AK of the waste materials, the levels of contamination measured in the environmental media (e.g., the results of the associated drill cuttings), and, if necessary, direct sampling of the containerized waste. If directly sampled, the following analyses will be performed: VOCs, SVOCs, radionuclides, total metals, and, if needed, toxicity characteristic metals and other analytes required by the receiving facility. The Laboratory expects most of these wastes to be nonhazardous liquid waste or radioactive liquid waste that will be sent to one of the Laboratory's wastewater treatment facilities where the WAC allows the waste to be received.

Table B-2.0-1
Summary of IDW Generation and Management

Waste Stream	Expected Waste Type	Expected Disposition
Drill Cuttings	Industrial LLW	Land application or treatment/disposal at an authorized on-site or off-site facility
Drilling Fluids and Development Water	Industrial LLW	Land application or treatment/disposal at an authorized on-site or off-site facility
Contact Waste	Industrial LLW	Disposal at an approved on- or off-site facility
Decontamination Fluids	Industrial LLW	Treatment at an on-site wastewater treatment facility

Appendix C

Evaluation of the Locations of the Existing and Newly Proposed Monitoring Wells for Detecting Potential Contaminants in the Regional Aquifer from Material Disposal Area C

C-1.0 INTRODUCTION

This appendix to the Phase III investigation work plan for Material Disposal Area (MDA) C discusses an assessment of the existing and proposed groundwater monitoring well network's ability to confidently detect potential contaminant arrival in the regional aquifer from contaminant sources within MDA C. The evaluation uses existing wells and considers various options for additional groundwater wells to meet the monitoring objectives described below.

C-2.0 CONTAMINANT TRANSPORT THROUGH THE VADOSE ZONE

Contaminant transport through the vadose zone is not explicitly considered in the modeling analyses presented below. Instead, the existing data about spatial distribution of vapor-phase trichloroethene (TCE) and tritium mass from pore gas collected in the vadose zone beneath MDA C are applied to evaluate the area of potential contaminant arrival at the top of the regional aquifer. The network efficiency is then evaluated assuming that the contaminant is already within the regional aquifer within the hypothesized arrival area.

The conceptual model of contaminant transport for vapor-phase TCE and tritium in the vadose zone is described in section 2.4 of the work plan. The conceptual model assumes the transport of these constituents to the water table is predominantly vertical and downward from the existing source areas near the ground surface at MDA C. However, there is also a component of upward and lateral diffusion driven by high concentration gradients toward the adjacent canyons and the mesa top due to continuous removal by atmospheric air flow. In the deeper sections of the vadose zone (at elevations lower than the elevation of the adjacent canyons bottoms), the transport is expected to be predominantly radial and driven by diffusion (section 2.4.2 and Stauffer et al. 2005, 090537). This model also assumes the infiltration recharge from the surface-water flow along the canyon bottoms to the north and to the south of MDA C is not affecting the contaminant transport.

This conceptualization is supported by the existing TCE and tritium vapor concentration data (Tables 2.3-2 and 2.3-3 in work plan). The concentration data have been analyzed to produce spatial estimates of the contaminant distribution in the vadose zone. Figure C-2.0-1 presents a depiction of TCE vapor concentrations at elevation of about 7050 ft (about 200 ft below the ground surface at the mesa top) based on existing data from vadose zone monitoring locations. At this elevation, some of highest TCE concentrations in the vadose zone are present (Figure C-2.0-1). Figure C-2.0-2 presents observed TCE concentrations at an elevation of about 6800 ft. A comparison of Figures C-2.0-1 and C-2.0-2 indicates the size and concentration of the TCE plume decreases with depth. The area associated with the highest concentrations at 6800 ft (Figure C-2.0-2) corresponds with an area associated with very high concentrations at 7050 ft (Figure C-2.0-1), indicating a vertical component of the contaminant transport between these elevations. The contour line of 40,000 $\mu g/m^3$ TCE concentration in Figure C-2.0-2 is applied to represent the most probable location where the TCE contamination would reach the regional aquifer. This location is based on an assumption of a dominantly vertical transport of the center of the vapor plume in the vadose zone between the elevation of 6800 ft and the regional aquifer at approximately 5900 ft.

Figure C-2.0-3 shows tritium vapor concentrations at an elevation of about 7200 ft (about 50 ft below the ground surface at the mesa top). At this elevation, some of highest tritium pore-gas concentrations in the vadose zone have been detected (Figure C-2.0-3). Figure C-2.0-4 presents detected tritium concentrations at an elevation of about 6750 ft. As is the case with TCE, the tritium vapor plume is more spatially constrained deeper in the vadose zone. The area of the highest concentrations at approximately 6750 ft (Figure C-2.0-4) generally corresponds with the area of the highest concentrations at approximately 7200 ft (Figure C-2.0-3). Again, these observations of spatial distribution of contaminant concentrations indicates that there is a predominantly vertical component of the contaminant transport between these elevations. The contour line of 20,000 pCi/L tritium concentration in Figure C-2.0-4 is applied to represent the most probable location where the tritium contamination would likely reach the regional aquifer. This location is based on an assumption of vertical transport of the center of the vapor plume in the vadose zone above the regional aquifer.

As a result, based on the existing pore-gas data for TCE and tritium, two potential breakthrough locations of contaminant arrival at the top of the regional aquifer have been identified for these two different sources. These locations are applied to model contaminant transport in the regional aquifer.

C-3.0 NETWORK EVALUATION OF THE REGIONAL MONITORING WELLS

A major objective of the numerical simulations is to analyze flow and contaminant transport directions near potential breakthrough locations at the regional aquifer beneath MDA C. Through this analysis, two new monitoring wells are proposed to provide efficient detection in the regional aquifer of potential plumes originating from MDA C. The regional aquifer beneath, and downgradient of, MDA C is within Puye Formation sediments.

The numerical simulation of contaminant transport in the regional aquifer is performed using an analytical model. The model simulates three-dimensional advective-dispersive contaminant transport in the regional aquifer from a contaminant source with a given volume (cf., Wexler 1992, 106994). Previously, this model has been applied to simulate chromium transport in the regional aquifer beneath Sandia Canyon (LANL 2007, 098938). Various hydrogeological parameters characterize the potential contaminant transport in the regional aquifer, and a distribution of values is used for each of the parameters. In the analyses presented below, the parameters include (1) groundwater flow directions, (2) hydraulic gradient, (3) aquifer permeability and porosity, (4) longitudinal and transverse dispersivities, and (5) size and location of the breakthrough location at the top of the regional. The model parameters are also listed in Table C-3.0-1. The model analysis incorporates the distribution of possible values for each of the parameters, as discussed below.

Groundwater flow directions and magnitudes 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). However, the groundwater flow directions in the regional aquifer beneath MDA C are uncertain because of the low density of existing wells in the immediate vicinity of MDA C. More specifically, there is a limited control on the regional flow directions west and north of MDA C (Figure C-3.0-1). To the south of MDA C near wells R-47 and R-17, flow directions appear to be to the northeast; the flow directions are not due east/southeast toward the Rio Grande as previously speculated. Alternative maps of the regional water table based on previous analyses are presented in other Los Alamos National Laboratory reports (LANL 2007, 095364; LANL 2008, 101932). The existing water-level data indicate a relatively complex structure of the regional flow that may be caused by (1) aquifer heterogeneity and anisotropy (stratification) and (2) the influence of water-supply pumping. Based on the current data, the regional flow downgradient from MDA C may be in directions varying between east-northeast and east-southeast, as presented in Figure C-3.0-1. Uncertainties in the flow directions and hydraulic gradients are incorporated in the evaluation of network efficiency (Table C-3.0-1).

Puye Formation sediments within the regional aquifer appear to be highly heterogeneous. The closest monitoring well downgradient from MDA C is well R-46 (at about 200–400 m [approximately 600-1200 ft]; Figure C-3.0-1). Permeability estimated at well R-46 during a single-hole pumping test (conducted as a part of the well development) is about 2 m/d (7 ft/d). Estimates of Puye Formation permeability in the regional aquifer at the monitoring wells farther downgradient of MDA C vary between 0.3 and 20 m/d (approximately 1–60 ft/d) (Table C-3.0-1). The uncertainty in porosity values for the Puye Formation sediments within regional aquifer units is based on data from the literature (Freeze and Cherry 1979, 088742) and site-specific knowledge (Keating et al. 2001, 095399) (Table C-3.0-1).

Dispersion of the contaminant plumes in the regional aquifer is represented in the model by longitudinal and transverse dispersivities (cf., Lichtner et al. 2002, 095397). Site-specific data supporting dispersivity values are not available. Based on data from literature, the selected range of values is reasonable for the spatial scale of simulated contaminant transport ([on the order of hundreds of meters] Neuman 1990, 090184) and the properties of the flow medium (Table C-3.0-1).

Contaminant transport in the regional aquifer is modeled from two potential breakthrough locations (Figure C-3.0-2). The selection of the breakthrough locations is discussed in the previous section of this appendix. Using two alternative breakthrough locations allows for a more conservative approach for analyzing monitoring network detection efficiencies. The simulated plumes migrate in the regional aquifer downgradient of these breakthrough locations. In addition, the analysis takes into account the uncertainty associated with the potential size of the breakthrough locations; the uncertainty ranges are presented in Table C-3.0-1.

To estimate uncertainty in the model predictions, a Monte Carlo analysis is performed. A set of 1000 uncorrelated, equally probable random realizations are generated using a Latin Hypercube sampling technique with the software Crystal Ball. Each realization includes eight random variables, representing various model parameters listed in Table C-3.0-1.

Simulated plumes are based on a unit concentration at the potential arrival location for each of the breakthrough areas. Therefore, the model produces concentrations at the monitoring wells that are relative to the original unit concentration at the breakthrough areas. The transport within the regional aquifer of a nonsorbing conservative contaminant is then simulated. No analytical detection limit or regulatory limits are used in this analysis because the predicted concentrations are relative, not absolute. Therefore, the modeling results do not indicate whether any of the plumes are associated with concentrations that could exceed regulatory standards or detection limits. However, the simulations yield information about flow directions and about relative magnitudes of concentrations at monitoring wells that are evaluated to determine the efficiency of the network.

This network analysis evaluates the existing R-46 location and nine new prospective monitoring well locations. The well locations are presented in Table C-3.0-2 and Figure C-3.0-2. The prospective regional monitoring well locations are labeled MW-H, MW-G, MW-1, MW-2, MW-3, MW-4, MW-N1, MW-N2, and MW-N3. All the locations are potentially suitable for drilling based on existing information about the terrain and construction locations.

C-4.0 MONITORING METRICS

The groundwater monitoring metric set for MDA C for this network evaluation is that the monitoring network must detect potential contaminant plumes in the regional aquifer with detection efficiency higher than 95%. In the model, successful detections are plumes detected by any of the existing or prospective monitoring wells near MDA C. The detection efficiency is the number of successfully detected plumes divided by the number of simulated plumes (1000 plumes). An additional metric is that the wells are located sufficiently close to the assumed breakthrough locations to support early detection (less than 5 yr) in the event that a contaminant were to arrive at the regional aquifer.

C-5.0 RESULTS

The detection efficiency of the regional monitoring wells to detect plumes potentially originating from MDA C is shown in Table C-5.0-1. Average pore (linear) velocity and travel times from the potential sources to the wells are also presented in the table. For the potential TCE plume, the results indicate that the proposed monitoring-well locations labeled as MW-G, MW-2, and MW-3 are capable individually of detecting potential plumes from the assumed breakthrough locations with detection efficiency above 95%. For the potential tritium plume, only the MW-3 location provides detection efficiency above 95%. Table C-5.0-1 lists the detection efficiency of MW-1 and MW-4 simultaneously; their combined efficiency is above 95% for both potential plumes. In addition, analyses were performed to evaluate the detection efficiency of various groups of monitoring wells. As a result, monitoring wells MW-1 and MW-4 are proposed to augment the existing monitoring network near MDA C.

The average pore (linear) velocity from the potential plume sources to the wells are listed in Table C-5.0-1. Also presented are the average travel times. It is important to note that the travel time from the potential sources to MW-1 and MW-4 is on the order of 5 yr or less. Installation of these two wells will provide early detection for potential contamination of the regional aquifer.

C-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.

Freeze, R.A., and J.A. Cherry, January 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey. (Freeze and Cherry 1979, 088742)

Keating, E.H., V.V. Vesselinov, Z. Lu, and E. Kwicklis, 2001. "Annual Report on Regional Aquifer Modeling and Data Analysis," Los Alamos National Laboratory document LA-UR-04-1420, Los Alamos, New Mexico. (Keating et al. 2001, 095399)

LANL (Los Alamos National Laboratory), March 2007. "2007 General Facility Information," Los Alamos National Laboratory document LA-UR-07-1839, Los Alamos, New Mexico. (LANL 2007, 095364)

LANL (Los Alamos National Laboratory), September 2007. "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon," Los Alamos National Laboratory document LA-UR-07-6018, Los Alamos, New Mexico. (LANL 2007, 098938)

LANL (Los Alamos National Laboratory), March 2008. "2008 General Facility Information," Los Alamos National Laboratory document LA-UR-08-1538, Los Alamos, New Mexico. (LANL 2008, 101932)

Lichtner, P.C., S. Kelkar, and B. Robinson, August 17, 2002. "New Form of Dispersion Tensor for Axisymmetric Porous Media with Implementation in Particle Tracking," *Water Resources Research,* Vol. 38, No. 8, pp. 21-1–21-16. (Lichtner et al. 2002, 095397)

Neuman, S.P., August 1990. “Universal Scaling of Hydraulic Conductivities and Dispersivities in Geologic Media,” *Water Resources Research,* Vol. 26, No. 8, pp. 1749-1758. (Neuman 1990, 090184)

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

Vesselinov, V.V., 2005. “An Alternative Conceptual Model of Groundwater Flow and Transport in Saturated Zone Beneath the Pajarito Plateau,” Los Alamos National Laboratory document LA-UR-05-6741, Los Alamos, New Mexico. (Vesselinov 2005, 090040)

Wexler, E.J., 1992. “Analytical Solutions for One-, Two-, and Three-Dimensional Solute Transport in Ground-Water Systems with Uniform Flow,” Chapter B7 of *Techniques of Water-Resources Investigations of the United States Geological Survey*, United States Government Printing Office, Washington, D.C. (Wexler 1992, 106994)

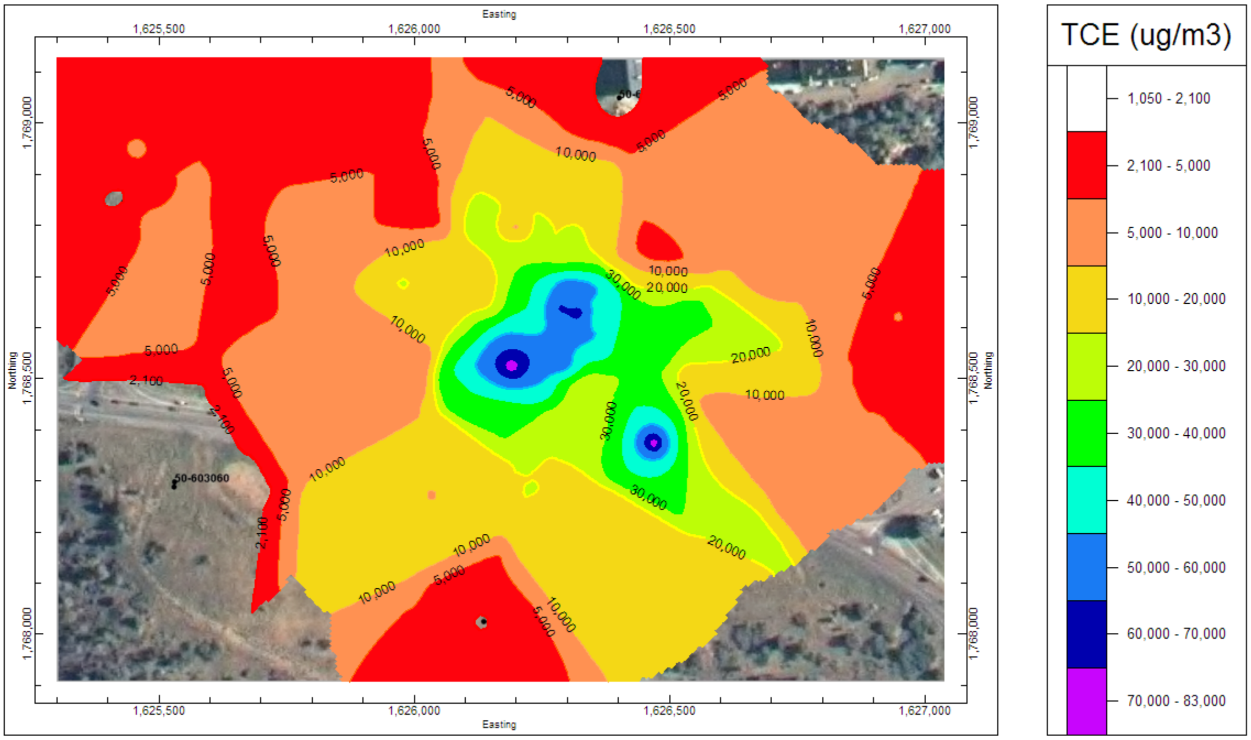


Figure C-2.0-1 TCE concentrations at elevation of 7050 ft

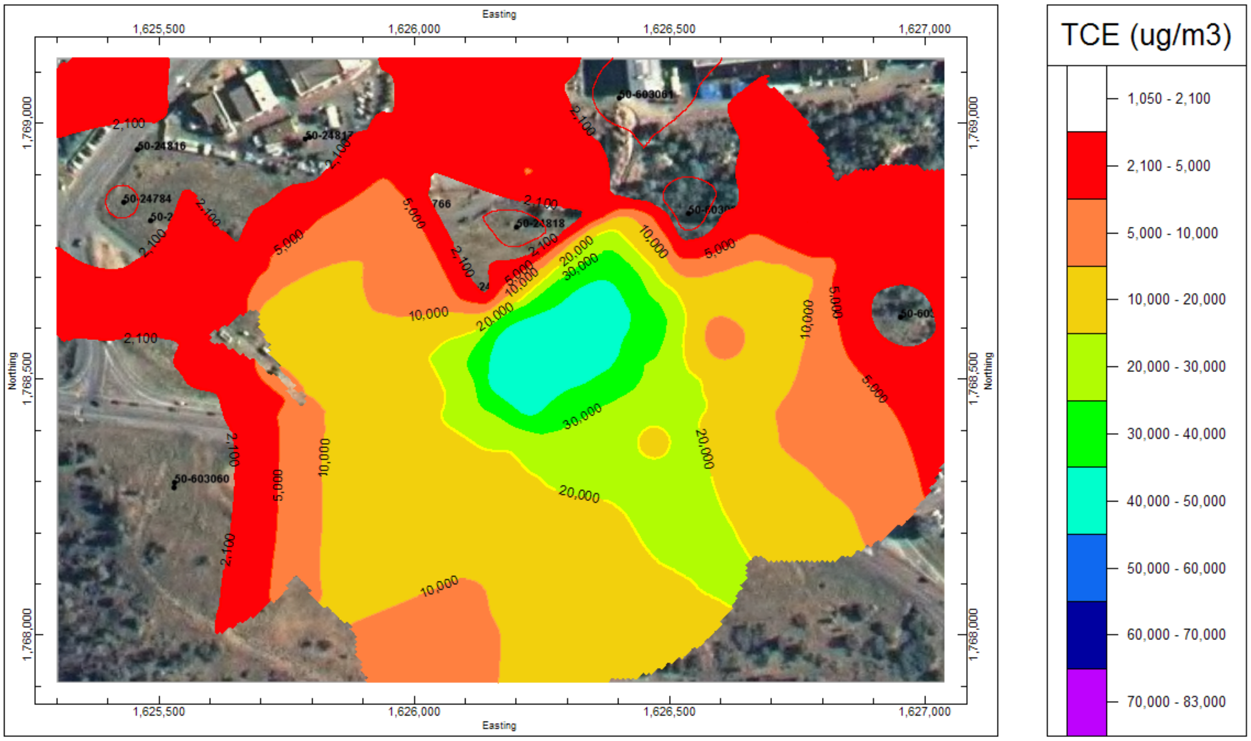


Figure C-2.0-2 TCE concentrations at elevation of 6800 ft

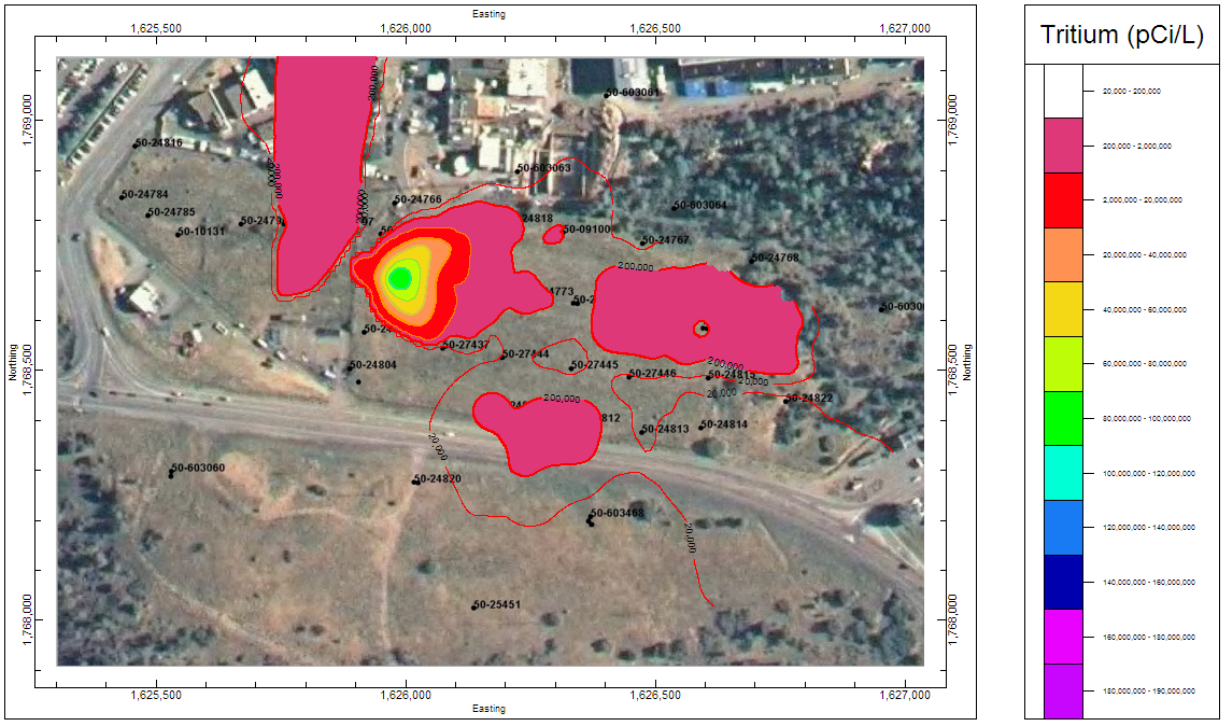


Figure C-2.0-3 Tritium concentrations at elevation of 7200 ft

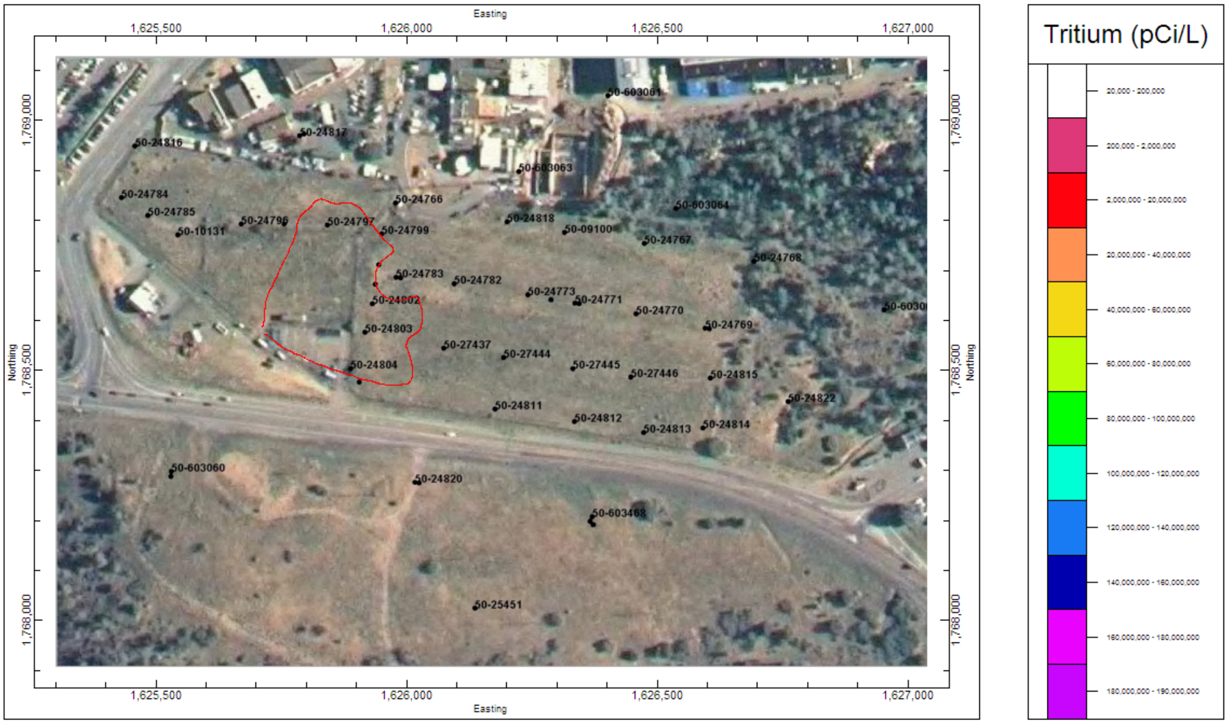
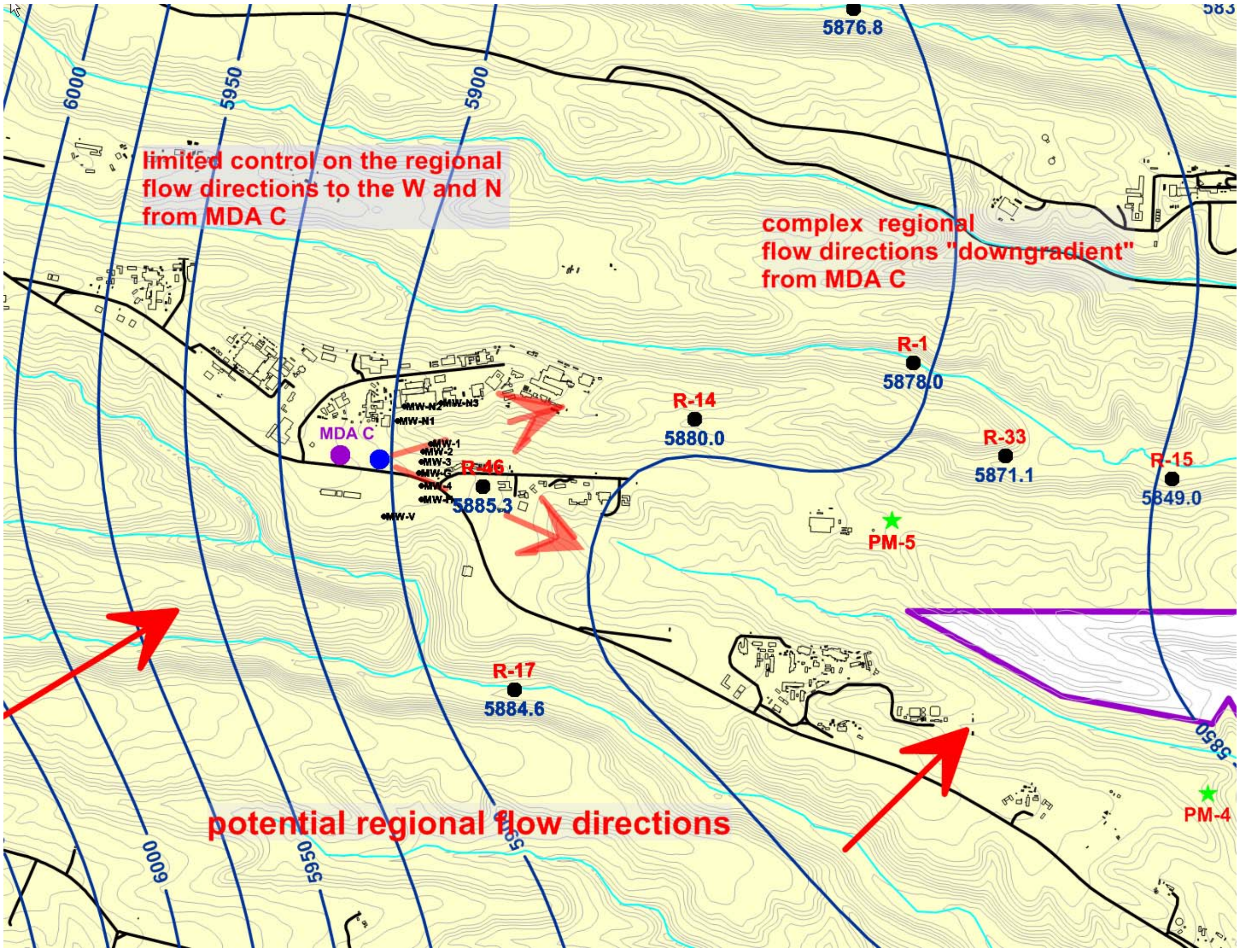


Figure C-2.0-4 Tritium concentrations at elevation of 6750 ft



Note: Existing (2009) and preliminary water-level data at the monitoring wells are used to estimate potential directions of the groundwater flow in the regional aquifer.

Figure C-3.0-1 Map of the elevation of the regional water table

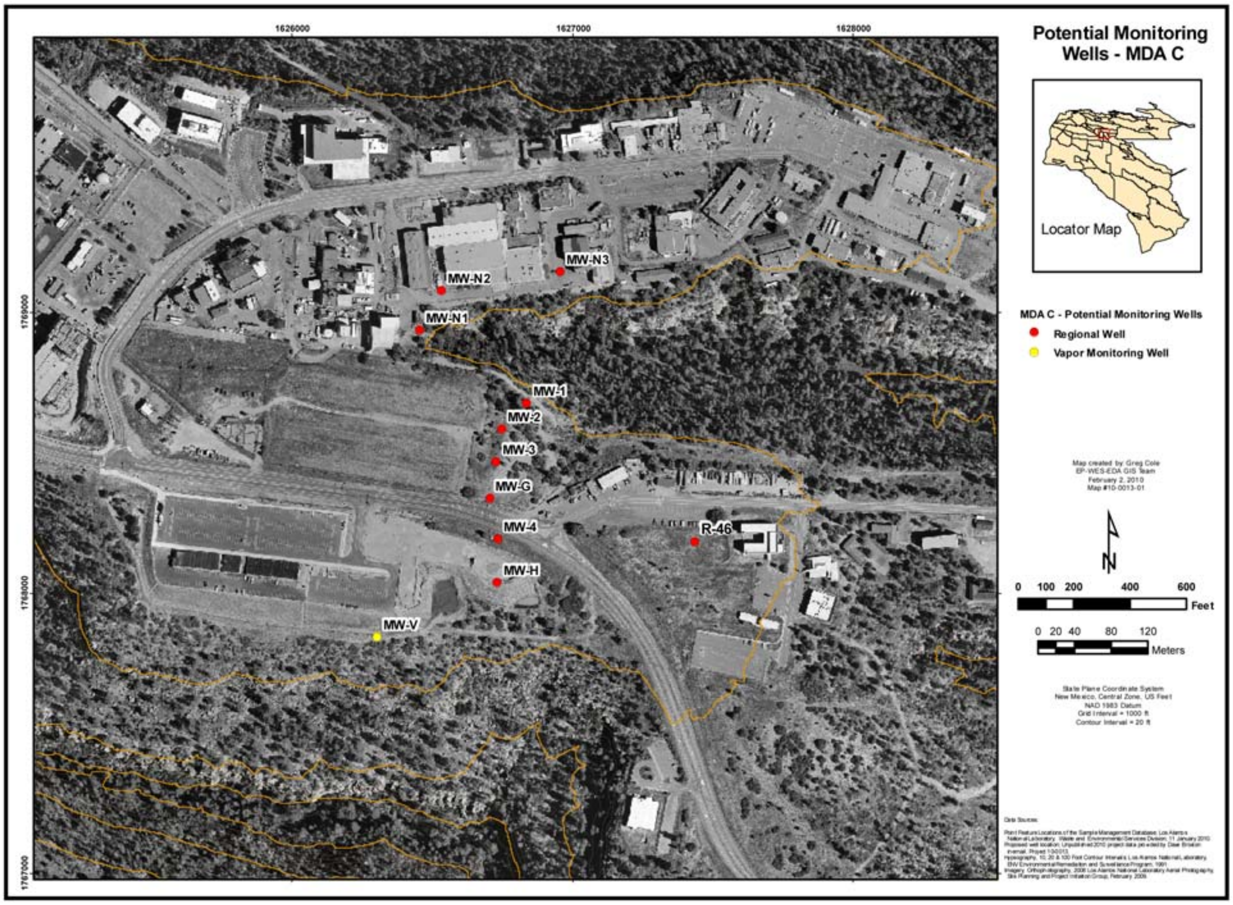


Figure C-3.0-2 Map of the existing and newly proposed regional monitoring wells near MDA C

Table C-3.0-1
Model Parameters to Evaluate the Monitoring Network of Regional Aquifer Wells Near MDA C

Parameter	Best Estimate	Range	
		Minimum	Maximum
Source x dimension (m)	50	10	100
Source y dimension (m)	50	10	100
Porosity (m^3/m^3)	0.1	0.05	0.15
Flow Angle (degrees)	0	–30	20
Hydraulic gradient (m/m)	0.014	0.022	0.011
Permeability (m/d)	2.3	0.3	20
Dispersivity longitudinal (m)	10	1	100
Dispersivity transverse (m)	1	1	10

Note: Each parameter has a range of values used in the model runs.

Table C-3.0-2
Locations of Potential New Regional Aquifer Monitoring Wells Near MDA C

Well	x (m)	y (m)
MW-G	495819.1	538989.4
MW-H	495827.3	538898.3
MW-1	495859.9	539092.7
MW-2	495832.2	539064.4
MW-3	495826.4	539029.7
MW-4	495828.2	538945.2
MW-V	495697.2	538838.9
MW-N1	495742.9	539172.0
MW-N2	495767.0	539221.8
MW-N3	495895.5	539235.3

Table C-5.0-1
Detection Efficiency of the Existing and Newly Proposed Monitoring Wells of Plumes Originating from the Two Potential Breakthrough Locations

Wells	TCE			Tritium		
	Detection Efficiency	Average Velocity (m/yr)	Average Travel Time (yr)	Detection Efficiency	Average Velocity (m/yr)	Average Travel Time (yr)
MW-G	96.0%	102.0	2.4	87.8%	149.1	4.4
MW-H	45.9%	112.1	4.4	54.1%	148.9	5.9
MW-1	82.8%	115.8	3.2	79.0%	155.8	4.9
MW-2	95.9%	105.0	2.5	90.1%	151.3	4.3
MW-3	99.8%	103.8	2.2	95.1%	150.6	4.2
MW-4	75.7%	108.5	3.3	72.0%	150.8	5.1
MW-N1	20.3%	88.3	3.8	45.4%	120.4	4.6
MW-N2	5.0%	101.6	5.5	25.6%	127.5	6.1
MW-N3	14.9%	129.4	6.9	30.1%	154.5	7.8
R-46	76.1%	174.5	6.0	67.9%	192.7	8.0
MW-1 + MW-4	99.5%	—*	—	99.8%	—	—

Note: Average pore (linear) velocity and travel time from the potential sources to the monitoring wells are also presented.

* — = Not calculated.