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Pilot Test Investigation Report for Evaluating Vapor-Sampling Systems at Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50

Los Alamos
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EXECUTIVE SUMMARY

This investigation report presents the results of a pilot test at Material Disposal Area (MDA) C, Solid Waste Management Unit 50-009, at Los Alamos National Laboratory. The objective of the pilot test is to evaluate three subsurface vapor-sampling systems, the packer system, the Flexible Liner Underground Technology (FLUTe) system, and the stainless-steel (SS) tubing system.

Subsurface vapor samples were collected from four sets of paired boreholes inside the MDA C boundary and to the north and south outside of the MDA C boundary. At each set of paired boreholes, subsurface vapor samples were collected from the same or similar depth interval(s) using different vapor-sampling systems. In the paired boreholes inside the MDA C boundary and in the paired boreholes to the north of the MDA C boundary, vapor samples were collected using a packer system in one of the paired boreholes and a Flexible Liner Underground Technology (FLUTe) system in the other boreholes. In the paired boreholes to the south of the MDA C boundary, vapor samples were collected using the FLUTe system, which was equipped with both nylon tubing and polyvinylidene fluoride (PVDF) tubing. In the paired boreholes to the east of borehole 50-24820 and to the south of the MDA C boundary, vapor samples were collected using the packer and the SS tubing systems in one borehole (in sequence) and the FLUTe system in the other borehole.

Vapor samples were analyzed for volatile organic compounds (VOCs) and tritium. Results of samples collected using different sampling systems were compared. The overall VOC concentrations were slightly greater when the FLUTe system was used than when the packer system was used in the paired boreholes to the north and outside of the MDA C boundary. However, the VOC concentrations were generally similar in the paired boreholes inside the MDA C boundary, except for three VOCs, which were higher in samples collected using the packer system. The overall VOC concentrations were greater when the SS tubing system was used than when packer system was used, and the overall VOC concentrations were slightly greater when the SS tubing system was used than when FLUTe system was used. The results of all three sampling systems used in the paired boreholes east of borehole 50-24820 and to the south of the MDA C boundary indicated that the fewest VOCs were detected when the SS tubing system was used. For the two types of tubing used in the FLUTe system, there was no difference in the results from samples collected using either nylon or PVDF tubing. For tritium, three sets of paired boreholes had comparable data in one or two depth intervals, while the other paired boreholes had sporadically detected concentrations. The reported tritium concentrations were higher when the FLUTe system was used than when the packer system was used in the paired boreholes inside the MDA C boundary and north of the MDA C boundary. However, tritium concentrations were lower when either the packer system or the FLUTe system was used, compared with when the SS tubing system was used in the paired boreholes east of borehole 50-24820 and to the south of the MDA C boundary.

Based on the pilot test results, the packer system is adequate for initial measuring of pore-gas concentrations, while the FLUTe system and the SS tubing system are preferable for subsurface vapor monitoring. None of the methods appear to result in adsorption of VOCs and tritium in the sampling train that clearly bias the results.

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1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or the Laboratory) is a multidisciplinary research facility that 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 above sea level.

The site addressed in this report, Solid Waste Management Unit 50-009, is also known as Material Disposal Area (MDA) C (Figure 1.0-1). It is an inactive 11.8-acre landfill consisting of 6 disposal pits, a chemical disposal pit, and 108 shafts (Figure 1.0-2) and is potentially contaminated with both hazardous and radioactive chemicals. 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 U.S. Department of Energy (DOE) policy.

Phase II investigation activities are currently being conducted at MDA C. These activities include drilling five new boreholes and extending nine existing boreholes to greater depths to collect tuff and pore-gas samples, according to the approved Phase II investigation work plan (LANL 2007, 098425; NMED 2007, 098440). NMED requested that a pilot test be conducted to evaluate and compare three different vapor-sampling systems, all of which have been used at the Laboratory, because of possible adsorption of contaminants to sampling tubing. This investigation report describes the pilot test activities conducted according to the approved pilot test work plan (LANL 2008, 101653) and NMED modifications (2008, 101113) and presents the results for each subsurface vapor-sampling system.

1.1 Background and Purpose of the Pilot Test

Subsurface pore-gas samples have been collected at MDA C using the packer system. This system uses an inflatable packer and a sample-train apparatus to pull subatmospheric air from the rock formation at desired sampling intervals. Teflon tubing is used to connect the sample train and the vapor inlet of the inflatable packer. The approved Phase II investigation work plan proposes that vapor-monitoring systems be installed after the sampling activities at MDA C are completed (LANL 2007, 098425). The approved Phase II work plan proposes to use a Flexible Liner Underground Technology (FLUTe) system for vapor monitoring (LANL 2007, 098425). The FLUTe system uses a flexible liner that provides a seal against the borehole wall once it is filled with sand. The sampling ports and the tubing are installed in the interior sleeves of the liner, and the tubing runs to the surface where vapor samples are collected. The FLUTe membrane liner is made of urethane-coated nylon fabric, and the tubing is made of nylon.

Vapor-sampling results at MDA H have raised concerns regarding the potential for adsorption of contaminants by the nylon membrane and tubing used in the FLUTe system. The potential adsorption of contaminants by the Teflon tubing used in the packer system is also a potential issue.

The purpose of the pilot test is to evaluate and compare volatile organic compound (VOC) and tritium concentrations in vapor samples collected using three different vapor-monitoring systems: the packer system previously used for vapor sampling at MDA C, the FLUTe system proposed in the approved Phase II investigation work plan, and a stainless-steel (SS) tubing system. All three systems have been used at the Laboratory for collecting vapor-phase samples at different sites. The pilot test evaluates these three systems at a single Laboratory site.

1.2 Three Vapor-Sampling Systems

The operation of the three vapor-sampling systems is described in detail below.

The packer system uses an inflatable packer and a sample-train apparatus to pull vapor from the rock formation at desired sampling intervals. The packer is lowered down the borehole and inflated with nitrogen to seal off a vapor inlet at the desired depth. The sample train is purged to ensure formation air is being collected. Teflon tubing connects the vapor inlet and the sample train and is replaced for every borehole to prevent cross-contamination. Sampling is performed by extracting the formation air through the vapor inlet at the desired depth.

The FLUTe system uses a flexible liner that provides a seal against the borehole wall. The sampling ports and the nylon tubing are installed in the interior sleeves of the liner. The liner is lowered into the borehole while the borehole is supported by a temporary casing, and it is filled with sand as the casing is withdrawn. The pressure of the sand inside the liner seals the liner against the borehole wall, pressing the sampling ports against the formation. Vapor is drawn through a permeable spacer material between the liner and the borehole wall and into the tubing. A diffusion barrier is installed in the permeable spacer material to minimize the potential for interactions with the material that could affect analyte concentrations. The standard nylon tubing can be replaced by polyvinylidene fluoride (PVDF) tubing for the FLUTe system.

The SS tubing system uses continuous lengths of 0.25-in.-outside diameter SS tubing with a single port installed at the target depth of each tube. Bentonite is used above and below each sampling port to seal off the interval to be sampled. The 5-ft space between the bentonite seals at each sampling interval is filled with sand. Sampling is performed by extracting the formation air through the sand layer and into the SS tubing. Figure 1.2-1 shows the final design drawings of the FLUTe and stainless-steel tubing systems at boreholes 50-603468 and 50-603373 respectively.

2.0 SCOPE OF ACTIVITES

This section describes the investigation activities conducted for the pilot test at MDA C in 2008. The quality procedures (QPs) and standard operating procedures (SOPs) used during the pilot test are listed in Table B-1.0-2 in Appendix B. The most current revisions of all QPs and SOPs were used. Specific details of the methods used for drilling and sampling activities are presented in Appendix B, along with descriptions of deviations from the approved pilot study work plan (LANL 2008, 101653).

2.1 Number, Locations, and Depths of Boreholes

The pilot test work plan identified five boreholes to be included in the pilot test: a set of two boreholes located adjacent to each other (50-24821 and 50-603373 [PT-1]), a borehole located inside the MDA C boundary (50-24771), a borehole located to the north of the MDA C boundary (50-24817), and a borehole located to the south of MDA C (50-24820) (LANL 2008, 101653). The five boreholes were planned to be extended with the hollow-stem auger (HSA) method to a depth of 300 ft below ground surface (bgs). After this depth was reached and vapor samples were collected using the packer system, each borehole was going to be extended by air-rotary (AR) drilling to a depth of 450 ft bgs. However, technical problems occurred during the first FLUTe installation at borehole 50-24820 that were associated with extending an auger-drilled borehole with casing advance AR drilling. The AR drilling did not exactly follow the 300-ft auger-drilled borehole. Additional space was created in the top 300 ft of the borehole that resulted in a collapse of the FLUTe system. To avoid this problem at the other pilot study boreholes, a paired borehole was installed adjacent to the auger-drilled borehole. All paired borehole were drilled using the casing advance AR method.

The pilot test includes a total of eight boreholes divided into four sets of paired boreholes. One set of paired boreholes is located inside the MDA C boundary (boreholes 50-24771 and 50-603471). The other three sets of paired boreholes are located outside the MDA C boundary. One set of paired boreholes is located to the north of the MDA C boundary (boreholes 50-24817 and 50-603383), one set of paired boreholes is located to the south of the MDA C boundary (boreholes 50-24820 and 50-603467), and one set of paired boreholes is located to the east of borehole 50-24820 and to the south of the MDA C boundary (boreholes 50-603373 and 50-603468). The paired boreholes are less than 10 ft apart. All the borehole locations for the pilot test are shown in Figure 2.1-1.

Borehole 50-24771 originally had a total depth (TD) of 150 ft bgs. It was extended to 300 ft bgs and sampled with a packer system using standard Teflon tubing. A new borehole, 50-603471, was drilled next to borehole 50-24771 to a TD of 450 ft bgs. It was installed with a FLUTe system using standard nylon tubing.

Borehole 50-24817 originally had a TD of 300 ft bgs. It was sampled with a packer system using standard Teflon tubing. A new borehole, 50-603383, was drilled next to borehole 50-24817 to a TD of 450 ft bgs. It was installed with a FLUTe system using standard nylon tubing.

Borehole 50-24820 originally had a TD of 250 bgs. It was extended to 600 ft bgs and was installed with a FLUTe system. The FLUTe system was equipped with two sets of tubing: one was standard nylon tubing and the other was PVDF tubing. A new 600-ft borehole, 50-603467, was drilled next to borehole 50-24820 to a TD of 600 ft bgs after the FLUTe system failed in borehole 50-24820. The new borehole was also installed with a FLUTe system equipped with standard nylon tubing and PVDF tubing.

Borehole 50-24821 originally had a TD of 250 ft bgs. Two new boreholes were drilled near borehole 50-24821. Borehole 50-603373, which is borehole PT-1 in the approved pilot test work plan (LANL 2008, 101653), was drilled to 300 ft bgs. It was sampled with a packer system first and then with an SS tubing system at the same depth intervals. The second new borehole, 50-603468, was drilled using the AR method to a TD of 450 ft bgs. It was installed with the FLUTe system using standard nylon tubing.

2.2 Drilling and Installation of Vapor-Sampling System

Boreholes were drilled using an HSA to a depth of 300 ft and then using AR drilling to extend the borehole to TD. The inside diameter of the HSA flights is 4 in. For AR drilling, casing is advanced as the drill bit advances and prevents sloughing of any material from soft, unconsolidated intervals into the borehole during drilling and after drilling is completed. The inside diameter of the casing is 9.625 in. In the pilot test, AR drilling was used to extend boreholes 50-24771, 50-24817, and 50-24820 and to drill new boreholes 50-603373, 50-603383, 50-603467, 50-603468, and 50-603471 to TD.

Borehole logs were recorded for all boreholes and included lithologic descriptions and notes regarding lithologic unit contacts, fractures encountered, and any other conditions that may have affected sampling results. Borehole and screening logs are provided in Appendix C.

For the installation of the FLUTe and SS tubing systems, the sand pack for the FLUTe system and the bentonite for the SS tubing system were placed in the boreholes using a tremie pipe. The outside diameter of the tremie pipe during FLUTe installation is 4 in. The outside diameter of the tremie pipe during SS tubing installation is 2 in.

2.3 Subsurface Vapor Sampling

2.3.1 Subsurface Vapor Sampling at Each Borehole

All subsurface vapor sampling was conducted in compliance with Section IX.B.2.g of the Consent Order. The vapor-sampling systems were purged to ensure rock formation air fills the systems. Purge times for each vapor-sampling system is based on the inside diameter of the tubing used (0.18 in. for all tubing); the length of tubing for each port; the nominal flow rate of the pumps (30 ft^3/h); and for the packer system, the void space associated with the packers. The time required to purge the entire tubing volume for the FLUTe and SS tubing systems and the tubing volume, plus packer void space for the packer system, was less than 1 min. Purge times for each system were 5, 10, and 20 min in each borehole. These purge times are conservative and allow for the complete purging of all parts of each sampling system to ensure that samples contain only formation air.

Vapor samples for VOC analysis were collected in SUMMA canisters, one sample per canister. One vapor sample was collected after each purge time. Therefore, a total of three SUMMA samples were collected at each depth interval. A silica gel sampler was used to collect the tritium sample at each depth after the SUMMA canister samples were collected. Table 2.3-1 presents the details of the vapor samples collected for the pilot test.

In paired boreholes 50-24771 and 50-603471, vapor samples were collected using the packer system and the FLUTe system, respectively. The sampling event in borehole 50-603471 occurred approximately 2 mo after sampling borehole 50-24771.

- In borehole 50-24771, vapor samples were collected using the packer system with standard Teflon tubing at 100 and 150 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected at each sampling depth. Thus, a total of six VOC samples and two tritium samples were collected from borehole 50-24771.
- In borehole 50-603471, vapor samples were collected using the FLUTe system with standard nylon tubing at 100 and 150 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected at each sampling depth. Thus, a total of six VOC samples and two tritium samples were collected from borehole 50-603471.

In paired boreholes 50-24817 and 50-603383, vapor samples were collected using the packer system and the FLUTe system, respectively. The sampling in borehole 50-603383 occurred approximately 1 mo after sampling borehole 50-24817.

- In borehole 50-24817, vapor samples were collected using the packer system with standard Teflon tubing at 140 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected from borehole 50-24817.
- In borehole 50-603383, vapor samples were collected using the FLUTe system with standard nylon tubing at 139 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected from borehole 50-603383.

In paired boreholes 50-24820 and 50-603467, vapor samples were collected using the FLUTe system equipped with two types of tubing, nylon, and PVDF. The sampling in borehole 50-603467 occurred approximately 8 wk after sampling borehole 50-24820.

- In borehole 50-24820, vapor samples were collected concurrently using the two types of tubing at 206 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, were collected using each type of tubing. Thus, a total of six VOC samples were collected in borehole 50-24820. The FLUTe system collapsed before the remaining VOC samples and tritium samples could be collected from this borehole.

- In borehole 50-603467, vapor samples were collected concurrently using the two types of tubing at 26 and 206 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected at each sampling depth using each type of tubing. Thus, a total of 12 VOC samples and 4 tritium samples were collected from borehole 50-603467.

In paired boreholes 50-603373 and 50-603468, vapor samples were collected first using the packer system and then using the SS tubing system in borehole 50-603373 and using the FLUTe system with standard nylon tubing in borehole 50-603468. The sampling event in borehole 50-603468 occurred approximately 2 mo after the SS tubing sampling in borehole 50-603373.

- In borehole 50-603373, vapor samples were collected first using the packer system with standard Teflon tubing and then using the SS tubing system. The packer system sampling was completed in 2 d at depth intervals of 30, 90, and 260 ft. The installation of the SS tubing system and the sampling at the 260-ft-depth interval were completed 15 d later. The installation of the SS tubing system and the sampling at the 30- and 90-ft depth intervals were completed 3 d later. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected at each sampling depth for each sampling system. Thus, a total of 18 VOC samples and 6 tritium samples were collected from borehole 50-603373.
- In borehole 50-603468, vapor samples were collected using the FLUTe system with standard nylon tubing at 30, 90, and 260 ft. Three VOC samples with purge times of 5, 10, 20 min, respectively, and one tritium sample were collected at each sampling depth. Thus, a total of nine VOC samples and three tritium samples were collected from borehole 50-603468.

2.3.2 Collection of Subsurface Vapor Samples

All vapor-sampling activities were performed according to the approved work plan as follows. Sample collection logs are included in Appendix E.

- The nominal flow rate for all tests was 30 ft^3/h. Actual flow rates were recorded during purging and sampling. The flow rate was measured using a Kobold Instruments, Inc., SCFH Air Meter.
- Vapor samples were collected in SUMMA canisters after each depth interval was purged for 5, 10, and 20 min.
- After the third SUMMA sample was collected at each depth interval, a vapor sample was collected using a silica gel sampler.
- Concentrations (percent) of methane, carbon dioxide, and oxygen were measured and recorded every 2 min during purging, between samples, and immediately before samples were collected. Concentrations were measured using a LANDTEC GEM 500 Gas Extraction Meter.
- Ambient-air temperature and barometric pressure were recorded immediately before each sample was collected.
- Any other field condition that may influence sampling results, if any, was recorded in a field notebook.

2.3.3 Analysis of Subsurface Vapor Samples

SUMMA canisters were submitted through the Laboratory's Sample Management Office (SMO) to an off-site contract analytical laboratory for analysis of VOCs by U.S. Environmental Protection Agency (EPA) Method TO-15.

Silica-gel samplers were submitted through the SMO to an off-site contract analytical laboratory for analysis of tritium by EPA Method 906.0.

All samples were submitted with requests for 15 workday returns of full analytical data packages.

3.0 ANALYTICAL RESULTS

The analytical methods and the data quality review are presented in Appendix D. The analytical suites and results are presented in Appendix E.

3.1 Boreholes 50-24771 and 50-603471

Two depth intervals, 100 ft and 150 ft, were sampled in boreholes 50-24771 and 50-603471. Table 3.1-1 presents the concentrations of VOCs detected in pore-gas samples from these two boreholes. The locations and concentrations are shown in Figure 3.1-1.

The following VOCs were detected in borehole 50-24771: carbon tetrachloride; chloroform; dichlorodifluoromethane; 1,2-dichloroethane; cis-1,2-dichloroethene; ethanol; methylene chloride; tetrachloroethene; 1,1,2-trichloro-1,2,2-trifluoroethane; and trichloroethene. Concentrations of these VOCs increased with depth or stayed relatively the same, except for ethanol, which was not detected in the deeper sample.

The following VOCs were detected in borehole 50-603471: 2-butanone; carbon tetrachloride; chloroform; dichlorodifluoromethane; 1,2-dichloroethane; cis-1,2-dichloroethene; 1,2-dichloropropane; methylene chloride; 2-propanol; tetrachloroethene; toluene; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,1-trichloroethane; 1,1,2-trichloroethane; and trichloroethene. Concentrations of these VOCs stayed relatively the same or increased slightly with depth, except for methylene chloride, 2-propanol, and tetrachloroethene. Methylene chloride and 2-propanol concentrations increased with depth by factors of 3 and 2, respectively, while concentrations of tetrachloroethene decreased with depth.

Tritium was detected at both depth intervals and concentrations decreased with depth in both boreholes. The tritium concentration at 100 ft was higher by a factor of approximately 2 when the FLUTe system was used, while the concentration at 150 ft was higher by a factor of 2 when the packer system was used. Tritium results are presented in Table 3.1-2 and Figure 3.1-2.

3.2 Boreholes 50-24817 and 50-603383

Only one depth interval, 140 ft in borehole 50-24817 and 139 ft in borehole 50-603383, was sampled. Table 3.2-1 presents the concentrations of VOCs detected in pore-gas samples in these two boreholes. The locations and concentrations are shown in Figure 3.2-1.

The following VOCs were detected in borehole 50-24817: acetone; carbon tetrachloride; chloroform; 1,2-dichloro-1,1,2,2-tetrafluoroethane; dichlorodifluoromethane; 1,1-dichloroethane; 1,1-dichloroethene; cis-1,2-dichloroethene; 1,2-dichloropropane; methylene chloride; n-heptane; tetrachloroethene; toluene; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,1-trichloroethane; trichloroethene; and trichlorofluoromethane.

The following VOCs were detected in borehole 50-603383: acetone; benzene; 1-butanol; 2-butanone; carbon tetrachloride; chlorobenzene; chlorodifluoromethane; chloroform; 1,2-dichloro-1,1,2,2-tetrafluoroethane; dichlorodifluoromethane; 1,1-dichloroethane; 1,1-dichloroethene; cis-1,2-dichloroethene; 1,2-dichloropropane; ethanol; hexane; methylene chloride; n-heptane; 2-propanol;

propylene; tetrachloroethene; tetrahydrofuran; toluene; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,1-trichloroethane; trichloroethene; and trichlorofluoromethane.

Tritium was detected at the only depth interval sampled in both boreholes. The concentration was substantially higher (by a factor of 5) using the FLUTe system. Tritium results are presented in Table 3.1-2 and Figure 3.1-2.

3.3 Boreholes 50-24820 and 50-603467

Only one depth interval, 206 ft, was sampled in borehole 50-24820. Two depth intervals, 26 and 206 ft, were sampled in borehole 50-603467. Table 3.3-1 presents the concentrations of VOCs detected in pore-gas samples in these two boreholes. The locations and concentrations are shown in Figure 3.3-1.

The following VOCs were detected in borehole 50-24820: acetone; benzene; carbon tetrachloride; chloroform; chloromethane; dichlorodifluoromethane; cis-1,2-dichloroethene; ethylbenzene, methylene chloride; tetrachloroethene; toluene; trichloroethene; xylene (total); and 1,2-xylene.

The following VOCs were detected in borehole 50-603467: acetone; 2-butanone; carbon disulfide; carbon tetrachloride; chloroform; cyclohexane; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; n-heptane; tetrachloroethene; tetrahydrofuran; toluene; and trichloroethene. Acetone, 2-butanone, carbon disulfide, cyclohexane, and tetrahydrofuran were detected at 26 ft but were not detected at 206 ft (Table 3.3-1). For samples collected with the nylon tubing, concentrations increased with depth for carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; and trichloroethene. Concentrations decreased with depth for n-heptane and toluene (Table 3.3-1). For samples collected with the PVDF tubing, concentrations increased with depth for methylene chloride and trichloroethene; increased slightly for cis-1,2-dichloroethene and tetrachloroethene; exhibited no change in concentrations for carbon tetrachloride, chloroform, and dichlorodifluoromethane; and decreased for n-heptane and toluene (Table 3.3-1).

A tritium sample was not collected in borehole 50-24820. In borehole 50-603467, tritium was detected at 206 ft in the sample collected with the PVDF tubing only; tritium was not detected at 26 ft using either tubing system and was not detected at 206 ft using the nylon tubing. Tritium results are presented in Table 3.1-2 and Figure 3.1-2.

3.4 Boreholes 50-603373 and 50-603468

Three depth intervals, 30, 90, and 260 ft, were sampled in boreholes 50-603373 and 50-603468. Table 3.4-1 presents the concentrations of VOCs detected in pore-gas samples in these two boreholes. The locations and concentrations are shown in Figure 3.4-1.

The following VOCs were detected in borehole 50-603373: acetone; benzene; 1,3-butadiene; 2-butanone; carbon tetrachloride; chloroform; cyclohexane; dichlorodifluoromethane; cis-1,2-dichloroethene; ethylbenzene; hexane; 4-methyl-2-pentanone; methylene chloride; n-heptane; propylene; tetrachloroethene; tetrahydrofuran; toluene; trichloroethene; 1,2-xylene; and 1,3-xylene+1,4-xylene. Concentrations increased with depth for carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; and trichloroethene in samples collected with the packer and SS tubing systems. Concentrations increased also for toluene in samples collected with the packer system (Table 3.4-1). Concentrations decreased with depth for acetone; benzene; 1,3-butadiene; 2-butanone; cyclohexane; ethylbenzene; hexane; 4-methyl-2-pentanone; n-heptane; propylene; tetrahydrofuran; 1,2-xylene; and 1,3-xylene+1,4-xylene in samples collected using the packer and SS tubing systems. Concentrations also decreased for toluene in samples collected with the SS tubing system (Table 3.4-1).

The following VOCs were detected in borehole 50-603468: acetone; benzene; 1,3-butadiene; 1-butanol; 2-butanone; carbon tetrachloride; chlorobenzene; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; 4-methyl-2-pentanone; methylene chloride; n-heptane; 2-propanol; propylene; tetrachloroethene; tetrahydrofuran; toluene; trichloroethene; and 1,2-xylene. Concentrations increased with depth for carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; and trichloroethene (Table 3.4-1). Concentrations decreased with depth for acetone; benzene; 1,3-butadiene; 1-butanol; 2-butanone; chlorobenzene; 4-methyl-2-pentanone; n-heptane; 2-propanol; propylene; tetrahydrofuran; toluene; and 1,2-xylene (Table 3.4-1).

In borehole 50-603373, tritium was detected at 30 and 260 ft in samples collected with packer system; concentrations decreased with depth. Tritium was detected at 90 and 260 ft in samples collected with SS tubing system; concentrations increased with depth. In borehole 50-603468, tritium was detected at 260 ft but not at 30 and 90 ft. Tritium results are presented in Table 3.1-2 and Figure 3.1-2.

4.0 EVALUATION OF VAPOR-SAMPLING SYSTEMS

4.1 Comparison of the Packer and FLUTe Systems

Boreholes 50-24771 and 50-24817 were sampled with the packer system, and boreholes 50-603471 and 50-603383 were sampled with the FLUTe system.

In paired boreholes 50-24817 and 50-603383, only one depth interval, 140 ft and 139 ft, respectively, was sampled in each borehole. Ten VOCs were detected in borehole 50-603383 but not in borehole 50-24817: benzene, 1-butanol, 2-butanone, chlorobenzene, chlorodifluoromethane, ethanol, hexane, 2-propanol, propylene, and tetrahydrofuran (Table 3.2-1). Seventeen VOCs were detected in both boreholes, with concentrations using the packer system less than concentrations in which the FLUTe system was used for acetone and n-heptane (Table 3.2-1). Concentrations were similar in both boreholes for carbon tetrachloride; chloroform; 1,2-dichloro-1,1,2,2-tetrafluoroethane; dichlorodifluoromethane; cis-1,2-dichloroethene; 1,1-dichloroethane; 1,1-dichloroethene; 1,2-dichloropropane; methylene chloride; tetrachloroethene; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,1-trichloroethane; trichloroethene; and trichlorofluoromethane (Table 3.2-1). Concentrations of toluene in which the packer system was used were higher than concentrations using the FLUTe system (Table 3.2-1).

In paired boreholes 50-24771 and 50-603471, two depth intervals (100 ft and 150 ft) were sampled in each borehole. Ethanol was the only VOC detected using the packer system in one sample, which was not detected using the FLUTe system. Butanone[2-], 1,2-dichloropropane; 2-propanol; toluene; 1,1,1-trichloroethane; and 1,1,2-trichloroethane were detected in only one or more samples using the FLUTe system. Nine VOCs were detected in both boreholes, with concentrations being similar for all but methylene chloride, tetrachloroethene, and trichloroethene. Concentrations for these three VOCs were higher in samples collected using the packer system by a factor of 2 to 5 for methylene chloride, a factor of less than 2 for tetrachloroethene, and by a factor of 2 for trichloroethene.

Tritium was detected at both depth intervals in boreholes 50-24771 and 50 603471, and concentrations decreased with depth in both boreholes with both systems. The tritium concentration at 100 ft was higher by a factor of approximately 2 when the FLUTe system (borehole 50-603471) was used, while the concentration at 150 ft was higher by a factor of 2 when the packer system (borehole 50-24471) was used. The tritium concentration detected at the one depth sampled in borehole 50-603383 with the FLUTe system was 5 times the concentration detected at the one depth sampled in borehole 50-24817 with the packer system (Table 3.1-2).

The results indicate that more VOCs were detected with the FLUTe system than with the packer system. Acetone and n-heptane were detected in both boreholes at higher concentrations in samples collected with the FLUTe system, toluene had higher concentrations in samples collected with the packer system, and 14 VOCs had similar concentrations between systems. Concentration differences were less than a factor of 2 (14 VOCs), approximately a factor of 2 (toluene), a factor of 2 to 3 (acetone), and a factor of 5 (n-heptane). Tritium generally had substantially higher concentrations (by factors of more than 2) in the samples using the FLUTe system than in the samples using the packer system. However, the tritium concentration at 150 ft was higher (by approximately a factor of 2) when the packer system was used than when the FLUTe system was used.

4.2 Comparison of Nylon and PVDF Tubing of FLUTe System

Paired boreholes 50-24820 and 50-603467 were sampled using the FLUTe system with two types of tubing—the standard nylon and the PVDF—and three purge times. Borehole 50-24820 was sampled at 206 ft, and borehole 50-603467 was sampled at 26 and 206 ft. Sampling with the two types of tubing was conducted concurrently.

Sample results at 206 ft in borehole 50-24820 indicated that concentrations varied over the three different purge times when the PVDF tubing was used. Concentrations for carbon tetrachloride, chloroform, dichlorodifluoromethane, methylene chloride, tetrachloroethene, and trichloroethene following the 5-min purge time were approximately 2 orders of magnitude less than the concentrations following the 10-min and the 20-min purge times. Concentrations of these VOCs following the 10-min purge time were approximately 2 to 3 times the concentrations following the 20-min purge time (Table 3.3-1). Concentrations varied slightly over the three purge times when the nylon tubing was used or reported no detections at all. Overall, detected VOC concentrations were higher when the nylon tubing was used than when the PVDF tubing was used.

Sample results in borehole 50-603467 indicated that concentrations were generally higher by approximately a factor of 3 when the PVDF tubing was used. Concentrations varied slightly over the three purge times for the nylon and PVDF tubing at each depth (Table 3.3-1). When either the nylon tubing or the PVDF tubing was used over three different purge times, concentrations did not vary substantially at each depth but may vary substantially between depths. The exceptions are the concentrations at 206 ft following the 5 min purge time compared with the concentrations after the 10-min and 20-min purge times. The concentrations following the 5-min purge time were approximately 3 times the concentrations following the later purge times. Concentrations increased from 26 to 206 ft when the nylon tubing was used for seven VOCs (carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; and trichloroethene), but only four VOCs had increasing concentrations with depth when the PVDF tubing was used (cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; and trichloroethene). Concentrations from 26 to 206 ft for the other VOCs decreased or remained similar (Table 3.3-1).

Tritium was detected only at 206 ft in borehole 50-603467 (280.3 pCi/L) with the PVDF tubing. Tritium was not detected at either 26 ft or 206 ft when the nylon tubing was used.

In summary, no difference in VOC concentrations was found for the two types of tubing used in the FLUTe system. Tritium was detected in one sample with the PVDF tubing at a low concentration.

4.3 Comparison of Packer and SS Systems

Borehole 50-603373 was initially sampled with the packer system and then subsequently sampled with the SS tubing system. Thirteen VOCs were detected with the packer system at 30 ft and sporadically at 90 ft only but were not detected in any of the SS tubing system samples at any depth: acetone; benzene; 1,3-butadiene; 2-butanone; cyclohexane; ethylbenzene; hexane; 4-methyl-2-pentanone; n-heptane; propylene; tetrahydrofuran, 1,2-xylene; and 1,3-xylene+1,4-xylene (Table 3.4-1). Seven VOCs (carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride [30 ft and 260 ft)]; tetrachloroethene, and trichloroethene) had concentrations in samples collected from some or all three depth intervals with the SS tubing system higher (by a factor of 4 or less) than the concentrations in samples collected with the packer system (Table 3.4-1). Concentrations for toluene at all depths and methylene chloride at 90 ft were less than the concentrations in samples collected using the packer system (toluene was not detected at 90 ft and 260 ft in the SS tubing system samples) (Table 3.4-1).

Tritium was only detected at 260 ft for both sampling systems. The concentration in the sample collected using the SS tubing system was approximately twice the concentration using the packer system.

The results indicated that more VOCs were detected using the packer system compared with the SS tubing system; however, concentrations of VOCs and tritium were generally higher by a factor of 4 or less when the SS tubing system was used than when the packer system was used.

4.4 Comparison of SS and FLUTe Systems

Paired boreholes 50-603373 and 50-603468 were sampled at the same depth intervals (30, 90, and 260 ft) when the SS tubing system and the FLUTe system were used, respectively. Twelve VOCs were detected with the FLUTe system but not with the SS tubing system (acetone; benzene; 1,3-butadiene; 1-butanol; 2-butanone; chlorobenzene; 4-methyl-2-pentanone; n-heptane; 2-propanol; propylene; tetrahydrofuran; and 1,2-xylene) (Table 3.4-1).

For the VOCs detected in both boreholes, concentrations in samples collected at 30 ft varied between the two sampling systems. Concentrations at 30 ft were higher for carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; tetrachloroethene; and trichloroethene in the samples collected when the SS tubing system was used by approximately a factor of 4 (Table 3.4-1). Methylene chloride was not detected at 30 ft in samples collected when the FLUTe system was used but was detected in samples collected when the SS tubing system was used (Table 3.4-1). Toluene concentrations at 30 ft were higher in the samples collected using the FLUTe system by almost 2 orders of magnitude. Concentrations at 90 ft were similar between boreholes and sampling systems, while at 260 ft, the concentrations in samples collected using the SS tubing were slightly higher by a factor of 2 or less (Table 3.4-1).

Tritium was detected at 260 ft in both boreholes but was detected only at shallower depths in borehole 50-603373. The tritium concentration in the sample collected with the SS tubing system in borehole 50-603373 at 260 ft was approximately 3 times the concentration in the sample collected with the FLUTe system.

The results indicated that more VOCs were detected using the FLUTe system than with the SS tubing system. However, VOC concentrations detected in samples collected using SS tubing system were generally slightly higher than or similar to concentrations detected in samples collected using the FLUTe system, except for toluene. The tritium concentration was higher by a factor of 3 in the sample collected using the SS tubing system.

4.5 Evaluation of the Three Vapor-Sampling Systems

Borehole 50-603373 was initially sampled using the packer system and subsequently sampled using the SS tubing system. Borehole 50-603468 was sampled using the FLUTe system with standard nylon tubing. Both boreholes were sampled at 30, 90, and 260 ft. Twenty-one VOCs were detected using the packer system, 8 VOCs were detected using the SS tubing system, and 20 VOCs were detected using the FLUTe system (Table 3.4-1).

For the eight VOCs (carbon tetrachloride; chloroform; dichlorodifluoromethane; cis-1,2-dichloroethene; methylene chloride; tetrachloroethene; toluene; and trichloroethene) detected using all three sampling systems, the concentrations at 30 ft varied as described for the FLUTE and SS tubing systems in section 4.4. Concentrations at 30 ft in samples collected using the packer system were generally similar to the concentrations in the samples collected using the FLUTe system, except for methylene chloride (not detected in the FLUTe system sample), tetrachloroethene (2 times higher in the packer system sample), and toluene (order of magnitude higher in the FLUTe system sample). Concentrations of the eight VOCs at 90 ft were similar for all three sampling systems, except for toluene, which was not detected in samples using the SS tubing system. Concentrations of the eight VOCs at 260 ft were similar in the samples collected using the SS tubing system and FLUTe system and were slightly higher than the concentrations in samples collected using the packer system.

4.6 Evaluation of Purge Time for VOC Sampling

Purge time is the time required to purge the entire tubing volume for the FLUTe and SS tubing systems and the tubing volume plus the packer void space for the packer system. Three vapor samples were collected from each sampling depth for VOC analysis: one sample following a 5-min purge, one sample following a 10-min purge, and one sample following a 20-min purge. Teflon tubing is used in the packer system, nylon (standard) and PVDF (this pilot test) tubing are used in the FLUTe system, and SS tubing is used in the SS tubing system.

The following VOC sampling events were conducted using the packer system:

- 100 and 150 ft in borehole 50-24771
- 140 ft in borehole 50-24817
- 30, 90, and 260 ft in borehole 50-603373

The concentrations of VOCs in the 5-min purge samples were compared with concentrations in the 10-min and 20-min purge samples for each of the above sampling events. Overall, the concentrations of VOCs in the 10- and 20-min purge samples were less than or similar to the concentrations in the 5-min purge samples. Concentrations in the 20-min purge samples were less, although to a smaller extent, than concentrations in the 10-min purge samples.

The following VOC sampling events were conducted using the FLUTe system with nylon tubing:

- 206 ft in borehole 50-24820
- 139 ft in borehole 50-603383
- 26 and 206 ft in borehole 50-603467
- 30, 90, and 260 ft in borehole 50-603468
- 100 and 150 ft in borehole 50-603471

The concentrations of VOCs in the 5-min purge samples were compared with concentrations in the 10-min and 20-min purge samples for each of the above sampling events. Overall, the concentrations of VOCs in the 10- and 20-min purge samples were similar to concentrations in the 5-min purge samples at each depth. As mentioned in section 4.2, samples collected using nylon tubing at 206 ft in borehole 50-603467 had concentrations in the 5-min purge sample approximately 2 to 3 times the concentrations in the 10-min and the 20-min purge samples. However, the concentrations in the 10-min and the 20-min purge samples were similar.

The following VOC sampling events were conducted using the FLUTe system with PVDF tubing:

- 206 ft in borehole 50-24820
- 26 and 206 ft in borehole 50-603467

As mentioned in section 4.2, concentrations at 206 ft in borehole 50-24820 in the 5-min purge sample were approximately 2 orders of magnitude less than the concentrations following the 10-min and the 20-min purge times. Concentrations of these VOCs following the 10-min purge time were approximately 2 to 3 times the concentrations following the 20-min purge time (Table 3.3-1). The concentrations of VOCs at 26 and 206 ft in borehole 50-603467 in the 10- and 20-min purge samples were very similar to concentrations in the 5-min purge samples within each depth interval.

The following VOC sampling events were conducted using the SS tubing system:

- 30, 90, and 260 ft in borehole 50-603373

The concentrations of VOCs in the 5-min purge samples were compared with concentrations in the 10-min and 20-min purge samples for the above sampling events. Overall, the concentrations of VOCs in the 10- and 20-min purge samples were similar to the concentrations in the 5-min purge samples within each sample depth.

In general, purge times of 5, 10, or 20 min did not affect VOC concentrations for the packer system, for the FLUTe system with either nylon or PVDF tubing, or for the SS tubing system.

5.0 STATISTICAL COMPARISON OF SAMPLE RESULTS

By the design of the pilot test and the MDA C vapor sampling approach, three VOC samples were collected (following 5-, 10-, and 20-min purge times) from each borehole/depth/sampling system. The three samples from each borehole/depth/sampling system are not true replicates because the second and third samples could be affected by extraction of the previous sample(s). In most cases, however, the difference between analytical results for the three purge times was relatively small. If the three purge time samples are assumed to represent independent samples (replicates), there are sufficient samples in most cases to statistically compare the sampling system results for each VOC at single sample depths.

A relative percent difference (RPD) was calculated for each VOC detected in both systems and a mean RPD value was calculated for all the VOCs for each system. The mean RPD qualitatively shows the magnitude and general trend of the difference between the two systems (a negative RPD value indicates that the second mean is lower than the first mean). The Student's *t*-test (paired two-tailed test) was used to compare result. Sample results are considered significantly different if the calculated p-value is 0.05 or less. If all three sample results were not available, the Student's *t*-test was not performed. The details of the RPD calculations and the statistical comparisons are presented in Appendix F.

5.1 Relative Percent Difference Results

For the comparison of the packer system with the FLUTe system in boreholes 50 24817 and 50 603383, the relative percent differences (RPDs) were both positive and negative. The mean RPD for all VOCs was positive (15.61), indicating that, in general, the analytical results were slightly higher for the FLUTe system samples. VOCs in boreholes 50-24771 and 50-603471 had both positive and negative RPDs at both depths. The mean RPDs for all VOCs were negative for the two depths sampled (-17.15 for 100 ft bgs and -27.86 for 150 ft bgs), indicating that in general, the analytical results were higher for the packer system samples.

For the comparison of the FLUTe system with nylon tubing to the FLUTe system with PVDF tubing in borehole 50-24820, the RPDs for all VOCs are negative, indicating that the analytical results are lower for samples from the PVDF tubing. In borehole 50 603467, the RPDs for all VOCs are positive at 26 ft bgs and negative at 206 ft bgs, indicating an inconsistent trend in this borehole.

For the comparison of the packer system with the SS system in borehole 50-603373, the mean RPDs for all sample depths are positive, indicating that the results from the SS system are higher than the results from the packer system.

For the comparison of the SS system results with the FLUTe system results in boreholes 50 603373 and 50-603468, the RPDs are generally negative, indicating that the FLUTe results are most often lower than the corresponding stainless steel results.

5.2 Student's *t*-test Results

For the comparison of the packer system with the FLUTe system in boreholes 50 24817 and 50-603383, 9 of 16 Student's *t*-test results show a significant difference. Six of the nine significant results had positive RPDs, indicating that the FLUTe system results were higher than the packer system results. For comparison of the packer system with the FLUTe system in boreholes 50 24771 and 50-603471, 4 of the 16 Student's *t*-test results show a significant difference. The majority of the results are not statistically different for the two systems.

For the comparison of the FLUTe/nylon system with the FLUTe/PVDF system in borehole 50-24820 (206 ft bgs) and borehole 50-603467 (26 ft and 206 ft bgs), 11 of 28 Student's *t*-test results show a significant difference between results. Ten of the significant results were for VOCs detected at 26 ft in borehole 50-603467 and had positive RPDs, indicating that the FLUTe/PVDF results were higher than the FLUTe/nylon results. However, at 206 ft bgs in borehole 50 24820, six of the seven Student's *t*-test results are greater than 0.05, indicating that the tubing results are not statistically different. At 206 ft in borehole 50-603467, none of the nine Student's *t*-test results showed significant differences, indicating similar results for the two types of tubing.

For the comparison of the packer system results with the SS system results in borehole 50-603373, all eight Student's *t*-test results from 30 ft bgs and all seven Student's *t*-test results from 260 ft bgs showed significant differences. At 90 ft bgs, none of the seven Student's *t*-test results showed significant differences. Fourteen of the 15 significant results had positive RPDs, indicating that the SS system results were higher than the packer system results.

For the comparison of the SS system results with the FLUTe system results in boreholes 50 603373 and 50-603468, 8 of the 21 Student's *t*-test results showed significant differences. Seven of the eight significant results had negative RPDs, indicating that the FLUTe system results were lower than the SS system results.

6.0 CONCLUSIONS

Subsurface vapor samples were collected from four sets of paired boreholes inside the MDA C boundary and to the north and south outside of the MDA C boundary. The overall VOC concentrations were slightly higher when the FLUTe system was used than when the packer system was used in paired boreholes 50-24817 and 50-603383. However, VOC concentrations were generally similar in paired boreholes 50-24471 and 50-603471, except for methylene chloride, tetrachloroethene, and trichloroethene, which were higher in samples collected using the packer system. The overall VOC concentrations were higher when the SS tubing system was used than when the packer system was used. The overall VOC concentrations were similar when the SS tubing system and the FLUTe system were used, although concentrations were slightly higher in the deepest sample when the SS tubing sample system was used. The concentrations detected for most VOCs were low and varied only slightly. The concentration differences reported were primarily related to the low levels present and not to the tubing systems used.

The fewest number of VOCs were detected using SS tubing system, while a similar number of VOCs were detected using the FLUTe system and the packer system in boreholes 50-603373 and 50-603468. In boreholes 50-24817 and 50-603383 and boreholes 5024471 and 50-603471, the FLUTe system detected more VOCs than the packer system.

There was no difference in the VOC concentrations reported in the samples collected using the FLUTe system with either nylon or PVDF tubing in boreholes 50-24820 and 50-603467. The number of VOCs detected was also similar between the two types of tubing, although the FLUTe system with the PVDF tubing detected a few VOCs in borehole 50-24820 at very low concentrations that were not reported in the system using the nylon tubing.

Purge times did not substantially affect VOC concentrations for any of the three sampling systems, although slightly lower concentrations were reported with longer purge time when using packer system in some boreholes.

The reported tritium concentrations were higher by a factor of 5 when using the FLUTe system compared with the packer system in the paired boreholes north of the MDA C boundary. The tritium concentration was 2.5 times higher when the FLUTe system was used compared with the packer system at 100 ft in the paired boreholes inside MDA C boundary but was 2 times higher at 150 ft using the packer system. The tritium concentration was higher by a factor of 2 or 3 when the SS tubing system was used compared with either the packer system or the FLUTe system in the paired boreholes east of borehole 50-24820 and to the south of the MDA C boundary. Tritium was sporadically detected in the other boreholes. This lack of comparable tritium results may be caused by the relatively low levels of tritium detected in most of the boreholes.

Based on the pilot test results, the packer system is adequate for initial measuring of pore-gas concentrations at a site. The FLUTe system and the SS tubing system are appropriate when installing a vapor-monitoring well for subsurface monitoring of pore gas for VOCs and tritium. The FLUTe system generally appeared to detect more VOCs than the packer system and the SS tubing system at similar concentrations, and concentrations were generally similar at each depth across the three systems. Most of the concentration differences among the systems were a factor of 2 or less and were not greater than a factor of 5, with one exception (toluene at 30 ft in boreholes 50-603373 and 50-60468). The SS tubing system reported a higher tritium concentration at one depth in one set of paired boreholes, and the FLUTe system reported substantially higher tritium concentrations at two depths in two other sets of paired boreholes.

Based on the Student's *t*-test results, it is not clear that significant differences exist consistently among the different sampling systems or tubing types. The RPDs among sampling systems and tubing types also are not consistent, with high variability in both magnitude and direction among VOCs and sample depths. The Student's *t*-tests were conducted on groups of three samples per borehole/depth/sampling system, the smallest sample count for which statistical analyses such as *t*-tests are generally applicable. Therefore, only limited value can be placed on the statistical results obtained.

Some general conclusions may be drawn regarding the sampling system statistical comparisons. In multiple direct comparisons between the various combinations of two sampling systems, the SS system tended to have higher concentrations of individual VOCs than either the packer system or the FLUTe system. No significant difference was observed between the packer and the FLUTe systems or between the two types of tubing used in the FLUTe system. There is also overlap in concentrations of VOCs among samples collected by all the systems.

None of the methods appear to result in adsorption of VOCs and tritium in the sampling train that clearly bias the results. Therefore, all systems tested appear appropriate for sampling VOCs and tritium in pore gas.

7.0 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; DOE–Los Alamos Site Office; EPA, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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NMED (New Mexico Environment Department), August 13, 2007. "Approval with Modifications for the Phase II Investigation Work Plan 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, 098440)

NMED (New Mexico Environment Department), March 28, 2008. "Approval with Modification, Pilot Test Work Plan for Evaluating Vapor-Sampling Systems at Material Disposal Area C," 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 2008, 101113)

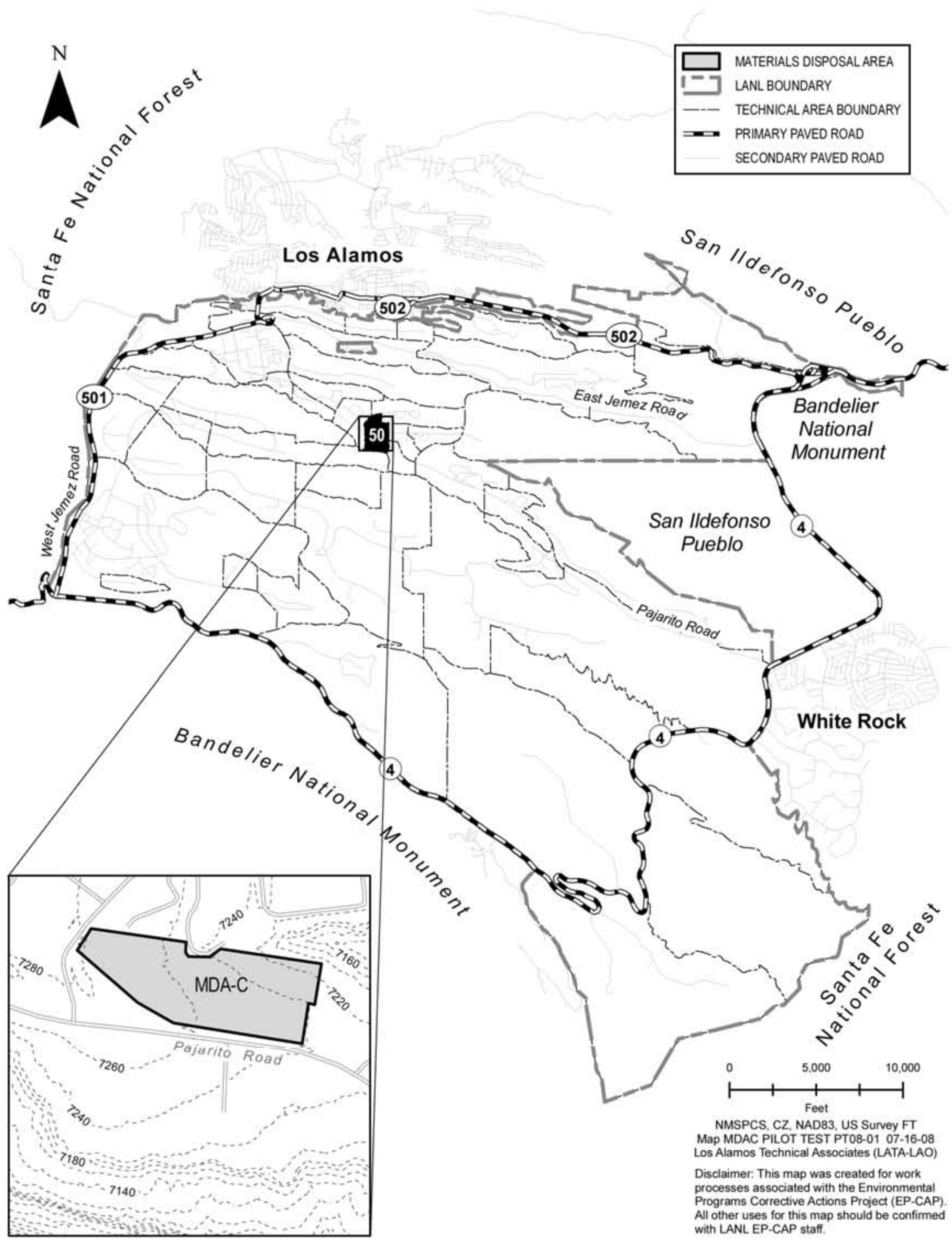


Figure 1.0-1 Location of MDA C with respect to Laboratory TAs and surrounding land holdings

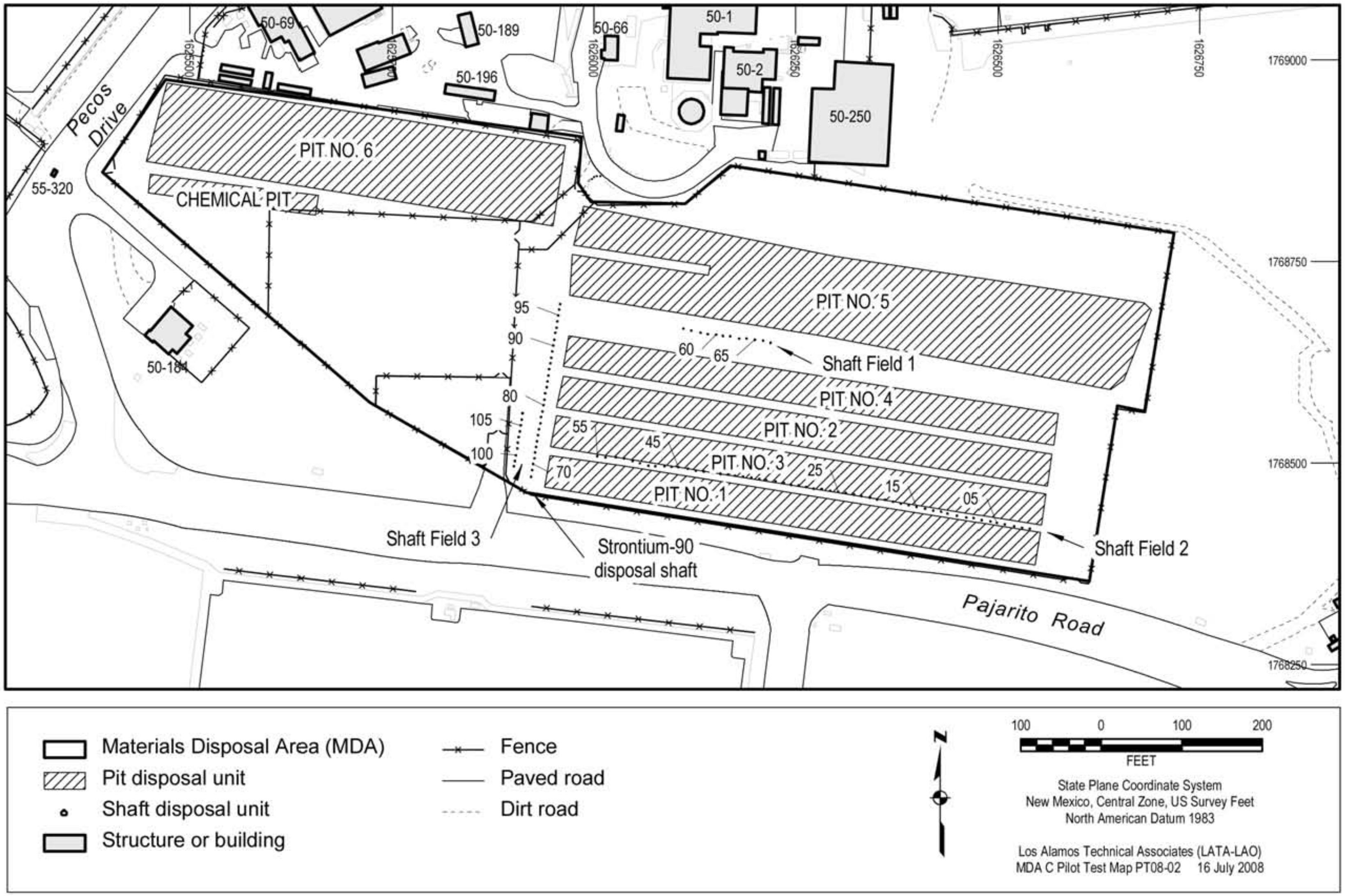


Figure 1.0-2 Location of pits and shafts at MDA C

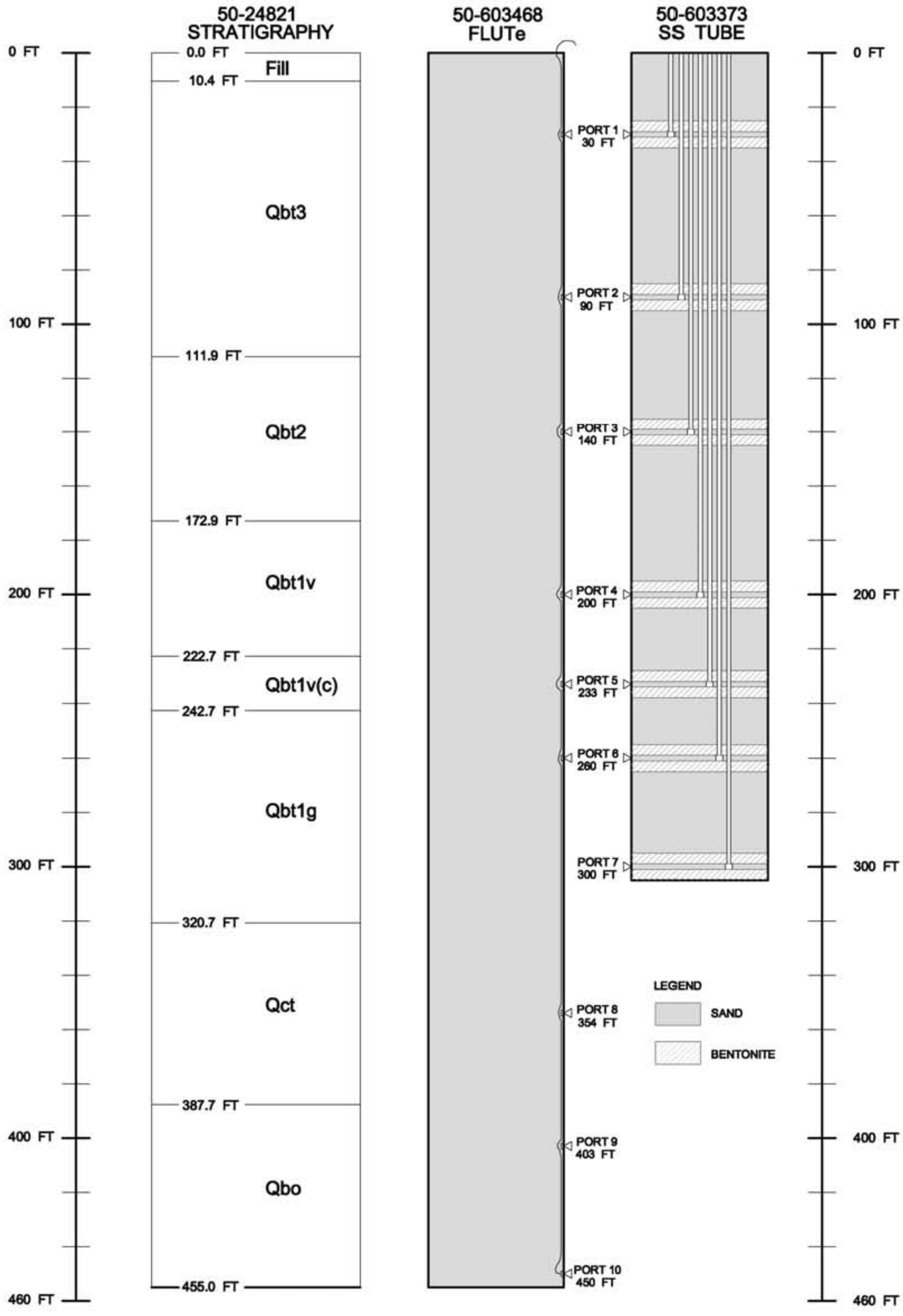


Figure 1.2-1 Installed FLUTe and SS vapor-sampling systems in pilot test boreholes 50-603468 and 50-603373 at MDA C

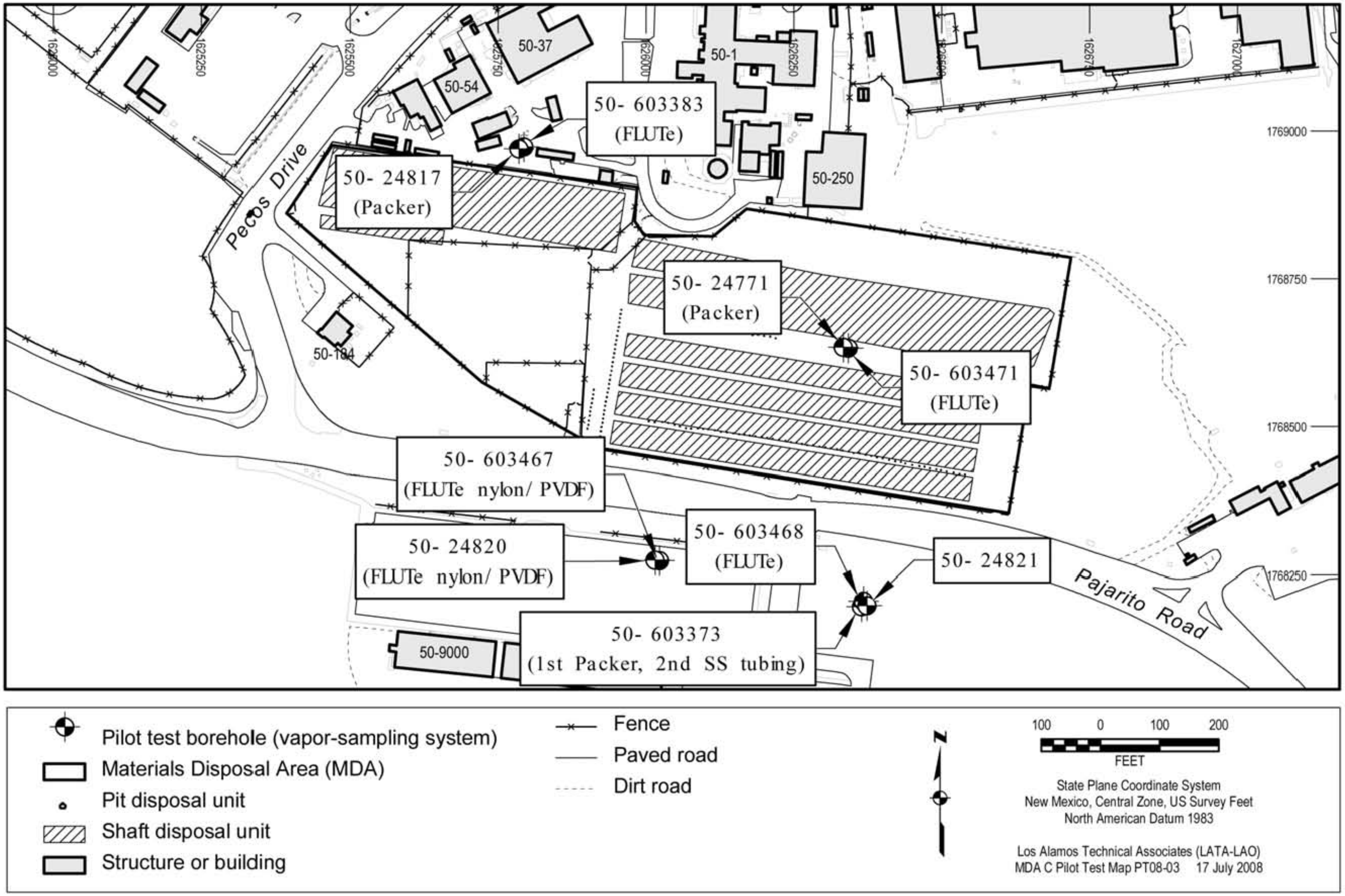
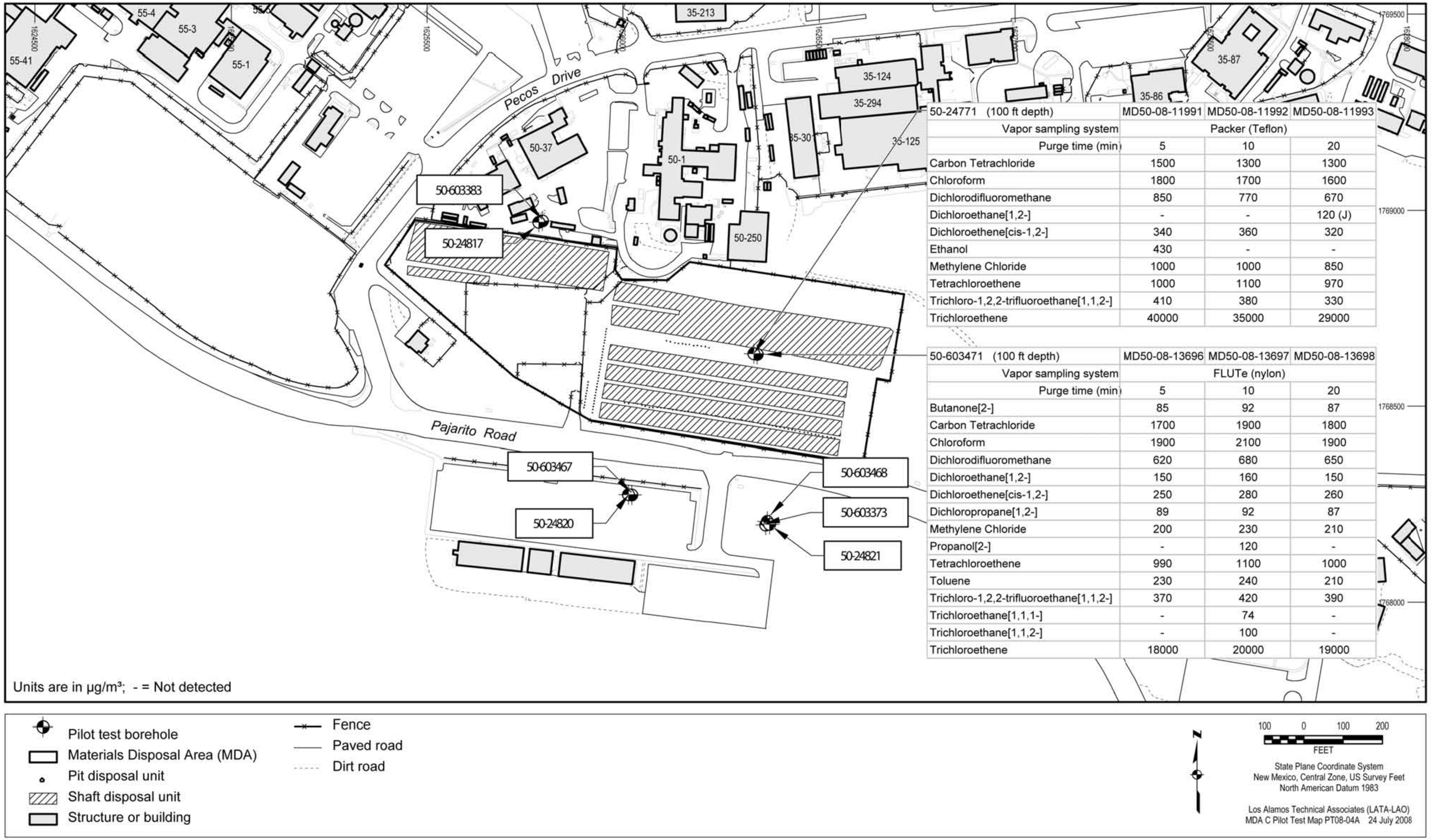


Figure 2.1-1 Pilot test borehole locations and vapor-sampling systems

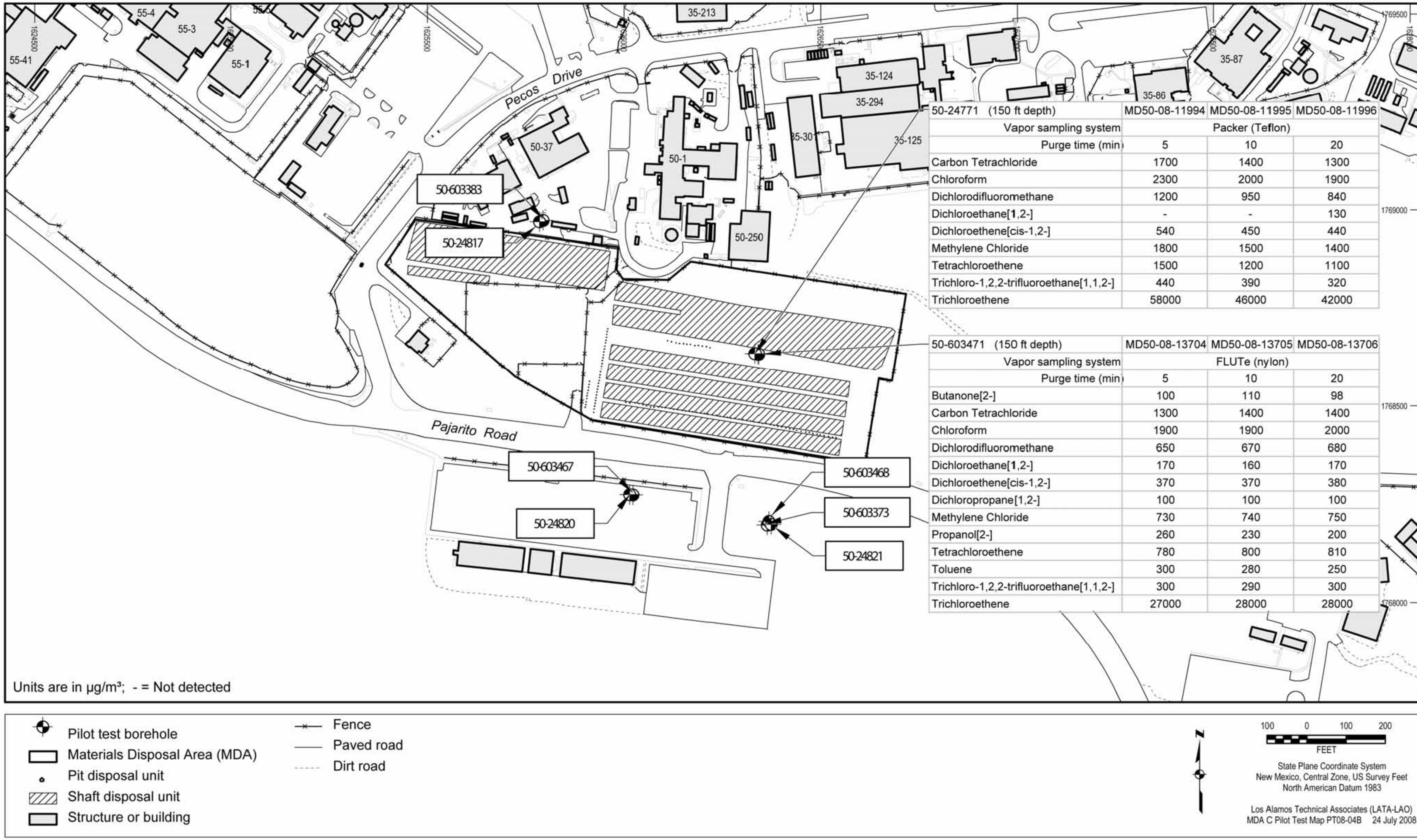


50-24771 (100 ft depth)	MD50-08-11991	MD50-08-11992	MD50-08-11993
Vapor sampling system	Packer (Teflon)		
Purge time (min)	5	10	20
Carbon Tetrachloride	1500	1300	1300
Chloroform	1800	1700	1600
Dichlorodifluoromethane	850	770	670
Dichloroethane[1,2-]	-	-	120 (J)
Dichloroethene[cis-1,2-]	340	360	320
Ethanol	430	-	-
Methylene Chloride	1000	1000	850
Tetrachloroethene	1000	1100	970
Trichloro-1,2,2-trifluoroethane[1,1,2-]	410	380	330
Trichloroethene	40000	35000	29000

50-603471 (100 ft depth)	MD50-08-13696	MD50-08-13697	MD50-08-13698
Vapor sampling system	FLUTe (nylon)		
Purge time (min)	5	10	20
Butanone[2-]	85	92	87
Carbon Tetrachloride	1700	1900	1800
Chloroform	1900	2100	1900
Dichlorodifluoromethane	620	680	650
Dichloroethane[1,2-]	150	160	150
Dichloroethene[cis-1,2-]	250	280	260
Dichloropropane[1,2-]	89	92	87
Methylene Chloride	200	230	210
Propanol[2-]	-	120	-
Tetrachloroethene	990	1100	1000
Toluene	230	240	210
Trichloro-1,2,2-trifluoroethane[1,1,2-]	370	420	390
Trichloroethane[1,1,1-]	-	74	-
Trichloroethane[1,1,2-]	-	100	-
Trichloroethene	18000	20000	19000

Units are in µg/m³; - = Not detected

Figure 3.1-1a Summary of VOCs detected in pilot test pore-gas samples at borehole 50-24771 and 50-603471 (100-ft depth)



50-24771 (150 ft depth)	MD50-08-11994	MD50-08-11995	MD50-08-11996
Vapor sampling system	Packer (Teflon)		
Purge time (min)	5	10	20
Carbon Tetrachloride	1700	1400	1300
Chloroform	2300	2000	1900
Dichlorodifluoromethane	1200	950	840
Dichloroethane[1,2-]	-	-	130
Dichloroethene[cis-1,2-]	540	450	440
Methylene Chloride	1800	1500	1400
Tetrachloroethene	1500	1200	1100
Trichloro-1,2,2-trifluoroethane[1,1,2-]	440	390	320
Trichloroethene	58000	46000	42000

50-603471 (150 ft depth)	MD50-08-13704	MD50-08-13705	MD50-08-13706
Vapor sampling system	FLUTe (nylon)		
Purge time (min)	5	10	20
Butanone[2-]	100	110	98
Carbon Tetrachloride	1300	1400	1400
Chloroform	1900	1900	2000
Dichlorodifluoromethane	650	670	680
Dichloroethane[1,2-]	170	160	170
Dichloroethene[cis-1,2-]	370	370	380
Dichloropropane[1,2-]	100	100	100
Methylene Chloride	730	740	750
Propanol[2-]	260	230	200
Tetrachloroethene	780	800	810
Toluene	300	280	250
Trichloro-1,2,2-trifluoroethane[1,1,2-]	300	290	300
Trichloroethene	27000	28000	28000

Figure 3.1-1b Summary of VOCs detected in pilot test pore-gas samples at borehole 50-24771 and 50-603471 (150-ft depth)

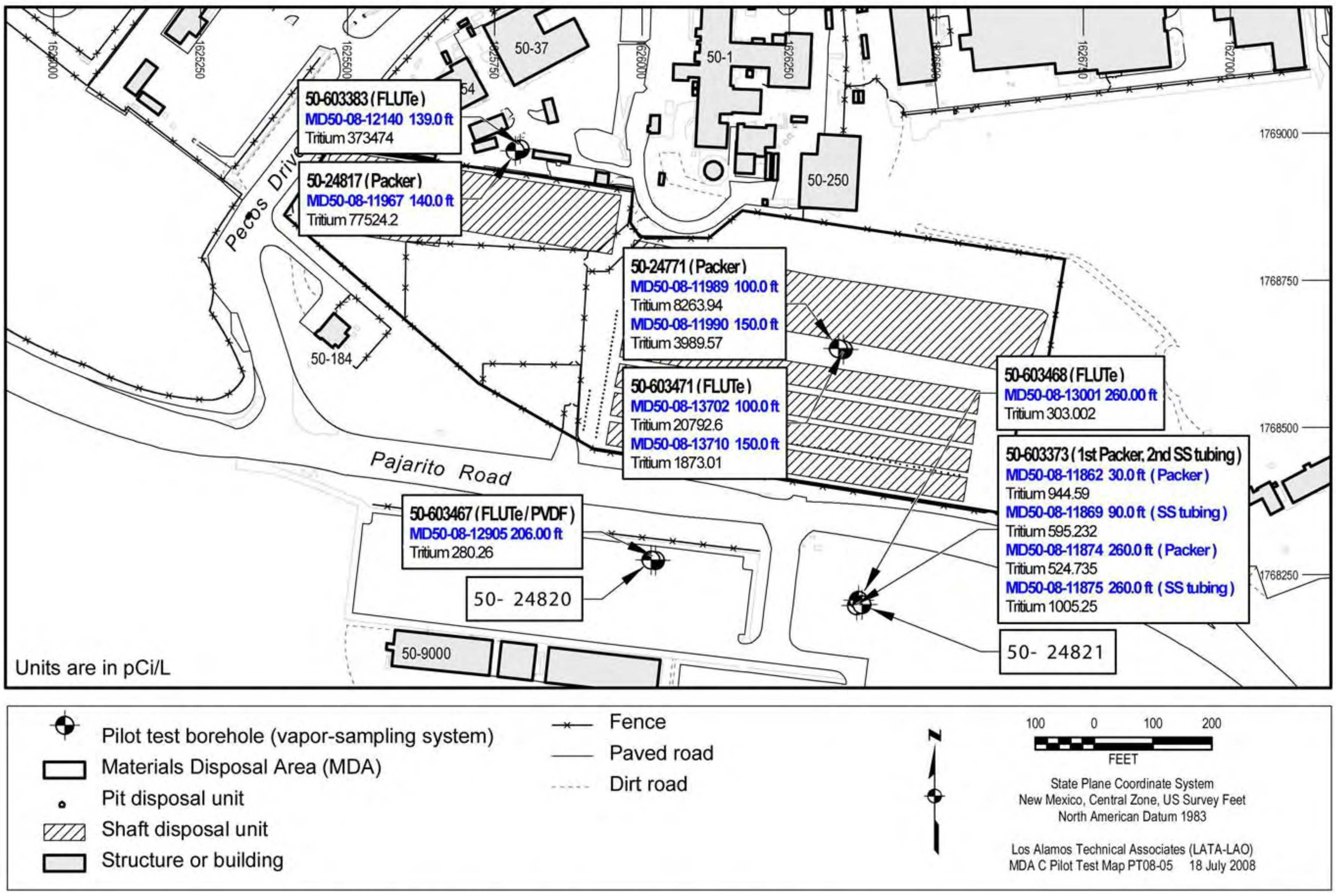
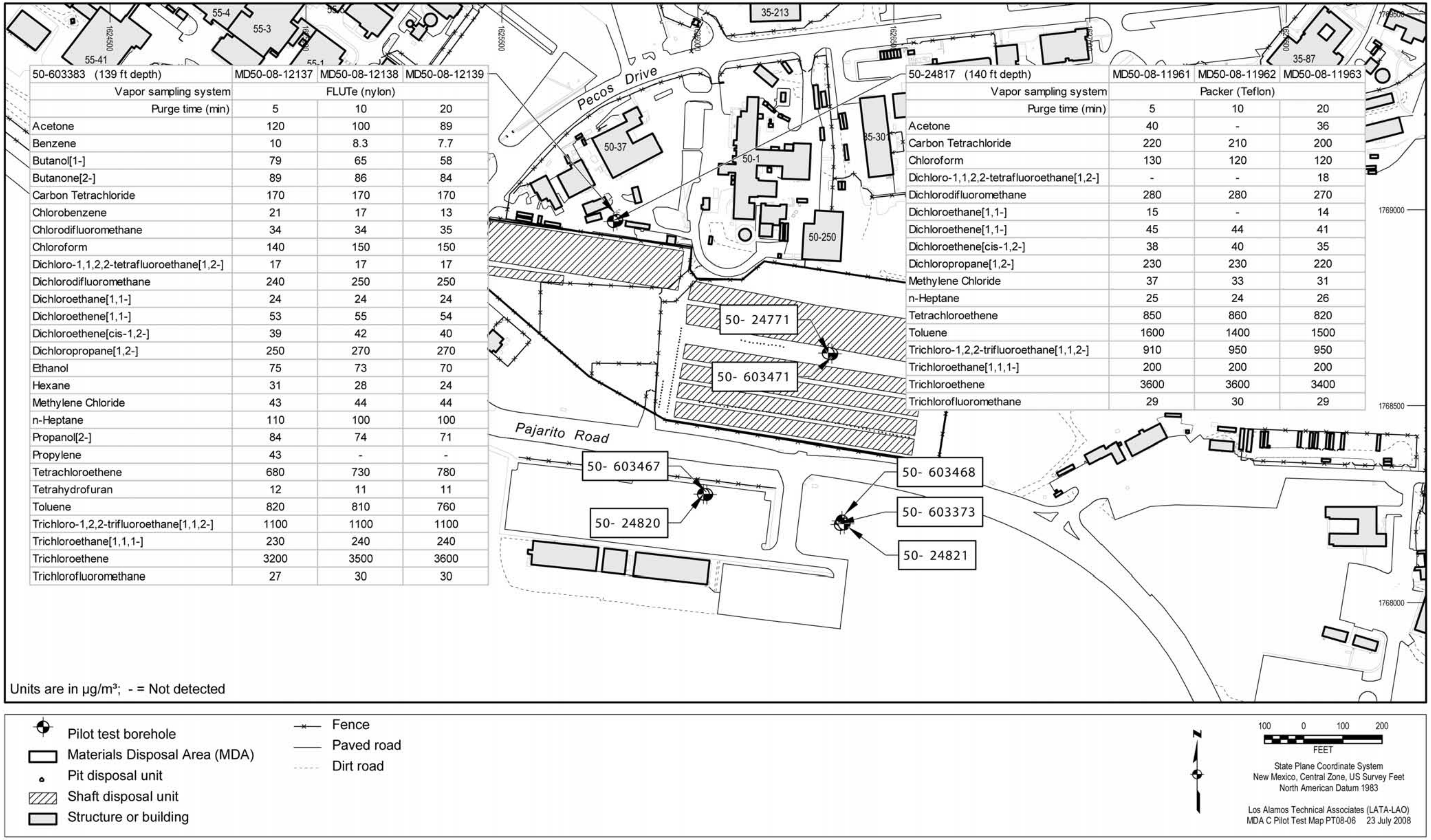


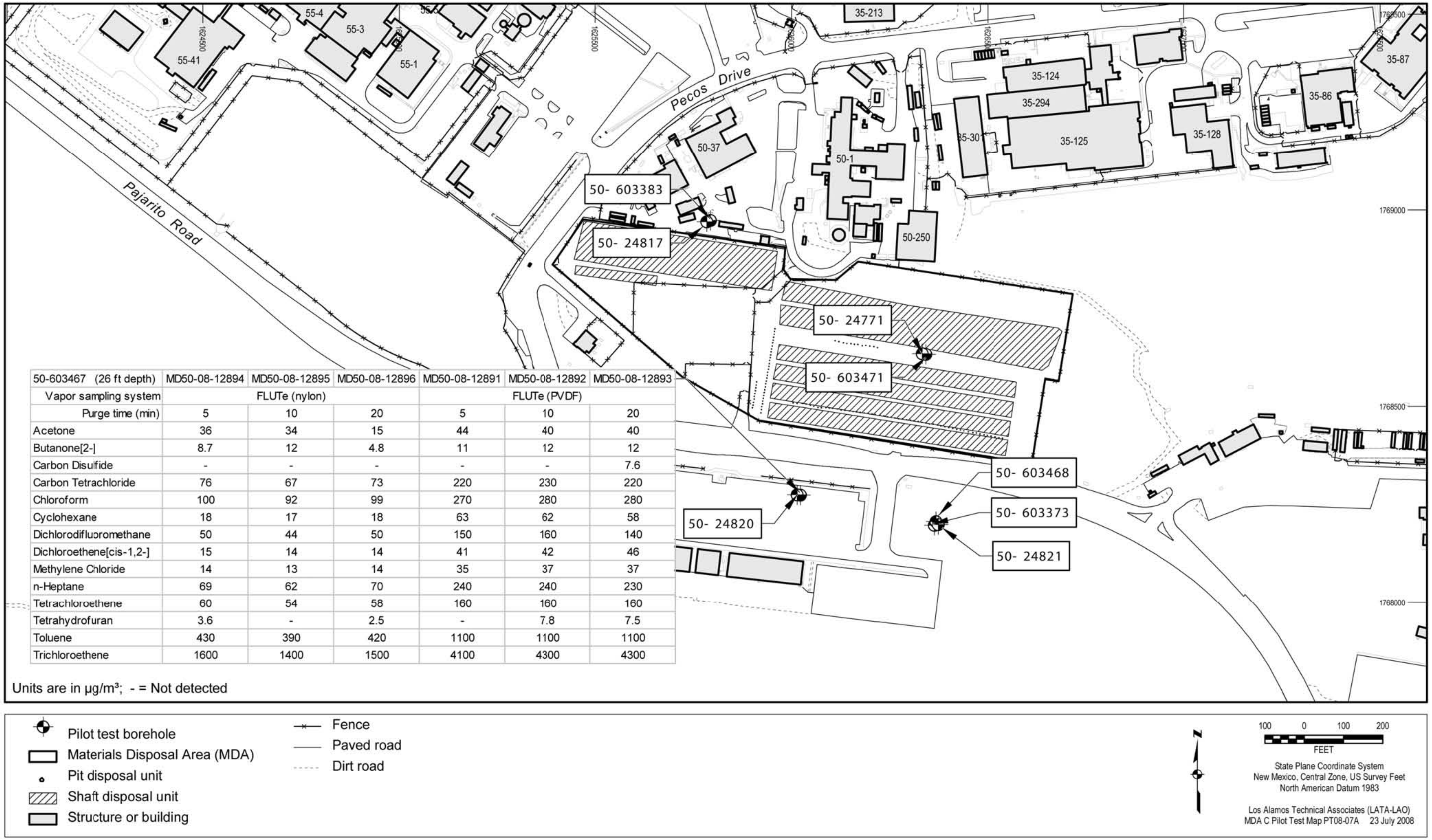
Figure 3.1-2 Summary of tritium detected in pilot test pore-gas samples at MDA C



50-603383 (139 ft depth)	MD50-08-12137	MD50-08-12138	MD50-08-12139
Vapor sampling system	FLUTe (nylon)		
Purge time (min)	5	10	20
Acetone	120	100	89
Benzene	10	8.3	7.7
Butanol[1-]	79	65	58
Butanone[2-]	89	86	84
Carbon Tetrachloride	170	170	170
Chlorobenzene	21	17	13
Chlorodifluoromethane	34	34	35
Chloroform	140	150	150
Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	17	17	17
Dichlorodifluoromethane	240	250	250
Dichloroethane[1,1-]	24	24	24
Dichloroethene[1,1-]	53	55	54
Dichloroethene[cis-1,2-]	39	42	40
Dichloropropane[1,2-]	250	270	270
Ethanol	75	73	70
Hexane	31	28	24
Methylene Chloride	43	44	44
n-Heptane	110	100	100
Propanol[2-]	84	74	71
Propylene	43	-	-
Tetrachloroethene	680	730	780
Tetrahydrofuran	12	11	11
Toluene	820	810	760
Trichloro-1,2,2-trifluoroethane[1,1,2-]	1100	1100	1100
Trichloroethane[1,1,1-]	230	240	240
Trichloroethene	3200	3500	3600
Trichlorofluoromethane	27	30	30

50-24817 (140 ft depth)	MD50-08-11961	MD50-08-11962	MD50-08-11963
Vapor sampling system	Packer (Teflon)		
Purge time (min)	5	10	20
Acetone	40	-	36
Carbon Tetrachloride	220	210	200
Chloroform	130	120	120
Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	-	-	18
Dichlorodifluoromethane	280	280	270
Dichloroethane[1,1-]	15	-	14
Dichloroethene[1,1-]	45	44	41
Dichloroethene[cis-1,2-]	38	40	35
Dichloropropane[1,2-]	230	230	220
Methylene Chloride	37	33	31
n-Heptane	25	24	26
Tetrachloroethene	850	860	820
Toluene	1600	1400	1500
Trichloro-1,2,2-trifluoroethane[1,1,2-]	910	950	950
Trichloroethane[1,1,1-]	200	200	200
Trichloroethene	3600	3600	3400
Trichlorofluoromethane	29	30	29

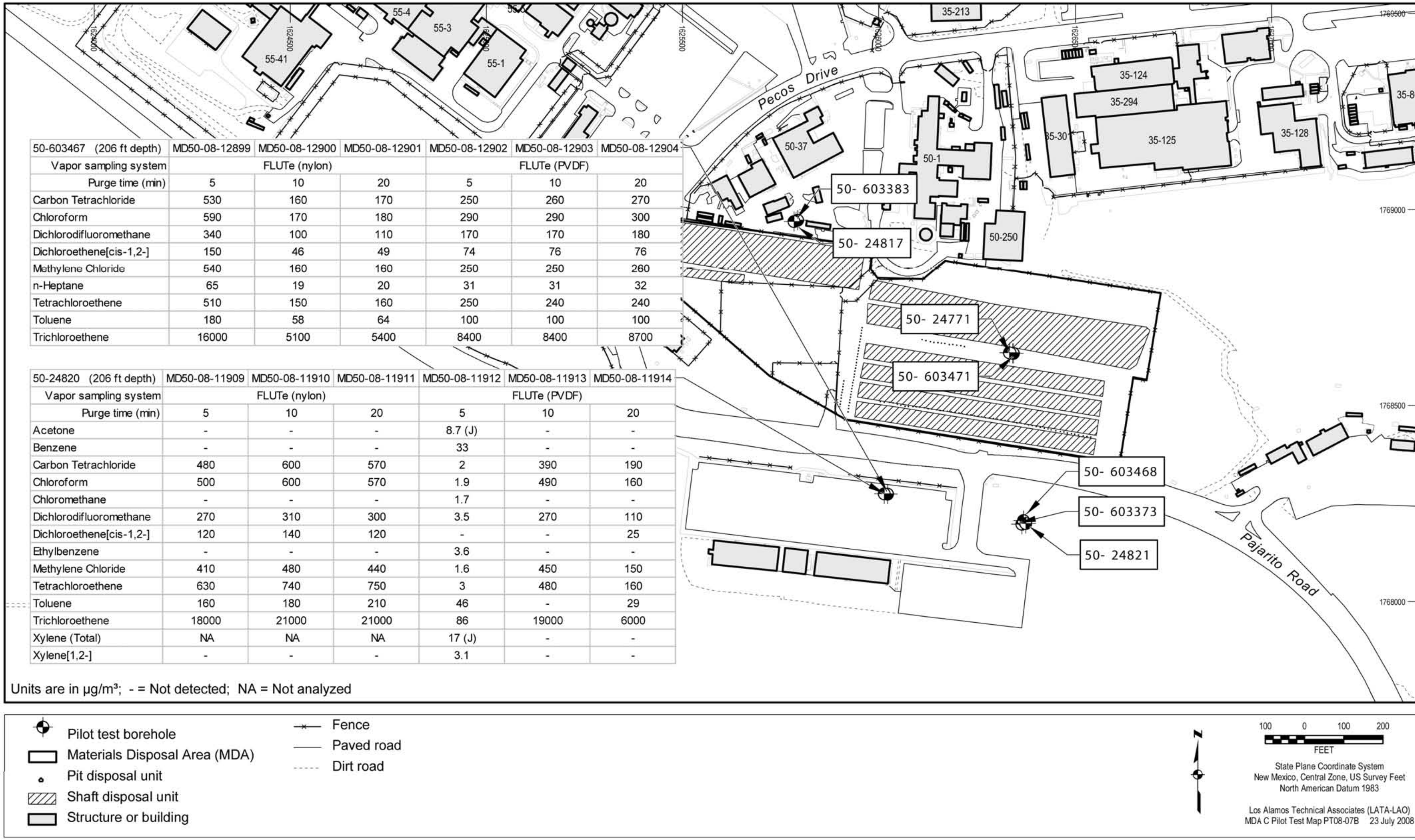
Figure 3.2-1 Summary of VOCs detected in pilot test pore-gas samples at boreholes 50-24817 and 50-603383



50-603467 (26 ft depth)	MD50-08-12894	MD50-08-12895	MD50-08-12896	MD50-08-12891	MD50-08-12892	MD50-08-12893
Vapor sampling system	FLUTe (nylon)			FLUTe (PVDF)		
Purge time (min)	5	10	20	5	10	20
Acetone	36	34	15	44	40	40
Butanone[2-]	8.7	12	4.8	11	12	12
Carbon Disulfide	-	-	-	-	-	7.6
Carbon Tetrachloride	76	67	73	220	230	220
Chloroform	100	92	99	270	280	280
Cyclohexane	18	17	18	63	62	58
Dichlorodifluoromethane	50	44	50	150	160	140
Dichloroethene[cis-1,2-]	15	14	14	41	42	46
Methylene Chloride	14	13	14	35	37	37
n-Heptane	69	62	70	240	240	230
Tetrachloroethene	60	54	58	160	160	160
Tetrahydrofuran	3.6	-	2.5	-	7.8	7.5
Toluene	430	390	420	1100	1100	1100
Trichloroethene	1600	1400	1500	4100	4300	4300

Units are in μg/m³; - = Not detected

Figure 3.3-1a Summary of VOCs detected in pilot test pore-gas samples from boreholes 50-24820 and 50-603467 (26-ft depth samples collected at 50-603467 only)

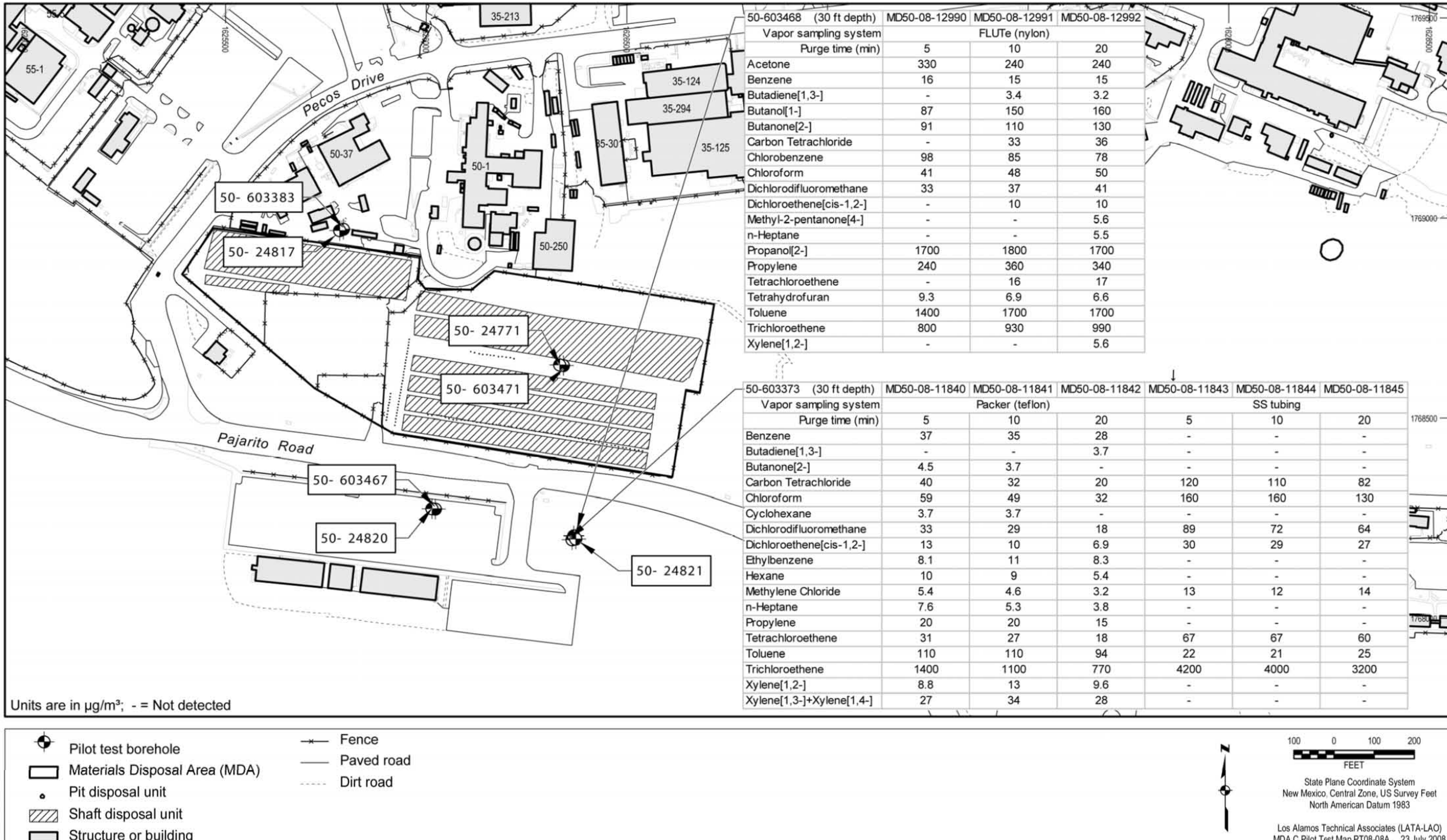


50-603467 (206 ft depth)	MD50-08-12899	MD50-08-12900	MD50-08-12901	MD50-08-12902	MD50-08-12903	MD50-08-12904
Vapor sampling system	FLUTe (nylon)			FLUTe (PVDF)		
Purge time (min)	5	10	20	5	10	20
Carbon Tetrachloride	530	160	170	250	260	270
Chloroform	590	170	180	290	290	300
Dichlorodifluoromethane	340	100	110	170	170	180
Dichloroethene[cis-1,2-]	150	46	49	74	76	76
Methylene Chloride	540	160	160	250	250	260
n-Heptane	65	19	20	31	31	32
Tetrachloroethene	510	150	160	250	240	240
Toluene	180	58	64	100	100	100
Trichloroethene	16000	5100	5400	8400	8400	8700

50-24820 (206 ft depth)	MD50-08-11909	MD50-08-11910	MD50-08-11911	MD50-08-11912	MD50-08-11913	MD50-08-11914
Vapor sampling system	FLUTe (nylon)			FLUTe (PVDF)		
Purge time (min)	5	10	20	5	10	20
Acetone	-	-	-	8.7 (J)	-	-
Benzene	-	-	-	33	-	-
Carbon Tetrachloride	480	600	570	2	390	190
Chloroform	500	600	570	1.9	490	160
Chloromethane	-	-	-	1.7	-	-
Dichlorodifluoromethane	270	310	300	3.5	270	110
Dichloroethene[cis-1,2-]	120	140	120	-	-	25
Ethylbenzene	-	-	-	3.6	-	-
Methylene Chloride	410	480	440	1.6	450	150
Tetrachloroethene	630	740	750	3	480	160
Toluene	160	180	210	46	-	29
Trichloroethene	18000	21000	21000	86	19000	6000
Xylene (Total)	NA	NA	NA	17 (J)	-	-
Xylene[1,2-]	-	-	-	3.1	-	-

Units are in µg/m³; - = Not detected; NA = Not analyzed

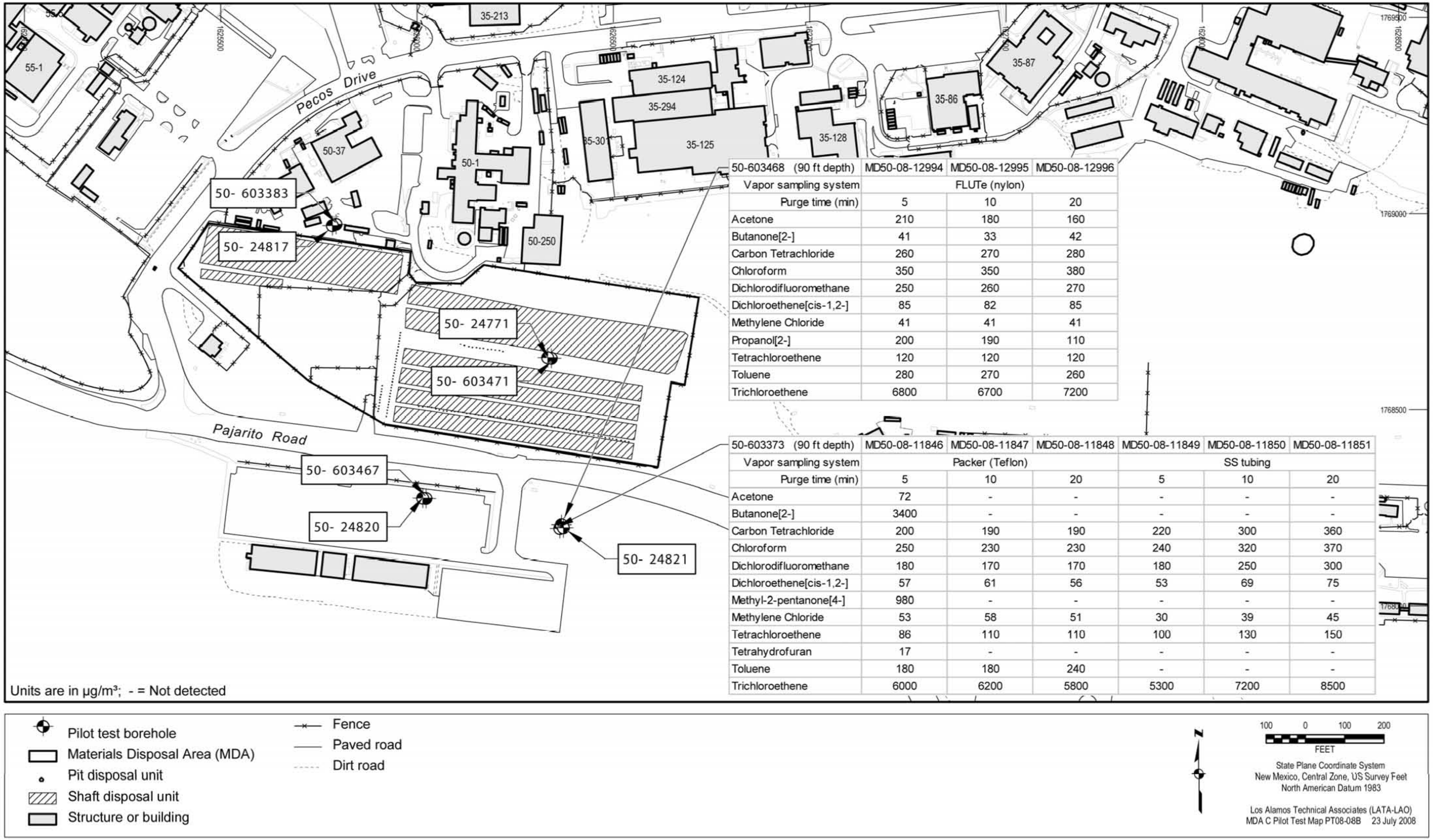
Figure 3.3-1b Summary of VOCs detected in pilot test pore-gas samples from boreholes 50-24820 and 50-603467 (206-ft depth)



50-603468 (30 ft depth)	MD50-08-12990	MD50-08-12991	MD50-08-12992
Vapor sampling system		FLUTe (nylon)	
Purge time (min)	5	10	20
Acetone	330	240	240
Benzene	16	15	15
Butadiene[1,3-]	-	3.4	3.2
Butanol[1-]	87	150	160
Butanone[2-]	91	110	130
Carbon Tetrachloride	-	33	36
Chlorobenzene	98	85	78
Chloroform	41	48	50
Dichlorodifluoromethane	33	37	41
Dichloroethene[cis-1,2-]	-	10	10
Methyl-2-pentanone[4-]	-	-	5.6
n-Heptane	-	-	5.5
Propanol[2-]	1700	1800	1700
Propylene	240	360	340
Tetrachloroethene	-	16	17
Tetrahydrofuran	9.3	6.9	6.6
Toluene	1400	1700	1700
Trichloroethene	800	930	990
Xylene[1,2-]	-	-	5.6

50-603373 (30 ft depth)	MD50-08-11840	MD50-08-11841	MD50-08-11842	MD50-08-11843	MD50-08-11844	MD50-08-11845
Vapor sampling system		Packer (teflon)			SS tubing	
Purge time (min)	5	10	20	5	10	20
Benzene	37	35	28	-	-	-
Butadiene[1,3-]	-	-	3.7	-	-	-
Butanone[2-]	4.5	3.7	-	-	-	-
Carbon Tetrachloride	40	32	20	120	110	82
Chloroform	59	49	32	160	160	130
Cyclohexane	3.7	3.7	-	-	-	-
Dichlorodifluoromethane	33	29	18	89	72	64
Dichloroethene[cis-1,2-]	13	10	6.9	30	29	27
Ethylbenzene	8.1	11	8.3	-	-	-
Hexane	10	9	5.4	-	-	-
Methylene Chloride	5.4	4.6	3.2	13	12	14
n-Heptane	7.6	5.3	3.8	-	-	-
Propylene	20	20	15	-	-	-
Tetrachloroethene	31	27	18	67	67	60
Toluene	110	110	94	22	21	25
Trichloroethene	1400	1100	770	4200	4000	3200
Xylene[1,2-]	8.8	13	9.6	-	-	-
Xylene[1,3-]+Xylene[1,4-]	27	34	28	-	-	-

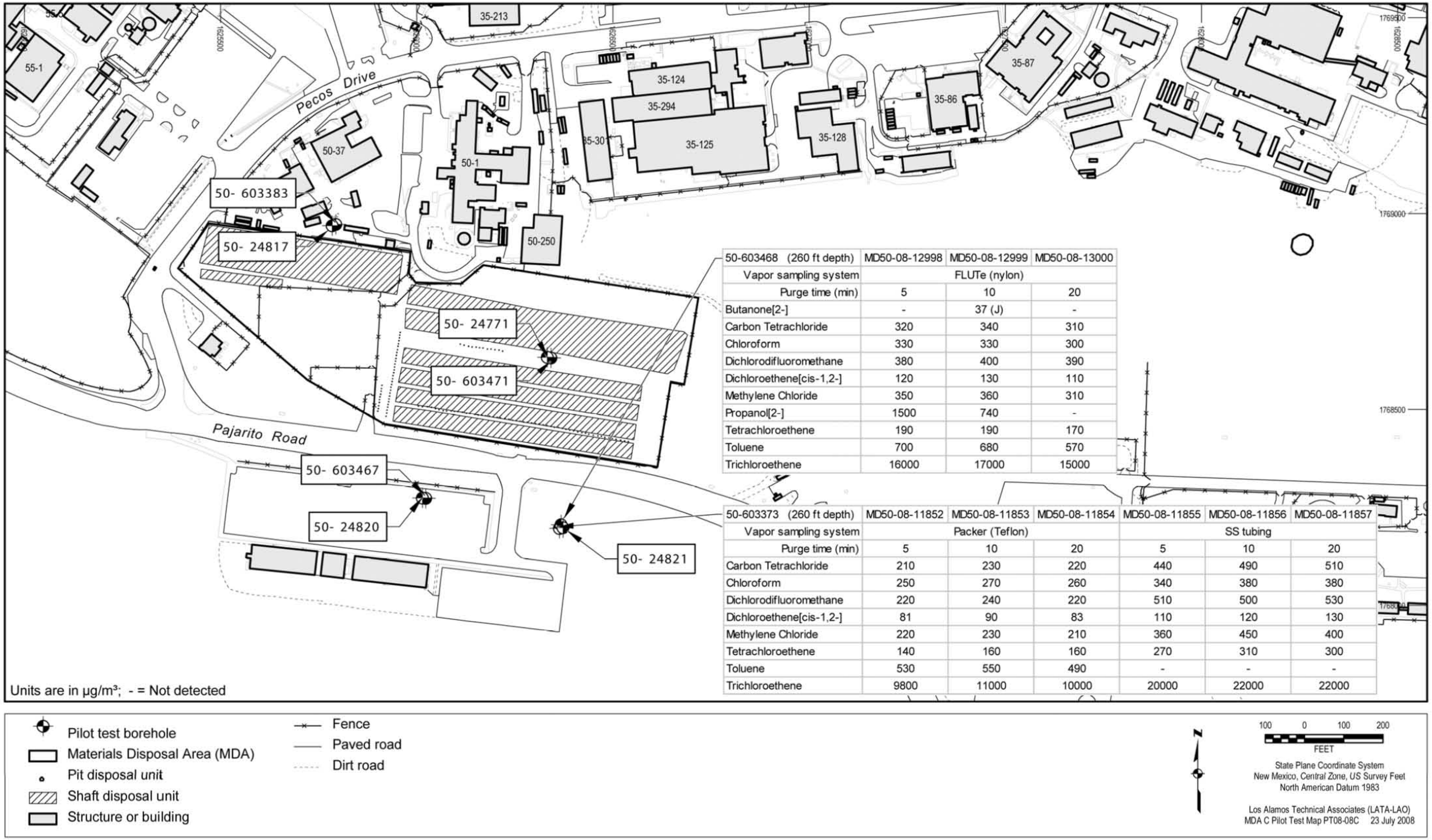
Figure 3.4-1a Summary of VOCs detected in pilot test pore-gas samples at boreholes 50-603373 and 50-603468 (30-ft depth)



50-603468 (90 ft depth)	MD50-08-12994	MD50-08-12995	MD50-08-12996
Vapor sampling system	FLUTe (nylon)		
Purge time (min)	5	10	20
Acetone	210	180	160
Butanone[2-]	41	33	42
Carbon Tetrachloride	260	270	280
Chloroform	350	350	380
Dichlorodifluoromethane	250	260	270
Dichloroethene[cis-1,2-]	85	82	85
Methylene Chloride	41	41	41
Propanol[2-]	200	190	110
Tetrachloroethene	120	120	120
Toluene	280	270	260
Trichloroethene	6800	6700	7200

50-603373 (90 ft depth)	MD50-08-11846	MD50-08-11847	MD50-08-11848	MD50-08-11849	MD50-08-11850	MD50-08-11851
Vapor sampling system	Packer (Teflon)			SS tubing		
Purge time (min)	5	10	20	5	10	20
Acetone	72	-	-	-	-	-
Butanone[2-]	3400	-	-	-	-	-
Carbon Tetrachloride	200	190	190	220	300	360
Chloroform	250	230	230	240	320	370
Dichlorodifluoromethane	180	170	170	180	250	300
Dichloroethene[cis-1,2-]	57	61	56	53	69	75
Methyl-2-pentanone[4-]	980	-	-	-	-	-
Methylene Chloride	53	58	51	30	39	45
Tetrachloroethene	86	110	110	100	130	150
Tetrahydrofuran	17	-	-	-	-	-
Toluene	180	180	240	-	-	-
Trichloroethene	6000	6200	5800	5300	7200	8500

Figure 3.4-1b Summary of VOCs detected in pilot test pore-gas samples at boreholes 50-603373 and 50-603468 (90-ft depth)



50-603468 (260 ft depth)	MD50-08-12998	MD50-08-12999	MD50-08-13000
Vapor sampling system	FLUTe (nylon)		
Purge time (min)	5	10	20
Butanone[2-]	-	37 (J)	-
Carbon Tetrachloride	320	340	310
Chloroform	330	330	300
Dichlorodifluoromethane	380	400	390
Dichloroethene[cis-1,2-]	120	130	110
Methylene Chloride	350	360	310
Propanol[2-]	1500	740	-
Tetrachloroethene	190	190	170
Toluene	700	680	570
Trichloroethene	16000	17000	15000

50-603373 (260 ft depth)	MD50-08-11852	MD50-08-11853	MD50-08-11854	MD50-08-11855	MD50-08-11856	MD50-08-11857
Vapor sampling system	Packer (Teflon)			SS tubing		
Purge time (min)	5	10	20	5	10	20
Carbon Tetrachloride	210	230	220	440	490	510
Chloroform	250	270	260	340	380	380
Dichlorodifluoromethane	220	240	220	510	500	530
Dichloroethene[cis-1,2-]	81	90	83	110	120	130
Methylene Chloride	220	230	210	360	450	400
Tetrachloroethene	140	160	160	270	310	300
Toluene	530	550	490	-	-	-
Trichloroethene	9800	11000	10000	20000	22000	22000

Figure 3.4-1c Summary of VOCs detected in pilot test pore-gas samples at boreholes 50-603373 and 50-603468 (260-ft depth)

Table 2.3-1
Summary of Pore-Gas Samples Collected for Pilot Test

Location ID	Sample ID	Depth (ft)	Vapor-Sampling System	Purge Time (min)	Tritium	VOC	Collection Date
Nested Boreholes 50-24771 and 50-603471							
50-24771	MD50-08-11991	100	Packer (Teflon)	5	—[a]	08-1094[b]	5/1/2008
50-24771	MD50-08-11992	100	Packer (Teflon)	10	—	08-1094	5/1/2008
50-24771	MD50-08-11993	100	Packer (Teflon)	20	—	08-1094	5/1/2008
50-24771	MD50-08-11989	100	Packer (Teflon)	n/a[c]	08-1093	—	5/1/2008
50-24771	MD50-08-11994	150	Packer (Teflon)	5	—	08-1097	5/1/2008
50-24771	MD50-08-11995	150	Packer (Teflon)	10	—	08-1097	5/1/2008
50-24771	MD50-08-11996	150	Packer (Teflon)	20	—	08-1097	5/1/2008
50-24771	MD50-08-11990	150	Packer (Teflon)	n/a	08-1096	—	5/1/2008
50-603471	MD50-08-13696	100	FLUTe (nylon)	5	—	08-1507	7/2/2008
50-603471	MD50-08-13697	100	FLUTe (nylon)	10	—	08-1507	7/2/2008
50-603471	MD50-08-13698	100	FLUTe (nylon)	20	—	08-1507	7/2/2008
50-603471	MD50-08-13702	100	FLUTe (nylon)	n/a	08-1508	—	7/2/2008
50-603471	MD50-08-13704	150	FLUTe (nylon)	5	—	08-1507	7/2/2008
50-603471	MD50-08-13705	150	FLUTe (nylon)	10	—	08-1507	7/2/2008
50-603471	MD50-08-13706	150	FLUTe (nylon)	20	—	08-1507	7/2/2008
50-603471	MD50-08-13710	150	FLUTe (nylon)	n/a	08-1508	—	7/2/2008
Nested Boreholes 50-24817 and 50-603383							
50-24817	MD50-08-11961	140	Packer (Teflon)	5	—	08-942	4/7/2008
50-24817	MD50-08-11962	140	Packer (Teflon)	10	—	08-942	4/7/2008
50-24817	MD50-08-11963	140	Packer (Teflon)	20	—	08-942	4/7/2008
50-24817	MD50-08-11967	140	Packer (Teflon)	n/a	08-943	—	4/7/2008
50-603383	MD50-08-12137	139	FLUTe (nylon)	5	—	08-1109	5/8/2008
50-603383	MD50-08-12138	139	FLUTe (nylon)	10	—	08-1109	5/8/2008
50-603383	MD50-08-12139	139	FLUTe (nylon)	20	—	08-1109	5/8/2008
50-603383	MD50-08-12140	139	FLUTe (nylon)	n/a	08-1110	—	5/8/2008
Nested Boreholes 50-24820 and 50-603467							
50-24820	MD50-08-11909	206	FLUTe (nylon)	5	—	08-958	4/8/2008
50-24820	MD50-08-11910	206	FLUTe (nylon)	10	—	08-958	4/8/2008
50-24820	MD50-08-11911	206	FLUTe (nylon)	20	—	08-958	4/8/2008
50-24820	MD50-08-11912	206	FLUTe (PVDF)	5	—	08-959	4/8/2008
50-24820	MD50-08-11913	206	FLUTe (PVDF)	10	—	08-959	4/8/2008
50-24820	MD50-08-11914	206	FLUTe (PVDF)	20	—	08-959	4/8/2008
50-603467	MD50-08-12894	26	FLUTe (nylon)	5	—	08-1266	6/2/2008
50-603467	MD50-08-12895	26	FLUTe (nylon)	10	—	08-1266	6/2/2008
50-603467	MD50-08-12896	26	FLUTe (nylon)	20	—	08-1266	6/2/2008
50-603467	MD50-08-12897	26	FLUTe (nylon)	n/a	08-1267	—	6/2/2008

Table 2.3-1 (continued)

Location ID	Sample ID	Depth (ft)	Vapor-Sampling System	Purge Time (min)	Tritium	VOC	Collection Date
50-603467	MD50-08-12891	26	FLUTe (PVDF)	5	—	08-1266	6/2/2008
50-603467	MD50-08-12892	26	FLUTe (PVDF)	10	—	08-1266	6/2/2008
50-603467	MD50-08-12893	26	FLUTe (PVDF)	20	—	08-1266	6/2/2008
50-603467	MD50-08-12898	26	FLUTe (PVDF)	n/a	08-1267	—	6/2/2008
50-603467	MD50-08-12899	206	FLUTe (nylon)	5	—	08-1276	6/2/2008
50-603467	MD50-08-12900	206	FLUTe (nylon)	10	—	08-1276	6/2/2008
50-603467	MD50-08-12901	206	FLUTe (nylon)	20	—	08-1276	6/2/2008
50-603467	MD50-08-12906	206	FLUTe (nylon)	n/a	08-1277	—	6/3/2008
50-603467	MD50-08-12902	206	FLUTe (PVDF)	5	—	08-1276	6/2/2008
50-603467	MD50-08-12903	206	FLUTe (PVDF)	10	—	08-1276	6/2/2008
50-603467	MD50-08-12904	206	FLUTe (PVDF)	20	—	08-1276	6/2/2008
50-603467	MD50-08-12905	206	FLUTe (PVDF)	n/a	08-1277	—	6/2/2008
Nested Boreholes 50-603373 and 50-603468							
50-603373	MD50-08-11840	30	Packer (Teflon)	5	—	08-920	4/3/2008
50-603373	MD50-08-11841	30	Packer (Teflon)	10	—	08-920	4/3/2008
50-603373	MD50-08-11842	30	Packer (Teflon)	20	—	08-920	4/3/2008
50-603373	MD50-08-11862	30	Packer (Teflon)	n/a	08-926	—	4/3/2008
50-603373	MD50-08-11843	30	SS Tubing	5	—	08-1030	4/21/2008
50-603373	MD50-08-11844	30	SS Tubing	10	—	08-1030	4/21/2008
50-603373	MD50-08-11845	30	SS Tubing	20	—	08-1030	4/21/2008
50-603373	MD50-08-11863	30	SS Tubing	n/a	08-1029	—	4/21/2008
50-603373	MD50-08-11846	90	Packer (Teflon)	5	—	08-915	4/2/2008
50-603373	MD50-08-11847	90	Packer (Teflon)	10	—	08-915	4/2/2008
50-603373	MD50-08-11848	90	Packer (Teflon)	20	—	08-915	4/2/2008
50-603373	MD50-08-11868	90	Packer (Teflon)	n/a	08-919	—	4/3/2008
50-603373	MD50-08-11850	90	SS Tubing	5	—	08-1030	4/21/2008
50-603373	MD50-08-11849	90	SS Tubing	10	—	08-1030	4/21/2008
50-603373	MD50-08-11851	90	SS Tubing	20	—	08-1030	4/21/2008
50-603373	MD50-08-11869	90	SS Tubing	n/a	08-1029	—	4/21/2008
50-603373	MD50-08-11853	260	Packer (Teflon)	5	—	08-915	4/2/2008
50-603373	MD50-08-11852	260	Packer (Teflon)	10	—	08-915	4/2/2008
50-603373	MD50-08-11854	260	Packer (Teflon)	20	—	08-915	4/2/2008
50-603373	MD50-08-11874	260	Packer (Teflon)	n/a	08-914	—	4/2/2008
50-603373	MD50-08-11855	260	SS Tubing	5	—	08-1021	4/18/2008
50-603373	MD50-08-11856	260	SS Tubing	10	—	08-1021	4/18/2008
50-603373	MD50-08-11857	260	SS Tubing	20	—	08-1021	4/18/2008
50-603373	MD50-08-11875	260	SS Tubing	n/a	08-1022	—	4/18/2008

Table 2.3-1 (continued)

Location ID	Sample ID	Depth (ft)	Vapor-Sampling System	Purge Time (min)	Tritium	VOC	Collection Date
50-603468	MD50-08-12990	30	FLUTe (nylon)	5	—	08-1379	6/17/2008
50-603468	MD50-08-12991	30	FLUTe (nylon)	10	—	08-1379	6/17/2008
50-603468	MD50-08-12992	30	FLUTe (nylon)	20	—	08-1379	6/17/2008
50-603468	MD50-08-12993	30	FLUTe (nylon)	n/a	08-1391	—	6/18/2008
50-603468	MD50-08-12994	90	FLUTe (nylon)	5	—	08-1396	6/19/2008
50-603468	MD50-08-12995	90	FLUTe (nylon)	10	—	08-1396	6/19/2008
50-603468	MD50-08-12996	90	FLUTe (nylon)	20	—	08-1396	6/19/2008
50-603468	MD50-08-12997	90	FLUTe (nylon)	n/a	08-1400	—	6/19/2008
50-603468	MD50-08-12998	260	FLUTe (nylon)	5	—	08-1396	6/19/2008
50-603468	MD50-08-12999	260	FLUTe (nylon)	10	—	08-1396	6/19/2008
50-603468	MD50-08-13000	260	FLUTe (nylon)	20	—	08-1396	6/19/2008
50-603468	MD50-08-13001	260	FLUTe (nylon)	n/a	08-1400	—	6/19/2008

[a] — = Analysis not requested.

[b] Analytical request number.

[c] n/a = Not applicable.

Table 3.1-1
Summary of VOCs Detected in
Pilot Test Pore-Gas Samples at Boreholes 50-24771 and 50-603471

Location ID	Sample ID	Depth (ft)	Vapor Sampling System	Purge Time (min)	Butanone[2-]	Carbon Tetrachloride	Chloroform	Dichlorodifluoromethane	Dichloroethane[1,2-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol	Methylene Chloride	Propanol[2-]	Tetrachloroethene	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethane[1,1,2-]	Trichloroethene
50-24771	MD50-08-11991	100	Packer (Teflon)	5	—*	1500	1800	850	—	340	—	430	1000	—	1000	—	410	—	—	40000
50-24771	MD50-08-11992	100	Packer (Teflon)	10	—	1300	1700	770	—	360	—	—	1000	—	1100	—	380	—	—	35000
50-24771	MD50-08-11993	100	Packer (Teflon)	20	—	1300	1600	670	120 (J)	320	—	—	850	—	970	—	330	—	—	29000
50-24771	MD50-08-11994	150	Packer (Teflon)	5	—	1700	2300	1200	—	540	—	—	1800	—	1500	—	440	—	—	58000
50-24771	MD50-08-11995	150	Packer (Teflon)	10	—	1400	2000	950	—	450	—	—	1500	—	1200	—	390	—	—	46000
50-24771	MD50-08-11996	150	Packer (Teflon)	20	—	1300	1900	840	130	440	—	—	1400	—	1100	—	320	—	—	42000
50-603471	MD50-08-13696	100	FLUTe (nylon)	5	85	1700	1900	620	150	250	89	—	200	—	990	230	370	—	—	18000
50-603471	MD50-08-13697	100	FLUTe (nylon)	10	92	1900	2100	680	160	280	92	—	230	120	1100	240	420	74	100	20000
50-603471	MD50-08-13698	100	FLUTe (nylon)	20	87	1800	1900	650	150	260	87	—	210	—	1000	210	390	—	—	19000
50-603471	MD50-08-13704	150	FLUTe (nylon)	5	100	1300	1900	650	170	370	100	—	730	260	780	300	300	—	—	27000
50-603471	MD50-08-13705	150	FLUTe (nylon)	10	110	1400	1900	670	160	370	100	—	740	230	800	280	290	—	—	28000
50-603471	MD50-08-13706	150	FLUTe (nylon)	20	98	1400	2000	680	170	380	100	—	750	200	810	250	300	—	—	28000

Note: Units are in $\mu g/m^3$.

* — = Not detected.

Table 3.1-2
Summary of Tritium Detected in
Pilot Test Pore-Gas Samples at MDA C

Location ID	Sample ID	Depth (ft)	Vapor-Sampling System	Tritium
50-24771	MD50-08-11989	100	Packer (Teflon)	8263.94
50-24771	MD50-08-11990	150	Packer (Teflon)	3989.57
50-603471	MD50-08-13702	100	FLUTe (nylon)	20792.6
50-603471	MD50-08-13710	150	FLUTe (nylon)	1873.01
50-24817	MD50-08-11967	140	Packer (Teflon)	77524.2
50-603383	MD50-08-12140	139	FLUTe (nylon)	373474
50-603467	MD50-08-12905	206	FLUTe (PVDF)	280.26
50-603373	MD50-08-11862	30	Packer (Teflon)	944.59
50-603373	MD50-08-11869	90	SS tubing	595.232
50-603373	MD50-08-11874	260	Packer (Teflon)	524.735
50-603373	MD50-08-11875	260	SS tubing	1005.25
50-603468	MD50-08-13001	260	FLUTe (nylon)	303.002

Note: Units are pCi/L.

Table 3.2-1
Summary of VOCs Detected
in Pilot Test Pore-Gas Samples at Boreholes 50-24817 and 50-603383

Location ID	Sample ID	Depth (ft)	Vapor Sampling System	Purge Time (min)	Acetone	Benzene	Butanol[1-]	Butanone[2-]	Carbon Tetrachloride	Chlorobenzene	Chlorodifluoromethane	Chloroform	Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Dichlorodifluoromethane	Dichloroethane[1,1-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dichloropropane[1,2-]	Ethanol	Hexane	Methylene Chloride	n-Heptane	Propanol[2-]	Propylene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloro-1,2,2-trifluoroethane[1,1,2-]	Trichloroethane[1,1,1-]	Trichloroethene	Trichlorofluoromethane
50-24817	MD50-08-11961	140	Packer (Teflon)	5	40	—[*]	—	—	220	—	—	130	—	280	15	45	38	230	—	—	37	25	—	—	850	—	1600	910	200	3600	29
50-24817	MD50-08-11962	140	Packer (Teflon)	10	—	—	—	—	210	—	—	120	—	280	—	44	40	230	—	—	33	24	—	—	860	—	1400	950	200	3600	30
50-24817	MD50-08-11963	140	Packer (Teflon)	20	36	—	—	—	200	—	—	120	18	270	14	41	35	220	—	—	31	26	—	—	820	—	1500	950	200	3400	29
50-603383	MD50-08-12137	139	FLUTe (nylon)	5	120	10	79	89	170	21	34	140	17	240	24	53	39	250	75	31	43	110	84	43	680	12	820	1100	230	3200	27
50-603383	MD50-08-12138	139	FLUTe (nylon)	10	100	8.3	65	86	170	17	34	150	17	250	24	55	42	270	73	28	44	100	74	—	730	11	810	1100	240	3500	30
50-603383	MD50-08-12139	139	FLUTe (nylon)	20	89	7.7	58	84	170	13	35	150	17	250	24	54	40	270	70	24	44	100	71	—	780	11	760	1100	240	3600	30

Note: Units are in $\mu g/m^3$.
[*] — = Not detected.

Table 3.3-1
Summary of VOCs Detected
in Pilot Test Pore-Gas Samples at Boreholes 50-24820 and 50-603467

Location ID	Sample ID	Depth (ft)	Vapor Sampling System	Purge Time (min)	Acetone	Benzene	Butanone[2-]	Carbon Disulfide	Carbon Tetrachloride	Chloroform	Chloromethane	Cyclohexane	Dichlorodifluoromethane	Dichloroethene[cis-1,2-]	Ethylbenzene	Methylene Chloride	n-Heptane	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloroethene	Xylene (Total)	Xylene[1,2-]
50-24820	MD50-08-11909	206	FLUTe (nylon)	5	—[a]	—	—	—	480	500	—	—	270	120	—	410	—	630	—	160	18000	NA[b]	—
50-24820	MD50-08-11910	206	FLUTe (nylon)	10	—	—	—	—	600	600	—	—	310	140	—	480	—	740	—	180	21000	NA	—
50-24820	MD50-08-11911	206	FLUTe (nylon)	20	—	—	—	—	570	570	—	—	300	120	—	440	—	750	—	210	21000	NA	—
50-24820	MD50-08-11912	206	FLUTe (PVDF)	5	8.7 (J)	33	—	—	2	1.9	1.7	NA[b]	3.5	—	3.6	1.6	NA	3	NA	46	86	17 (J)	3.1
50-24820	MD50-08-11913	206	FLUTe (PVDF)	10	—	—	—	—	390	490	—	NA	270	—	—	450	NA	480	NA	—	19000	—	—
50-24820	MD50-08-11914	206	FLUTe (PVDF)	20	—	—	—	—	190	160	—	NA	110	25	—	150	NA	160	NA	29	6000	—	—
50-603467	MD50-08-12894	26	FLUTe (nylon)	5	36	—	8.7	—	76	100	—	18	50	15	—	14	69	60	3.6	430	1600	NA	—
50-603467	MD50-08-12895	26	FLUTe (nylon)	10	34	—	12	—	67	92	—	17	44	14	—	13	62	54	—	390	1400	NA	—
50-603467	MD50-08-12896	26	FLUTe (nylon)	20	15	—	4.8	—	73	99	—	18	50	14	—	14	70	58	2.5	420	1500	NA	—
50-603467	MD50-08-12891	26	FLUTe (PVDF)	5	44	—	11	—	220	270	—	63	150	41	—	35	240	160	—	1100	4100	NA	—
50-603467	MD50-08-12892	26	FLUTe (PVDF)	10	40	—	12	—	230	280	—	62	160	42	—	37	240	160	7.8	1100	4300	NA	—
50-603467	MD50-08-12893	26	FLUTe (PVDF)	20	40	—	12	7.6	220	280	—	58	140	46	—	37	230	160	7.5	1100	4300	NA	—
50-603467	MD50-08-12899	206	FLUTe (nylon)	5	—	—	—	—	530	590	—	—	340	150	—	540	65	510	—	180	16000	NA	—
50-603467	MD50-08-12900	206	FLUTe (nylon)	10	—	—	—	—	160	170	—	—	100	46	—	160	19	150	—	58	5100	NA	—
50-603467	MD50-08-12901	206	FLUTe (nylon)	20	—	—	—	—	170	180	—	—	110	49	—	160	20	160	—	64	5400	NA	—
50-603467	MD50-08-12902	206	FLUTe (PVDF)	5	—	—	—	—	250	290	—	—	170	74	—	250	31	250	—	100	8400	NA	—
50-603467	MD50-08-12903	206	FLUTe (PVDF)	10	—	—	—	—	260	290	—	—	170	76	—	250	31	240	—	100	8400	NA	—
50-603467	MD50-08-12904	206	FLUTe (PVDF)	20	—	—	—	—	270	300	—	—	180	76	—	260	32	240	—	100	8700	NA	—

Note: Units are in $\mu g/m^3$.

[a] — = Not detected.

[b] NA = Not analyzed.

Table 3.4-1
Summary of VOCs Detected in
Pilot Test Pore-Gas Samples at Boreholes 50-603373 and 50-603468

Location ID	Sample ID	Depth (ft0	Vapor-Sampling System	Purge Time (min)	Acetone	Benzene	Butadiene[1,3-]	Butanol[1-]	Butanone[2-]	Carbon Tetrachloride	Chlorobenzene	Chloroform	Cyclohexane	Dichlorodifluoromethane	Dichloroethene[cis-1,2-]	Ethylbenzene	Hexane	Methyl-2-pentanone[4-]	Methylene Chloride	n-Heptane	Propanol[2-]	Propylene	Tetrachloroethene	Tetrahydrofuran	Toluene	Trichloroethene	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
50-603373	MD50-08-11840	30	Packer (Teflon)	5	—*	37	—	—	4.5	40	—	59	3.7	33	13	8.1	10	—	5.4	7.6	—	20	31	—	110	1400	8.8	27
50-603373	MD50-08-11841	30	Packer (Teflon)	10	—	35	—	—	3.7	32	—	49	3.7	29	10	11	9	—	4.6	5.3	—	20	27	—	110	1100	13	34
50-603373	MD50-08-11842	30	Packer (Teflon)	20	—	28	3.7	—	—	20	—	32	—	18	6.9	8.3	5.4	—	3.2	3.8	—	15	18	—	94	770	9.6	28
50-603373	MD50-08-11843	30	SS Tubing	5	—	—	—	—	—	120	—	160	—	89	30	—	—	—	13	—	—	—	67	—	22	4200	—	—
50-603373	MD50-08-11844	30	SS Tubing	10	—	—	—	—	—	110	—	160	—	72	29	—	—	—	12	—	—	—	67	—	21	4000	—	—
50-603373	MD50-08-11845	30	SS Tubing	20	—	—	—	—	—	82	—	130	—	64	27	—	—	—	14	—	—	—	60	—	25	3200	—	—
50-603373	MD50-08-11846	90	Packer (Teflon)	5	72	—	—	—	3400	200	—	250	—	180	57	—	—	980	53	—	—	—	86	17	180	6000	—	—
50-603373	MD50-08-11847	90	Packer (Teflon)	10	—	—	—	—	—	190	—	230	—	170	61	—	—	—	58	—	—	—	110	—	180	6200	—	—
50-603373	MD50-08-11848	90	Packer (Teflon)	20	—	—	—	—	—	190	—	230	—	170	56	—	—	—	51	—	—	—	110	—	240	5800	—	—
50-603373	MD50-08-11849	90	SS Tubing	5	—	—	—	—	—	220	—	240	—	180	53	—	—	—	30	—	—	—	100	—	—	5300	—	—
50-603373	MD50-08-11850	90	SS Tubing	10	—	—	—	—	—	300	—	320	—	250	69	—	—	—	39	—	—	—	130	—	—	7200	—	—
50-603373	MD50-08-11851	90	SS Tubing	20	—	—	—	—	—	360	—	370	—	300	75	—	—	—	45	—	—	—	150	—	—	8500	—	—
50-603373	MD50-08-11852	260	Packer (Teflon)	5	—	—	—	—	—	210	—	250	—	220	81	—	—	—	220	—	—	—	140	—	530	9800	—	—
50-603373	MD50-08-11853	260	Packer (Teflon)	10	—	—	—	—	—	230	—	270	—	240	90	—	—	—	230	—	—	—	160	—	550	11000	—	—
50-603373	MD50-08-11854	260	Packer (Teflon)	20	—	—	—	—	—	220	—	260	—	220	83	—	—	—	210	—	—	—	160	—	490	10000	—	—
50-603373	MD50-08-11855	260	SS Tubing	5	—	—	—	—	—	440	—	340	—	510	110	—	—	—	360	—	—	—	270	—	—	20000	—	—
50-603373	MD50-08-11856	260	SS Tubing	10	—	—	—	—	—	490	—	380	—	500	120	—	—	—	450	—	—	—	310	—	—	22000	—	—
50-603373	MD50-08-11857	260	SS Tubing	20	—	—	—	—	—	510	—	380	—	530	130	—	—	—	400	—	—	—	300	—	—	22000	—	—
50-603468	MD50-08-12990	30	FLUTe (nylon)	5	330	16	—	87	91	—	98	41	—	33	—	—	—	—	—	—	1700	240	—	9.3	1400	800	—	—
50-603468	MD50-08-12991	30	FLUTe (nylon)	10	240	15	3.4	150	110	33	85	48	—	37	10	—	—	—	—	—	1800	360	16	6.9	1700	930	—	—
50-603468	MD50-08-12992	30	FLUTe (nylon)	20	240	15	3.2	160	130	36	78	50	—	41	10	—	—	5.6	—	5.5	1700	340	17	6.6	1700	990	5.6	—
50-603468	MD50-08-12994	90	FLUTe (nylon)	5	210	—	—	—	41	260	—	350	—	250	85	—	—	—	41	—	200	—	120	—	280	6800	—	—
50-603468	MD50-08-12995	90	FLUTe (nylon)	10	180	—	—	—	33	270	—	350	—	260	82	—	—	—	41	—	190	—	120	—	270	6700	—	—
50-603468	MD50-08-12996	90	FLUTe (nylon)	20	160	—	—	—	42	280	—	380	—	270	85	—	—	—	41	—	110	—	120	—	260	7200	—	—
50-603468	MD50-08-12998	260	FLUTe (nylon)	5	—	—	—	—	—	320	—	330	—	380	120	—	—	—	350	—	1500	—	190	—	700	16000	—	—
50-603468	MD50-08-12999	260	FLUTe (nylon)	10	—	—	—	—	37 (J)	340	—	330	—	400	130	—	—	—	360	—	740	—	190	—	680	17000	—	—
50-603468	MD50-08-13000	260	FLUTe (nylon)	20	—	—	—	—	—	310	—	300	—	390	110	—	—	—	310	—	—	—	170	—	570	15000	—	—

Note: Units are in $\mu g/m^3$.

* — = Not detected.

Appendix A

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

A-1.0 ACRONYMS AND ABBREVIATIONS

AR	air rotary
bgs	below ground surface
CCV	continuing calibration verification
COC	chain of custody
Consent Order	Compliance Order on Consent
DOE	Department of Energy [U.S.]
EP	Environmental Programs [Directorate]
EPA	Environmental Protection Agency [U.S.]
ERSS	Environment and Remediation Support Services
ER ID	Environmental Remediation and Surveillance Program identification number
FD	field duplicate
FLUTe	Flexible Liner Underground Technology
FD	field duplicate
HSA	hollow-stem auger
ICV	initial calibration verification
IDW	investigation-derived waste
LANL	Los Alamos National Laboratory
LCS	laboratory control sample
MDA	Material Disposal Area
NMED	New Mexico Environment Department
OU	operable unit
PID	photoionization detector
PVDF	polyvinylidene fluoride
QA/QC	quality assurance/quality control
QP	quality procedure
RCT	radiological control technician
RPD	relative percent difference
RPF	Records Processing Facility
SMO	Sample Management Office
SOP	standard operating procedure
SOW	statement of work
SS	stainless steel
SVOC	semivolatile organic compound
TA	technical area
TD	total depth
VOC	volatile organic compound

A-2.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	by	To Obtain U.S. 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

Field Methods

B-1.0 INTRODUCTION

This appendix summarizes field methods used for the pilot test at Material Disposal Area (MDA) C at Technical Area 50 (TA-50), also referred to as Solid Waste Management Unit 50-009. Table B-1.0-1 provides general method information, and the following sections provide a more detailed description of the field methods. All activities were conducted in accordance with the applicable Environmental Programs (EP) Directorate standard operating procedures (SOPs) and quality procedures (QPs), which are listed in Table B-1.0-2 and may be found at the following web address: http://erproject.lanl.gov/documents/procedures/sops.html.

B-2.0 EXPLORATORY DRILLING CHARACTERIZATION

No exploratory drilling characterization was conducted during the pilot test. All drilling was conducted for the purpose of collecting investigation samples. Only pore-gas samples were collected as part of the pilot test.

B-3.0 FIELD-SCREENING METHODS

This section summarizes the field-screening methods used during the pilot test. Field screening for volatile organic compounds (VOCs) and radioactivity was performed at the time of collection of each pore-gas sample. The field-screening results will be presented in the MDA C Phase II investigation report.

B-3.1 Field Screening for VOCs

Pore-gas screening was conducted using a MiniRAE 2000 photoionization detector (PID) equipped with an 11.7 electronvolt lamp during drilling. Screening was performed at the sample collection point, and the screening measurement was compared with ambient air screening results. The results were recorded on each sample collection log (Appendix E) at the time of the screening measurement.

B-3.2 Field Screening for Radioactivity

Radiation screening was conducted by a Los Alamos National Laboratory radiological control technician (RCT) using an Eberline E-600 radiation meter with an SHP-380AB alpha/beta scintillation detector during drilling. The Eberline E-600 with attachment SHP-380AB consists of a dual phosphor plate covered by two mylar windows housed in a light-excluding metal body. The phosphor plate is a plastic scintillator for the detection of beta emissions and is thinly coated with zinc sulfide for the detection of alpha emissions. The operational range varies from trace emissions to 1 mil disintegration per minute.

B-4.0 FIELD INSTRUMENT CALIBRATION

All instruments were calibrated before use. Calibration of the PID was conducted at least daily by site crew. Calibration of the Eberline E-600 was conducted by the RCT. All calibrations were performed according to the manufacturers' specifications and requirements.

B-4.1 PID Calibration

The PID was calibrated both to ambient air and a standard reference gas (100 ppm isobutylene). The ambient-air calibration determined the zero point of the instrument sensor calibration curve in ambient air.

Calibration with the standard reference gas determined a second point of the sensor calibration curve. Each calibration was within 10% of 100 ppm isobutylene, qualifying the instrument for use.

The following calibration information was recorded daily:

- instrument identification number
- date and time
- concentration and type of calibration gas used (isobutylene at 100 ppm)
- name of the personnel performing the calibration

All daily calibration procedures for the MiniRAE 2000 PID met the manufacturer's specifications for standard reference gas calibration and the requirements of EP-DIR-SOP-5006, "Control of Measuring and Test Equipment, Revision 0."

B-4.2 Eberline E-600 Instrument Calibration

The Eberline E-600 was calibrated daily by the RCT before local background levels for radioactivity were measured. The instrument was calibrated using plutonium-239 and chloride-36 sources for alpha and beta emissions, respectively. The following five checks were performed as part of the calibration procedures: calibration date, physical damage, battery, response to a source of radioactivity, and background. All calibrations performed for the Eberline E-600 met the manufacturer's specifications, the requirements of EP-DIR-SOP-5006, and the applicable radiation detection instrument manual.

B-5.0 SUBSURFACE PORE-GAS SAMPLING

This section summarizes the methods used for collecting subsurface pore-gas samples according to the approved MDA C pilot test investigation work plan and New Mexico Environment Department (NMED) modifications (LANL 2008, 101653; NMED 2008, 101113).

B-5.1 Subsurface Pore-Gas Sampling Methods

Subsurface pore-gas sampling was performed using three vapor-sampling systems: the packer system, the Flexible Liner Underground Technology (FLUTe) system, and the stainless-steel (SS) tubing system.

The packer system uses an inflatable packer and a sample-train apparatus to pull vapor from the rock formation at desired sampling intervals as described in EP-ERSS-SOP-5074, "Sampling of Subatmospheric Air." The packer is lowered down the borehole and inflated with nitrogen to seal off a vapor inlet at the desired depth. The sample train is purged to ensure formation air is being collected. Teflon tubing connects the vapor inlet and the sample train and is replaced for every borehole to prevent cross-contamination. Sampling is performed by extracting the formation air through the vapor inlet at the desired depth. Leak check on the sample train was required before every sampling or screening activity and was performed on the Teflon tubing and packer connections.

The FLUTe system uses a flexible liner that provides a seal against the borehole wall. The sampling ports and the nylon tubing are installed in the interior sleeves of the liner. The liner is lowered into the borehole while the borehole is supported by a temporary casing and filled with sand as the casing is withdrawn. The pressure of sand inside the liner seals the liner against the borehole wall, pressing the sampling ports against the formation. Vapor is drawn through a permeable spacer material between the liner and the borehole wall and into the tubing. A diffusion barrier is installed in the permeable spacer material to minimize the potential for interactions with the material that could affect analyte concentrations. The standard nylon tubing can be replaced by polyvinylidene fluoride (PVDF) tubing for the FLUTe system.

The SS tubing system uses continuous lengths of 0.25-in.-outside diameter SS tubing with a single port installed at the target depth of each tube. Bentonite is used above and below each sampling port to seal off the interval to be sampled. The 5-ft space between the bentonite seals at each sampling interval is filled with sand. Sampling is performed by extracting the formation air through the sand layer and into the SS tubing.

Purge time is the time required to purge the entire tubing volume for the FLUTe and SS tubing systems and the tubing volume plus the packer void space for the packer system. During the purge, percent oxygen, percent carbon dioxide, and percent methane readings from the sample train exhaust were collected every several minutes using a LANDTEC GEM-500 gas extraction meter to ensure all ambient air was evacuated from the system. These parameters are provided in Appendix C. At the end of every purge cycle, a PID reading was collected from the air in the sample train apparatus. Subsurface pore-gas samples were collected in SUMMA canisters and submitted to the Sample Management Office (SMO) for shipment to the analytical laboratory for VOC analysis using U.S. Environmental Protection Agency (EPA) Method TO-15. Samples were also collected in silica gel sample tubes for tritium analysis using EPA Method 906.0.

B-5.2 Quality Assurance/Quality Control Samples

Quality assurance (QA)/quality control (QC) for pilot test pore-gas samples consisted of field duplicates and field trip blanks. Field duplicate samples were collected at a frequency of at least 1 duplicate sample for every 10 samples, as an evaluation of the reproducibility of field-sampling techniques. The QA/QC samples were collected in accordance with EP-ERSS-SOP-5059, "Field Quality Control Samples, Revision 0."

B-5.3 Sample Documentation and Handling

Field personnel completed a sample collection log and associated chain-of-custody (COC) form for each sample. Samples were handled in accordance with EP-ERSS-SOP-5057, "Handling, Packaging, and Transporting Field Samples, Revision 0" and EP-ERSS-SOP-5056, "Sample Containers and Preservation, Revision 0."

Samples were transported to the SMO before they were shipped to the analytical laboratory. The SMO personnel reviewed and approved the sample collection logs and COC forms and accepted custody of the samples.

B-5.4 Decontamination of Sampling Equipment

The split-spoon core barrel and all other sampling equipment that made (or could have made) contact with sample material were decontaminated after each 2.5-ft core was retrieved and logged. Decontamination included wiping the equipment with Fantastik and paper towels. Decontamination of the drilling equipment was conducted before mobilization of the drill rig to another borehole to avoid cross-contamination between samples and borehole locations. Decontamination activities were performed in accordance with EP-ERSS-SOP-5061, “Field Decontamination of Equipment, Revision 0,” and EP-ERSS-SOP-5059, “Field Quality Control Samples, Revision 0.”

B-6.0 INVESTIGATION-DERIVED WASTE STORAGE AND DISPOSAL

Investigation-derived waste (IDW) generated during this investigation consisted of drill cuttings, personal protective equipment, and sampling supplies and plastics. All IDW generated during the MDA C field investigation was managed in accordance with the procedures described in Appendix B of the approved Phase II MDA C work plan (LANL 2007, 098425). These procedures incorporate the requirements of all applicable EPA and NMED regulations, U.S. Department of Energy (DOE) orders, and Laboratory implementation requirements. The IDW from this pilot test is part of the Phase II investigation waste and the details of handling of the IDW will be presented in the Phase II investigation report.

B-7.0 DEVIATIONS FROM THE WORK PLAN

B-7.1 Pilot Test Boreholes

The approved work plan proposed to extend four existing boreholes (50-24771, 50-24817, 50-24820, and 50-24821) and advance one new borehole (PT-1, i.e., borehole 50-603373) (LANL 2008, 101653). During the pilot test drilling activities, an additional four new boreholes were drilled within 10 ft of the existing proposed pilot test boreholes.

- Borehole 50-603471 was drilled within 10 ft of borehole 50-24771 and was sampled with the FLUTe system at the same depth intervals as borehole 50-24771.
- Borehole 50-603383 was drilled within 10 ft of borehole 50-24817 and was sampled with the FLUTe system at a similar depth interval as borehole 50-24817.
- Borehole 50-603467 was drilled within 10 ft of borehole 50-24820 and was sampled with the FLUTe system equipped with nylon and PVDF tubing at the same depth interval as borehole 50-24820.
- Borehole 50-603468 was drilled within 10 ft of boreholes 50-24821 and 50-603373 and was sampled with the FLUTe system at the same depth intervals as borehole 50-603373.
- Borehole 50-24771 was extended using the hollow-stem auger (HSA) drilling first and then air-rotary drilling, not just HSA drilling as presented in the approved pilot test work plan.
- The sampling with the FLUTe system in borehole 50-24817 was at 139 ft, not at 140 ft as proposed in the approved pilot test work plan.
- The sampling in borehole 50-603467 was at 26 and 206 ft, not at 20 and 200 ft as proposed in the approved pilot test work plan for borehole 50-24820.

B-7.2 Organic Chemical Analyses

Different laboratories analyzed VOC pore-gas samples and as a result the standard list of analytes was different between the analytical laboratories. For samples collected using the FLUTe system at 206 ft in borehole 50-24820: xylene (total) was not analyzed for in samples collected with nylon tubing; cyclohexane, n-heptane, and tetrahydrofuran were not analyzed for in samples collected with PVDF tubing. Xylene (total) was not analyzed for in samples collected from borehole 50-603467.

B-8.0 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 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; DOE-Los Alamos Site Office; EPA, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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 2008. "Pilot Test Work Plan for Evaluating Vapor-Sampling Systems at Material Disposal Area C," Los Alamos National Laboratory document LA-UR-08-1614, Los Alamos, New Mexico. (LANL 2008, 101653)

NMED (New Mexico Environment Department), March 28, 2008. "Approval with Modification, Pilot Test Work Plan for Evaluating Vapor-Sampling Systems at Material Disposal Area C," 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 2008, 101113)

Table B-1.0-1
Summary Description of Field Investigation Methods

Method	Summary
Handling, Packaging, and Shipping of Samples	Field team members label samples before packing and ensure that the sample containers and the containers used for transport 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. The SMO arranges for shipping the samples to analytical laboratories. The field team member must inform the SMO when levels of radioactivity are in the action-level or limited-quantity ranges.
Sample Control and Field Documentation	The collection, screening, and transport of samples are documented on standard forms generated by the SMO. These include sample collection logs, COC forms, and sample container labels. Collection logs are completed at the time of sample collection and are signed by the sampler and a reviewer who verify the logs for completeness and accuracy. Corresponding labels are applied to each sample container. COC forms are completed and assigned to verify that the samples are not left unattended.
Field QC Samples	Field QC samples are collected as directed in the Compliance Order on Consent as follows: Field Duplicate: At a frequency 10%; collected at the same time as a regular sample and submitted for the same analyses. Trip Blanks: Required for all field events that include the collection of samples for VOC analysis. Trip blanks are nitrogen samples run through sample tables into SUMMA canisters.
Field Decontamination of Drilling and Sampling Equipment	Dry decontamination is the preferred method to minimize the generation of liquid waste. Dry decontamination may include the use of a wire brush or other tool for removal of soil or other material adhering to the sampling equipment, followed by the use of Fantastik 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.
Containers and Preservation of Samples	Specific requirements/processes for sample containers, preservation techniques, and holding times are based on EPA guidance for environmental sampling, preservation, and QA. Specific requirements for each sample are printed on the sample collection logs provided by the SMO (size and type of container: glass, amber glass, polyethylene, preservative, etc.).

Table B-1.0-1 (continued)

Method	Summary
Subsurface Pore Gas Sampling for VOCs	The packer system uses an inflatable packer and a sample-train apparatus to pull vapor from the rock formation at desired sampling intervals. The packer is lowered down the borehole and inflated with nitrogen to seal off a vapor inlet at the desired depth. The sample train is then purged to ensure formation air is being collected. Teflon tubing connects the vapor inlet and the sample train and is replaced for every borehole to prevent cross-contamination. Sampling is performed by extracting the formation air through the vapor inlet at the desired depth. The FLUTe system uses a flexible liner that provides a seal against the borehole wall. The sampling ports and the nylon tubing are installed in the interior sleeves of the liner. The liner is lowered into the borehole while the borehole is supported by a temporary casing then filled with sand as the casing is withdrawn. The pressure of sand inside the liner seals the liner against the borehole wall, pressing the sampling ports against the formation. Vapor is drawn through a permeable spacer material between the liner and the borehole wall and into the tubing. A diffusion barrier is installed in the permeable spacer material to minimize the potential for interactions with the material that could affect analyte concentrations. The standard nylon tubing can be replaced by PVDF tubing for the FLUTe system. The SS tubing system uses continuous lengths of 0.25-in.-outside diameter SS tubing with a single port installed at the target depth of each tube. Bentonite is used above and below each sampling port to seal off the interval to be sampled. The 5-ft space between the bentonite seals at each sampling interval is filled with sand. Sampling is performed by extracting the formation air through the sand layer and into the SS tubing. Purge time is the time required to purge the entire tubing volume for the FLUTe and SS tubing systems and the tubing volume plus the packer void space for the packer system. Theoretically, required purge time is less than 1 min. During the purge, percent oxygen, percent carbon dioxide, and percent methane readings from the sample train exhaust were collected every several minutes using a LANDTEC GEM-500 gas extraction meter to ensure all ambient air was evacuated from the system. At the end of every purge cycle, a PID reading was collected from the air in the sample-train apparatus. Subsurface pore-gas samples were collected in SUMMA canisters and submitted to the SMO for shipment to the analytical laboratory for VOC analysis using EPA Method TO-15.
Subsurface Pore-Gas Moisture Sampling for Tritium	The process for sampling subsurface pore-gas moisture for tritium is performed using the vapor-sampling system that is used for VOC sampling. After the purge of the vapor-sampling system, a Teflon tube filled with silica gel is used to capture the pore-gas moisture. The Teflon tube is sent to an analytical laboratory for analysis for moisture and tritium using EPA Method 906.0.

Table B-1.0-2
QPS and SOPs Used for the Pilot Test Activities at MDA C

EP-DIR-SOP-4003, Records Management
EP-DIR-SOP-4001, Document Control
EP-DIR-SOP-5006, Control of Measuring and Test Equipment
QP-5.7, Notebook Documentation for Environmental Restoration Technical Activities
ISD 315-1.1, Conduct of Operations Manual
LIR401-10-01.2, Stop Work and Restart
EP-ERSS-SOP-5055, General Instructions for Field Investigations
EP-ERSS-SOP-5056, Sample Containers and Preservation
EP-ERSS-SOP-5057, Handling, Packaging, and Transporting Field Samples
EP-ERSS-SOP-5058. Sample Control and Field Documentation
EP-ERSS-SOP-5059, Field Quality Control Samples
EP-ERSS-SOP-5061, Field Decontamination of Equipment
SOP-01.12, Field Site Closeout Checklist
EP-ERSS-SOP-5028, Coordinating and Evaluating Geodetic Surveys
EP-ERSS-SOP-5074, Sampling of Subatmospheric Air
SOP-06.33, Headspace Vapor Screening with a Photoionization Detector
SOP-12.01, Field Logging, Handling, and Documentation of Borehole Materials

Note: These procedures are available at http://erproject.lanl.gov/documents/procedures/sops.html.

Appendix C

Borehole and Screening Logs
(on CD included with this document)

Appendix D

Analytical Program

D-1.0 INTRODUCTION

This appendix discusses analytical methods and the data quality review for the pore-gas samples collected and analyzed for the pilot test at Material Disposal Area (MDA) C at Los Alamos National Laboratory (the Laboratory).

The analytical program used for this investigation includes submission of samples to approved contract laboratories, with specific requirements for analytical methods, data quality, and reporting. Quality assurance (QA), quality control (QC), and data validation procedures were implemented in accordance with the requirements of the “Quality Assurance Project Plan Requirements for Sampling and Analysis” (LANL 1996, 054609) and the analytical services statement of work (SOW) for contract laboratories (LANL 2000, 071233). The results of the QA/QC activities were used to estimate accuracy, bias, and precision of the analytical measurements. QC samples included method blanks, blank spikes, matrix spikes, and laboratory control samples (LCSs) to assess accuracy and bias. Internal standards, external standards, surrogates, and tracers were also used to assess accuracy.

The type and frequency of QC analyses are described in the analytical services SOW (LANL 2000, 071233), along with the applicable analytical methods. Other QC factors, such as sample preservation and holding times, were also assessed in accordance with the requirements outlined in Environmental Programs (EP) Directorate-Environment and Remediation Support Services (ERSS) standard operating procedure (SOP) 5056, “Sample Containers and Preservation, Revision 0.” Evaluating these QC indicators allows estimates to be made of the accuracy, bias, and precision of the analytical suites. A focused data validation was also performed for all the data packages (also referred to as request numbers).

The following SOPs were used for data validation:

- EP-ERSS-SOP-5161, “Routine Validation of Volatile Organic Data, Revision 0”
- EP-ERSS-SOP-5166, “Routine Validation of Chemical Separation Alpha Spectrometry, Gas Proportional Counting, and Liquid Scintillation Data, Revision 0”

The focused validation included a more detailed review of the data generated by the analytical laboratory. The analytical data and instrument printouts used during focused validation are provided on compact disc in Appendix E.

Analytical data were reviewed and evaluated based on U.S. Environmental Protection Agency (EPA) National Functional Guidelines for organic chemical data review where applicable (EPA 1999, 066649). As a result of the data validation and assessment efforts, qualifiers may be assigned to the analytical records as appropriate. The data qualifiers used in the data validation procedures are defined in Appendix A.

The vapor samples collected in this pilot test were shipped through the Laboratory’s Sample Management Office (SMO) to off-site contract laboratories for analyses of volatile organic chemicals (VOCs) and tritium. The samples are accompanied by full chain-of-custody (COC) and QC documentation. The analytical method for VOCs is EPA Method TO-15, and the target compound list is in the analytical services SOW (LANL 2000, 071233). The analytical method for tritium is EPA Method 906.6 by liquid scintillation.

D-2.0 ANALYSIS SUMMARY

A total of 63 vapor samples (plus 6 field duplicate [FD] samples) were analyzed for VOCs; a total of 19 vapor samples (plus 2 FDs) were analyzed for tritium.

D-2.1 QA/QC Summary

All QC procedures were followed as required in the analytical services SOW (LANL 2000, 071233) and applicable corresponding EPA methodologies.

There were no rejected sample results for this pilot test.

D-2.1.1 Maintenance of COC

COC forms were maintained properly for all samples (Appendix E).

D-2.1.2 Sample Documentation

Samples were properly documented on sample collection logs in the field (Appendix E).

D-2.1.3 Sample Dilutions

Samples were diluted for organic chemical analyses and were not diluted for tritium analysis.

D-2.1.4 Sample Preservation

Preservation criteria were met for all samples.

D-2.1.5 Holding Times

Holding time criteria were met for all samples.

D-2.1.6 Qualifiers and Reason Codes for VOC Results

Among the 5730 VOC results (plus 434 FD VOC results), 4 results were qualified as estimated (J), 182 results (plus 13 FD results) were qualified as estimated not detected (UJ), and the remaining 966 results (plus 99 FD results) did not have qualifiers assigned or were not qualified (NQ).

- For the four VOC results that were qualified as estimated (J), one was qualified by the external laboratory, one was qualified because the affected results were not analyzed with a valid 5-point calibration curve and/or a standard at the reporting limit, and the other two were qualified because the initial calibration verification (ICV) and/or continuing calibration verification (CCV) was recovered outside the method-specific limits.
- For the 182 VOC results (plus 13 FD results) that were qualified as estimated not detected (UJ), 1 was qualified because the affected results were not analyzed with a valid 5-point calibration curve and/or a standard at the reporting limit, 96 (plus 5 FD results) were qualified because the affected analytes were analyzed with an initial calibration curve that exceeded the percent relative standard deviation criteria and/or the associated multipoint calibration correlation coefficient was <0.995, 76 (plus 7 FD results) were qualified because the ICV and/or CCV were recovered

outside the method-specific, and 9 (plus 1 FD result) were qualified because the LCS percent recovery was less than the lower acceptance limit but >10%.

D-2.1.7 Qualifiers and Reason Codes for Tritium Results

The 17 tritium results (plus 2 FD tritium results) did not have any QA/QC issues, which resulted in no qualifiers being assigned.

D-2.1.8 Laboratory and FDs

Laboratory and field duplicates collected indicated acceptable precision for all results.

D-3.0 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 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 U.S. Department of Energy–Los Alamos Site Office; EPA, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

EPA (U.S. Environmental Protection Agency), October 1999. "USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review," EPA540/R-99/008, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1999, 066649)

LANL (Los Alamos National Laboratory), March 1996. "Quality Assurance Project Plan Requirements for Sampling and Analysis," Los Alamos National Laboratory document LA-UR-96-441, Los Alamos, New Mexico. (LANL 1996, 054609)

LANL (Los Alamos National Laboratory), December 2000. "University of California, Los Alamos National Laboratory (LANL), I8980SOW0-8S, Statement of Work for Analytical Laboratories," Rev. 1, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2000, 071233)

Appendix E

Analytical Suites and Results and Sample Collection Logs
(on CD included with this document)

Appendix F

Statistical Analyses

F-1.0 INTRODUCTION

The objective of the pilot test is to compare analytical results for volatile organic compounds (VOCs) in samples collected using three vapor-sampling systems (packer system, stainless steel [SS] system, and Flexible Liner Underground Technology [FLUTe] system). In addition, a FLUTe system (boreholes 50-24820 and 50-603467) was used to collect samples through two separate sample trains consisting of (1) nylon tubing and (2) polyvinylidene fluoride (PVDF) tubing to compare the VOC results from the two tubing types.

In each borehole and sample depth, three consecutive samples were collected using sampling system purge times of 5, 10, and 20 min. These three results were averaged to obtain a single representative concentration for each VOC/depth/sampling system combination (Table F-1.2-1). The means for each VOC were compared with either the paired vapor-sampling systems or with the two FLUTe tubing types. A relative percent difference (RPD) was calculated for each VOC. Only VOCs detected in both systems for each paired comparison received statistical analyses.

F-1.1 Statistical Methods

F-1.1.1 RPD

The RPD is defined as

$$RPD = \frac{Mean2 - Mean1}{\left(\frac{Mean2 + Mean1}{2}\right)} * 100$$

Where RPD = relative percent difference,
Mean2 = mean of the three results from the second vapor-sampling system, and
Mean1 = mean of the three results from the first vapor-sampling system.

The RPD qualitatively shows the difference of the two results for a particular VOC in a particular borehole or at two adjacent (less than 10 ft apart) boreholes with the same sample depths. A mean RPD value was calculated for the group of VOCs for each comparison. The mean RPD qualitatively shows the magnitude and general trend of the difference between the two systems (a negative RPD value indicates that the second mean is lower than the first mean).

F-1.1.2 Student's t-test

By the design of the pilot test and the MDA C vapor-sampling approach, three VOC samples were collected (following 5-, 10-, and 20-min purge times) from each borehole/depth/sampling system. These three samples are not true replicates because the second and third samples could be affected by extraction of the previous sample(s). In most cases, however, the difference between analytical results for the three purge times was relatively small. If the three purge time samples are assumed to represent independent samples (replicates), there are sufficient samples in most cases to compare the sampling system results with each VOC at single sample depths using Student's *t*-test.

Student's *t*-test is used to evaluate the probability that the distributions of two groups are statistically different from one another (as opposed to being different solely as the result of chance variations). For example, a Student's *t*-test was performed for each analyte, comparing the results of the three samples collected from a single depth with the SS system (borehole 50-603373) with the comparable results collected using the FLUTe system in adjacent borehole 50-603468. The Student's *t*-test used was a paired two-tailed test. In some cases, all three sample results were not available and the Student's *t*-test could not be performed. The two groups of sample results in each test are considered significantly different if the calculated p-value is 0.05 or less; p-values greater than 0.05 indicate the two groups are not significantly different.

F-1.2 RPD Results

The calculated RPDs are presented in Tables F-1.2-1 to F-1.2-5.

For the comparison of the packer/Teflon system with the FLUTe/nylon system, VOCs in boreholes 50-24817 and 50-603383 (140 ft and 139 ft below ground surface [bgs], respectively) had both positive and negative RPDs (Table F-1.2-1). The mean RPD for all VOCs, however, was positive (15.61), indicating that in general, the analytical results were slightly higher for the FLUTe/nylon system samples. VOCs in boreholes 50-24771 and 50-603471 also had both positive and negative RPDs at both depths (100 ft and 150 ft bgs) (Table F-1.2-2). The mean RPDs for all VOCs were both negative for the two depths sampled (-17.15 for 100 ft bgs and -27.86 for 150 ft bgs), indicating that in general, the analytical results were higher for the packer/Teflon system samples. No consistent trend can be found for the results from the packer/Teflon system and the FLUTe/nylon system.

For the comparison of the FLUTe system with nylon tubing to the FLUTe system with PVDF tubing in borehole 50-24820 at 206 ft bgs, the RPDs for all VOCs are negative, indicating that the analytical results are lower for samples from the PVDF tubing (Table F-1.2-3). In borehole 50-603467, the RPDs for all VOCs are positive at 26 ft bgs and negative at 206 ft bgs, indicating an inconsistent trend in this borehole (Table F-1.2-3).

For the comparison of the packer/Teflon system results with the SS system results in borehole 50-603373 (Table F-1.2-4), the mean RPDs for all sample depths are positive, indicating that the results from the SS system are higher than the results from the packer/Teflon system.

For the comparison of the SS system results with the FLUTe system results in boreholes 50-603373 and 50-603468 (Table F-1.2-5), the RPDs are generally negative, indicating that the FLUTe system results are most often lower than the SS system results. The mean RPD for the results at 30 ft bgs is -59.65, the mean RPD at 90 ft bgs is slightly positive (5.5), and the mean RPD at 260 ft bgs is negative (-24.52) but smaller in magnitude than at 30 ft bgs.

F-1.3 Student's *t*-test Results

The calculated p-values from the Student's *t*-test are presented in Tables F-1.2-1 to F-1.2-5.

For the comparison of the packer/Teflon system with the FLUTe/nylon system in boreholes 50-24817 and 50-603383 (Table F-1.2-1), 9 of 16 Student's *t*-test results show a significant difference. One Student's *t*-test could not be performed because two results for 1,2-dichloro-1,1,2,2-tetrafluoroethane were nondetects. Six of the 9 significant results had positive RPDs, indicating that the FLUTe/nylon sample results were higher than the packer/Teflon results. For comparison of the packer/Teflon system with the FLUTe/nylon system in boreholes 50-24771 and 50-603471 (Table-F-1.2-2), 4 of the 16 Student's *t*-test results show a significant difference between the packer/Teflon system results and the

FLUTe/nylon system results. Two Student's *t*-tests could not be performed because two results were nondetects for each analyte. The majority of the results are not statistically different for the two systems.

For the comparison of the FLUTe/nylon system with the FLUTe/PVDF system in borehole 50-24820 at 206 ft bgs (Table F-1.2-3) and borehole 50-603467 at 26 ft and 206 ft bgs (Table F-1.2-3), 11 of 28 Student's *t*-test results show a significant difference between results. Two Student's *t*-tests could not be performed because the sample size is too small because of nondetects. Ten of the significant results were for VOCs detected at 26 ft in borehole 50-603467 and had positive RPDs, indicating that the FLUTe/PVDF results were higher than the FLUTe/nylon results. However, at 206 ft bgs in borehole 50-24820, six of the seven Student's *t*-test results are not significant, indicating that the results are similar. At 206 ft in borehole 50-603467, none of the nine Student's *t*-test results showed significant differences, indicating similar results for the two types of tubing.

For the comparison of the packer/Teflon system results with the SS system results in borehole 50-603373 (Table F-1.2-4), all eight Student's *t*-test results from 30 ft bgs and all seven Student's *t*-test results from 260 ft bgs showed significant differences. At 90 ft bgs, none of the seven Student's t-test results showed significant differences. Fourteen of the 15 significant results had positive RPDs, indicating that the SS system results were higher than the packer/Teflon system results.

For the comparison of the SS system results with the FLUTe/nylon system results in boreholes 50-603373 and 50-603468 (Table F-1.2-5), 8 of the 21 Student's *t*-test results showed significant differences. Seven of the eight significant results had negative RPDs, indicating that the FLUTe/nylon system results were lower than the SS system results.

F-2.0 Summary

Based on the Student's *t*-test results, it is not clear that significant differences exist consistently among the different sampling systems or tubing types. The RPDs among sampling systems and tubing types also are not consistent and demonstrate high variability in both magnitude and direction among VOCs and sample depths. The Student's *t*-tests were conducted on groups of three samples per borehole/depth/sampling system, the smallest sample count for which statistical analyses such as Student's *t*-tests are generally applicable. Therefore, only limited value can be placed on the statistical results obtained.

Despite the limited utility of the statistical comparisons, some general conclusions may be drawn regarding the sampling system comparisons. In multiple direct comparisons between the various combinations of two sampling systems, the SS system tended to have higher concentrations of individual VOCs than either the packer system or the FLUTe/nylon system. No significant difference was observed for the packer and the FLUTe systems and the two types of tubing used in the FLUTe system. While these general trends exist, there also is an overlap in concentrations of VOCs among samples collected by all the systems.

Table F-1.2-1
Comparisons of Packer and FLUTe Sampling Systems in Boreholes 50-24817 and 50-603383

Borehole ID	50-24817 (140-ft depth)				50-603383 (139-ft depth)					
Vapor sampling system	Packer (Teflon)				FLUTe (nylon)					
Sample ID	MD50-08-11961	MD50-08-11962	MD50-08-11963		MD50-08-12137	MD50-08-12138	MD50-08-12139			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Acetone	40	–[a]	36	38.00	120	100	89	103.00	92.20	0.127506
Carbon tetrachloride	220	210	200	210.00	170	170	170	170.00	-21.05	**0.020204**
Chloroform	130	120	120	123.33	140	150	150	146.67	17.28	0.072827
Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	–	–	18	18.00	17	17	17	17.00	-5.71	n/a[b]
Dichlorodifluoromethane	280	280	270	276.67	240	250	250	246.67	-11.46	**0.035099**
Dichloroethane[1,1-]	15	–	14	14.50	24	24	24	24.00	49.35	**0.033475**
Dichloroethene[1,1-]	45	44	41	43.33	53	55	54	54.00	21.92	**0.018054**
Dichloroethene[cis-1,2-]	38	40	35	37.67	39	42	40	40.33	6.84	0.156726
Dichloropropane[1,2-]	230	230	220	226.67	250	270	270	263.33	14.97	0.053271
Methylene chloride	37	33	31	33.67	43	44	44	43.67	25.86	**0.040706**
Heptane[n-]	25	24	26	25.00	110	100	100	103.33	122.08	**0.00186**
Tetrachloroethene	850	860	820	843.33	680	730	780	730.00	-14.41	0.098368
Toluene	1600	1400	1500	1500.00	820	810	760	796.67	-61.25	**0.006693**
Trichloro-1,2,2-trifluoroethane[1,1,2-]	910	950	950	936.67	1100	1100	1100	1100.00	16.04	**0.006598**
Trichloroethane[1,1,1-]	200	200	200	200.00	230	240	240	236.67	16.79	**0.008163**
Trichloroethene	3600	3600	3400	3533.33	3200	3500	3600	3433.33	-2.87	0.622036
Trichlorofluoromethane	29	30	29	29.33	27	30	30	29.00	-1.14	0.741801
								Mean RPD =	**15.61**	

Note: Values in bold indicate a significant difference.
[a] – = Not detected.
[b] n/a = Not applicable.

Table F-1.2-2
Comparisons of Packer and FLUTe Sampling Systems in Boreholes 50-24771 and 50-603471

Borehole ID	50-24771 (100-ft depth)				50-603471 (100-ft depth)					
Vapor sampling system	Packer (Teflon)				FLUTe (nylon)					
Sample ID	MD50-08-11991	MD50-08-11992	MD50-08-11993		MD50-08-13696	MD50-08-13697	MD50-08-13698			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	1500	1300	1300	1366.67	1700	1900	1800	1800.00	27.37	0.069051
Chloroform	1800	1700	1600	1700.00	1900	2100	1900	1966.67	14.55	0.094178
Dichlorodifluoromethane	850	770	670	763.33	620	680	650	650.00	-16.04	0.207801
Dichloroethane[1,2-]	—[a]	—[a]	120 (J)	120.00	150	160	150	153.33	24.39	n/a[b]
Dichloroethene[cis-1,2-]	340	360	320	340.00	250	280	260	263.33	-25.41	**0.012976**
Methylene chloride	1000	1000	850	950.00	200	230	210	213.33	-126.65	**0.004414**
Tetrachloroethene	1000	1100	970	1023.33	990	1100	1000	1030.00	0.65	0.634852
Trichloro-1,2,2-trifluoroethane[1,1,2-]	410	380	330	373.33	370	420	390	393.33	5.22	0.579916
Trichloroethene	40000	35000	29000	34666.67	18000	20000	19000	19000.00	-58.39	**0.045968**
								Mean RPD =	**-17.15**	
Borehole ID	**50-24771 (150-ft depth)**				**50-603471 (150-ft depth)**					
Vapor sampling system	Packer (Teflon)				FLUTe (nylon)					
Sample ID	MD50-08-11994	MD50-08-11995	MD50-08-11996		MD50-08-13704	MD50-08-13705	MD50-08-13706			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	1700	1400	1300	1466.67	1300	1400	1400	1366.67	-7.06	0.579916
Chloroform	2300	2000	1900	2066.67	1900	1900	2000	1933.33	-6.67	0.455669
Dichlorodifluoromethane	1200	950	840	996.67	650	670	680	666.67	-39.68	0.103512
Dichloroethane[1,2-]	—	—	130	130.00	170	160	170	166.67	24.72	n/a
Dichloroethene[cis-1,2-]	540	450	440	476.67	370	370	380	373.33	-24.31	0.092543
Methylene chloride	1800	1500	1400	1566.67	730	740	750	740.00	-71.68	**0.022364**
Tetrachloroethene	1500	1200	1100	1266.67	780	800	810	796.67	-45.56	0.067737
Trichloro-1,2,2-trifluoroethane[1,1,2-]	440	390	320	383.33	300	290	300	296.67	-25.49	0.133333
Trichloroethene	58000	46000	42000	48666.67	27000	28000	28000	27666.67	-55.02	0.054846
								Mean RPD =	**-27.86**	

Note: Values in bold indicate a significant difference.

[a] – = Not detected.

[b] n/a = Not applicable.

Table F-1.2-3
Comparisons of Nylon and PVDF Tubing of FLUTe Sampling Systems in Boreholes 50-24820 and 50-603467

Borehole ID	50-603467 (26-ft depth)									
Vapor sampling system	FLUTe (nylon)				FLUTe (PVDF)					
Sample ID	MD50-08-12894	MD50-08-12895	MD50-08-12896		MD50-08-12891	MD50-08-12892	MD50-08-12893			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Acetone	36	34	15	28.33	44	40	40	41.33	37.32	0.163752
Butanone[2-]	8.7	12	4.8	8.50	11	12	12	11.67	31.40	0.274344
Carbon tetrachloride	76	67	73	72.00	220	230	220	223.33	102.48	**0.001515**
Chloroform	100	92	99	97.00	270	280	280	276.67	96.16	**0.000849**
Cyclohexane	18	17	18	17.67	63	62	58	61.00	110.17	**0.001476**
Dichlorodifluoromethane	50	44	50	48.00	150	160	140	150.00	103.03	**0.005466**
Dichloroethene[cis-1,2-]	15	14	14	14.33	41	42	46	43.00	100.00	**0.003764**
Methylene chloride	14	13	14	13.67	35	37	37	36.33	90.67	**0.00151**
Heptane[n-]	69	62	70	67.00	240	240	230	236.67	111.75	**0.000952**
Tetrachloroethene	60	54	58	57.33	160	160	160	160.00	94.48	**0.000295**
Tetrahydrofuran	3.6	—[a]	2.5	3.05	—	7.8	7.5	7.65	85.98	n/a[b]
Toluene	430	390	420	413.33	1100	1100	1100	1100.00	90.75	**0.000306**
Trichloroethene	1600	1400	1500	1500.00	4100	4300	4300	4233.33	95.35	**0.001928**
								Mean RPD =	**88.43**	

Location ID	50-24820 (206-ft depth)									
Vapor sampling system	FLUTe (nylon)				FLUTe (PVDF)					
Sample ID	MD50-08-11909	MD50-08-11910	MD50-08-11911		MD50-08-11912	MD50-08-11913	MD50-08-11914			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	480	600	570	550.00	2	390	190	194.00	-95.70	**0.045115**
Chloroform	500	600	570	556.67	1.9	490	160	217.30	-87.70	0.10184
Dichlorodifluoromethane	270	310	300	293.33	3.5	270	110	127.83	-78.59	0.13064
Dichloroethene[cis-1,2-]	120	140	120	126.67	—	—	25	25.00	-134.07	n/a
Methylene chloride	410	480	440	443.33	1.6	450	150	200.53	-75.42	0.161912
Tetrachloroethene	630	740	750	706.67	3	480	160	214.33	-106.91	0.051818
Toluene	160	180	210	183.33	46	—	29	37.50	-132.08	0.142176
Trichloroethene	18000	21000	21000	20000.00	86	19000	6000	8362.00	-82.07	0.140407
								Mean RPD =	**-99.07**	

Table F-1.2-3 (continued)

Borehole ID	50-603467 (206-ft depth)									
Vapor sampling system	FLUTe (nylon)				FLUTe (PVDF)					
Sample ID	MD50-08-12899	MD50-08-12900	MD50-08-12901		MD50-08-12902	MD50-08-12903	MD50-08-12904			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	530	160	170	286.67	250	260	270	260.00	-9.76	0.852758
Chloroform	590	170	180	313.33	290	290	300	293.33	-6.59	0.899496
Dichlorodifluoromethane	340	100	110	183.33	170	170	180	173.33	-5.61	0.911955
Dichloroethene[cis-1,2-]	150	46	49	81.67	74	76	76	75.33	-8.07	0.872523
Methylene chloride	540	160	160	286.67	250	250	260	253.33	-12.35	0.819402
Heptane[n-]	65	19	20	34.67	31	31	32	31.33	-10.10	0.848066
Tetrachloroethene	510	150	160	273.33	250	240	240	243.33	-11.61	0.818653
Toluene	180	58	64	100.67	100	100	100	100.00	-0.66	0.988128
Trichloroethene	16000	5100	5400	8833.33	8400	8400	8700	8500.00	-3.85	0.935264
								Mean RPD =	**-7.62**	

Note: Values in bold indicate a significant difference.
[a] – = Not detected.
[b] n/a = Not applicable.

Table F-1.2-4
Comparisons of Packer and Stainless Steel Sampling Systems in Borehole 50-603373

Borehole ID	50-603373 (30-ft depth)									
Vapor sampling system	Packer (Teflon)				Stainless Steel					
Sample ID	MD50-08-11840	MD50-08-11841	MD50-08-11842		MD50-08-11843	MD50-08-11844	MD50-08-11845			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	40	32	20	30.67	120	110	82	104.00	108.91	**0.005979**
Chloroform	59	49	32	46.67	160	160	130	150.00	105.08	**0.001443**
Dichlorodifluoromethane	33	29	18	26.67	89	72	64	75.00	95.08	**0.006546**
Dichloroethene[cis-1,2-]	13	10	6.9	9.97	30	29	27	28.67	96.81	**0.002346**
Methylene chloride	5.4	4.6	3.2	4.40	13	12	14	13.00	98.85	**0.016012**
Tetrachloroethene	31	27	18	25.33	67	67	60	64.67	87.41	**0.002005**
Toluene	110	110	94	104.67	22	21	25	22.67	-128.80	**0.006237**
Trichloroethene	1400	1100	770	1090.00	4200	4000	3200	3800.00	110.84	**0.002771**
								Mean RPD =	**71.77**	

Borehole ID	50-603373 (90-ft depth)									
Vapor sampling system	Packer (Teflon)				Stainless Steel					
Sample ID	MD50-08-11846	MD50-08-11847	MD50-08-11848		MD50-08-11849	MD50-08-11850	MD50-08-11851			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	200	190	190	193.33	220	300	360	293.33	41.10	0.148743
Chloroform	250	230	230	236.67	240	320	370	310.00	26.83	0.238202
Dichlorodifluoromethane	180	170	170	173.33	180	250	300	243.33	33.60	0.205707
Dichloroethene[cis-1,2-]	57	61	56	58.00	53	69	75	65.67	12.40	0.367664
Methylene chloride	53	58	51	54.00	30	39	45	38.00	-34.78	0.0893
Tetrachloroethene	86	110	110	102.00	100	130	150	126.67	21.57	0.088294
Trichloroethene	6000	6200	5800	6000.00	5300	7200	8500	7000.00	15.38	0.415461
								Mean RPD =	**16.59**	

Borehole ID	50-603373 (260-ft depth)									
Vapor sampling system	Packer (Teflon)				Stainless Steel					
Sample ID	MD50-08-11852	MD50-08-11853	MD50-08-11854		MD50-08-11855	MD50-08-11856	MD50-08-11857			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	210	230	220	220.00	440	490	510	480.00	74.29	**0.004409**
Chloroform	250	270	260	260.00	340	380	380	366.67	34.04	**0.006767**
Dichlorodifluoromethane	220	240	220	226.67	510	500	530	513.33	77.48	**0.002559**
Dichloroethene[cis-1,2-]	81	90	83	84.67	110	120	130	120.00	34.53	**0.026252**
Methylene chloride	220	230	210	220.00	360	450	400	403.33	58.82	**0.015815**
Tetrachloroethene	140	160	160	153.33	270	310	300	293.33	62.69	**0.001696**
Trichloroethene	9800	11000	10000	10266.67	20000	22000	22000	21333.33	70.04	**0.002206**
								Mean RPD =	58.84	

Note: Values in bold indicate a significant difference.

Table F-1.2-5
Comparisons of Stainless Steel and FLUTe Sampling Systems in Boreholes 50-603373 and 50-603468

Borehole ID	50-603373 (30-ft depth)				50-603468 (30-ft depth)					
Vapor sampling system	Stainless Steel				FLUTe (nylon)					
Sample ID	MD50-08-11843	MD50-08-11844	MD50-08-11845		MD50-08-12990	MD50-08-12991	MD50-08-12992			
Purge time (min)	5	10	20	Mean Sample Results	**5**	**10**	**20**	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	120	110	82	104.00	—*	33	36	34.50	-100.36	0.157176
Chloroform	160	160	130	150.00	41	48	50	46.33	-105.60	**0.013146**
Dichlorodifluoromethane	89	72	64	75.00	33	37	41	37.00	-67.86	0.058783
Dichloroethene[cis-1,2-]	30	29	27	28.67	—	10	10	10.00	-96.55	**0.035331**
Tetrachloroethene	67	67	60	64.67	—	16	17	16.50	-118.69	0.05405
Toluene	22	21	25	22.67	1400	1700	1700	1600.00	194.41	**0.003969**
Trichloroethene	4200	4000	3200	3800.00	800	930	990	906.67	-122.95	**0.014698**
								Mean RPD =	**-59.65**	

Borehole ID	50-603373 (90-ft depth)				50-603468 (90-ft depth)					
Vapor sampling system	Stainless Steel				FLUTe (nylon)					
Sample ID	MD50-08-11849	MD50-08-11850	MD50-08-11851		MD50-08-12994	MD50-08-12995	MD50-08-12996			
Purge time (min)	5	10	20	Mean Sample Results	**5**	**10**	**20**	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	220	300	360	293.33	260	270	280	270.00	-8.28	0.571607
Chloroform	240	320	370	310.00	350	350	380	360.00	14.93	0.24335
Dichlorodifluoromethane	180	250	300	243.33	250	260	270	260.00	6.62	0.624177
Dichloroethene[cis-1,2-]	53	69	75	65.67	85	82	85	84.00	24.50	0.116914
Methylene chloride	30	39	45	38.00	41	41	41	41.00	7.59	0.562405
Tetrachloroethene	100	130	150	126.67	120	120	120	120.00	-5.41	0.691393
Trichloroethene	5300	7200	8500	7000.00	6800	6700	7200	6900.00	-1.44	0.915384
								Mean RPD =	**5.50**	

Table F-1.2-5 (continued)

Borehole ID	50-603373 (260-ft depth)				50-603468 (26 ft depth)					
Vapor sampling system	Stainless Steel				FLUTe (nylon)					
Sample ID	MD50-08-11855	MD50-08-11856	MD50-08-11857		MD50-08-12998	MD50-08-12999	MD50-08-13000			
Purge time (min)	5	10	20	Mean Sample Results	5	10	20	Mean Sample Results	RPD (%)	*t*-test
Carbon tetrachloride	440	490	510	480.00	320	340	310	323.33	-39.00	**0.02147**
Chloroform	340	380	380	366.67	330	330	300	320.00	-13.59	0.147987
Dichlorodifluoromethane	510	500	530	513.33	380	400	390	390.00	-27.31	**0.009363**
Dichloroethene[cis-1,2-]	110	120	130	120.00	120	130	110	120.00	0.00	1
Methylene chloride	360	450	400	403.33	350	360	310	340.00	-17.04	0.14079
Tetrachloroethene	270	310	300	293.33	190	190	170	183.33	-46.15	**0.018743**
Trichloroethene	20000	22000	22000	21333.33	16000	17000	15000	16000.00	-28.57	**0.026271**
								Mean RPD =	**-24.52**	

Note: Values in bold indicate a significant difference
* – = Not detected.