

# **Final Report for Targeted Investigations at Murdock, Nebraska, in 2004**

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**Environmental  
Research Division**

**Argonne National Laboratory**



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**United States Department of Energy**

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## Notation

AGEM	Applied Geosciences and Environmental Management
AMSL	above mean sea level
ASTM	American Society for Testing and Materials
atm	atmosphere(s)
ATSDR	Agency for Toxic Substances and Disease Registry
BGL	below ground level
° C	degree(s) Celsius
CCC	Commodity Credit Corporation
CD	compact disk
CLP	Contract Laboratory Program
cm	centimeter(s)
COC	chain of custody
d	day(s)
DF	dilution factor
ECPT	electronic cone penetrometer
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
g	gram(s)
gal	gallon(s)
GC-ECD	gas chromatograph-electron capture detector
GC-MS	gas chromatograph-mass spectrometer
gpm	gallon(s) per minute
hr	hour(s)
in.	inch(es)
lb	pound(s)
µg/kg	microgram(s) per kilogram
µg/L	microgram(s) per liter
µS/cm	microsiemen(s) per centimeter
m	meter(s)
mi	mile(s)
min	minute(s)
mL	milliliter(s)
mol	mole(s)
NAD	North American Datum
NDEQ	Nebraska Department of Environment Quality

NGVD	National Geodetic Vertical Datum
NHHS	Nebraska Health and Human Services
OEHHA	Office of Environmental Health Hazard Assessment (California)
ppbv	part(s) per billion by volume
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RPD	relative percent difference
SDG	sample delivery group
TOC	top of casing
USDA	U.S. Department of Agriculture
VOC	volatile organic compound
yr	year(s)

## **Final Report for Targeted Investigations at Murdock, Nebraska, in 2004**

### **Executive Summary**

The Environmental Research Division of Argonne National Laboratory has performed a targeted investigation at Murdock, Nebraska, on behalf of the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA). The investigation was initiated to address concerns of the U.S. Environmental Protection Agency (EPA) about (1) a potential threat to water resources northwest of Murdock, beyond the area of observed contaminant discharge to the unnamed tributary to Pawnee Creek; and (2) the potential effect on groundwater of a continuing, uncharacterized contaminant source in the vadose zone soils beneath the former CCC/USDA grain storage facility at Murdock.

The technical objectives of the targeted investigation were to accomplish the following:

1. Determine the continuity, thickness, and hydrogeologic characteristics of the aquifer in the vicinity of the Pawnee Creek tributary.
2. Characterize the present distribution of carbon tetrachloride contamination in groundwater and surface water in the area north of Waverly Road.
3. Determine the patterns of groundwater flow in the vicinity of the Pawnee Creek tributary and their relationship to the expected migration of the identified carbon tetrachloride plume.
4. Identify and delineate the presence of carbon tetrachloride in vadose zone soils in the northern portion of the former CCC/USDA facility that might pose a continuing source of contamination to the aquifer, and determine soil properties affecting vertical contaminant migration.
5. Evaluate contaminant migration from soil to groundwater, and analyze indoor air potentially affected by vapor intrusion at residences built on the former CCC/USDA facility.

6. Evaluate the potential suitability of phytoremediation for this site.

The targeted investigation at Murdock was performed in two main field mobilizations in April and June 2004. Data generated were integrated with the results of earlier investigations at Murdock to produce the following findings with regard to the technical objectives:

- *Objective 1: Determine aquifer characteristics near the tributary creek.*

The aquifer is thinner and less permeable north of Waverly Road than south of this road; the aquifer is absent along the creek because of erosion and subsequent deposition of locally saturated silts and clays.

- *Objective 2: Characterize contaminant distribution in groundwater and surface water north of Waverly Road.*

The carbon tetrachloride plume in groundwater ends along the channel of the tributary creek, about 1,300 ft north of Waverly Road. Discharge from two of the seven tile lines that collect shallow groundwater from the interpreted area of the groundwater plume contained carbon tetrachloride at levels of 88 µg/L and 8.2 µg/L. Surface water in the tributary was contaminated with carbon tetrachloride near the interpreted end of the groundwater plume and near these two tile discharge points. No contamination was found in surface water farther downstream in the tributary creek, beyond 2,000 ft north of Waverly Road.

The maximum carbon tetrachloride concentration in the groundwater plume at Murdock has historically occurred at the SB68 location, south of Waverly Road. The carbon tetrachloride values there have decreased steadily: 7,800 µg/L in 1996–1967, 1,831 µg/L in 1999, 1,072 µg/L in 2002, 991 µg/L in 2004.

- *Objective 3: Determine patterns of groundwater flow near the tributary creek and their effects on contaminant migration.*

The 2004 targeted investigation confirmed that groundwater flow converges toward the tributary creek channel. This finding, along with the distribution of carbon tetrachloride in groundwater, surface water, and drain tile discharge

near the creek and the absence of aquifer sands beneath the tributary, indicates that (1) contaminated groundwater is being discharged to the tributary and (2) no contaminants are migrating within the sediments beneath the tributary.

- *Objective 4: Delineate a potential continuing source of carbon tetrachloride in vadose zone soils of the former CCC/USDA facility, and determine soil properties affecting vertical contaminant migration.*

The results of the present investigation showed that near-surface soils across the northern portion of the former CCC/USDA facility are not contaminated at levels above the quantitation limit of 10 µg/kg; no unacceptable health risks arise from exposure to these soils.

Vadose zone soil in the north-central part of the former facility (below the area of the former Quonset huts) contained carbon tetrachloride contamination at two depth intervals, with a maximum concentration of 361 µg/kg at 29 ft below ground level. Access restrictions precluded subsurface soil sampling in the western part of the former facility, where carbon tetrachloride was found in near-surface soils.

- *Objective 5: Evaluate contaminant migration from soil to groundwater and effects on indoor air at residences built on the former CCC/USDA facility.*

For the location at the former CCC/USDA facility with the maximum carbon tetrachloride concentration in vadose zone soil, model-predicted concentrations in groundwater under the vadose zone are less than 23 µg/L over the next 80 yr, decreasing with time.

Air sampling in basements and a crawl space at four residences built on the former CCC/USDA facility revealed maximum concentrations of carbon tetrachloride and chloroform of 4 µg/m<sup>3</sup> and 3 µg/m<sup>3</sup>, respectively, far below results of the EPA's 1988 sampling. Comparison with the EPA's noncancer chronic inhalation reference exposure levels indicates no apparent unacceptable health risks.

- *Objective 6: Evaluate the suitability of phytoremediation.*

The ecosystem and the physical setting along the creek tributary represent a promising environment for implementation of phytoremediation to remove carbon tetrachloride. Contaminant concentrations and depth to groundwater are suitable for application of this remedy.

On the basis of the observations summarized above, the following remedial options are suggested for the Murdock site:

- *Use phytoremediation to decrease the mass of carbon tetrachloride discharged to the tributary to Pawnee Creek.*

Ideally, planting for phytoremediation would occur in the area with the highest contaminant concentrations and the shallowest depth to groundwater. Phytoremediation would (1) extract contaminated groundwater from the aquifer before it reaches the creek, (2) degrade the carbon tetrachloride, (3) promote beneficial development of the local ecosystem, and (4) enhance recreational opportunities for the community. A phased approach is recommended for implementation.

- *Use groundwater extraction and surface treatment to decrease carbon tetrachloride levels in the most concentrated part of the existing plume and contain the potentially continuing source at the former CCC/USDA facility.*

Use of the extraction well installed recently (with the approval of the CCC/USDA and the EPA) on the grounds of the Elmwood-Murdock Public School, south of Waverly Road, would remove contaminated groundwater from the central part of the plume and intercept any additional carbon tetrachloride from the upgradient, potentially continuing soil source at the former CCC/USDA facility. Seasonal pumping and use of the spray irrigation treatment equipment developed for use at Utica, Nebraska, would simultaneously treat the extracted groundwater and irrigate the school's athletic fields. The spray irrigation process is designated as a form of air stripping incorporating beneficial reuse of the treated water.

## 1 Introduction

On April 1, 2003, representatives of the Commodity Credit Corporation of the U.S. Department of Agriculture (CCC/USDA) and Argonne National Laboratory met with representatives of the U.S. Environmental Protection Agency, Region VII (EPA); the Nebraska Department of Environmental Quality (NDEQ); and Nebraska Health and Human Services (NHHS) to discuss the current regulatory and technical status of the environmental investigations at the former CCC/USDA grain bin site in Murdock, Nebraska. The investigations are being performed by Argonne (under the direction of the CCC/USDA) to characterize and evaluate the potential remedial needs associated with the carbon tetrachloride contamination identified in groundwater and surface waters in the vicinity of the town. This contamination has been linked to former CCC/USDA grain storage activities at Murdock.

Table 1.1 presents a brief summary of the regulatory, site characterization, and remedial assessment activities to date at Murdock. Figure 1.1 illustrates the extent of the groundwater carbon tetrachloride plume, estimated on the basis of sampling performed by Argonne in June 2002. Figure 1.2 presents the 2002 interpretation of the site hydrogeology in a cross section extending northwestward from the former CCC/USDA grain storage facility, along the approximate axis of the groundwater plume.

In reviewing the available information for Murdock, the EPA identified two specific areas of technical concern regarding the distribution and potential fate of the carbon tetrachloride contamination at the site that might significantly affect the selection of an appropriate remedial strategy:

- Periodic sampling (by Argonne) of surface water at the headwaters of the unnamed tributary to Pawnee Creek northwest of Murdock and sampling of the effluent from natural seepage points and agricultural drain tile lines that contribute to the creek (Figure 1.3) demonstrated discharge of contaminated groundwater from the aquifer to the headwaters area north of Waverly Road. The EPA noted, however, that no conclusive evidence is available to demonstrate whether complete capture and removal of the carbon tetrachloride plume from the aquifer are occurring by this mechanism. Specifically, the EPA questioned whether contamination continuing to migrate in the deeper subsurface beneath the tributary to Pawnee Creek might

TABLE 1.1 Summary of regulatory, site characterization, and remedial assessment activities at Murdock, Nebraska, prior to the 2004 targeted investigation.

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**History of Actions**

1986	Removal action by EPA; town connected to rural water district.
1986	Preliminary assessment and site inspection conducted by EPA.
1998	Engineering assessment/cost analysis conducted by EPA.
1991	Administrative Order on Consent signed by EPA and CCC/USDA; further activities required in three modules.
1993	Module 1, site characterization and evaluation of remedial alternatives, completed by CCC/USDA.
1994	Completion of Module 1 accepted by EPA.
1994	<i>Human Health Baseline Risk Assessment and Ecological Assessment</i> prepared by Nebraska Department of Health.
1996	<i>Draft Removal Action</i> document issued by EPA; "no action" selected as preferred alternative, contingent on actions by CCC/USDA to document natural attenuation of groundwater plume.
1996–1999	Groundwater sampling, monitoring well installation, and modeling of groundwater flow and contaminant transport conducted by CCC/USDA, per recommendations of <i>Draft Removal Action</i> .
2000	<i>Draft Plan for Module 2 Remedy Design</i> issued by CCC/USDA.
2002	<i>Draft Proposed Plan for the Murdock Contamination Site</i> issued by EPA.

**Results of CCC/USDA Field Investigations**

- Network of permanent monitoring points was installed in 1999 and earlier to facilitate tracking of plume and monitoring of groundwater levels.
- Groundwater sampling was performed to map plume in 1991–1993, 1996–1997, 1999, 2002.
- Maximum carbon tetrachloride concentrations at most locations in plume have decreased significantly since 1991–1993.
- Stability since 1991 of carbon tetrachloride concentrations at well 2S near former CCC/USDA facility suggests possible continuing soil source of contamination.
  - Problem: Limited current access to northern portion of former CCC/USDA facility for soil sampling — area is now a housing development.
  - 1992 soil sampling in accessible areas identified no soil contamination.
- Groundwater flow patterns and configuration of the plume have been consistent since 1991, despite seasonal and longer-term fluctuations in water levels.

**Results of CCC/USDA Groundwater Flow and Contaminant Transport Modeling in 2000**

- Data from field studies were used to develop site-specific predictive models of groundwater flow and contaminant transport, in keeping with 1996 EPA recommendations.
  - Analyses of flow patterns and surface seeps demonstrated that discharge of contaminated groundwater occurs to the unnamed tributary to Pawnee Creek, northwest of town.
-

pose a threat to groundwater resources beyond the area of presently observed contaminant discharge.

- Concentrations of carbon tetrachloride measured in groundwater from shallow monitoring well 2S, near the north-central boundary of the property formerly occupied by the CCC/USDA grain storage facility (Figure 1.1), have remained relatively constant (at approximately 40–100 µg/L) since Argonne began periodic sampling of this well in 1991, with no clear trend of decreasing values. The observed concentrations suggest that a continuing, uncharacterized source of carbon tetrachloride contamination to groundwater remains in the vadose zone soils beneath the former grain storage facility, upgradient of this well.

To address these concerns, the CCC/USDA and Argonne proposed a series of targeted field investigations at the Murdock site. Four technical objectives were originally proposed in the *Work Plan* for this targeted investigation (Argonne 2003), and two additional objectives were authorized as the field work progressed and information accumulated. The combined technical objectives of this investigation were to accomplish the following:

1. Determine the continuity, thickness, and hydrogeologic characteristics of the aquifer in the vicinity of the Pawnee Creek tributary.
2. Characterize the present distribution of carbon tetrachloride contamination in groundwater and surface water in the area north of Waverly Road.
3. Determine the patterns of groundwater flow in the vicinity of the Pawnee Creek tributary and their relationship to the expected migration of the identified carbon tetrachloride plume.
4. Identify and delineate the presence of carbon tetrachloride in vadose zone soils in the northern portion of the former CCC/USDA facility that might pose a continuing source of contamination to the aquifer, and determine soil properties affecting vertical contaminant migration.

5. Evaluate contaminant migration from soil to groundwater, and analyze indoor air potentially affected by vapor intrusion at residences built on the former CCC/USDA facility.
  
6. Evaluate the potential suitability of phytoremediation for this site.

The major field work for these investigations was performed in April and June 2004. During this period, an additional task to install an extraction well near the Elmwood-Murdock Public School (west of Wyoming Street in Figure 1.1) was authorized by the CCC/USDA and approved by the EPA. Detailed information about this well will be reported separately. As a service to the local community, groundwater pumped seasonally from this well will be made available for irrigation of the school's athletic fields. For this purpose, the contaminated groundwater will be simultaneously treated and discharged by using the spray irrigation treatment process developed by Argonne at Utica, Nebraska.

This report documents the results of the targeted investigation activities at Murdock, as recommended in the *Work Plan* (Argonne 2003). Section 1 provides a brief background for the targeted investigation at Murdock and outlines the specific technical objectives of the investigation. Section 2 describes the investigative methods used during the targeted investigation, and Section 3 presents the results. Section 4 discusses and interprets the results in the context of the specific technical objectives outlined in Section 1. Section 5 summarizes the conclusion of the investigation relative to the technical objectives and presents recommendations for further work at the site.

Because of the focus of this report on the 2004 investigation at Murdock, materials from the previous reports for the Murdock site and relevant sections of the *Master Work Plan* for investigations in Nebraska (Argonne 2002) are not repeated in detail. Consequently, these documents must also be consulted to obtain the full details of the investigative program at Murdock.

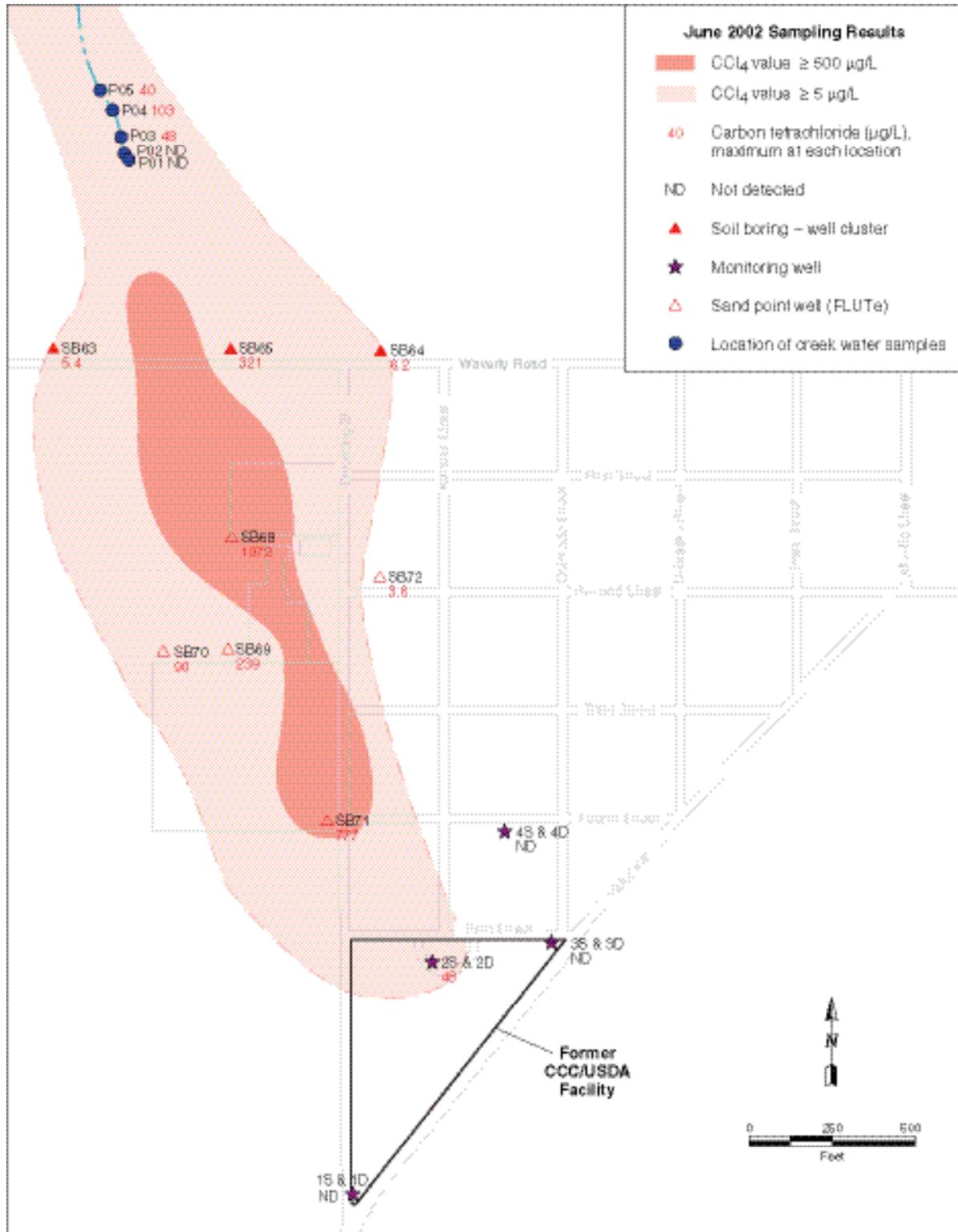


FIGURE 1.1 Maximum carbon tetrachloride concentrations at Murdock in June 2002, with interpreted groundwater plume (shaded areas).

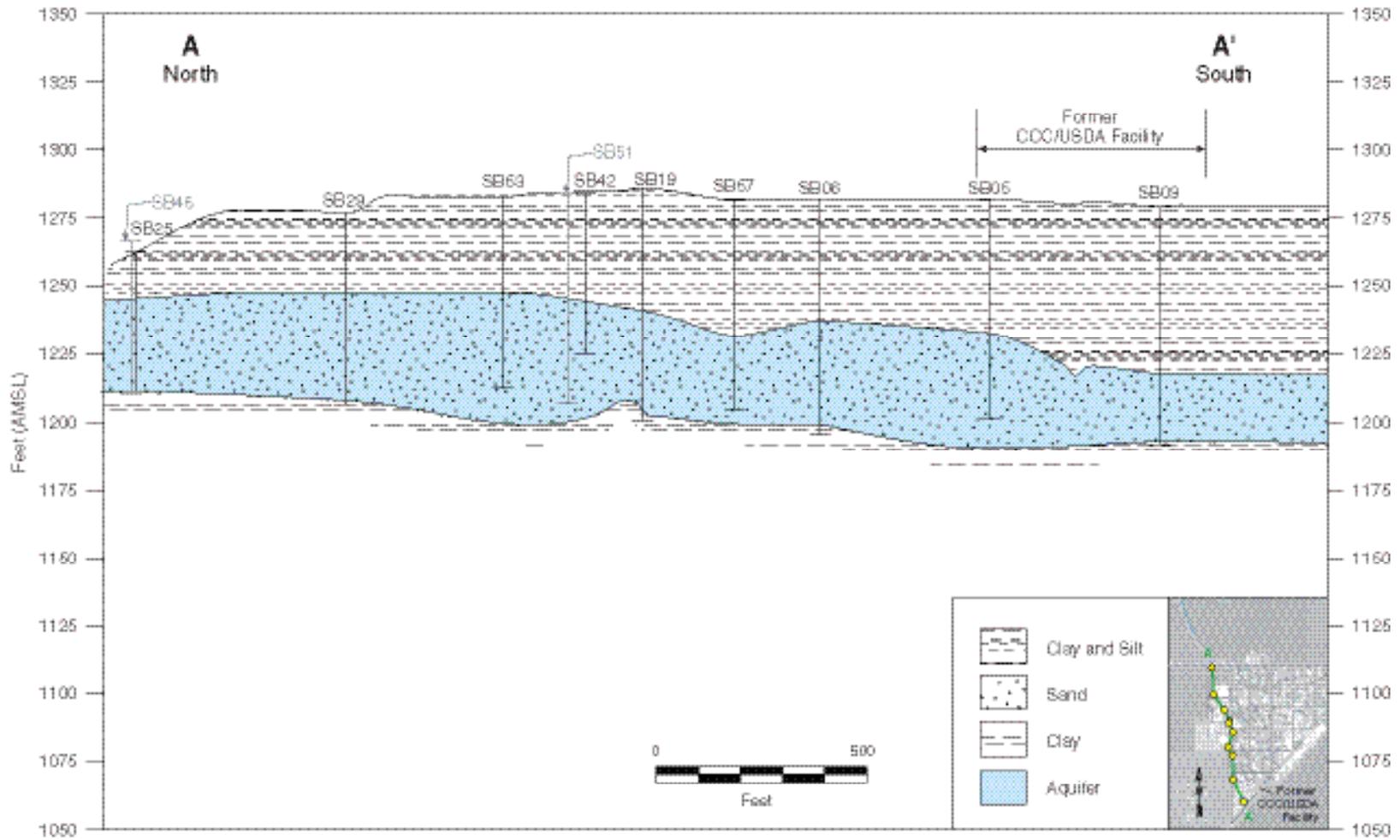


FIGURE 1.2 Hydrogeologic cross section A-A , showing the configuration of the aquifer along the approximate axis of the groundwater carbon tetrachloride plume at Murdock, as interpreted in 2002.

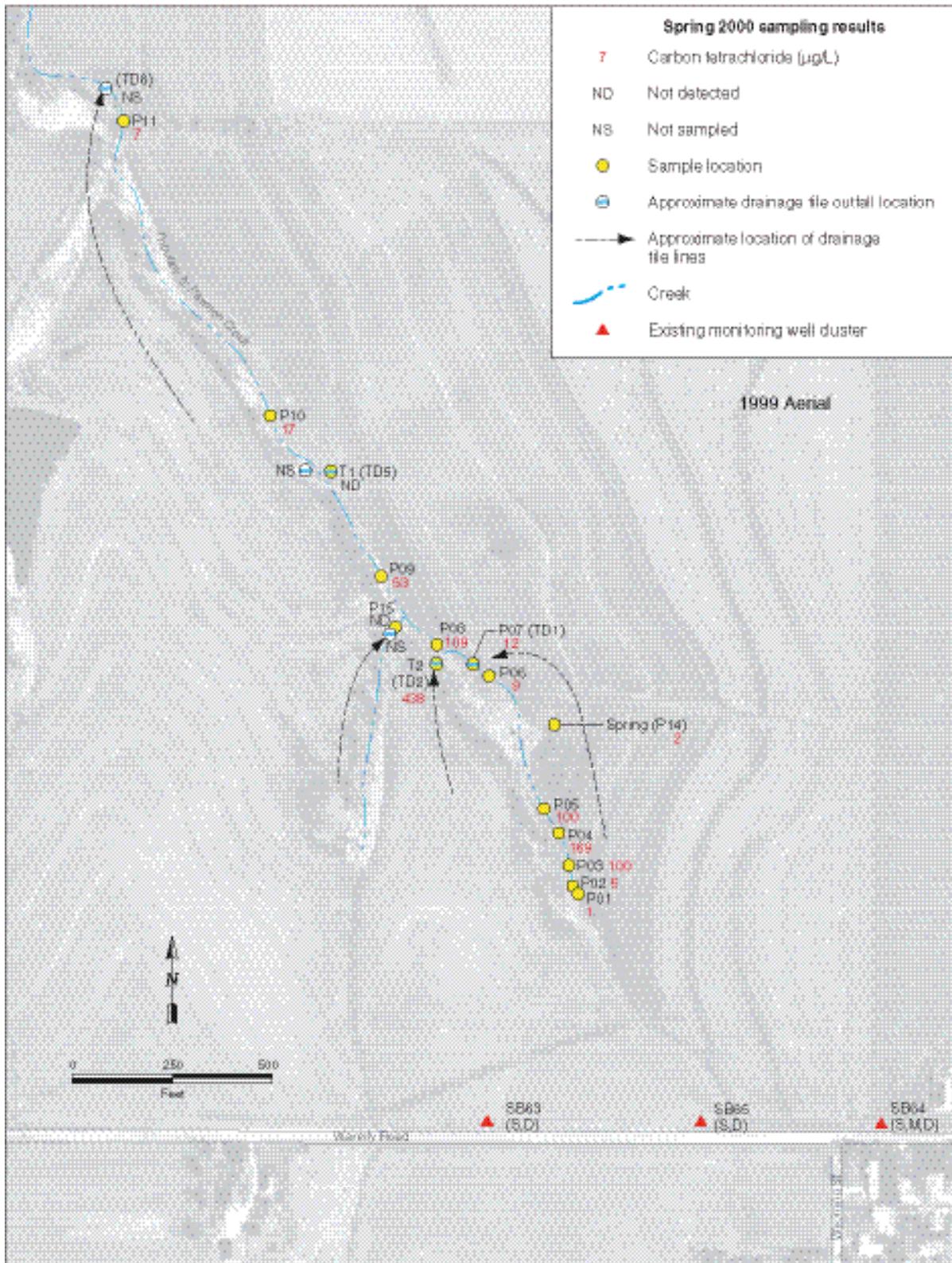


FIGURE 1.3 Maximum carbon tetrachloride concentrations in surface waters, groundwater seepage, and drain tile effluents sampled along the tributary to Pawnee Creek near Murdock in February–April 2000.

## 2 Investigative Methods

The Murdock targeted investigation was performed by using multiple complementary investigative techniques to acquire data relevant to each of the specific technical objectives. The interpretations being developed can be tested independently against multiple lines of evidence. Individual data sets acquired by a particular technique can thus also be interpreted in multiple ways to yield information addressing more than one specific technical objective. Throughout the field program, a comprehensive quality assurance/quality control (QA/QC) program was implemented to confirm the reliability of all information as it was accumulated. With this approach, an integrated, technically defensible model of the hydrogeologic environment and the distribution and migration of carbon tetrachloride within this setting was developed as the specific technical objectives were addressed.

The specific technical objectives and the investigation program proposed to achieve them were discussed in the *Work Plan* for this investigation (Argonne 2003). Procedures for the individual techniques employed by Argonne at this site are in the *Master Work Plan* (Argonne 2002). This section provides a brief overview of the methods used to implement the targeted investigation at Murdock and also identifies certain modifications made to the field program in response to the new information obtained during the study.

The activities in the targeted investigation are summarized in Table 2.1, and the locations of these activities are shown in Figure 2.1.

### 2.1 Method to Determine the Continuity, Thickness, and Hydrogeologic Characteristics of the Aquifer in the Vicinity of the Pawnee Creek Tributary

The previous investigations at Murdock demonstrated that the contaminated aquifer there is laterally continuous throughout the area south of Waverly Road and is 15–48 ft thick. The identified distribution of carbon tetrachloride within the aquifer indicates that contaminants originating at the former CCC/USDA grain storage facility have migrated toward the tributary creek; contaminants have also been detected in the creek's headwaters north of Waverly Road. The extent and hydraulic properties of the aquifer north of Waverly Road are expected to have a significant controlling influence on the migration of carbon tetrachloride to the creek, but until 2004 no subsurface investigations in this northern area had been permitted by the property

TABLE 2.1 Locations of activities in the 2004 targeted investigation at Murdock, Nebraska.

Location	Soil Coring for Lithology	Soil Sampling for VOCs <sup>a</sup>	Other Soil Analyses	ECPT Sensor Log	Temporary Piezometer (abandoned after use)	Previously Existing Monitoring Well	Water Sampling and Analysis <sup>b</sup>	Slug Test	Whole-Air Sample
HC01–HC56		NS							
HC57		NS, SS							
1–4						x	GW		
MW6						x	GW		
WP44						x			
WP49						x			
WP54						x			
SB51						x			
SB63						x	GW		
SB64						x	GW		
SB65						x	GW		
SB68						x	GW		
SB69						x	GW		
SB70						x	GW		
SB71						x	GW		
SB72						x	GW		
SB74	x			x	x		GW	x	
SB75	x			x	x		GW	x	
SB76	x			x	x		GW	x	
SB77	x			x	x		GW	x	
SB78				x					
SB79	x			x			GW		
SB80				x	x		GW	x	
SB81				x	x		GW	x	
SB82				x					
SB83	x		x <sup>c</sup>	x			GW		
SB84 (no GW recovery)				x					
SB85 (location HC52)	x	SS	x <sup>d</sup>	x			GW		
SB86 (location HC53)	x	SS	x <sup>d</sup>	x			GW		
TEST-1							GW		
GWEX-1 <sup>e</sup>									
SWP01–SWP06							SW		
SWP08–SWP16							SW		
SWSEEP							SW		
Tile drains TD1–TD6							T		
100 Liberty Circle (McHugh)									x
400 Liberty Circle (Wager)									x
417 Liberty Circle (Backemeyer)									x
620–622 Freedom Circle (Graham)									x

<sup>a</sup> NS, near surface; SS, subsurface.

<sup>b</sup> GW, groundwater; SW, surface water; T, tile outflow. Samples were analyzed in the laboratory for VOCs and in the field for temperature, pH, and conductivity.

<sup>c</sup> Subsurface samples were subjected to particle size analysis.

<sup>d</sup> Subsurface soil samples collected for VOCs analyses were logged in the field.

<sup>e</sup> Waste water sampled for VOCs analyses before disposal.

owner. Meeting this objective would yield site-specific hydrostratigraphic data in the area around the creek and thereby aid in identification of groundwater flow and contaminant migration pathway(s).

Eight investigative locations north of Waverly Road were proposed in Section 2.1.1 of the *Work Plan* (Argonne 2003) to address this objective. Nine new locations north of Waverly Road were actually tested (Figure 2.2). The additional location was sited to determine the hydrogeologic properties of the aquifer (and contaminant distribution; see Section 2.2) immediately east and upgradient of the persistent spring identified as point P14 in Figure 1.3.

The investigative techniques used to determine the spatial distribution and hydrogeologic characteristics of the aquifer in the area around the creek included electronic profiling of soils with the electronic cone penetrometer (ECPT); confirmatory coring with the cone penetrometer and the Geoprobe; visual description of core materials; and evaluation and display of the data in logs, maps, and cross sections to aid in interpretation. Hydraulic properties of the aquifer and saturated soils beneath the creek were examined by the installation of temporary piezometers, the measurement of groundwater levels, and slug testing of the materials at the temporary piezometers. The resulting data were integrated, within the context of the regional and local hydrogeologic setting, to develop an internally consistent picture (based on multiple lines of evidence) of the factors controlling groundwater flow and contaminant migration at this site.

The results of these investigations are presented in Section 3 and discussed in Section 4.1.

## **2.2 Method to Characterize the Present Distribution of Carbon Tetrachloride Contamination in Groundwater and Surface Water in the Area North of Waverly Road**

The investigation of this objective was guided by the hydrogeologic results and interpretations derived from activities described in Section 2.1.

Groundwater samples intended for analysis of volatile organic compounds (VOCs) were collected at the locations shown in Figure 2.3 at depths chosen to (1) characterize and bound the plume near the tributary to Pawnee Creek both vertically and areally and (2) identify relationships between contaminants in groundwater and surface water. Surface water was collected along a segment of the creek extending approximately 2,500 ft downgradient from the

headwaters, as proposed in the *Work Plan* (Argonne 2003; Figure 2.3). Previous Argonne sampling suggested that the carbon tetrachloride concentrations in surface waters in this area could indicate the extent of downstream effects due to discharge of contaminated groundwater to the creek.

Water discharged from six tile lines that drain shallow groundwater from beneath the surrounding farm fields into the creek was collected for VOCs analyses (Figure 2.3). The location of the discharge from a seventh drain tile line reported by the landowner could not be identified in the field, and no water sample could be collected. Weekly monitoring of discharge from the tile lines is continuing.

Additional sampling of groundwater for VOCs analyses was conducted at the existing permanent monitoring points at Murdock (all located on or south of Waverly Road; Figure 2.3) to permit the contemporaneous mapping of carbon tetrachloride concentrations throughout the plume. The results of water sampling and analyses for VOCs are summarized in Section 3.6. The identified distribution of carbon tetrachloride contamination in groundwater and surface water is described in Section 4.2.

### **2.3 Method to Determine the Patterns of Groundwater Flow in the Vicinity of the Pawnee Creek Tributary and Their Relationship to the Expected Migration of the Identified Carbon Tetrachloride Plume**

The activities performed to determine groundwater flow patterns and their relationship to plume migration built on the findings of the hydrogeologic characterization described in Section 2.1 and the contaminant delineation outlined in Section 2.2. All of the field activities discussed in Sections 2.1 and 2.2 contributed to the accomplishment of this objective.

Six temporary piezometers were installed north of Waverly Road (Figure 2.4) to provide detailed information on groundwater levels and apparent hydraulic gradients near the creek headwaters. Elevations of the surface water sampling locations in the creek were surveyed to investigate the relationships between groundwater and surface water levels and hence to determine the areal extent of groundwater discharge to surface water. The results, in conjunction with the data generated in the investigations described in Sections 2.1 and 2.2, were used to evaluate whether the contaminated groundwater is being completely intercepted by the creek.

The temporary piezometers installed specifically for the 2004 targeted investigation (now abandoned), together with the monitoring wells installed previously, formed a network for monitoring water levels in the aquifer across the entire site. The results of the water level measurements are presented in Section 3.4. An analysis of groundwater flow patterns and their relationship to the carbon tetrachloride plume migration is in Section 4.3.

Argonne's investigations have identified a number of drain tile lines in the area around the tributary creek. In the targeted investigation, the locations and extents of drain tile lines were mapped, and rates of flow from the drain tiles were measured by installing flow meters. The results to date are presented in Section 3.7. The presence of drain tiles near the creek could locally affect the pattern of groundwater and contaminant discharge to the creek. The results of flow rate determinations and VOCs analyses for the drain tile outflow (described in Section 2.2) were used to evaluate the transport of contaminated groundwater to the surface through the tiles.

#### **2.4 Method to Identify and Delineate the Presence of Carbon Tetrachloride in Vadose Zone Soils in the Northern Portion of the Former CCC/USDA Facility That Might Pose a Continuing Source of Contamination to the Aquifer, and to Determine Soil Properties Affecting Vertical Contaminant Migration**

An initial program of near-surface soil sampling for VOCs analyses was followed by deeper vertical-profile soil sampling and VOCs analyses through the vadose zone at selected locations in the northern portion of the former CCC/USDA facility to address this objective. Previous Argonne investigations have demonstrated that analysis of near-surface soils for carbon tetrachloride by the headspace method (a modification of EPA Method 5021) is a sensitive and positive indicator of potential deeper vadose zone soil contamination. In this application, the headspace data are not used quantitatively but are examined for distribution patterns to prioritize areas for follow-up subsurface soil sampling and analysis. In conjunction with the headspace analyses, the near-surface soils were also examined by using purge-and-trap sample preparation with analysis on a gas chromatograph-mass spectrometer (GC-MS) system (EPA Methods 5030B and 8260B) as a quantitative basis for the evaluation of potential health risks associated with the near-surface soils.

Near-surface samples were collected in the northern part of the former CCC/USDA facility (shaded area in Figure 2.1) to investigate (1) the sites of the former grain storage structures and chemical storage building and (2) more recent features, such as pavements, that

might restrict the vertical infiltration of precipitation and hence prolong the leaching of potential carbon tetrachloride contamination from the vadose zone soils into the aquifer. The results of the VOCs analyses of near-surface soils are presented in Section 3.2.1 and discussed in relation to this technical objective in Section 4.4.

Distribution patterns observed in the results of headspace analyses of near-surface soil samples were used to select locations for additional sampling of soils from the ground surface to the top of the saturated zone, to confirm the presence of carbon tetrachloride contamination in the deeper vadose zone. The results of the subsurface soil analyses are summarized in Section 3.2.2 and interpreted in Section 4.4.

To provide a quantitative basis for estimating vertical migration — over time — of residual contamination in the vadose zone soils to groundwater, core samples of contaminated sediments were collected. These samples were analyzed to determine physical and chemical properties that affect contaminant migration in the unsaturated zone, including bulk dry density, porosity, moisture content, total organic matter content, and carbon content. The results of these analyses are presented in Section 3.2.3 and are used as model parameters for the simulation of contaminant migration in the vadose zone as discussed in Section 4.4.4.

## **2.5 Method to Evaluate Contaminant Migration from Soil to Groundwater, and to Analyze Indoor Air Potentially Affected by Vapor Intrusion at Residences Built on the Former CCC/USDA Facility**

After carbon tetrachloride was found in the deep vadose zone at one location at the former CCC/USDA facility during this investigation, the investigation was expanded to include (1) an analysis for contaminant migration through the soil-to-groundwater pathway by using the EPA one-dimensional vadose zone leaching model (VLEACH; Ravi and Johnson 1997) and (2) indoor air sampling to determine any exposure through the vapor intrusion to indoor air pathway within the residences built on the former CCC/USDA facility.

The vertical mobilization and migration of organic contaminants in the vadose zone involve complex processes that are difficult to simulate accurately. Argonne used a simplified approach in developing a vadose zone transport model that accounted for partitioning of contaminants among the vapor, dissolved, and adsorbed phases. The modeling was carried out by

using the VLEACH model, as implemented in the WHI UnSat Suite (Waterloo Hydrogeologic, Inc., 2000).

Indoor air was collected in specially prepared canisters for the determination of VOCs. The samples were analyzed by GC-MS according to EPA Method TO-15 (EPA 1999). Basement air from residences to which access was granted was drawn — through a sampling train that regulated the rate and duration of air collection — into a preevacuated, passivated canister. For the sample analysis, a known volume of sample was introduced into a multisorbent concentration tube to dry and concentrate the sample. The sample was released by thermal desorption and transferred to the GC-MS unit for separation and analysis. Detection limits were 0.5 ppbv. The results are presented in Section 3.8 and discussed in Section 4.5.2.

## **2.6 Method to Evaluate the Potential Suitability of Phytoremediation for This Site**

Phytoremediation is a remedial option that involves the use of vascular plants, algae, and fungi to remove and control contaminants and to enhance contaminant degradation through the metabolic activity of microorganisms present in the rhizosphere (the area adjacent to and influenced by plant root systems; McCutcheon and Schnoor 2003).

Phytoremediation is most successful where highly contaminated groundwater occurs near the surface. The suitability of conditions for phytoremediation in the area north of Waverly Road was evaluated (1) by characterizing the present distribution of carbon tetrachloride through sampling of groundwater, surface water, and discharge from drain tile lines and (2) by logging the stratigraphic sequence with the electronic cone penetrometer. The results of this evaluation are discussed in Section 4.6.

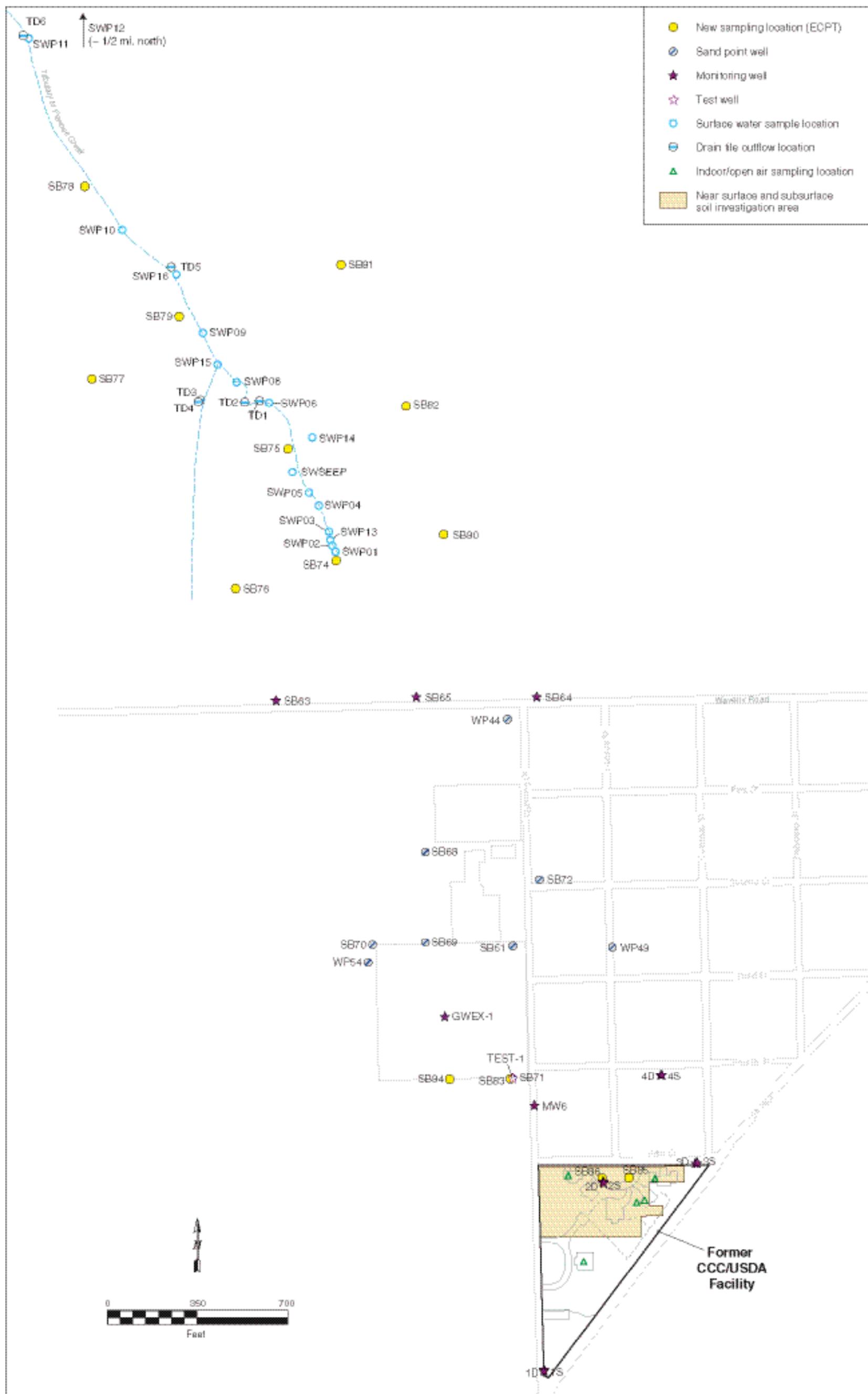


FIGURE 2.1 Locations of all field activities in the 2004 targeted investigation at Murdock.



FIGURE 2.2 New cone penetrometer sampling locations in the 2004 targeted investigation at Murdock.

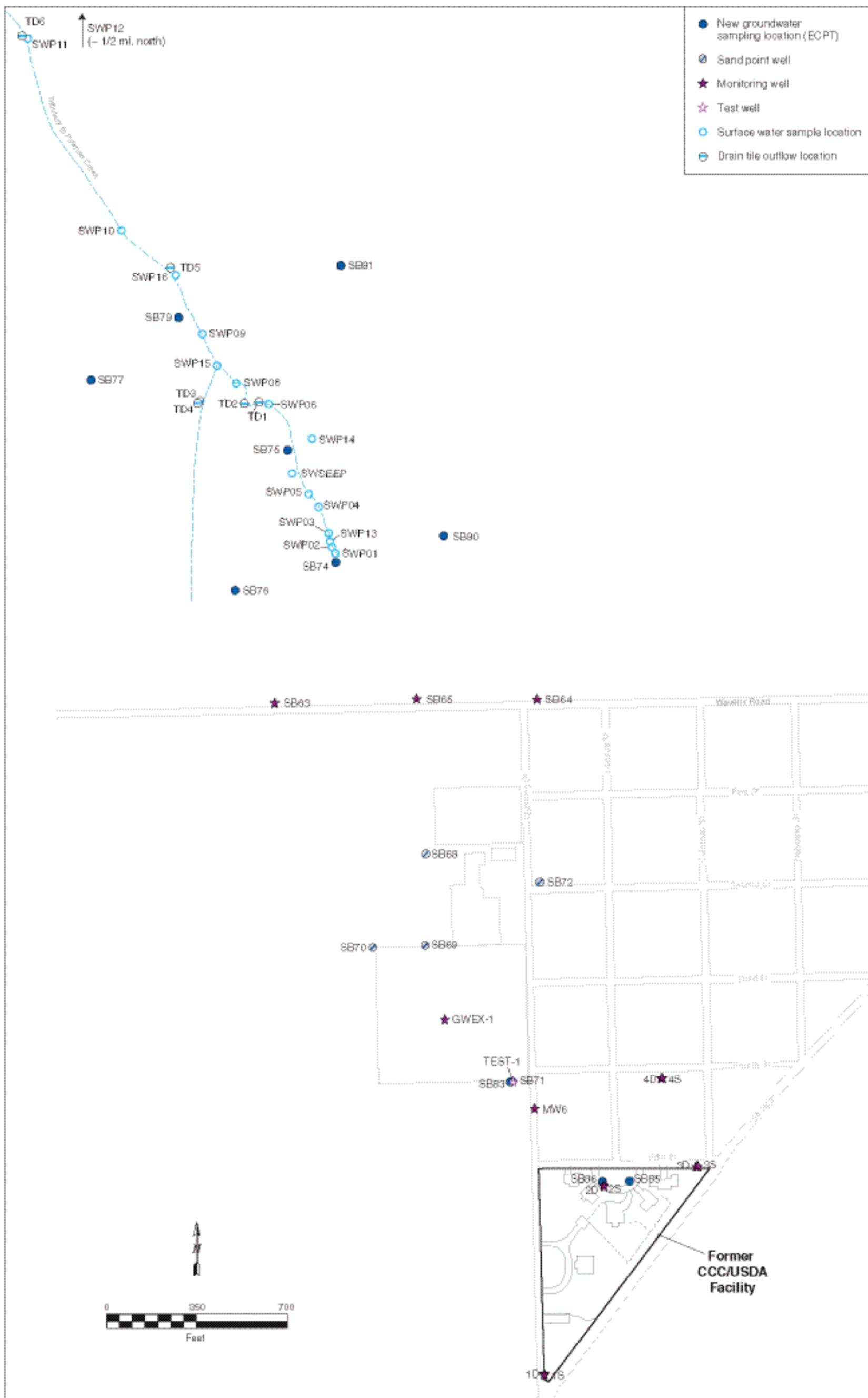


FIGURE 2.3 Water sampling locations in the 2004 targeted investigation at Murdock.

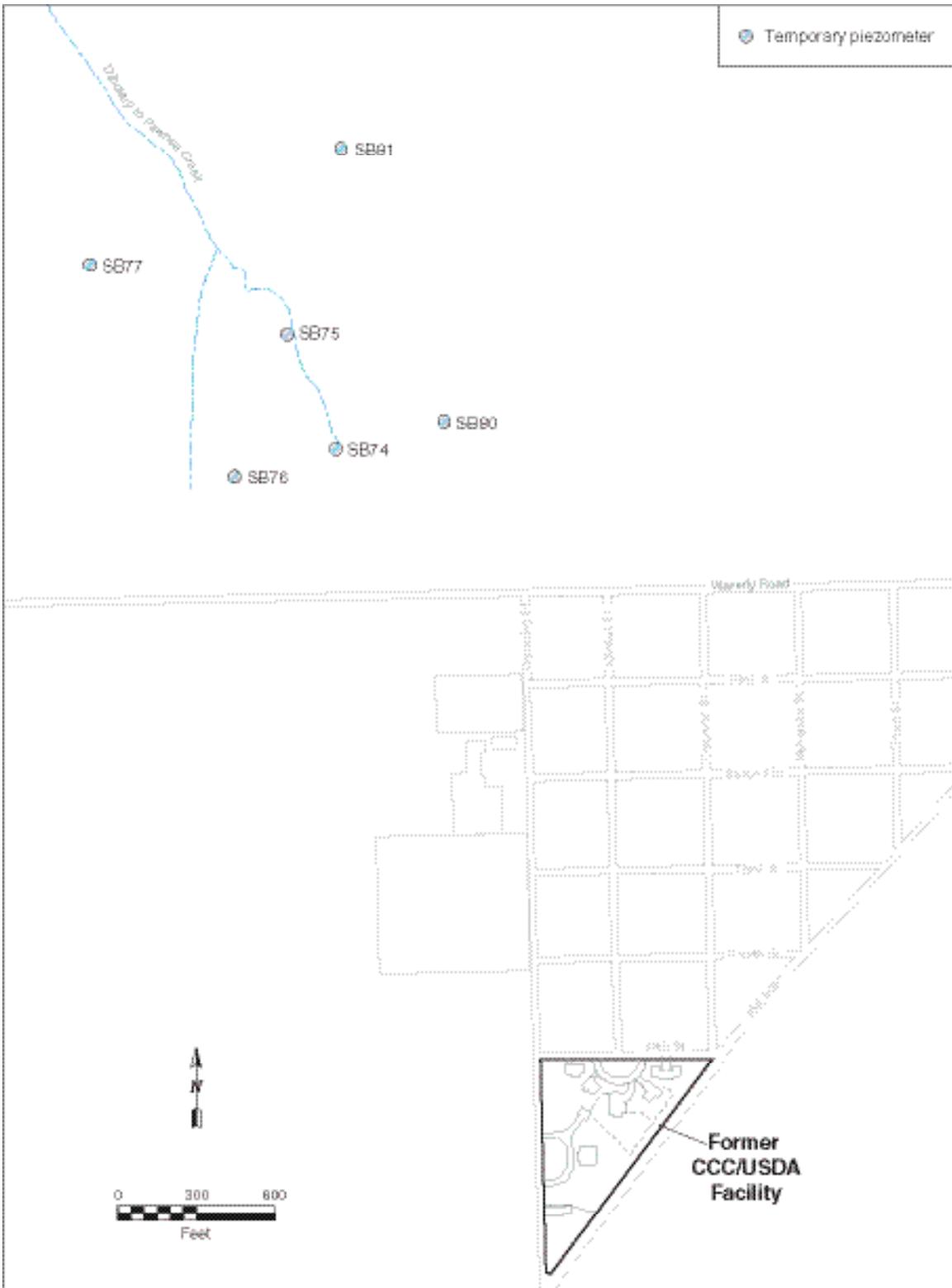


FIGURE 2.4 Locations of temporary piezometers (now abandoned) installed for the 2004 targeted investigation at Murdock.

### 3 Field and Laboratory Data

The methods used in this targeted investigation are described in Section 2. In this section, data generated by the field and laboratory studies are presented in general categories reflecting the types of test performed or the medium analyzed. In Section 4, these data are integrated and interpreted in the context of the technical objectives.

The targeted investigation was performed in several field work sessions in April–August 2004. The locations of all activities are shown in Figure 2.1, and the activities are summarized in Table 2.1. Data collected from the field activities and laboratory analyses are in the appendixes in this volume and the supplements on the accompanying compact disk (CD).

#### 3.1 Electronic Cone Penetrometer Sensor Data and Confirmatory Soil Logging

Electronic sensor profiling and subsurface geologic coring with direct-push technology were used in the targeted investigation to (1) identify major hydrostratigraphic units around the Pawnee Creek tributary north of Waverly Road, (2) examine the extent and hydrologic characteristics of the saturated permeable zone that forms the aquifer, and (3) obtain vadose zone sediment cores for VOCs analyses. Thirteen locations (SB74–SB86, Figure 2.2) were investigated by using the Argonne track-mounted cone penetrometer vehicle and a Geoprobe direct-push unit. The operation of these vehicles was in accordance with procedures described in the *Master Work Plan* (Argonne 2002, Section 6).

Logs of tip and sleeve friction and conductivity data were collected at SB74–SB86 by using ECPT sensing technology. The ECPT sensor logs were used as a guide for the general identification of major stratigraphic units and to select intervals for confirmatory coring. Soil cores were collected by using the cone penetrometer at SB74–SB77, SB79, and SB83. A limited number of soil cores were initially collected at SB74 with a Geoprobe unit, but subsequent coring at this location was performed with the cone penetrometer because of difficulties in achieving penetration with the Geoprobe. Subsurface soil samples collected for VOCs analyses at SB85–SB86 (discussed in Section 3.2.2) were also examined in the field and logged lithologically. All ECPT sensor logs and soil core descriptions are in Appendix A.

## 3.2 Soil Analysis Data

The program of near-surface and subsurface soil sampling was designed to identify the presence of carbon tetrachloride in vadose zone soils at the former CCC/USDA facility that might pose a continuing source of contamination to the aquifer. The program was performed in two field sessions: May 25–28, 2004, and June 28–30, 2004. Analytical results are in Appendix B.

### 3.2.1 Contaminant Data for Near-Surface Soils

Near-surface soil sampling was conducted at locations shown in Figure 3.1 to identify and prioritize parts of the former CCC/USDA facility for subsurface soil sampling and VOCs analyses. Argonne's experience is that the presence of carbon tetrachloride in near-surface soils is often diagnostic of deeper subsurface carbon tetrachloride contamination that might represent a present or former source of contamination to groundwater. Sampling locations were chosen to investigate (1) the sites of the former grain storage structures; (2) the site of the former carbon tetrachloride storage building; and (3) more recent features, such as pavement, that might restrict the vertical infiltration of precipitation and hence prolong the leaching of potential carbon tetrachloride contamination from the vadose zone soils into the aquifer.

Locations in the northern portion of the former CCC/USDA facility were identified for near-surface soil sampling on the basis of landmarks visible on aerial photographs from 1965 and 1999, as proposed in the *Work Plan* (Argonne 2003). Some sample collection planned in the north-central portion of the former facility could not be performed because access to one of the current residential properties in this area was denied (Figure 3.1). On May 25–27, 2004, samples were collected at 51 locations (HC01–HC51; Figure 3.1). Additional near-surface soil sampling occurred on June 30, 2004, at locations HC52–HC57 (Figure 3.1). Near-surface soil sampling locations HC52 and HC53 were along Liberty Circle, at soil borings SB85 and SB86, respectively (Section 3.2.2). Near-surface soil sampling locations HC54–HC57 were at a former carbon tetrachloride storage building recently recognized through assistance from the local community.

A total of 108 near-surface soil samples were collected with a hand-driven ESP™ sampler, in accordance with procedures in the *Master Work Plan* (Argonne 2002, Section 6.1.1). At each of the 54 locations, a sample was taken from (1) the topsoil underlying any landscaping

fill at about 1 ft below ground level (BGL) and (2) either topsoil or clay with graded humic staining at about 3 ft BGL.

The near-surface soil samples were placed in jars, sealed, preserved on dry ice, and shipped to the Applied Geosciences and Environmental Management (AGEM) Laboratory at Argonne National Laboratory for analysis. The samples were analyzed (Argonne 2002, Section 6.3.1) by (1) a headspace method with a gas chromatograph and electron capture detector (GC-ECD; modified EPA Method 5021) and (2) a purge-and-trap sample preparation method with analysis on a GC-MS system (EPA Methods 5030B and 8260B).

The headspace analysis was used to achieve the low detection limits required to evaluate possible contaminant distribution patterns, for use in guiding subsurface soil sampling. The results of the headspace analyses for shallow (1 ft BGL) and deeper (3 ft BGL) near-surface soils are mapped in Figures 3.2 and 3.3, respectively, and presented in Appendix B, Table B.1. These results are discussed in Section 4.4.1. Low concentrations of carbon tetrachloride were detected by headspace analysis in soils from both depth intervals across much of the site, most commonly in association with the locations of the former grain storage bins and with pavements.

The purge-and-trap data were used to support risk assessment calculations for the near-surface soils (Section 4.4.3). The results of these purge-and-trap analyses are in Appendix B, Table B.1. Neither carbon tetrachloride nor chloroform was detected above a quantitation limit of 10 µg/kg in any of the near-surface soils prepared by the purge-and-trap method and analyzed with the GC-MS system.

### **3.2.2 Contaminant Data for Subsurface Soils**

Subsurface soil samples collected during this investigation were analyzed to provide a preliminary indication of carbon tetrachloride and chloroform levels remaining in the deep vadose zone beneath the northern portion of the former CCC/USDA facility.

The deeper soil sampling locations were selected on the basis of the distribution of relatively higher carbon tetrachloride levels observed in the headspace analyses of the near-surface soils. Three sampling locations were proposed in a letter report (Argonne 2004) submitted to the CCC/USDA and the EPA on June 18, 2004. Vertical-profile soil sampling was performed at two proposed locations (SB85 and SB86, Figure 3.1) on June 28–29, 2004.

Subsurface soil sampling originally approved at the third location in the western portion of the study area could not be performed because access to this location was denied by the property owner. The complete vertical soil profile at each location sampled (SB85 and SB86) includes two near-surface soil samples collected at 1 ft and 3 ft BGL (Section 3.2.1) and more than 30 “subsurface” soil samples recovered with the cone penetrometer at 2-ft intervals from 3 ft BGL to the top of the aquifer. Descriptions of the subsurface soils collected at these locations are in Appendix B, Table B.2.

Additional deeper soil sampling was conducted near the former chemical storage building at location HC57 (Figure 3.1). Permission was given only for use of a hand-driven device for soil sampling because of the proximity of the current residence and residential activities at this location. Eleven soil samples (two near-surface samples and nine “subsurface” samples) were taken at HC57 from hand-driven, sleeved cores recovered with an ESP™ sampler (Argonne 2002, Section 6.1.1). Soil sampling was stopped at depth of 22 ft BGL because of limitations of the sampler.

The subsurface soil samples were placed in 125-mL jars and immediately preserved on dry ice for shipment to the AGEM Laboratory. The samples were analyzed for VOCs by using the purge-and-trap GC-MS method.

The results of the analyses of subsurface soil samples from locations HC57, SB85, and SB86 (Appendix B, Table B.3) are shown in vertical profiles in Figure 3.4. Carbon tetrachloride was detected in 23 of the 77 subsurface samples (above the quantitation limit of 10 µg/kg for the purge-and-trap GC-MS method), at concentrations up to 361 µg/kg.

### **3.2.3 Soil Property Data for Vadose Zone Samples**

Two subsurface soil samples from the contaminated intervals at SB85 (29–30 ft and 51–52 ft BGL) were selected for the determination of parameters that affect contaminant migration in the unsaturated zone. The analyses performed were for total organic matter and carbon contents, moisture content, specific gravity, porosity, and bulk density. Total organic matter and carbon contents were determined by using the Walkley-Black OM test method. The measurement of moisture content was according to American Society for Testing and Materials (ASTM) Standard D2616. Specific gravity was measured in accordance with ASTM Standard

D854-00. Porosity and bulk density were determined by using the U.S. Corps of Engineers Method EM1110-2-1906. The results of these analyses are in Appendix B, Table B.4.

#### **3.2.4 Particle Size Analyses for the Aquifer Materials**

To help in selecting a location for the proposed extraction well near the Elmwood-Murdock Public School, two cone penetrometer core samples were collected within the aquifer at intervals of 60–63 ft and 51.4–52.0 ft BGL at SB83. The samples were shipped to HWS Consulting Group, Inc., Lincoln, Nebraska, for particle size analysis according to the procedure outlined in ASTM Standard D422-63 (reported in 1990 and 1998), as described in the *Master Work Plan* (Argonne 2002, Section 4.3.1.3). The results of the particle size analysis are in Appendix B, Table B.5.

### **3.3 Coordinates Survey Data**

Accurate location information for the activities performed in the field is required to provide horizontal and vertical control for stratigraphic correlation, water level measurement, and hydrogeologic mapping. The locations of the new investigative borings (SB74–SB86), reference points for the elevations and locations of surface water along the tributary creek, and locations of the tile drain outflows sampled were surveyed by Fine Line Land Surveying, Lincoln, Nebraska. The results of the coordinates survey are in Appendix C.

### **3.4 Groundwater Level Data**

#### **3.4.1 Temporary Piezometer Installations**

The ECPT sensor log characteristics and confirmatory soil core data were interpreted to select stratigraphic intervals for the installation of temporary piezometers in the vicinity of the tributary creek. Six temporary piezometers were constructed in the area north of Waverly Road (Figure 3.5).

The temporary piezometers were constructed with 1-in.-diameter polyvinyl chloride (PVC) screens and riser, by using a slight modification of the standard procedure for piezometer

installation with the cone penetrometer. Sand was placed as a filter pack around the screened interval, and bentonite grout was used to seal the remainder of the annulus from the top of the filter pack to the surface, but no permanent surface housing was installed. Instead, a temporary waterproof enclosure was provided at each location. Construction data for the temporary piezometers are summarized in Table 3.1. The temporary piezometers remained in place less than ten days and were abandoned in compliance with NDEQ requirements by removing the PVC casings and screens and grouting the boreholes through a tremie pipe.

The temporary piezometers, together with the previously installed monitoring wells and sand point wells at the Murdock site, formed a monitoring network for the measurement of water levels in the entire area affected by the carbon tetrachloride plume. The locations of the temporary piezometers, the monitoring wells, and sand point wells are shown in Figure 3.5.

### 3.4.2 Groundwater Level Measurements

To document water levels in the entire investigation area during the targeted investigation, groundwater levels were measured by hand both in the temporary piezometers and in the monitoring wells and sand point wells (Figure 3.5). Manual measurements were read to the nearest 0.01 ft with an electronic water level sensor from a surveyed reference mark. The hand-measured water level data are in Appendix D, Table D.1. The results indicate a general pattern of decreasing groundwater levels toward the creek. These results are discussed further in Section 4.3.

TABLE 3.1 Construction data for temporary piezometers.<sup>a</sup>

Boring	Bottom of Hole (depth, ft BGL)	Screened Interval	
		Depth (ft BGL)	Elevation (ft AMSL)
SB74	22.6	16.6–22.6	1216.8–1210.8
SB75	15.0	5.0–15.0	1218.3–1208.4
SB76	46.0	36.0–46.0	1213.1–1203.1
SB77	22.0	14.0–22.0	1215.7–1207.7
SB80	59.0	49.0–59.0	1211.0–1201.0
SB81	35.7	25.7–35.7	1215.4–1205.4

<sup>a</sup> The temporary piezometers remained in place less than ten days and were abandoned in compliance with NDEQ requirements by removing the PVC casings and screens and grouting the boreholes through a tremie pipe.

### 3.5 Slug Test Data

Slug tests were performed at the six temporary piezometer locations (SB74–SB77 and SB80–SB81) near the creek (Figure 3.5). The tests at SB76 and SB80–SB81 were performed by using pressurized air to depress and stabilize the water level within the piezometer casing. To initiate each test, the air pressure was released to create a condition equivalent to an instantaneous drop in head. This pneumatic test method could not be used at SB74, SB75, and SB77, because the static water level at each of these locations was within the screened interval. Slug tests in these piezometers were conducted by quickly lowering (or withdrawing) a 4-ft-long, 0.5-in.-diameter solid steel rod into the casing to perturb the static water column.

The water level responses for each test were recorded by using a downhole pressure transducer connected to an automatic data logger (Hermit™ 1000C) capable of data acquisition at a high rate. The slug test procedure was repeated a minimum of three times at each location. For each test, the data were plotted with an interpretive fit to a straight line (Supplement 1 to this report [on CD]).

### 3.6 Groundwater and Surface Water Analyses

Groundwater sampling in the saturated zone near the creek, north of Waverly Road, was performed with the cone penetrometer, as outlined in the *Master Work Plan* (Argonne 2002, Section 6.1.2). Samples were collected by pushing the penetrometer rods with a disposable tip to the target water-bearing zone. The rods were then withdrawn a predetermined distance to expose an internal filter screen section into which groundwater passed. Groundwater was sampled at SB74–SB77 and SB79–SB81 by using a bailer inserted through PVC riser attached to the filter screen.

All groundwater sampling holes were abandoned by grouting with a tremied bentonite slurry, in compliance with NDEQ requirements.

Groundwater samples were also collected at existing monitoring points to determine the present configuration of the carbon tetrachloride plume in the area south of Waverly Road. Two additional groundwater samples were taken from the aquifer unit at the subsurface soil sampling locations (SB85 and SB86) at the former CCC/USDA facility. Two groundwater samples were collected at SB83 and at an offset hole adjacent to SB83 (TEST-1 in Figure 2.3), placed in an

attempt to select a site for an extraction well. Descriptions of the groundwater samples are in Appendix E, Table E.1.

Surface water samples were collected at 16 locations along the creek. The sampling was performed according to the procedures in the *Master Work Plan* (Argonne 2002, Section 6.1.2). Descriptions of the surface water samples are in Appendix F, Table F.1.

All water sampling locations are shown in Figure 2.3.

### **3.6.1 Field Measurements for Groundwater Samples**

The measurement of selected parameters at the time of sampling provides immediate results that can sometimes aid in the evaluation of groundwater relationships in the field. Groundwater temperature, pH, and conductivity were measured for samples collected at one or more depths at each of the sampled locations, by using a Checkmate field meter system after calibration with the appropriate standard solutions (Argonne 2002, Section 6.3.2.2). The results of the field measurements are in Appendix E, Table E.2.

### **3.6.2 Contaminant Data for Groundwater and Surface Water Samples**

Groundwater and surface water samples collected for VOCs analyses were preserved in the field by cooling to 4°C, then shipped to the AGEM Laboratory for analysis in accordance with the procedures described in the *Master Work Plan* (Argonne 2002, Sections 6.2 and 6.3.2.1). Replicate groundwater samples were collected for verification analyses with EPA Contract Laboratory Program (CLP) methodology.

The results of the VOCs analyses on groundwater samples are in Appendix E, Table E.3. Carbon tetrachloride was found in groundwater at 16 of the 24 groundwater sampling locations, at concentrations of 1.2–991 µg/L (Figure 3.6). Chloroform was identified in groundwater at 9 of the 24 groundwater sampling locations, at concentrations of 1.2–19 µg/L (Figure 3.7). The highest concentration of carbon tetrachloride found in groundwater occurred at monitoring well SB68M, 1,500 ft north and downgradient from the former CCC/USDA facility. The highest level of chloroform occurred at SB86, beneath the former CCC/USDA facility.

Carbon tetrachloride was detected in 10 of 16 surface water samples collected near the headwater of the tributary to Pawnee Creek (Figure 3.6 and Table F.2 in Appendix F). Concentrations of carbon tetrachloride in these samples were 1.4–281 µg/L. No contamination was detected in surface water at distances greater than 1,000 ft downstream from the first occurrence of water at the headwaters of the creek.

### **3.7 Distribution of Drain Tiles and Analysis Data for Discharged Water**

An extensive investigation was conducted to locate drain tiles near the tributary creek. Seven drain tiles were identified. The locations and extents of these tile lines beneath the current agricultural fields surrounding the creek were mapped on the basis of information provided by Hauschild Construction Company, Avoca, Nebraska. This company installed the original drain tiles in 1968 and later expanded the tile system in 1996 and 1999. The estimated locations of six drain tile lines (TD1–TD5, and TD7) were identified, as shown in Figure 3.8. The extent of tile line TD6, however, remains unknown as of this reporting and could not be shown in Figure 3.8. The depths of the tiles are generally 4–5 ft BGL. These drain tiles were installed to intercept precipitation and runoff that locally infiltrate from the surface, as well as groundwater migrating northward, toward the creek.

Persistent drainage was observed from tiles TD1–TD6 but not from TD7. Flow meters were installed on each of the six active tiles to measure their flow rates over time. The incremental production and cumulative production from each drain tile are being recorded weekly. The results through mid July 2004 are in Appendix F, Table F.3.

Samples of the water discharged from the drain tiles were collected for VOCs analyses. The results are in Appendix F, Table F.2. In this sampling during the 2004 targeted investigation, carbon tetrachloride was detected only at TD1 (8.2 µg/L) and at TD2 (88 µg/L).

### **3.8 Indoor Air Analysis**

To detect intrusion of contaminant vapors arising from subsurface soil contamination, indoor air sampling was performed within the basement or crawl space at the residences on the former CCC/USDA facility to which access was granted. Two duplexes and four single-family residences, owned by Backemeyer, Graham, McHugh, Wager, Levell, and Shafer, respectively,

have been built on the former CCC/USDA facility (Figure 3.9). On August 4, 2004, with permission from the owners, sampling canisters (one in each location) were placed in the basements of the McHugh house, the Wager house, and one side of one duplex (Backemeyer), as well as in the crawl space between the two sides of the other duplex (Graham). Air samples collected over a 24-hr interval were shipped to Severn-Trent Laboratory in Burlington, Vermont, for analysis for 63 VOCs. An air sample of ambient background air was collected outside the Wager residence for comparison. The descriptions of the air samples and the results for VOCs detected at one or more locations are in Appendix G. The results are discussed in Section 4.5.2.

### 3.9 Quality Control Data for Soil, Water, and Air Analyses

The QA/QC procedures followed during the 2004 field investigation for sample collection, handling, and analysis are described in detail in the *Master Work Plan* (Argonne 2002) and the targeted investigation *Work Plan* (Argonne 2003). Results of the QA/QC activities are summarized as follows:

- Sample integrity was maintained successfully throughout the collection, shipping, and analysis activities by the use of custody seals and chain-of-custody records. A few minor transcription errors in some sample identifiers as recorded on chain-of-custody forms or analytical data reports were resolved by comparison of the various records.
- All samples were received with custody seals intact and adequately preserved. All samples were analyzed within required holding times.
- Carbon tetrachloride and chloroform were not detected in trip blanks accompanying water samples shipped for organic analysis, nor in the field blank, equipment rinsates, or laboratory method blanks analyzed with the samples.
- Groundwater and surface water samples were analyzed for 23 VOCs, including carbon tetrachloride and chloroform, at the AGEM Laboratory by using EPA Method 524.2 (the purge-and-trap method). Quality control limits were met for the analyses. Accuracy and precision of the analytical methodology were evident in the analysis of blind replicate samples and

duplicate analyses of selected samples. For samples in which no contamination was detected, the associated QC analyses showed similar results. For samples in which carbon tetrachloride was detected, the relative percent difference values between the initial analyses and the associated QC analyses were 0–28.7%, with an average of 8.3%. Chloroform results were similarly consistent. The groundwater and surface water analytical data from the AGEM Laboratory are acceptable for quantitative determination of contaminant distribution.

- Quality control limits were met in verification organic analyses of replicate (split) groundwater and surface water samples with EPA CLP methodology at Clayton Laboratory, Novi, Michigan. The results support the AGEM Laboratory data.
- Near-surface soil samples were analyzed for carbon tetrachloride and chloroform at the AGEM Laboratory by using a modification of the protocol in EPA Method 5021 (headspace analysis on a GC-ECD system) to achieve the low detection limits required for determination of contaminant distribution across the site. A background soil sample was collected to provide a baseline for the survey. Secondary QC analyses of blind replicates, as well as samples selected by the laboratory for duplicate analyses by the headspace method, were consistent with the primary analyses of the samples. The headspace data are acceptable for qualitative determination of contaminant distribution.
- Soil samples were analyzed for carbon tetrachloride and chloroform at the AGEM Laboratory by using EPA Methods 5030B and 8260B (purge-and-trap sample preparation and analysis on a GC-MS system) to quantify contaminant concentrations. The QC limits were met for the analyses. Accuracy and precision of the analytical methodology were evident in the analysis of blind replicate samples, as well as duplicate analyses of selected samples. For samples in which no contamination was detected, the associated QC analyses showed similar results. For samples in which carbon tetrachloride was detected, the relative percent difference values between the initial analyses and the associated QC analyses were 4.7–15.4%. Chloroform results were similarly consistent. The soil purge-and-trap analytical data from the AGEM

Laboratory are acceptable for quantitative determination of contaminant distribution and for risk analysis.

- Verification purge-and-trap analyses of replicate soil samples with EPA Methods 5030B and 8260B at Severn-Trent Laboratory, Colchester, Vermont, support the AGEM Laboratory data. For samples in which no contamination was detected above the method quantitation limit, the associated QC analyses showed similar results. For samples in which carbon tetrachloride was detected, the relative percent difference values between the initial analyses and the associated QC analyses were 8.5–24.3%.
- Indoor air samples were analyzed at Severn-Trent Laboratory with EPA Method TO-15. The QC limits were met, and accuracy and precision in the analytical methodology were evident in the duplicate analyses of QC samples. The analytical data from Severn-Trent Laboratory are acceptable for screening of indoor air contamination.

A detailed QA/QC report addressing activities related to sample collection, handling, and analysis is in Supplement 2 to this report (on CD).

### **3.10 Waste Characterization Data**

Groundwater purged prior to sampling of the monitoring wells historically having carbon tetrachloride concentrations above the maximum contaminant level of 5 µg/L was placed in drums and allowed to volatilize. Composite samples from the drums indicated carbon tetrachloride concentrations of 1.5–9.6 µg/L. After aeration, a composite sample showed no contamination, and the waste purge water was disposed of on-site.

During drilling of both the unsuccessful GWEXTEST well (location TEST-1 in Figure 2.1) and the subsequent GWEX-1 well, soil cuttings were accumulated in roll-off containers. Composite samples of the drill cuttings from both installations showed that no contamination was present, and the waste soil was transported to the Milford Landfill in Milford, Nebraska. Development water from both installations was containerized and transported to the publicly owned treatment works in Eagle, Nebraska. Prior to transport and disposal, analysis of a composite sample of the development water from the GWEXTEST installation showed that

chloroform was present at a concentration of 39 µg/L. Carbon tetrachloride was not detected. Analysis of a composite sample of the development water from the GWEX-1 installation showed that carbon tetrachloride was present at a concentration of 63 µg/L, and chloroform was present at 1.2 µg/L. Results are in Table S.2.2, Supplement 2 (on CD).

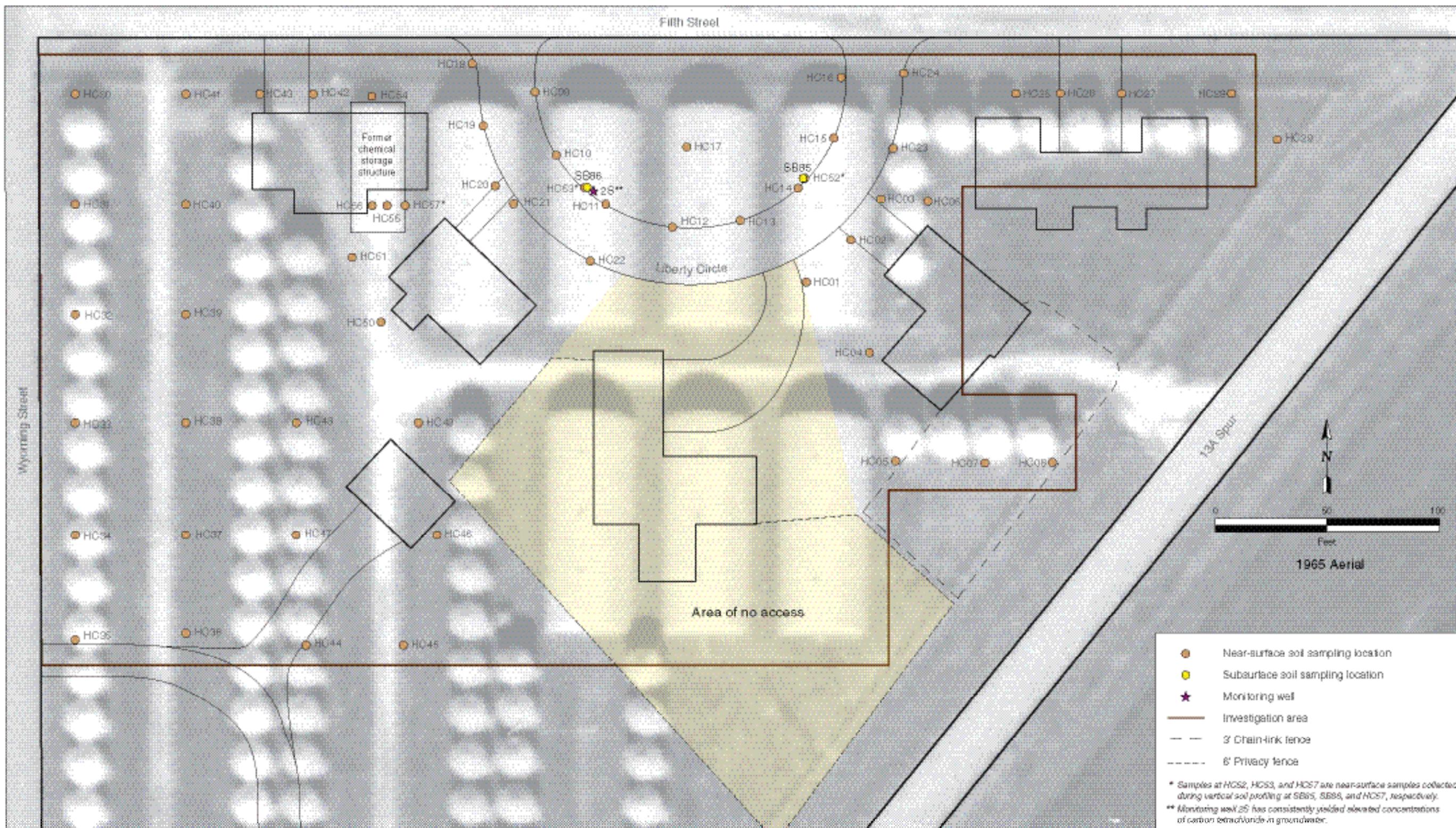


FIGURE 3.1 Locations of near-surface and deeper subsurface soil samples at the former CCC/USDA facility, with outlines of current structures, roads, and driveways superimposed on an aerial photograph depicting the locations of grain and chemical storage structures. Source of photograph: USDA 1965.

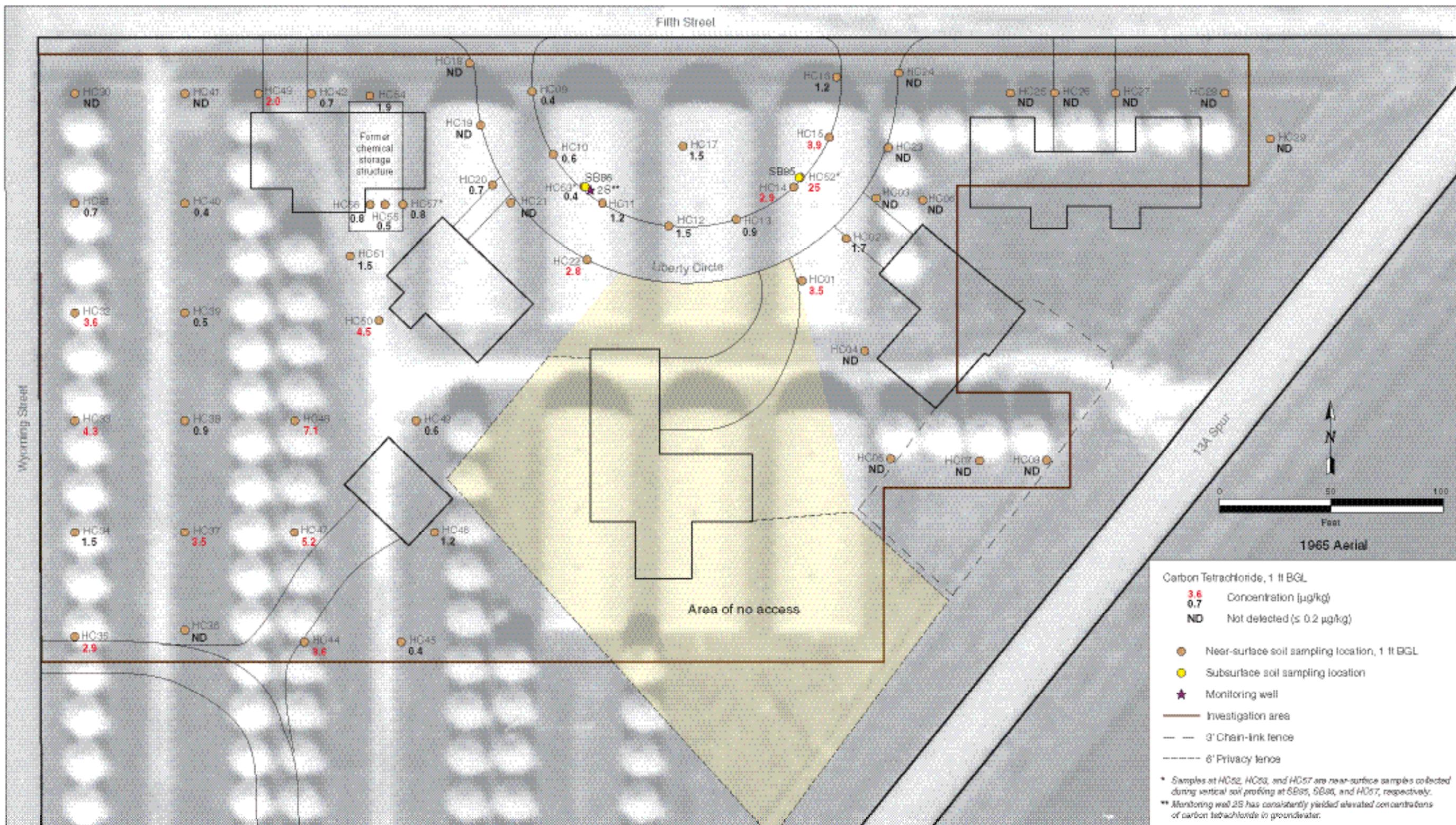


FIGURE 3.2 Results of headspace analyses for carbon tetrachloride in near-surface soil samples at approximately 1 ft BGL. The outlines of current structures, roads, and driveways are superimposed on an aerial photograph depicting the locations of grain and chemical storage structures at the former CCC/USDA facility. Source of photograph: USDA 1965.

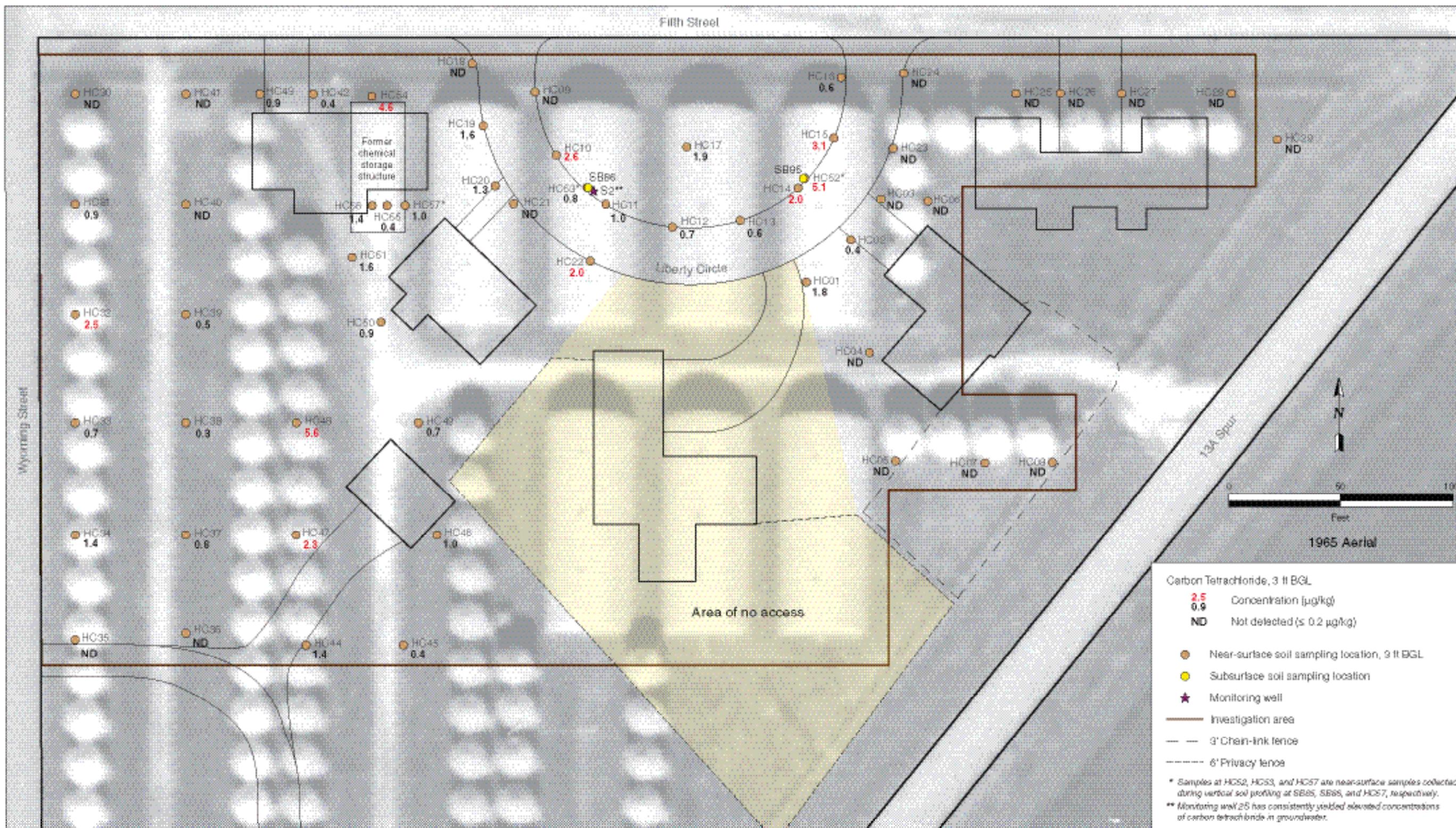


FIGURE 3.3 Results of headspace analyses for carbon tetrachloride in near-surface soil samples at approximately 3 ft BGL. The outlines of current structures, roads, and driveways are superimposed on an aerial photograph depicting the locations of grain and chemical storage structures at the former CCC/USDA facility. Source of photograph: USDA 1965.



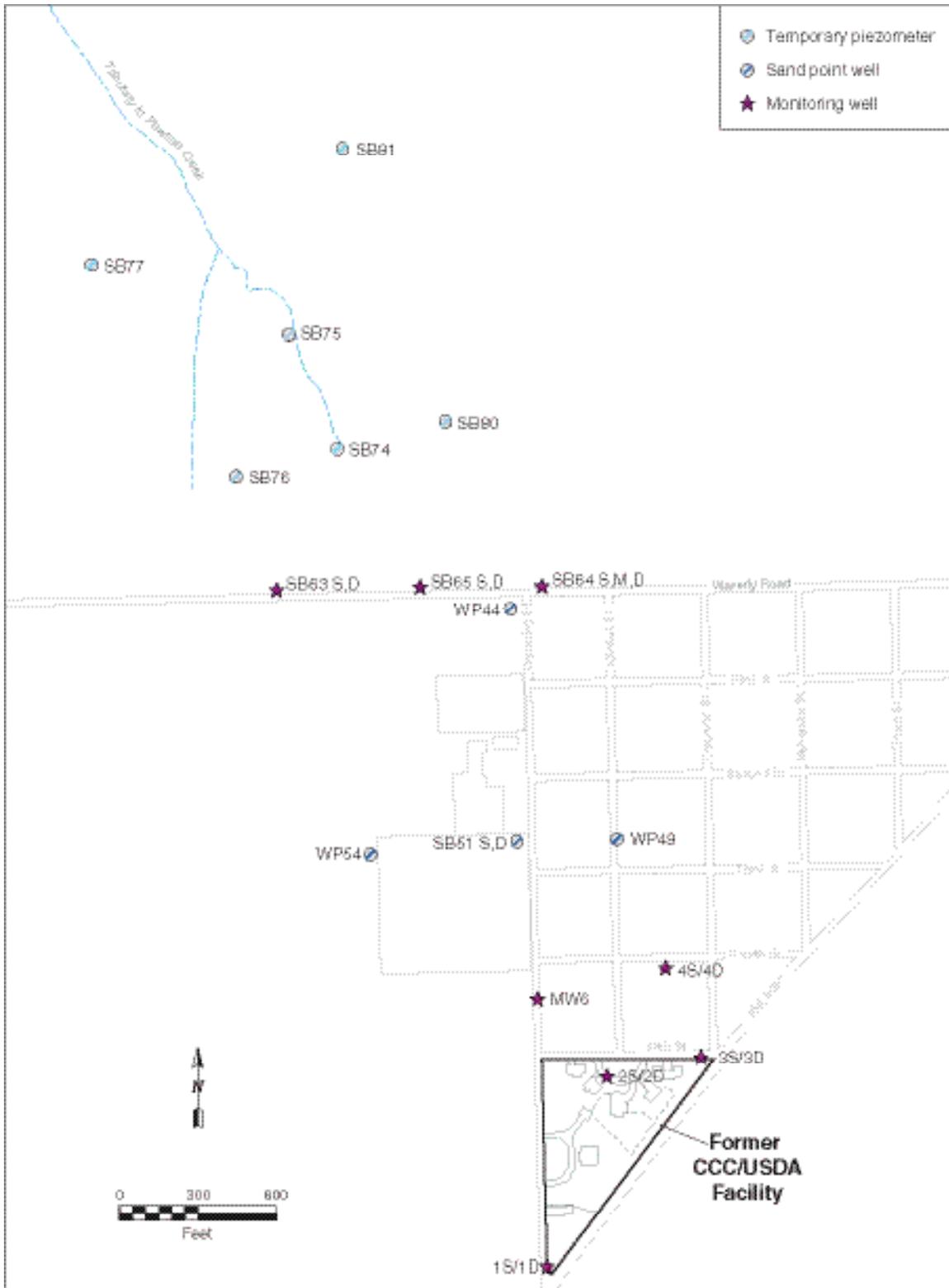


FIGURE 3.5 Locations of the temporary piezometers, monitoring wells, and sand point wells used for water level measurements during the 2004 targeted investigation at Murdock.

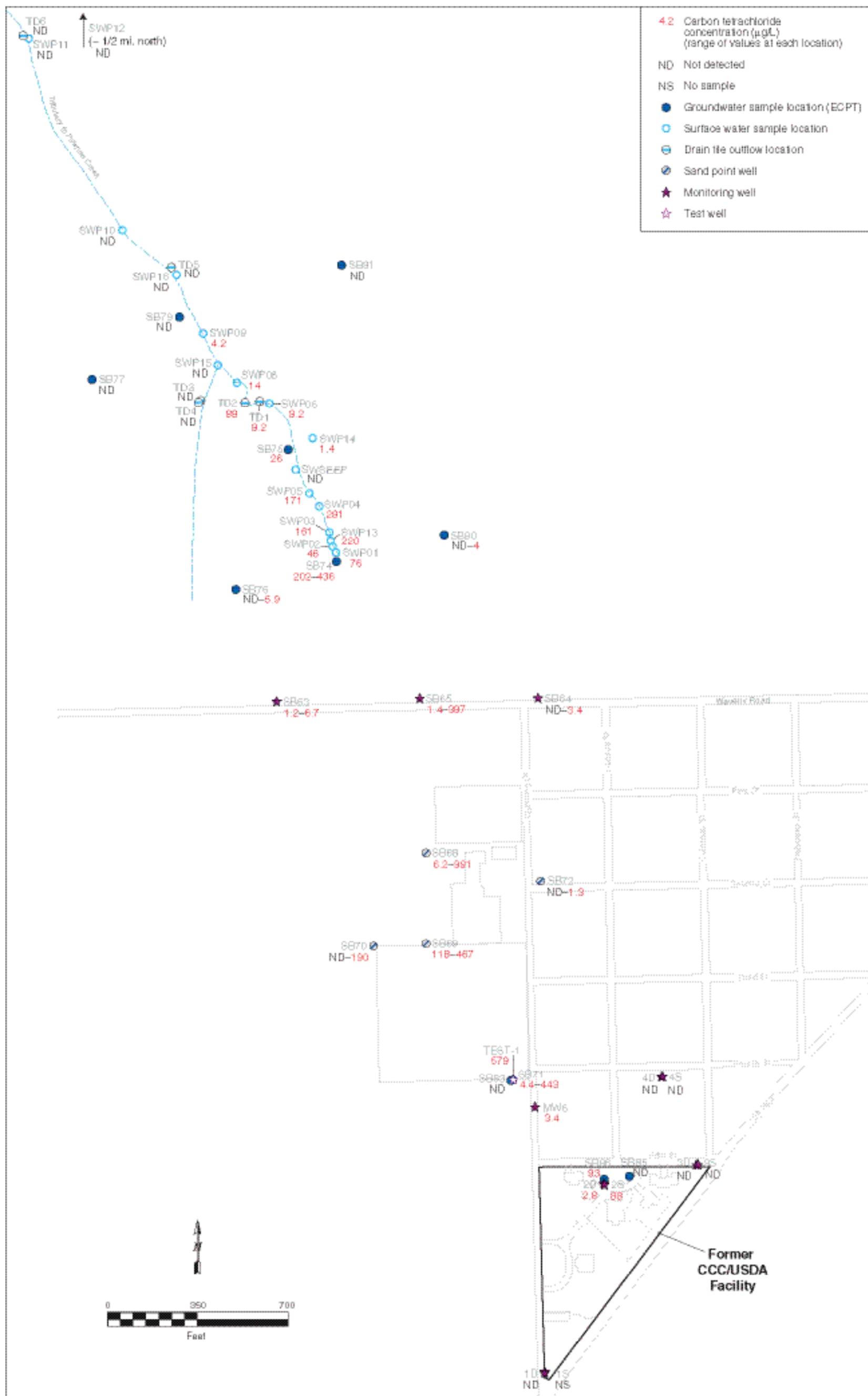


FIGURE 3.6 Results of analyses of water samples for carbon tetrachloride during the 2004 targeted investigation at Murdock.

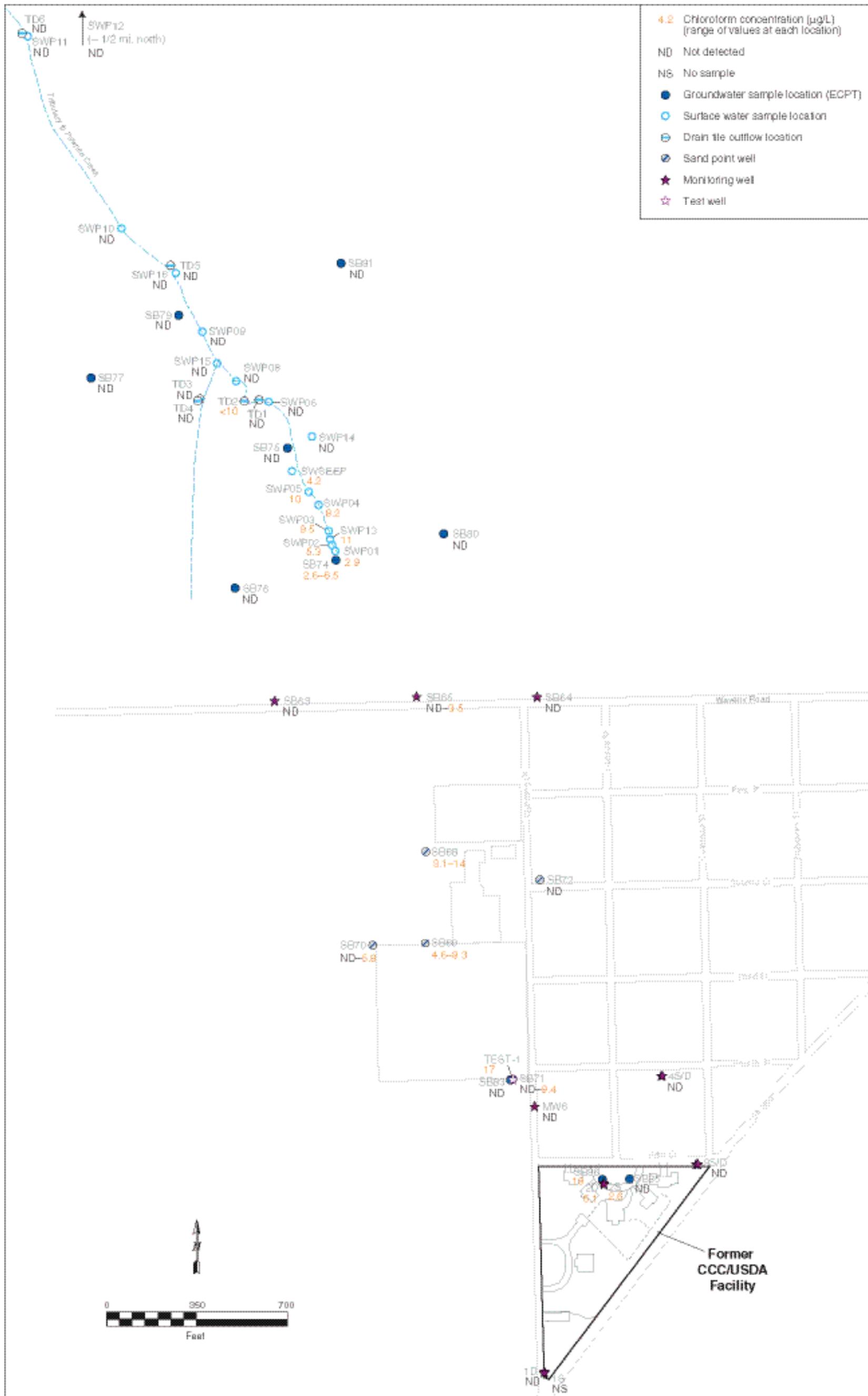


FIGURE 3.7 Results of analyses of water samples for chloroform during the 2004 targeted investigation at Murdock.

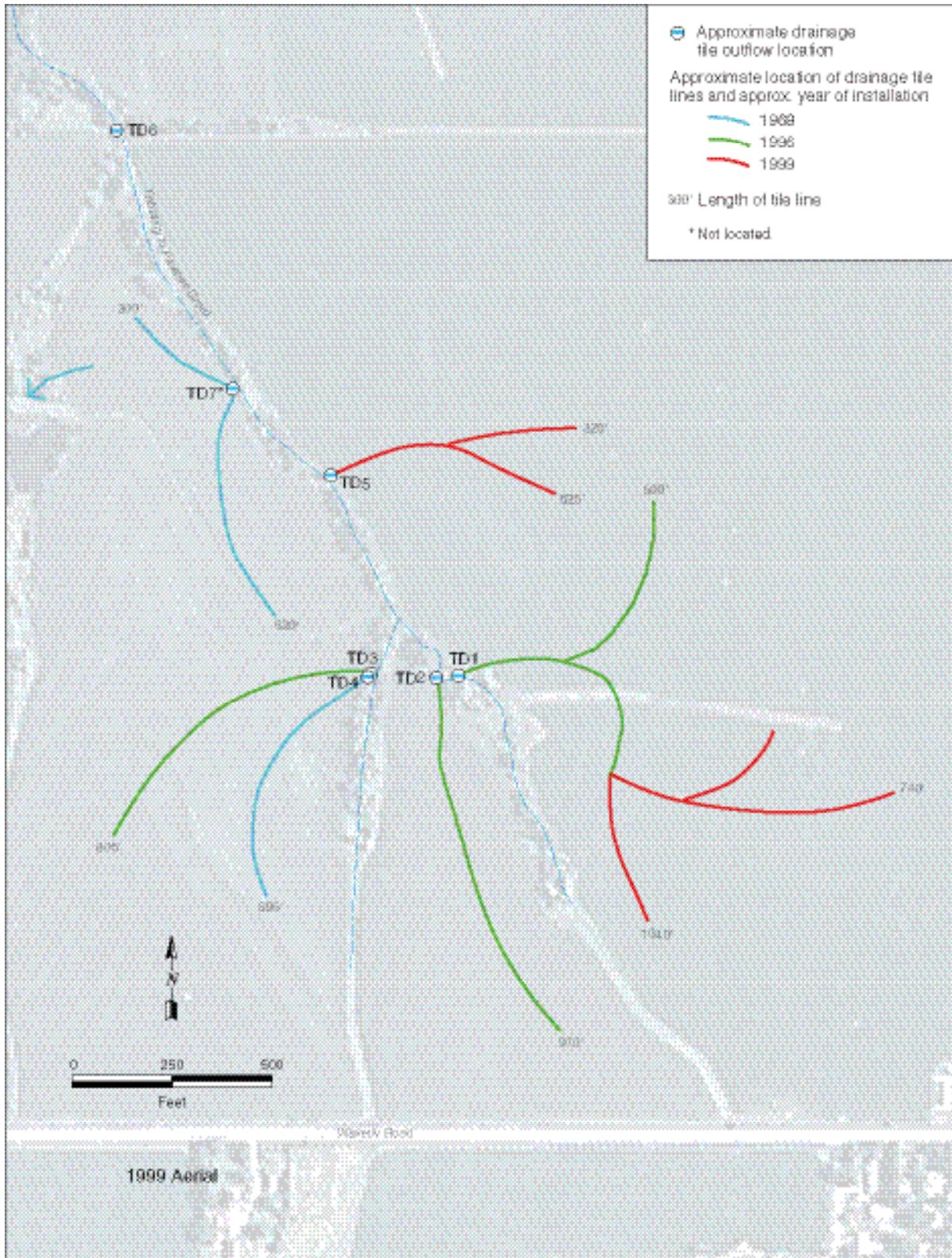


FIGURE 3.8 Locations of tile drain lines in the study area at Murdock.



FIGURE 3.9 Air sampling locations at the former CCC/USDA facility.

## 4 Interpretation of Results

In this section, the results of the targeted investigation are discussed, interpreted, and integrated (Sections 4.1–4.6) in the context of the technical objectives identified in Section 1.

### 4.1 Determine the Continuity, Thickness, and Hydrogeologic Characteristics of the Aquifer in the Vicinity of the Pawnee Creek Tributary

#### 4.1.1 Continuity and Thickness of the Aquifer in the Vicinity of the Tributary Creek

The hydrostratigraphic information obtained in previous investigations indicates that the aquifer is laterally continuous throughout the area south of Waverly Road. In contrast, erosion along the tributary creek (north of Waverly Road) is expected to have significantly thinned or totally removed the aquifer there.

This investigation tested nine locations along the creek and on its topographically high flanks. Lithologic and moisture data obtained through direct observation of selected core samples and ECPT electronic logs were used to interpret the hydrostratigraphic sequences in this area. As expected, the aquifer was identified on the topographically high flanks of the creek (SB76–SB77 and SB80–SB82) but was found to be absent along the creek at SB75, SB79, and SB78 (Figure 4.1). Because of depositional facies changes, the aquifer sands are finer grained and more silty near the creek than south of Waverly Road. The unit overlying the aquifer near the creek was a brown-gray silty clay containing abundant iron oxide, manganese oxide, and calcite precipitates. Most of this unit was moist to wet. A dark gray, dense, silty clay was identified underlying the aquifer unit. To illustrate the three-dimensional geometry of the aquifer near the creek, three hydrogeologic cross sections, at the locations shown in Figure 4.1, were constructed and interpreted.

Hydrogeologic cross section B–B , shown in Figure 4.2, includes most of section A–A (SB46 to SB06; see Figure 1.2) and extends from northwest to southeast across the area affected by the carbon tetrachloride plume. This section was constructed to depict the hydrogeology that controls groundwater flow between the former CCC/USDA grain storage facility and the tributary creek. In the construction of section B–B , results from previous investigations for all borings on and south of Waverly Road were integrated with hydrostratigraphic data obtained in

this 2004 targeted investigation from selected core samples and ECPT electronic logs at SB74, SB75, SB79, and SB78.

As illustrated along the line of cross section B–B , the aquifer extends north of Waverly Road. However, the thickness of the unit decreases significantly, from 24 ft at monitoring well SB65 to 11 ft at SB74, until it is pinched out at SB75. The aquifer sand unit is absent at locations SB79 and SB78, hydraulically downgradient from SB75. The absence of the aquifer along the tributary creek effectively eliminates the potential for contaminated groundwater to migrate under the creek.

Figure 4.3 depicts hydrogeologic cross section C–C , which begins on the west flank of the tributary creek (SB76), passes through a location in the creek headwaters at SB74, and continues to the east flank of the creek (SB80). The aquifer is laterally continuous along this line south of the tributary creek, but the lateral change in thickness of the aquifer is significant. Along the two flanks of the creek, the aquifer unit is 25 ft (SB76) to 35 ft (SB80) thick. By contrast, the aquifer thickness is reduced by more than half to 11 ft at SB74. The silty clay unit overlying the aquifer was mostly moist to wet at SB74; this silty clay provides the pathway for groundwater migration from the aquifer to the tributary creek (about 70 ft to the northwest).

Hydrogeologic cross section D–D (Figure 4.4) was constructed from southwest to northeast across the tributary creek, downgradient from the convergence of waterways (Figure 4.1). Section line D–D illustrates that the aquifer is pinched out near the creek (SB79) but continues to persist on the topographically high flanks. Near the creek where the aquifer unit is absent, a unit of silty clay was found at SB79. The top part of this silty clay was saturated to a depth of about 17 ft BGL. The relatively low permeability observed for this unit significantly reduces the migration of groundwater downgradient along the creek. The aquifer is thinner at the two flanks in northern cross section D–D than in southern cross section C–C . The change in thickness from south to north is from 25 ft (SB76) to 8 ft (SB77) on the west flank of the creek and from 35 ft (SB80) to 14 ft (SB81) on the east flank.

#### **4.1.2 Hydraulic Properties of the Aquifer in the Vicinity of the Tributary Creek**

The findings in Section 4.1.1 suggest that the lateral and vertical extents of the aquifer change significantly near the tributary creek because of the depositional environment and erosion. The change appears to alter the hydraulic properties of the aquifer. To assist in

characterizing the aquifer, slug tests were performed at five piezometer locations near the creek (at SB74, SB76, SB77, SB80, SB81; Figure 2.4). An additional test was performed to determine the properties of the saturated silty clay along the creek where the aquifer is absent (SB75).

The analysis methods of Bouwer and Rice (Bouwer and Rice 1976; Bouwer 1989) and Hvorslev (1951) were used to interpret the water level response data obtained from the slug tests. The complete data and interpretive fits of theoretical straight-line trends to each slug test data set are in Supplement 1 (on CD). The resulting hydraulic conductivity ( $K_h$ ) values estimated from the analyses are summarized in Table 4.1. For each data set, the estimated  $K_h$  value calculated

TABLE 4.1 Hydraulic conductivity estimates from slug tests at Murdock.

Boring	Shown in Figure	Test Method	Data Set <sup>a</sup>	$K_h$ Value (ft/d) for Analysis Method <sup>b</sup>		Ratio (%) (Bouwer-Rice/Hvorslev)
				Hvorslev	Bouwer-Rice	
SB74	4.2	Slug	(in) Test 2, Step 0	3.04	2.84	93
			(out) Test 2, Step 1	1.07	1.00	93
			(in) Test 2, Step 2	2.79	2.61	94
			(out) Test 2, Step 3	1.23	1.15	93
SB75	4.2	Slug	(in) Test 1, Step 0	0.07	0.05	71
			(out) Test 1, Step 1	0.02	0.02	100
			(in) Test 1, Step 2	0.08	0.07	88
			(out) Test 1, Step 3	0.02	0.02	100
SB76	4.3	Air	Test 0, Step 0	1.72	1.54	90
			Test 0, Step 1	2.70	2.41	89
			Test 0, Step 2	2.74	2.44	89
SB77	4.4	Slug	(in) Test 0, Step 0	0.27	0.21	78
			(out) Test 0, Step 1	0.23	0.18	78
			(in) Test 0, Step 2	0.29	0.23	79
			(out) Test 0, Step 3	0.20	0.15	75
SB80	4.3	Air	Test 1, Step 0	0.92	0.85	92
			Test 1, Step 1	0.94	0.86	91
			Test 1, Step 2	1.02	0.94	92
SB81	4.4	Air	Test 2, Step 0	0.85	0.70	82
			Test 2, Step 1	1.02	0.85	83
			Test 2, Step 2	1.08	0.90	83

<sup>a</sup> Complete results for the tests and steps summarized here are in Supplement 1 (on CD). A test consists of a group of water level response data sets recorded in a series of individual sluggings (steps) for a well. All of data sets for each location were analyzed and reported.

<sup>b</sup> Results were interpreted by using the analysis methods of Bouwer and Rice (Bouwer and Rice 1976; Bouwer 1989) and Hvorslev (1951), as implemented in the commercial well test software analysis package AqteSolv for Windows.

with the Bouwer and Rice analysis method either fell at the Hvorslev analysis value for the same data set or was less than 30% lower. The estimated  $K_h$  values for the aquifer ranged from 0.15 ft/d at SB77 to 3.04 ft/d at SB74. The estimated  $K_h$  values for the saturated silty clay along the creek (average 0.04 ft/d at SB75) are lower by one or two orders of magnitude than the values estimated for the aquifer. The low hydraulic conductivity values of the sediments along the creek should prevent contaminated groundwater from migrating in a continuous path under the creek.

## 4.2 Characterize the Present Distribution of Carbon Tetrachloride Contamination in Groundwater and Surface Water in the Area North of Waverly Road

Groundwater sampling, guided by the hydrogeologic interpretation of the aquifer discussed in Section 4.1, was performed at 7 locations north of Waverly Road (Figure 4.5). Surface water was also sampled at 16 locations along the upper reach of the tributary creek to identify areas where contaminated groundwater is being discharged to the creek. The results of VOCs analyses on these groundwater and surface water samples were used to map the spatial distribution of carbon tetrachloride in the vicinity of the creek (Figure 4.5). The vertical and lateral distributions of carbon tetrachloride in the aquifer are presented on cross section B–B , extending from the former CCC/USDA facility to the tributary creek and running along the creek, as well as on traverse cross sections C–C and D–D , constructed roughly perpendicular to the flow direction of the creek (Figures 4.6–4.8).

The results shown in Figures 4.5 and 4.6 indicate that the carbon tetrachloride plume in groundwater originating beneath the former CCC/USDA facility terminates near the tributary creek, approximately 1,300 ft north and downgradient of Waverly Road (between SB75 and SB79). Along the approximate axis of the plume, the concentration of carbon tetrachloride in the aquifer approaching the creek is 436  $\mu\text{g/L}$  at SB74 (Figure 4.6). As the aquifer unit is pinched out beneath the creek, the concentration of carbon tetrachloride decreases rapidly to 26  $\mu\text{g/L}$  at SB75 and to “not detected” at SB79. These results confirm that contaminants are not migrating under the creek at and downstream from SB79. Within the aquifer unit near the creek, contaminant concentrations are higher in the lower part of the unit (Section B–B , Figure 4.6).

Figures 4.7 and 4.8 illustrate the vertical and lateral distributions of carbon tetrachloride along the cross sections spanning the tributary creek. Figure 4.7 (cross section C–C ) indicates that the highest contaminant levels occur near the axis of the creek and that the plume is bounded

by low concentrations (5.9  $\mu\text{g/L}$  and 4.0  $\mu\text{g/L}$ ) along the flanks of the creek. Cross section D–D (Figure 4.8), located 1,000 ft downgradient from section C–C, illustrates that no contamination was found in groundwater under or flanking the creek. This result suggests that all contaminants in groundwater are captured by the creek or the tile drains, entering surface water south of cross section D–D. The low concentration of carbon tetrachloride found at SWP09 (4.2  $\mu\text{g/L}$ ; Figures 4.5 and 4.8) is likely a result of mixing of carbon-tetrachloride-free groundwater discharged to the creek with contaminated water migrating from upgradient locations (e.g., tile drain TD2, discharge from which contained carbon tetrachloride at 88  $\mu\text{g/L}$  [Figure 4.5]).

Carbon tetrachloride was found in surface water from 10 locations at concentrations of 1.4–281  $\mu\text{g/L}$ . Surface water samples with concentrations above 100  $\mu\text{g/L}$  were limited to the headwaters area farthest upgradient (SWP03–SWP05 and SWP13). This area apparently captures the central part of the plume seeping from the groundwater system, resulting in the high levels of contaminant in surface water directly downgradient from SB74 (Figure 4.5). No contamination was found in surface water in the tributary creek farther than 2,000 ft north (downgradient) of Waverly Road. The distribution of carbon tetrachloride in surface water is consistent with the extent of the plume identified in groundwater. The main body of Pawnee Creek, more than 1 mi north of the headwaters area of the tributary creek, appears not to be affected by the plume in the aquifer.

In this targeted investigation, six of seven drain tile lines were located along the tributary creek, as discussed in Section 4.3. These tiles collect shallow groundwater and precipitation percolating through the shallow soil from beneath the surrounding farm fields and drain the water into the creek. Water discharged from the six active drain tiles was collected and analyzed for VOCs. Carbon tetrachloride was found in discharge from only two lines, TD1 and TD2, which extend across the area affected by the carbon tetrachloride plume in groundwater (see discussion in Section 4.3). The concentrations of carbon tetrachloride in tile drain discharges were 8.2  $\mu\text{g/L}$  at TD1 and 88  $\mu\text{g/L}$  at TD2 (Figure 4.5). These results further confirm the extent of the contaminant plume in groundwater identified through analysis of surface water and groundwater samples.

In addition to detailed characterization near the tributary creek, groundwater samples were also collected from existing wells and well clusters located on and south of Waverly Road (Figure 4.5). Results of VOCs analyses on these samples were integrated with contaminant data collected near the creek to map the present configuration of the carbon tetrachloride plume in groundwater across the entire Murdock site. The plume, constructed on the basis of the highest

concentration of carbon tetrachloride at each location, is shown in Figure 4.5. Comparison to results from previous sampling events in 1991–1993, 1996–1997, 1999, and 2002 (Figure 4.9) indicates that the present distribution of carbon tetrachloride is similar to that identified in 2002, though a general decrease in carbon tetrachloride concentrations in groundwater is evident. The highest concentration in the plume, at SB68, has decreased from 7,800 µg/L in 1996–1997 and 1,831 µg/L in 1999 to recent maximum levels of 1,072 µg/L in 2002 and 991 in 2004.

The present vertical distribution of carbon tetrachloride in the aquifer is depicted in Figure 4.6 along cross section B–B , which follows the main body of the plume from the former CCC/USDA facility in the south and to the headwaters area of the tributary creek in the north. At the former CCC/USDA facility, the highest concentrations of carbon tetrachloride are in the upper part of the aquifer. Progressing toward the creek, however, the maximum concentrations shift toward the bottom of the unit. The carbon tetrachloride plume appears to be moving gradually downward vertically within the aquifer as the plume migrates northwestward from the former CCC/USDA facility. This observation is consistent with the concept of continued downward migration of the contaminant with time and distance from the source area, as well as with thinning of the aquifer to the northwest.

#### **4.3 Determine the Patterns of Groundwater Flow in the Vicinity of the Pawnee Creek Tributary and Their Relationship to the Expected Migration of the Identified Carbon Tetrachloride Plume**

The previous investigations at Murdock demonstrated that groundwater flow, and hence contaminant migration, across the site is initially northwestward from beneath the former CCC/USDA facility, then northward to the headwaters of the tributary creek. To gather more detailed information about the flow pattern near the creek, six temporary piezometers were installed across the area, some along the creek and some on its topographically high flanks. These temporary piezometers, together with the existing monitoring wells and sand point wells at the Murdock site, formed a groundwater level monitoring network across the entire study area during the 2004 targeted investigation (Figure 4.10).

Groundwater levels were measured by hand with a water level meter prior to, during, and at the end of the first field event of the targeted investigation (on March 26, April 6, and April 12, 2004); this field event included major activity near the tributary creek. Results of groundwater level monitoring are in Table D.1 in Appendix D. Groundwater level data collected

from the monitoring network permitted mapping of the complete potentiometric surface along the pathway of contaminant migration identified in the aquifer, extending from the former CCC/USDA facility toward the headwaters area of the creek. The mechanically contoured potentiometric surface shown in Figure 4.10 is based on hand measurements made on April 12, 2004, at the end of the first field event, plus surface water elevations estimated from elevations on the creek bed surveyed at surface water sampling locations. The surface water was consistently less than 1 ft deep, typically about 6 in. deep.

The hydraulic gradient appears to be significantly different north of Waverly Road and south of that position. Near and northwest of the former CCC/USDA facility, including locations WP54, SB51, WP49, MW6, 1D, 2D, 3D, and 4D, the hydraulic gradient is relatively flat, approximating a value of 0.0012. This low hydraulic gradient indicates the potential for high aquifer transmissivity in the area. Contributing factors to the high transmissivity are the thickness and hydraulic conductivity of the aquifer.

North of Waverly Road and near the tributary creek, however, the hydraulic gradient (0.024) is 20 times the value south of Waverly Road (Figure 4.10), suggesting low transmissivity in the aquifer near the creek. This result is consistent with a thinning aquifer unit with low hydraulic conductivity, as identified in the targeted investigation near the creek and as discussed in Section 4.1. Groundwater is generally interpreted to flow in the downgradient direction, perpendicular to the potentiometric surface. The flow patterns north of Waverly Road are depicted in Figure 4.11 as arrows. Near the creek, groundwater converges from all directions toward the trend of the creek channel, which functions as a discharge boundary for the groundwater system.

The flow pattern south of Waverly Road is consistent with the pattern identified in previous investigations.

In Figure 4.11, the present carbon tetrachloride plume identified in Section 4.2 is superimposed on the flow directions and the potentiometric surface contour map. The present distribution of carbon tetrachloride is consistent with the interpreted flow patterns, indicating that contaminant migration is controlled by the groundwater flow system illustrated in Figure 4.11. Near the creek, the identified lateral extent of the plume lies within the contaminant migration pathways expected on the basis of the groundwater flow pattern verified in this investigation. This evidence, combined with an absence of evidence for the extension of the aquifer beneath the

creek, strongly supports the interpretation that the creek captures all contaminated groundwater originating from the former CCC/USDA facility.

Previous surface water monitoring and sampling (spring 2000) identified several drain tiles along the tributary creek that discharge water to the creek continuously (Figure 3 in Argonne 2003). To evaluate the effects of the drain tiles on migration of contaminated groundwater near the creek, the detailed location of each tile line was established more accurately in the 2004 targeted investigation with assistance from Hauschild Construction Company, Avoca, Nebraska, and with reference to the company's original maps. This company installed and expanded the tile lines in 1968, 1996, and 1999.

As shown in Figure 4.12, six tile lines (TD1–TD5 and TD7) were mapped on the basis of information from the Hauschild Construction Company. The discharge point from tile TD7 could not be found in the field. The discharge point of tile line TD6 was found along the creek, but no information was available on the extent of the tile line itself. Tile lines TD1–TD4 extend across or around the area potentially affected by contaminated groundwater. Tile lines TD5–TD7, however, lie downgradient of the interpreted contaminated area and have no apparent effect on contaminant migration in groundwater.

All tile lines were installed at a depth of 4–5 ft BGL. Figure 4.12 shows the tile lines superimposed on contours indicating depths to groundwater and on the interpreted outline of the carbon tetrachloride plume. Where the depth to groundwater exceeds 5 ft BGL, tile lines apparently drain only rainwater percolated through the shallow soil above the tile. Where the depth to groundwater is less than 5 ft BGL, tile lines predominantly drain groundwater to the tributary creek. Figure 4.12 shows that one segment of tile line TD2 and one segment of tile line TD1 are within the plume area where depth to groundwater is less than 5 ft BGL. These two segments drain contaminated groundwater to the creek. About 630 ft of tile line TD2 runs parallel to and near the central plume in the area of shallow groundwater; this segment constitutes 65% of the entire line TD2. Carbon tetrachloride contamination was confirmed (88  $\mu\text{g/L}$ ) in discharge from the outflow point for tile line TD2. In the case of tile line TD1, only 7% (160 ft) of the line intercepts the plume in the area of shallow groundwater. A low concentration of carbon tetrachloride (8.2  $\mu\text{g/L}$ ) was found in the discharge from the TD1 outflow point. Contaminated discharge from TD2 and TD1 could account for the carbon tetrachloride values found in downgradient surface water samples (14  $\mu\text{g/L}$  at SWP14 and 4.2  $\mu\text{g/L}$  at SWP09; Figure 4.5).

The discharge flow rates from drain tiles TD1–TD6 were monitored by recording incremental and cumulative production weekly (Table F.3 in Appendix F). Tile lines TD1 and TD6 had the highest discharge rates, recorded at 3–5 times those measured for the other drain tiles (Figure 4.13). In the headwaters of the tributary creek, water drained through TD1–TD4 at 19,000–30,000 gal/d during the period from June 3, 2004, to July 16, 2004. Of this total amount, water potentially contaminated with carbon tetrachloride (discharged from tile lines TD1 and TD2) totaled about 13,000–26,000 gal/d.

#### **4.4 Identify and Delineate the Presence of Carbon Tetrachloride in Vadose Zone Soils in the Northern Portion of the Former CCC/USDA Facility That Might Pose a Continuing Source of Contamination to the Aquifer, and Determine Soil Properties Affecting Vertical Contaminant Migration**

##### **4.4.1 Presence of Carbon Tetrachloride in Near-Surface Soils**

As discussed in Section 3.2.1, near-surface soil samples were collected in the northern portion of the former CCC/USDA facility for VOCs analyses by modified EPA Method 5021 (headspace method). Results are presented in Figure 4.14 for shallow near-surface soils (1 ft BGL) and in Figure 4.15 for deeper near-surface soils (3 ft BGL). This section interprets the headspace concentration data used to identify the composite distribution pattern of more elevated concentrations in shallow and deeper near-surface soils. The patterns or groupings of more elevated near-surface headspace concentrations of carbon tetrachloride were interpreted to indicate areas of potential contamination in deeper subsurface soils.

The highest relative carbon tetrachloride concentrations observed in the headspace analyses of shallow near-surface soils (1 ft BGL) were detected in three main areas of the former facility. The pattern, shown in Figure 4.14 in relationship to the former storage structures, indicates high concentrations in the western portion of the facility beneath former bins, in the north-central portion below former Quonset huts, and in the northwest portion around the former chemical storage structure.

The pattern of headspace data for carbon tetrachloride in the deeper near-surface soils (3 ft BGL; Figure 4.15) highlights the same three areas in the west, north-central, and northwest portions of the former facility. The identified areas of higher concentrations are again consistently associated with former storage structures.

Combining the shallow (1-ft BGL) and deeper (3 ft BGL) near-surface headspace data patterns yielded a composite distribution of the relatively higher carbon tetrachloride concentrations in near-surface soils (Figure 4.16). The higher concentrations are in (1) the area of the former circular grain bins in the western portion of the investigation area; (2) three isolated areas at the former Quonset huts near the current semicircular roadway, Liberty Circle; and (3) the area surrounding the former chemical storage structure. The consistent occurrence of relatively higher headspace concentrations at both 1 ft BGL and 3 ft BGL in these identified areas is interpreted to indicate areas where deeper subsurface soils are most likely contaminated. Subsurface soil profiling locations for this investigation were selected within these prioritized areas, as discussed in Section 4.4.2.

#### **4.4.2 Presence of Carbon Tetrachloride in Subsurface Soils**

Vertical profiling of subsurface soils was performed at three locations selected on the basis of the composite pattern of higher headspace concentrations of carbon tetrachloride in near-surface soils (Figure 4.16). Subsurface soil sampling could not be conducted at some proposed locations because access to some residential areas for this activity was denied. Locations SB85 and SB86 were selected within the north-central portion of the former facility, under the former Quonset huts and along the present pavement of Liberty Circle. The pavement might restrict the vertical infiltration of precipitation and hence prolong the leaching of potential carbon tetrachloride contamination from vadose zone soils into the aquifer. The location of SB86 is also near (about 16 ft northwest of) monitoring well 2S; carbon tetrachloride has consistently been detected over the past decade in groundwater samples from this well. The third subsurface soil sampling location (HC57; Figure 4.16) was placed near the former chemical storage structure. Limitations associated with the current residence at this third location restricted vertical-profile sampling there to what could be accomplished with a hand-driven device. Vertical-profile soil sampling proposed for a location in the western portion of the former CCC/USDA facility (related to former grain bins) could not be carried out because of denial of access for this activity by the property owner. This proposed location was selected on the basis of the composite pattern of contamination in near-surface soils.

All soil samples from cores collected in the vadose zone at SB85, SB86, and HC57 were analyzed by EPA Methods 5030B and 8260B (purge-and-trap GC-MS), with a quantitation limit of 10 µg/kg. Results are displayed by depth in Figure 4.17 with the lithology for SB85 and SB86.

Carbon tetrachloride was detected in the subsurface soils at both SB85 and SB86, as predicted by the screening tool of near-surface soil sampling. At SB85, concentrations of carbon tetrachloride ranged from not detected to 361 µg/L (Figure 4.17). The vertical distribution of carbon tetrachloride shows elevated concentrations in two intervals: 13–361 µg/kg at 21–35 ft BGL and 18–189 µg/kg at 49–57 ft BGL. In contrast, relatively low carbon tetrachloride concentrations (6.5–21 µg/kg) were identified at 47–61 ft BGL in SB86. No chloroform was detected above the quantitation limit in vadose zone soils at these two locations.

Groundwater below the vadose zone soil at SB85 was tested and found to be uncontaminated. At SB86, groundwater contained carbon tetrachloride at 93 µg/L (71–76 ft BGL; Figure 4.6). A similar concentration (88 µg/L) was found at nearby monitoring well location 2S (70.5–80.5 ft BGL). The potential effect on groundwater of remaining contaminants in vadose zone soils is discussed in Section 4.5.

Neither carbon tetrachloride nor chloroform was detected in subsurface soils at HC57 from near the surface to 22 ft BGL, the maximum depth accessible with the hand-driven device.

#### **4.4.3 Health Risks Associated with Exposure to Near-Surface Soils**

As discussed in Section 3.2.1, the near-surface soil samples collected at the former CCC/USDA facility were analyzed by EPA Methods 5030B and 8260B (purge-and-trap GC-MS) to support a health risk assessment. Neither carbon tetrachloride nor chloroform was detected above the quantitation limit of 10 µg/kg in any of these samples.

Levels of soil contamination required to surpass EPA limits for risks due to ingestion and inhalation of carbon tetrachloride in soils have been calculated by using parameters defined as reasonable maximum exposure levels for average Americans (EPA 1989a, 1991). The pathways considered were direct ingestion of contaminated soil, inhalation of contaminated dust (indoors and outdoors), and ingestion of vegetables and fruits grown in contaminated soil.

The results show that a carbon tetrachloride concentration of 5,800 µg/kg in soil would be required to yield a carcinogenic risk of 1E-4, the maximum risk for soil required to yield the maximum allowable hazard index of 2,333 µg/kg. The absence of carbon tetrachloride at or near this level in the near-surface soil samples indicates that there is no unacceptable health risk due to near-surface soils at the former Murdock CCC/USDA facility.

#### **4.4.4 Physical and Chemical Properties of the Contaminated Vadose Zone Soils**

As discussed in Section 4.4.2, a relatively high concentration of carbon tetrachloride was found in the subsurface soils at SB85. Contamination was detected at two depth intervals (21–35 ft BGL and 49–57 ft BGL) in the vertical profiling. To estimate the vertical migration of the remaining soil contaminants, core samples collected from the two contaminated intervals were analyzed for properties that potentially affect vertical movement. The properties tested include bulk dry density, porosity, moisture content, total organic matter content, and carbon content. The results of these analyses are shown in Appendix B, Table B.4. Average values for these properties were used as model input for simulations of vertical contaminant migration through the vadose zone to groundwater, as discussed in Section 4.5.

### **4.5 Evaluate Contaminant Migration from Soil to Groundwater, and Analyze Indoor Air Potentially Affected by Vapor Intrusion at Residences Built on the Former CCC/USDA Facility**

#### **4.5.1 Evaluate Contaminant Migration from Soil to Groundwater**

As discussed in Section 4.4.2, vertical distributions of carbon tetrachloride were delineated in the vadose zone at SB85 and SB86 below the former Quonset huts on the north-central part of the former CCC/USDA facility.

The identified contaminants currently remaining in the soil at this location are expected to migrate vertically downward and provide a continuing source for the groundwater plume. Comparison with the soil screening levels for carbon tetrachloride provided by the EPA (1996) indicates that the highest level of contamination in soil at SB86 is below the soil screening level of 70  $\mu\text{g}/\text{kg}$  for a default dilution attenuation factor of 20. The contaminant concentration at SB85, however, reaches 361  $\mu\text{g}/\text{kg}$ , as discussed in Section 4.4.2. Further analysis of the exposure pathway to groundwater at SB85 is therefore warranted.

To quantitatively estimate the potential impact of the identified vadose zone contaminants on groundwater, a vertical contaminant transport model was developed for the vadose zone. The model simulation results predicted potential vertical contaminant migration and quantified the effect of this migration on groundwater.

#### 4.5.1.1 Model for Vertical Contaminant Transport in the Vadose Zone

The vertical mobilization and migration of organic contaminants in the vadose zone involve complex processes such as sorption, degradation, hydrolysis, volatilization, and air diffusion. It would be difficult to simulate all of these processes accurately, because the many uncertainties associated with the physical, chemical, and biological characteristics of the vadose zone limit our ability to calibrate a model. A simplified approach was therefore adopted in developing the vadose zone transport model. This approach accounts for the key processes by which contaminants are continuously partitioned among the vapor, dissolved, and adsorbed phases. The simulated leaching of contaminants through the vadose zone by this approach represents a conservative worst-case scenario for contaminant release to groundwater, ignoring the potential loss of contaminants from the system due to biodegradation, hydrolysis, and air diffusion.

The transport modeling was carried out by using the EPA's one-dimensional finite-difference vadose zone leaching model VLEACH, as implemented in WHI UnSat Suite (Waterloo Hydrogeologic, Inc., 2000). To evaluate the potential effect on groundwater of the existing carbon tetrachloride in soil, leaching of the contaminant through the vadose zone was simulated with the model for the areas near SB85.

The vadose zone was divided vertically into multiple cells to emulate the detailed contaminant distribution along the soil profile. On the basis of the identified soil contaminant distribution at SB85, the vertical profile of the model was constructed with 17 cells. The concentrations of carbon tetrachloride shown for SB85 in Figure 4.17 were initially assigned to the cells for the transport simulations.

The soil parameters for transport modeling were based on measurements (Appendix B, Table B.4) for a soil sample collected within each of the two contaminated intervals at SB85. Averaged values for bulk density, effective porosity, water content, and organic content measured in the contaminated soil samples were assigned uniformly to the model's soil profiles. Chemical parameters for carbon tetrachloride migration, including solubility, partition coefficient, and Henry's law constant, were derived from published values (Schwille 1988). Simulation of diffusion in free air was not attempted; an air diffusion coefficient of zero was assigned to the model to generate conservative estimates for contaminant leaching. All soil and chemical parameters used are listed in Table 4.2. The range of recharge rates through the vadose

zone near the former CCC/USDA facility, 10–35 in./yr, was based on the calibrated flow model developed previously (Argonne 2000).

#### 4.5.1.2 Simulation Results

The transport and fate of carbon tetrachloride in the vapor, dissolved, and adsorbed phases were simulated for 80 yr with a 1-yr time step. The model predicted the concentration of carbon tetrachloride in pore water (aqueous phase) at the base of the vadose zone, before leaching to groundwater, over time. Figure 4.18 shows the simulation results for recharge rates of 10 in./yr and 35 in./yr. The results indicate that the concentration of carbon tetrachloride in pore water about to enter groundwater will reach a maximum of 65–75 µg/L within 75 yr, depending on the rate of rainwater infiltration to groundwater. The potential effect on groundwater of a maximum carbon tetrachloride concentration of 65–75 µg/L will depend on mixing between the contaminated pore water and clean groundwater from upgradient locations. Further dilution of contaminant concentrations is expected through the mixing process discussed below.

TABLE 4.2 Soil and chemical parameters for the vadose zone transport model.

Parameter	Value for Source Area near SB85
Bulk density (g/cm <sup>3</sup> )	1.72
Water content	0.28
Effective porosity	0.35
Fraction organic content (%)	0.17
Water solubility (mg/L)	785 <sup>a</sup>
Partition coefficient (mL/g)	439 <sup>a</sup>
Henry's law constant (atm·m <sup>3</sup> /mol)	0.023 <sup>a</sup>

<sup>a</sup> Source of data: Schwille (1988).

#### 4.5.1.3 Mixing in the Aquifer below the Contaminated Soil and Its Potential Effect on Groundwater

Mixing is expected in the top layer of the aquifer when contaminated pore water from the vadose zone leaches to groundwater. The 2004 targeted investigation at Murdock found higher concentrations of carbon tetrachloride in the upper part of the aquifer near the source areas at the former CCC/USDA facility (Figure 4.6). Mixing appears to occur between the vertical flows of contaminated leach water from the overlying vadose zone and uncontaminated groundwater from the upgradient area. The leach water flow ( $Q_L$ ) can be approximated by the recharge rate ( $R_L$ ) (10 or 35 in./yr) and applied to the source areas ( $A_S$ ). The maximum potential source area around SB85 is about 30 ft by 70 ft, as indicated by the pattern of higher headspace carbon tetrachloride concentrations in near-surface soils (Figure 4.16).

The relationship

$$Q_L = A_S R_L , \quad (4.1)$$

with the parameters in Table 4.2, yields estimated leach water flow rates of 4.8 and 16.8 ft<sup>3</sup>/d, respectively, for  $R_L$  values of 10 and 35 in./yr.

The groundwater flow ( $Q_G$ ) below the source areas can be estimated from Darcy's law:

$$Q_G = A K dh/dl . \quad (4.2)$$

Here

$Q_G$  = groundwater flow, L<sup>3</sup>/T (volume/time in ft<sup>3</sup>/d)

$A$  = cross sectional area of flow, L<sup>2</sup> (area in ft<sup>2</sup>) = 490 ft<sup>2</sup> (the width of the source area [70 ft], × thickness [7 ft] of the upper part of the aquifer)

$K$  = hydraulic conductivity, L/T (length/time in ft/d) = 53 ft/d (Argonne 2000)

$dh/dl$  = hydraulic gradient = 0.0012

Calculations with Equation 4.2 and the parameters in Table 4.2 yielded a probable groundwater flow rate of 31.2 ft<sup>3</sup>/d below the source area around SB85.

The concentration of carbon tetrachloride in groundwater after mixing can be estimated by the following equation:

$$C_{mix} = (C_G Q_G + C_L Q_L) / (Q_G + Q_L) . \quad (4.3)$$

Here

$C_{mix}$  = contaminant concentration after mixing, M/L<sup>3</sup> (mass/volume in µg/L)

$C_G$  = contaminant concentration in the upgradient groundwater before mixing, M/L<sup>3</sup> (mass/volume in µg/L) = 0 µg/L

$C_L$  = contaminant concentration in leach water before mixing, M/L<sup>3</sup> (mass/volume in µg/L); maximum concentrations = 65–75 µg/L, derived from the vertical contaminant transport model discussed in Section 4.5.1.2

$Q_L$  = leach water flow, L<sup>3</sup>/T (volume/time in ft<sup>3</sup>/d) = 4.8–16.8 ft<sup>3</sup>/d

The estimated maximum concentration of carbon tetrachloride is 10–23 µg/L, depending on the infiltration rate (10 or 35 in./yr). Figure 4.19 shows the predicted concentrations of carbon tetrachloride in groundwater over time.

The simulation results for the SB85 location suggest that the identified remaining contamination in vadose zone may provide a continuing source to the groundwater plume. However, the groundwater contamination is expected to be at a very low level (less than 23 µg/L) within the simulated 80 yr. With a continuing source at this level, the carbon tetrachloride plume in the aquifer at Murdock is expected to decrease in concentration continuously, as we have observed from 1991 to the present.

#### 4.5.2 Analyze Indoor Air Potentially Affected by Vapor Intrusion at Residences Built on the Former CCC/USDA Facility

Indoor air was sampled at four residences constructed on the former CCC/USDA facility. Access to two additional residences on the former facility was denied by the owners. A background ambient air sample was collected outside one of the residences. The results are in Figure 4.20 and in Table G.1, Appendix G.

No carbon tetrachloride was detected in air samples from basement of the Wager residence and the crawl space below one side of the Backemeyer duplex, or in the background air sample collected outside the Wager residence. A low concentration of chloroform ( $3 \mu\text{g}/\text{m}^3$ ) was found in the air sample collected in the basement of the Wager residence.

The air sample collected in the basement of the McHugh residence contained carbon tetrachloride at  $4.0 \mu\text{g}/\text{m}^3$ . No chloroform was detected in this air sample. This basement is partially finished and partially carpeted. Parts of the basement are used for craft projects and for storage. The sampler was placed on the floor in an unfinished area of the basement, near a gas water heater, a gas furnace (not in use in the summer), and a plastic Christmas tree.

The sample from the Graham duplex was collected in an unused, 4-ft-deep crawl space between the two residential units. The bottom of the crawl space was lined with black plastic. This sample contained carbon tetrachloride at  $3.6 \mu\text{g}/\text{m}^3$  but no chloroform above the quantitation limit.

In 1987 and 1988, an EPA contractor, Black and Veatch, collected multiple indoor air samples in the basement and the living room/family room at the McHugh residence. Carbon tetrachloride was found in all of these samples at  $1\text{--}34 \mu\text{g}/\text{m}^3$  (Black & Veatch 1988). These results indicated higher concentrations of carbon tetrachloride ( $9\text{--}34 \mu\text{g}/\text{m}^3$ ) in the basement, possibly because of decreased air circulation compared to the living area. The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated these 1988 results and concluded that carbon tetrachloride and chloroform concentrations detected in household air in Murdock homes do *not* appear to (1) be different from levels found in other homes across the country or (2) present an imminent public health threat (ATSDR 1988). The maximum concentration of carbon tetrachloride found in the basement air at the McHugh residence in the 2004 targeted investigation ( $4 \mu\text{g}/\text{m}^3$ ) is far below the 1988 results.

The U.S. EPA has not established a reference concentration (an estimate that is likely to be without adverse health effect) for either carbon tetrachloride or chloroform (EPA 2004a,b). The California EPA has established chronic reference exposure levels via inhalation of 40  $\mu\text{g}/\text{m}^3$  for carbon tetrachloride and 300  $\mu\text{g}/\text{m}^3$  for chloroform (OEHHA 2004a,b), representing concentrations at and below which adverse health effects are unlikely. The maximum concentrations of carbon tetrachloride (4  $\mu\text{g}/\text{m}^3$ ) and chloroform (3  $\mu\text{g}/\text{m}^3$ ) detected in the 2004 indoor air sampling at Murdock are much lower than these reference exposure levels, indicating that no unacceptable human health risk is associated with exposure to the basement air in these residences.

The EPA has classified both carbon tetrachloride and chloroform as probable human carcinogens. Reports have noted the occurrence of liver cancer in workers exposed to high levels of carbon tetrachloride via inhalation; however, the data are insufficient to establish a cause-and-effect relationship. No information is available on cancer incidence in humans or animals after inhalation exposure to chloroform (ATSDR 1997).

The EPA uses mathematical models, based on human and animal studies, to estimate the probability that a person will develop cancer from continuously breathing air containing a specified concentration of a chemical. For carbon tetrachloride, the EPA has calculated an inhalation unit risk of  $1.5 \times 10^{-5} \text{ m}^3/\mu\text{g}$  (EPA 2004a). This unit risk is an estimate of the excess cancer risk resulting from a lifetime (70 yr) of continuous exposure to a contaminant at a concentration of 1  $\mu\text{g}/\text{m}^3$ . Long-term exposure to the maximum concentration of 4  $\mu\text{g}/\text{m}^3$  detected at Murdock in 2004 might result in the low to very low increased lifetime cancer risk defined by the EPA as 1 additional cancer in a population of 10,000–100,000 people exposed.

For chloroform, the EPA has not derived an oral carcinogenic potency slope or an inhalation unit risk (EPA 2004b). The EPA has determined that although chloroform is likely to be carcinogenic to humans by all routes of exposure under high-exposure conditions, chloroform is not likely to cause cancer in humans by any route of exposure under exposure conditions that do not cause cell death and regrowth.

#### **4.6 Evaluate the Potential Suitability of Phytoremediation for This Site**

The EPA Region VII office recently issued the document *EPA Approved 2004 Nebraska Section 303(d) List of Impaired Waters Requiring TMDL (Total Maximum Daily Loads)*. This list

(NDEQ 2004) includes Pawnee Creek (LP1-11600), indicating that carbon tetrachloride impairs aquatic life in the creek.

One of the primary technical objectives of Argonne's 2004 targeted investigation was to characterize the present distribution of carbon tetrachloride contamination in the groundwater and surface water in the area north of Waverly Road. The targeted investigation results indicate that the subsurface stratigraphic sequence and the contaminant distribution in the aquifer unit at Murdock make phytoremediation suitable for consideration as a remedial option for the carbon tetrachloride contamination reaching Pawnee Creek.

The primary objectives to be achieved through use of phytoremediation at Murdock are as follows:

- Hydraulically control the carbon tetrachloride present in the shallow groundwater north of Waverly Road and prevent its discharge into the tributary of Pawnee Creek.
- Promote removal of carbon tetrachloride from the contaminated groundwater aquifer through uptake by plants, with further biological degradation taking place in the rhizosphere.
- Provide an additional polishing stage for remaining carbon tetrachloride by establishing a downstream wetlands with aquatic plants that will assure complete degradation of any carbon tetrachloride in the surface waters of Pawnee Creek.

The stratigraphic sequence north of Waverly Road thins from 30 ft to essentially zero, with a corresponding reduction in the depth to the top of groundwater (Figure 4.21). The areal distribution of carbon tetrachloride, as defined through analysis of subsurface groundwater samples collected with the cone penetrometer unit (SB74–SB81), water samples recovered from the outflow areas of the tile drain system (TD1–TD6), and surface water samples (SWP01–SWP06, SWP08–SWP16 and SWSEEP), is also depicted in Figure 4.21, along with the area tentatively believed to be suitable for planting.

Cross section B–B (Figure 4.22) further illustrates the progressive thinning of the aquifer unit northwest of Waverly Road due to erosional downcutting of the sand aquifer unit and deposition of the overlying clay and silt sequence, together with the vertical and lateral distributions of carbon tetrachloride in the aquifer unit. Also shown in relation to the hydrostratigraphy and the contaminant distribution are the areas proposed for phytoremediation and subsequent treatment in constructed wetlands. Ideally, planting would occur in the area with the highest contaminant concentration and the shallowest depth to groundwater.

The depth to groundwater is a critical factor in the success of a plant-based remedial option, as the root systems must reach the capillary fringe to take the contaminant-bearing water into their systems for subsequent transpiration and biological degradation. This process is illustrated schematically in Figure 4.23.

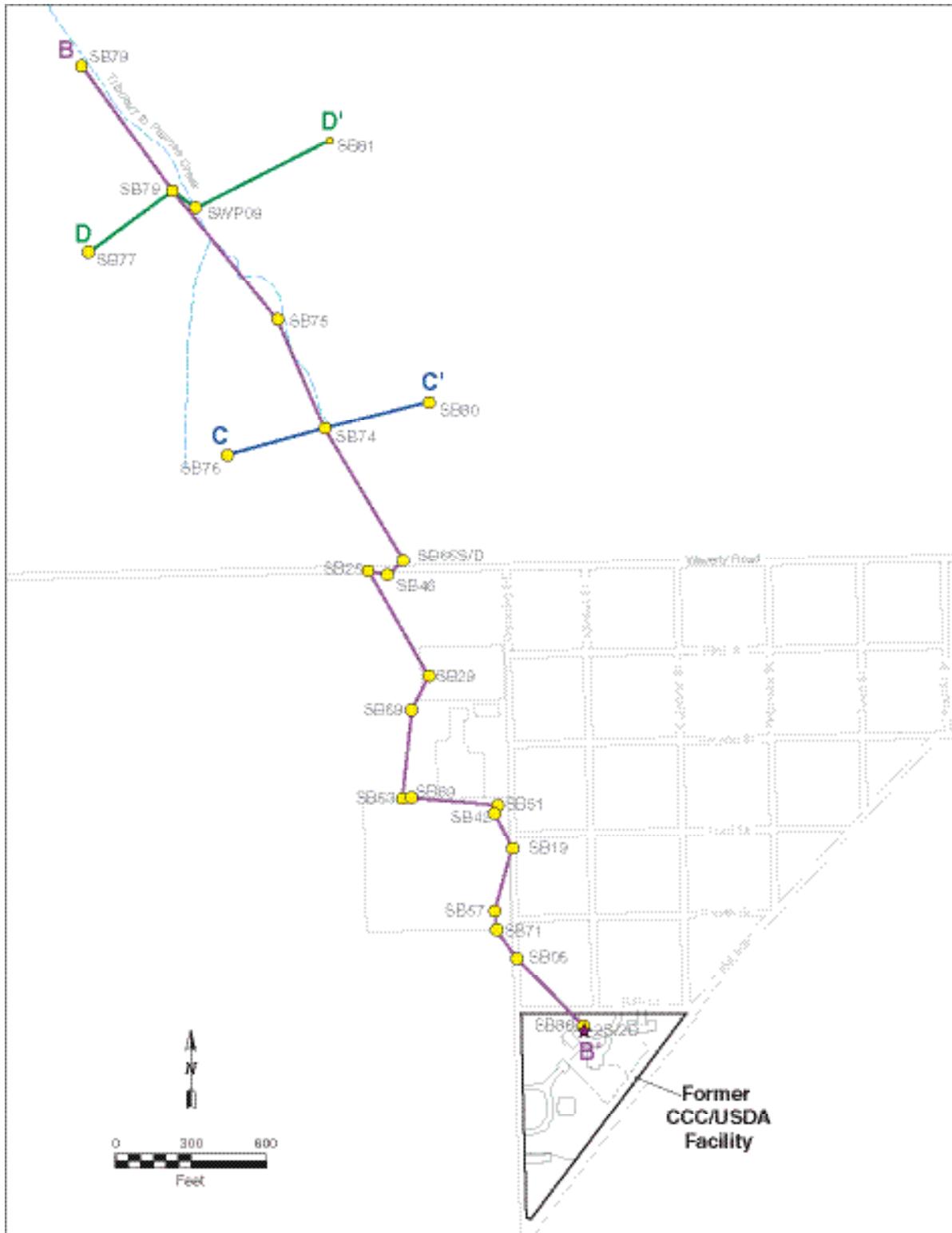


FIGURE 4.1 Location of interpretive hydrogeologic cross sections B-B , C-C , and D-D .

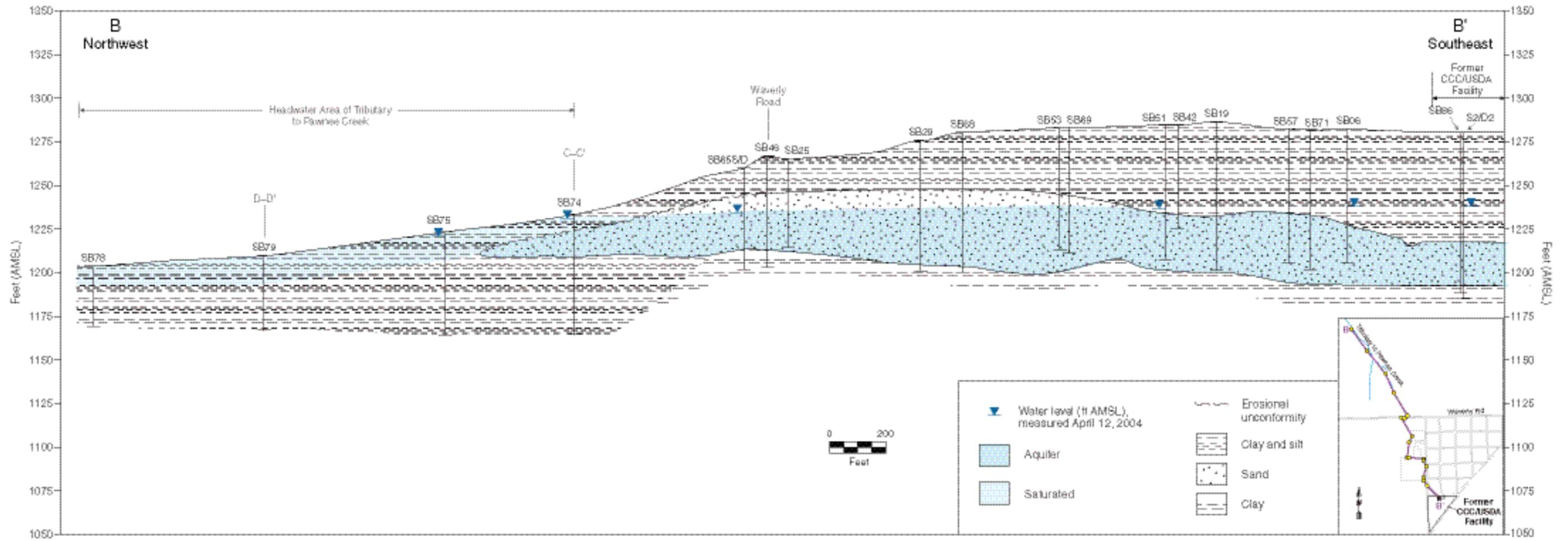


FIGURE 4.2 Interpretive northwest-to-southeast hydrogeologic cross section B-B (vertically exaggerated).

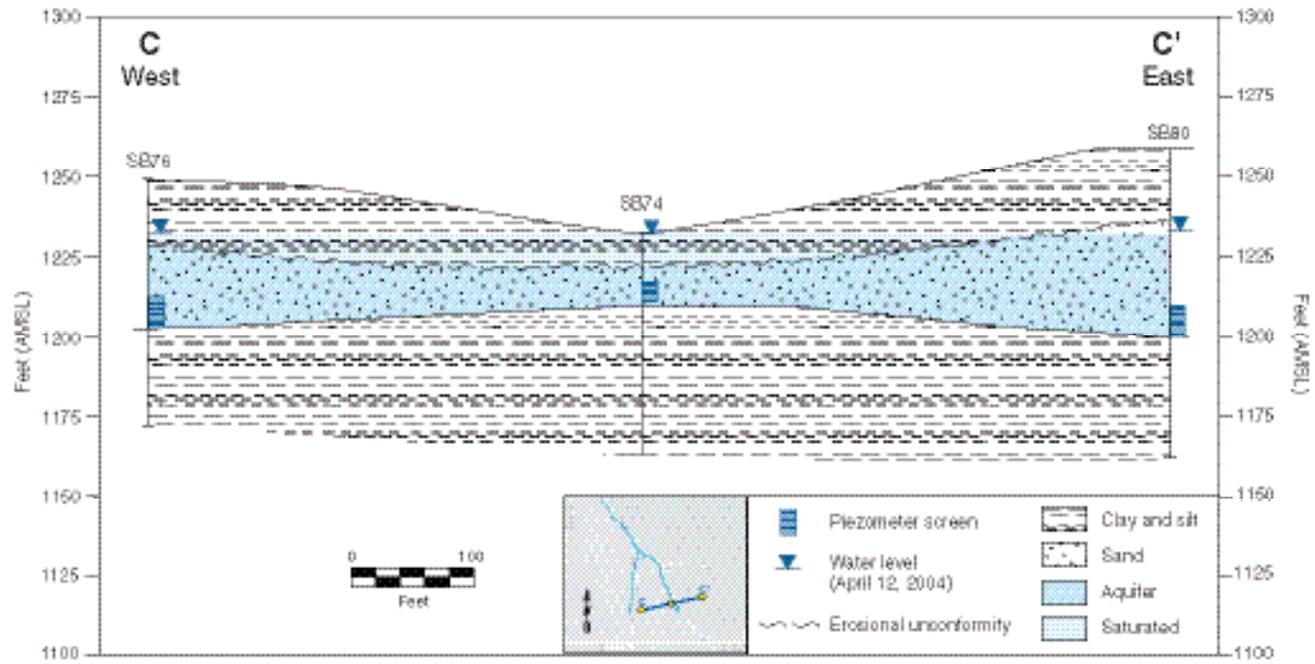


FIGURE 4.3 Interpretive west-to-east hydrogeologic cross section C-C (vertically exaggerated).

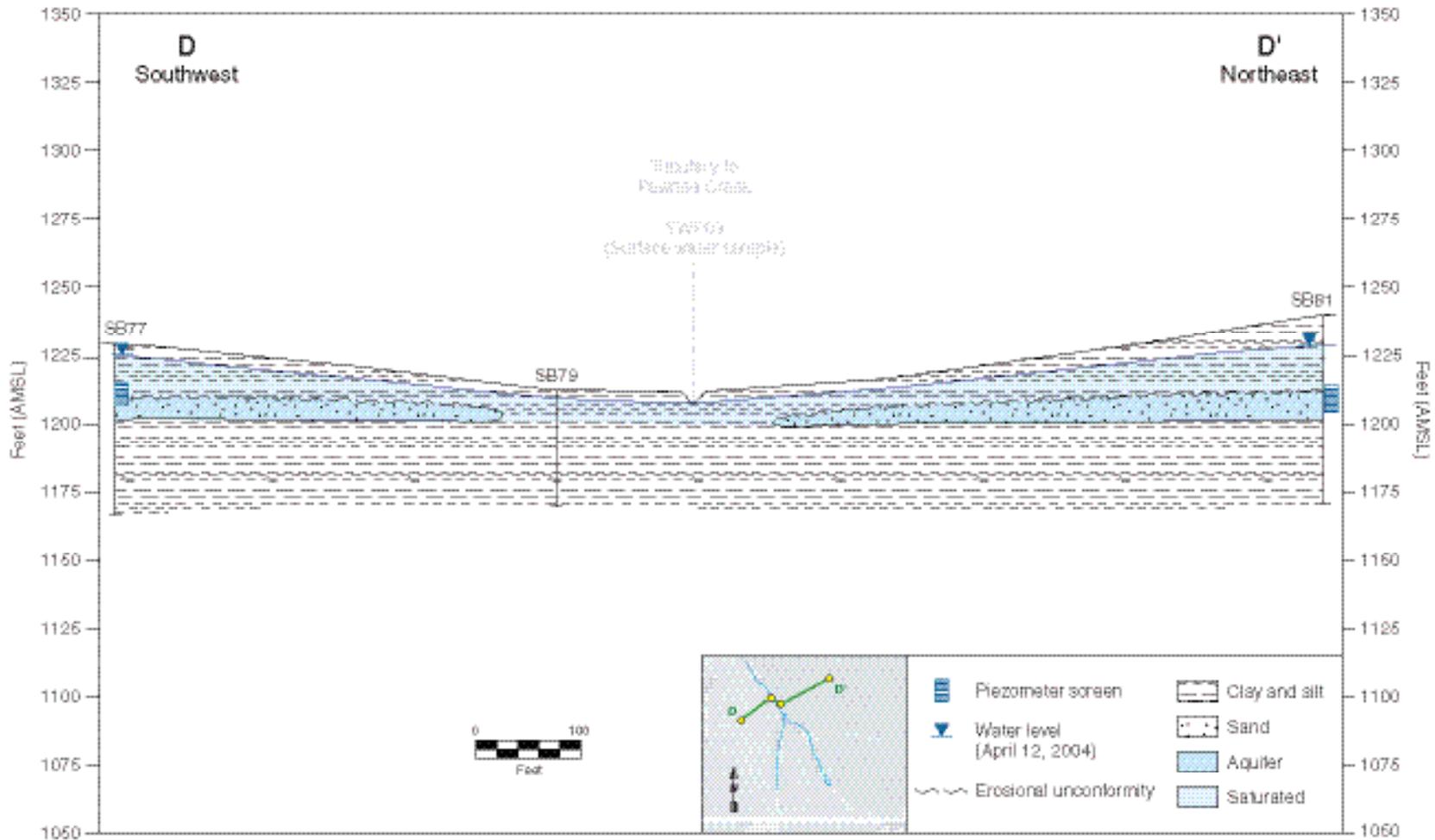


FIGURE 4.4 Interpretive southwest-to-northeast hydrogeologic cross section D-D (vertically exaggerated).

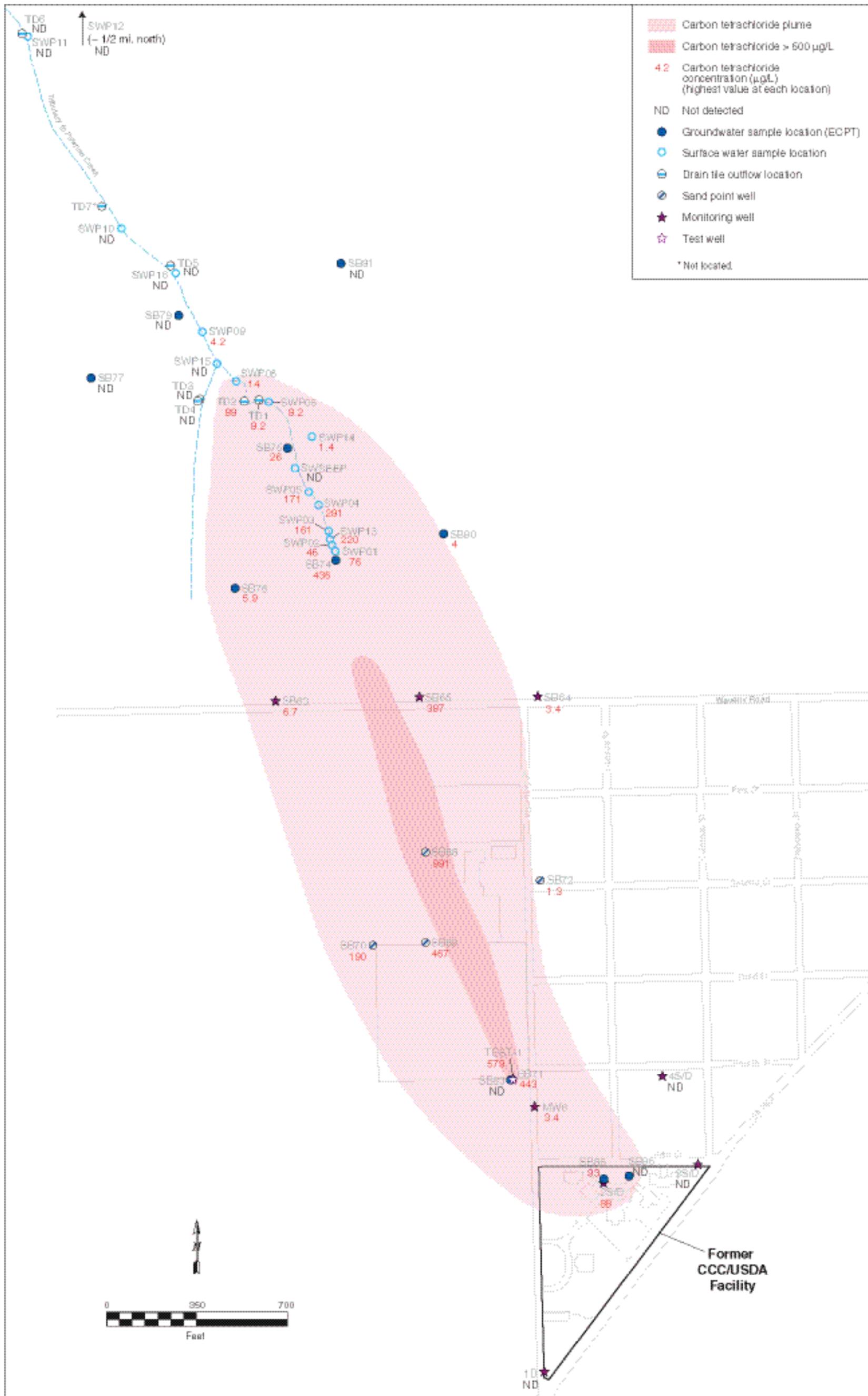


FIGURE 4.5 Maximum carbon tetrachloride concentrations in groundwater and surface water at Murdock in March–April 2004. Shading indicates interpreted groundwater plume.

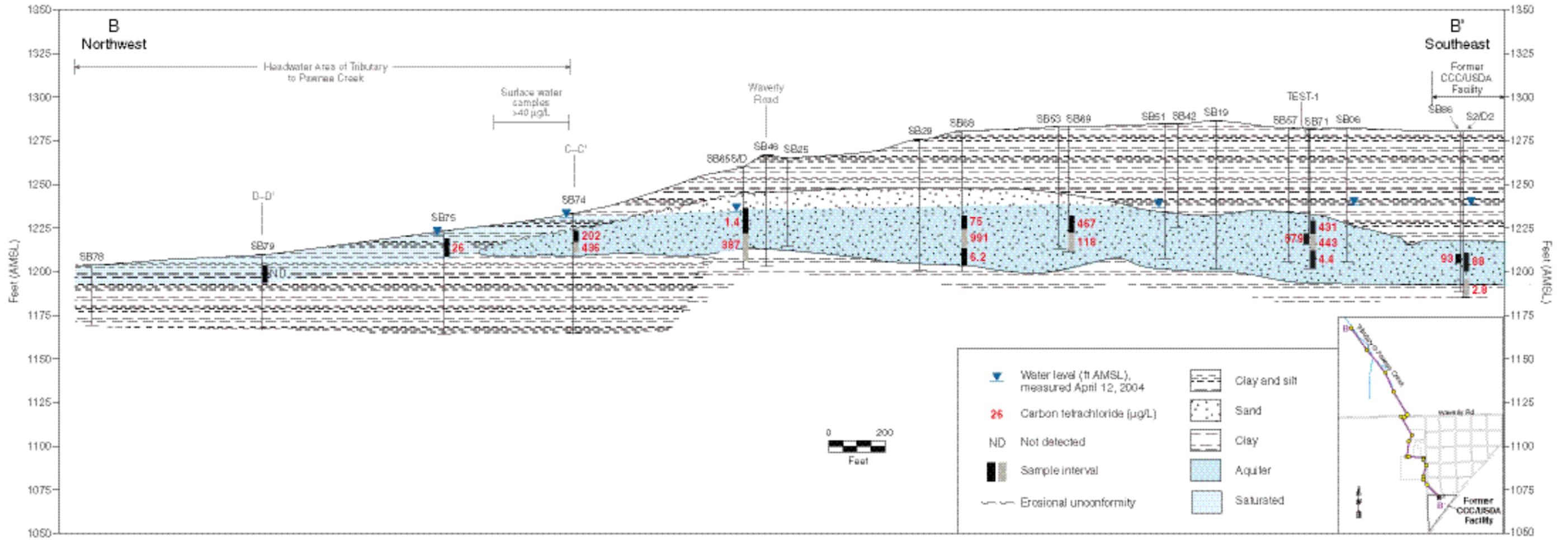


FIGURE 4.6 Distribution of carbon tetrachloride in groundwater in the aquifer at Murdock during targeted investigation sampling in 2004, displayed on northwest-to-southeast cross section B-B .

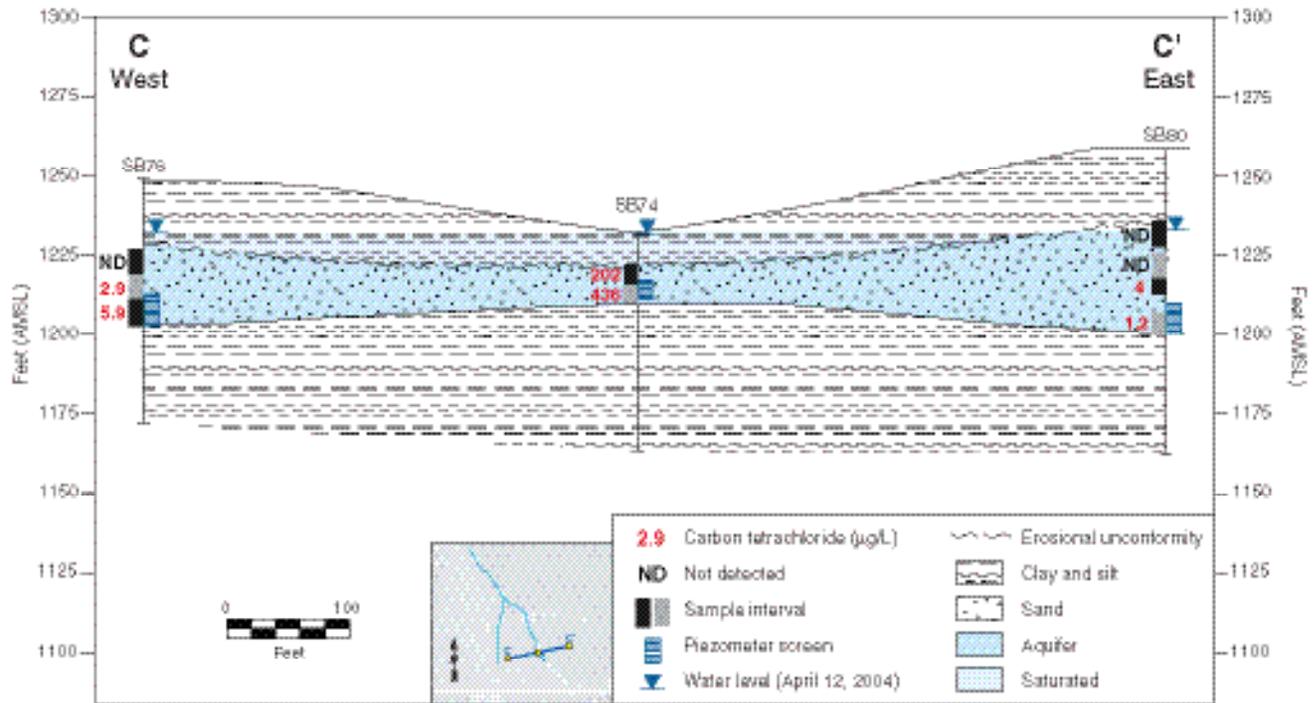


FIGURE 4.7 Distribution of carbon tetrachloride in groundwater in the aquifer at Murdock during targeted investigation sampling in 2004, displayed on west-to-east cross section C-C .

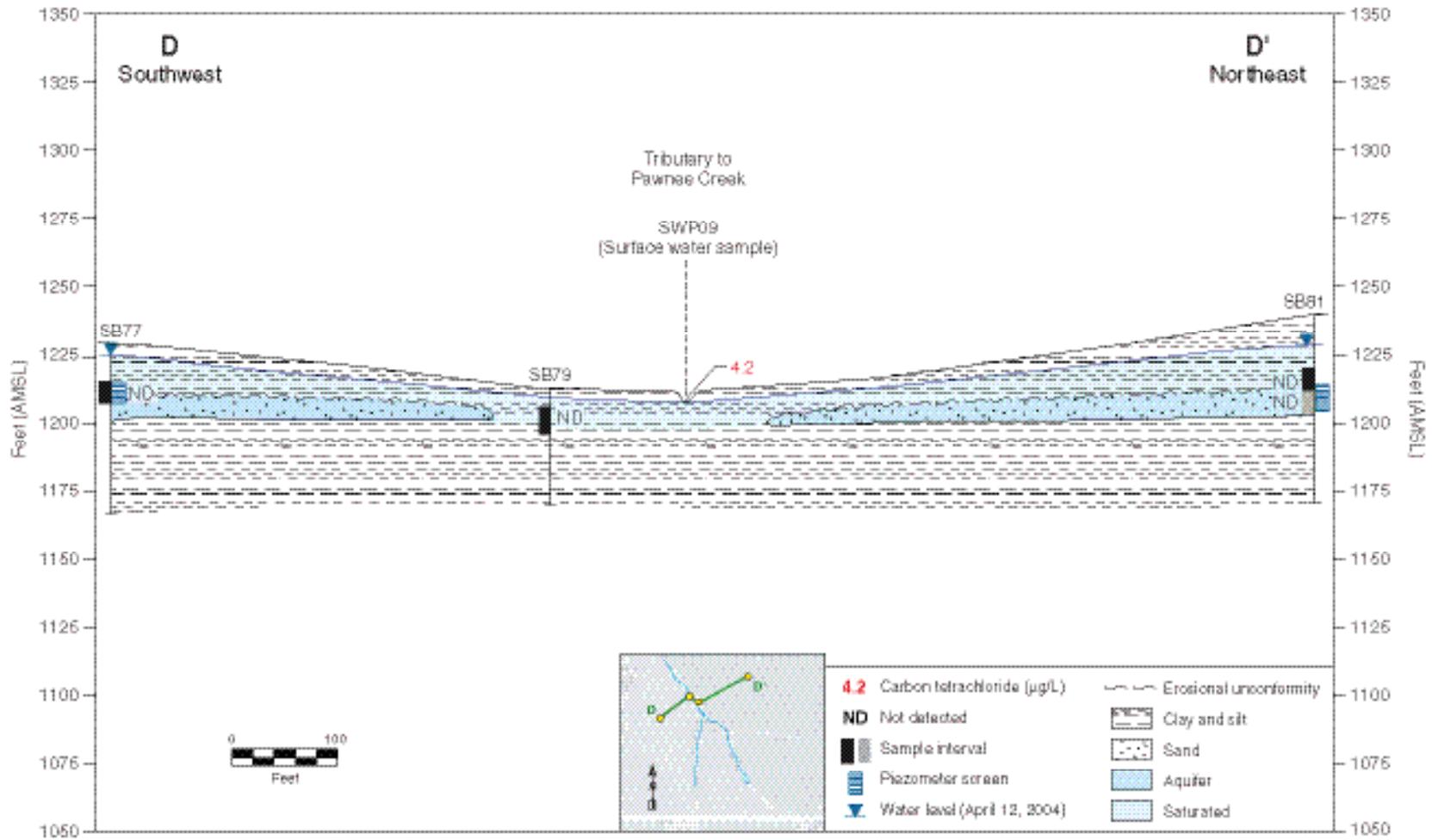


FIGURE 4.8 Distribution of carbon tetrachloride in groundwater in the aquifer at Murdock during targeted investigation sampling in 2004, displayed on southwest-to-northeast cross section D-D'.



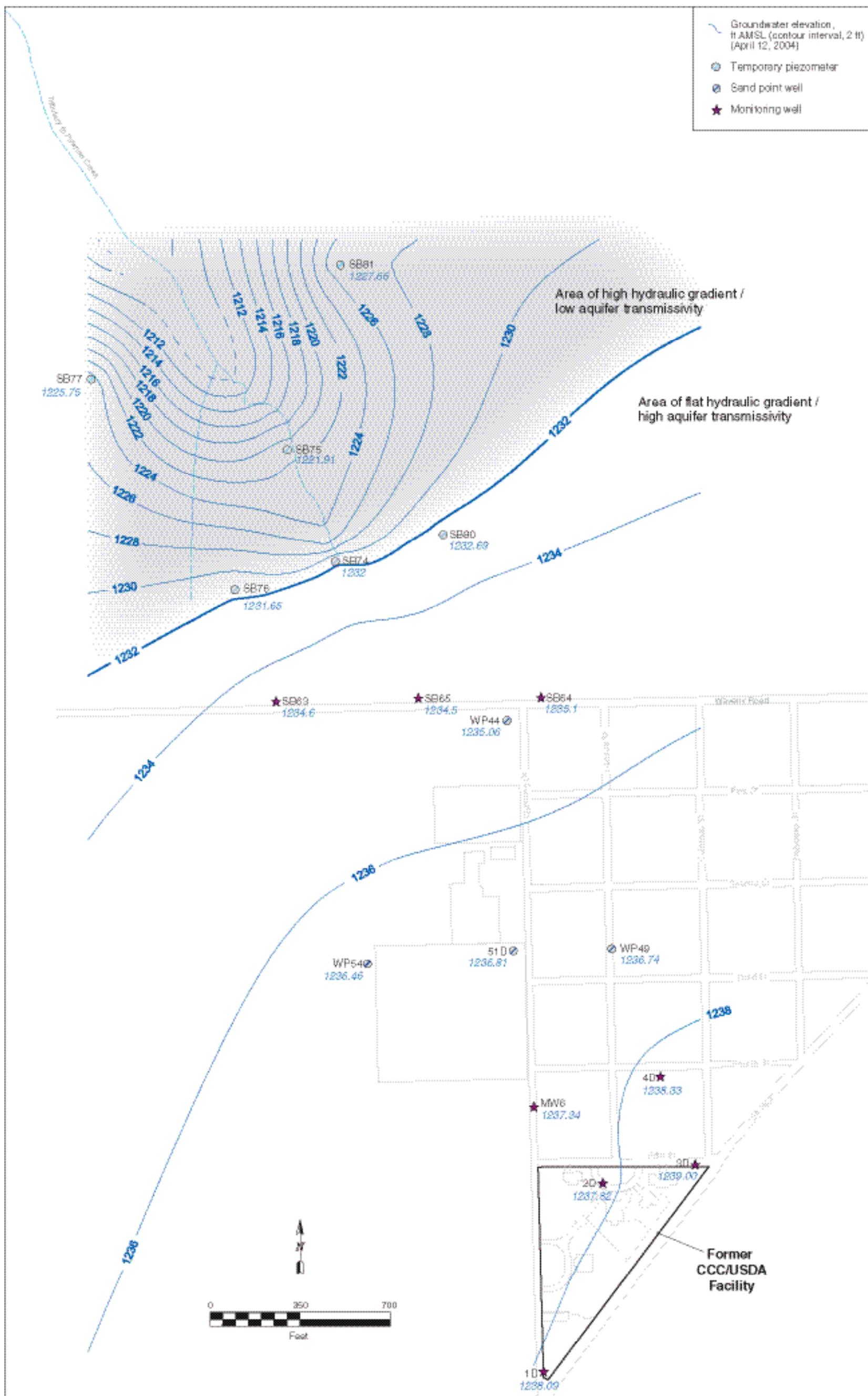


FIGURE 4.10 Potentiometric surface for the aquifer at Murdock on April 12, 2004.

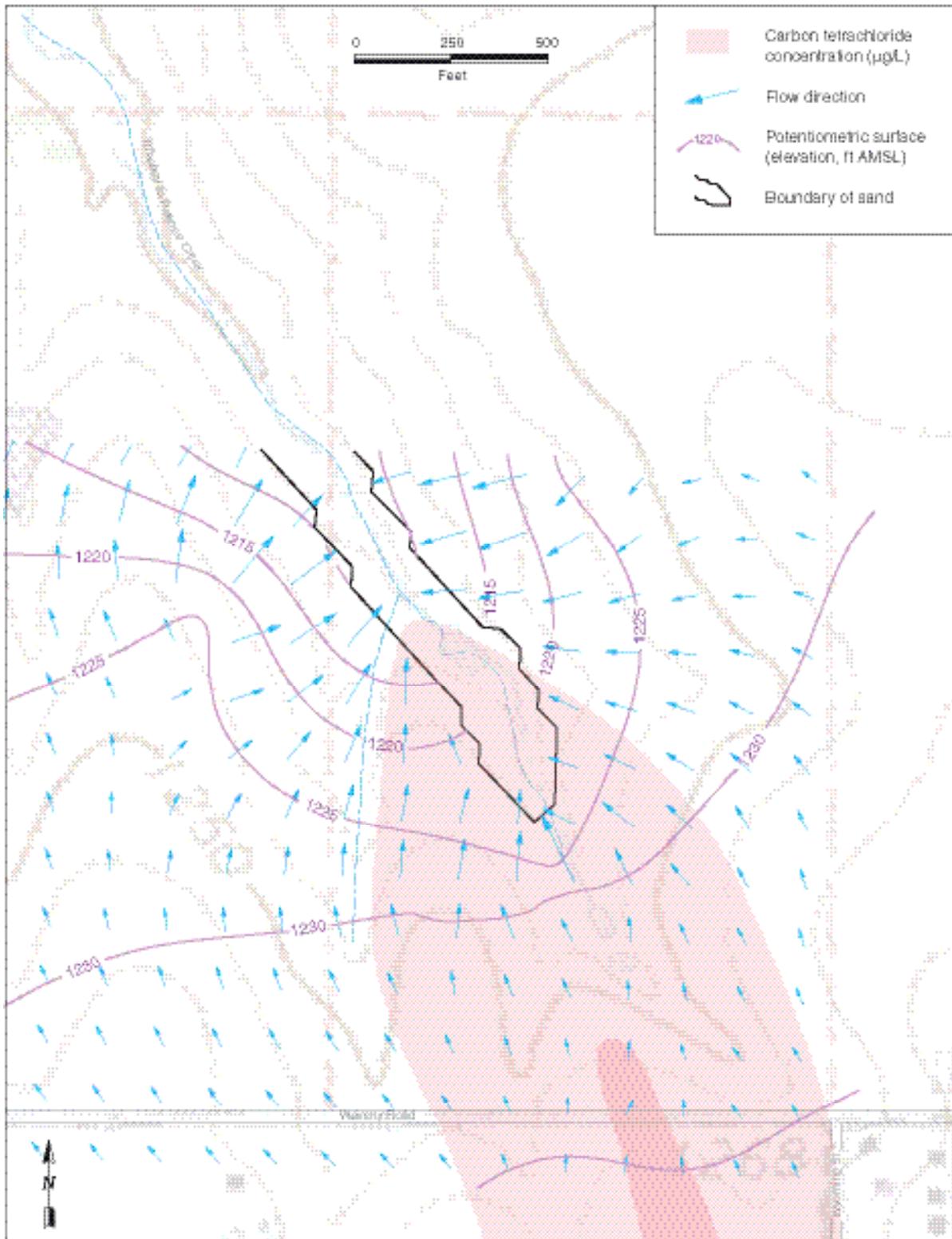


FIGURE 4.11 Potentiometric surface, groundwater flow, and identified carbon tetrachloride plume in the headwaters area of the tributary creek.

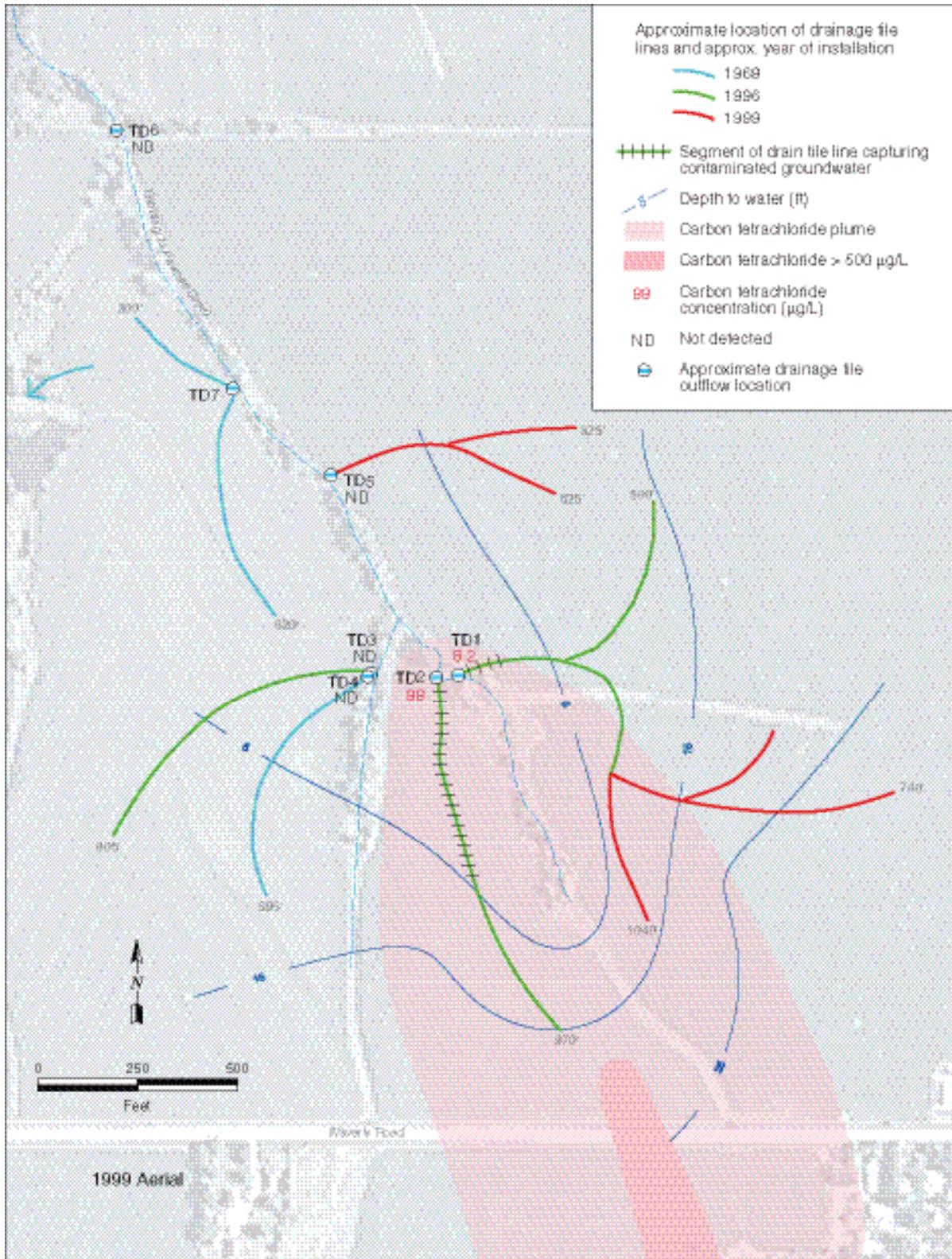


FIGURE 4.12 Estimated locations of drain tile lines, superimposed on contours of depth to groundwater and the identified carbon tetrachloride plume in the headwaters area of the tributary creek.

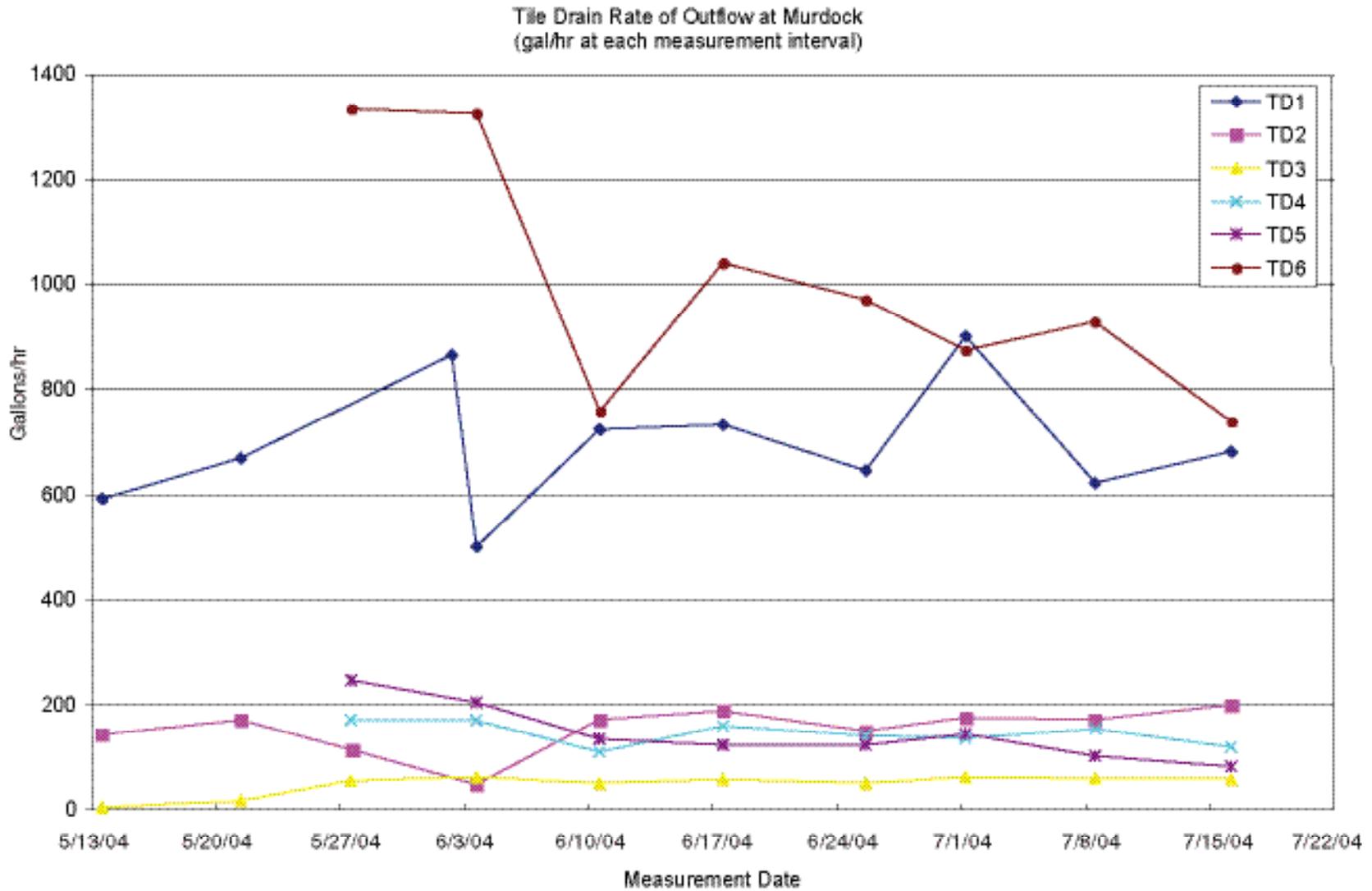


FIGURE 4.13 Discharge rates measured at active drain tiles in June–July 2004.

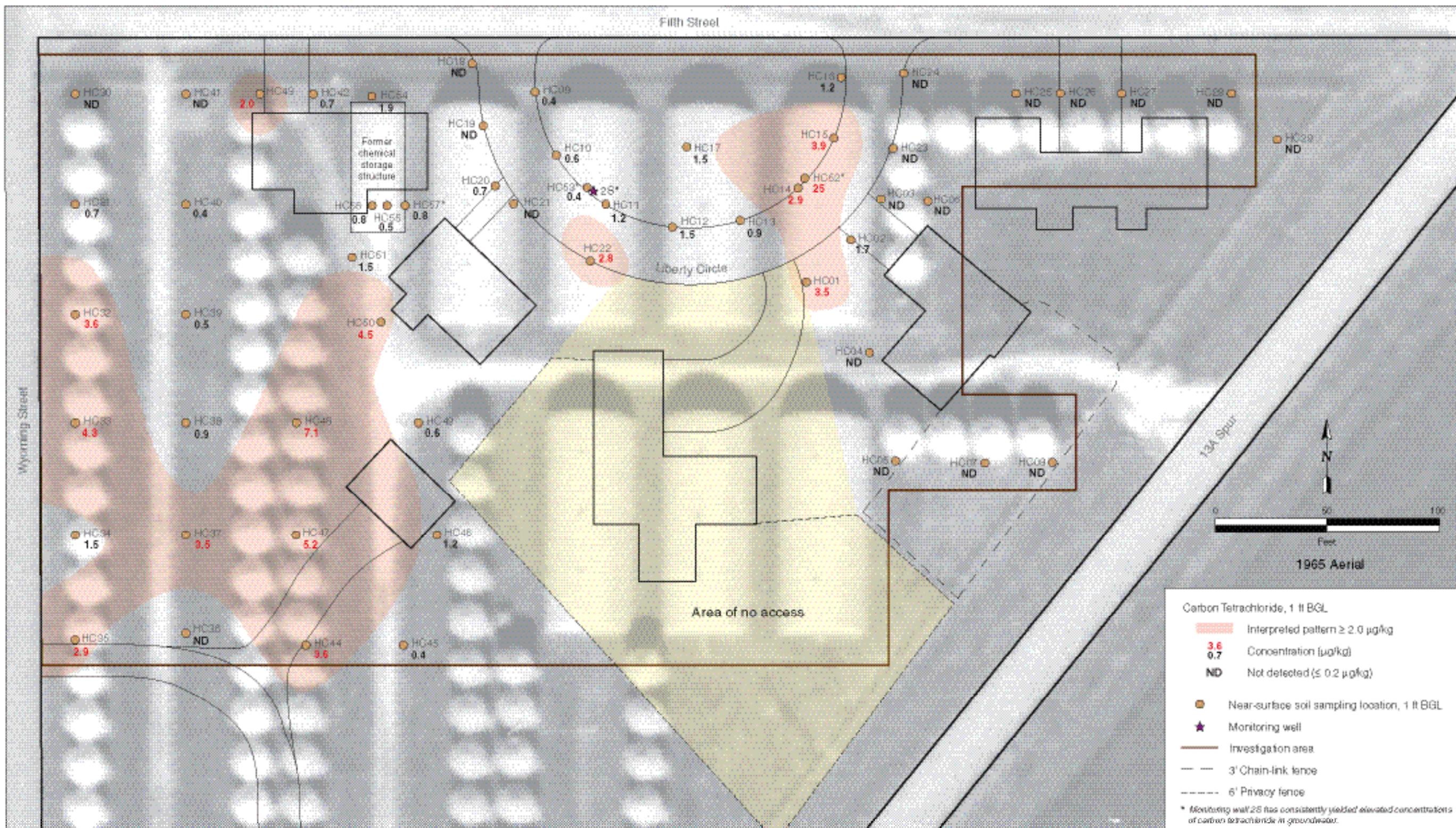


FIGURE 4.14 Interpreted pattern of higher carbon tetrachloride concentrations (by headspace analysis) in soil samples at approximately 1 ft BGL, superimposed on an aerial photograph showing the locations of former grain storage structures at the former CCC/USDA facility and outlines of current structures, roads, and driveways. Source of photograph: USDA 1965.

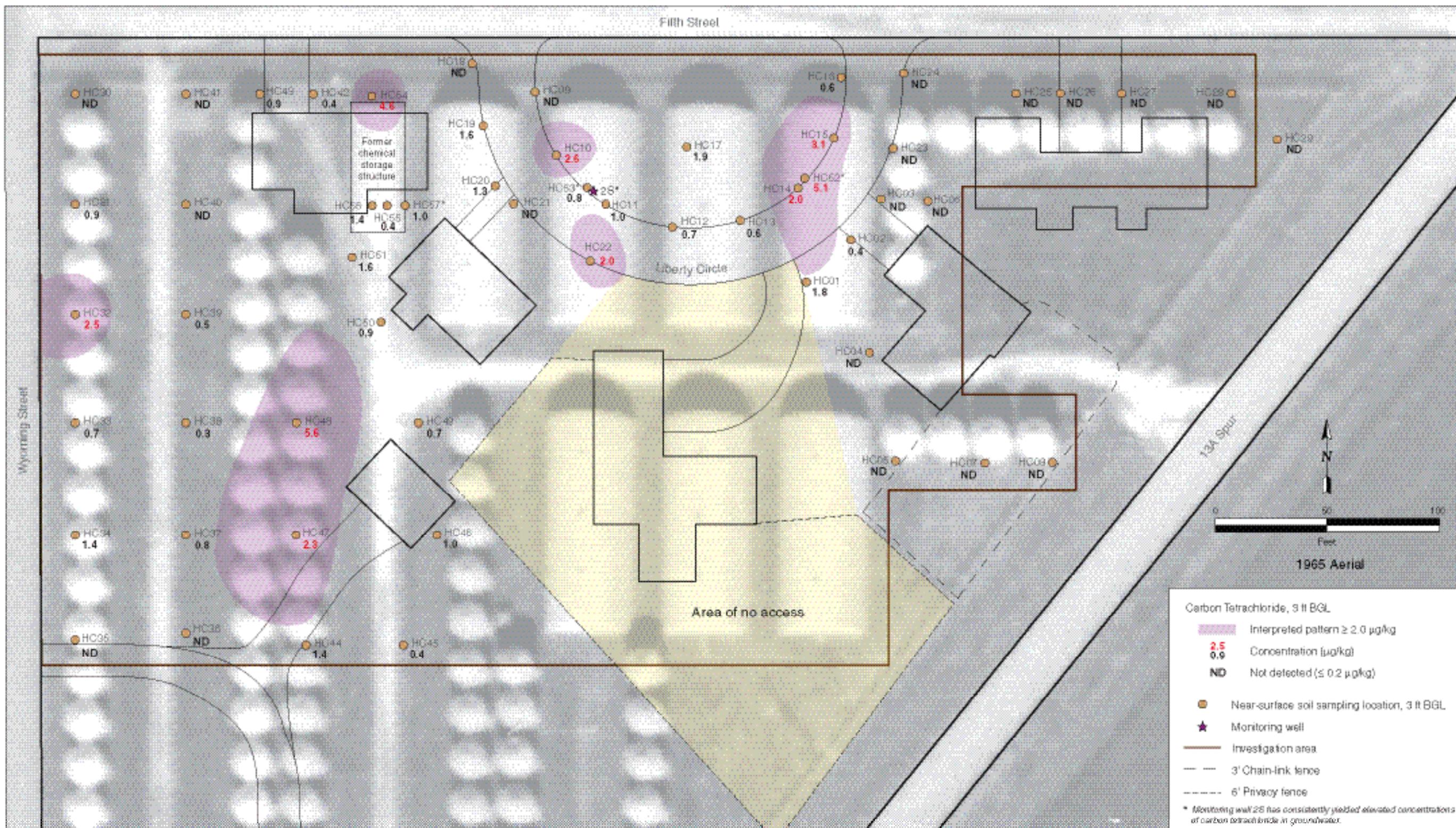


FIGURE 4.15 Interpreted pattern of higher carbon tetrachloride concentrations (by headspace analysis) in soil samples at approximately 3 ft BGL, superimposed on an aerial photograph depicting the locations of grain storage structures at the former CCC/USDA facility and outlines of current structures, roads, and driveways. Source of photograph: USDA 1965.

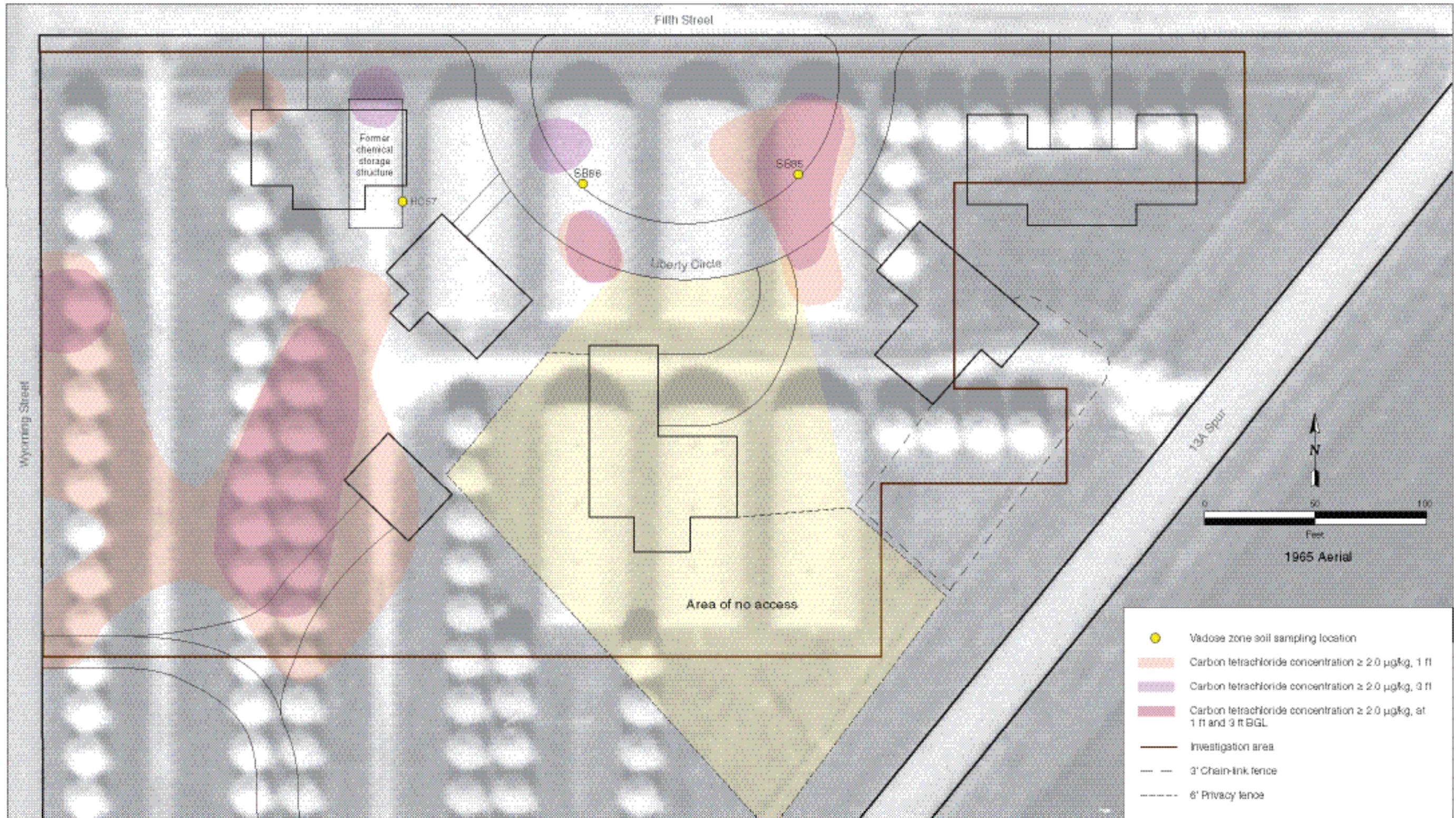


FIGURE 4.16 Locations of vertical-profile soil sampling in the vadose zone at SB85, SB86, and HC57, in relation to the interpreted composite pattern of higher headspace carbon tetrachloride concentrations in combined shallow and deeper near-surface soils. Source of photograph: USDA 1965.

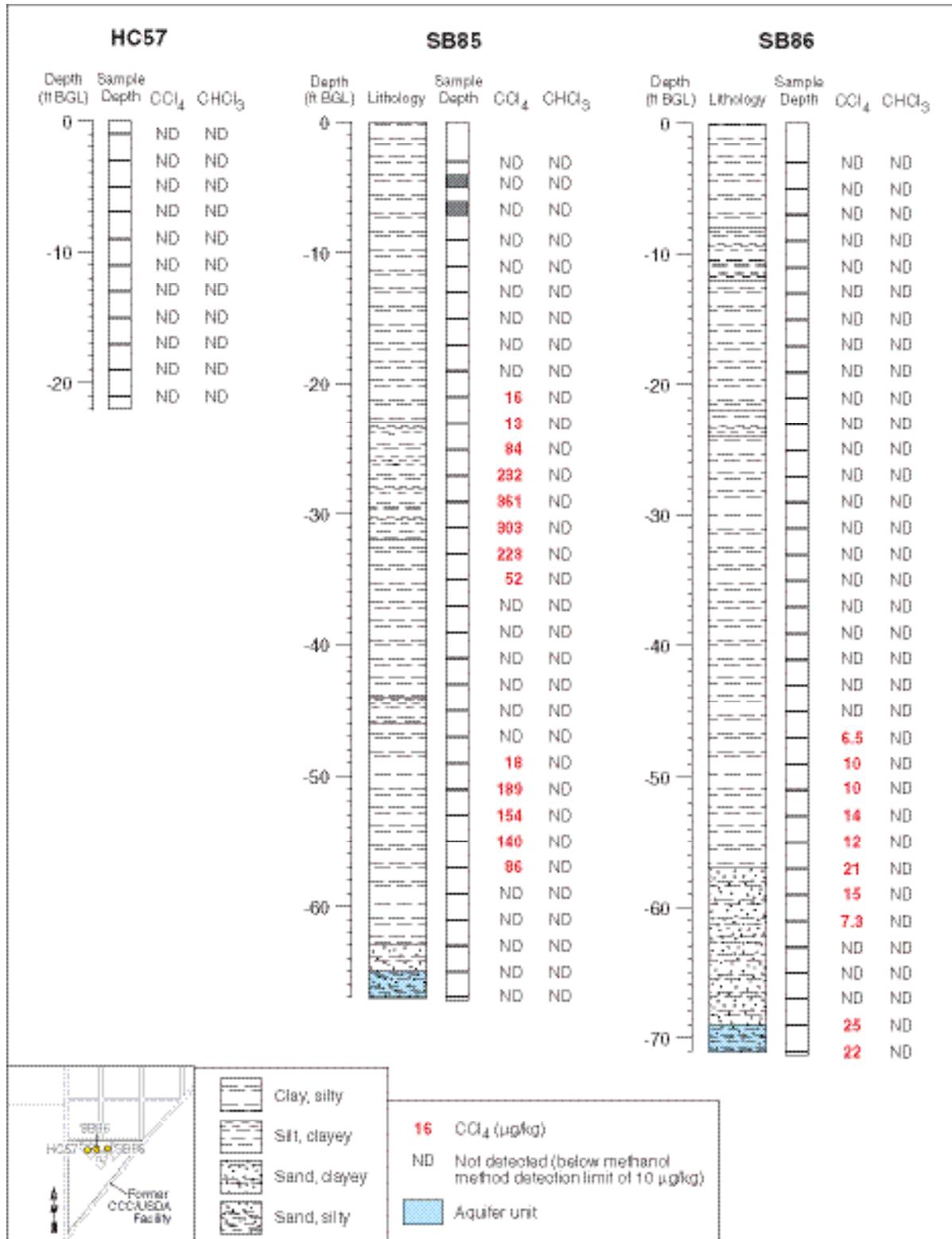


FIGURE 4.17 Results of purge-and-trap analyses for carbon tetrachloride and chloroform on subsurface soil samples from locations SB85, SB86, and HC57 at the former CCC/USDA facility, displayed by depth, with lithologic logs for SB85 and SB86.

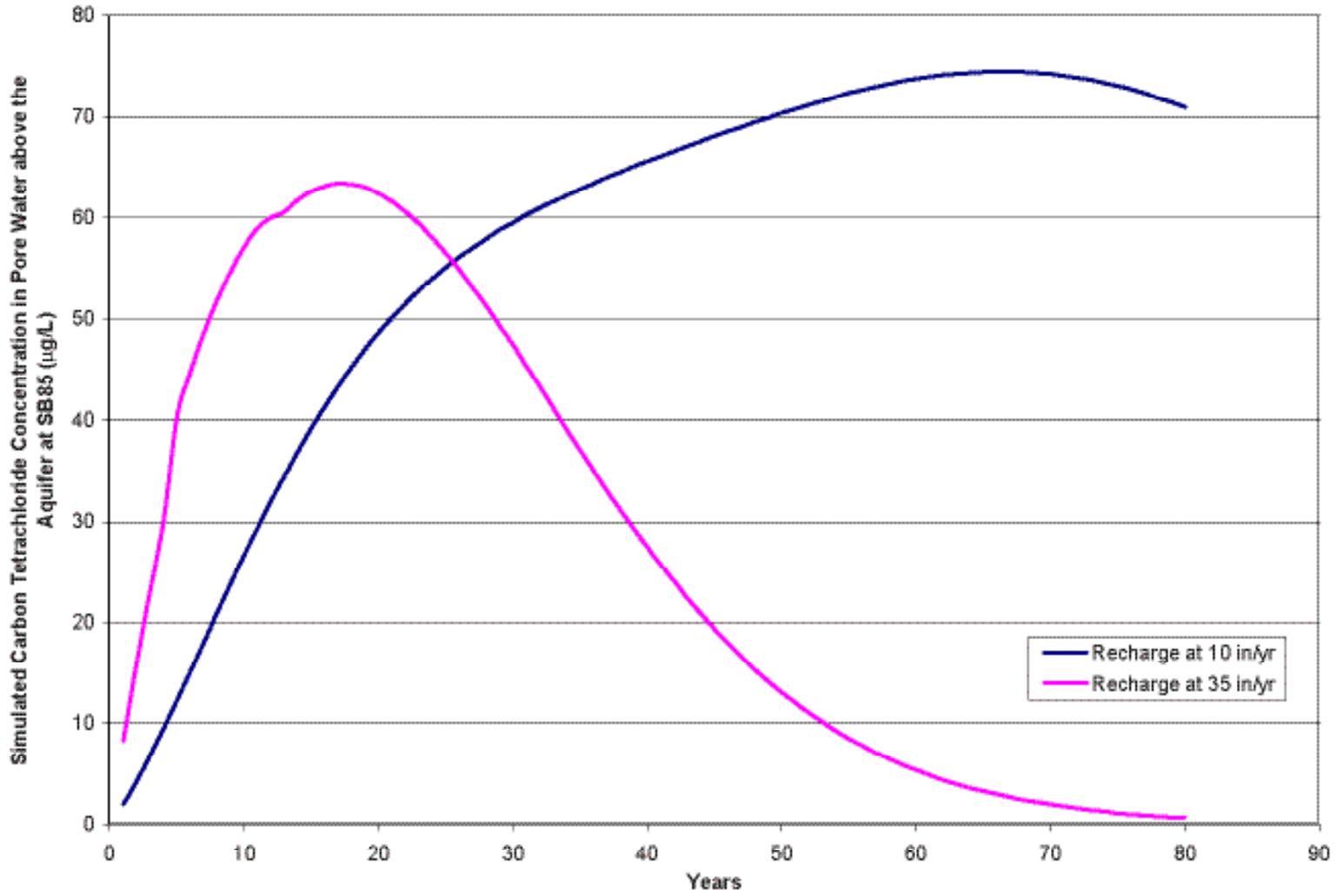


FIGURE 4.18 Simulated concentrations over 80 yr for carbon tetrachloride in pore water above the aquifer (65 ft BGL) at SB85, resulting from vertical migration of carbon tetrachloride presently remaining in the vadose zone.

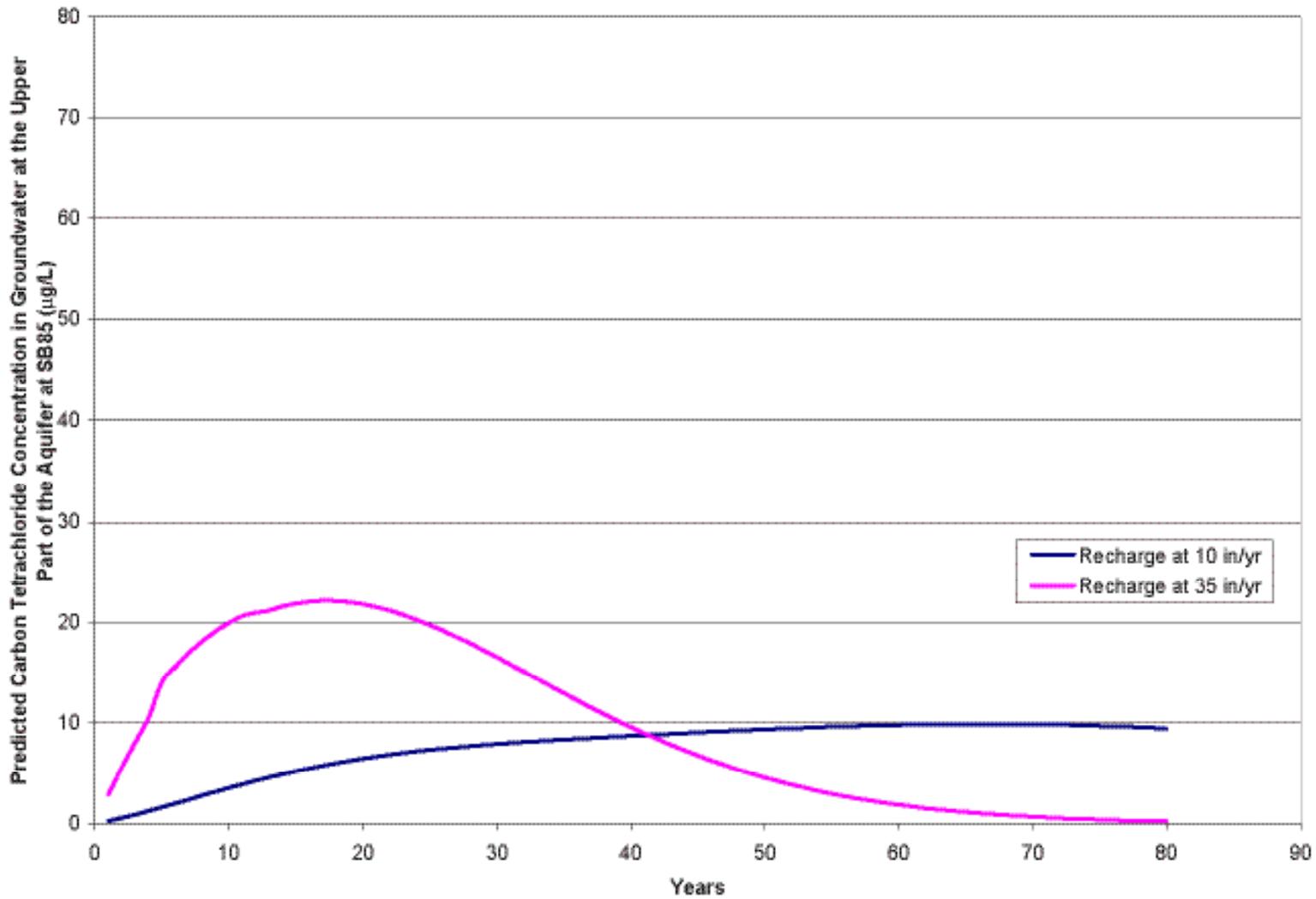


FIGURE 4.19 Predicted concentrations over 80 yr for carbon tetrachloride in groundwater in the upper part of the aquifer at SB85, resulting from vertical migration of carbon tetrachloride presently remaining in the vadose zone.

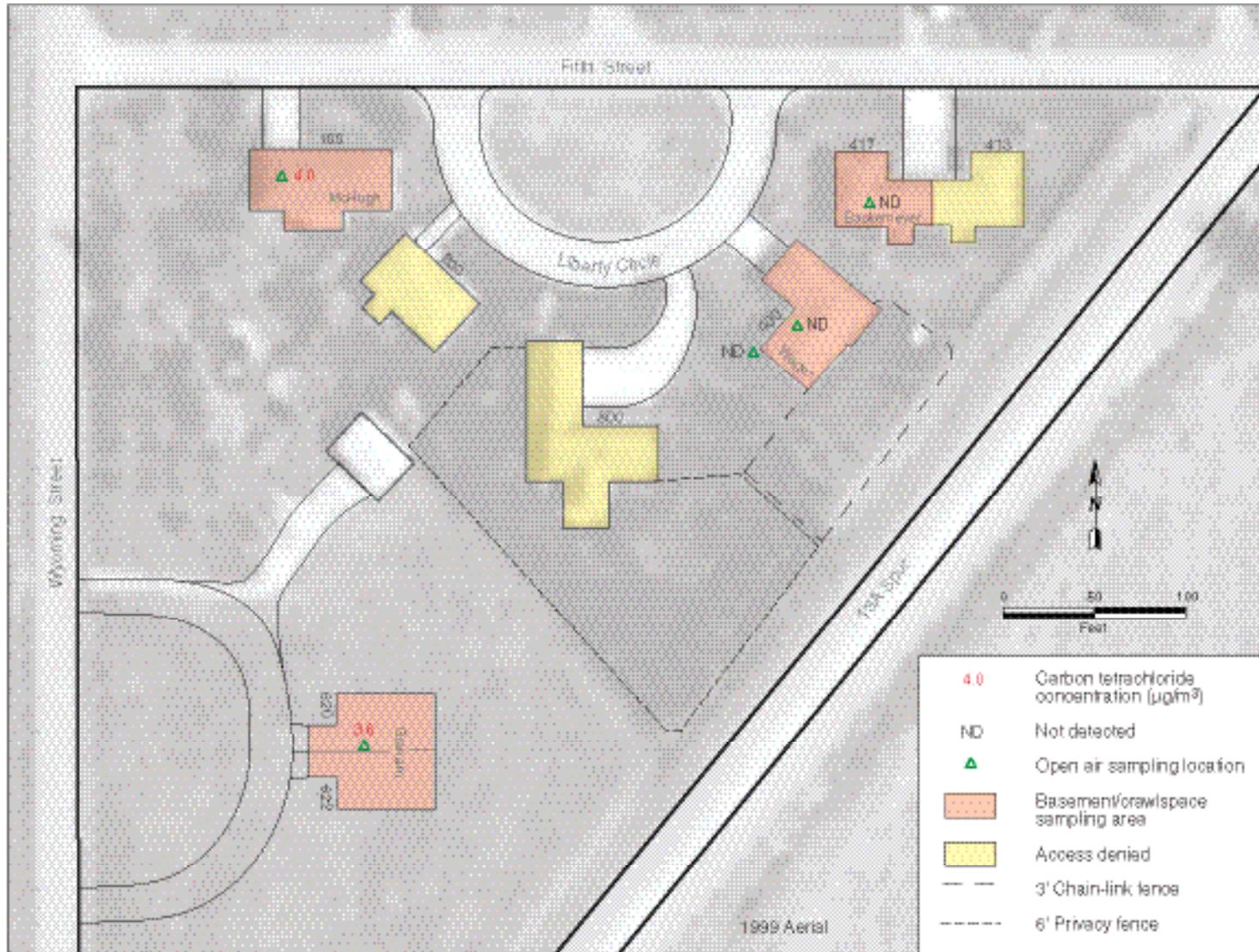


FIGURE 4.20 Carbon tetrachloride concentrations in air samples collected in August 2004 in residences built on the former Murdock CCC/USDA facility.

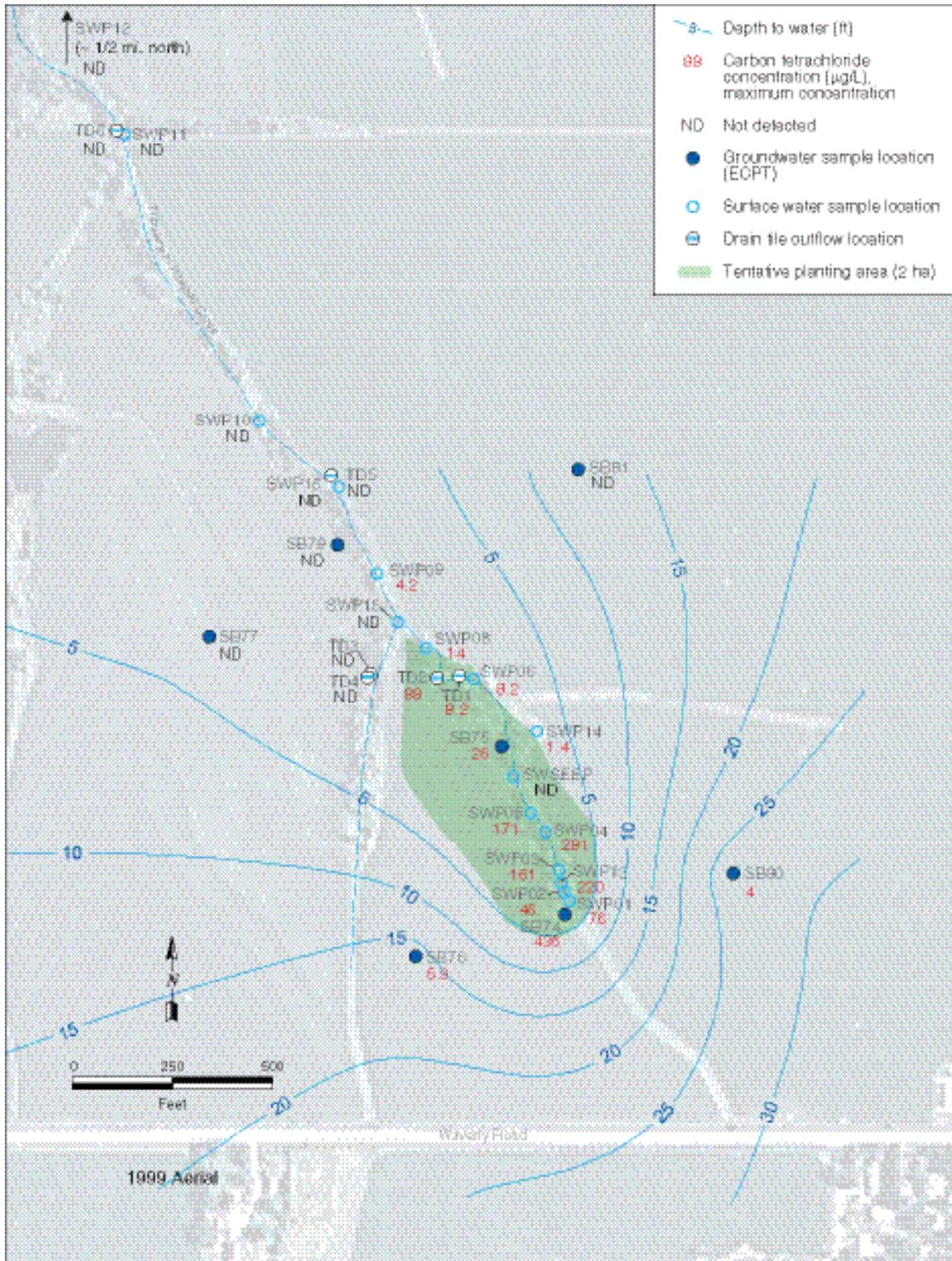


FIGURE 4.21 Interpreted depth to groundwater and carbon tetrachloride distribution near the tributary to Pawnee Creek during the 2004 targeted investigation, based on analytical results for groundwater samples collected with the cone penetrometer, water samples recovered from tile drain outflows, and surface water samples. Also shown is the tentative planting area.

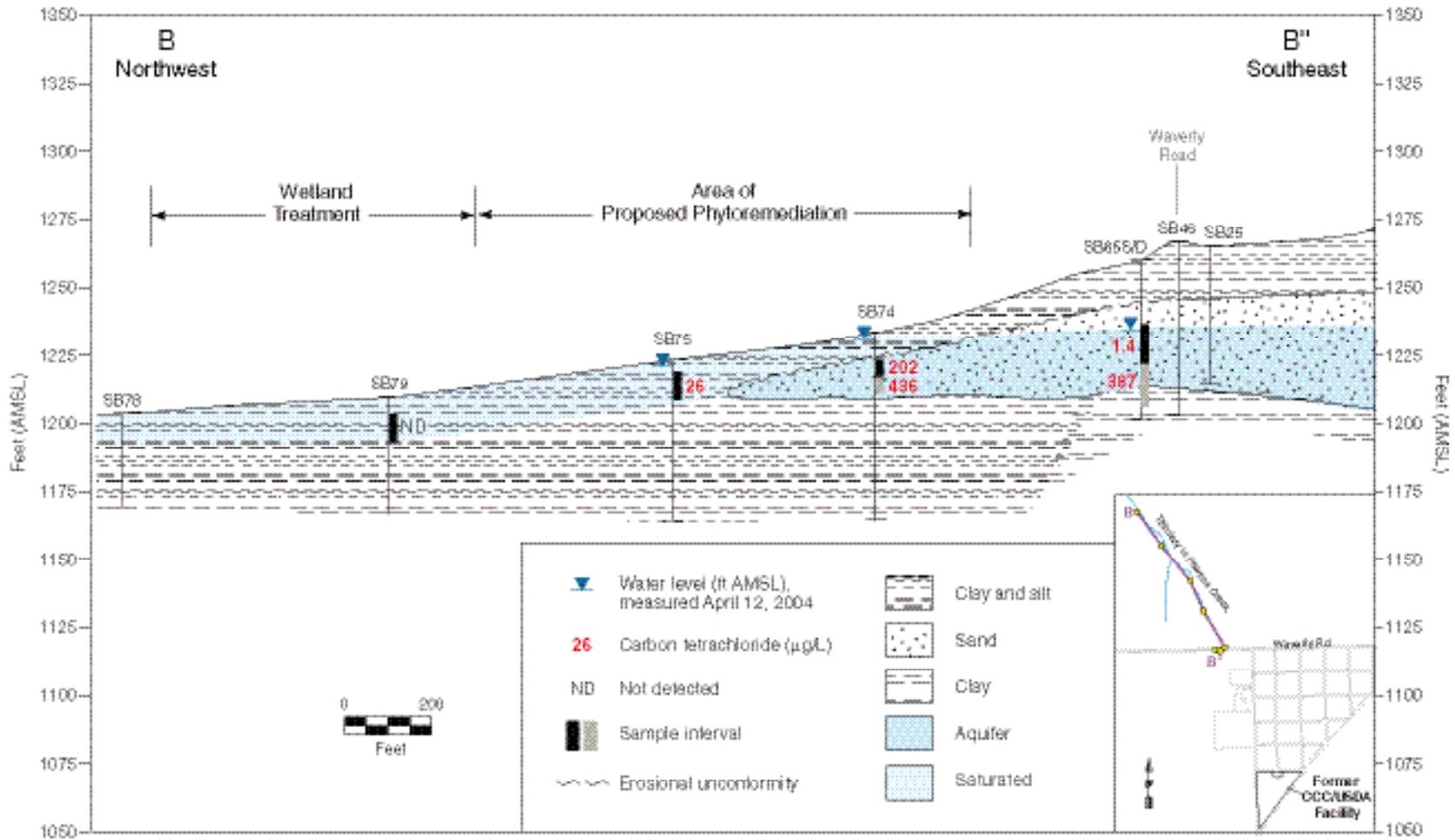


FIGURE 4.22 Interpreted northwest-to-southeast cross section B-B (vertically exaggerated) through the area north of Waverly Road, running parallel to the tributary to Pawnee Creek and illustrating the progressive erosion of the aquifer unit and the lateral and vertical distributions of carbon tetrachloride contamination, as well as the areas of proposed phytoremediation and constructed wetland treatment.

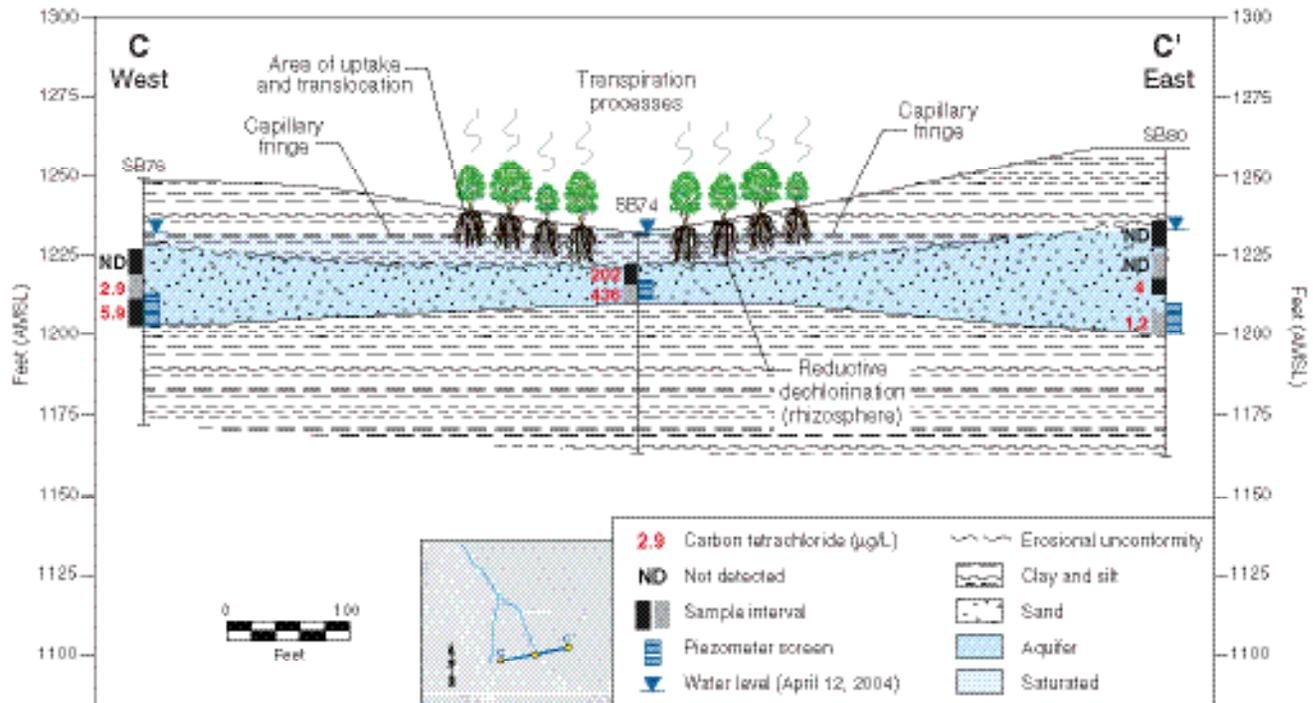


FIGURE 4.23 Schematic west-to-east cross section C-C (vertically exaggerated) illustrating the conceptual design for proposed phytoremediation processes near the tributary to Pawnee Creek and indicating areas of contaminant uptake and transpiration.

## 5 Conclusions and Recommendations

### 5.1 Conclusions

The results of the targeted investigations at Murdock support the following conclusions relative to the technical objectives identified for this study (Section 1):

1. *Determine the continuity, thickness, and hydrogeologic characteristics of the aquifer in the vicinity of the Pawnee Creek tributary.*

The aquifer is laterally continuous throughout the investigation area south of Waverly Road. The aquifer there consists of silty, fine to medium grained sands approximately 15–48 ft thick. The aquifer sands thin significantly north of Waverly Road, becoming finer grained as a result of both depositional facies changes and erosional downcutting in the headwaters area of the tributary creek. The absence of the aquifer sands along the creek itself is due to erosion. More recent silts and clays deposited there subsequently are locally saturated. The depositional setting of the tributary therefore forms a natural hydraulic barrier to further groundwater (and contaminant) migration northward within the aquifer.

Estimates of the hydraulic conductivity of the aquifer sands and the creek bed silts and clays were obtained from slug tests performed at six locations north of Waverly Road. The resulting hydraulic conductivity values for the aquifer sands (0.15–3.04 ft/d) are lower by more than an order of magnitude than the values determined previously for the thicker aquifer sands in the southern portion of the study area. The observed decrease in the hydraulic conductivity of the aquifer near the tributary creek is qualitatively consistent with the finer grained character and decreased thickness of the sands in this area. The hydraulic conductivity values estimated for the saturated stream bed silts and clays along the tributary creek were extremely low (0.02–0.07 ft/d).

2. *Characterize the present distribution of carbon tetrachloride contamination in groundwater and surface water in the area north of Waverly Road.*

The groundwater plume at Murdock extends northwestward from the former CCC/USDA facility into the headwaters area of the tributary creek. Carbon tetrachloride concentrations measured during the targeted investigation in the area north of Waverly Road ranged from not detected to 436 µg/L. The plume tapers progressively with distance northwestward and terminates along the creek channel approximately 1,300 ft north of Waverly Road. Surface water sampling demonstrated that the decreased width of the groundwater plume and its downgradient limit effectively coincide with the area where discharge of contaminated groundwater to the creek was observed. Carbon tetrachloride concentrations in surface waters there ranged from < 5 µg/L to 281 µg/L and decreased progressively with distance downstream. No carbon tetrachloride was found in the creek water at concentrations above the maximum contaminant level of 5 µg/L at distances greater than 1,500 ft north of Waverly Road. The main body of Pawnee Creek, more than 1 mi north of the headwaters area of the tributary creek, appears not to be affected by the plume in the aquifer.

The results of the 2004 targeted investigation complete the delineation of the lateral and vertical extents of the carbon tetrachloride plume at Murdock. The present results confirm that the maximum carbon tetrachloride concentration in groundwater (at SB68) has decreased steadily, from 7,800 µg/L in 1996–1967 to 1,831 µg/L in 1999, 1,072 µg/L in 2002, and 991 µg/L in 2004.

3. *Determine the patterns of groundwater flow in the vicinity of the Pawnee Creek tributary, and their relationship to the expected migration of the identified carbon tetrachloride plume.*

Groundwater flow near the tributary creek converges toward the creek channel, which forms a local discharge boundary for the aquifer. The identified groundwater flow patterns are consistent with the mapped distribution of carbon tetrachloride in the subsurface and surface waters north of Waverly Road. These patterns support the premise that the contaminant plume is being intercepted by the creek. These observations, together with the

absence of permeable aquifer sands due to erosion of the aquifer unit, support the conclusion that no migration of contaminated groundwater is occurring beneath the creek or beyond the presently identified downgradient limits of the carbon tetrachloride plume.

Mapping of water levels along the groundwater migration pathway from the former CCC/USDA facility to the discharge area at the creek showed that the hydraulic gradients driving groundwater flow near the creek are up to 20 times those found in the portion of the aquifer south of Waverly Road. These locally higher gradients are a reflection of both the reduced thickness and the lower hydraulic conductivities of the aquifer sands in this area.

Seven known agricultural drain tile lines under the fields north of Waverly Road capture infiltrating surface water and shallow groundwater and discharge it to the creek. Only two segments of the identified drain tile lines are expected to intercept contaminated shallow groundwater. The first of these segments, about 630 ft long (representing 65% of the total length of tile line TD2), lies along the approximate central axis of the contaminant plume. Carbon tetrachloride was found in the discharge from this tile line at a concentration of 88 µg/L. The second tile line segment expected to intercept contaminated shallow groundwater is only 160 ft long and represents 7% of the total length of tile line TD1. A low concentration of carbon tetrachloride (8.2 µg/L) was detected in the discharge from this line.

4. *Identify and delineate the presence of carbon tetrachloride in vadose zone soils in the northern portion of the former CCC/USDA facility that might pose a continuing source of contamination to the aquifer, and determine soil properties affecting vertical contaminant migration.*

Sampling of near-surface soils in the northern portion of the former CCC/USDA facility revealed no contamination of these materials above a quantitation limit of 10 µg/kg, as determined by purge-and-trap GC-MS analysis. The results indicate that no unacceptable health risk arises from exposure to the near-surface soils at the former CCC/USDA facility, on the basis of EPA guidance levels for soil screening.

Headspace analyses of the near-surface soil samples served as a more sensitive, but qualitative, screening method for identifying the possible distribution patterns of low levels of carbon tetrachloride contamination in the near-surface soils, which Argonne's experience has shown can be indicative of deeper subsurface soil contamination. On the basis of the headspace results, three areas of the former facility were targeted for additional subsurface soil sampling: (1) the western portion of the study area, near the site of several former circular grain storage bins; (2) the northern portion of the area, near the former site of several Quonset storage buildings; and (3) near the site of a former chemical storage building toward the northwest corner of the facility.

Vertical-profile sampling of soil through the vadose zone was performed at the location of the former Quonset huts (SB85 and SB86). Access for subsurface sampling at the location of the former circular bins was denied by the current property owner, and the use of only a hand-driven sampling device (which enabled limited penetration of the vadose zone) was permitted near the site of the former chemical storage building.

Carbon tetrachloride concentrations exceeding the EPA screening guidance level for this contaminant in soils ( $70 \mu\text{g}/\text{kg}$ ) were identified in one (SB85) of two borings near the former Quonset huts. The carbon tetrachloride levels at this location ranged from  $13 \mu\text{g}/\text{kg}$  to  $361 \mu\text{g}/\text{kg}$ . Carbon tetrachloride was not detected in subsurface soils near the former chemical storage building, to a maximum penetrated depth of 22 ft BGL.

5. *Evaluate contaminant migration from soil to groundwater, and analyze indoor air potentially affected by vapor intrusion at residences built on the former CCC/USDA facility.*

The potential effect of the identified subsurface contamination as a future source of carbon tetrachloride to the groundwater was investigated by using a conservative, one-dimensional vadose zone contaminant transport model developed by the EPA (VLEACH) to simulate the expected leaching of carbon tetrachloride from the soils. The soil physical parameters and contaminant transport parameters required as inputs to the model, plus the starting distribution of carbon tetrachloride concentrations in the vadose zone,

were obtained from the site-specific data collected in boring SB85 and from appropriate published values.

The model simulations predicted maximum carbon tetrachloride concentrations of 10-23  $\mu\text{g/L}$  in groundwater below the vadose zone near SB85 over the next 80 yr. At this level of predicted contributions, the maximum carbon tetrachloride levels in the body of the Murdock groundwater plume are expected to decrease with time, thus continuing the trend of declining concentrations documented at the site since 1991.

The highest concentration of carbon tetrachloride detected during 2004 indoor air sampling at Murdock, 4  $\mu\text{g/m}^3$ , is far below the concentrations detected in the 1988 air sampling events. Comparison with the noncancer chronic inhalation reference exposure level for carbon tetrachloride indicates no apparent health risk arising from exposure to the household air at the residences built on the former CCC/USDA facility. On the basis of the inhalation unit risk estimate of the EPA's Integrated Risk Information System, the carcinogenic risk due to lifetime exposure to the basement air is below the upper limit ( $10^{-4}$ ) of the established acceptable range (EPA 2004a).

The maximum concentration of chloroform detected in 2004 was 3  $\mu\text{g/m}^3$ , in the basement of the Wager residence. Long-term inhalation exposure of this level of chloroform in the air poses no noncancerogenic or carcinogenic health risk (EPA 2004b).

6. *Evaluate the potential suitability of phytoremediation for this site.*

The suitability of conditions north of Waverly Road for phytoremediation was evaluated through characterization of (1) the distribution of carbon tetrachloride in groundwater, surface water, and discharge from drain tile lines and (2) the stratigraphic sequence near the tributary to Pawnee Creek.

The investigation demonstrated progressive thinning of the aquifer toward the tributary creek, as well as suitable groundwater depth and contaminant distribution for phytoremediation.

## 5.2 Recommendations

On the basis of the above observations, the following preliminary remedial action alternatives are suggested for the Murdock site:

- *Decrease the mass of carbon tetrachloride discharged to the tributary creek through the use of innovative phytoremediation techniques.*

The agricultural fields and associated riparian ecosystem along the tributary creek represent a promising environment for the potential implementation of innovative phytoremediation technologies for the treatment of carbon tetrachloride. Use of these technologies would protect the watershed from the potentially detrimental effects of contaminated groundwater discharge to the surface in the headwaters area north of Waverly Road. Phytoremediation would both (1) extract much of the contaminated groundwater from the aquifer before it reaches the creek (through root uptake and subsequent transpiration within vegetation) and (2) degrade the carbon tetrachloride, either within the plants or via enhanced bioremediation activity in the plant root zone (the rhizosphere). Implementation of phytoremediation would also promote beneficial development of the local ecosystem and could enhance recreational opportunities for the Murdock community.

The phytoremediation options proposed for evaluation at the Murdock site include (1) establishment of perennial vegetation in some of the presently cultivated fields, (2) enhancement of the riparian buffer area along the tributary creek, and (3) development of a wetland for remediation of any contaminated groundwater that might still reach the surface. A phased approach is recommended for the design, implementation, optimization, and monitoring of phytoremediation at Murdock:

- *Use groundwater extraction and surface treatment to decrease carbon tetrachloride levels in the central, most concentrated part of the existing plume and contain the potentially continuing source at the former CCC/USDA facility.*

The use of an extraction well on the grounds of the Elmwood-Murdock Public School, installed by Argonne with the approval of the CCC/USDA and the EPA, is expected to remove contaminated groundwater from the central, more concentrated portion of the carbon tetrachloride plume. The operation of this well would also intercept any additional carbon tetrachloride contamination contributed to the aquifer from the potentially continuing source identified upgradient in the vadose zone soils at the former CCC/USDA facility.

To facilitate beneficial use of the extracted groundwater for irrigating the school athletic fields, seasonal pumping of this well is recommended. Under this alternative, simultaneous (1) treatment of the extracted groundwater and (2) watering of the athletic fields would be performed with the spray irrigation treatment process and equipment originally developed by Argonne for use at the Utica, Nebraska, former CCC/USDA facility. This process is a form of air stripping, in which carbon tetrachloride is volatilized from the groundwater as it is sprayed on the fields.

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**Appendix A:**

**Electronic Cone Penetrometer Logs  
and Geologic Logs**

**Argonne National Laboratory**

**Well ID: SB74**

**Project: Murdock T.J.**

**Elevation: 1233.43 ft.**

**Log Date: 04/03/2004**

**Rig: CPT**

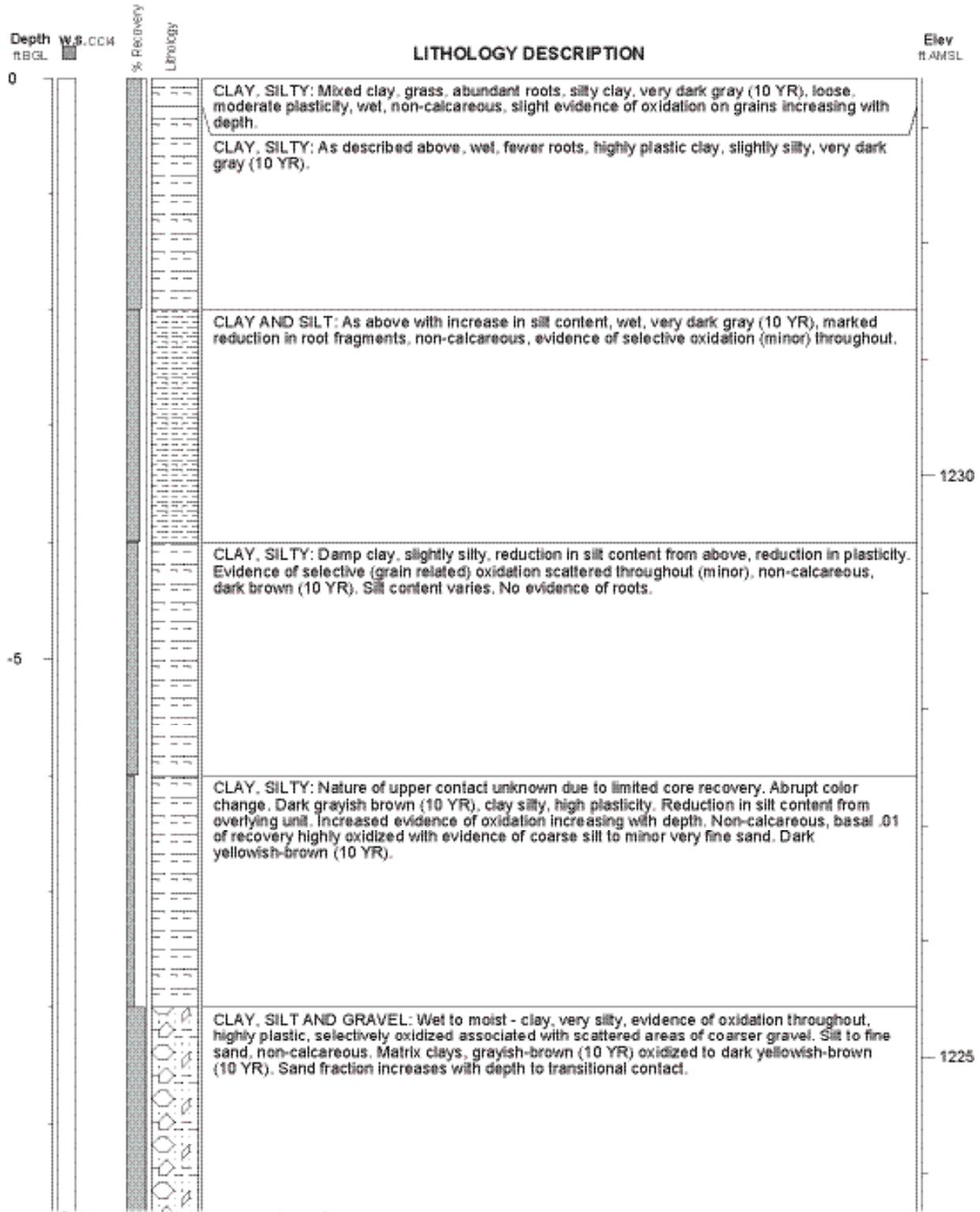
**Geologist: Lorraine LaFreniere**

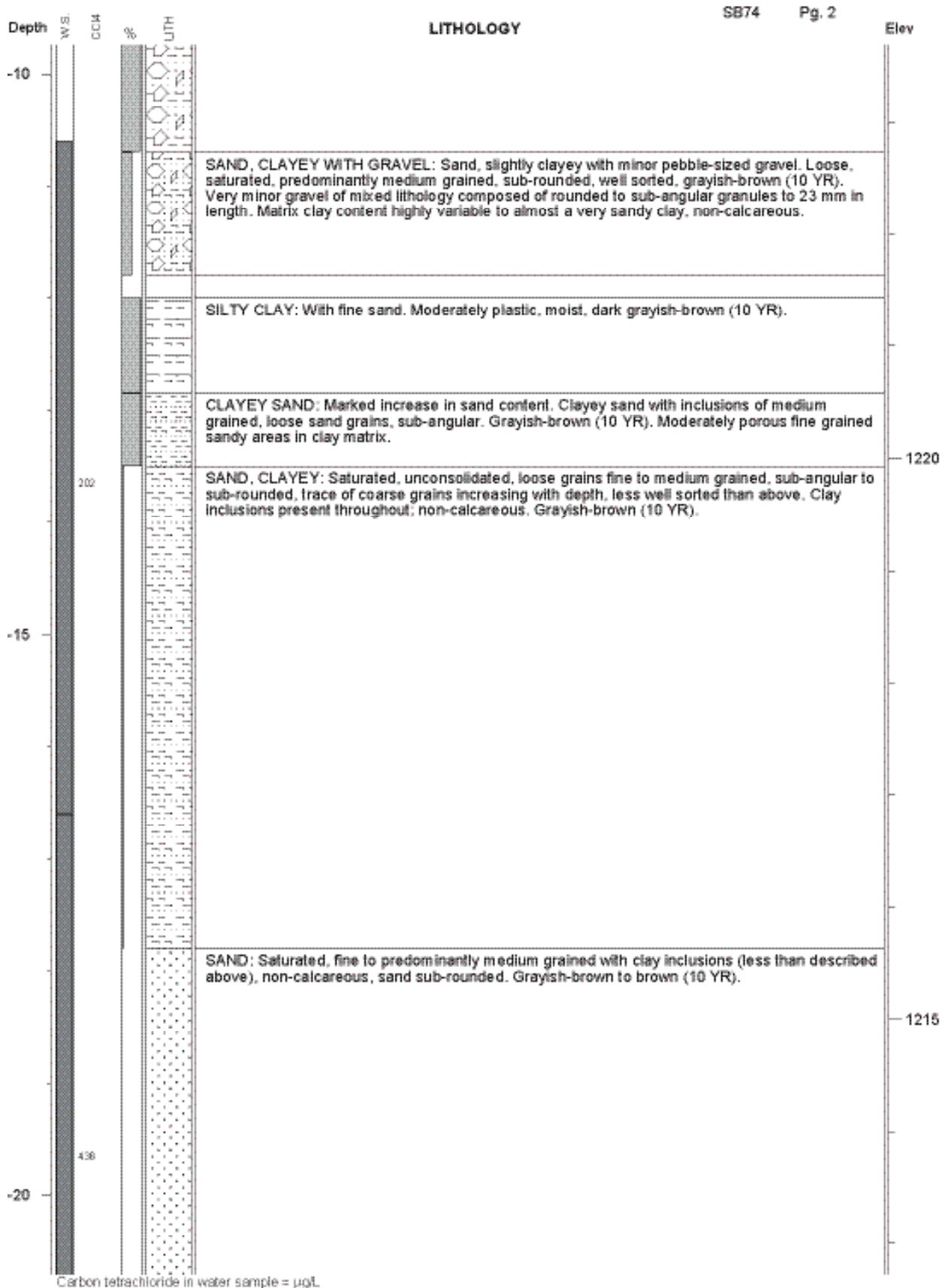
**Depth: 69.02 ft.**

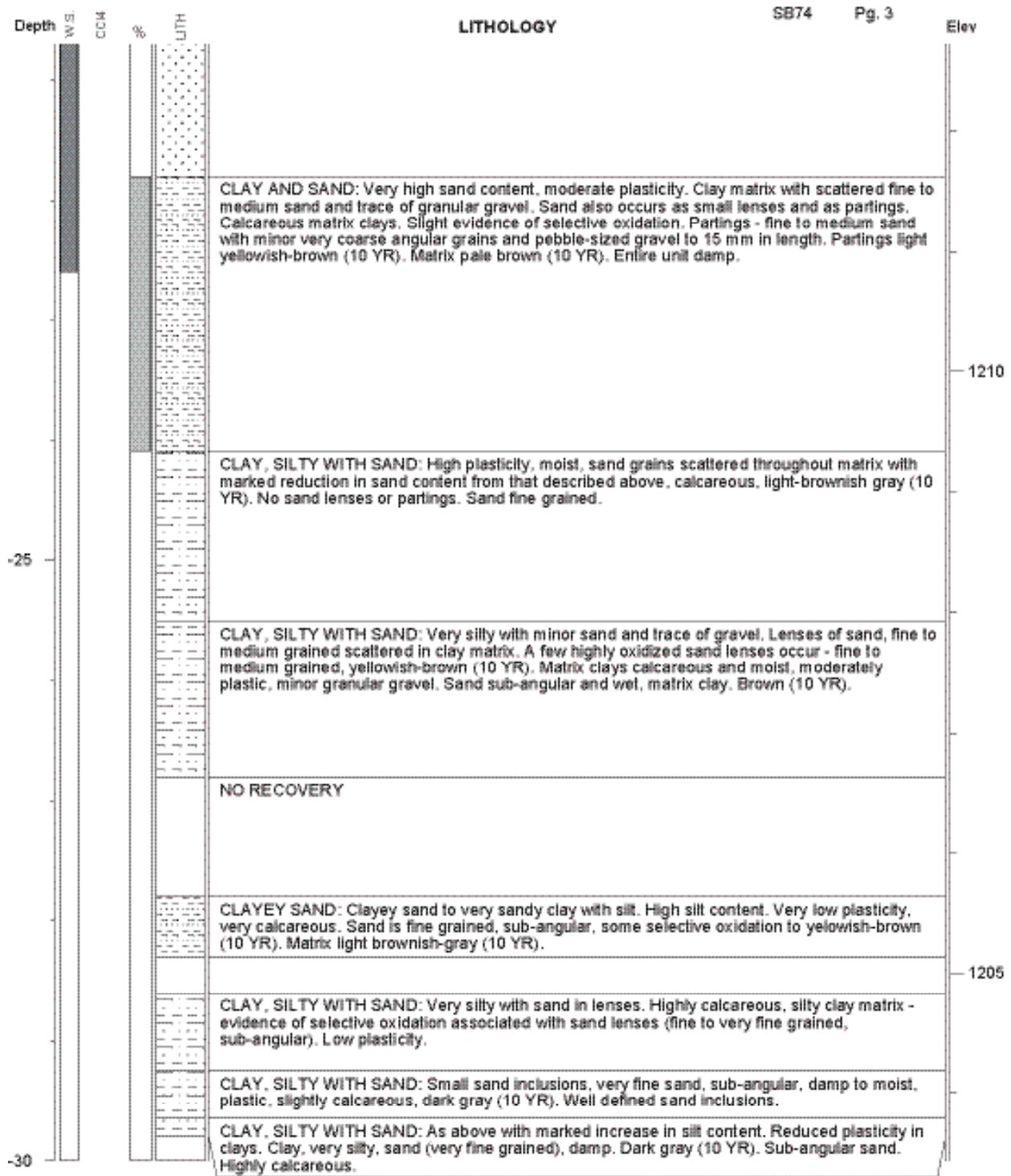
**Driller: Travis & Daryl**

**Company: Argonne**

**Cored Interval: 0 to 29.8' BGL**







Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB74**

**Project: Murdock T.I.**

**Elevation: 1233.43 ft.**

**Log Date: 04/03/2004**

**Rig: CPT**

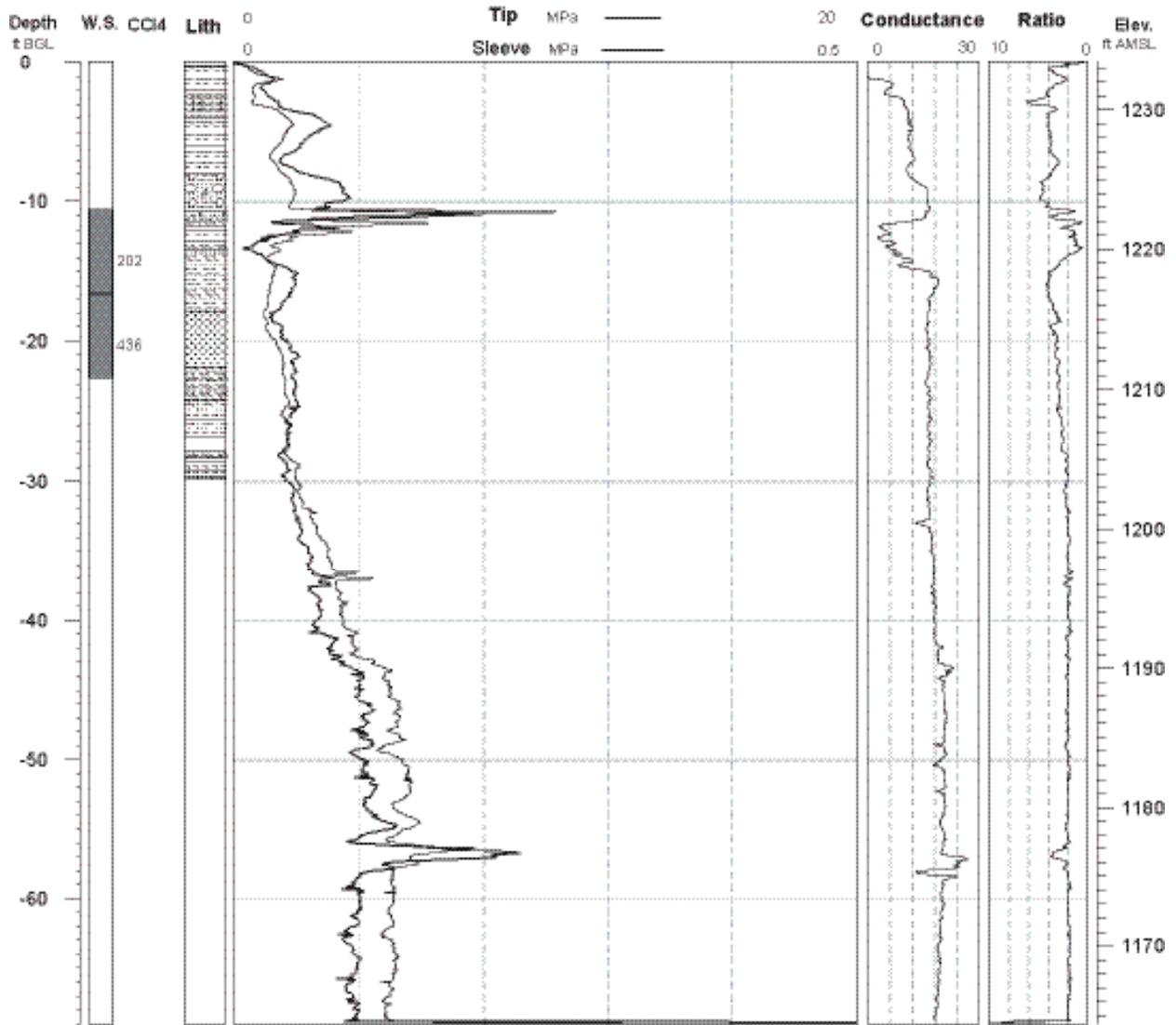
**Geologist: Lorraine LaFreniere**

**Depth: 69.02 ft.**

**Plot Date: 04/05/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Well ID: SB75**

**Project: Murdock T.J.**

**Elevation: 1223.35 ft.**

**Log Date: 04/03/2004**

**Rig: CPT**

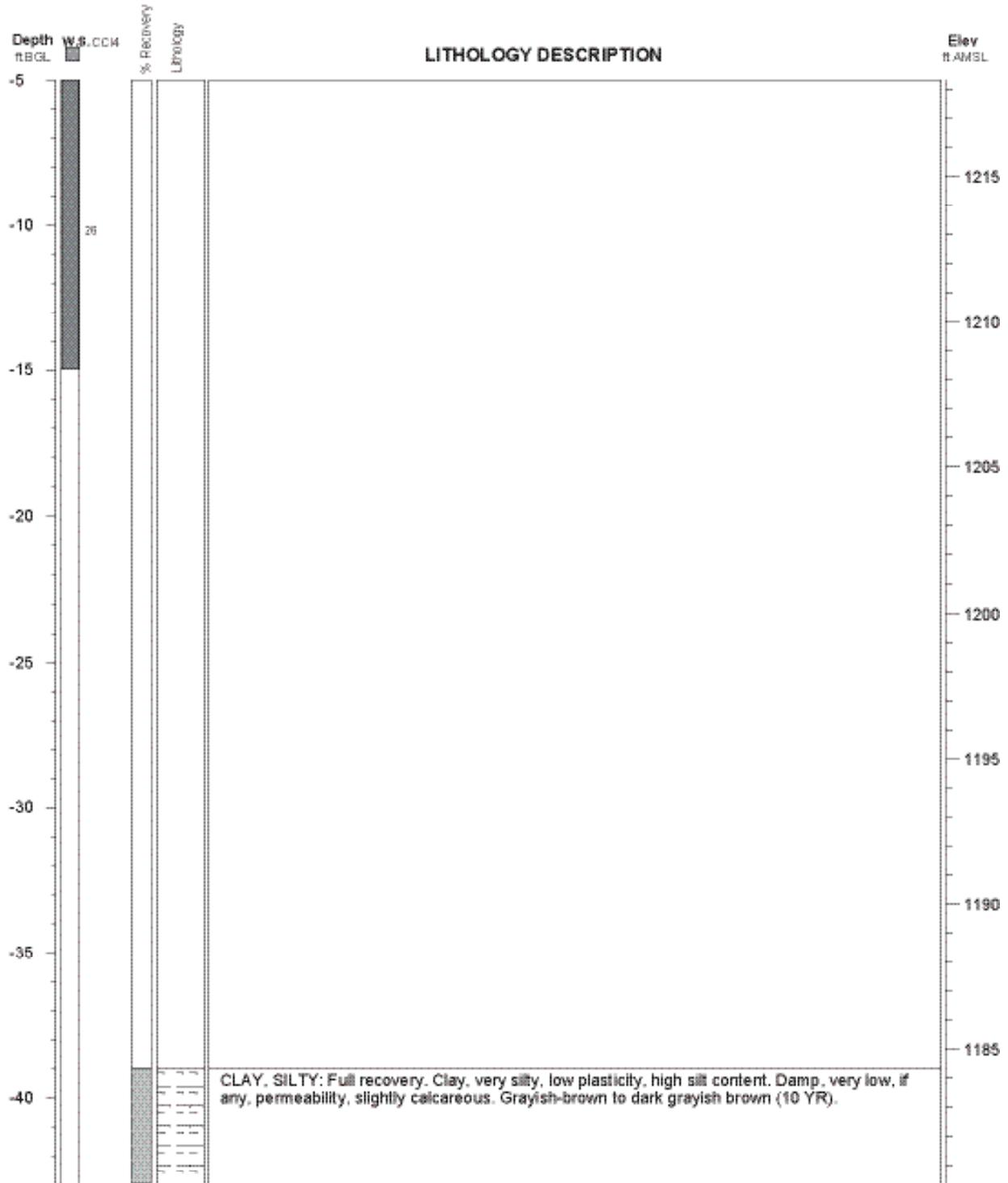
**Geologist: Lorraine LaFreniere**

**Depth: 59.12 ft.**

**Driller: Travis & Daryl**

**Company: Argonne**

**Cored Interval: 39' to 43' BGL**



### Argonne National Laboratory

Boring ID: SB75

Project: Murdock T.I.

Elevation: 1223.35 ft.

Log Date: 04/03/2004

Rig: CPT

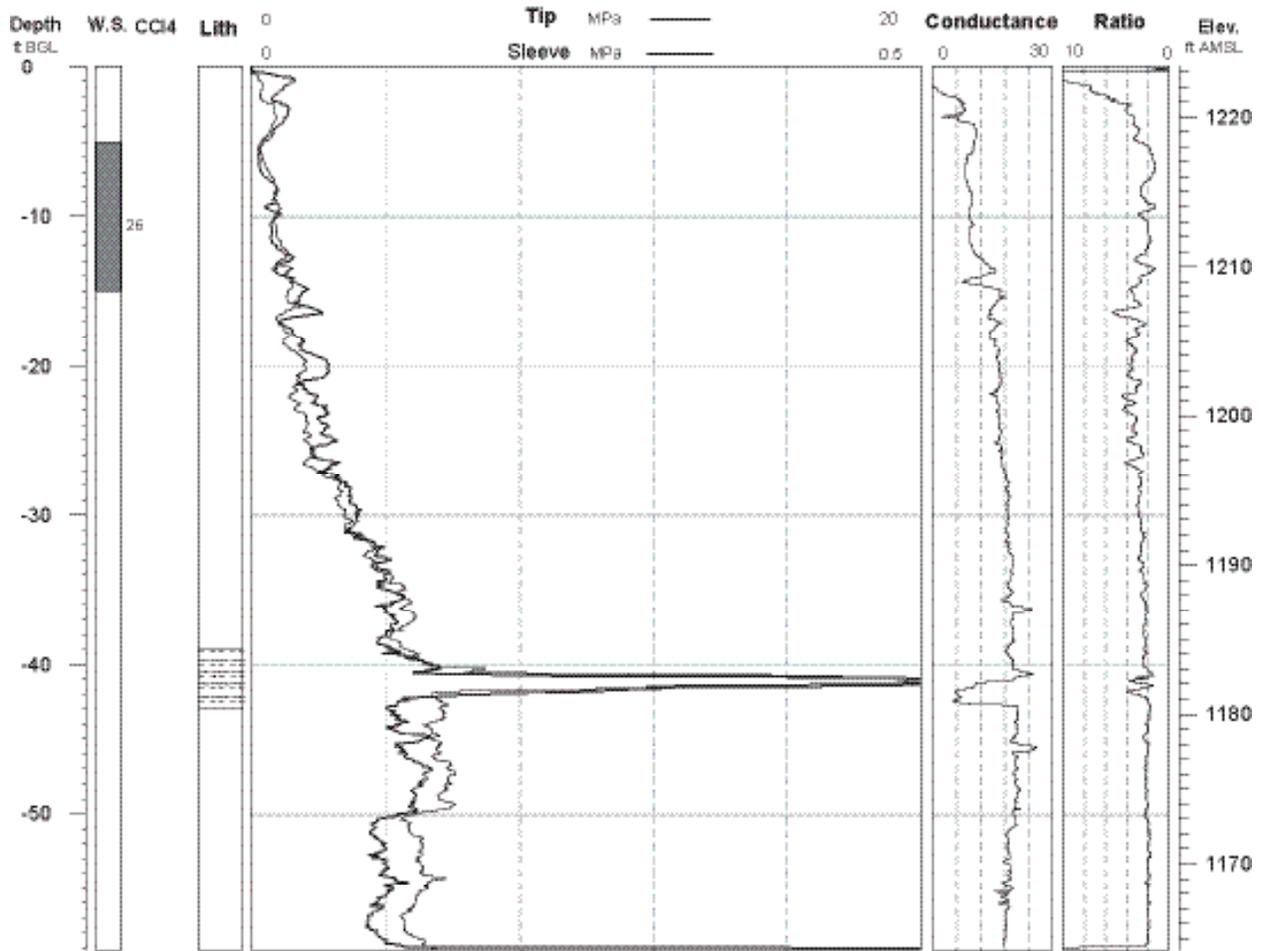
Geologist: Lorraine LaFreniere

Depth: 59.12 ft.

Plot Date: 04/05/2004

Driller: Travis & Daryl

Company: Argonne



Carbon tetrachloride in water sample = µg/L

**Argonne National Laboratory**

**Well ID: SB76**

**Project: Murdock T.J.**

**Elevation: 1249.13 ft.**

**Log Date: 04/02/2004**

**Rig: CPT**

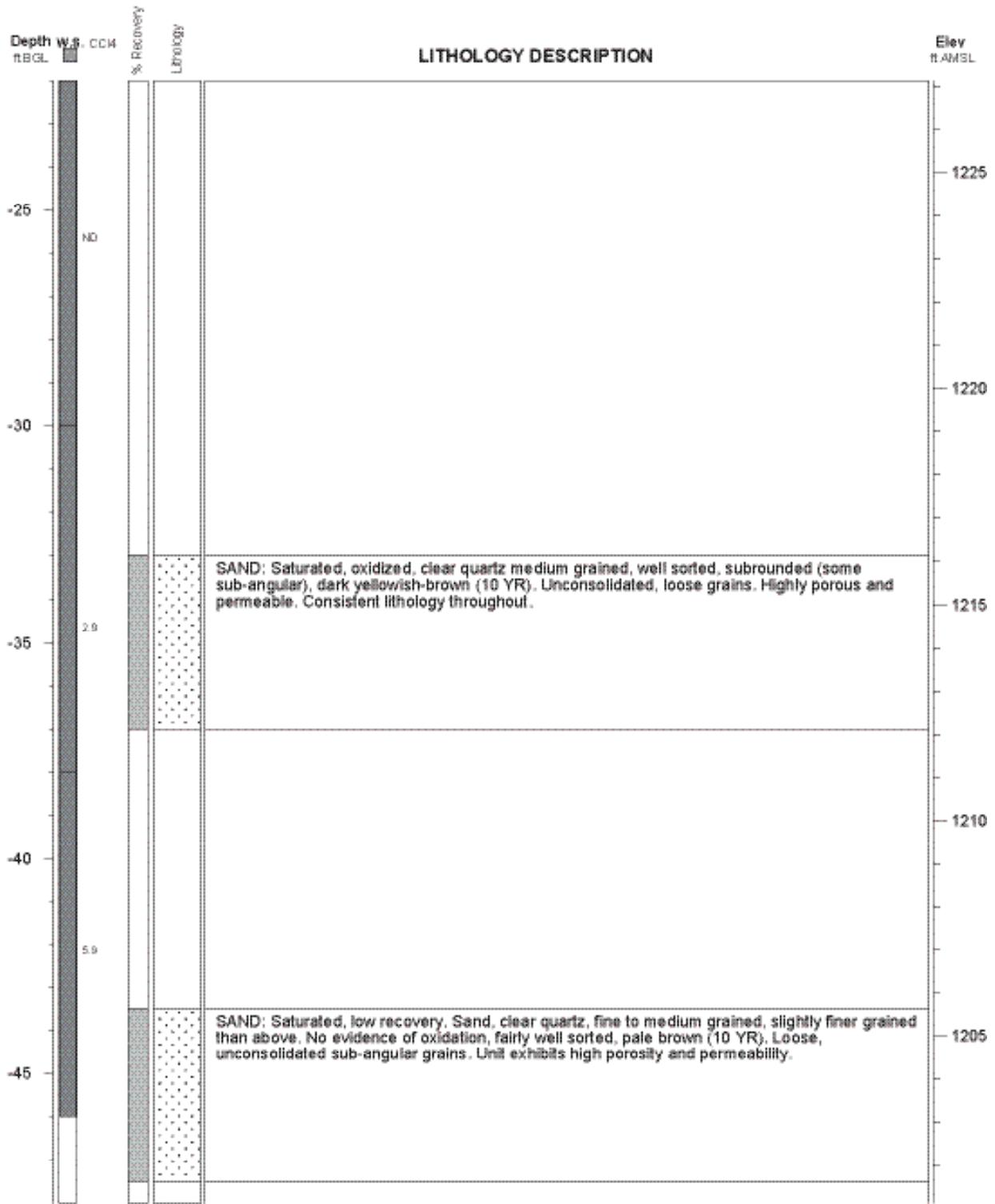
**Geologist: Lorraine LaFreniere**

**Depth: 76.64 ft.**

**Driller: Travis Kammler**

**Company: Argonne**

**Cored Interval: 33' to 37" and 43.5' to 47.5' BGL**



Carbon tetrachloride in water sample = µg/L

**Argonne National Laboratory**

**Boring ID: SB76**

**Project: Murdock T.I.**

**Elevation: 1249.13 ft.**

**Log Date: 04/02/2004**

**Rig: CPT**

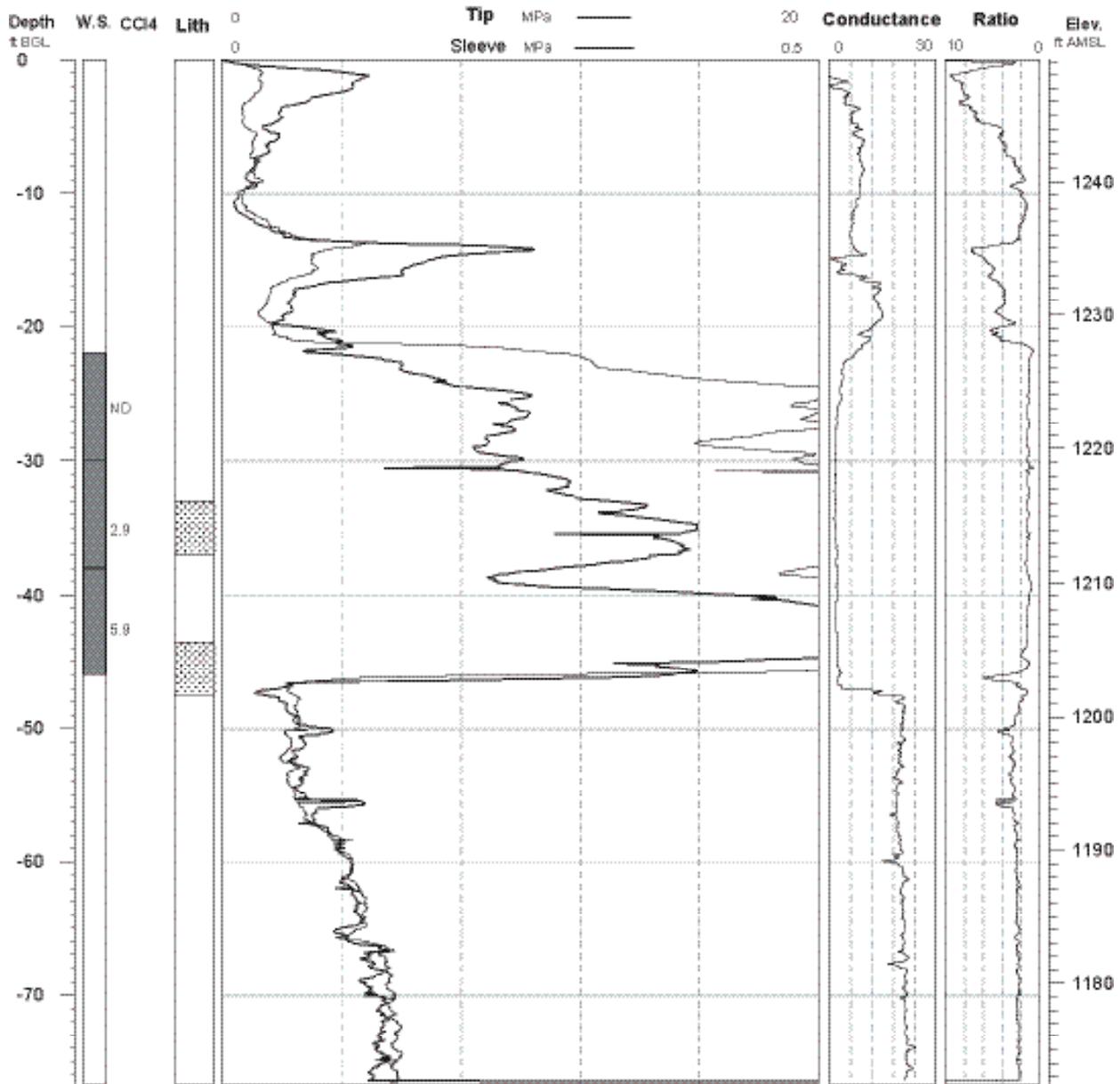
**Geologist: Lorraine LaFreniere**

**Depth: 76.64 ft.**

**Plot Date: 04/05/2004**

**Driller: Travis Kammler**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

Well ID: SB77

Project: Murdock T.J.

Elevation: 1229.65 ft.

Log Date: 04/02/2004

Rig: CPT

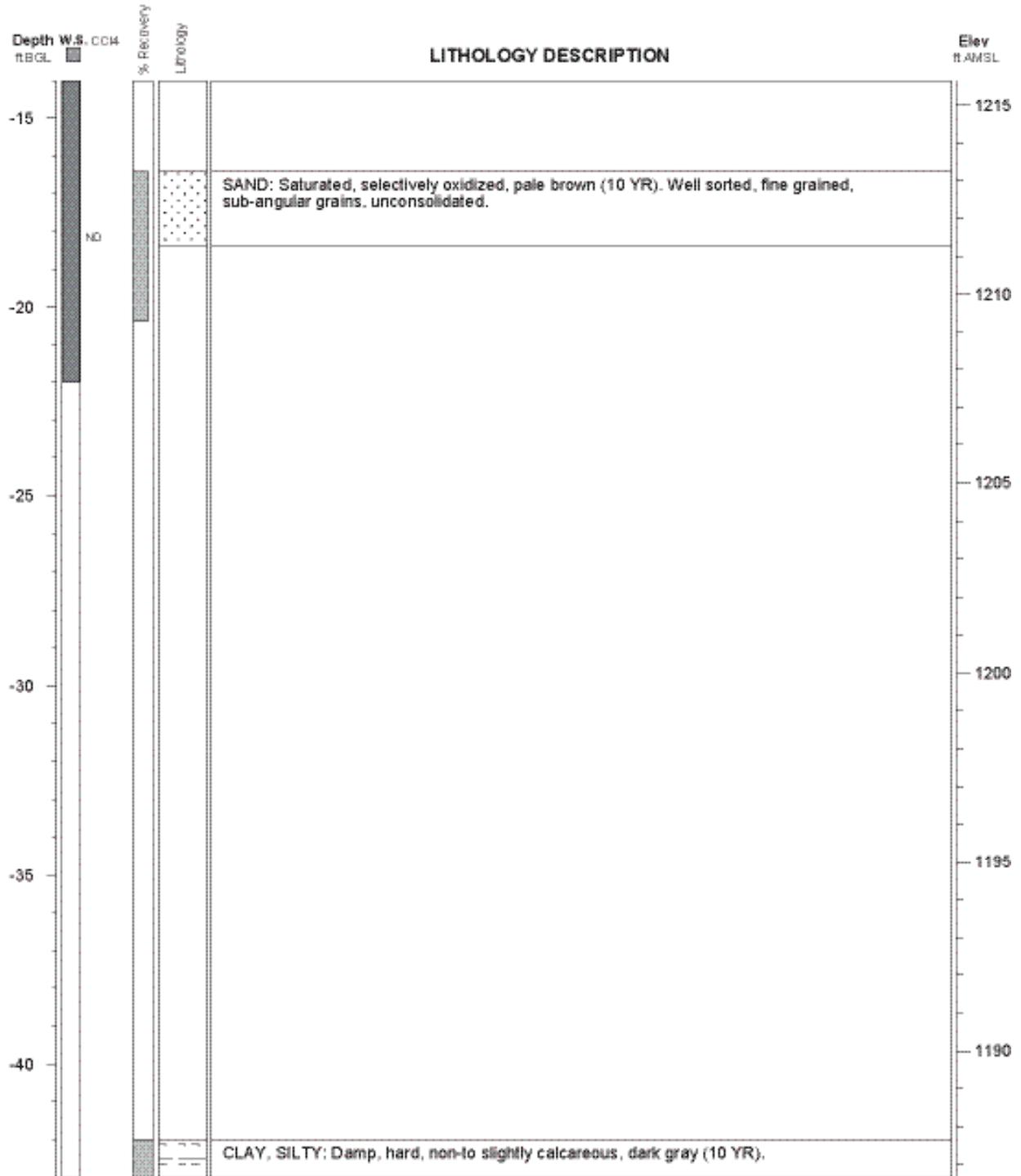
Geologist: Lorraine LaFreniere

Depth: 62.53 ft.

Driller: Travis Kammler

Company: Argonne

Cored Interval: 16.4' to 20.4' and 42' to 43' BGL



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB77**

**Project: Murdock T.I.**

**Elevation: 1229.65 ft.**

**Log Date: 04/02/2004**

**Rig: CPT**

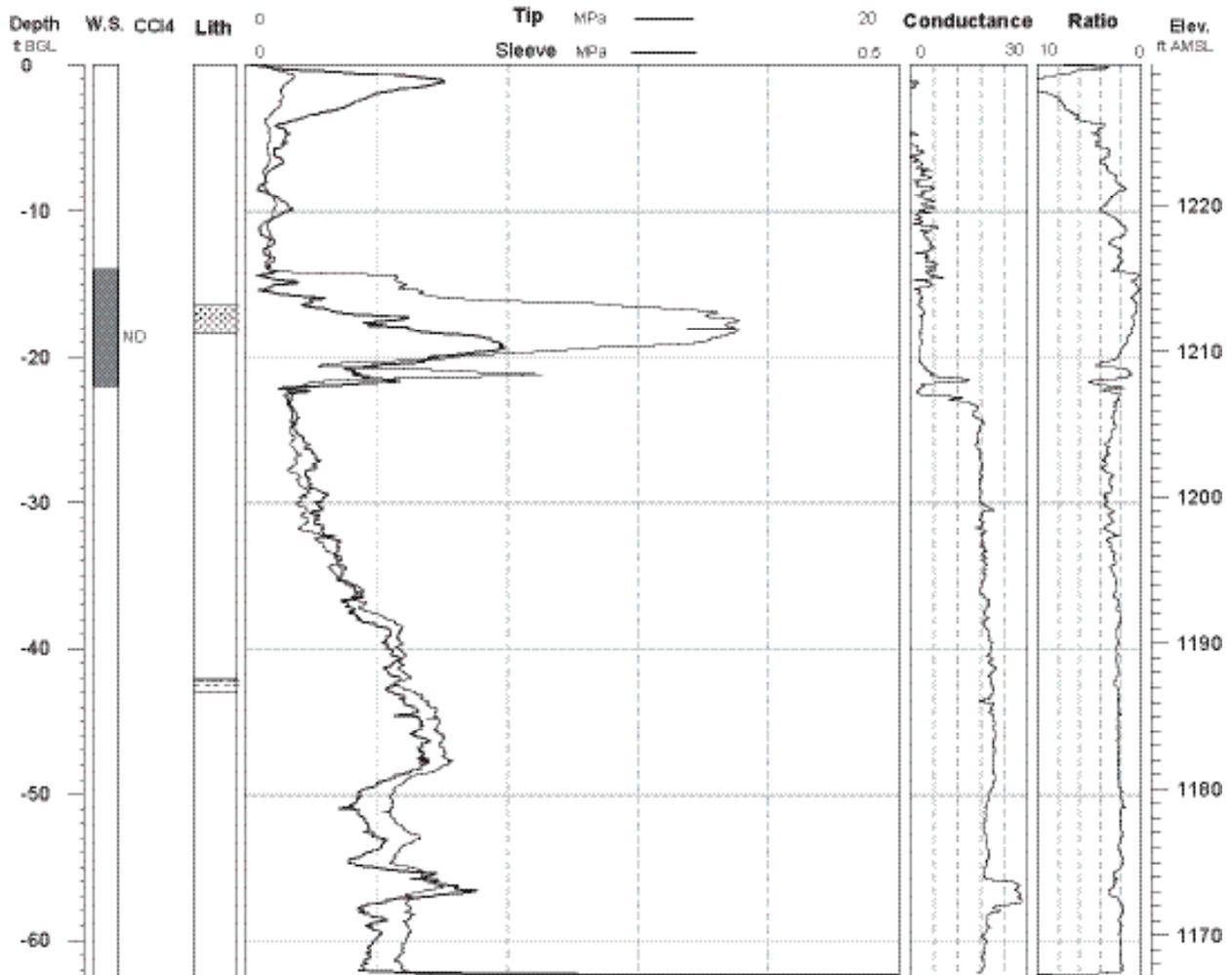
**Geologist: Lorraine LaFreniere**

**Depth: 62.53 ft.**

**Plot Date: 04/05/2004**

**Driller: Travis Kammler**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

### Argonne National Laboratory

Boring ID: SB78

Project: Murdock T.I.

Elevation: 1203.77 ft.

Log Date: 04/03/2004

Rig: CPT

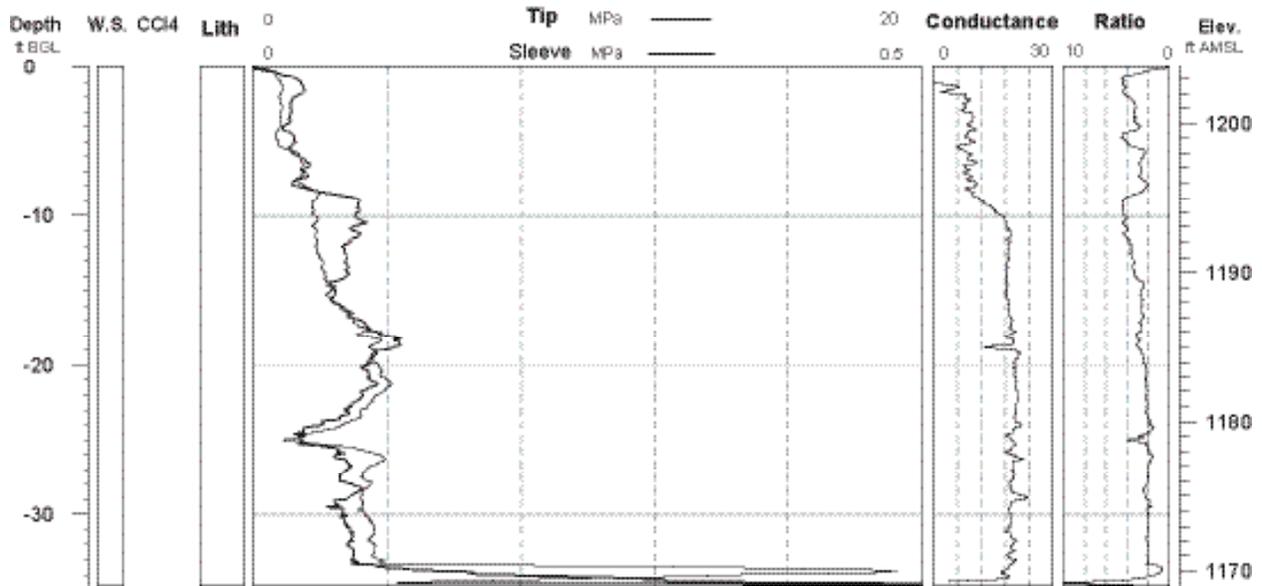
Geologist: Lorraine LaFreniere

Depth: 34.71 ft.

Plot Date: 04/05/2004

Driller: Travis & Daryl

Company: Argonne



**Argonne National Laboratory**

**Well ID: SB79**

**Project: Murdock T.J.**

**Elevation: 1209.82 ft.**

**Log Date: 04/03/2004**

**Rig: CPT**

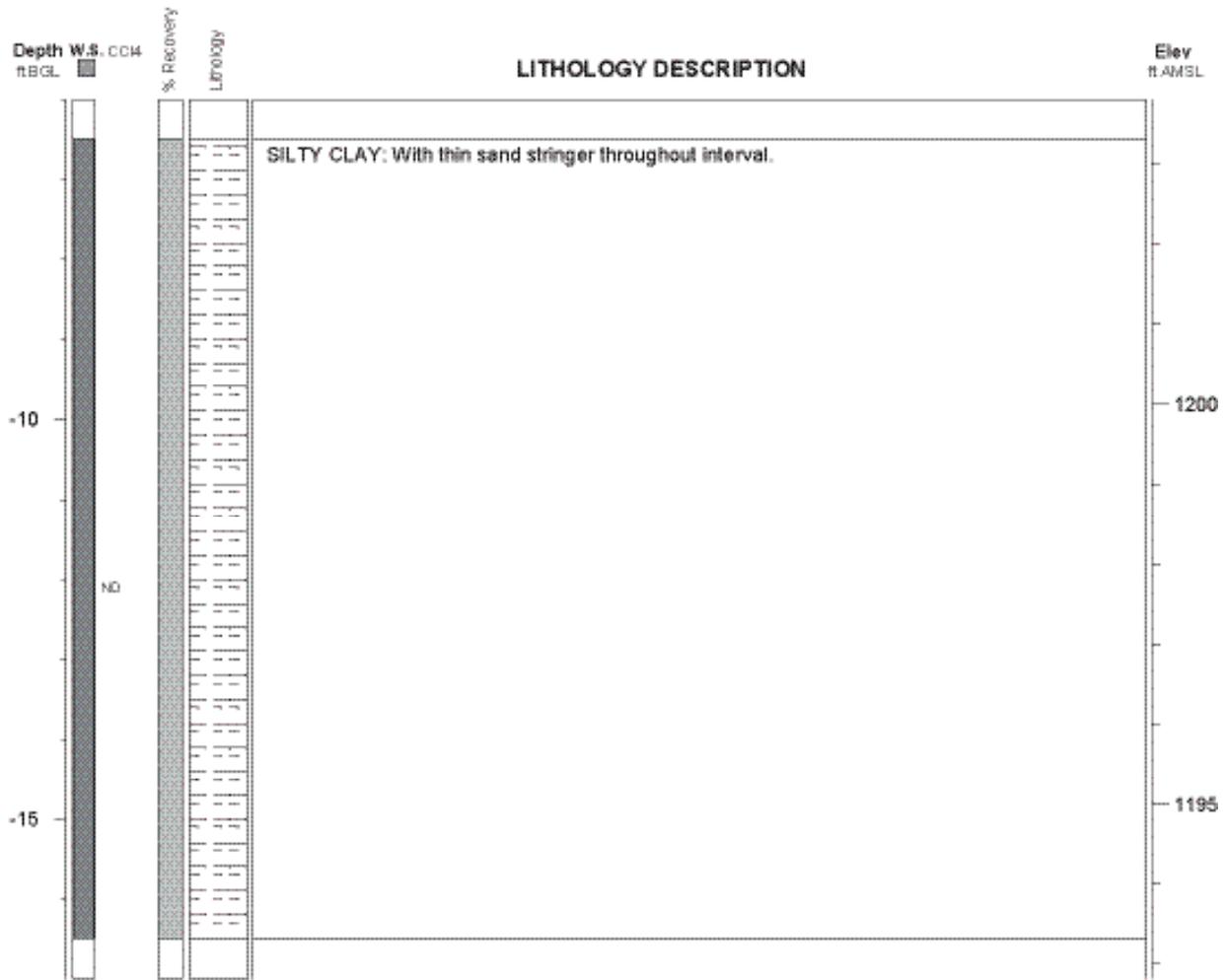
**Geologist: Lorraine LaFreniere**

**Depth: 42.84 ft.**

**Driller: Travis & Daryl**

**Company: Argonne**

**Cored Interval: 6.5' to 16.5' BGL**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB79**

**Project: Murdock T.I.**

**Elevation: 1209.82 ft.**

**Log Date: 04/03/2004**

**Rig: CPT**

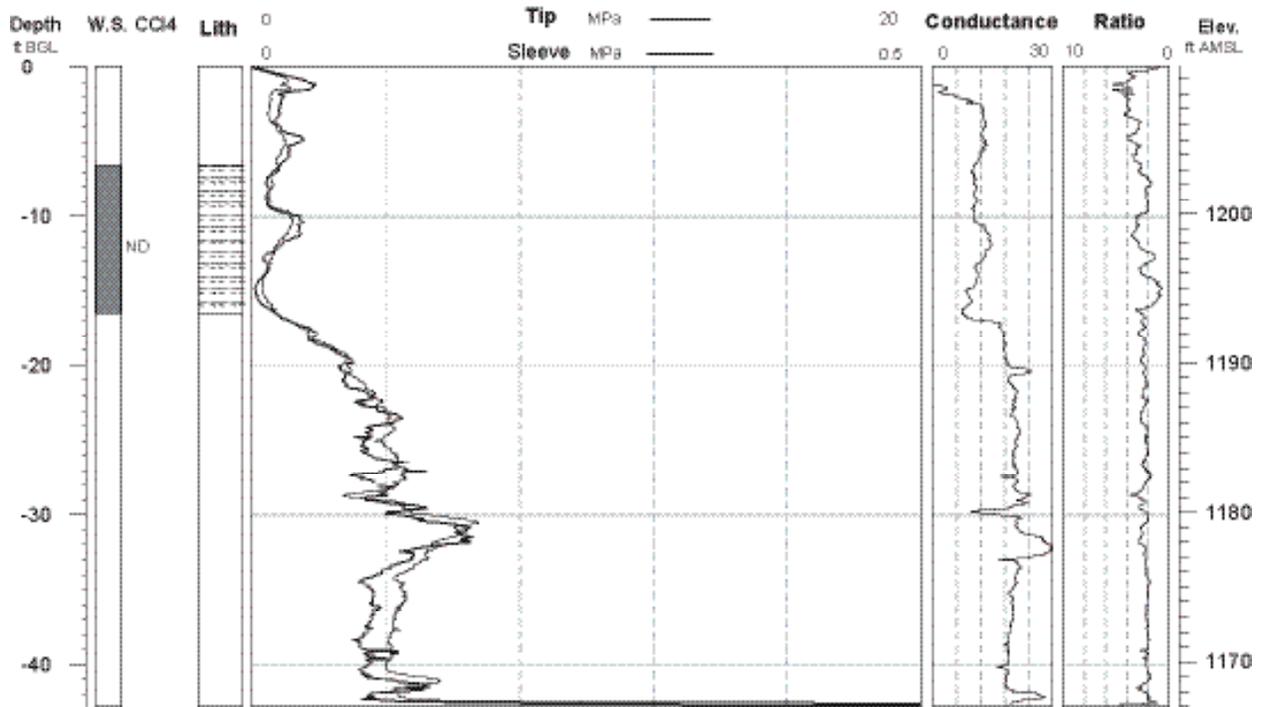
**Geologist: Lorraine LaFreniere**

**Depth: 42.84 ft.**

**Plot Date: 04/05/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB80**

**Project: Murdock T.I.**

**Elevation: 1259.97 ft.**

**Log Date: 04/04/2004**

**Rig: CPT**

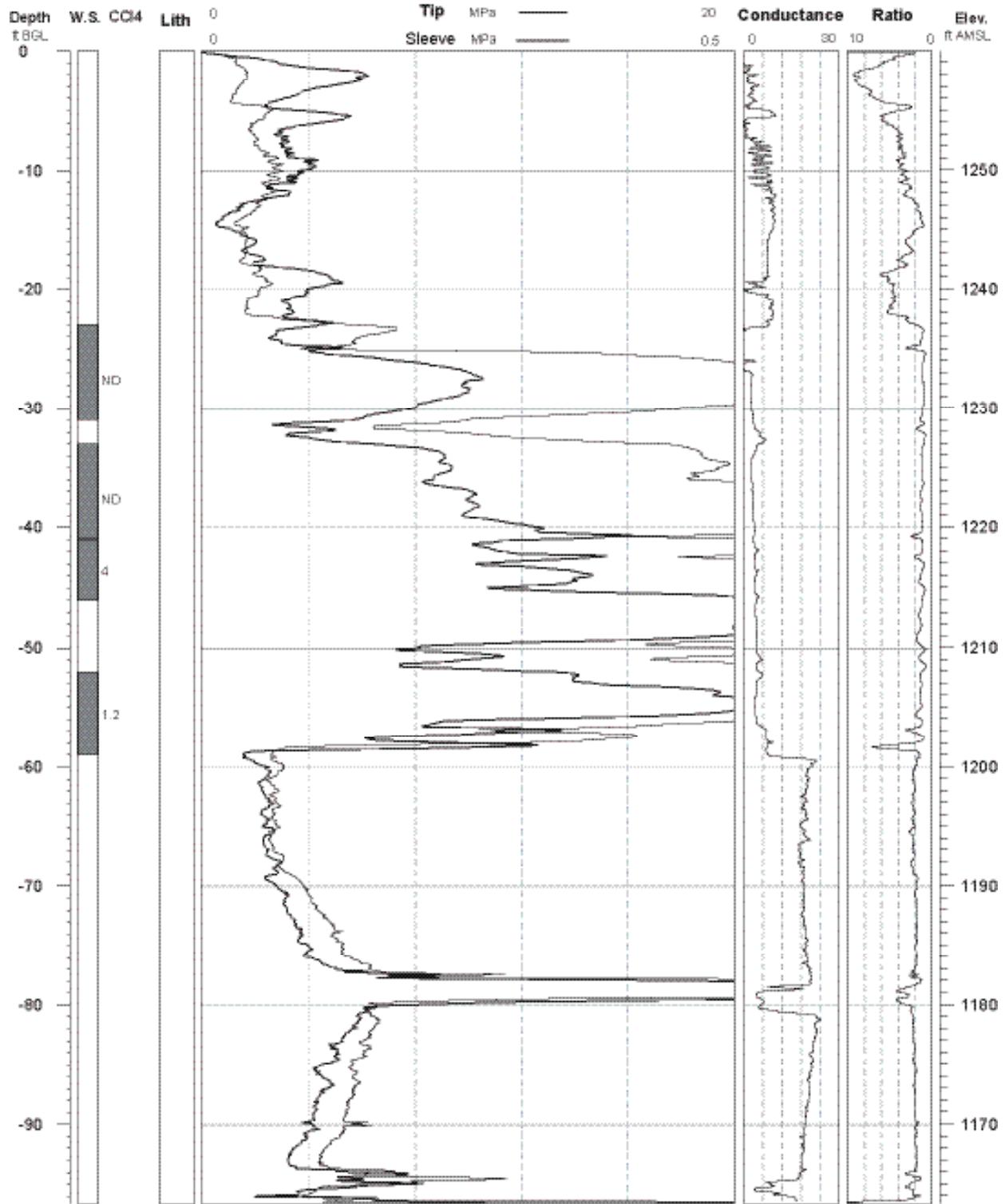
**Geologist: Lorraine LaFreniere**

**Depth: 96.65 ft.**

**Plot Date: 04/05/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB81**

**Project: Murdock T.I.**

**Elevation: 1241.06 ft.**

**Log Date: 04/05/2004**

**Rig: CPT**

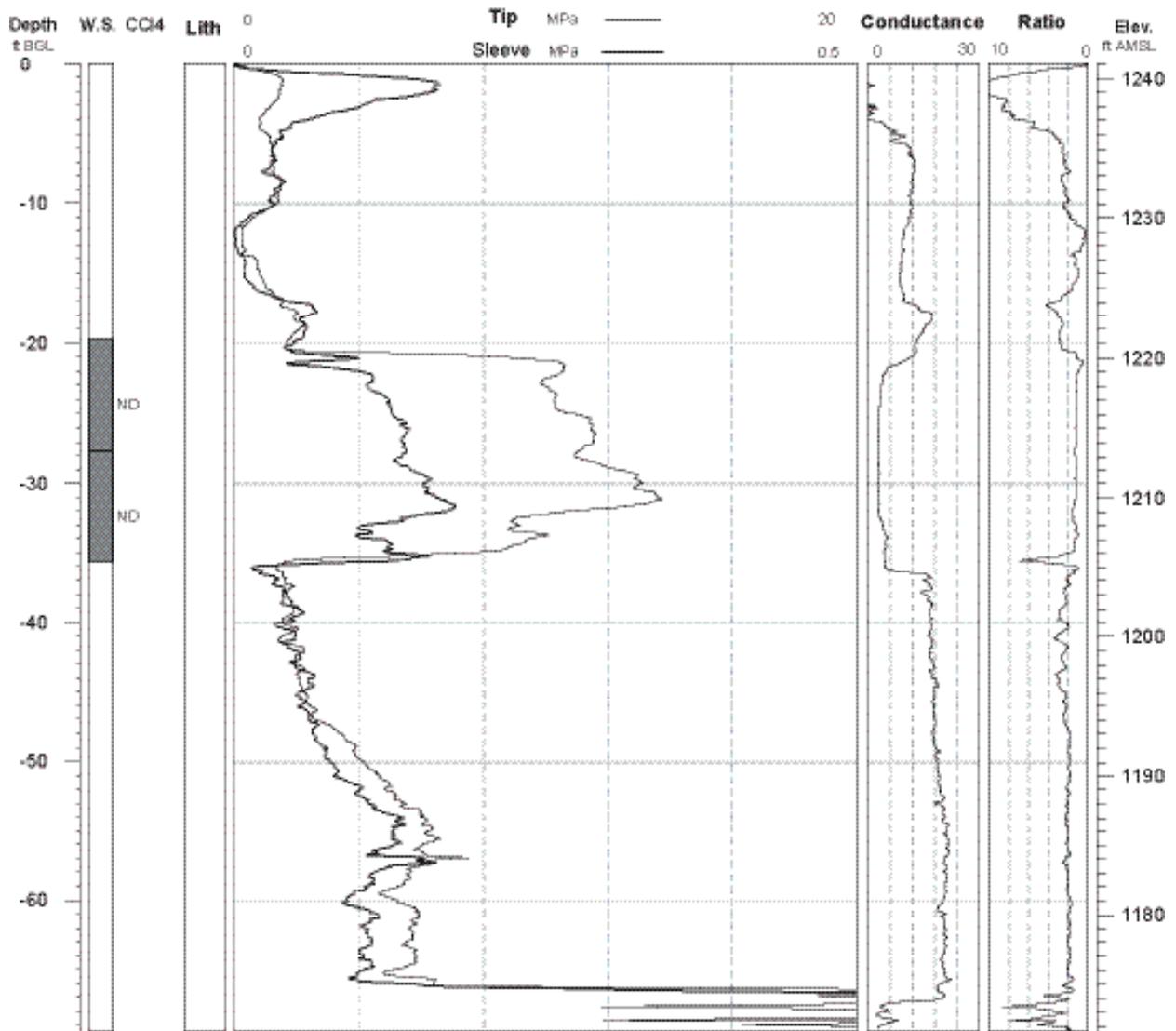
**Geologist: Lorraine LaFreniere**

**Depth: 69.42 ft.**

**Plot Date: 04/06/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

**Argonne National Laboratory**

**Boring ID: SB82**

**Project: Murdock T.I.**

**Elevation: 1237.85 ft.**

**Log Date: 04/05/2004**

**Rig: CPT**

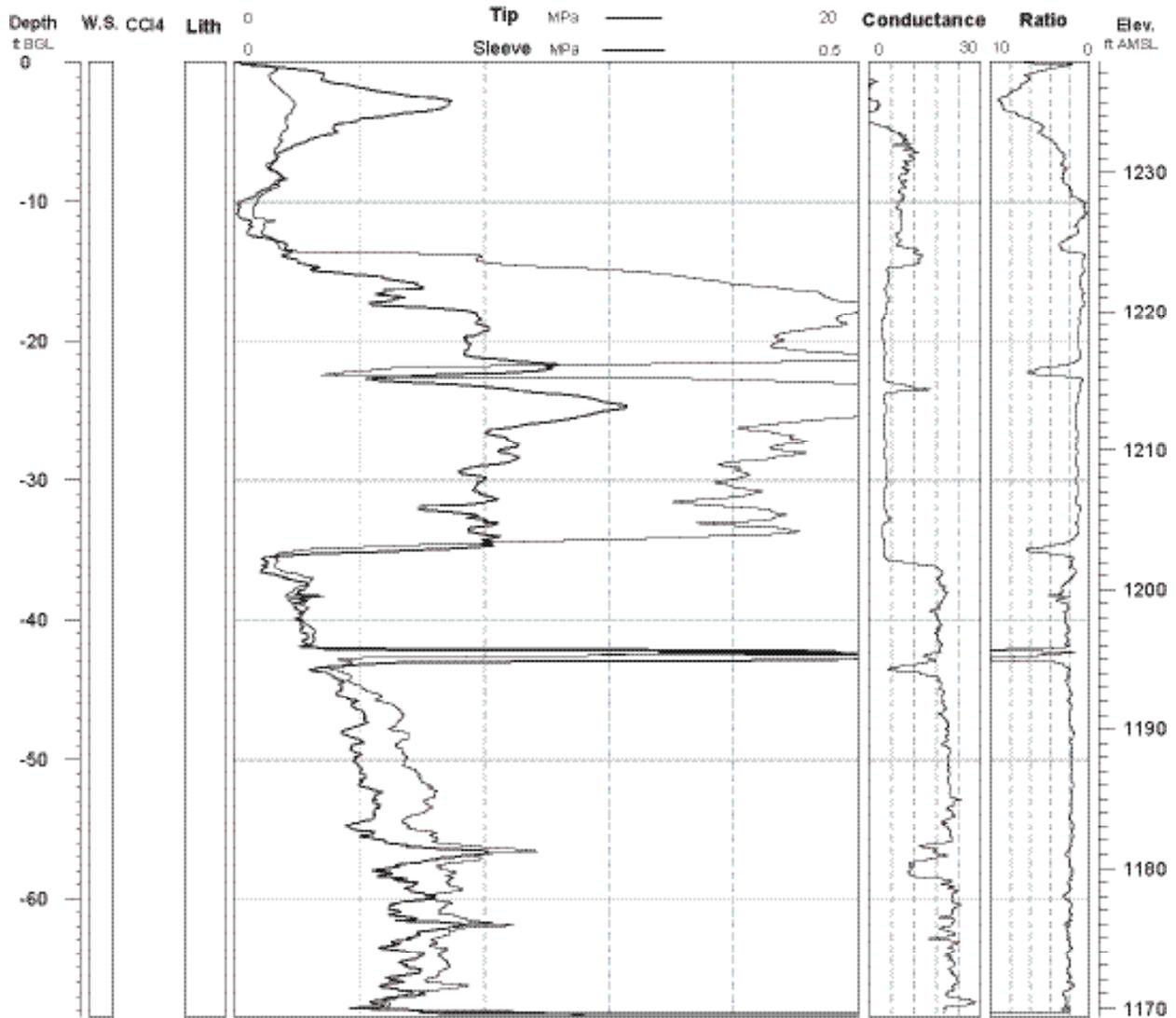
**Geologist: Lorraine LaFreniere**

**Depth: 68.37 ft.**

**Plot Date: 04/06/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



**Argonne National Laboratory**

**Well ID: SB83**

**Project: Murdock T.I.**

**Elevation: 1275.79 ft.**

**Log Date: 04/06/2004**

**Rig: 40-ton truck**

**Geologist: Lorraine LaFreniere**

**Depth: 90.35 ft.**

**Driller: Travis & Daryl**

**Company: Argonne**

**Cored Interval: 50' to 54' and 60' to 63' BGL**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

Argonne National Laboratory

Boring ID: SB83

Project: Murdock T.I.

Elevation: 1275.79 ft.

Log Date: 04/06/2004

Rig: 40-ton truck

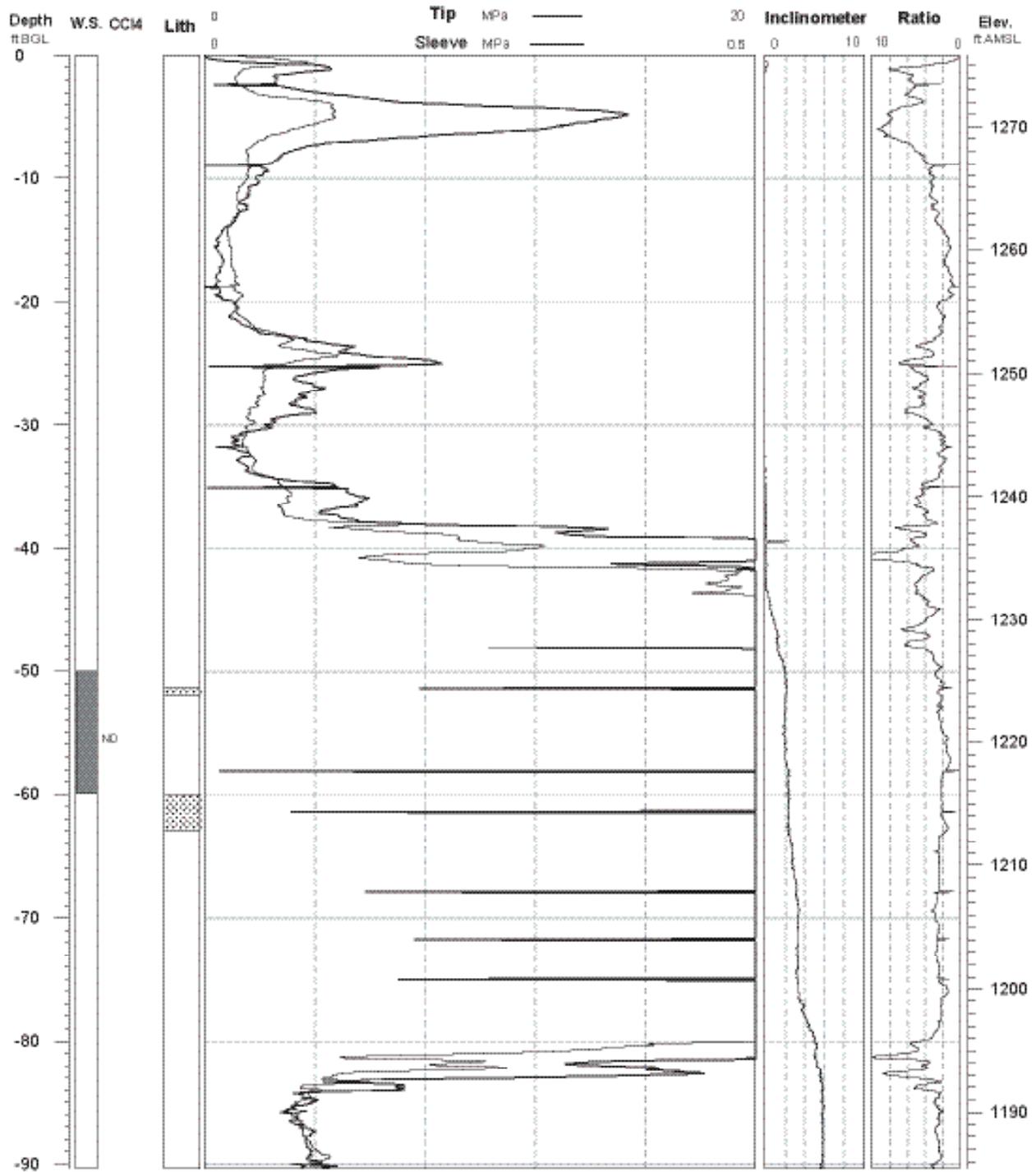
Geologist: Lorraine LaFreniere

Depth: 90.35 ft.

Plot Date: 04/07/2004

Driller: Travis & Daryl

Company: Argonne



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

### Argonne National Laboratory

Boring ID: SB84

Project: Murdock T.I.

Elevation: 1274.77 ft.

Log Date: 04/07/2004

Rig: CPT

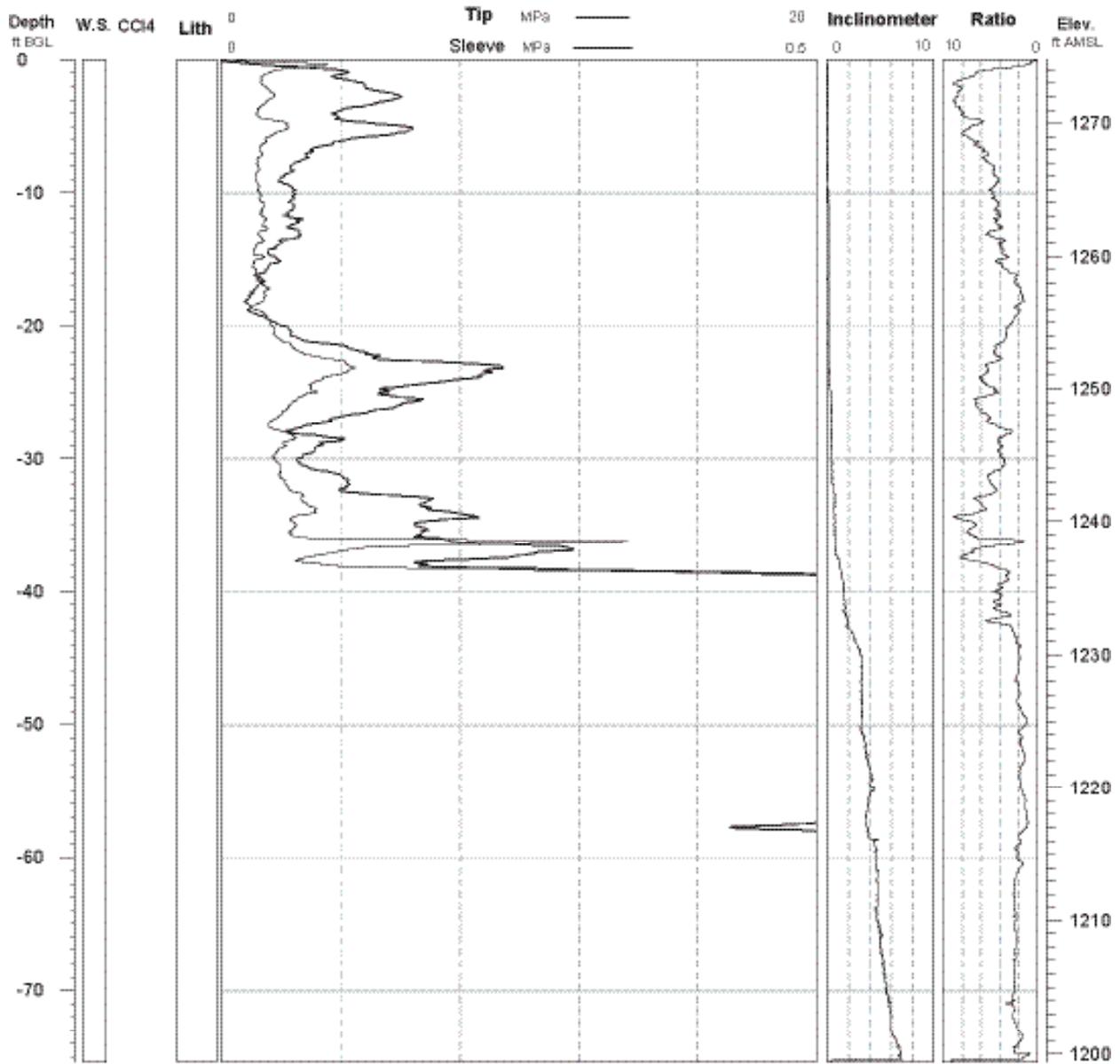
Geologist: Lorraine LaFreniere

Depth: 75.39 ft.

Plot Date: 04/08/2004

Driller: Travis & Daryl

Company: Argonne



**Argonne National Laboratory**

**Boring ID: SB85**

**Project: Murdock T.I.**

**Elevation: 1280.50 ft. est.**

**Log Date: 06/28/2004**

**Rig: CPT**

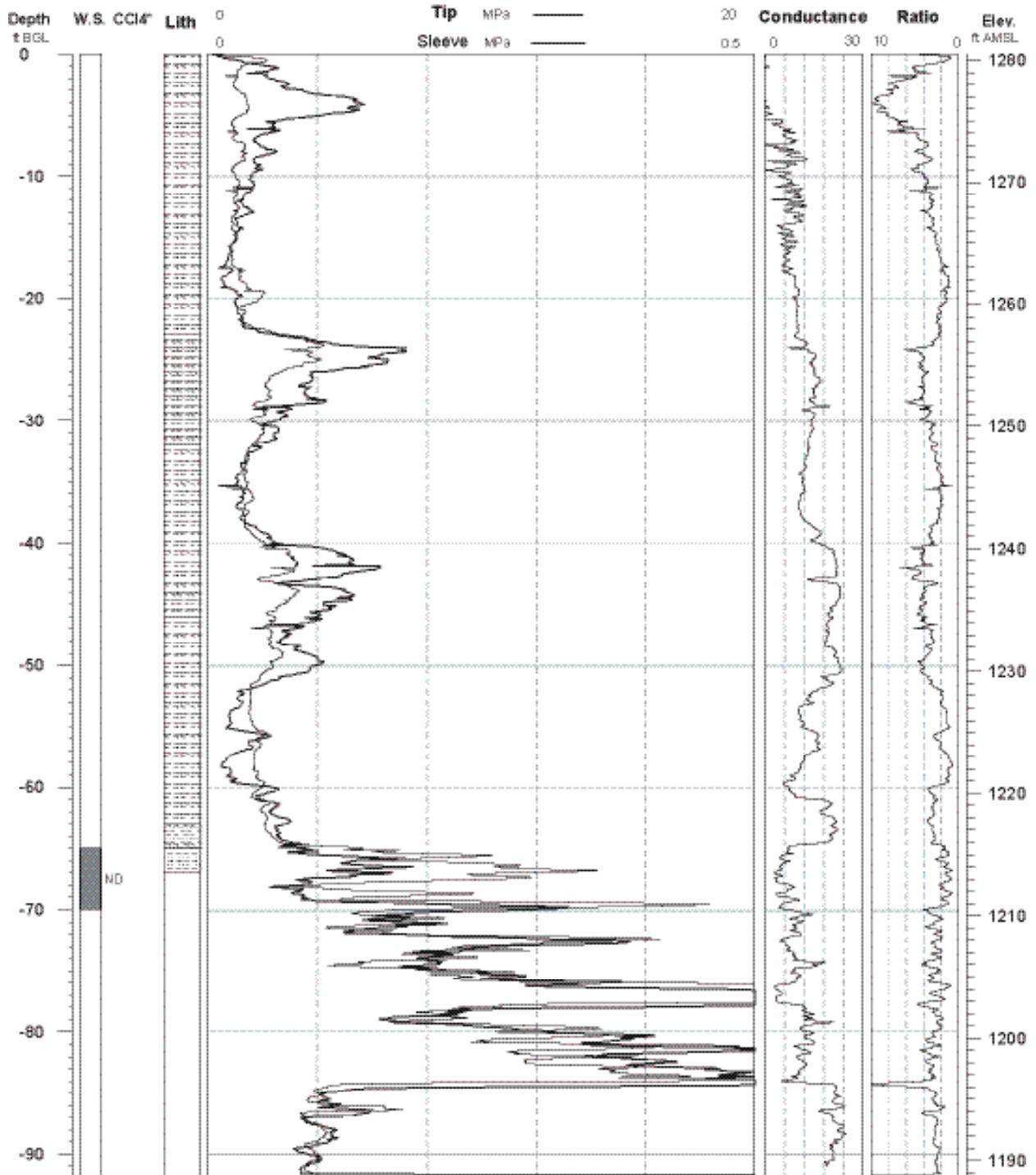
**Geologist: Lorraine LaFreniere**

**Depth: 91.86 ft.**

**Plot Date: 06/29/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

\*See Appendix B, Tables B.2 and B.3, for descriptions of and analytical results for vadose-zone soil samples.

**Argonne National Laboratory**

**Boring ID: SB86**

**Project: Murdock T.I.**

**Elevation: 1280.5 ft. est.**

**Log Date: 06/29/2004**

**Rig: CPT**

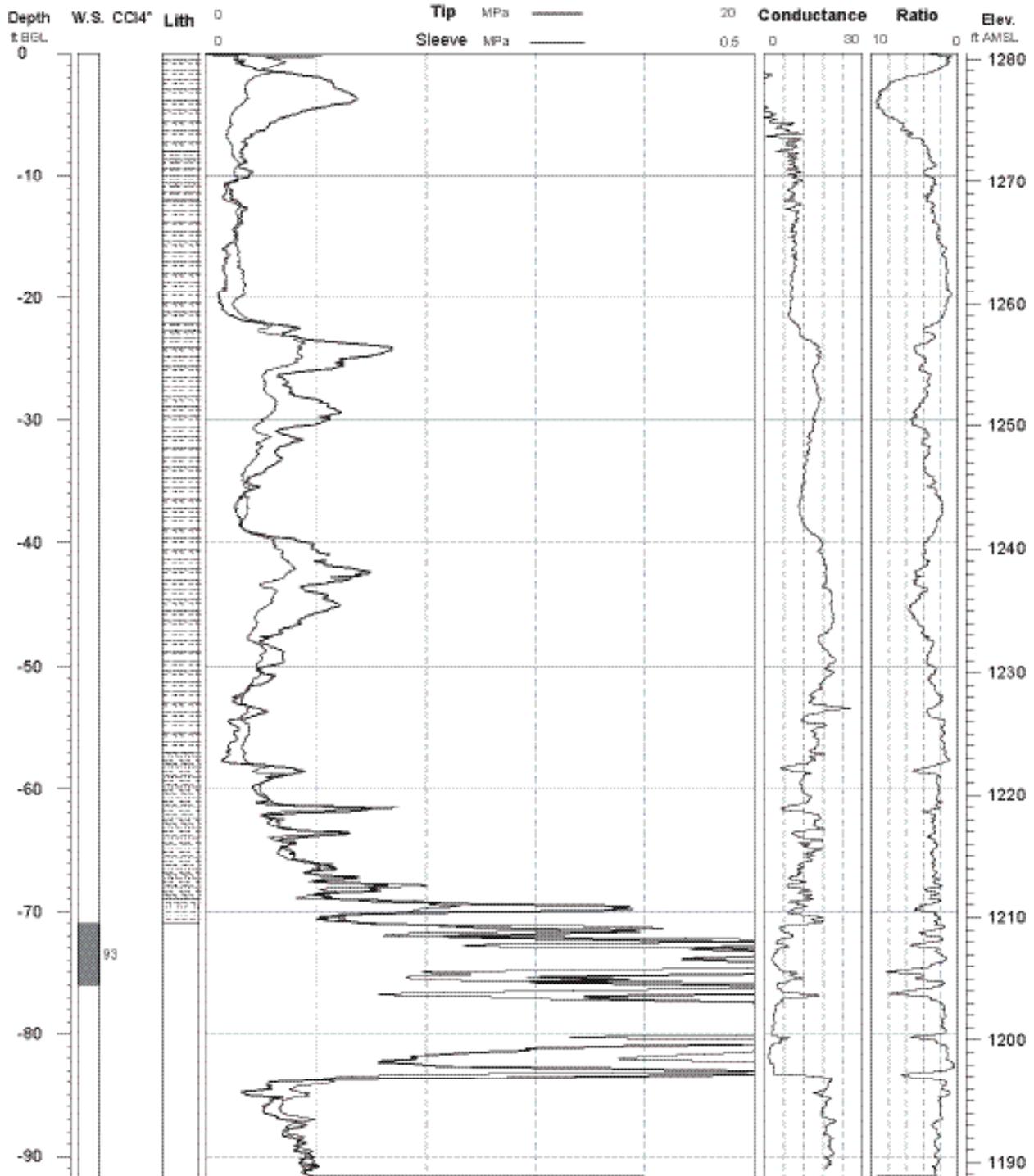
**Geologist: Lorraine LaFreniere**

**Depth: 91.86 ft.**

**Plot Date: 06/30/2004**

**Driller: Travis & Daryl**

**Company: Argonne**



Carbon tetrachloride in water sample =  $\mu\text{g/L}$

\*See Appendix B, Tables B.2 and B.3, for descriptions of and analytical results for vadose-zone soil samples.

**Appendix B:**  
**Soil Sample Data**

TABLE B.1 Carbon tetrachloride and chloroform concentrations in near-surface soil samples collected to determine the contaminant distribution across the former CCC/USDA facility during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/kg)			
				Headspace Analysis <sup>a</sup>		Purge-and-Trap Analysis <sup>b</sup>	
				Carbon Tetrachloride	Chloroform	Carbon Tetrachloride	Chloroform
HC01	MUHC01T-S-17058	1	5/25/04	3.5	ND <sup>c</sup>	ND	ND
HC01	MUHC01B-S-17059	3	5/25/04	1.8	ND	ND	ND
HC02	MUHC02T-S-17060	1	5/25/04	1.7	0.9	ND	ND
HC02	MUHC02B-S-17061	3	5/25/04	0.4	ND	ND	ND
HC03	MUHC03T-S-17062	1	5/25/04	ND	ND	ND	ND
HC03	MUHC03B-S-17063	3	5/25/04	ND	ND	ND	ND
HC04	MUHC04T-S-17064	1	5/25/04	ND	ND	ND	ND
HC04	MUHC04B-S-17065	3	5/25/04	ND	ND	ND	ND
HC05	MUHC05T-S-17066	1	5/25/04	ND	ND	ND	ND
HC05	MUHC05B-S-17067	3	5/25/04	ND	ND	ND	ND
HC06	MUHC06T-S-17068	1	5/25/04	ND	ND	ND	ND
HC06	MUHC06B-S-17069	3	5/25/04	ND	ND	ND	ND
HC07	MUHC07T-S-17070	1	5/25/04	ND	ND	ND	ND
HC07	MUHC07B-S-17071	3	5/25/04	ND	ND	ND	ND
HC08	MUHC08T-S-17072	1	5/25/04	ND	ND	ND	ND
HC08	MUHC08B-S-17073	3	5/25/04	ND	ND	ND	ND
HC09	MUHC09T-S-17074	1	5/25/04	0.4	ND	ND	ND
HC09	MUHC09B-S-17075	3	5/25/04	ND	ND	ND	ND
HC10	MUHC10T-S-17076	1	5/25/04	0.6	ND	ND	ND
HC10	MUHC10B-S-17077	3	5/25/04	2.6	ND	ND	ND
HC11	MUHC11T-S-17078	1	5/25/04	1.2	ND	ND	ND
HC11	MUHC11B-S-17079	3	5/25/04	1.0	ND	ND	ND
HC12	MUHC12T-S-17080	1	5/25/04	1.5	ND	ND	ND
HC12	MUHC12B-S-17081	3	5/25/04	0.7	ND	ND	ND
HC13	MUHC13T-S-17082	1	5/25/04	0.9	ND	ND	ND
HC13	MUHC13B-S-17083	3	5/25/04	0.6	ND	ND	ND
HC14	MUHC14T-S-17084	1	5/25/04	2.9	ND	ND	ND
HC14	MUHC14B-S-17085	3	5/25/04	2.0	ND	ND	ND
HC15	MUHC15T-S-17086	1	5/25/04	3.9	ND	ND	ND
HC15	MUHC15B-S-17087	3	5/25/04	3.1	ND	ND	ND
HC16	MUHC16T-S-17088	1	5/25/04	1.2	ND	ND	ND
HC16	MUHC16B-S-17089	3	5/25/04	0.6	ND	ND	ND
HC17	MUHC17T-S-17090	1	5/25/04	1.5	ND	ND	ND
HC17	MUHC17B-S-17091	3	5/25/04	1.9	ND	ND	ND
HC18	MUHC18T-S-17092	1	5/26/04	ND	0.9	ND	ND
HC18	MUHC18B-S-17093	3	5/26/04	ND	ND	ND	ND
HC19	MUHC19T-S-17094	1	5/26/04	ND	ND	ND	ND
HC19	MUHC19B-S-17095	3	5/26/04	1.6	0.9	ND	ND
HC20	MUHC20T-S-17096	1	5/26/04	0.7	ND	ND	ND
HC20	MUHC20B-S-17097	3	5/26/04	1.3	ND	ND	ND
HC21	MUHC21T-S-17098	1	5/26/04	ND	ND	ND	ND
HC21	MUHC21B-S-17099	3	5/26/04	ND	ND	ND	ND
HC22	MUHC22T-S-17100	1	5/26/04	2.8	ND	ND	ND
HC22	MUHC22B-S-17101	3	5/26/04	2.0	ND	ND	ND
HC23	MUHC23T-S-17102	1	5/26/04	ND	ND	ND	ND
HC23	MUHC23B-S-17103	3	5/26/04	ND	ND	ND	ND
HC24	MUHC24T-S-17104	1	5/26/04	ND	ND	ND	ND
HC24	MUHC24B-S-17105	3	5/26/04	ND	ND	ND	ND
HC25	MUHC25T-S-17106	1	5/26/04	ND	ND	ND	ND
HC25	MUHC25B-S-17107	3	5/26/04	ND	ND	ND	ND

TABLE B.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/kg)			
				Headspace Analysis <sup>a</sup>		Purge-and-Trap Analysis <sup>b</sup>	
				Carbon Tetrachloride	Chloroform	Carbon Tetrachloride	Chloroform
HC26	MUHC26T-S-17108	1	5/26/04	ND	ND	ND	ND
HC26	MUHC26B-S-17109	3	5/26/04	ND	ND	ND	ND
HC27	MUHC27T-S-17110	1	5/26/04	ND	ND	ND	ND
HC27	MUHC27B-S-17111	3	5/26/04	ND	ND	ND	ND
HC28	MUHC28T-S-17112	1	5/26/04	ND	ND	ND	ND
HC28	MUHC28B-S-17113	3	5/26/04	ND	ND	ND	ND
HC29	MUHC29T-S-17114	1	5/26/04	ND	ND	ND	ND
HC29	MUHC29B-S-17115	3	5/26/04	ND	ND	ND	ND
HC30	MUHC30T-S-17116	1	5/26/04	ND	ND	ND	ND
HC30	MUHC30B-S-17117	3	5/26/04	ND	ND	ND	ND
HC31	MUHC31T-S-17118	1	5/26/04	0.7	ND	ND	ND
HC31	MUHC31B-S-17119	3	5/26/04	0.9	ND	ND	ND
HC32	MUHC32T-S-17120	1	5/26/04	3.6	ND	ND	ND
HC32	MUHC32B-S-17121	3	5/26/04	2.5	ND	ND	ND
HC33	MUHC33T-S-17122	1	5/26/04	4.3	ND	ND	ND
HC33	MUHC33B-S-17123	3	5/26/04	0.7	ND	ND	ND
HC34	MUHC34T-S-17124	1	5/26/04	1.5	ND	ND	ND
HC34	MUHC34B-S-17125	3	5/26/04	1.4	ND	ND	ND
HC35	MUHC35T-S-17126	1	5/26/04	2.9	ND	ND	ND
HC35	MUHC35B-S-17127	3	5/26/04	ND	ND	ND	ND
HC36	MUHC36T-S-17128	1	5/26/04	ND	ND	ND	ND
HC36	MUHC36B-S-17129	3	5/26/04	ND	ND	ND	ND
HC37	MUHC37T-S-17130	1	5/26/04	3.5	ND	ND	ND
HC37	MUHC37B-S-17131	3	5/26/04	0.8	ND	ND	ND
HC38	MUHC38T-S-17132	1	5/26/04	0.9	ND	ND	ND
HC38	MUHC38B-S-17133	3	5/26/04	0.3	ND	ND	ND
HC39	MUHC39T-S-17134	1	5/26/04	0.5	ND	ND	ND
HC39	MUHC39B-S-17135	3	5/26/04	0.5	ND	ND	ND
HC40	MUHC40T-S-17136	1	5/26/04	0.4	ND	ND	ND
HC40	MUHC40B-S-17137	3	5/26/04	ND	ND	ND	ND
HC41	MUHC41T-S-17138	1	5/26/04	ND	ND	ND	ND
HC41	MUHC41B-S-17139	3	5/26/04	ND	ND	ND	ND
HC42	MUHC42T-S-17140	1	5/27/04	0.7	ND	ND	ND
HC42	MUHC42B-S-17141	3	5/27/04	0.4	ND	ND	ND
HC43	MUHC43T-S-17142	1	5/27/04	2.0	2.2	ND	ND
HC43	MUHC43B-S-17143	3	5/27/04	0.9	ND	ND	ND
HC44	MUHC44T-S-17144	1	5/27/04	3.6	ND	ND	ND
HC44	MUHC44B-S-17145	3	5/27/04	1.4	ND	ND	ND
HC45	MUHC45T-S-17146	1	5/27/04	0.4	ND	ND	ND
HC45	MUHC45B-S-17147	3	5/27/04	0.4	ND	ND	ND
HC46	MUHC46T-S-17148	1	5/27/04	1.2	ND	ND	ND
HC46	MUHC46B-S-17149	3	5/27/04	1.0	ND	ND	ND
HC47	MUHC47T-S-17150	1	5/27/04	5.2	ND	ND	ND
HC47	MUHC47B-S-17151	3	5/27/04	2.3	ND	ND	ND
HC48	MUHC48T-S-17152	1	5/27/04	7.1	ND	ND	ND
HC48	MUHC48B-S-17153	3	5/27/04	5.6	ND	ND	ND
HC49	MUHC49T-S-17154	1	5/27/04	0.6	ND	ND	ND
HC49	MUHC49B-S-17155	3	5/27/04	0.7	ND	ND	ND
HC50	MUHC50T-S-17156	1	5/27/04	4.5	ND	ND	ND
HC50	MUHC50B-S-17157	3	5/27/04	0.9	ND	ND	ND
HC51	MUHC51T-S-15663	1	5/27/04	1.5	1.8	ND	ND

TABLE B.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/kg)			
				Headspace Analysis <sup>a</sup>		Purge-and-Trap Analysis <sup>b</sup>	
				Carbon Tetrachloride	Chloroform	Carbon Tetrachloride	Chloroform
HC51	MUHC51B-S-15664	3	5/27/04	1.6	ND	ND	ND
HC52 <sup>d</sup>	MUHC52-S-17188	1	6/30/04	25	1	ND	ND
HC52 <sup>d</sup>	MUHC52-S-17189	3	6/30/04	5.1	ND	ND	ND
HC53 <sup>e</sup>	MUHC53-S-17190	1	6/30/04	0.4	ND	ND	ND
HC53 <sup>e</sup>	MUHC53-S-17191	3	6/30/04	0.8	ND	ND	ND
HC54	MUHC54-S-15589	1	6/30/04	1.9	ND	ND	ND
HC54	MUHC54-S-15590	3	6/30/04	4.6	ND	ND	ND
HC55	MUHC55-S-15591	1	6/30/04	0.5	ND	ND	ND
HC55	MUHC55-S-15592	3	6/30/04	0.4	ND	ND	ND
HC56	MUHC56-S-17179	1	6/30/04	0.8	ND	ND	ND
HC56	MUHC56-S-17180	3	6/30/04	1.4	ND	ND	ND
HC57	MUHC57-S-17181	1	6/30/04	0.8	ND	ND	ND
HC57	MUHC57-S-17182	3	6/30/04	1	ND	ND	ND

<sup>a</sup> The reporting limit for the qualitative headspace analysis is 0.2 µg/kg for carbon tetrachloride and 0.75 µg/kg for chloroform.

<sup>b</sup> The quantitation limit for purge and trap analysis is 10 µg/kg.

<sup>c</sup> N D , contaminant not detected at the appropriate quantitation limit.

<sup>d</sup> HC52 is the same location as SB85 (Tables B.2–B.4).

<sup>e</sup> HC53 is the same location as SB86 (Tables B.2–B.4).

TABLE B.2 Subsurface soil samples collected at locations SB85 and SB86 during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Description
SB85	MUSB85-S-17208	3	6/28/04	Clay, silty, dark brown, noncalcareous, plastic, damp. 85% recovery.
SB85	MUSB85-S-17209	5	6/28/04	As above, damp.
SB85	MUSB85-S-17210	7	6/28/04	Clay, silty, with trace of medium grained sand. Moist, very plastic, with iron oxide inclusions.
SB85	MUSB85-S-17211	9	6/28/04	Clay, silty, damp, plastic, brown, noncalcareous. Selective oxidation associated with occasional sand grains.
SB85	MUSB85-S-17212	11	6/28/04	As above with slight increase in silt content, damp to moist, noncalcareous.
SB85	MUSB85-S-17213	13	6/28/04	Clay, silty, damp to moist, plastic, brown, noncalcareous, with less evidence of oxidation.
SB85	MUSB85-S-17214	15	6/28/04	Clay, silty, moist, plastic, noncalcareous, with evidence of selective oxidation associated with occasional fine to medium grained sand.
SB85	MUSB85-S-17215	17	6/28/04	Very moist silty clay, coarse silt, with evidence of minor selective oxidation associated with medium to coarse sand grains. Brown, highly plastic.
SB85	MUSB85-S-17216	19	6/28/04	As above, with slight increase in grain size. Clay, very silty, coarse silt to very fine sand, moist, highly plastic, noncalcareous, with selective oxidation as above.
SB85	MUSB85-S-17217	21	6/28/04	Clay, silty, damp, plastic, noncalcareous, brown.
SB85	MUSB85-S-17218	23	6/28/04	Clay to clayey silt, damp to dry, nonplastic, with minor clay content. Coarse silt, brown.
SB85	MUSB85-S-17219	25	6/28/04	Silt, clayey with occasional sand. Heavily oxidized, nonplastic, slightly damp sand, yellowish brown.
SB85	MUSB85-S-17220	27	6/28/04	Clayey silt to very silty clay, slightly plastic, slightly damp, yellowish brown, with some reduction in oxidation.
SB85	MUSB85-S-17221	29	6/28/04	Silt, clay with minor sand, oxidized, damp, with low plasticity. Noncalcareous, yellow-brown.
SB85	MUSB85-S-17222	31	6/28/04	As above with marked increase in sand. Very silty clay with fine to medium grained angular to subangular sand, mixed lithology, yellowish brown.
SB85	MUSB85-S-17223	33	6/28/04	Clay, silty with sand, with moderate plasticity. Noncalcareous. Fine to medium grained sand throughout, damp to moist, dark yellowish brown.
SB85	MUSB85-S-17224	35	6/28/04	As above with decreased sand content. Fine grained sand predominates.
SB85	MUSB85-S-17225	37	6/28/04	Clay, silty with minor fine sand. Moderate plasticity, damp to moist, noncalcareous, dark yellowish brown.
SB85	MUSB85-S-17226	39	6/28/04	Clay, very silty with trace granular gravel (angular) and minor fine to medium sand. Noncalcareous, damp, brown. Reduction in plasticity as silt content increases.
SB85	MUSB85-S-17227	41	6/28/04	Clay, very silty with minor fine to medium grained sand and trace of granular gravel. Low plasticity. Damp, noncalcareous, dark yellowish brown.
SB85	MUSB85-S-17228	43	6/28/04	As above with slight increase in fine to medium sand, yellowish brown.
SB85	MUSB85-S-17229	45	6/28/04	Silt, clayey, damp. Noncalcareous, nonplastic, brown. Minor constituent of weathered granules, heavily oxidized.
SB85	MUSB85-S-17230	47	6/28/04	Very silty clay with fine to medium grained sand throughout. Noncalcareous with low plasticity, brown.
SB85	MUSB85-S-17231	49	6/28/04	Silty clay with minor fine to medium grained sand (minor). Moderate plasticity, noncalcareous, damp, yellowish brown.
SB85	MUSB85-S-17232	51	6/28/04	As above. Highly plastic, moist, noncalcareous, yellowish brown. Slight increase in sand content.
SB85	MUSB85-S-17233	53	6/28/04	Very sandy, silty clay. Abundant fine to medium sand, mixed lithology, subrounded. Noncalcareous, damp.

TABLE B.2 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
SB85	MUSB85-S-17234	55	6/28/04	Silt, clayey to silty clay, with sand. Noncalcareous, moist, very pale brown, slight plasticity.
SB85	MUSB85-S-17235	57	6/28/04	Clay, silty with sand, very moist to wet. Noncalcareous, fine sand, well sorted, moderate plasticity, pale brown.
SB85	MUSB85-S-17236	59	6/28/04	Clay, sandy with silt. Nonplastic. Crumbly, damp, pale brown.
SB85	MUSB85-S-17237	61	6/28/04	Clay, silty with fine to medium grained sand. Noncalcareous, yellowish brown, damp.
SB85	MUSB85-S-17238	63	6/28/04	Transition to very fine clayey sand. Well sorted, damp, light brownish gray.
SB85	MUSB85-S-17239	65	6/28/04	Wet silty sand, very fine to fine grained. Subangular to subrounded, poorly sorted, pale brown.
SB85	MUSB85-S-17240	67	6/28/04	Wet silty sand to sandy silt. Sand very fine to fine grained, subangular to subrounded, very poorly sorted, pale brown. Wet saturated sand at base of recovered sequence.
SB86	MUSB86-S-17244	3	6/29/04	Clay, silty, noncalcareous, moderate plasticity, damp, dark grayish brown.
SB86	MUSB86-S-17242	5	6/29/04	Very silty clay, damp. Noncalcareous, low to moderate plasticity, dark grayish brown. Two colors of soil in sample were analyzed at AGEM Laboratory as composite by purge-and-trap method but separately by the headspace method.
SB86	MUSB86-S-17242-A	5	6/29/04	Sample identification for headspace analysis of light brown portion of sample.
SB86	MUSB86-S-17242-B	5	6/29/04	Sample identification for headspace analysis of black portion of sample.
SB86	MUSB86-S-17243	7	6/29/04	Clay, silty, noncalcareous, with minor evidence of fine sand. Moderate plasticity, damp, dark grayish brown. Evidence of selective oxidation.
SB86	MUSB86-S-17245	9	6/29/04	Very clayey silt, low plasticity, damp, brown. Noncalcareous with evidence of selective oxidation.
SB86	MUSB86-S-17246	11	6/29/04	As above, damp.
SB86	MUSB86-S-17247	13	6/29/04	Clay, very silty, damp, noncalcareous.
SB86	MUSB86-S-17248	15	6/29/04	Very silty clay, low to moderate plasticity, noncalcareous, brown.
SB86	MUSB86-S-17249	17	6/29/04	Clay, silty with sand, very moist, noncalcareous, moderate to good plasticity, brown.
SB86	MUSB86-S-17250	19	6/29/04	Clay, silty, moist, noncalcareous. Evidence of selective oxidation associated with iron-oxide-coated grains (coarse). Moderate to good plasticity.
SB86	MUSB86-S-17251	21	6/29/04	Clay, silty with sand, damp to moist, noncalcareous. Selective oxidation associated with medium grained sand inclusions. Moderate to good plasticity, dark grayish brown.
SB86	MUSB86-S-17252	23	6/29/04	Silt, very clayey, highly oxidized, dry to damp, crumbly in appearance. Nonplastic matrix clays, brown with strong brown oxidized areas.
SB86	MUSB86-S-17253	25	6/29/04	Clay, very silty, heavy oxidation associated with sand grains, matrix clays, brown with strong brown oxidized areas. Low plasticity, damp.
SB86	MUSB86-S-17254	27	6/29/04	As above with heavy oxidation, damp.
SB86	MUSB86-S-17255	29	6/29/04	Clay, very silty noncalcareous, damp, low to moderate plasticity. Less oxidized than overlying material. Matrix clays, yellowish brown.
SB86	MUSB86-S-17256	31	6/29/04	Very silty clay with sand, fine to medium grained, mixed lithology with sand throughout matrix. Low plasticity, yellowish brown, oxidized.
SB86	MUSB86-S-17257	33	6/29/04	Clay, silty with sand, damp to moist sand (10–15%). Moderate plasticity, noncalcareous, selective oxidation.
SB86	MUSB86-S-17158	35	6/29/04	As above, dark yellowish brown.

TABLE B.2 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
SB86	MUSB86-S-17159	37	6/29/04	Silty clay with minor sand, moderate to high plasticity, damp to moist, noncalcareous, brown.
SB86	MUSB86-S-17160	39	6/29/04	Silty clay with sand (7–10%). Low plasticity, damp, noncalcareous. Selective oxidation, black oxidation associated with larger grains, brown to strong brown.
SB86	MUSB86-S-17161	41	6/29/04	Clay, very silty with sand and trace heavily oxidized medium grained sand. Damp to dry, crumbly, low to no plasticity. Noncalcareous, oxidized, dark brown, damp.
SB86	MUSB86-S-17162	43	6/29/04	Very silty clay with sand and trace of heavily oxidized medium grained sand, trace granular gravel. Noncalcareous, damp, brown.
SB86	MUSB86-S-17163	45	6/29/04	Clay, silty with sand. Sand medium grained, angular to subangular, quartz. Damp, brown, oxidized.
SB86	MUSB86-S-17164	47	6/29/04	Clay, silty with sand and trace granular gravel. Damp, selectively oxidized, noncalcareous, brown, medium grained sand heavily oxidized in part.
SB86	MUSB86-S-17165	49	6/29/04	Clay, silty with sand (sand 10%). High plasticity, damp, noncalcareous, brown.
SB86	MUSB86-S-17166	51	6/29/04	Clay, silty with sand, moist. High plasticity, marked reduction in silt and sand content, sand angular to subangular, medium grained. Increase in moisture. Brown with minor black oxidized.
SB86	MUSB86-S-17167	53	6/29/04	Clay, very silty with sand, medium grained. Moderate plasticity, damp to moist, pale brown.
SB86	MUSB86-S-17168	55	6/29/04	Clay, silty with sand, abundant fine grained sand. Very moist, pale brown, noncalcareous.
SB86	MUSB86-S-17169	57	6/29/04	Sandy clay, moist to wet, fine sand, well sorted throughout clay matrix. Moderate plasticity, noncalcareous, pale brown.
SB86	MUSB86-S-17170	59	6/29/04	Clayey sand, moist (sand 75%). Change in character of the sand. Fine to coarse sand, subangular, mixed lithology including feldspars. Sand in inclusions in part, brown to pale brown, noncalcareous, crumbly in parts.
SB86	MUSB86-S-17171	61	6/29/04	Sand, very clayey. Sand fine to coarse grained as above. Moist, low plasticity, brown to pale brown.
SB86	MUSB86-S-17172	63	6/29/04	Sand, clayey with silt to sand. Damp, nonplastic, noncalcareous. Trace oxidation, yellowish brown.
SB86	MUSB86-S-17173	65	6/29/04	Sand, silty with clay. Fine to coarse grained sand. Damp to moist, low plasticity to nonplastic. Noncalcareous, yellowish brown, mottled in appearance.
SB86	MUSB86-S-17174	67	6/29/04	Color change. Markedly less oxidation. Sand, clayey. Sand predominates, fine to very fine grained, damp, brown.
SB86	MUSB86-S-17175	69	6/29/04	Sand, very silty. Fine to very fine grained, wet, light to yellowish brown.
SB86	MUSB86-S-17176	71	6/29/04	Sand with some clay. Very fine to fine grained, wet, light yellowish brown. Clay lenses in sand unit.

TABLE B.3 Results of carbon tetrachloride and chloroform analyses on subsurface soil samples collected during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Concentration ( $\mu\text{g}/\text{kg}$ )	
				Carbon Tetrachloride	Chloroform
HC57	MUHC57-S-17183	5	6/30/04	ND <sup>a</sup>	ND
HC57	MUHC57-S-17184	7	6/30/04	ND	ND
HC57	MUHC57-S-17185	9	6/30/04	ND	ND
HC57	MUHC57-S-17186	11	6/30/04	ND	ND
HC57	MUHC57-S-17187	13	6/30/04	ND	ND
HC57	MUHC57-S-17192	15	6/30/04	ND	ND
HC57	MUHC57-S-17193	17	6/30/04	ND	ND
HC57	MUHC57-S-17194	19	6/30/04	ND	ND
HC57	MUHC57-S-17195	21	6/30/04	ND	ND
SB85	MUSB85-S-17208	3	6/28/04	ND	ND
SB85	MUSB85-S-17209	5	6/28/04	ND	ND
SB85	MUSB85-S-17210	7	6/28/04	ND	ND
SB85	MUSB85-S-17211	9	6/28/04	ND	ND
SB85	MUSB85-S-17212	11	6/28/04	ND	ND
SB85	MUSB85-S-17213	13	6/28/04	ND	ND
SB85	MUSB85-S-17214	15	6/28/04	ND	ND
SB85	MUSB85-S-17215	17	6/28/04	ND	ND
SB85	MUSB85-S-17216	19	6/28/04	ND	ND
SB85	MUSB85-S-17217	21	6/28/04	16	ND
SB85	MUSB85-S-17218	23	6/28/04	13	ND
SB85	MUSB85-S-17219	25	6/28/04	84	ND
SB85	MUSB85-S-17220	27	6/28/04	232	ND
SB85	MUSB85-S-17221	29	6/28/04	361	ND
SB85	MUSB85-S-17222	31	6/28/04	303	ND
SB85	MUSB85-S-17223	33	6/28/04	223	ND
SB85	MUSB85-S-17224	35	6/28/04	52	ND
SB85	MUSB85-S-17225	37	6/28/04	ND	ND
SB85	MUSB85-S-17226	39	6/28/04	ND	ND
SB85	MUSB85-S-17227	41	6/28/04	ND	ND
SB85	MUSB85-S-17228	43	6/28/04	ND	ND
SB85	MUSB85-S-17229	45	6/28/04	ND	ND
SB85	MUSB85-S-17230	47	6/28/04	ND	ND
SB85	MUSB85-S-17231	49	6/28/04	18	ND
SB85	MUSB85-S-17232	51	6/28/04	189	ND
SB85	MUSB85-S-17233	53	6/28/04	154	ND
SB85	MUSB85-S-17234	55	6/28/04	140	ND
SB85	MUSB85-S-17235	57	6/28/04	86	ND
SB85	MUSB85-S-17236	59	6/28/04	ND	ND
SB85	MUSB85-S-17237	61	6/28/04	ND	ND
SB85	MUSB85-S-17238	63	6/28/04	ND	ND
SB85	MUSB85-S-17239	65	6/28/04	ND	ND
SB85	MUSB85-S-17240	67	6/28/04	ND	ND
SB86	MUSB86-S-17244	3	6/29/04	ND	ND
SB86	MUSB86-S-17242	5	6/29/04	ND	ND
SB86	MUSB86-S-17243	7	6/29/04	ND	ND
SB86	MUSB86-S-17245	9	6/29/04	ND	ND
SB86	MUSB86-S-17246	11	6/29/04	ND	ND
SB86	MUSB86-S-17247	13	6/29/04	ND	ND
SB86	MUSB86-S-17248	15	6/29/04	ND	ND
SB86	MUSB86-S-17249	17	6/29/04	ND	ND

TABLE B.3 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/kg)	
				Carbon Tetrachloride	Chloroform
SB86	MUSB86-S-17250	19	6/29/04	ND	ND
SB86	MUSB86-S-17251	21	6/29/04	ND	ND
SB86	MUSB86-S-17252	23	6/29/04	ND	ND
SB86	MUSB86-S-17253	25	6/29/04	ND	ND
SB86	MUSB86-S-17254	27	6/29/04	ND	ND
SB86	MUSB86-S-17255	29	6/29/04	ND	ND
SB86	MUSB86-S-17256	31	6/29/04	ND	ND
SB86	MUSB86-S-17257	33	6/29/04	ND	ND
SB86	MUSB86-S-17158	35	6/29/04	ND	ND
SB86	MUSB86-S-17159	37	6/29/04	ND	ND
SB86	MUSB86-S-17160	39	6/29/04	ND	ND
SB86	MUSB86-S-17161	41	6/29/04	ND	ND
SB86	MUSB86-S-17162	43	6/29/04	ND	ND
SB86	MUSB86-S-17163	45	6/29/04	ND	ND
SB86	MUSB86-S-17164	47	6/29/04	6.5 J <sup>b</sup>	ND
SB86	MUSB86-S-17165	49	6/29/04	10	ND
SB86	MUSB86-S-17166	51	6/29/04	10	ND
SB86	MUSB86-S-17167	53	6/29/04	14	ND
SB86	MUSB86-S-17168	55	6/29/04	12	ND
SB86	MUSB86-S-17169	57	6/29/04	21	ND
SB86	MUSB86-S-17170	59	6/29/04	15	ND
SB86	MUSB86-S-17171	61	6/29/04	7.3 J	ND
SB86	MUSB86-S-17172	63	6/29/04	ND	ND
SB86	MUSB86-S-17173	65	6/29/04	ND	ND
SB86	MUSB86-S-17174	67	6/29/04	ND	ND
SB86	MUSB86-S-17175	69	6/29/04	25	ND
SB86	MUSB86-S-17176	71	6/29/04	22	ND

<sup>a</sup> ND, not detected at the quantitation limit of 10 µg/kg for purge-and-trap analysis.

<sup>b</sup> J, estimated concentration below the quantitation limit of 10 µg/kg for the purge-and-trap method.

TABLE B.4 Soil property data for subsurface soil samples collected at SB85 during the 2004 targeted investigation at Murdock, Nebraska.

Location	Depth (ft BGL)	Bulk Dry Density (lb/ft <sup>3</sup> )	Moisture Content (%)	Specific Gravity	Porosity (%)	Total Organic Matter (%)	Carbon Content (%)
SB85	29–30	109.84	25.65	2.698	34.76	0.3	0.17
SB85	52–53	105.22	29.87	2.652	36.42	0.3	0.17

TABLE B.5 Particle size analysis results for subsurface soil samples collected at SB83 during the 2004 targeted investigation at Murdock, Nebraska.

Location	Depth (ft BGL)	Percent of Material Passing through Sieve Size												
		1 in.	3/4 in.	1/2 in.	3/8 in.	#4	#10	#18	#35	#40	#50	#60	#100	#200
SB83	51.4–52.0	100	100	100	100	100	100	100	100	99.9	97.9	90.3	22.7	7.9
SB83	60.0–63.0	100	100	100	100	100	100	100	100	99.9	98	89.5	26	9

**Appendix C:**  
**Coordinates Survey Data**

TABLE C.1 Coordinates survey data for the 2004 targeted investigation sampling locations at Murdock, Nebraska.

Location	Horizontal Location <sup>a</sup> (ft)		Elevation <sup>b</sup> (ft AMSL)	
	Northing	Easting	Representative Ground Surface	Reference <sup>c</sup>
<i>Existing locations</i>				
1D	418389.443	2666873.256		1280.550
1S	418397.295	2666873.690		1280.540
2D	419134.531	2667095.023		1280.520
2S	419130.993	2667097.971		1280.530
3D	419211.186	2667456.074		1278.110
3S	419210.871	2667461.491		1278.080
4D	419555.208	2667320.762		1281.540
4S	419555.078	2667314.790		1281.500
MW6	419428.097	2666823.878		1282.440
SB51D	420040.275	2666735.847	1284.970	1284.790
SB51S	420048.758	2666735.085	1284.660	1284.460
SB63D	420998.111	2665801.412	1257.860	1257.410
SB63S	420998.070	2665795.340	1258.000	1257.500
SB64D	421025.466	2666830.446	1269.690	1269.200
SB64M	421024.416	2666814.750	1269.140	1268.660
SB64S	421024.139	2666810.730	1268.960	1268.360
SB65D	421018.499	2666353.529	1260.330	1259.880
SB65S	421018.179	2666344.337	1260.690	1260.300
SB68	420417.445	2666387.683	1280.250	
SB69	420064.799	2666392.056	1283.320	
SB70	420049.253	2666187.556	1281.580	
SB71	419535.025	2666735.422	1281.880	
SB72	420310.619	2666828.110	1286.380	
WP44	420939.307	2666701.586	1269.190	1268.840
WP49	420049.845	2667118.110	1288.570	1288.240
WP54	419983.035	2666168.335	1282.380	1281.960
<i>New locations in 2004 targeted investigation</i>				
SB74	421548.700	2666025.144	1233.430	
SB75	421984.723	2665833.068	1223.350	
SB76	421436.907	2665636.152	1249.130	
SB77	422250.143	2665066.834	1229.650	
SB78	423001.066	2665029.247	1203.770	
SB79	422497.135	2665403.900	1209.820	
SB80	421659.121	2666444.174	1259.970	
SB81	422708.643	2666031.907	1241.060	
SB82	422156.763	2666291.558	1237.850	
SB83 <sup>d</sup>	419533.954	2666730.356	1281.880	
SB84 <sup>d</sup>	419533.307	2666473.794	1281.000	
SB85 <sup>e</sup>	419133.300	2667195.800	1280.500	
SB86 <sup>e</sup>	419122.500	2667106.000	1280.500	
TEST-1 <sup>e</sup>	419540.000	2666737.000		
GWEX-1 <sup>e</sup>	419776.000	2666470.000		

TABLE C.1 (Cont.)

Location	Horizontal Location <sup>a</sup> (ft)		Elevation <sup>b</sup> (ft AMSL)	
	Northing	Easting	Representative Ground Surface	Reference <sup>c</sup>
<i>New locations in 2004 targeted investigation (Cont.)</i>				
TD1	422177.815	2665721.765	1213.680	
TD2	422176.352	2665634.514	1213.330	
TD3	422165.147	2665484.232	1219.010	
TD4	422183.038	2665489.127	1218.450	
TD5	422668.810	2665359.161	1206.560	
TD6	423570.341	2664764.623	1196.160	
<i>Surface water sampling locations</i>				
SWP01	421582.508	2666018.838	1229.150	
SWP02	421602.101	2666004.128	1226.520	
SWP03	421660.372	2666003.476	1224.290	
SWP04	421736.767	2665956.505	1223.490	
SWP05	421799.425	2665916.357	1222.100	
SWSEEP <sup>d,e</sup>	421890.000	2665835.000	1222.000	
SWP06	422155.032	2665768.686	1214.240	
SWP08	422228.358	2665628.307	1210.990	
SWP09	422420.858	2665507.895	1207.830	
SWP10	422805.989	2665173.892	1204.410	
SWP11	423560.088	2664759.434	1194.080	
SWP12 <sup>f</sup>				
SWP13 <sup>d,e</sup>	421635.000	2666003.000	1225.000	
SWP14	422024.323	2665938.149	1223.440	
SWP15	422268.306	2665560.482	1209.660	
SWP16 <sup>d,e</sup>	422653.000	2665370.000	1206.000	

<sup>a</sup> Horizontal coordinates are target location centers. Northings and eastings are Nebraska State Plane Coordinates. Horizontal datum is North American Datum (NAD) 83.

<sup>b</sup> Vertical datum is National Geodetic Vertical Datum (NGVD) 88.

<sup>c</sup> Location for measurement of water level.

<sup>d</sup> Estimated elevation.

<sup>e</sup> Estimated location.

<sup>f</sup> Estimated location: 0.5 mi north of SWP11.

**Appendix D:**

**Hand-Measured Water Level Data**

TABLE D.1 Hand-measured water levels during the 2004 targeted investigation at Murdock, Nebraska.

Location	Elevation of TOC <sup>a</sup> (ft AMSL)	March 26, 2004			April 6, 2004			April 12, 2004		
		Time of Measurement	Measured Water Level (ft below TOC)	Static Water Level (ft AMSL)	Time of Measurement	Measured Water Level (ft below TOC)	Static Water Level (ft AMSL)	Time of Measurement	Measured Water Level (ft below TOC)	Static Water Level (ft AMSL)
1S	1280.54	_b	-	-	8:26	-	-	13:31	-	-
1D	1280.55	15:14	42.38	1238.17	8:26	42.26	1238.29	13:30	42.46	1238.09
2S	1280.53	15:35	42.60	1237.93	8:53	42.43	1238.10	13:06	42.60	1237.93
2D	1280.52	15:38	42.72	1237.80	8:54	42.51	1238.01	13:08	42.70	1237.82
3S	1278.08	NM <sup>c</sup>	NM	NM	8:43	38.44	1239.64	13:24	38.69	1239.39
3D	1278.11	NM	NM	NM	8:44	39.10	1239.01	13:22	39.11	1239.00
4S	1281.50	NM	NM	NM	9:04	36.70	1244.80	13:13	36.74	1244.76
4D	1281.54	NM	NM	NM	9:07	43.01	1238.53	13:15	43.21	1238.33
MW6	1282.44	15:06	45.08	1237.36	9:42	44.92	1237.52	13:01	45.10	1237.34
WP44	1268.84	14:17	33.74	1235.10	10:32	33.63	1235.21	12:07	33.78	1235.06
WP49	1288.24	14:31	51.44	1236.80	9:34	51.33	1236.91	12:35	51.50	1236.74
SB51S	1284.46	16:20	47.38	1237.08	9:23	47.58	1236.88	12:41	47.59	1236.87
SB51D	1284.79	16:17	47.89	1236.90	9:25	47.84	1236.95	12:42	47.98	1236.81
WP54	1281.96	16:27	45.42	1236.54	10:13	45.43	1236.53	12:50	45.50	1236.46
SB63S	1257.50	12:17	22.98	1234.52	11:04	22.74	1234.76	11:57	22.92	1234.58
SB63D	1257.41	12:22	22.90	1234.51	11:03	22.66	1234.75	11:55	22.85	1234.56
SB64S	1268.36	14:01	33.28	1235.08	10:41	33.18	1235.18	12:13	33.28	1235.08
SB64M	1268.66	14:03	33.56	1235.10	10:42	33.47	1235.19	12:11	33.57	1235.09
SB64D	1269.20	14:04	34.16	1235.04	10:43	34.05	1235.15	12:19	34.15	1235.05
SB65S	1260.30	12:31	25.84	1234.46	10:51	25.63	1234.67	11:46	25.79	1234.51
SB65D	1259.88	12:35	25.44	1234.44	10:54	25.24	1234.64	11:49	25.40	1234.48
SB74	1234.28	NM	NM	NM	11:35	2.15	1232.13	10:43	2.28	1232.00
SB75	1224.47	NM	NM	NM	11:30	2.49	1221.98	11:15	2.56	1221.91
SB76	1249.23	NM	NM	NM	11:40	17.31	1231.92	10:47	17.58	1231.65
SB77	1230.44	NM	NM	NM	11:17	4.12	1226.32	10:55	4.69	1225.75
SB80	1261.49	NM	NM	NM	11:53	28.71	1232.78	11:31	28.80	1232.69
SB81	1242.42	NM	NM	NM	12:04	14.52	1227.90	11:25	14.76	1227.66

<sup>a</sup> TOC, top of casing.

<sup>b</sup> Well was dry.

<sup>c</sup> Not measured.

**Appendix E:**  
**Groundwater Sample Data**

TABLE E.1 Groundwater samples collected to characterize the distribution of carbon tetrachloride during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Monitoring well samples</i>				
1S	MU1S-no sample	30.0–40.0	3/31/04	Well dry. Water level indicator struck mud. No sample collected.
1D	MU1D-W-15626	85.0–95.0	3/30/04	Depth to water from top of casing (TOC) = 42.49 ft. Depth of well = 95.10 ft. Sample collected after purging dry twice with slow recharge. Approximately 20 gal purged.
2S	MU2S-W-15596	70.5–80.5	3/31/04	Depth to water from TOC = 42.67 ft. Depth of well = 78.08 ft. Sample collected after purging approximately 69 gal. Purge water containerized.
2D	MU2D-W-15595	85.0–95.0	3/31/04	Depth to water from TOC = 43.00 ft. Depth of well = 95.80 ft. Sample collected after pumping dry and returning after recharge.
3S	MU3S-W-15631	64.0–74.0	3/30/04	Depth to water from TOC = 38.64 ft. Depth of well = 75.34 ft. Sample collected after purging approximately 23 gal.
3D	MU3D-W-15630	80.0–90.0	3/30/04	Depth to water from TOC = 38.08 ft. Depth of well = 90.34 ft. Sample collected after purging approximately 37 gal.
4S	MU4S-W-15629	30.0–40.0	3/30/04	Depth to water from TOC = 37.08 ft. Depth of well = 39.9 ft. Bailed dry after removing 0.5 gal. Returned later to collect sample without field measurements.
4D	MU4D-W-15628	80.0–90.0	3/30/04	Depth to water from TOC = 43.17 ft. Depth of well = 89.08 ft. Sample collected after purging approximately 23 gal.
MW06	MUMW06-W-15599	78.0–83.0	3/31/04	Depth to water from TOC = 45.11 ft. Depth of well = 80.75 ft. Sample collected after purging approximately 18 gal.
SB63S	MUSB63S-W-15601	23.0–38.0	3/31/04	Depth to water from TOC = 22.72 ft. Depth of well = 38.56 ft. Sample collected after purging approximately 9 gal.
SB63D	MUSB63D-W-15607	36.5–51.5	3/31/04	Depth to water from TOC = 22.66 ft. Depth of well = 51.13 ft. Sample collected after purging approximately 14 gal.
SB64S	MUSB64S-W-15600	30.0–50.0	3/31/04	Depth to water from TOC = 32.27 ft. Depth of well = 50.18 ft. Sample collected after purging approximately 10 gal.
SB64M	MUSB64M-W-15605	48.5–68.5	3/31/04	Depth to water from TOC = 33.55 ft. Depth of well = 68.55 ft. Sample collected after purging approximately 19 gal.
SB64D	MUSB64D-W-15606	67.0–87.0	3/31/04	Depth to water from TOC = 34.16 ft. Depth of well = 87.8 ft. Sample collected after purging approximately 90 gal.
SB65S	MUSB65S-W-15609	23.7–38.7	4/1/04	Depth to water from TOC = 25.67 ft. Depth of well = 39.84 ft. Sample collected after purging approximately 7 gal.

TABLE E.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Monitoring well samples (Cont.)</i>				
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/04	Depth to water from TOC = 25.29 ft. Depth of well = 54.70 ft. Sample collected after purging approximately 15 gal.
<i>FLUTE samples</i>				
SB68S	MUSB68S-W-15612	49.0–56.5	4/1/04	FLUTE sample.
SB68M	MUSB68M-W-15613	57.2–67.2	4/1/04	FLUTE sample.
SB68D	MUSB68D-W-15614	67.8–77.8	4/1/04	FLUTE sample.
SB69M	MUSB69M-W-15623	51.9–61.9	4/2/04	FLUTE sample.
SB69D	MUSB69D-W-15622	62.2–72.2	4/1/04	FLUTE sample.
SB70S	MUSB70S-W-15619	50.8–58.3	4/2/04	FLUTE sample.
SB70M	MUSB70M-W-15620	58.4–68.4	4/1/04	FLUTE sample.
SB70D	MUSB70D-W-15621	68.9–78.9	4/2/04	FLUTE sample.
SB71S	MUSB71S-W-15615	53.1–60.6	4/1/04	FLUTE sample.
SB71M	MUSB71M-W-15616	60.7–70.7	4/1/04	FLUTE sample.
SB71D	MUSB71D-W-15617	70.0–80.0	4/1/04	FLUTE sample.
SB72S	MUSB72S-no sample	49.0–56.5	4/2/04	FLUTE was dry; no sample collected.
SB72M	MUSB72M-W-15736	59.7–69.7	4/2/04	FLUTE sample.
SB72D	MUSB72D-W-15735	70.0–80.0	4/2/04	FLUTE sample.
<i>Cone penetrometer samples</i>				
SB74	MUSB74-W-15644	10.6–16.6	4/4/04	Upper part of aquifer unit. Abundant, immediate water. Low turbidity.
SB74	MUSB74-W-15645	16.6–22.6	4/4/04	Abundant, immediate water and rising rapidly.
SB75	MUSB75-W-15643	5.0–15.0	4/3/04	Set temporary sand point in silty clay interval. Water light gray-brown with moderate turbidity, settling quickly.
SB76	MUSB76-W-15635	22.0–30.0	4/2/04	Water immediately and rising rapidly. Moderately to slightly turbid, settling quickly. Upper 8 ft of aquifer at this location is downgradient from monitoring well SB63.
SB76	MUSB76-W-15638	30.0–38.0	4/2/04	Abundant water. Intermediate 8 ft of aquifer at this location.
SB76	MUSB76-W-15637	38.0–46.0	4/2/04	Abundant recovery. Slight to moderate turbidity. Lower 8 ft of aquifer at this location.

TABLE E.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Cone penetrometer samples (Cont.)</i>				
SB77	MUSB77-W-15640	14.0–22.0	4/3/04	Sampling entire 8-ft interval of lower sand aquifer.
SB79	MUSB79-W-15641	6.5–16.5	4/3/04	Sample derived from clay unit below aquifer (sand). Water level 21.6 ft and rising slowly. Dark with high turbidity and high suspended sediments.
SB80	MUSB80-W-15647	23.0–31.0	4/4/04	Upper sand unit. Water slightly turbid, light gray, with suspended sediment settling out rapidly.
SB80	MUSB80-W-15649	33.0–41.0	4/4/04	Abundant recovery. Light gray with light to moderate turbidity. Sediment in suspension settling quickly.
SB80	MUSB80-W-15648	41.0–46.0	4/4/04	Immediate water recovery, rapidly rising. Light gray with moderate turbidity. Sediment settling quickly.
SB80	MUSB80-W-15651	52.0–59.0	4/4/04	Abundant water, low turbidity.
SB81	MUSB81-W-15652	19.7–27.7	4/5/04	Abundant, immediate water. Slight turbidity, light gray silt.
SB81	MUSB81-W-15654	27.7–35.7	4/5/04	Abundant recovery. Very clear water, very low turbidity, gray silt.
SB83	MUSB83-W-15656	50.0–60.0	4/6/04	Light gray water. Sand settled out quickly.
SB84	MUSB84-no sample	38.0–41.0	4/7/04	No water recovered. Upper 4 ft of fine sand, saturated interval. Very difficult penetration with cone penetrometer
SB85	MUSB85-W-17241	65.0–70.0	6/28/04	Sample collected from top 5 ft of saturated/wet sand aquifer zone. Good water recovery.
SB86	MUSB86-W-17178	71.0–76.0	6/29/04	Sample collected from upper 5 ft of saturated sand unit. Ample water production.
TEST1	MUGWEXTEST-W-15594	60.0–65.0	6/28/04	Sample collected at test hole location for new GWEX well at school. Limited water available.

TABLE E.2 Field measurements during collection of groundwater samples in the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Temperature (°C)	pH	Conductivity (µS/cm)
1D	MU1D-W-15626	85.0–95.0	3/30/04	13.1	6.84	454
2S	MU2S-W-15596	70.5–80.5	3/31/04	14.2	6.42	534
2D	MU2D-W-15595	85.0–95.0	3/31/04	13.3	11.28	531
3S	MU3S-W-15631	64.0–74.0	3/30/04	13.6	6.29	519
3D	MU3D-W-15630	80.0–90.0	3/30/04	14.3	7.23	635
4S	MU4S-W-15629	30.0–40.0	3/30/04	NR <sup>a</sup>	NR	NR
4D	MU4D-W-15628	80.0–90.0	3/30/04	13.5	6.59	831
MW6	MUMW06-W-15599	78.0–83.0	3/31/04	14.6	6.55	601
SB63S	MUSB63S-W-15601	23.0–38.0	3/31/04	13.8	6.46	375
SB63D	MUSB63D-W-15607	36.5–51.5	3/31/04	13.1	6.40	347
SB64S	MUSB64S-W-15600	30.0–50.0	3/31/04	14.9	6.64	681
SB64M	MUSB64M-W-15605	48.5–68.5	3/31/04	13.8	6.56	914
SB64D	MUSB64D-W-15606	67.0–87.0	3/31/04	13.8	6.66	1,133
SB65S	MUSB65S-W-15609	23.7–38.7	4/1/04	13.5	6.19	410
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/04	13.2	6.58	492
SB68S	MUSB68S-W-15612	49.0–56.5	4/1/04	NR	NR	NR
SB68M	MUSB68M-W-15613	57.2–67.2	4/1/04	NR	NR	NR
SB68D	MUSB68D-W-15614	67.8–77.8	4/1/04	18.9	6.29	302
SB69M	MUSB69M-W-15623	51.9–61.9	4/2/04	NR	6.71	298
SB69D	MUSB69D-W-15622	62.2–72.2	4/1/04	14.7	6.77	606
SB70S	MUSB70S-W-15619	50.8–58.3	4/2/04	13.5	6.58	498
SB70M	MUSB70M-W-15620	58.4–68.4	4/1/04	13.3	6.60	529
SB70D	MUSB70D-W-15621	68.9–78.9	4/2/04	13.3	6.97	576
SB71S	MUSB71S-W-15615	53.1–60.6	4/1/04	14.7	6.33	348
SB71M	MUSB71M-W-15616	60.7–70.7	4/1/04	13.5	6.53	510
SB71D	MUSB71D-W-15617	70.0–80.0	4/1/04	13.6	6.57	656
SB72M	MUSB72M-W-15736	59.7–69.7	4/2/04	16.1	6.55	641
SB72D	MUSB72D-W-15735	70.0–80.0	4/2/04	13.2	6.64	721
SB74	MUSB74-W-15644	10.6–16.6	4/4/04	11.1	6.62	465
SB74	MUSB74-W-15645	16.6–22.6	4/4/04	11.8	6.65	521
SB75	MUSB75-W-15643	5.0–15.0	4/3/04	13.5	6.50	436
SB76	MUSB76-W-15635	22.0–30.0	4/2/04	14.9	6.68	628
SB76	MUSB76-W-15638	30.0–38.0	4/2/04	17.9	6.58	499
SB76	MUSB76-W-15637	38.0–46.0	4/2/04	14.5	6.68	441
SB77	MUSB77-W-15640	14.0–22.0	4/3/04	12.6	6.92	363
SB79	MUSB79-W-15641	6.5–16.5	4/3/04	10.8	7.00	741
SB80	MUSB80-W-15647	23.0–31.0	4/4/04	15.5	6.81	585
SB80	MUSB80-W-15649	33.0–41.0	4/4/04	17.2	6.80	677
SB80	MUSB80-W-15648	41.0–46.0	4/4/04	15.9	6.81	904
SB80	MUSB80-W-15651	52.0–59.0	4/4/04	16.2	6.76	941
SB81	MUSB81-W-15652	19.7–27.7	4/5/04	16.9	6.76	485
SB81	MUSB81-W-15654	27.7–35.7	4/5/04	15.8	7.04	541
SB83	MUSB83-W-15656	50.0–60.0	4/6/04	16.2	6.99	488
SB85	MUSB85-W-17241	65.0–70.0	6/28/04	NR	NR	NR
SB86	MUSB86-W-17178	71.0–76.0	6/29/04	NR	NR	NR
TEST1	MUGWEXTEST-W-15594	60.0–65.0	6/28/04	NR	NR	NR

<sup>a</sup> N R , not recorded.

TABLE E.3 Results of analyses of groundwater samples for volatile organic compounds in the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/L)			
				Carbon Tetrachloride	Chloroform	1,1,2-Tri- chloroethane	Tetra- chloroethene
<i>Monitoring well samples</i>							
1D	MU1D-W-15626	85.0–95.0	3/30/04	ND <sup>a</sup>	ND	ND	ND
2S	MU2S-W-15596	70.5–80.5	3/31/04	88	2.6	ND	ND
2D	MU2D-W-15595	85.0–95.0	3/31/04	2.8	5.1	ND	ND
3S	MU3S-W-15631	64.0–74.0	3/30/04	ND	ND	ND	ND
3D	MU3D-W-15630	80.0–90.0	3/30/04	ND	ND	ND	ND
4S	MU4S-W-15629	30.0–40.0	3/30/04	ND	ND	ND	ND
4D	MU4D-W-15628	80.0–90.0	3/30/04	ND	ND	ND	ND
MW6	MUMW06-W-15599	78.0–83.0	3/31/04	3.4	ND	ND	ND
SB63S	MUSB63S-W-15601	23.0–38.0	3/31/04	1.2	ND	ND	ND
SB63D	MUSB63D-W-15607	36.5–51.5	3/31/04	6.7	ND	ND	ND
SB64S	MUSB64S-W-15600	30.0–50.0	3/31/04	3.4	ND	ND	ND
SB64M	MUSB64M-W-15605	48.5–68.5	3/31/04	1.7	ND	ND	ND
SB64D	MUSB64D-W-15606	67.0–87.0	3/31/04	ND	ND	ND	ND
SB65S	MUSB65S-W-15609	23.7–38.7	4/1/04	1.4	ND	ND	ND
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/04	387	3.5	ND	ND
<i>FLUTe samples</i>							
SB68S	MUSB68S-W-15612	49.0–56.5	4/1/04	75	3.1	ND	ND
SB68M	MUSB68M-W-15613	57.2–67.2	4/1/04	991	14	ND	ND
SB68D	MUSB68D-W-15614	67.8–77.8	4/1/04	6.2	3.4	ND	ND
SB69M	MUSB69M-W-15623	51.9–61.9	4/2/04	467	9.3	ND	ND
SB69D	MUSB69D-W-15622	62.2–72.2	4/1/04	118	4.6	ND	ND
SB70S	MUSB70S-W-15619	50.8–58.3	4/2/04	190	5.8	ND	ND
SB70M	MUSB70M-W-15620	58.4–68.4	4/1/04	90	1.2	ND	ND
SB70D	MUSB70D-W-15621	68.9–78.9	4/2/04	ND	ND	ND	ND
SB71S	MUSB71S-W-15615	53.1–60.6	4/1/04	431	9.4	ND	ND
SB71M	MUSB71M-W-15616	60.7–70.7	4/1/04	443	6.6	ND	ND
SB71D	MUSB71D-W-15617	70.0–80.0	4/1/04	4.4	ND	ND	ND
SB72M	MUSB72M-W-15736	59.7–69.7	4/2/04	ND	ND	ND	ND
SB72D	MUSB72D-W-15735	70.0–80.0	4/2/04	1.3	ND	ND	ND
<i>Cone penetrometer samples</i>							
SB74	MUSB74-W-15644	10.6–16.6	4/4/04	202	2.6	ND	ND
SB74	MUSB74-W-15645	16.6–22.6	4/4/04	436	6.5	ND	ND
SB75	MUSB75-W-15643	5.0–15.0	4/3/04	26	ND	ND	ND
SB76	MUSB76-W-15635	22.0–30.0	4/2/04	ND	ND	ND	ND
SB76	MUSB76-W-15638	30.0–38.0	4/2/04	2.9	ND	ND	ND
SB76	MUSB76-W-15637	38.0–46.0	4/2/04	5.9	ND	ND	ND
SB77	MUSB77-W-15640	14.0–22.0	4/3/04	ND	ND	ND	ND
SB79	MUSB79-W-15641	6.5–16.5	4/3/04	ND	ND	ND	ND

TABLE E.3 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Concentration (µg/L)			
				Carbon Tetrachloride	Chloroform	1,1,2-Tri- chloroethane	Tetra- chloroethene
<i>Cone penetrometer samples (Cont.)</i>							
SB80	MUSB80-W-15647	23.0–31.0	4/4/04	ND	ND	ND	ND
SB80	MUSB80-W-15649	33.0–41.0	4/4/04	ND	ND	ND	ND
SB80	MUSB80-W-15648	41.0–46.0	4/4/04	4	ND	ND	ND
SB80	MUSB80-W-15651	52.0–59.0	4/4/04	1.2	ND	ND	ND
SB81	MUSB81-W-15652	19.7–27.7	4/5/04	ND	ND	ND	ND
SB81	MUSB81-W-15654	27.7–35.7	4/5/04	ND	ND	ND	ND
SB83	MUSB83-W-15656	50.0–60.0	4/6/04	ND	ND	ND	ND
SB85	MUSB85-W-17241	65.0–70.0	6/28/04	ND	ND	ND	ND
SB86	MUSB86-W-17178	71.0–76.0	6/29/04	93	19	ND	ND
TEST1	MUGWEXTEST-W-15594	60.0–65.0	6/28/04	579	17	6.4	187

<sup>a</sup> ND , contaminant not detected.

**Appendix F:**

**Surface Water Sample Data and  
Drain Tile Flow Data**

TABLE F.1 Surface water and tile outflow samples collected to characterize the distribution of carbon tetrachloride during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Sample Date	Description
<i>Surface water samples</i>			
SWP01	MUSWP01-W-15745	4/2/04	Surface water sample collected from creek.
SWP02	MUSWP02-W-15746	4/2/04	Surface water sample collected from creek.
SWP03	MUSWP03-W-15747	4/2/04	Surface water sample collected from creek.
SWP04	MUSWP04-W-15748	4/2/04	Surface water sample collected from creek.
SWP05	MUSWP05-W-15749	4/2/04	Surface water sample collected from creek.
SWP06	MUSWP06-W-15751	4/2/04	Surface water sample collected from creek.
SWP08	MUSWP08-W-15754	4/2/04	Surface water sample collected from creek.
SWP09	MUSWP09-W-15758	4/2/04	Surface water sample collected from creek.
SWP10	MUSWP10-W-15761	4/2/04	Surface water sample collected from creek.
SWP11	MUSWP11-W-15762	4/2/04	Surface water sample collected from creek.
SWP12	MUSWP12-W-15741	4/3/04	Surface water sample collected from creek.
SWP13	MUSWEX6-W-15764	4/2/04	Surface water sample collected from creek about 25 ft south of SWP03.
SWP14	MUSWP14-W-15750	4/2/04	Surface water sample collected from creek.
SWP15	MUSWP15-W-15755	4/2/04	Surface water sample collected from creek.
SWP16	MUSW4T5-W-15759	4/2/04	Spring sample about 15 ft south of TD5.
SWSEEP	MUSWSEEP1-W-15740	4/3/04	Seep sample.
<i>Tile outflow samples</i>			
TD1	MUSWP07-W-15752	4/2/04	Tile outflow sample.
TD2	MUSWT2-W-15753	4/2/04	Tile outflow sample.
TD3	MUSW4T3-W-15756	4/2/04	Tile outflow sample.
TD4	MUSW4T4-W-15757	4/2/04	Tile outflow sample.
TD5	MUSWT1-W-15760	4/2/04	Tile outflow sample.
TD6	MUSW4T6-W-15763	4/2/04	Tile outflow sample.

TABLE F.2 Results of analyses for volatile organic compounds on surface water and tile outflow samples collected during the 2004 targeted investigation at Murdock, Nebraska.

Location	Sample	Sample Date	Concentration (µg/L)	
			Carbon Tetrachloride	Chloroform
SWP01	MUSWP01-W-15745	4/2/04	76	2.9
SWP02	MUSWP02-W-15746	4/2/04	46	5.3
SWP03	MUSWP03-W-15747	4/2/04	161	9.5
SWP04	MUSWP04-W-15748	4/2/04	281	8.2
SWP05	MUSWP05-W-15749	4/2/04	171	10
SWP06	MUSWP06-W-15751	4/2/04	8.2	ND
SWP08	MUSWP08-W-15754	4/2/04	14	ND
SWP09	MUSWP09-W-15758	4/2/04	4.2	ND
SWP10	MUSWP10-W-15761	4/2/04	ND <sup>a</sup>	ND
SWP11	MUSWP11-W-15762	4/2/04	ND	ND
SWP12	MUSWP12-W-15741	4/3/04	ND	ND
SWP13	MUSWEX6-W-15764	4/2/04	220	11
SWP14	MUSWP14-W-15750	4/2/04	1.4	ND
SWP15	MUSWP15-W-15755	4/2/04	ND	ND
SWT16	MUSW4T5-W-15759	4/2/04	ND	ND
SWSEEP	MUSWSEEP1-W-15740	4/3/04	ND	4.2
TD1	MUSWP07-W-15752	4/2/04	8.2	ND
TD2	MUSWT2-W-15753	4/2/04	88	< 10 <sup>b</sup>
TD3	MUSW4T3-W-15756	4/2/04	ND	ND
TD4	MUSW4T4-W-15757	4/2/04	ND	ND
TD5	MUSWT1-W-15760	4/2/04	ND	ND
TD6	MUSW4T6-W-15763	4/2/04	ND	ND

<sup>a</sup> ND , contaminant not detected at a quantitation limit of 1 µg/L.

<sup>b</sup> Analyzed at dilution to quantify carbon tetrachloride.

TABLE F.3 Flow rate measurements for drain tiles during the 2004 targeted investigation at Murdock, Nebraska.

Date	TD1		TD2		TD3		TD4		TD5		TD6	
	Total (gal)	Average Daily (gal/hr)										
04/27/04	465	-	56,155	-	4,154	-	-	-	-	-	-	-
05/13/04	227,415	590.09	110,415	141.05	5,187	2.69	-	-	-	-	-	-
05/21/04	352,586	667.82	142,155	169.45	7,982	14.93	532	-	623	-	710	-
05/27/04	-	-	158,985	112	15,926	53	25,715	169	37,116	244	199,710	1,332
06/02/04	598,810	864	-	-	-	-	-	-	-	-	-	-
06/03/04	615,470	499	166,594	45	26,163	60	54,173	168	71,294	202	423,515	1,324
06/10/04	735,795	722	194,952	170	34,209	48	72,170	108	93,430	133	550,000	757
06/17/04	858,155	732	226,074	186	43,651	57	98,540	158	113,762	122	723,145	1,039
06/25/04	982,105	644	254,648	148	53,106	49	125,314	139	137,068	121	909,755	969
07/01/04	1,103,851	900	278,128	174	61,264	60	143,586	135	156,351	143	1,027,775	873
07/08/04	1,212,485	620	307,920	170	71,345	58	170,238	151	173,835	100	1,190,010	927
07/16/04	1,337,700	680	344,362	198	81,720	56	191,810	118	188,668	80	1,326,178	737

**Appendix G:**

**Air Sample Data**

TABLE G.1 Results of analyses for volatile organic compounds on air samples collected during the 2004 targeted investigation at Murdock, Nebraska.

	Concentration in Sample									
	MU-MCHUGH-A-15665 (100 Liberty Circle)		MU-WAGER-A-15666 (400 Liberty Circle)		MU-BACKM-A-15667 (417 Fifth Street)		MU-BG-A-15668 (Outside 400 Liberty Circle)		MU-GRAHAM-A-15669 (622 Freedom Circle)	
	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>
Dichlorodifluoromethane	5.9	29	0.68	3.4	6.5	32	0.56	2.8	2.9	14
Chloromethane	0.81	1.7	9.4	19	0.78	1.6	0.5 U <sup>a</sup>	1 U	2.7	5.6
Trichlorofluoromethane	0.5	2.8	2	11	3.5	20	0.5 U	2.8 U	1	5.6
Methylene chloride	2.6 Q <sup>b</sup>	9 Q	1.1 Q	3.8 Q	0.5 U	1.7 U	0.5 U	1.7 U	0.5 U	1.7 U
Chloroform	0.5 U	2.4 U	0.61 Q	3 Q	0.5 U	2.4 U	0.5 U	2.4 U	0.5 U	2.4 U
1,1,1-Trichloroethane	1.4	7.6	4	22	0.5 U	2.7 U	0.5 U	2.7 U	0.5 U	2.7 U
Carbon tetrachloride	0.63	4	0.50 U	3.1 U	0.5 U	3.1 U	0.5 U	1.6 U	0.57	3.6
Benzene	9.3	30	13	42	1.3	4.2	0.5 U	1.6 U	1.8	5.8
Trichloroethene	2.4	13	0.50 U	2.7 U	0.5 U	2.7 U	0.5 U	2.7 U	0.5 U	2.7 U
Toluene	36	140	32	120	4	15	1.1	4.1	10	38
Tetrachloroethene	3.4	23	3.3	22	0.5 U	3.4 U	0.5 U	3.4 U	0.5 U	3.4 U
Ethylbenzene	3.2	14	3.5	15	0.5 U	2.2 U	0.5 U	2.2 U	0.69	3
Xylene ( <i>m, p</i> )	9.6	42	9.2	40	1	4.3	0.5 U	2.2 U	2.2	9.6
Styrene	2.8	12	2.6	11	0.5 U	2.1 U	0.5 U	2.1 U	0.66	2.8
Xylene ( <i>o</i> )	3.5	15	2.8	12	0.5 U	2.2 U	0.5 U	2.2 U	0.83	3.6
1,4-Dichlorobenzene	0.97	5.8	3.9	23	0.55	3.3	0.5 U	3 U	0.5 U	3 U
1,3,5-Trimethylbenzene	0.97	4.8	0.54	2.7	0.5 U	2.5 U	0.5 U	2.5 U	0.5 U	2.5 U
1,2,4-Trimethylbenzene	3.2	16	2.2	11	0.5 U	2.5 U	0.5 U	2.5 U	2.1	10
1,3-Butadiene	0.5 U	1.1 U	5	11	0.5 U	1.1 U	0.5 U	1.1 U	0.5 U	1.1 U
Carbon disulfide	0.78	2.4	0.50 U	1.6 U	0.5 U	1.6 U	0.5 U	1.6 U	0.5 U	1.6 U
Acetone	38 D <sup>c</sup>	90 D	66 D	160 D	18	43	5 U	12 U	34 D	81 D
Isopropyl alcohol	62 D	150 D	5 U	12 U	5 U	12 U	5 U	12 U	5 U	12 U
Cyclohexane	2 Q	6.9 Q	1.1 Q	3.8 Q	0.5 U	1.7 U	0.5 U	1.7 U	0.5 U	1.7 U
Methyl ethyl ketone	5.6	17	12	35	2.1	6.2	0.5 U	1.5 U	0.5 U	1.5 U
Methyl isobutyl ketone	0.5 U	2 U	0.78	3.2	0.5 U	2 U	0.5 U	2 U	0.5 U	2 U
4-Ethyltoluene	3	15	2.1	10	0.5 U	2.5 U	0.5 U	2.5 U	1.1	5.4
2,2,4-Trimethylpentane	4.6	21	2.1	9.8	0.5 U	2.3 U	0.5 U	2.3 U	1.9	8.9

TABLE G.1 (Cont.)

	Concentration in Sample									
	MU-MCHUGH-A-15665 (100 Liberty Circle)		MU-WAGER-A-15666 (400 Liberty Circle)		MU-BACKM-A-15667 (417 Fifth Street)		MU-BG-A-15668 (Outside 400 Liberty Circle)		MU-GRAHAM-A-15669 (622 Freedom Circle)	
	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>	ppbv	µg/m <sup>3</sup>
<i>n</i> -Hexane	6.9	24	3.7	13	1.1	3.9	0.51	1.8	2	7
Tetrahydrofuran	5 U	15 U	4.4 J <sup>d</sup> Q	13 JQ	5 U	15 U	5 U	15 U	5 U	15 U
<i>n</i> -Heptane	2.5	10	4.9	20	0.5 U	2 U	0.5 U	2 U	0.66	2.7
Xylene (total)	14	61	12	52	1.1	4.8	0.5 U	2.2 U	3.2	14

<sup>a</sup> U, contaminant not detected at indicated quantitation limit.

<sup>b</sup> Q, qualifier signal failed the ratio test.

<sup>c</sup> D, analysis at dilution to quantify contaminant. Outside calibration range at zero dilution.

<sup>d</sup> J, estimated concentration below quantitation limit.

## **Supplementary Material for Draft Report for Targeted Investigations at Murdock, Nebraska, in 2004**

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### **Contents:**

S1_slugtests.pdf	Supplement 1: Slug Test Data
S2_qualitycontrol.pdf	Supplement 2: Quality Control for Sample Collection, Handling, and Analysis

September 2004

Work sponsored by Commodity Credit Corporation, United States Department of Agriculture

**Supplement 1:**

**Slug Test Data**

TABLE S1.1 Slug test data for boring SB74 (effective saturated thickness = 20.55 ft; length of well = 20.55 ft; length of screen = 10 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $Kz/Kr = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2	Test 2 Step 3
0	2.216	1.536	2.456	0.894
0.0033	3.747	1.095	3.048	1.209
0.0066	1.398	1.095	1.328	1.064
0.01	0.623	1.064	0.629	1.045
0.0133	0.453	1.064	0.409	1.026
0.0166	0.541	1.039	0.661	1.007
0.02	0.667	1.026	0.566	0.995
0.0233	0.705	1.013	0.604	0.988
0.0266	0.686	1.007	0.642	0.982
0.03	0.654	1.001	0.648	0.976
0.0333	0.648	0.995	0.636	0.969
0.0366	0.661	0.988	0.617	0.957
0.04	0.648	0.982	0.61	0.95
0.0433	0.642	0.976	0.604	0.95
0.0466	0.642	0.969	0.598	0.944
0.05	0.629	0.963	0.585	0.938
0.0533	0.604	0.963	0.579	0.932
0.0566	0.61	0.957	0.573	0.925
0.06	0.61	0.95	0.56	0.919
0.0633	0.573	0.944	0.554	0.919
0.0666	0.554	0.944	0.547	0.913
0.07	0.566	0.938	0.541	0.913
0.0733	0.573	0.938	0.535	0.906
0.0766	0.56	0.932	0.522	0.9
0.08	0.554	0.925	0.516	0.9
0.0833	0.541	0.925	0.51	0.894
0.0866	0.535	0.919	0.503	0.887
0.09	0.529	0.919	0.497	0.887
0.0933	0.522	0.913	0.484	0.881
0.0966	0.516	0.913	0.478	0.881
0.1	0.503	0.906	0.466	0.875
0.1033	0.491	0.906	0.466	0.869
0.1066	0.491	0.9	0.459	0.869
0.11	0.484	0.894	0.453	0.862
0.1133	0.484	0.894	0.453	0.856
0.1166	0.478	0.887	0.453	0.856
0.12	0.472	0.887	0.44	0.856
0.1233	0.466	0.881	0.434	0.85
0.1266	0.459	0.881	0.428	0.85
0.13	0.453	0.875	0.421	0.843
0.1333	0.447	0.875	0.415	0.837
0.1366	0.44	0.869	0.409	0.837
0.14	0.434	0.869	0.409	0.831
0.1433	0.428	0.862	0.403	0.831
0.1466	0.421	0.862	0.396	0.825
0.15	0.421	0.856	0.396	0.818
0.1533	0.415	0.856	0.39	0.818
0.1566	0.409	0.85	0.384	0.812
0.16	0.403	0.85	0.377	0.812
0.1633	0.396	0.843	0.371	0.812
0.1666	0.39	0.843	0.365	0.806

TABLE S1.1 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2	Test 2 Step 3
0.17	0.39	0.843	0.365	0.799
0.1733	0.384	0.837	0.359	0.799
0.1766	0.377	0.837	0.352	0.799
0.18	0.371	0.831	0.352	0.793
0.1833	0.371	0.831	0.346	0.793
0.1866	0.365	0.825	0.34	0.787
0.19	0.359	0.825	0.34	0.787
0.1933	0.359	0.818	0.333	0.78
0.1966	0.352	0.818	0.333	0.78
0.2	0.346	0.812	0.327	0.774
0.2033	0.346	0.812	0.321	0.774
0.2066	0.34	0.812	0.321	0.768
0.21	0.333	0.806	0.314	0.768
0.2133	0.333	0.806	0.314	0.762
0.2166	0.327	0.799	0.308	0.762
0.22	0.321	0.799	0.308	0.755
0.2233	0.321	0.793	0.302	0.755
0.2266	0.314	0.793	0.302	0.749
0.23	0.314	0.793	0.296	0.749
0.2333	0.308	0.787	0.296	0.749
0.2366	0.308	0.787	0.296	0.743
0.24	0.302	0.787	0.289	0.743
0.2433	0.302	0.78	0.289	0.736
0.2466	0.296	0.78	0.283	0.736
0.25	0.296	0.774	0.283	0.73
0.2533	0.289	0.774	0.277	0.73
0.2566	0.289	0.768	0.277	0.73
0.26	0.283	0.768	0.277	0.724
0.2633	0.283	0.768	0.27	0.724
0.2666	0.277	0.762	0.27	0.724
0.27	0.277	0.762	0.27	0.717
0.2733	0.27	0.755	0.264	0.717
0.2766	0.27	0.755	0.264	0.711
0.28	0.27	0.755	0.264	0.711
0.2833	0.264	0.749	0.264	0.711
0.2866	0.264	0.749	0.258	0.705
0.29	0.264	0.743	0.258	0.699
0.2933	0.258	0.743	0.258	0.699
0.2966	0.258	0.743	0.251	0.699
0.3	0.258	0.736	0.251	0.692
0.3033	0.251	0.736	0.251	0.692
0.3066	0.251	0.73	0.245	0.686
0.31	0.251	0.73	0.245	0.686
0.3133	0.251	0.73	0.245	0.686
0.3166	0.251	0.73	0.245	0.68
0.32	0.245	0.724	0.239	0.68
0.3233	0.245	0.724	0.239	0.673
0.3266	0.245	0.717	0.239	0.673
0.33	0.239	0.717	0.239	0.673
0.3333	0.239	0.711	0.239	0.667
0.35	0.233	0.699	0.226	0.654
0.3666	0.226	0.686	0.22	0.642
0.3833	0.22	0.673	0.214	0.629

TABLE S1.1 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2	Test 2 Step 3
0.4	0.214	0.661	0.207	0.617
0.4166	0.207	0.648	0.201	0.604
0.4333	0.201	0.636	0.195	0.592
0.45	0.195	0.629	0.188	0.579
0.4666	0.188	0.617	0.182	0.566
0.4833	0.182	0.604	0.176	0.56
0.5	0.176	0.598	0.17	0.547
0.5166	0.17	0.585	0.17	0.535
0.5333	0.163	0.573	0.163	0.522
0.55	0.157	0.566	0.157	0.516
0.5666	0.157	0.554	0.157	0.503
0.5833	0.151	0.547	0.151	0.497
0.6	0.144	0.535	0.144	0.484
0.6166	0.144	0.529	0.144	0.478
0.6333	0.138	0.516	0.138	0.466
0.65	0.132	0.51	0.138	0.459
0.6666	0.132	0.497	0.132	0.447
0.6833	0.125	0.491	0.132	0.44
0.7	0.119	0.484	0.125	0.434
0.7166	0.119	0.472	0.125	0.422
0.7333	0.113	0.466	0.119	0.415
0.75	0.113	0.459	0.119	0.409
0.7666	0.107	0.447	0.119	0.396
0.7833	0.107	0.44	0.113	0.39
0.8	0.1	0.434	0.113	0.384
0.8166	0.1	0.428	0.107	0.377
0.8333	0.1	0.422	0.107	0.371
0.85	0.094	0.415	0.1	0.359
0.8666	0.094	0.403	0.1	0.352
0.8833	0.088	0.396	0.1	0.346
0.9	0.088	0.39	0.094	0.34
0.9166	0.088	0.384	0.094	0.333
0.9333	0.081	0.377	0.094	0.327
0.95	0.081	0.371	0.094	0.321
0.9666	0.075	0.365	0.088	0.314
0.9833	0.075	0.359	0.088	0.308
1	0.075	0.352	0.088	0.302
1.2	0.05	0.27	0.062	0.226
1.4	0.037	0.22	0.05	0.176
1.6	0.031	0.176	0.044	0.138
1.8	0.025	0.144	0.037	0.107
2	0.018	0.119	0.025	0.081
2.2	0.012	0.094	0.025	0.062
2.4	0.012	0.081	0.018	0.05
2.6	0.006	0.062	0.018	0.037
2.8		0.05	0.012	0.031
3		0.044	0.012	0.025
3.2		0.037	0.012	0.018
3.4		0.031	0.012	0.012
3.6		0.025	0.012	0.006
3.8		0.018	0.012	

TABLE S1.1 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2	Test 2 Step 3
4		0.012	0.012	
4.2		0.012	0.012	
4.4		0.012	0.006	
4.6		0.012		
4.8		0.012		
5		0.012		
5.2		0.006		

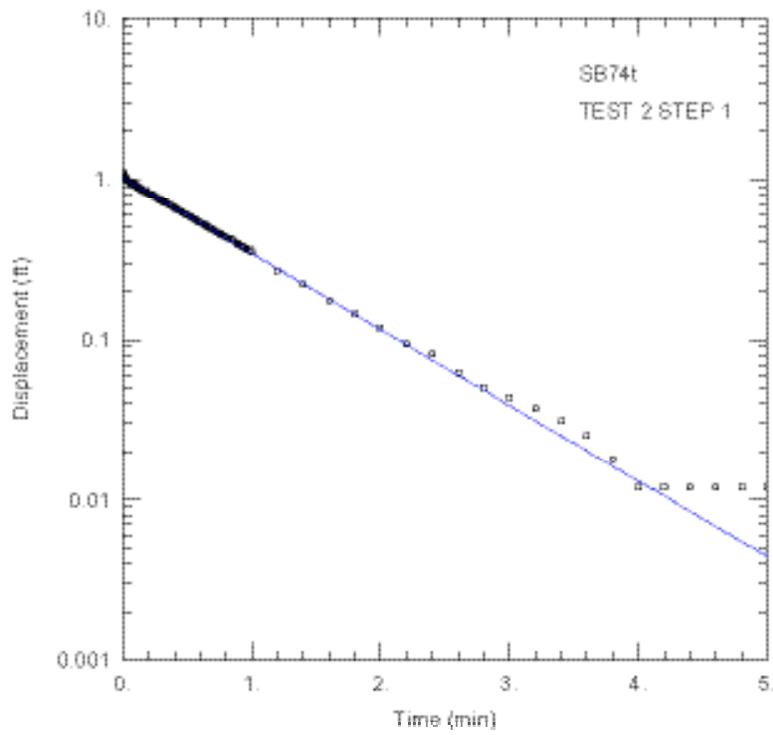
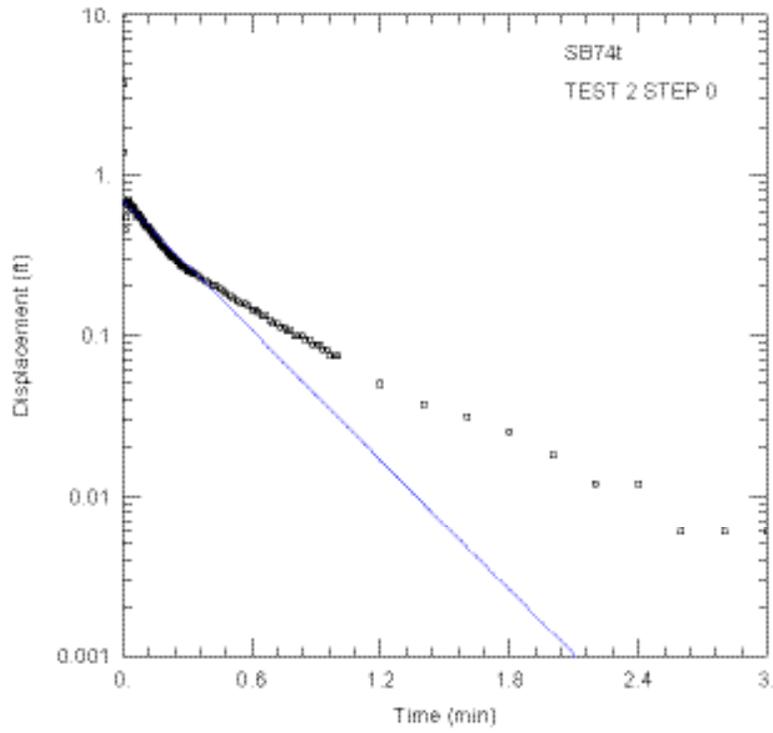


FIGURE S1.1 Slug test water level response and interpretive fit for the data for SB74.

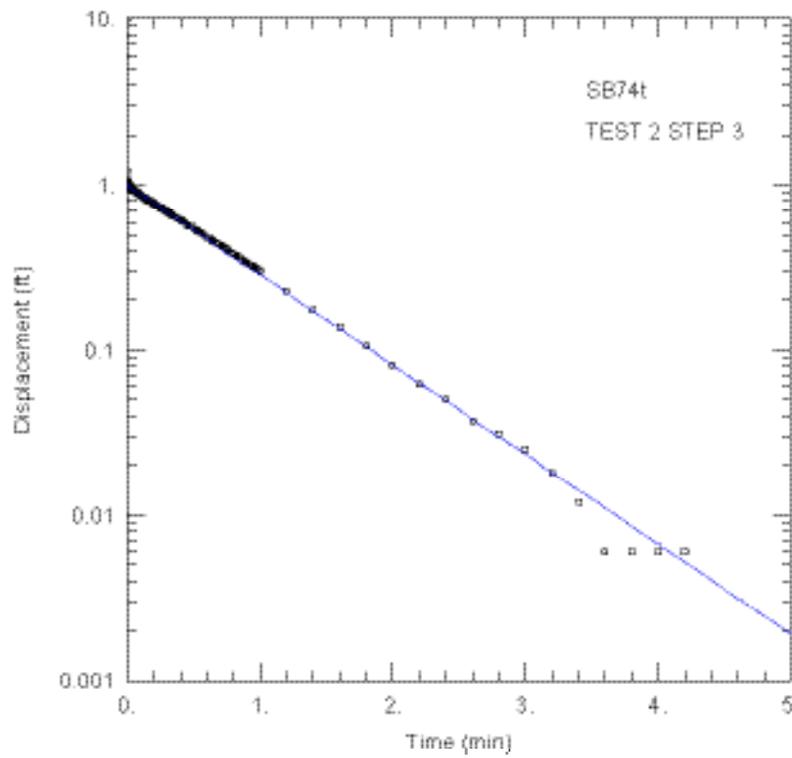
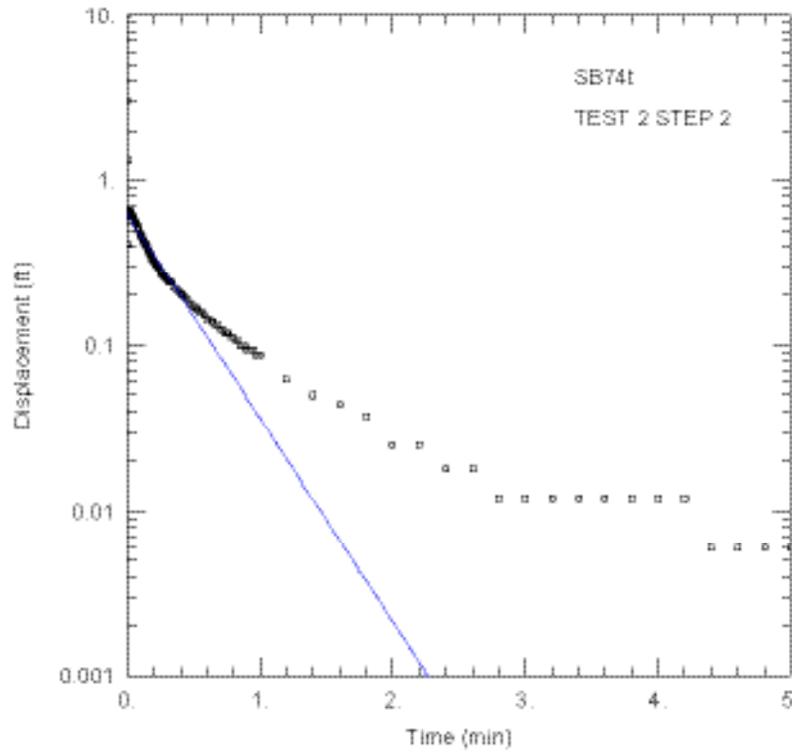


FIGURE S1.1 (Cont.)

TABLE S1.2 Slug test data for boring SB75 (effective saturated thickness = 13.21 ft; length of well = 13.21 ft; length of screen = 10 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $Kz/Kr = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
0	2.813	0.856	2.14	-0.705
0.0033	6.572	-0.547	5.477	0.295
0.0066	1.743	2.555	1.517	2.681
0.01	-1.623	1.107	-1.762	0.616
0.0133	-0.213	0.396	-0.61	0.616
0.0166	1.775	1.573	1.454	1.642
0.02	1.875	1.044	1.51	0.868
0.0233	0.78	0.805	0.327	0.856
0.0266	0.258	1.271	-0.05	1.252
0.03	0.881	0.994	0.629	0.912
0.0333	1.303	0.994	0.956	0.981
0.0366	1.051	1.132	0.629	1.095
0.04	0.742	0.994	0.371	0.95
0.0433	0.843	1.051	0.553	1.013
0.0466	1.051	1.063	0.705	1.019
0.05	1.007	1.019	0.61	0.969
0.0533	0.875	1.057	0.516	1.013
0.0566	0.893	1.032	0.591	0.988
0.06	0.982	1.038	0.642	0.981
0.0633	0.969	1.044	0.591	0.994
0.0666	0.919	1.032	0.566	0.981
0.07	0.931	1.044	0.598	0.988
0.0733	0.956	1.032	0.61	0.988
0.0766	0.95	1.038	0.585	0.975
0.08	0.931	1.032	0.585	0.988
0.0833	0.937	1.032	0.598	0.981
0.0866	0.944	1.032	0.591	0.981
0.09	0.937	1.032	0.585	0.988
0.0933	0.937	1.032	0.591	0.981
0.0966	0.937	1.032	0.591	0.981
0.1	0.937	1.032	0.591	0.981
0.1033	0.937	1.032	0.591	0.981
0.1066	0.937	1.032	0.591	0.981
0.11	0.937	1.032	0.591	0.981
0.1133	0.937	1.032	0.591	0.981
0.1166	0.937	1.032	0.591	0.975
0.12	0.937	1.026	0.585	0.975
0.1233	0.937	1.032	0.591	0.975
0.1266	0.937	1.032	0.591	0.975
0.13	0.937	1.026	0.585	0.975
0.1333	0.937	1.032	0.585	0.975
0.1366	0.931	1.026	0.585	0.975
0.14	0.937	1.032	0.585	0.975
0.1433	0.937	1.026	0.585	0.975
0.1466	0.931	1.019	0.591	0.975
0.15	0.931	1.032	0.579	0.975
0.1533	0.931	1.026	0.579	0.975
0.1566	0.931	1.026	0.598	0.975
0.16	0.931	1.026	0.585	0.969
0.1633	0.931	1.026	0.579	0.975
0.1666	0.931	1.026	0.585	0.975

TABLE S1.2 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
0.17	0.931	1.026	0.591	0.969
0.1733	0.931	1.026	0.585	0.975
0.1766	0.931	1.026	0.579	0.969
0.18	0.931	1.026	0.585	0.975
0.1833	0.931	1.026	0.585	0.969
0.1866	0.931	1.026	0.579	0.969
0.19	0.931	1.026	0.579	0.969
0.1933	0.931	1.019	0.585	0.969
0.1966	0.931	1.026	0.579	0.969
0.2	0.925	1.019	0.579	0.969
0.2033	0.925	1.026	0.585	0.969
0.2066	0.925	1.019	0.579	0.963
0.21	0.925	1.019	0.579	0.969
0.2133	0.925	1.019	0.579	0.975
0.2166	0.925	1.019	0.579	0.969
0.22	0.925	1.019	0.579	0.969
0.2233	0.925	1.019	0.579	0.969
0.2266	0.925	1.019	0.572	0.969
0.23	0.925	1.019	0.579	0.969
0.2333	0.925	1.019	0.579	0.969
0.2366	0.925	1.019	0.579	0.969
0.24	0.925	1.019	0.579	0.969
0.2433	0.925	1.019	0.579	0.969
0.2466	0.925	1.019	0.579	0.963
0.25	0.925	1.013	0.572	0.969
0.2533	0.919	1.019	0.579	0.963
0.2566	0.919	1.013	0.579	0.969
0.26	0.919	1.019	0.572	0.963
0.2633	0.919	1.013	0.572	0.963
0.2666	0.919	1.013	0.579	0.963
0.27	0.919	1.013	0.579	0.963
0.2733	0.919	1.013	0.572	0.963
0.2766	0.919	1.013	0.572	0.963
0.28	0.919	1.013	0.572	0.963
0.2833	0.919	1.013	0.572	0.963
0.2866	0.919	1.013	0.572	0.963
0.29	0.919	1.013	0.572	0.963
0.2933	0.919	1.013	0.572	0.963
0.2966	0.919	1.013	0.572	0.963
0.3	0.919	1.013	0.572	0.963
0.3033	0.919	1.007	0.572	0.963
0.3066	0.919	1.013	0.572	0.963
0.31	0.912	1.007	0.572	0.963
0.3133	0.919	1.013	0.572	0.963
0.3166	0.912	1.007	0.572	0.963
0.32	0.912	1.013	0.572	0.963
0.3233	0.912	1.013	0.572	0.963
0.3266	0.912	1.013	0.572	0.963
0.33	0.912	1.007	0.566	0.963
0.3333	0.912	1.007	0.572	0.963
0.35	0.912	1.007	0.572	0.956
0.3666	0.912	1.007	0.566	0.956
0.3833	0.906	1	0.566	0.956

TABLE S1.2 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
0.4	0.906	1	0.566	0.95
0.4166	0.906	1	0.566	0.956
0.4333	0.906	1	0.566	0.944
0.45	0.9	1	0.56	0.95
0.4666	0.9	0.994	0.56	0.95
0.4833	0.9	0.994	0.56	0.95
0.5	0.9	0.994	0.56	0.944
0.5166	0.893	0.994	0.56	0.944
0.5333	0.893	0.994	0.553	0.944
0.55	0.893	0.994	0.553	0.944
0.5666	0.887	0.994	0.553	0.944
0.5833	0.887	0.994	0.553	0.944
0.6	0.887	0.994	0.553	0.944
0.6166	0.881	0.994	0.547	0.937
0.6333	0.881	0.988	0.547	0.937
0.65	0.881	0.988	0.547	0.937
0.6666	0.875	0.988	0.547	0.937
0.6833	0.875	0.988	0.547	0.937
0.7	0.875	0.988	0.541	0.937
0.7166	0.875	0.988	0.541	0.937
0.7333	0.868	0.988	0.541	0.931
0.75	0.868	0.988	0.541	0.931
0.7666	0.868	0.981	0.541	0.931
0.7833	0.862	0.981	0.541	0.931
0.8	0.862	0.981	0.535	0.931
0.8166	0.862	0.981	0.535	0.931
0.8333	0.862	0.981	0.535	0.931
0.85	0.862	0.981	0.535	0.931
0.8666	0.856	0.975	0.535	0.925
0.8833	0.856	0.975	0.535	0.925
0.9	0.856	0.975	0.528	0.925
0.9166	0.849	0.975	0.528	0.925
0.9333	0.849	0.975	0.528	0.925
0.95	0.849	0.975	0.528	0.925
0.9666	0.849	0.975	0.528	0.925
0.9833	0.849	0.975	0.528	0.925
1	0.843	0.969	0.522	0.919
1.2	0.824	0.956	0.509	0.912
1.4	0.812	0.95	0.497	0.9
1.6	0.793	0.937	0.491	0.893
1.8	0.78	0.937	0.478	0.887
2	0.761	0.925	0.465	0.874
2.2	0.749	0.919	0.459	0.868
2.4	0.736	0.912	0.446	0.862
2.6	0.717	0.9	0.434	0.856
2.8	0.711	0.893	0.428	0.843
3	0.692	0.887	0.415	0.843
3.2	0.679	0.881	0.402	0.837
3.4	0.667	0.868	0.396	0.83
3.6	0.654	0.868	0.384	0.818
3.8	0.642	0.856	0.377	0.811

TABLE S1.2 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
4	0.629	0.849	0.371	0.811
4.2	0.616	0.843	0.358	0.799
4.4	0.604	0.837	0.352	0.799
4.6	0.591	0.83	0.346	0.793
4.8	0.585	0.824	0.333	0.786
5	0.572	0.818	0.327	0.78
5.2	0.56	0.811	0.321	0.774
5.4	0.547	0.811	0.308	0.767
5.6	0.541	0.805	0.302	0.761
5.8	0.528	0.793	0.295	0.755
6	0.516	0.793	0.289	0.755
6.2	0.509	0.78	0.276	0.749
6.4	0.497	0.78	0.27	0.742
6.6	0.491	0.774	0.264	0.736
6.8	0.484	0.767	0.258	0.73
7	0.478	0.767	0.251	0.73
7.2	0.465	0.755	0.245	0.723
7.4	0.459	0.755	0.239	0.717
7.6	0.453	0.749	0.232	0.711
7.8	0.44	0.742	0.22	0.711
8	0.434	0.736	0.214	0.704
8.2	0.428	0.736	0.214	0.698
8.4	0.415	0.73	0.207	0.698
8.6	0.402	0.723	0.201	0.692
8.8	0.396	0.717	0.195	0.686
9	0.39	0.717	0.188	0.679
9.2	0.384	0.711	0.176	0.679
9.4	0.377	0.704	0.176	0.673
9.6	0.365	0.704	0.169	0.667
9.8	0.358	0.698	0.163	0.667
10	0.352	0.692	0.157	0.66
12	0.283	0.66	0.1	0.629
14	0.214	0.623	0.056	0.579
16	0.163	0.591		0.553
18	0.113	0.572		0.528
20	0.069	0.547		0.509
22	0.031	0.522		0.49
24		0.509		0.478
26		0.497		0.465
28		0.484		0.453
30		0.472		0.44
32		0.465		0.428
34		0.453		0.421
36		0.446		0.415
38		0.44		0.409
40		0.434		0.402
42		0.428		0.396
44		0.428		0.396
46		0.421		0.39
48		0.415		0.383
50		0.415		0.383
52		0.415		0.383
54		0.409		0.377
56		0.409		0.377

TABLE S1.2 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
58		0.402		0.371
60		0.402		0.371
62		0.402		0.371
64		0.396		0.365
66		0.396		0.365
68		0.396		0.365
70		0.396		0.365
72		0.396		0.365
74		0.39		0.365
76		0.39		0.358
78		0.39		0.358
80				0.358
82				0.358
84				0.358
86				0.358
88				0.358
90				0.358
92				0.358
94				0.358
96				0.358
98				0.358
100				0.358
115				0.352
130				0.352
145				0.352
160				0.346
175				0.346
190				0.346
205				0.346
220				0.346
235				0.346
250				0.346
265				0.346
280				0.346
295				0.346
310				0.346
325				0.346
340				0.346
355				0.346
370				0.346
385				0.339
400				0.339
415				0.339
430				0.339
445				0.339
460				0.339
475				0.339
490				0.339
505				0.339
520				0.339
535				0.339
550				0.339
565				0.339
580				0.339

TABLE S1.2 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2	Test 1 Step 3
595				0.339
610				0.339
625				0.339
640				0.339
655				0.339
670				0.339
685				0.339
700				0.339
715				0.339
730				0.339
745				0.339
760				0.339
775				0.339
790				0.339
805				0.339
820				0.346
835				0.339
850				0.339
865				0.346
880				0.346
895				0.346

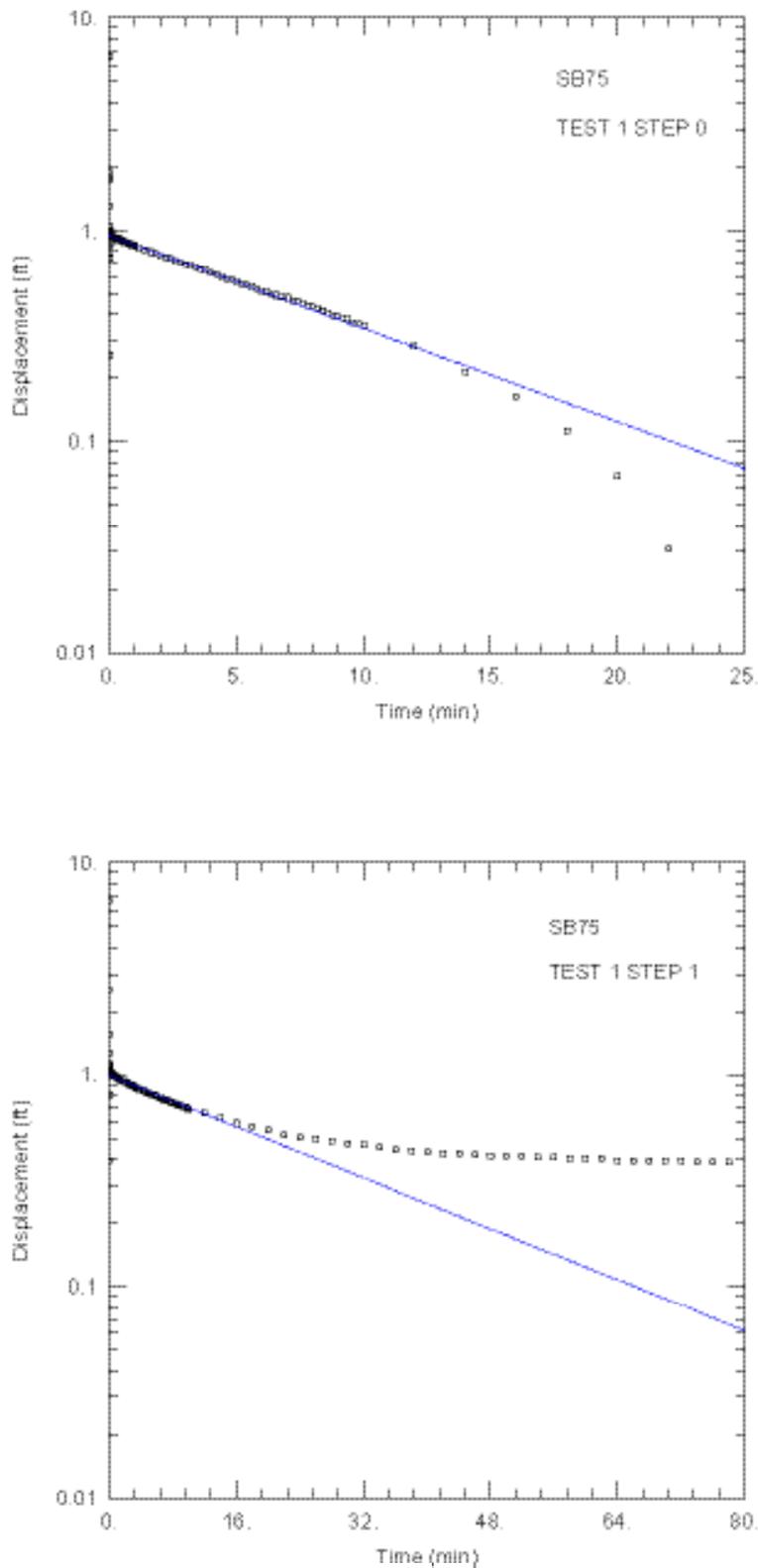


FIGURE S1.2 Slug test water level response and interpretive fit for the data for SB75.

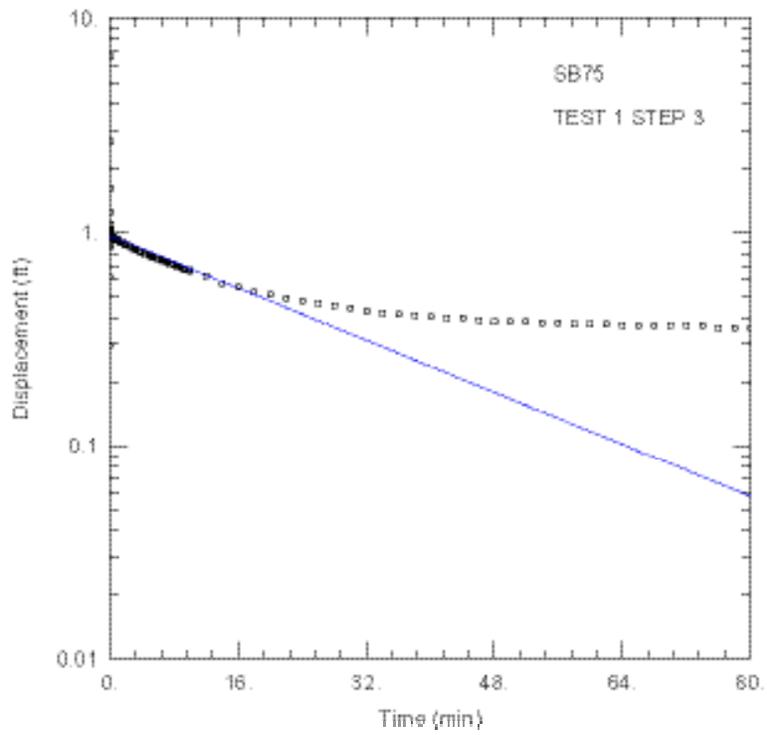
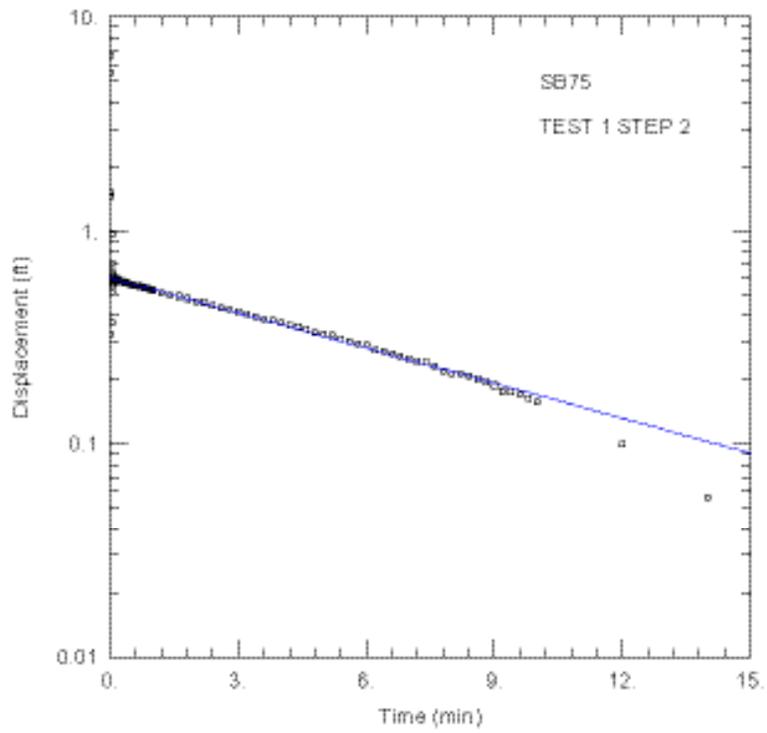


FIGURE S1.2 (Cont.)

TABLE S1.3 Slug test data for boring SB76 (effective saturated thickness = 25 ft; length of well = 25 ft; length of screen = 10 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $Kz/Kr = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2
0	9.444	9.312	11.835
0.0033	7.651	8.595	10.168
0.0066	7.507	8.469	9.985
0.01	7.406	8.331	9.828
0.0133	7.324	8.205	9.671
0.0166	7.255	8.079	9.52
0.02	7.192	7.96	9.375
0.0233	7.123	7.84	9.231
0.0266	7.054	7.727	9.092
0.03	6.991	7.614	8.947
0.0333	6.928	7.5	8.822
0.0366	6.871	7.393	8.696
0.04	6.808	7.286	8.564
0.0433	6.745	7.192	8.438
0.0466	6.682	7.091	8.318
0.05	6.626	6.991	8.199
0.0533	6.569	6.89	8.079
0.0566	6.506	6.796	7.96
0.06	6.45	6.708	7.846
0.0633	6.393	6.607	7.733
0.0666	6.336	6.525	7.626
0.07	6.292	6.431	7.513
0.0733	6.229	6.343	7.406
0.0766	6.179	6.255	7.299
0.08	6.116	6.173	7.198
0.0833	6.072	6.091	7.091
0.0866	6.022	6.003	6.991
0.09	5.965	5.921	6.89
0.0933	5.909	5.846	6.796
0.0966	5.858	5.764	6.695
0.1	5.808	5.682	6.601
0.1033	5.758	5.6	6.506
0.1066	5.707	5.525	6.418
0.11	5.657	5.449	6.324
0.1133	5.607	5.374	6.236
0.1166	5.556	5.298	6.148
0.12	5.506	5.229	6.06
0.1233	5.462	5.153	5.971
0.1266	5.411	5.091	5.883
0.13	5.367	5.015	5.802
0.1333	5.317	4.946	5.713
0.1366	5.267	4.883	5.638
0.14	5.229	4.82	5.556
0.1433	5.179	4.751	5.474
0.1466	5.135	4.694	5.399
0.15	5.084	4.625	5.323
0.1533	5.047	4.562	5.248
0.1566	4.996	4.499	5.172
0.16	4.958	4.436	5.097
0.1633	4.914	4.373	5.028
0.1666	4.87	4.31	4.958

TABLE S1.3 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2
0.17	4.833	4.254	4.883
0.1733	4.789	4.197	4.814
0.1766	4.744	4.14	4.751
0.18	4.7	4.084	4.682
0.1833	4.663	4.027	4.619
0.1866	4.625	3.97	4.556
0.19	4.581	3.914	4.487
0.1933	4.537	3.857	4.424
0.1966	4.499	3.807	4.361
0.2	4.461	3.75	4.298
0.2033	4.424	3.706	4.235
0.2066	4.386	3.656	4.178
0.21	4.348	3.606	4.115
0.2133	4.31	3.555	4.059
0.2166	4.273	3.505	4.002
0.22	4.235	3.461	3.945
0.2233	4.197	3.411	3.889
0.2266	4.166	3.366	3.838
0.23	4.128	3.316	3.775
0.2333	4.09	3.272	3.725
0.2366	4.052	3.228	3.675
0.24	4.021	3.184	3.624
0.2433	3.983	3.146	3.574
0.2466	3.952	3.102	3.524
0.25	3.914	3.058	3.473
0.2533	3.882	3.014	3.423
0.2566	3.845	2.976	3.373
0.26	3.807	2.932	3.329
0.2633	3.775	2.895	3.278
0.2666	3.744	2.857	3.234
0.27	3.706	2.813	3.19
0.2733	3.675	2.775	3.146
0.2766	3.643	2.737	3.102
0.28	3.612	2.699	3.058
0.2833	3.587	2.674	3.014
0.2866	3.549	2.636	2.97
0.29	3.524	2.599	2.932
0.2933	3.486	2.561	2.888
0.2966	3.461	2.529	2.85
0.3	3.429	2.498	2.813
0.3033	3.398	2.46	2.769
0.3066	3.373	2.422	2.731
0.31	3.341	2.385	2.693
0.3133	3.31	2.36	2.655
0.3166	3.278	2.322	2.618
0.32	3.253	2.29	2.58
0.3233	3.228	2.259	2.542
0.3266	3.197	2.227	2.504
0.33	3.171	2.196	2.473
0.3333	3.146	2.171	2.435
0.35	3.008	2.026	2.271
0.3666	2.882	1.894	2.114
0.3833	2.756	1.762	1.976

TABLE S1.3 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2
0.4	2.636	1.648	1.837
0.4166	2.517	1.548	1.718
0.4333	2.416	1.441	1.604
0.45	2.309	1.346	1.491
0.4666	2.215	1.258	1.397
0.4833	2.114	1.176	1.296
0.5	2.02	1.101	1.214
0.5166	1.932	1.025	1.132
0.5333	1.85	0.963	1.057
0.55	1.768	0.9	0.981
0.5666	1.693	0.837	0.918
0.5833	1.623	0.78	0.855
0.6	1.548	0.736	0.799
0.6166	1.485	0.686	0.748
0.6333	1.416	0.642	0.698
0.65	1.353	0.604	0.648
0.6666	1.296	0.566	0.61
0.6833	1.239	0.528	0.566
0.7	1.195	0.49	0.528
0.7166	1.139	0.459	0.497
0.7333	1.088	0.434	0.465
0.75	1.051	0.402	0.434
0.7666	1	0.377	0.402
0.7833	0.956	0.358	0.383
0.8	0.912	0.333	0.365
0.8166	0.874	0.314	0.339
0.8333	0.837	0.295	0.314
0.85	0.799	0.276	0.295
0.8666	0.761	0.251	0.27
0.8833	0.73	0.245	0.258
0.9	0.698	0.232	0.239
0.9166	0.667	0.22	0.226
0.9333	0.642	0.201	0.207
0.95	0.616	0.195	0.195
0.9666	0.591	0.176	0.182
0.9833	0.56	0.17	0.17
1	0.541	0.163	0.163
1.2	0.327	0.069	0.081
1.4	0.195	0.037	0.05
1.6	0.119	0.031	0.031
1.8	0.075	0.018	0.025
2	0.05	0.025	0.025
2.2	0.031	0.018	0.018
2.4	0.018	0.018	0.018
2.6	0.025	0.012	0.012
2.8	0.012	0.012	0.018
3	0.012		0.012
3.2			0.012

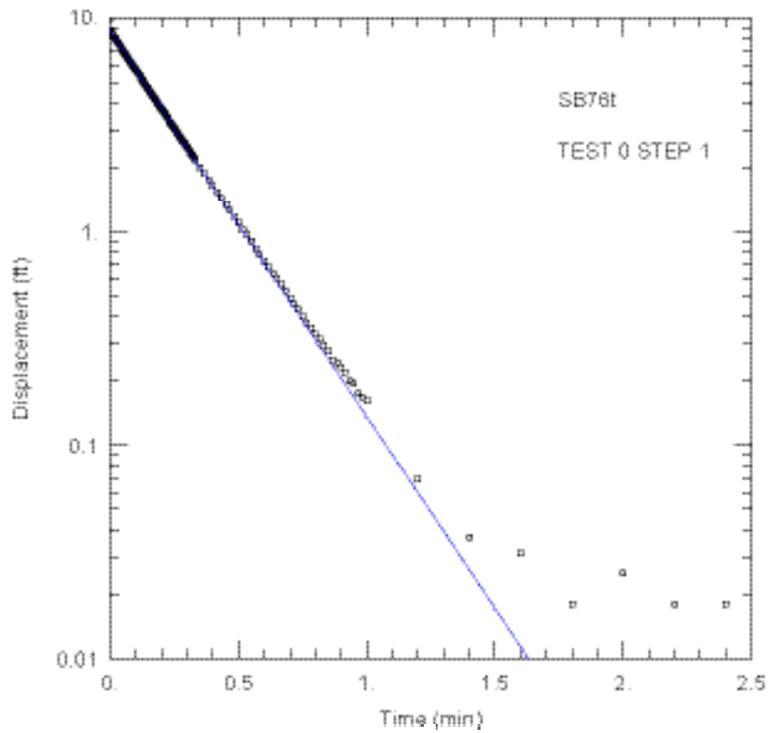
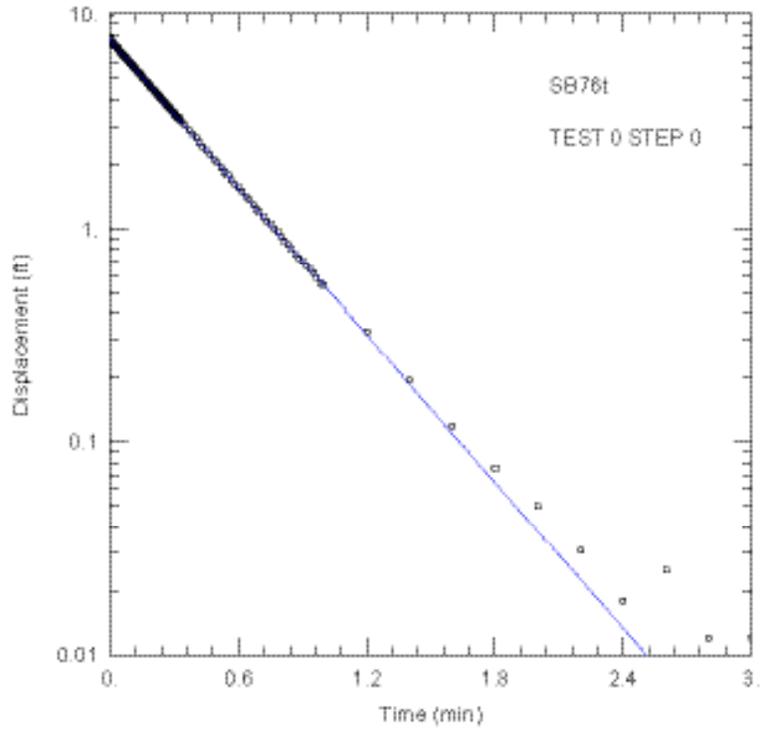


FIGURE S1.3 Slug test water level response and interpretive fit for the data for SB76.

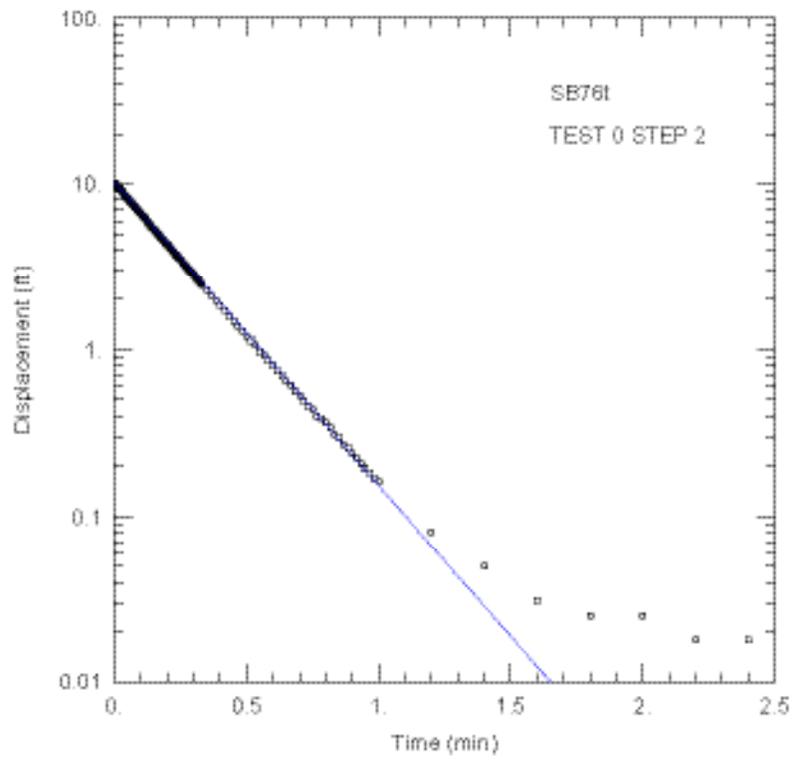


FIGURE S1.3 (Cont.)

TABLE S1.4 Slug test data for boring SB77 (effective saturated thickness = 8 ft; length of well = 8 ft; length of screen = 8 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $K_z/K_r = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2	Test 0 Step 3
0	1.038	0.188	4.086	0.938
0.0033	1.391	-0.251	1.838	-0.402
0.0066	2.178	1.315	-0.629	0.516
0.01	2.159	1.894	-0.944	1.8
0.0133	1.448	0.78	0.339	1.391
0.0166	0.912	0.623	1.208	0.598
0.02	0.371	1.164	1.347	0.736
0.0233	0.553	1.082	0.931	1.164
0.0266	1.145	0.812	0.522	0.982
0.03	1.271	0.95	0.516	0.787
0.0333	0.988	1.001	0.749	0.919
0.0366	0.793	0.894	0.881	0.957
0.04	0.875	0.925	0.83	0.868
0.0433	1.019	0.938	0.73	0.881
0.0466	1.007	0.906	0.698	0.906
0.05	0.919	0.912	0.749	0.881
0.0533	0.906	0.912	0.793	0.875
0.0566	0.95	0.906	0.774	0.875
0.06	0.956	0.9	0.742	0.868
0.0633	0.938	0.9	0.736	0.868
0.0666	0.925	0.894	0.749	0.868
0.07	0.931	0.894	0.755	0.862
0.0733	0.938	0.894	0.862	0.862
0.0766	0.931	0.887	1.177	0.856
0.08	0.925	0.887	0.623	0.856
0.0833	0.925	0.881	0.465	0.856
0.0866	0.925	0.881	0.667	0.856
0.09	0.925	0.875	0.856	0.849
0.0933	0.919	0.875	0.843	0.849
0.0966	0.919	0.875	0.717	0.849
0.1	0.912	0.868	0.661	0.849
0.1033	0.912	0.868	0.705	0.849
0.1066	0.912	0.868	0.755	0.843
0.11	0.912	0.862	0.755	0.843
0.1133	0.906	0.862	0.717	0.843
0.1166	0.906	0.856	0.705	0.837
0.12	0.906	0.856	0.717	0.837
0.1233	0.9	0.856	0.723	0.837
0.1266	0.9	0.856	0.723	0.831
0.13	0.9	0.849	0.711	0.831
0.1333	0.9	0.849	0.705	0.837
0.1366	0.893	0.849	0.705	0.831
0.14	0.893	0.849	0.711	0.824
0.1433	0.893	0.849	0.705	0.831
0.1466	0.893	0.843	0.705	0.824
0.15	0.887	0.843	0.698	0.824
0.1533	0.887	0.843	0.698	0.824
0.1566	0.887	0.837	0.698	0.818
0.16	0.887	0.837	0.698	0.818
0.1633	0.881	0.837	0.692	0.818
0.1666	0.881	0.837	0.692	0.818

TABLE S1.4 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2	Test 0 Step 3
0.17	0.881	0.837	0.692	0.818
0.1733	0.875	0.831	0.692	0.812
0.1766	0.875	0.831	0.686	0.812
0.18	0.875	0.831	0.686	0.812
0.1833	0.875	0.831	0.686	0.812
0.1866	0.875	0.831	0.686	0.805
0.19	0.868	0.824	0.679	0.812
0.1933	0.868	0.824	0.679	0.805
0.1966	0.868	0.824	0.679	0.805
0.2	0.868	0.824	0.673	0.805
0.2033	0.862	0.824	0.673	0.799
0.2066	0.862	0.818	0.673	0.799
0.21	0.862	0.824	0.673	0.799
0.2133	0.862	0.818	0.667	0.799
0.2166	0.856	0.818	0.667	0.799
0.22	0.856	0.818	0.667	0.793
0.2233	0.856	0.812	0.667	0.793
0.2266	0.856	0.812	0.667	0.793
0.23	0.849	0.812	0.661	0.793
0.2333	0.849	0.812	0.661	0.793
0.2366	0.849	0.812	0.661	0.793
0.24	0.849	0.805	0.661	0.787
0.2433	0.849	0.805	0.654	0.787
0.2466	0.843	0.805	0.654	0.787
0.25	0.843	0.805	0.654	0.787
0.2533	0.843	0.805	0.654	0.78
0.2566	0.843	0.805	0.654	0.787
0.26	0.843	0.805	0.654	0.78
0.2633	0.837	0.799	0.648	0.78
0.2666	0.837	0.799	0.648	0.78
0.27	0.837	0.799	0.648	0.774
0.2733	0.837	0.799	0.648	0.78
0.2766	0.837	0.799	0.648	0.774
0.28	0.83	0.793	0.642	0.774
0.2833	0.83	0.799	0.642	0.774
0.2866	0.83	0.793	0.642	0.774
0.29	0.83	0.793	0.642	0.774
0.2933	0.824	0.793	0.642	0.774
0.2966	0.824	0.793	0.635	0.774
0.3	0.824	0.793	0.635	0.768
0.3033	0.824	0.793	0.635	0.774
0.3066	0.824	0.787	0.635	0.768
0.31	0.818	0.787	0.635	0.768
0.3133	0.818	0.787	0.635	0.768
0.3166	0.818	0.787	0.629	0.768
0.32	0.818	0.787	0.629	0.768
0.3233	0.818	0.787	0.629	0.761
0.3266	0.812	0.787	0.629	0.761
0.33	0.812	0.78	0.629	0.761
0.3333	0.812	0.78	0.623	0.761
0.35	0.805	0.774	0.623	0.761
0.3666	0.799	0.774	0.616	0.749
0.3833	0.799	0.768	0.61	0.742

TABLE S1.4 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2	Test 0 Step 3
0.4	0.793	0.761	0.604	0.742
0.4166	0.786	0.755	0.598	0.736
0.4333	0.78	0.755	0.591	0.73
0.45	0.774	0.749	0.585	0.73
0.4666	0.768	0.742	0.585	0.724
0.4833	0.761	0.736	0.579	0.724
0.5	0.761	0.73	0.572	0.717
0.5166	0.755	0.73	0.566	0.711
0.5333	0.749	0.724	0.566	0.711
0.55	0.742	0.717	0.56	0.705
0.5666	0.742	0.717	0.553	0.698
0.5833	0.736	0.711	0.547	0.698
0.6	0.73	0.705	0.547	0.698
0.6166	0.73	0.705	0.541	0.692
0.6333	0.723	0.698	0.535	0.686
0.65	0.717	0.692	0.535	0.686
0.6666	0.717	0.692	0.528	0.68
0.6833	0.711	0.686	0.528	0.68
0.7	0.705	0.686	0.522	0.673
0.7166	0.705	0.68	0.516	0.667
0.7333	0.698	0.673	0.516	0.667
0.75	0.692	0.673	0.509	0.661
0.7666	0.686	0.667	0.509	0.661
0.7833	0.686	0.667	0.503	0.661
0.8	0.679	0.661	0.497	0.654
0.8166	0.673	0.654	0.497	0.654
0.8333	0.673	0.654	0.491	0.648
0.85	0.667	0.648	0.491	0.648
0.8666	0.667	0.648	0.484	0.642
0.8833	0.661	0.642	0.484	0.642
0.9	0.654	0.642	0.478	0.636
0.9166	0.654	0.636	0.472	0.636
0.9333	0.648	0.636	0.472	0.629
0.95	0.648	0.629	0.465	0.629
0.9666	0.642	0.629	0.465	0.629
0.9833	0.642	0.623	0.459	0.623
1	0.635	0.623	0.459	0.617
1.2	0.585	0.579	0.421	0.579
1.4	0.553	0.541	0.39	0.547
1.6	0.516	0.51	0.358	0.522
1.8	0.484	0.484	0.333	0.497
2	0.453	0.459	0.314	0.472
2.2	0.421	0.44	0.289	0.447
2.4	0.396	0.415	0.27	0.421
2.6	0.371	0.39	0.251	0.403
2.8	0.352	0.371	0.232	0.384
3	0.327	0.352	0.22	0.365
3.2	0.308	0.34	0.201	0.346
3.4	0.289	0.321	0.188	0.333
3.6	0.276	0.308	0.176	0.314
3.8	0.258	0.289	0.163	0.302

TABLE S1.4 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)			
	Test 0 Step 0	Test 0 Step 1	Test 0 Step 2	Test 0 Step 3
4	0.245	0.277	0.151	0.289
4.2	0.226	0.258	0.138	0.277
4.4	0.207	0.245	0.132	0.264
4.6	0.195	0.239	0.119	0.258
4.8	0.182	0.226	0.113	0.245
5	0.169	0.214	0.107	0.233
5.2	0.157	0.201	0.094	0.226
5.4	0.151	0.195	0.088	0.214
5.6	0.138	0.188	0.081	0.207
5.8	0.125	0.182	0.075	0.201
6	0.119	0.176	0.069	0.188
6.2	0.107	0.163	0.062	0.188
6.4	0.1	0.157	0.062	0.176
6.6	0.094	0.157	0.056	0.17
6.8	0.088	0.151	0.056	0.163
7	0.088	0.144	0.05	0.157
7.2	0.075	0.138	0.05	0.151
7.4	0.069	0.132	0.05	0.151
7.6	0.062	0.132	0.05	0.144
7.8	0.056	0.126	0.044	0.138
8	0.05	0.126	0.037	0.132
8.2	0.044	0.119	0.037	0.126
8.4	0.044	0.113	0.037	0.126
8.6	0.037	0.107	0.031	0.119
8.8	0.037	0.107	0.031	0.119
9	0.031	0.1	0.025	0.113
9.2	0.031	0.1	0.025	0.107
9.4	0.031	0.094	0.025	0.1
9.6	0.025	0.094	0.025	0.1
9.8	0.025	0.094	0.025	0.1
10	0.025	0.088	0.018	0.094
12		0.075		0.075

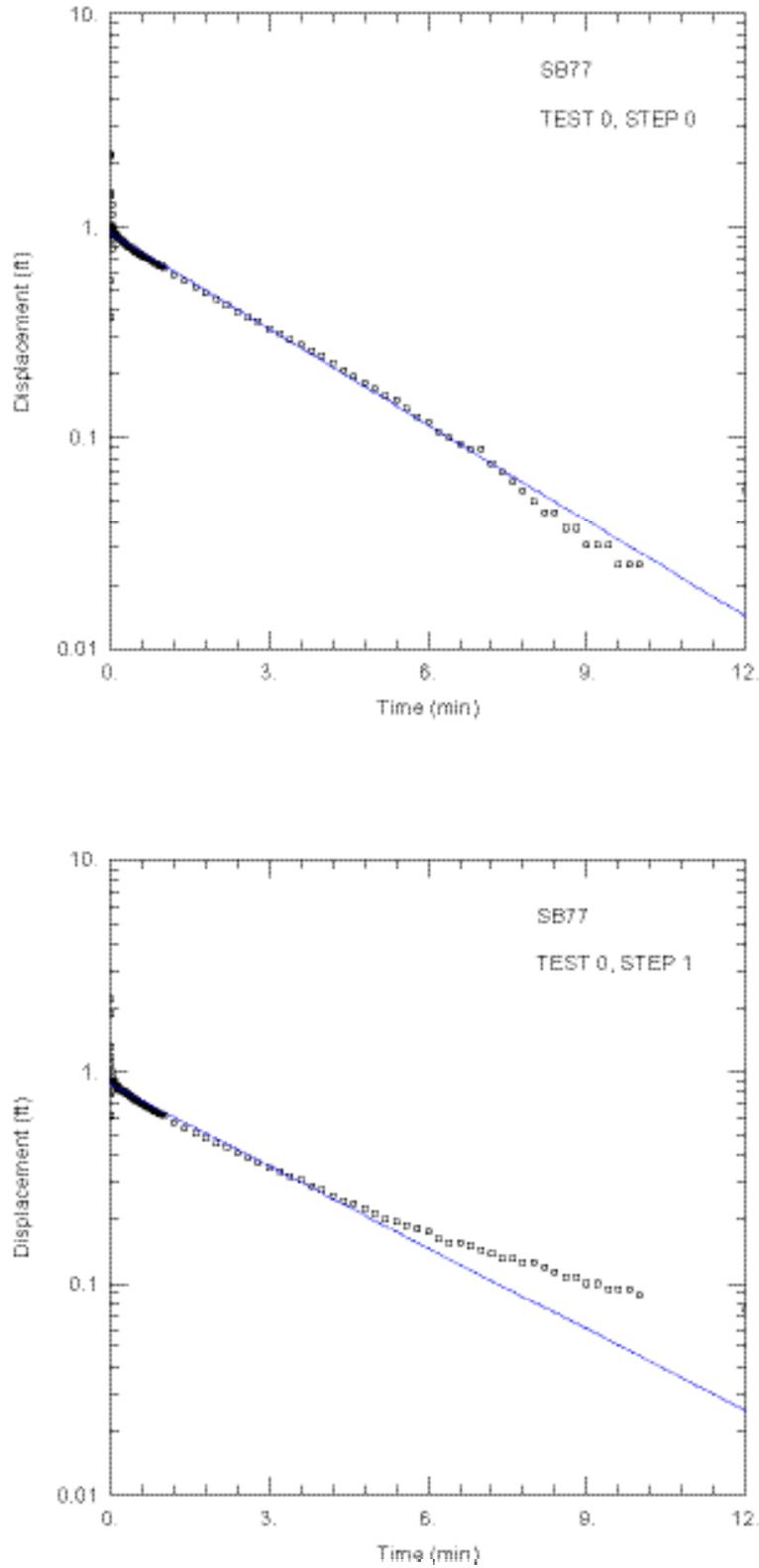


FIGURE S1.4 Slug test water level response and interpretive fit for the data for SB77.

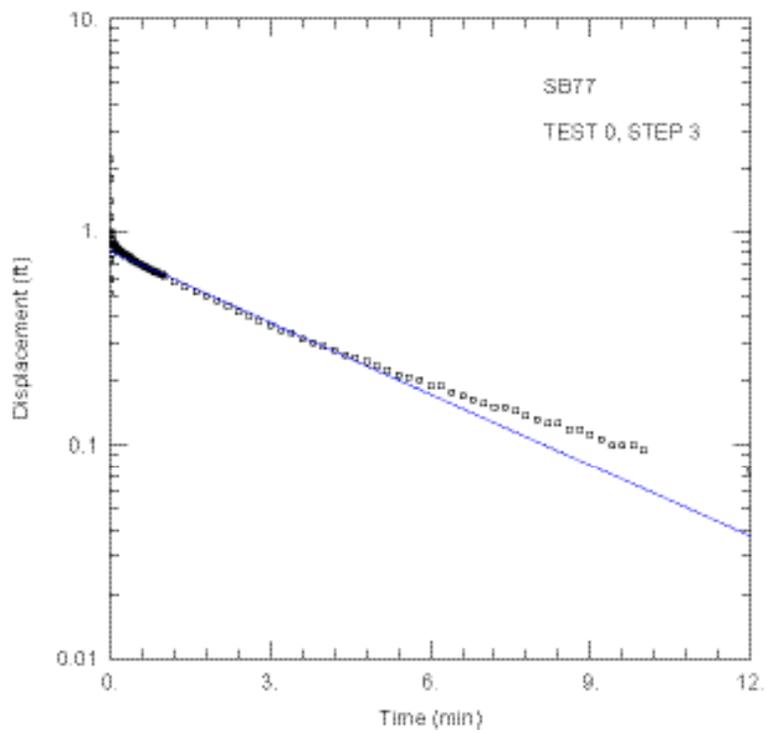
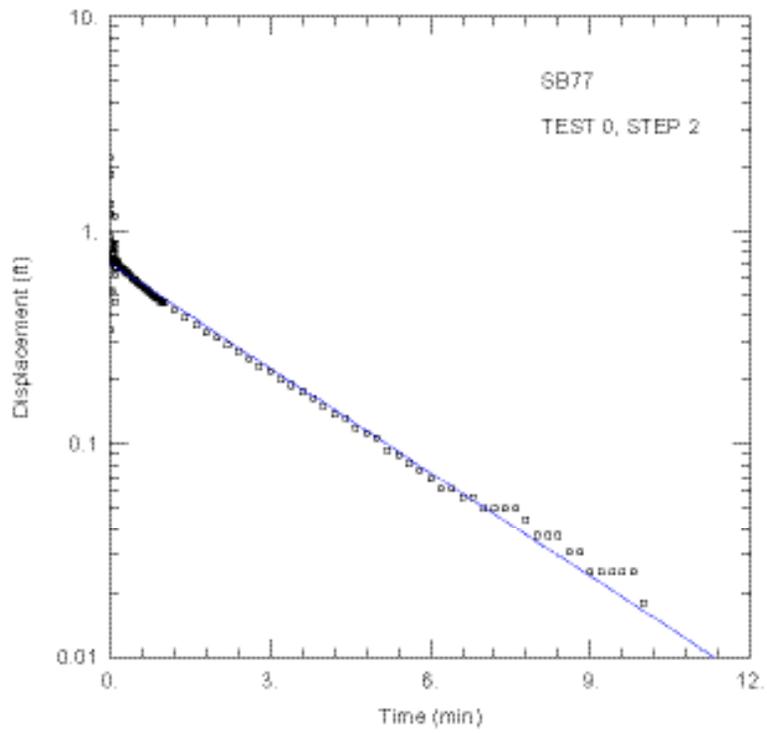


FIGURE S1.4 (Cont.)

TABLE S1.5 Slug test data for boring SB80 (effective saturated thickness = 31.49 ft; length of well = 31.49 ft; length of screen = 10 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $K_z/K_r = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2
0	13.268	17.262	9.079
0.0033	6.462	7.405	8.997
0.0066	9.79	9.268	6.77
0.01	8.991	9.758	6.336
0.0133	8.651	9.5	6.506
0.0166	8.727	9.387	6.43
0.02	8.708	9.349	6.386
0.0233	8.639	9.305	6.349
0.0266	8.594	9.255	6.311
0.03	8.557	9.205	6.279
0.0333	8.513	9.167	6.242
0.0366	8.469	9.117	6.21
0.04	8.431	9.073	6.172
0.0433	8.393	9.022	6.141
0.0466	8.355	8.978	6.109
0.05	8.311	8.934	6.072
0.0533	8.274	8.89	6.04
0.0566	8.236	8.84	6.009
0.06	8.192	8.796	5.971
0.0633	8.154	8.758	5.946
0.0666	8.116	8.714	5.908
0.07	8.072	8.664	5.877
0.0733	8.041	8.626	5.845
0.0766	8.003	8.582	5.814
0.08	7.965	8.544	5.782
0.0833	7.928	8.5	5.751
0.0866	7.89	8.462	5.719
0.09	7.846	8.418	5.688
0.0933	7.814	8.374	5.656
0.0966	7.777	8.337	5.625
0.1	7.733	8.299	5.594
0.1033	7.701	8.255	5.568
0.1066	7.663	8.211	5.537
0.11	7.626	8.179	5.505
0.1133	7.594	8.135	5.474
0.1166	7.556	8.097	5.449
0.12	7.519	8.06	5.417
0.1233	7.487	8.016	5.392
0.1266	7.45	7.972	5.361
0.13	7.412	7.94	5.329
0.1333	7.38	7.896	5.304
0.1366	7.343	7.858	5.273
0.14	7.305	7.821	5.248
0.1433	7.267	7.783	5.222
0.1466	7.236	7.745	5.191
0.15	7.204	7.714	5.166
0.1533	7.173	7.676	5.134
0.1566	7.135	7.638	5.109
0.16	7.104	7.6	5.084
0.1633	7.066	7.556	5.052
0.1666	7.034	7.519	5.027

TABLE S1.5 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2
0.17	7.003	7.481	5.002
0.1733	6.965	7.437	4.977
0.1766	6.934	7.412	4.952
0.18	6.902	7.38	4.927
0.1833	6.864	7.343	4.901
0.1866	6.839	7.299	4.876
0.19	6.802	7.267	4.845
0.1933	6.77	7.229	4.82
0.1966	6.739	7.192	4.794
0.2	6.701	7.16	4.769
0.2033	6.669	7.129	4.738
0.2066	6.638	7.091	4.719
0.21	6.606	7.066	4.688
0.2133	6.575	7.028	4.662
0.2166	6.544	6.99	4.637
0.22	6.518	6.959	4.612
0.2233	6.487	6.915	4.593
0.2266	6.462	6.883	4.562
0.23	6.43	6.852	4.543
0.2333	6.393	6.82	4.518
0.2366	6.361	6.789	4.492
0.24	6.336	6.751	4.467
0.2433	6.304	6.72	4.442
0.2466	6.273	6.682	4.423
0.25	6.248	6.669	4.398
0.2533	6.216	6.638	4.373
0.2566	6.185	6.594	4.348
0.26	6.16	6.562	4.329
0.2633	6.128	6.525	4.304
0.2666	6.097	6.493	4.285
0.27	6.065	6.468	4.26
0.2733	6.04	6.43	4.235
0.2766	6.009	6.405	4.209
0.28	5.984	6.367	4.19
0.2833	5.952	6.336	4.165
0.2866	5.927	6.298	4.146
0.29	5.896	6.279	4.121
0.2933	5.864	6.242	4.102
0.2966	5.839	6.216	4.077
0.3	5.807	6.179	4.058
0.3033	5.782	6.154	4.039
0.3066	5.757	6.122	4.014
0.31	5.726	6.097	3.995
0.3133	5.701	6.065	3.97
0.3166	5.675	6.028	3.951
0.32	5.644	6.003	3.932
0.3233	5.625	5.977	3.907
0.3266	5.594	5.952	3.888
0.33	5.562	5.914	3.87
0.3333	5.537	5.889	3.844
0.35	5.405	5.751	3.75
0.3666	5.285	5.606	3.656
0.3833	5.159	5.48	3.561

TABLE S1.5 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2
0.4	5.046	5.354	3.467
0.4166	4.927	5.222	3.379
0.4333	4.82	5.103	3.291
0.45	4.7	4.977	3.209
0.4666	4.593	4.864	3.121
0.4833	4.486	4.75	3.045
0.5	4.386	4.631	2.964
0.5166	4.285	4.524	2.888
0.5333	4.178	4.417	2.806
0.55	4.077	4.31	2.737
0.5666	3.983	4.209	2.661
0.5833	3.888	4.102	2.592
0.6	3.794	4.008	2.529
0.6166	3.712	3.914	2.466
0.6333	3.618	3.819	2.403
0.65	3.536	3.725	2.334
0.6666	3.454	3.637	2.278
0.6833	3.372	3.549	2.215
0.7	3.291	3.473	2.158
0.7166	3.215	3.385	2.101
0.7333	3.14	3.297	2.045
0.75	3.064	3.215	1.994
0.7666	2.989	3.14	1.938
0.7833	2.919	3.07	1.887
0.8	2.857	2.995	1.843
0.8166	2.781	2.926	1.793
0.8333	2.718	2.85	1.749
0.85	2.649	2.775	1.705
0.8666	2.586	2.718	1.661
0.8833	2.529	2.643	1.617
0.9	2.466	2.586	1.579
0.9166	2.41	2.517	1.535
0.9333	2.353	2.46	1.497
0.95	2.297	2.397	1.453
0.9666	2.24	2.341	1.416
0.9833	2.19	2.284	1.378
1	2.133	2.227	1.34
1.2	1.629	1.705	0.988
1.4	1.22	1.271	0.723
1.6	0.912	0.944	0.516
1.8	0.679	0.692	0.377
2	0.509	0.516	0.283
2.2	0.377	0.39	0.207
2.4	0.283	0.276	0.157
2.6	0.207	0.214	0.113
2.8	0.157	0.157	0.081
3	0.126	0.119	0.056
3.2	0.088	0.088	0.056
3.4	0.069	0.069	0.031
3.6	0.056	0.056	0.025
3.8	0.044	0.044	0.025

TABLE S1.5 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 1 Step 0	Test 1 Step 1	Test 1 Step 2
4	0.037	0.031	0.018
4.2	0.025	0.025	0.018
4.4	0.018	0.018	0.018
4.6	0.018	0.018	0.006
4.8	0.018	0.025	0.018
5	0.012	0.025	0.012
5.2	0.012	0.025	0.006
5.4	0.012	0.012	0.012
5.6	0.006	0.012	0.006
5.8		0.018	0.012
6		0.012	0.012
6.2		0.006	0.006

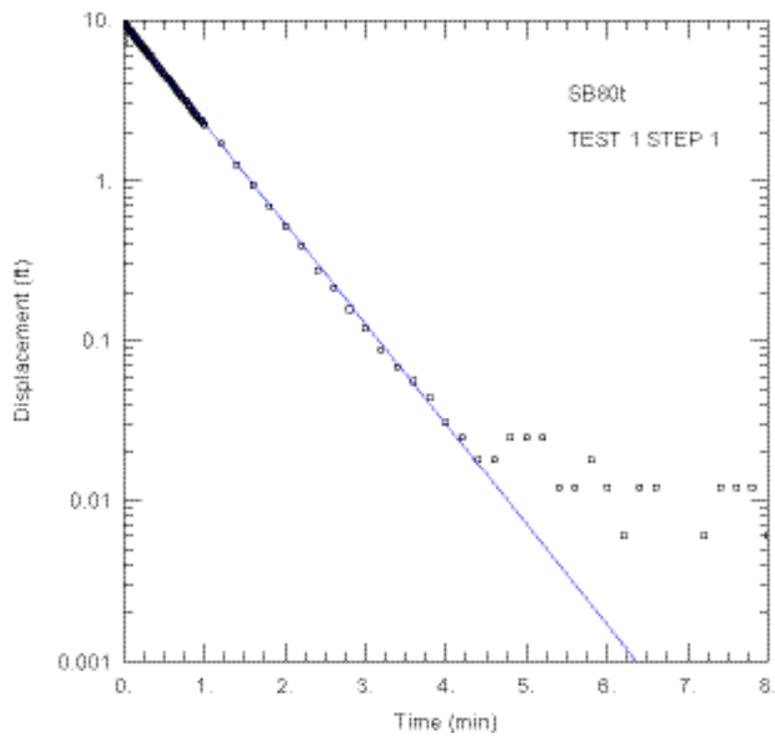
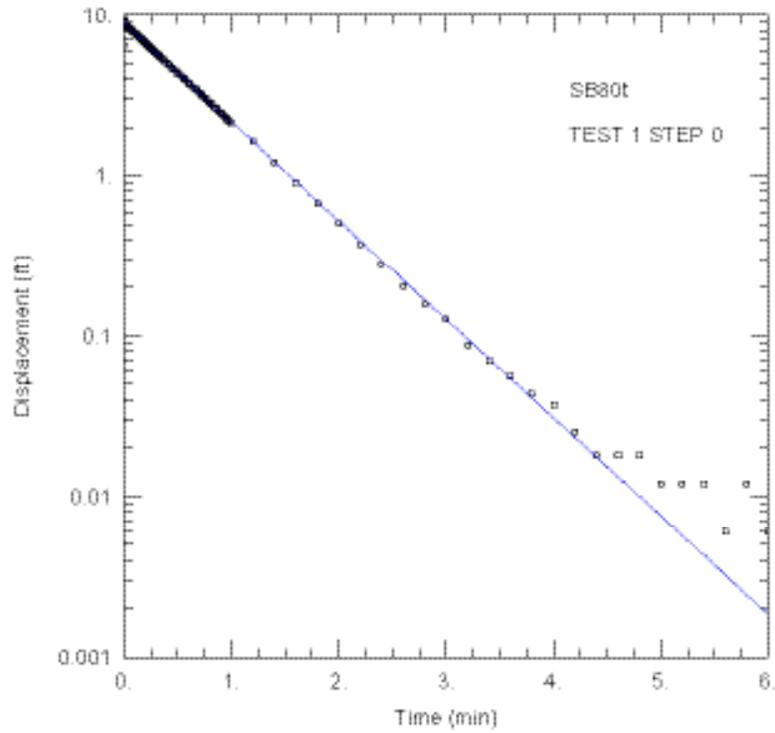


FIGURE S1.5 Slug test water level response and interpretive fit for the data for SB80.

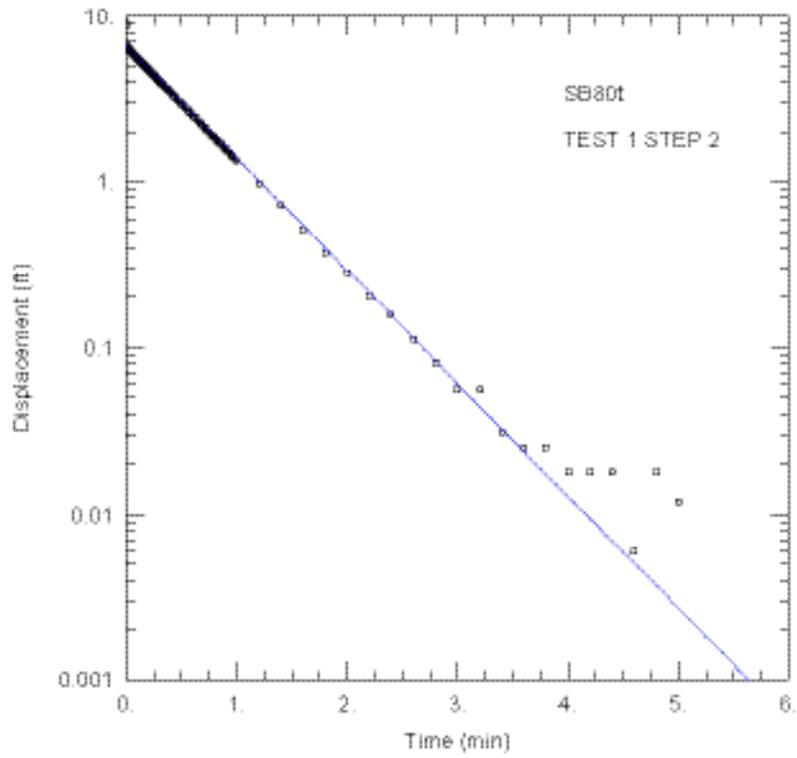


FIGURE S1.5 (Cont.)

TABLE S1.6 Slug test data for boring SB81 (effective saturated thickness = 15.36 ft; length of well = 15.36 ft; length of screen = 10 ft; casing radius = 0.04167 ft; borehole radius = 0.05469 ft;  $Kz/Kr = 1$ ).

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2
0	7.972	16.192	15.337
0.0033	7.475	8.242	8.959
0.0066	7.21	8.538	9.318
0.01	6.613	8.519	9.173
0.0133	6.537	8.412	9.148
0.0166	6.512	8.349	9.085
0.02	6.399	8.33	9.003
0.0233	6.38	8.242	8.947
0.0266	6.304	8.198	8.89
0.03	6.311	8.141	8.827
0.0333	6.292	8.091	8.783
0.0366	6.267	8.034	8.72
0.04	6.229	7.997	8.676
0.0433	6.204	7.953	8.557
0.0466	6.166	7.896	8.538
0.05	6.141	7.858	8.513
0.0533	6.116	7.808	8.469
0.0566	6.091	7.764	8.412
0.06	6.065	7.72	8.349
0.0633	6.034	7.676	8.311
0.0666	6.009	7.632	8.261
0.07	5.971	7.588	8.204
0.0733	5.952	7.55	8.154
0.0766	5.921	7.512	8.116
0.08	5.895	7.462	8.066
0.0833	5.864	7.424	8.016
0.0866	5.833	7.374	7.965
0.09	5.814	7.336	7.921
0.0933	5.782	7.298	7.883
0.0966	5.757	7.254	7.827
0.1	5.732	7.217	7.783
0.1033	5.713	7.173	7.745
0.1066	5.682	7.135	7.701
0.11	5.656	7.097	7.644
0.1133	5.631	7.059	7.6
0.1166	5.606	7.015	7.556
0.12	5.581	6.99	7.519
0.1233	5.556	6.933	7.481
0.1266	5.531	6.902	7.424
0.13	5.505	6.864	7.393
0.1333	5.486	6.827	7.349
0.1366	5.455	6.783	7.305
0.14	5.43	6.745	7.261
0.1433	5.411	6.707	7.217
0.1466	5.38	6.676	7.173
0.15	5.367	6.644	7.135
0.1533	5.336	6.606	7.097
0.1566	5.317	6.569	7.047
0.16	5.285	6.531	7.009
0.1633	5.266	6.493	6.965
0.1666	5.235	6.462	6.927

TABLE S1.6 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2
0.17	5.216	6.43	6.889
0.1733	5.191	6.392	6.852
0.1766	5.172	6.355	6.808
0.18	5.147	6.317	6.776
0.1833	5.122	6.286	6.732
0.1866	5.109	6.248	6.701
0.19	5.084	6.216	6.663
0.1933	5.052	6.179	6.625
0.1966	5.046	6.147	6.581
0.2	5.015	6.122	6.543
0.2033	4.989	6.078	6.499
0.2066	4.971	6.046	6.468
0.21	4.952	6.015	6.43
0.2133	4.92	5.99	6.392
0.2166	4.901	5.958	6.355
0.22	4.882	5.921	6.317
0.2233	4.864	5.889	6.286
0.2266	4.851	5.851	6.248
0.23	4.82	5.826	6.216
0.2333	4.794	5.795	6.172
0.2366	4.769	5.763	6.141
0.24	4.75	5.726	6.103
0.2433	4.738	5.7	6.072
0.2466	4.706	5.675	6.034
0.25	4.694	5.637	6.009
0.2533	4.675	5.606	5.965
0.2566	4.65	5.575	5.933
0.26	4.631	5.543	5.895
0.2633	4.612	5.518	5.858
0.2666	4.587	5.486	5.839
0.27	4.568	5.461	5.801
0.2733	4.549	5.43	5.77
0.2766	4.53	5.398	5.732
0.28	4.511	5.367	5.7
0.2833	4.492	5.342	5.663
0.2866	4.474	5.31	5.637
0.29	4.461	5.279	5.606
0.2933	4.436	5.254	5.568
0.2966	4.417	5.235	5.537
0.3	4.398	5.203	5.505
0.3033	4.379	5.166	5.474
0.3066	4.36	5.14	5.442
0.31	4.335	5.115	5.411
0.3133	4.323	5.084	5.386
0.3166	4.304	5.059	5.354
0.32	4.278	5.033	5.323
0.3233	4.253	5.008	5.291
0.3266	4.241	4.971	5.266
0.33	4.228	4.952	5.235
0.3333	4.203	4.92	5.203
0.35	4.115	4.788	5.065
0.3666	4.027	4.662	4.92
0.3833	3.939	4.543	4.788

TABLE S1.6 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2
0.4	3.857	4.423	4.65
0.4166	3.775	4.31	4.53
0.4333	3.693	4.197	4.411
0.45	3.624	4.09	4.278
0.4666	3.536	3.983	4.165
0.4833	3.467	3.882	4.046
0.5	3.391	3.781	3.926
0.5166	3.31	3.681	3.825
0.5333	3.259	3.586	3.725
0.55	3.196	3.492	3.612
0.5666	3.121	3.398	3.517
0.5833	3.051	3.316	3.423
0.6	2.982	3.228	3.328
0.6166	2.919	3.146	3.24
0.6333	2.85	3.064	3.152
0.65	2.794	2.982	3.064
0.6666	2.743	2.907	2.982
0.6833	2.68	2.831	2.901
0.7	2.617	2.762	2.825
0.7166	2.567	2.693	2.743
0.7333	2.517	2.624	2.674
0.75	2.46	2.554	2.592
0.7666	2.403	2.492	2.523
0.7833	2.353	2.422	2.46
0.8	2.303	2.359	2.391
0.8166	2.265	2.303	2.328
0.8333	2.215	2.24	2.271
0.85	2.164	2.183	2.208
0.8666	2.127	2.133	2.145
0.8833	2.07	2.076	2.076
0.9	2.032	2.026	2.032
0.9166	1.988	1.969	1.969
0.9333	1.944	1.919	1.913
0.95	1.9	1.869	1.856
0.9666	1.862	1.825	1.812
0.9833	1.831	1.78	1.762
1	1.787	1.73	1.718
1.2	1.403	1.302	1.258
1.4	1.082	0.956	0.906
1.6	0.843	0.698	0.66
1.8	0.648	0.516	0.472
2	0.497	0.377	0.346
2.2	0.39	0.277	0.251
2.4	0.302	0.214	0.188
2.6	0.232	0.157	0.144
2.8	0.182	0.119	0.1
3	0.138	0.088	0.075
3.2	0.113	0.075	0.062
3.4	0.081	0.05	0.037
3.6	0.069	0.044	0.031
3.8	0.05	0.031	0.031

TABLE S1.6 (Cont.)

Elapsed Time (min)	Residual Drawdown (ft)		
	Test 2 Step 0	Test 2 Step 1	Test 2 Step 2
4	0.037	0.025	0.025
4.2	0.037	0.019	0.019
4.4	0.031	0.012	0.019
4.6	0.019	0.019	0.012
4.8	0.025	0.006	0.012
5	0.012	0.006	0.012
5.2	0.012	0.012	0.012
5.4	0.012	0.006	0.012
5.6	0.006	0.012	0.006
5.8		0.019	
6		0.006	

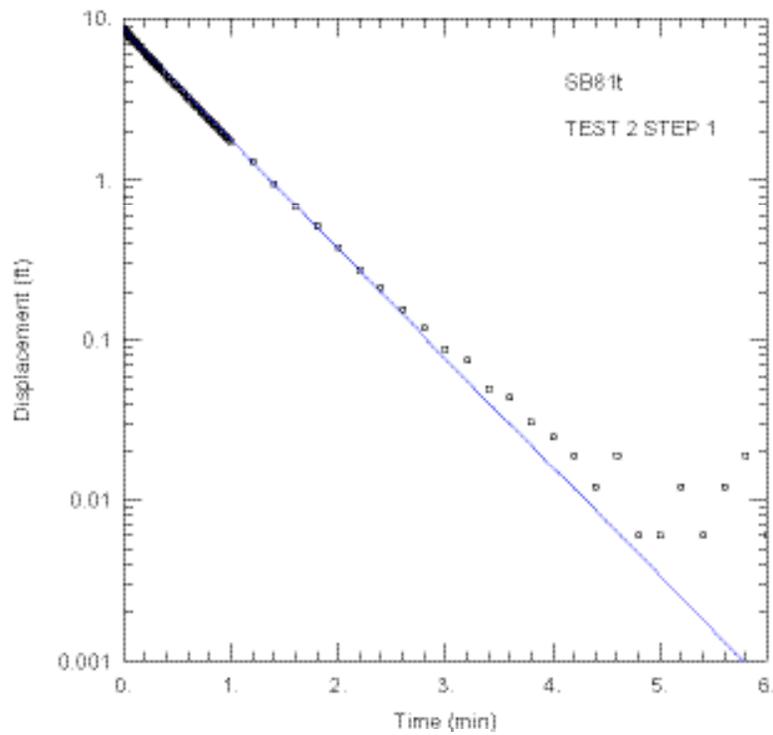
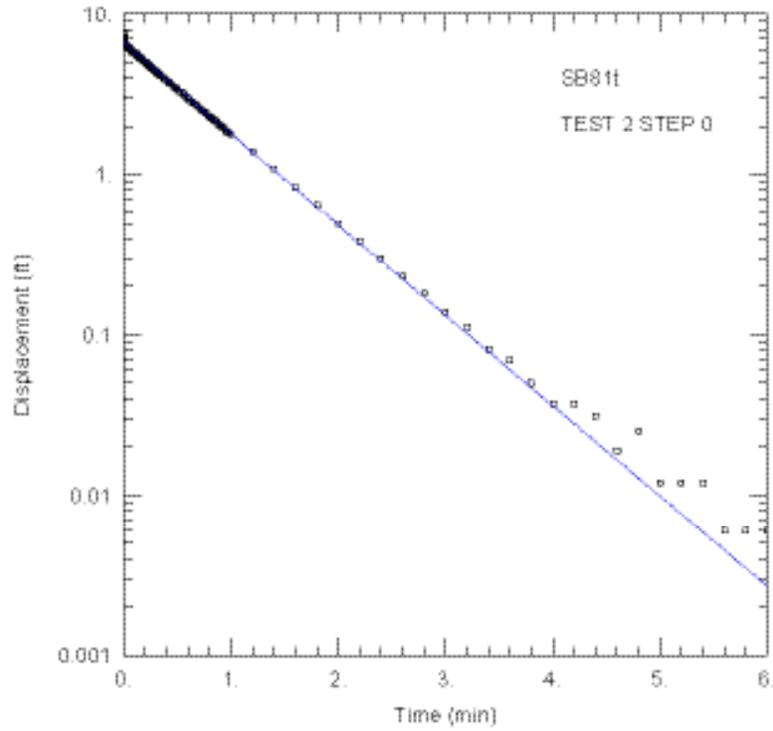


FIGURE S1.6 Slug test water level response and interpretive fit for the data for SB81.

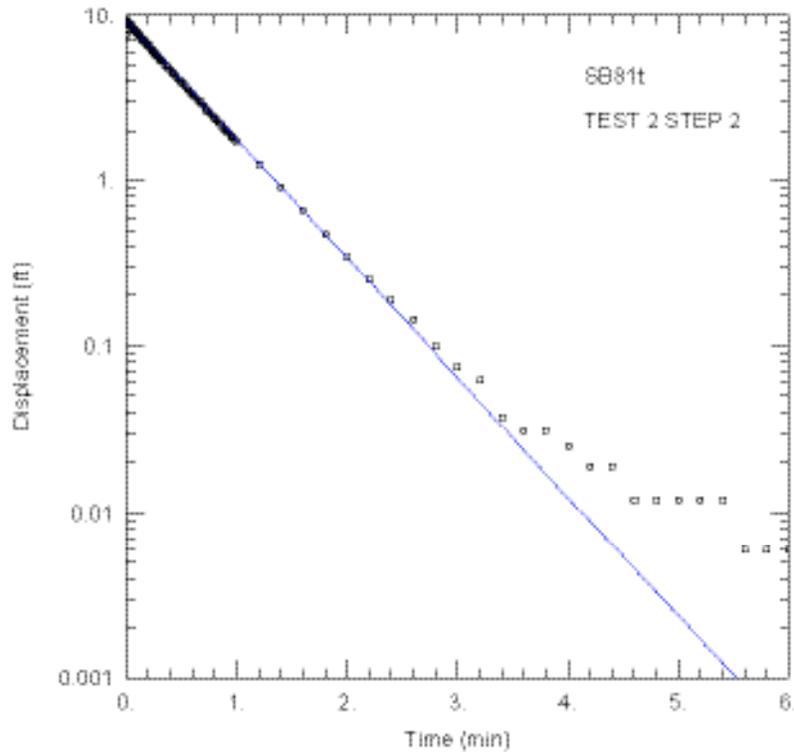


FIGURE S1.6 (Cont.)

**Supplement 2:**

**Quality Control for Sample Collection, Handling, and Analysis**

## Supplement 2:

### Quality Control for Sample Collection, Handling, and Analysis

Groundwater, surface water and tile outflow, and near-surface and subsurface soils were sampled in March–June 2004 at Murdock, Nebraska, to augment existing contaminant data. Indoor air sampling was conducted in August 2004. Throughout the investigation, QA/QC samples were collected to monitor sample collection, handling, and analysis. The QA/QC procedures followed are described in detail in the *Master Work Plan* (Argonne 2002) and the site-specific *Work Plan* for the targeted investigation (Argonne 2003). Evaluation of the organic analytical data was consistent with regulatory guidelines (EPA 1994).

#### S2.1 Sampling to Monitor Sampling Collection, Handling, and Analysis

Sample collection and handling were monitored by the documentation of samples as they were collected and the use of chain-of-custody (COC) forms and custody seals to ensure sample integrity during handling and shipment. Minor transcription errors in identifiers for some samples as listed on the COC records, sample containers, or analytical data reports were resolved by comparison of the various records.

The QA/QC samples collected included a background soil sample, a field blank, equipment rinsates, and trip blanks. Blind field replicate samples were collected, and other samples were selected for duplicate analyses as a measure of analytical precision. The QA/QC samples are listed in Table S2.1. Analytical results for carbon tetrachloride and chloroform in QA/QC samples collected to monitor sample collection and handling are in Table S2.2.

##### S2.1.1 Background Soil Sample

Analysis of the background surface soil sample MUQCBG-S-15585 provided a baseline for the near-surface soil survey conducted in May 2004.

### **S2.1.2 Field Blank**

Analysis of the field blank MUQCFB-W-15603 indicated that water used for equipment decontamination and other activities did not introduce contamination to the collected samples.

### **S2.1.3 Equipment Rinsates**

Analysis of the rinsate samples indicated that decontamination procedures were adequate to prevent cross-contamination of samples during collection.

### **S2.1.4 Trip Blanks**

Analysis of 19 trip blanks, prepared and included in shipments of samples shipped for organic analysis, indicated that cross-contamination of samples did not occur during shipment.

### **S2.1.5 Replicate Samples and Duplicate Analyses**

As an indicator of the consistency of the sampling methodology and to provide a measure of analytical precision, blind replicate groundwater, surface water, and soil samples were collected. In addition, samples were selected by the AGEM Laboratory for duplicate organic analyses. Selected groundwater samples were shipped to a second laboratory for verification analysis. Blind replicate samples, samples selected for duplicate analyses, and samples selected for verification organic analysis are identified in Table S2.1.

## **S2.2 Quality Control for Organic Analysis of Water Samples**

Fifty-four groundwater samples (8 blind replicate samples and the samples identified in Table F.1) and 24 surface water and tile outflow samples (2 blind replicate samples and the samples identified Table G.1) were collected in March–June 2004 for organic analysis. These samples and the associated QC samples were shipped immediately to the AGEM Laboratory for analysis with EPA Method 524.2 (EPA 1995). To enable verification of the accuracy of the results, duplicate (split) groundwater samples were collected. On the basis of its results, the

AGEM Laboratory selected some of the duplicate samples for shipment to Clayton Laboratory and verification analysis with CLP methodology (EPA 1989b).

The following sections describe QC measures followed during analysis of the water samples and the quality of the organic analytical data from each laboratory. Analytical data from the AGEM Laboratory are discussed in Section S2.2.1, and analytical data from Clayton Laboratory are discussed in Section S2.2.2. The analytical results from the two laboratories are compared in Section S2.2.3.

### **S2.2.1 Organic Analysis of Water Samples at the AGEM Laboratory**

Water samples shipped to the AGEM Laboratory were analyzed by the purge-and-trap method with a GC-MS system. For the purge-and-trap analyses, the VOCs in a groundwater sample were extracted (purged) from the sample matrix by bubbling an inert gas through the sample. The purged components were trapped in a specified sorbent tube. After the purging, the sorbent tube was heated and backflushed with an inert gas to desorb the components into the GC-MS system. The compounds eluting from the GC column were identified by retention time and by comparison with reference library spectra. The concentration of each component was calculated by comparison of the MS response for the quantitation ion to the response for corresponding calibration curves, internal standards, or both. Calibration checks with each sample delivery group (SDG) were required to be within  $\pm 20\%$  of the standard.

Water samples submitted to the AGEM Laboratory for organic analysis were analyzed in 14 SDGs. Table S2.3 identifies the groundwater samples, surface water and tile outflow samples, and associated QC samples analyzed in the SDGs. The QA/QC procedures followed included analysis of instrument calibration check standards, analysis of laboratory blanks, monitoring of surrogate spike recovery, and duplicate laboratory analyses. Significant results include the following:

- Samples shipped to the AGEM Laboratory were received with custody seals intact and at the appropriate temperature. All samples were analyzed within required holding times.

- Contaminants of concern were not detected in laboratory method blanks analyzed with the samples.
- For each SDG, analytical instrument calibration was monitored by the analysis of calibration check standards. Table S2.3 shows the relative percent difference (RPD) values between the known and calculated concentrations of the standards. The concentrations of calibration check standards measured in all SDGs were within the acceptable range of  $\pm 20\%$ . Because a result for the initial calibration standard in SDG 04-4-8 was outside the acceptable range for carbon tetrachloride, a second calibration standard was run; this standard met the requirement.
- Surrogate standard determinations were performed on samples and blanks by using surrogate spike compounds fluorobenzene, 1,2-dichlorobenzene-d<sub>4</sub>, and 4-bromofluorobenzene. Table S2.3 shows the percent recoveries of these system-monitoring compounds for each of the analyses. With the following four exceptions, the surrogate recoveries achieved were above the minimum value of 80% in the initial analysis or a reanalysis.
  - Groundwater sample MU4S-W-15629 was analyzed in SDG 04-3-31 with recovery of surrogate compound 1,2-dichlorobenzene-d<sub>4</sub> at 79.1%. Recoveries of the other surrogate compounds were within the acceptable range. Limited sample volume prevented reanalysis. The detection of no contamination in the sample is consistent with historical results. Because the recovery of 1,2-dichlorobenzene-d<sub>4</sub> was only slightly below the required value of 80%, the data are accepted without qualification.
  - Trip blank MUQCTB-W-15597 was analyzed in SDG 04-3-31 with low recovery for two of the three surrogate compounds. No contamination was detected in the associated samples, indicating that cross-contamination of the samples did not occur during shipping and handling. The trip blank result is accepted without qualification.
  - Trip blank MUQCTB-W-15608 was analyzed in SDG 04-4-1 with low recovery for all three surrogate compounds. Results for samples associated

with the trip blank indicate that cross-contamination of the samples did not occur during shipping and handling. The trip blank result is accepted without qualification.

- Replicate groundwater sample MUSB74-W-15646 was analyzed undiluted in SDG 04-4-6 with low recovery for all three surrogate compounds. Carbon tetrachloride was outside the calibration limit for the analysis, and the sample was successfully reanalyzed at dilution factor 10 in SDG 04-4-7 to quantify the concentration of carbon tetrachloride. The chloroform concentration detected only in the undiluted replicate (analyzed with low surrogate recovery) is accepted with qualification.
- As a measure of consistency in the sampling and analytical methodologies, 8 blind replicate groundwater samples and 2 blind replicate surface water samples were collected and analyzed. In addition, 2 of the replicates and 17 samples were selected by the laboratory for duplicate analyses. Table S2.4 summarizes the analytical results for the initial samples and the associated secondary QC analyses. The results show good agreement, indicating consistency in both the sampling and analytical methodologies. For samples in which no contamination was detected, the associated QC analyses showed similar results. For samples in which carbon tetrachloride was detected, the RPD values between the initial analyses and the associated QC analyses were 0–28.7%, with an average of 8.3%. For samples in which quantified concentrations of chloroform were reported, the RPD values between the initial analyses and the associated QC analyses were 3.8–22.2%, with an average of 9.7%.

The analytical data from the AGEM Laboratory are acceptable for quantitative determination of contaminant distribution in groundwater and surface water.

### **S2.2.2 Organic Analysis of Water Samples at Clayton Laboratory**

In accordance with the QA/QC procedures defined in the *Master Work Plan* (Argonne 2002), the analyses of water samples at the AGEM Laboratory with EPA Method 524.2 were verified by analysis with EPA-defined CLP methodology. On the basis of its results, the AGEM

Laboratory selected replicate samples (identified in Table S2.1) for the verification analysis. A comparison of the AGEM Laboratory and CLP analytical results for the replicate samples is in Section S2.2.3. Below is a discussion of the quality of the CLP analytical data.

Five replicate (split) groundwater samples were shipped to Clayton Laboratory for organic analysis with CLP methodology. The samples were sent in one shipment with a trip blank. A complete CLP data package was provided. The QA/QC procedures followed included initial and continuing calibration of instruments, analysis of laboratory blanks, monitoring of surrogate spike recovery, and matrix spike/matrix spike duplicate analyses. Significant results include the following:

- Samples shipped to the CLP laboratory were received with custody seals intact and at the appropriate temperature. The samples were analyzed 12–13 days after collection, just within the maximum holding time of 14 days.
- Analytical instruments were properly tuned; initial and continuing calibration checks remained within the allowable ranges for carbon tetrachloride and chloroform, the contaminants of concern.
- Contaminants of concern were not detected in the laboratory method blanks. Acetone and 2-butanone were present at low concentrations (3 µg/L and 7 µg/L, respectively) in the trip blank.
- Surrogate standard determinations were performed on samples and blanks by using the surrogate spike compounds toluene-d<sub>8</sub>, 4-bromofluorobenzene, and 1,2-dichloroethane-d<sub>4</sub>. Table S2.5 shows the percent recoveries of the system-monitoring compounds for each CLP analysis. For all analyses, recoveries of the surrogate spikes were within the acceptable ranges (identified in Table S2.5) specific to the surrogates.
- To evaluate the matrix effect of samples on the analytical methodology, a matrix spike/matrix spike duplicate analysis was performed in accordance with CLP protocol by using matrix spike compounds 1,1-dichloroethene, trichloroethene, chlorobenzene, toluene, and benzene. Table S2.6 shows the percent recovery of each spike compound and the calculated RPD value

between the spike and spike duplicate results. The QC parameters were within the acceptable range.

Organic analytical data from Clayton Laboratory for the replicate groundwater samples are acceptable for comparison to the AGEM Laboratory data.

### **S2.2.3 Verification Organic Analysis of Water Samples**

In accordance with the QA/QC procedures defined in the *Master Work Plan* (Argonne 2002), selected replicates of the water samples analyzed at the AGEM Laboratory with EPA Method 524.2 were subjected to verification analysis at Clayton Laboratory with CLP methodology. Five groundwater samples analyzed at the AGEM Laboratory were subjected to the verification analysis (9.3% of the 54 groundwater samples). Table S2.7 compares the results for carbon tetrachloride and chloroform obtained with EPA Method 524.2 and CLP methodology.

Carbon tetrachloride results reported by the two laboratories are in good agreement. Two samples analyzed at the AGEM Laboratory with no detection or low detection (approximately 1 µg/L) of carbon tetrachloride were analyzed at Clayton Laboratory with similar results. Three samples with carbon tetrachloride present above the maximum contaminant level of 5 µg/L had RPD values between the two laboratories of 2–21.4%.

Chloroform results are less consistent between the two laboratories. The cause might have been degradation prior to analysis at Clayton Laboratory resulting from the difference in holding times at the two laboratories. Two samples analyzed at the AGEM Laboratory with no detection of chloroform were analyzed at Clayton Laboratory with similar results. However, for the three samples in which chloroform was present, the RPD values between the two laboratories were 3–140%. In addition, methylene chloride (a degradation product of chloroform, which in turn is a degradation product of carbon tetrachloride) was reported by Clayton Laboratory in the two groundwater samples with the highest RPD values between chloroform concentrations. In contrast, no methylene chloride was detected by the AGEM Laboratory.

Analytical results for water samples analyzed at the AGEM Laboratory with EPA Method 524.2 are supported by the analytical results for replicate samples analyzed at Clayton Laboratory with EPA CLP methodology.

### **S2.3 Quality Control for Organic Analysis of Soil Samples**

Near-surface soil sampling was conducted at 57 locations across the former CCC/USDA facility in May–June 2004 to determine whether a pattern of carbon tetrachloride concentrations was evident that might indicate potential subsurface zones of contamination at the locations of former grain storage structures and a former carbon tetrachloride storage building. A total of 125 near-surface soil samples (including 2 samples from each of the 57 sampling locations, 1 background sample, and 10 blind field replicates) were collected for carbon tetrachloride and chloroform analyses at the AGEM Laboratory with a modification of EPA Method 5021 (headspace analysis on a GC-ECD system) to achieve method detection limits of 0.20 µg/kg for carbon tetrachloride and 0.75 µg/kg for chloroform. These qualitative data were used to evaluate the pattern of contamination across the former CCC/USDA facility. Quantitative contaminant concentrations at a quantitation limit of 10 µg/kg were obtained through sample preparation and analysis for VOCs, including carbon tetrachloride and chloroform, with EPA Methods 5030B and 8260B (a purge-and-trap GC-MS method), as referenced in the EPA's SW-846 test methods (<http://www.epa.gov/epaoswer/hazwaste/test/main.htm>).

On the basis of the qualitative headspace results, subsurface soil sampling was conducted in June 2004 at three soil boring locations (HC57, SB85, and SB86), and 77 subsurface soil samples were collected. These samples were analyzed at the AGEM Laboratory with the purge-and-trap GC-MS method.

To verify the accuracy of the quantitative purge-and-trap results for both the near-surface and subsurface soil samples, random samples were split and prepared for independent analysis by the same method. On the basis of its results, the AGEM Laboratory selected split samples for the verification analysis at Severn-Trent Laboratory in Colchester, Vermont.

The following sections describe QC measures followed during analysis of the soil samples and discuss the quality of the organic analytical data from each laboratory. Analytical data from the AGEM Laboratory are discussed in Section S2.3.1, and analytical data from Severn-Trent

Laboratory are discussed in Section S2.3.2. The analytical results from the two laboratories are compared in Section S2.3.3.

### **S2.3.1 Analysis of Soil Samples at the AGEM Laboratory**

Soil samples were quick-frozen on dry ice as they were collected. At the AGEM Laboratory, the VOCs present in each soil sample were extracted with methanol from the sample matrix.

For the headspace soil analyses, each methanol extract was placed in a sealed headspace vial with the internal standard solution. The samples were placed in a headspace sampler and analyzed by using a modification of EPA Method 5021. An 11-point calibration of the GC system was established on the basis of the mass of known quantities of carbon tetrachloride and chloroform in the range 0.125–4 ng. A limitation of the chloroform analysis is the presence of chloroform (at very low concentration) in the methanol solvent used in standard preparation. Quality control analyses were performed for 20 near-surface soil sampling locations (including the background location) through the analysis of blind field replicate samples or duplicate analyses of samples selected by the laboratory (Table S2.8). Consistency is evident in the analysis of the near-surface soil samples by the headspace method, and the analytical data obtained with this method are acceptable for qualitative determination of contaminant distribution.

For the purge-and-trap soil analyses, an aliquot of the methanol extract was purged, and the volatile species were transferred to a sorbent tube. After purging, the sorbent tube was heated and backflushed with an inert gas to desorb the components into the GC-MS system. The compounds eluting from the GC column were identified by retention time and by comparison with reference library spectra. The concentration of each component was calculated by comparison of the MS response for the quantitation ion to the response on corresponding calibration curves, for internal standards, or both.

Soil samples were analyzed at the AGEM Laboratory with the purge-and-trap method in 17 SDGs, as shown in Table S2.9. The QA/QC procedures followed included initial and continuing calibration of instruments, analysis of laboratory blanks, monitoring of surrogate spike

recovery, analysis of replicate samples, and duplicate analyses of selected samples. Significant results include the following:

- Soil samples were received with custody seals intact and at the appropriate temperature. All samples were analyzed within required holding times.
- Contaminants of concern were not detected in the laboratory method blanks. Methylene chloride was present in the methanol used for soil extraction but is not reported for the soil analyses.
- For each SDG, analytical instrument calibration was monitored by the analysis of calibration check standards. Table S2.9 shows the RPD values between the known and calculated concentrations of the standards. The concentrations of calibration check standards measured in all SDGs were within the acceptable range of  $\pm 20\%$ .
- Surrogate standard determinations were performed on the samples and blanks by using the surrogate spike compounds fluorobenzene, 4-bromofluorobenzene, and 1,2-dichlorobenzene- $d_4$ . Table S2.9 shows the percent recoveries of these system-monitoring compounds for each analysis. In the analyses of the following two soil samples, the surrogate recovery was outside the acceptable range of 80–120%:
  - In the analysis of near-surface soil sample MUHC05B-S-17067 in SDG 04-6-10, the recoveries of all three surrogate compounds were below the specified limit of 80%. The sample was subsequently reanalyzed in SDG 04-6-11 with recovery of one surrogate compound above the 120% limit. High surrogate recovery would not inhibit detection of contamination; the “not detected” result is accepted without qualification.
  - In the analysis of near-surface soil sample MUHC55-S-15591 in SDG 04-7-8, the recoveries of surrogate compounds fluorobenzene and 4-bromofluorobenzene were below the specified limit of 80%. The sample (collected at a depth of 1 ft BGL) was not reanalyzed. The “not detected” result for the sample analysis is consistent with the result for the sample

collected at a depth of 3 ft, as well as with results from analysis of the 1-ft BGL sample by the headspace method. The “not detected” result is accepted without qualification.

- Blind replicates of 10 near-surface soil samples and 8 subsurface soil samples were collected in the field. Four of these replicates and an additional 17 soil samples were selected by the AGEM Laboratory for duplicate organic analyses by the purge-and-trap method. Table S2.10 compares the initial and secondary QC analytical results for soil samples analyzed by the purge-and-trap method. Samples in which contamination was not detected at the method quantitation limit of 10 µg/kg were reanalyzed with similar results. For the three samples in which carbon tetrachloride was detected, the initial and secondary analytical results show good agreement, with RPD values of 4.7–15.4%.

The analytical data from the AGEM Laboratory are acceptable for quantitative determination of contaminant distribution in the near-surface and subsurface soils.

### **S2.3.2 Analysis of Soil Samples at Severn-Trent Laboratory**

In accordance with the QA/QC procedures defined in the *Master Work Plan* (Argonne 2002), selected soil samples prepared and analyzed at the AGEM Laboratory for carbon tetrachloride and chloroform with EPA Methods 5030B and 8260B were subjected to verification analysis with the same methods at a second laboratory. The analytical results from the two laboratories are compared in Section S2.3.3. Below is a discussion of the quality of the organic analytical data from Severn-Trent Laboratory.

Fourteen replicate soil samples (including eight near-surface soil samples and six subsurface soil samples) were sent to Severn-Trent Laboratory in two shipments, with a trip/field blank of the methanol used for sample extraction in each shipment. Complete data packages were provided. The QA/QC procedures followed included initial and continuing

calibration of instruments, analysis of laboratory blanks, monitoring of surrogate spike recovery, and matrix spike/matrix spike duplicate analyses. Significant results include the following:

- Soil samples shipped to the Severn-Trent Laboratory were received with custody seals intact and at the appropriate temperature. All samples were analyzed within required holding times.
- Analytical instruments were properly tuned; initial and continuing calibration checks remained within the allowable range.
- Contaminants of concern were not detected in the trip/field blanks or laboratory method blanks.
- Surrogate standard determinations were performed on samples and blanks by using the surrogate spike compounds toluene-d<sub>8</sub>, 1,2-dichloroethane-d<sub>4</sub>, 4-bromofluorobenzene, and 1,2-dichlorobenzene-d<sub>4</sub>. Table S2.11 shows the percent recoveries for the system-monitoring compounds in each analysis. The recoveries of the surrogate spikes were within the acceptable range (identified in Table S2.11) specific to each surrogate.
- To evaluate the matrix effect of samples on the analytical methodology, matrix spike/matrix spike duplicate analyses were performed with a suite of matrix spike compounds including carbon tetrachloride and chloroform. Table S2.12 shows the recoveries of carbon tetrachloride and chloroform in these analyses, as well as the calculated RPD values between the spike and spike duplicate analytical results. The QC limits (identified in Table S2.12) were achieved for these analyses.

The organic analytical data from Severn-Trent Laboratory for the replicate soil samples are acceptable for comparison with the AGEM Laboratory data.

### **S2.3.3 Verification Analysis of Soil Samples**

In accordance with the QA/QC procedures defined in the *Master Work Plan* (Argonne 2002), selected replicates of the soil samples prepared and analyzed for carbon tetrachloride and chloroform at the AGEM Laboratory with EPA Methods 5030B and 8260B were subjected to verification analysis at a second laboratory. Of the 191 soil samples (excluding the background sample) analyzed at the AGEM Laboratory for carbon tetrachloride and chloroform, 14 samples (7% of 191 samples) were subjected to the verification analysis. Table S2.13 compares the analytical results for the soil samples analyzed at both laboratories.

Results from the two analytical laboratories are consistent over the range of carbon tetrachloride concentrations detected during the investigation. Samples analyzed at the AGEM Laboratory in which no carbon tetrachloride was detected were analyzed at Severn-Trent Laboratory with similar results, although for near-surface soil sample MUHC48T-S-17152 — in which no contamination was detected by the AGEM Laboratory — an estimated concentration below the quantitation limit of 10 µg/kg was reported by Severn-Trent. For the three samples analyzed at the AGEM Laboratory in which carbon tetrachloride was detected above the quantitation limit, similar concentrations were reported by Severn-Trent, with RPD values of 8.5–24.3% between the two laboratories. Detections by the AGEM Laboratory of 1,1,1-trichloroethane at trace concentrations below the quantitation limit in several subsurface soil samples collected at the SB85 location were verified in analysis at Severn-Trent Laboratory. Analytical data obtained with EPA Methods 5030B and 8260B at the AGEM Laboratory are supported by the data from Severn-Trent Laboratory.

## **S2.4 Quality Control for Organic Analysis of Air Samples**

Indoor air samples were collected from the basement areas of four residences in Murdock, and a background sample was collected outside one residence. The samples were analyzed at Severn-Trent Laboratory (Colchester, Vermont) with EPA Method TO-15 (EPA 1999). Target limits were met for instrument calibration. The method blanks associated with the analyses were free of contamination. As a measure of analytical precision, two QC samples were analyzed in duplicate (Table S2.14). For these QC samples, the derived recoveries of two chemicals (1,2,4-trichlorobenzene and hexachlorobutadiene) did trend high, but neither chemical was detected in the collected samples. The other target analytes were recovered well in each of the QC samples. The detections of several chemicals are qualified (Table S2.14) because of poor MS signal response. The analytical data are acceptable for screening of indoor air contamination.

TABLE S2.1 Quality control samples collected during the targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Background soil samples</i>				
QC	MUQCBG-S-15585	1	5/27/04	Background near-surface soil sample from cultivated ground east of Murdock, at the southeast corner of the intersection of Church and Waverly Roads.
<i>Field blank</i>				
QC	MUQCFB-W-15603	— <sup>a</sup>	3/31/04	Blank of water used for equipment decontamination during this sampling event.
<i>Equipment rinsates</i>				
QC	MUQCRI-W-15602	—	3/31/04	Rinsate of decontaminated sampling hose after collection of sample MUSB63S-W-15601.
QC	MUQCRI-W-15604	—	3/31/04	Rinsate of decontaminated bailer after collection of sample MU2D-W-15595.
QC	MUQCBR-W-15636	—	4/2/04	Rinsate of decontaminated bailer after collection of sample MUSB76-W-15636.
QC	MUQCBR-W-15642	—	4/3/04	Rinsate of decontaminated bailer after collection of sample MUSB79-W-15641.
QC	MUSB80-W-15650	—	4/4/04	Rinsate of decontaminated bailer after collection of sample MUSB80-W-15649.
QC	MUQCBR-W-15655	—	4/5/04	Rinsate of decontaminated bailer after collection of sample MUSB81-W-15654.
<i>Trip blanks shipped with soil samples for organic analysis</i>				
QC	MUQCTB-S-15514	—	5/26/04	Trip blank sent to the AGEM Laboratory with samples listed on COCs 3451, 3449, 3447, and 3450.
QC	MUQCTB-S-15662	—	5/27/04	Trip blank sent to the AGEM Laboratory with samples listed on COCs 3856 and 3857.
QC	MU-S-MEOHBLANK	—	6/7/04	Trip blank sent to Severn-Trent Laboratory for verification organic analysis with soil samples listed on COC 4009.
QC	MUQCTB-S-15586	—	6/28/04	Trip blank sent to the AGEM Laboratory with soil samples listed on COCs 3454, 3455, 3460.
QC	MUQCTB-S-15685	—	6/29/04	Trip blank sent to the AGEM Laboratory with soil samples listed on COCs 3456, 3457, 3458.
QC	MUQCTB-S-15688	—	6/30/04	Trip blank sent to the AGEM Laboratory with soil samples listed on COCs 3459 and 3858.
QC	MU-S-MEOHBLANK2	—	7/6/04	Trip blank sent to Severn-Trent Laboratory for verification organic analysis with soil samples listed on COC 4011.
<i>Trip blanks shipped with water samples for organic analysis</i>				
QC	MUQCTB-W-15597	—	3/30/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 993.
QC	MUQCTB-W-15608	—	3/31/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 3624.
QC	MUQCTB-W-15624	—	4/1/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 1025.
QC	MUQCTB-W-15738	—	4/2/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 3231.
QC	MUQCTB-W-15739	—	4/2/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 1026 and COC 1027.
QC	MUQCTB-W-15742	—	4/3/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 3232.
QC	MUQCTB-W-15784	—	4/5/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 3233.

TABLE S2.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Trip blanks shipped with water samples for organic analysis (Cont.)</i>				
QC	MUTB-W-15000	–	4/5/04	Trip blank sent to Clayton Laboratory for verification organic analysis with water samples listed on COC 4006.
QC	MUSB83-W-15657	–	4/6/04	Trip blank sent to the AGEM Laboratory with samples listed on COC 3234.
QC	WAQCTB-W-13426	–	4/24/04	Trip blank sent to the AGEM Laboratory with water samples listed on COC 3250 (Waverly project samples) and COC 14502 (Murdock drum sample).
QC	MUQCTB-W-15686	–	6/29/04	Trip blank sent to the AGEM Laboratory with water samples listed on COC 3446.
QC	MUQCTB-W-17198	–	6/30/04	Trip blank sent to the AGEM Laboratory with water samples listed on COC 3859.
<i>Waste characterization samples</i>				
QC	MUQCWADR1-W-15781	–	4/5/04	Waste purge water in drum #1.
QC	MUQCWADR2-W-15782	–	4/5/04	Waste purge water in drum #2.
QC	MUQCWADR3-W-15783	–	4/5/04	Waste purge water in drum #3.
QC	MUQCDR-W-APR24	–	4/24/04	Composite sample after aeration from three drums containing purge water.
QC	MU-S-15587	–	6/8/04	Composite sample of drill cuttings from unsuccessful GWEXTEST well.
QC	MU-W-15591	–	6/8/04	Composite sample of development water from unsuccessful GWEXTEST well.
QC	MU-GWEX2 soil	–	8/3/04	Composite sample of drill cuttings from successful GWEX-1 well.
QC	MU-GWEX2 water	–	8/3/04	Composite sample of development water from successful GWEX-1 well.
<i>Blind replicate soil samples</i>				
HC25	MUQCDS-S-15508	1	5/26/04	Replicate of near-surface soil sample MUHC25T-S-17106.
HC25	MUQCDS-S-15509	3	5/26/04	Replicate of near-surface soil sample MUHC25B-S-17107.
HC27	MUQCDS-S-15510	1	5/26/04	Replicate of near-surface soil sample MUHC27T-S-17110.
HC27	MUQCDS-S-15511	3	5/26/04	Replicate of near-surface soil sample MUHC27B-S-17111.
HC28	MUQCDS-S-15512	1	5/26/04	Replicate of near-surface soil sample MUHC28T-S-17112.
HC28	MUQCDS-S-15513	3	5/26/04	Replicate of near-surface soil sample MUHC28B-S-17113.
HC35	MUQCDS-S-15660	1	5/26/04	Replicate of near-surface soil sample MUHC35T-S-17126.
HC35	MUQCDS-S-15661	3	5/26/04	Replicate of near-surface soil sample MUHC35B-S-17127.
HC49	MUQCDS-S-15583	1	5/27/04	Replicate of near-surface soil sample MUHC49T-S-17154.
HC49	MUQCDS-S-15584	3	5/27/04	Replicate of near-surface soil sample MUHC49B-S-17155.
HC57	MUQCDS-S-17197	17	6/30/04	Replicate of subsurface soil sample MUHC57-S-17193.
HC57	MUQCDS-S-17196	21	6/30/04	Replicate of subsurface soil sample MUHC57-S-17195.
SB85	MUQCDS-S-11299	19	6/28/04	Replicate of subsurface soil sample MUSB85-S-17216.
SB85	MUQCDS-S-15502	39	6/28/04	Replicate of subsurface soil sample MUSB85-S-17226.
SB85	MUQCDS-S-15524	59	6/28/04	Replicate of subsurface soil sample MUSB85-S-17236.
SB86	MUQCDS-S-15587	23	6/29/04	Replicate of subsurface soil sample MUSB86-S-17252.

TABLE S2.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Blind replicate soil samples (Cont.)</i>				
SB86	MUQCDS-S-15588	55	6/29/04	Replicate of subsurface soil sample MUSB86-S-17168.
SB86	MUQCDS-S-15593	63	6/29/04	Replicate of subsurface soil sample MUSB86-S-17172.
<i>Soil samples selected by the AGEM Laboratory for duplicate analyses by the headspace method</i>				
HC03	MUHC03B-S-17063	3	5/25/04	Near-surface soil sample.
HC04	MUHC04B-S-17065	3	5/25/04	Near-surface soil sample.
HC07	MUHC07T-S-17070	1	5/25/04	Near-surface soil sample.
HC10	MUHC10B-S-17077	3	5/25/04	Near-surface soil sample.
HC16	MUHC16B-S-17089	3	5/25/04	Near-surface soil sample.
HC20	MUHC20B-S-17097	3	5/26/04	Near-surface soil sample.
HC30	MUHC30T-S-17116	1	5/26/04	Near-surface soil sample.
HC32	MUHC32T-S-17120	1	5/26/04	Near-surface soil sample.
HC49	MUHC49B-S-17155	3	5/27/04	Near-surface soil sample.
HC57	MUHC57-S-17181	1	6/30/04	Near-surface soil sample.
QC	MUQCBG-S-15585	1	5/27/04	Background soil sample.
<i>Soil samples selected by the AGEM Laboratory for duplicate analyses by the purge-and-trap method</i>				
HC02	MUHC02T-S-17060	1	5/25/04	Near-surface soil sample.
HC03	MUHC03B-S-17063	3	5/25/04	Near-surface soil sample.
HC09	MUHC09T-S-17074	1	5/25/04	Near-surface soil sample.
HC10	MUHC10T-S-17076	1	5/25/04	Near-surface soil sample.
HC17	MUHC17T-S-17090	1	5/25/04	Near-surface soil sample.
HC22	MUHC22B-S-17101	3	5/26/04	Near-surface soil sample.
HC25	MUHC25T-S-17106	1	5/26/04	Near-surface soil sample.
HC28	MUQCDS-S-15512	1	5/26/04	Replicate of near-surface soil sample MUHC28T-S-17112.
HC35	MUQCDS-S-15661	3	5/26/04	Replicate of near-surface soil sample MUHC35B-S-17127.
HC36	MUHC36B-S-17129	3	5/26/04	Near-surface soil sample.
HC50	MUHC50T-S-17156	1	5/27/04	Near-surface soil sample.
HC52	MUHC52-S-17189	3	6/30/04	Near-surface soil sample.
HC56	MUHC56-S-17180	3	6/30/04	Near-surface soil sample.
SB85	MUSB85-S-17208	3	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUSB85-S-17210	7	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUQCDS-S-11299	19	6/28/04	Replicate of subsurface soil sample MUSB85-S-17216.
SB85	MUSB85-S-17226	39	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUSB85-S-17235	57	6/28/04	Cone penetrometer push subsurface soil sample.

TABLE S2.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Soil samples selected by the AGEM Laboratory for duplicate analyses by the purge-and-trap method (Cont.)</i>				
SB85	MUQCDU-S-15524	59	6/28/04	Replicate of subsurface soil sample MUSB85-S-17236.
SB86	MUSB86-S-17247	13	6/29/04	Cone penetrometer push subsurface soil sample.
SB86	MUSB86-S-17165	49	6/29/04	Cone penetrometer push subsurface soil sample.
<i>Soil samples selected for verification organic analysis at Severn-Trent Laboratory</i>				
HC12	MUHC12B-S-17081	3	5/25/04	Near-surface soil sample.
HC17	MUHC17B-S-17091	3	5/25/04	Near-surface soil sample.
HC22	MUHC22T-S-17100	1	5/26/04	Near-surface soil sample.
HC24	MUHC24B-S-17105	3	5/26/04	Near-surface soil sample.
HC26	MUHC26T-S-17108	1	5/26/04	Near-surface soil sample.
HC26	MUHC26B-S-17109	3	5/26/04	Near-surface soil sample.
HC45	MUHC45B-S-17147	3	5/27/04	Near-surface soil sample.
HC48	MUHC48T-S-17152	1	5/27/04	Near-surface soil sample.
SB85	MUSB85-S-17222	31	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUSB85-S-17226	39	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUSB85-S-17231	49	6/28/04	Cone penetrometer push subsurface soil sample.
SB85	MUSB85-S-17233	53	6/28/04	Cone penetrometer push subsurface soil sample.
SB86	MUSB86-S-17249	17	6/29/04	Cone penetrometer push subsurface soil sample.
SB86	MUSB86-S-17250	19	6/29/04	Cone penetrometer push subsurface soil sample.
<i>Blind replicate groundwater and surface water samples</i>				
2S	MUQCDU-W-15598	70.5–80.5	3/31/04	Replicate of groundwater sample MU2S-W-15596.
3S	MUQCDU-W-15632	64.0–74.0	3/30/04	Replicate of groundwater sample MU3S-W-15631.
SB65D	MUQCDU-W-15611	38.0–53.0	4/1/04	Replicate of groundwater sample MUSB65D-W-15610.
SB68M	MUQCDU-W-15618	57.2–67.2	4/1/04	Replicate of groundwater sample MUSB68M-W-15613.
SB72D	MUQCDU-W-15737	70.0–80.0	4/2/04	Replicate of groundwater sample MUSB72D-W-15735.
SB74	MUSB74-W-15646	16.6–22.6	4/4/04	Replicate of groundwater sample MUSB74-W-15645.
SB76	MUSB76-W-15639	30.0–38.0	4/2/04	Replicate of groundwater sample MUSB76-W-15638.
SB81	MUSB81-W-15653	19.7–27.7	4/5/04	Replicate of groundwater sample MUSB81-W-15652.
SWP14	MUQCDU-W-15743	–	4/2/04	Replicate of surface water sample MUSWP14-W-15750.
TD2	MUQCDU-W-15744	–	4/2/04	Replicate of surface water (tile outflow) sample MUSWT2-W-15753.

TABLE S2.1 (Cont.)

Location	Sample	Depth (ft BGL)	Sample Date	Description
<i>Water samples selected by the AGEM Laboratory for duplicate organic analyses by the purge-and-trap method</i>				
3S	MU3S-W-15631	64.0–74.0	3/30/04	Groundwater sample.
SB63D	MUSB63D-W-15607	36.5–51.5	3/31/04	Groundwater sample.
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/04	Groundwater sample.
SB69M	MUSB69M-W-15623	51.9–61.9	4/2/04	Groundwater sample.
SB70D	MUSB70D-W-15621	68.9–78.9	4/2/04	Groundwater sample.
SB71S	MUSB71S-W-15615	53.1–60.6	4/1/04	Groundwater sample.
SB74	MUSB74-W-15644	10.6–16.6	4/4/04	Cone penetrometer push groundwater sample.
SB79	MUSB79-W-15641	6.5–16.5	4/3/04	Cone penetrometer push groundwater sample.
SB81	MUSB81-W-15653	19.7–27.7	4/5/04	Replicate of cone penetrometer push groundwater sample MUSB81-W-15652.
SWP05	MUSWP05-W-15749	–	4/2/04	Surface water sample.
SWP09	MUSWP09-W-15758	–	4/2/04	Surface water sample.
TD2	MUSWT2-W-15753	–	4/2/04	Surface water (tile outflow) sample.
TD2	MUQCDU-W-15744	–	4/2/04	Replicate of surface water (tile outflow) sample MUSWT2-W-15753.
<i>Water samples selected for verification organic analysis at Clayton Laboratory</i>				
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/04	Groundwater sample.
SB65S	MUSB65S-W-15609	23.7–38.7	4/1/04	Groundwater sample.
SB68D	MUSB68D-W-15614	67.8–77.8	4/1/04	Groundwater sample.
SB68M	MUQCDU-W-15618	57.2–67.2	4/1/04	Replicate of groundwater sample MUSB68M-W-15613.
SB76	MUSB76-W-15635	22.0–30.0	4/2/04	Cone penetrometer push groundwater sample.

<sup>a</sup> Depth is not applicable.

TABLE S2.2 Results of carbon tetrachloride and chloroform analyses on quality control samples collected to monitor sample collection and handling.

Sample	Sample Date	Concentration ( $\mu\text{g}/\text{kg}$ in soil; $\mu\text{g}/\text{L}$ in water)		Quantitation Limit
		Carbon Tetrachloride	Chloroform	
<i>Background soil sample</i>				
MUQCBG-S-15585	5/27/04	ND <sup>a</sup>	ND	10
<i>Field blank</i>				
MUQCFB-W-15603	3/31/04	ND	ND	1
<i>Equipment rinsates</i>				
MUQCRI-W-15602	3/31/04	ND	ND	1
MUQCRI-W-15604	3/31/04	ND	ND	1
MUQCBR-W-15636	4/2/04	ND	ND	1
MUQCBR-W-15642	4/3/04	ND	ND	1
MUSB80-W-15650	4/4/04	ND	ND	1
MUQCBR-W-15655	4/5/04	ND	ND	1
<i>Trip blanks shipped with water samples for organic analysis</i>				
MUQCTB-W-15597	3/30/04	ND	ND	1
MUQCTB-W-15608	3/31/04	ND	ND	1
MUQCTB-W-15624	4/1/04	ND	ND	1
MUQCTB-W-15738	4/2/04	ND	ND	1
MUQCTB-W-15739	4/2/04	ND	ND	1
MUQCTB-W-15742	4/3/04	ND	ND	1
MUQCTB-W-15784	4/5/04	ND	ND	1
MUTB-W-15000	4/5/04	ND	ND	5
MUSB83-W-15657	4/6/04	ND	ND	1
WAQCTB-W-13426	4/24/04	ND	ND	1
MUQCTB-W-15686	6/29/04	ND	ND	1
MUQCTB-W-17198	6/30/04	ND	ND	1
<i>Trip blanks shipped with soil samples for organic analysis</i>				
MUQCTB-S-15514	5/26/04	ND	ND	10
MUQCTB-S-15662	5/27/04	ND	ND	10
MU-S-MEOHBLANK	6/7/04	ND	ND	10
MUQCTB-S-15586	6/28/04	ND	ND	10
MUQCTB-S-15685	6/29/04	ND	ND	10
MUQCTB-S-15688	6/30/04	ND	ND	10
MU-S-MEOHBLANK2	7/6/04	ND	ND	10
<i>Waste characterization samples</i>				
MUQCWADR1-W-15781	4/5/04	1.5	ND	1
MUQCWADR2-W-15782	4/5/04	9.6	ND	1
MUQCWADR3-W-15783	4/5/04	8.1	ND	1
MUQCWADR-W-APR24	4/24/04	ND	ND	1
MU-S-15587	6/8/04	ND	ND	10
MU-W-15591	6/8/04	ND	39	1
MU-GWEX2 soil	8/3/04	ND	ND	10
MU-GWEX2 water	8/3/04	63	1.2	1

<sup>a</sup> ND, not detected at the quantitation limit indicated.

TABLE S2.3 Results of organic analyses on quality control samples collected to monitor analyses of water samples by the purge-and-trap method at the AGEM Laboratory.

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-3-31, analysis date March 31, 2004</i>							
20-µg/L standard	87	88	88	20.3	1.5	18.84	5.9
Laboratory blank	100	100	100				
MU4S-W-15629	86	79 <sup>c</sup>	81	Accepted. Consistent with historical results.			
MUQCDU-W-15632	94	93	92				
MU4D-W-15628	91	90	88				
MU3D-W-15630	86	83	82				
MU3S-W-15631	88	86	83				
MU1D-W-15626	86	85	83				
MUQCTB-W-15597	81	77 <sup>c</sup>	74 <sup>c</sup>	Accepted. Results for associated samples show that cross-contamination did not occur.			
<i>SDG 04-4-1, analysis date April 1, 2004</i>							
20-µg/L standard	94	91	97	20.55	2.7	18.57	7.4
Laboratory blank	112	118	119				
MU2D-W-15595	90	87	92				
MUSB64S-W-15600	82	84	86				
MUSB64M-W-15605	82	88	93				
MUSB63S-W-15601	68 <sup>c</sup>	78 <sup>c</sup>	76 <sup>c</sup>	Reanalysis in SDG 04-4-2 within limits.			
MU2S-W-15596	91	91	91				
MUSB63D-W-15607	86	90	90				
MUSB63D-W-15607DUP	83	80	84				
MUMW06-W-15599	83	79 <sup>c</sup>	83	Reanalysis in SDG 04-4-2 within limits.			
MUSB64D-W-15606	82	81	83				
MUQCDU-W-15598	84	85	84				
MUQCRI-W-15604	99	99	102				
MUQCTB-W-15608	74 <sup>c</sup>	71 <sup>c</sup>	69 <sup>c</sup>	Accepted. Results for associated samples show that cross-contamination did not occur.			
MUQCFCB-W-15603	88	86	86				
MUQCRI-W-15602	83	85	88				

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-1, analysis date April 1, 2004 (Cont.)</i>							
Laboratory blank	100	100	100				
MU3S-W-15631DUP	100	101	102				
<i>SDG 04-4-2, analysis date April 2, 2004</i>							
20-µg/L standard	102	101	94	23.24	14.9	20.99	4.8
Laboratory blank	100	100	100				
MUSB65S-W-15609	116	115	124 <sup>c</sup>	Reanalysis in SDG 04-4-6 within limits.			
MUSB65D-W-15610	116	123 <sup>c</sup>	125 <sup>c</sup>	Reanalysis in SDG 04-4-6 within limits.			
MUQCDU-W-15611	101	107	109	Analysis at dilution factor of 5 (DF5) for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB68S-W-15612	108	117	117	Analysis at DF10 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB68M-W-15613	101	107	108	Analysis at DF20 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB68D-W-15614	96	107	104	Analysis at DF20 for carbon tetrachloride . Analysis at DF1 in SDG 04-4-13.			
MUSB71S-W-15615	94	97	101				
MUSB71S-W-15615DUP	88	94	96	Duplicate analysis for carbon tetrachloride at DF20.			
MUSB71M-W-15616	100	103	105	Analysis at DF10 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB71D-W-15617	105	103	109	Outside calibration for carbon tetrachloride at DF1. Analysis at DF10 in SDG 04-4-8.			
MUQCDU-W-15618	96	94	97				
MUSB70M-W-15620	100	102	106	Analysis at DF10 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB69D-W-15622	86	88	89				
MUQCTB-W-15624	106	102	105				
Laboratory blank	100	100	100				
MUMW06-W-15599	107	106	106				
MUSB63S-W-15601	105	105	106				

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-4, analysis date April 4, 2004</i>							
20-µg/L standard	107	107	98	23.56	16.3	20.68	3.3
Laboratory blank	100	100	100				
MUSB70S-W-15619	96	96	97	Analysis at DF2 for carbon tetrachloride.			
MUSB70D-W-15621	107	108	105				
MUSB69M-W-15623	99	101	101	Analysis at DF20 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13.			
MUSB69M-W-15623DUP	97	101	100	Duplicate analysis for carbon tetrachloride at DF20.			
MUSB76-W-15635	97	113	110				
MUSB76-W-15638	100	107	104				
MUSB76-W-15639	98	104	102				
MUSB72D-W-15735	97	93	96				
MUSB72M-W-15736	91	86	87				
MUSB76-W-15637	93	93	90				
MUQCDU-W-15737	94	93	93				
MUQCBR-W-15636	90	88	88				
MUQCTB-W-15738	90	73 <sup>c</sup>	72 <sup>c</sup>	Reanalysis in SDG 04-4-8 within limits.			
Laboratory blank	96	90	88				
<i>SDG 04-4-5, analysis date April 5, 2004</i>							
20-µg/L standard	111	119	127 <sup>c</sup>	20.9	4.4	18.51	7.7
Laboratory blank	100	100	100				
MUSWP01-W-15745	106	110	109				
MUSWP02-W-15746	105	108	107				
MUSWP03-W-15747	104	107	103				
MUSWP04-W-15748	99	104	103				
MUSWP05-W-15749	97	98	96				
MUSWP06-W-15751	102	107	100				
MUSWP07-W-15752	101	100	100				
MUSWP08-W-15754	99	102	96				
MUSWP15-W-15755	99	100	99				

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-5, analysis date April 5, 2004 (Cont.)</i>							
MUSW4T3-W-15756	95	98	94				
MUSW4T4-W-15757	97	98	95				
MUSWP09-W-15758	96	93	91				
MUSWP09-W-15758DUP	98	98	95				
MUQCTB-W-15739	100	99	97				
MUSW4T5-W-15759	75 <sup>c</sup>	83	73 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits.			
MUSWT1-W-15760	99	109	102				
MUSWP10-W-15761	97	112	107				
MUSWP11-W-15762	99	108	102				
MUSW4T6-W-15763	100	108	102				
MUSWT2-W-15753	97	104	99	Analysis at DF10 for carbon tetrachloride.			
MUSWT2-W-15753DUP	94	101	97	Secondary analysis for carbon tetrachloride at DF5.			
MUQCDU-W-15744	95	101	96	Analysis at DF10 for carbon tetrachloride.			
MUQCDU-W-15744DUP	96	101	96	Secondary analysis for carbon tetrachloride at DF5.			
<i>SDG 04-4-6, analysis date April 6, 2004</i>							
20-µg/L standard	86	89	104	21.92	9.2	18.45	8.1
Laboratory blank	100	100	100				
MUSB74-W-15644	89	89	89	Outside calibration for carbon tetrachloride at DF1. Analysis at DF5 in SDG 04-4-7.			
MUSB74-W-15645	90	92	89	Outside calibration for carbon tetrachloride at DF1. Analysis at DF10 in SDG 04-4-7.			
MUSB80-W-15647	77 <sup>c</sup>	82	79 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits.			
MUSB80-W-15648	88	91	89				
MUSB80-W-15649	74 <sup>c</sup>	78 <sup>c</sup>	77 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits.			
MUSB80-W-15651	86	81	80				
MUSB77-W-15640	82	83	81				
MUSB79-W-15641	80	78 <sup>c</sup>	77 <sup>c</sup>	Reanalysis in SDG 04-4-9 within limits.			
MUSB75-W-15643	84	81	78 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits.			
MUSB81-W-15654	82	72 <sup>c</sup>	67 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits.			

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-6, analysis date April 6, 2004 (Cont.)</i>							
MUSB81-W-15652	84	85	79 <sup>c</sup>	Reanalysis in SDG 04-4-7 within limits. Low recovery at DF1. Analysis at DF10 in SDG 04-4-7.			
MUSB74-W-15646	68 <sup>c</sup>	63 <sup>c</sup>	60 <sup>c</sup>				
MUSB81-W-15653	86	89	86	Analysis at DF10 for carbon tetrachloride. Analysis at DF1 in SDG 04-4-13. Duplicate analysis for carbon tetrachloride at DF10. Outside calibration for carbon tetrachloride at DF1. Analysis at DF5 in SDG 04-4-7.			
MUSB81-W-15653DUP	83	86	81				
Laboratory blank	100	100	100				
MUSWEEP1-W-15740	86	83	81				
MUSWP12-W-15741	100	105	103				
MUSWP14-W-15750	99	100	101				
MUSB65S-W-15609	92	89	89				
MUSB65D-W-15610	92	88	87				
MUSB65D-W-15610DUP	91	85	85				
MUSB70D-W-15621DUP	84	83	85				
MUSWEX6-W-15764	95	91	91				
MUSWP05-W-15749DUP	88	88	89				
<i>SDG 04-4-7, analysis date April 7, 2004</i>							
20-µg/L standard	97	96	106	19.64	1.8	17.59	12.8
Laboratory blank	100	100	100				
MUSB74-W-15646	110	113	111	Analysis at DF10 for carbon tetrachloride. Analysis at DF10 for carbon tetrachloride.			
MUSB74-W-15645	106	109	103				
MUSB74-W-15644	96	99	92	Analysis at DF5 for carbon tetrachloride. Duplicate analysis for carbon tetrachloride at DF10.			
MUSB74-W-15644DUP	87	89	87				
MUSB81-W-15654	98	100	94	Reanalysis in SDG 04-4-9 within limits.			
MUSB80-W-15649	93	100	92				
MUSB79-W-15641	70 <sup>c</sup>	75 <sup>c</sup>	64 <sup>c</sup>				
MUSB75-W-15643	105	106	103				
MUSB81-W-15652	85	94	84				
MUSB80-W-15647	99	105	100				

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-7, analysis date April 7, 2004 (Cont.)</i>							
MUSWEX6-W-15764	87	88	84	Analysis at DF5 for carbon tetrachloride.			
MUSW4T5-W-15759	89	87	84				
<i>SDG 04-4-8, analysis date April 8, 2004</i>							
20-µg/L standard at 10:44	91	97	114	26.59	28.3 <sup>c</sup>	22.9	13.5
20-µg/L standard at 11:38	91	97	114	20.13	6.4	17.93	10.9
Laboratory blank	100	100	100				
MUSB83-W-15656	88	94	90	Reanalysis in SDG 04-4-9 within limits.			
MUSB83-W-15657	108	111	104				
MUQCDU-W-15743	94	100	92				
MUQCWADR1-W-15781	99	100	96				
MUQCTB-W-15742	87	83	77 <sup>c</sup>				
MUQCTB-W-15738	92	94	85				
MUQCWADR2-W-15782	86	87	81				
MUQCWADR3-W-15783	93	96	89				
MUQCBR-W-15655	86	84	81				
MUQCBR-W-15642	101	98	92				
MUSB80-W-15650	93	88	83				
MUQCTB-W-15784	92	90	82				
MUQCDU-W-15618	93	93	86				
<i>SDG 04-4-9, analysis date April 9, 2004</i>							
20-µg/L standard	96	104	110	19.57	2.2	17.45	13.6
Laboratory blank	100	100	100				
MUSB79-W-15641	89	95	93				
MUSB79-W-15641DUP	86	91	84				
MUQCTB-W-15742	89	91	84				

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/L)	R P D <sup>b</sup>	Concentration (µg/L)	R P D <sup>b</sup>
<i>SDG 04-4-13, analysis date April 13, 2004</i>							
20-µg/L standard	96	95	125 <sup>c</sup>	19.93	0.4	16.81	17.3
Laboratory blank	100	100	100				
MUSB71M-W-15616	97	99	99	Analysis at DF1 for chloroform.			
MUSB69M-W-15623	98	95	98	Analysis at DF1 for chloroform.			
MUSB69D-W-15622	84	83	81	Analysis at DF1 for chloroform.			
MUSB71S-W-15615	90	88	89	Analysis at DF1 for chloroform.			
MUSB68S-W-15612	89	84	82	Analysis at DF1 for chloroform.			
MUQCDU-W-15611	88	84	85	Analysis at DF1 for chloroform.			
MUSB68M-W-15613	88	81	81	Analysis at DF1 for chloroform.			
MUSB65D-W-15610	88	81	83	Analysis at DF1 for chloroform.			
<i>SDG 04-4-27, analysis date April 27, 2004</i>							
20-µg/L standard	100	99	115	23.8	17.3	21.34	6.5
Laboratory blank	109	110	114				
WAQCTB-W-13426	99	95	96				
<i>SDG 04-4-28, analysis date April 28, 2004</i>							
20-µg/L standard	102	106	120	22.1	9.9	19.42	2.9
Laboratory blank	100	100	100				
MUQCDR-W-APR24	99	106	105				
<i>SDG 04-6-30, analysis date June 30, 2004</i>							
20-µg/L standard	117	102	113	23.47	15.9	23.25	15
Laboratory blank	100	100	100				
MUGWEXTEST-W-15594	101	96	97	Outside calibration for carbon tetrachloride at DF1. Analysis at DF10 in SDG 04-7-1.			

TABLE S2.3 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
				Carbon Tetrachloride		Chloroform	
	Fluorobenzene	1,2-Dichloro- benzene-d <sup>4</sup>	4-Bromo- fluorobenzene	Concentration (µg/L)	RPD <sup>b</sup>	Concentration (µg/L)	RPD <sup>b</sup>
<i>SDG 04-6-30, analysis date June 30, 2004 (Cont.)</i>							
MUSB85-W-17241	97	95	95				
MUQCTB-W-15686	87	89	87				
<i>SDG 04-7-1, analysis date July 1, 2004</i>							
20-µg/L standard	81	80	80	18.43	8.1	17.68	12.1
Laboratory blank	100	100	100				
MUGWEXTEST-W-15594	85	90	86	Analysis at DF10 for carbon tetrachloride.			
MUSB86-W-17178	97	95	94				
MUQCTB-W-17198	110	109	109				

<sup>a</sup> Quality control limit for recovery of surrogate compounds: 80–120%.

<sup>b</sup> Quality control limit for RPD for calibration check standards: ±20%.

<sup>c</sup> Surrogate recovery outside quality control limit.

TABLE S2.4 Results of duplicate carbon tetrachloride and chloroform analyses of water samples at the AGEM Laboratory in the targeted investigation at Murdock, Nebraska.

Location	Depth (ft BGL)	Sample Date	Sample	Analysis	Concentration (µg/L)	
					Carbon Tetrachloride	Chloroform
<i>Groundwater samples</i>						
2S	70.5–80.5	3/31/04	MU2S-W-15596	Monitoring well sample	88	2.6
			MUQCDDU-W-15598	Blind replicate	93	2.7
3S	64.0–74.0	3/30/04	MU3S-W-15631	Monitoring well sample	ND <sup>a</sup>	ND
			MU3S-W-15631DUP	Duplicate analysis	ND	ND
			MUQCDDU-W-15632	Blind replicate	ND	ND
SB63D	36.5–51.5	3/31/04	MUSB63D-W-15607	Monitoring well sample	6.7	ND
			MUSB63D-W-15607DUP	Duplicate analysis	6.6	ND
SB65D	38.0–53.0	4/1/04	MUSB65D-W-15610	Monitoring well sample	387	3.5
			MUSB65D-W-15610DUP	Duplicate analysis	360	< 10 <sup>b</sup>
			MUQCDDU-W-15611	Blind replicate	470	3.3
SB68M	57.2–67.2	4/1/04	MUSB68M-W-15613	FLUTe sample	991	14
			MUQCDDU-W-15618	Blind replicate	928	15
SB69M	51.9–61.9	4/2/04	MUSB69M-W-15623	FLUTe sample	467	9.3
			MUSB69M-W-15623DUP	Duplicate analysis	468	< 20 <sup>c</sup>
SB70D	68.9–78.9	4/2/04	MUSB70D-W-15621	FLUTe sample	ND	ND
			MUSB70D-W-15621DUP	Duplicate analysis	ND	ND
SB71S	53.1–60.6	4/1/04	MUSB71S-W-15615	FLUTe sample	431	9.4
			MUSB71S-W-15615DUP	Duplicate analysis	445	< 20 <sup>c</sup>
SB72D	70.0–80.0	4/2/04	MUSB72D-W-15735	FLUTe sample	1.3	ND
			MUQCDDU-W-15737	Blind replicate	1.3	ND
SB74	10.6–16.6	4/4/04	MUSB74-W-15644	Cone penetrometer push sample	202	2.6
			MUSB74-W-15644DUP	Duplicate analysis	226	< 10 <sup>b</sup>
SB74	16.6–22.6	4/4/04	MUSB74-W-15645	Cone penetrometer push sample	436	6.5
			MUSB74-W-15646	Blind replicate	415	9.7 S <sup>d</sup>
SB76	30.0–38.0	4/2/04	MUSB76-W-15638	Cone penetrometer push sample	2.9	ND
			MUSB76-W-15639	Blind replicate	3.8	ND
SB79	6.5–16.5	4/3/04	MUSB79-W-15641	Cone penetrometer push sample	ND	ND
			MUSB79-W-15641DUP	Duplicate analysis	ND	ND
SB81	19.7–27.7	4/5/04	MUSB81-W-15652	Cone penetrometer push sample	ND	ND
			MUSB81-W-15653	Blind replicate	ND	ND
			MUSB81-W-15653DUP	Duplicate analysis	ND	ND

TABLE S2.4 (Cont.)

Location	Depth (ft BGL)	Sample Date	Sample	Analysis	Concentration (µg/L)	
					Carbon Tetrachloride	Chloroform
<i>Surface water and tile outflow samples</i>						
SWP05	-	4/2/2004	MUSWP05-W-15749	Surface water sample	171	10
			MUSWP05-W-15749DUP	Duplicate analysis	128	7.9
SWP09	-	4/2/2004	MUSWP09-W-15758	Surface water sample	4.2	ND
			MUSWP09-W-15758DUP	Duplicate analysis	4.2	ND
SWP14	-	4/2/2004	MUSWP14-W-15750	Surface water sample	1.4	ND
			MUQCDCU-W-15743	Blind replicate	1.4	ND
TD2	-	4/2/2004	MUSWT2-W-15753	Tile outflow sample	88	< 10 <sup>b</sup>
			MUSWT2-W-15753DUP	Duplicate analysis	88	< 5 <sup>e</sup>
			MUQCDCU-W-15744	Blind replicate	88	< 10 <sup>b</sup>
			MUQCDCU-W-15744DUP	Duplicate analysis	87	< 5 <sup>e</sup>

<sup>a</sup> ND, contaminant not detected.

<sup>b</sup> Analysis at dilution factor 10; chloroform result not quantified.

<sup>c</sup> Analysis at dilution factor 20; chloroform result not quantified.

<sup>d</sup> S, surrogate recovery outside quality control range of ±20% for chloroform analysis at dilution factor 1.

<sup>e</sup> Analysis at dilution factor 5; chloroform result not quantified.

TABLE S2.5 Recovery of system-monitoring compounds in organic analyses of water samples by CLP methodology at Clayton Laboratory.

Sample	Analysis Date	Sample Delivery Group	Recovery <sup>a</sup> (%)		
			Toluene-d <sub>8</sub>	Bromofluoro-benzene	1,2-Dichloroethane-d <sub>4</sub>
VBLKLO	4/14/2004	4040161-ARG180	100	102	98
MUSB76-W-15635MS	4/14/2004	4040161-ARG180	100	110	96
MUSB76-W-15635MSD	4/14/2004	4040161-ARG180	100	106	96
MUSB76-W-15635	4/14/2004	4040161-ARG180	98	108	100
MUQCDU-W-15618	4/14/2004	4040161-ARG180	98	104	110
MUSB65S-W-15609	4/14/2004	4040161-ARG180	102	102	98
MUSB65D-W-15610	4/14/2004	4040161-ARG180	100	102	106
MUTB-W-15000	4/14/2004	4040161-ARG180	98	104	102
VBLKLP	4/15/2004	4040161-ARG180	100	100	96
MUSB68D-W-15614	4/15/2004	4040161-ARG180	102	100	96
MUQCDU-W-15618DL	4/15/2004	4040161-ARG180	100	98	98
MUSB65D-W-15610DL	4/15/2004	4040161-ARG180	100	100	108
VHBLKLA	4/15/2004	4040161-ARG180	100	100	98

<sup>a</sup> Quality control limits for recovery are as follows:

<u>Analyte</u>	<u>QC Limits (%)</u>
Toluene-d <sub>8</sub>	88–110
Bromofluorobenzene	86–115
1,2-Dichloroethane-d <sub>4</sub>	76–114

TABLE S2.6 Recovery and relative percent difference values for spike/spike duplicate organic analyses of water samples with CLP methodology at Clayton Laboratory.

Compound	Concentration (µg/L)			Recovery (%)			Difference (%)		
	Sample	Spike Added	Spike Analysis	Duplicate Analysis	Spike Analysis	Duplicate Analysis	QC Limits	RPD	QC Limit
<i>Spike/spike duplicate analysis of MUSB76-W-15635 with SDG 4040161-ARG180</i>									
1,1-Dichloroethene	0	50	44	45	88	90	61–145	2	14
Trichloroethene	0	50	41	42	82	84	71–120	2	14
Benzene	0	50	43	43	86	86	76–127	0	11
Toluene	0	50	46	45	92	90	76–125	2	13
Chlorobenzene	0	50	46	46	92	92	75–130	0	13

TABLE S2.7 Carbon tetrachloride and chloroform concentrations in water samples selected for verification organic analysis during the targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Carbon Tetrachloride			Chloroform		
				Concentration (µg/L)			Concentration (µg/L)		
				AGEM <sup>a</sup>	Clayton <sup>b</sup>	RPD <sup>c</sup>	AGEM <sup>a</sup>	Clayton <sup>b</sup>	RPD <sup>c</sup>
SB65S	MUSB65S-W-15609	23.7–38.7	4/1/2004	1.4	1 J <sup>d</sup>	33	1 U <sup>e</sup>	5 U	–
SB65D	MUSB65D-W-15610	38.0–53.0	4/1/2004	387	410	5.7	3.5	20	140 <sup>f</sup>
SB68M	MUQCDCU-W-15618	57.2–67.2	4/1/2004	928	910	2	15	57	116 <sup>f</sup>
SB68D	MUSB68D-W-15614	67.8–77.8	4/1/2004	6.2	5	21.4	3.4	3.3 J	3
SB76	MUSB76-W-15635	22.0–30.0	4/2/2004	1 U	5 U	–	1 U	5 U	–

<sup>a</sup> Organic analysis at the AGEM Laboratory with purge-and-trap Method 524.2.

<sup>b</sup> Organic analysis at Clayton Laboratory with CLP methodology.

<sup>c</sup> Relative percent difference.

<sup>d</sup> J, estimated concentration below quantitation limit of 5 µg/L.

<sup>e</sup> U, contaminant not detected at indicated method quantitation limit.

<sup>f</sup> Degradation of the sample prior to analysis by Clayton Laboratory might have resulted from a delay in analysis. Methylene chloride, a degradation product of chloroform (which in turn is a degradation product of carbon tetrachloride), was detected at Clayton Laboratory but not at the AGEM Laboratory.

TABLE S2.8 Results for carbon tetrachloride and chloroform in dual analyses of soil samples with the headspace method at the AGEM Laboratory.

Location	Depth (ft BGL)	Sample Date	Sample	Concentration (µg/kg)		
				Carbon Tetrachloride	Chloroform	
HC03	3	5/25/04	MUHC03B-S-17063	Sample	ND <sup>a</sup>	ND
HC03	3	5/25/04	MUHC03B-S-17063DUP	Duplicate analysis	ND	ND
HC04	3	5/25/04	MUHC04B-S-17065	Sample	ND	ND
HC04	3	5/25/04	MUHC04B-S-17065DUP	Duplicate analysis	ND	ND
HC07	1	5/25/04	MUHC07T-S-17070	Sample	ND	ND
HC07	1	5/25/04	MUHC07T-S-17070DUP	Duplicate analysis	ND	ND
HC10	3	5/25/04	MUHC10B-S-17077	Sample	2.57	ND
HC10	3	5/25/04	MUHC10B-S-17077DUP	Duplicate analysis	2.51	ND
HC16	3	5/25/04	MUHC16B-S-17089	Sample	0.59	ND
HC16	3	5/25/04	MUHC16B-S-17089DUP	Duplicate analysis	0.59	ND
HC20	3	5/26/04	MUHC20B-S-17097	Sample	1.3	ND
HC20	3	5/26/04	MUHC20B-S-17097DUP	Duplicate analysis	1.34	ND
HC25	1	5/26/04	MUHC25T-S-17106	Sample	ND	ND
HC25	1	5/26/04	MUQCDS-S-15508	Blind replicate	ND	ND
HC25	3	5/26/04	MUHC25B-S-17107	Sample	ND	ND
HC25	3	5/26/04	MUQCDS-S-15509	Blind replicate	ND	ND
HC27	1	5/26/04	MUHC27T-S-17110	Sample	ND	ND
HC27	1	5/26/04	MUQCDS-S-15510	Blind replicate	ND	ND
HC27	3	5/26/04	MUHC27B-S-17111	Sample	ND	ND
HC27	3	5/26/04	MUQCDS-S-15511	Blind replicate	ND	ND
HC28	1	5/26/04	MUHC28T-S-17112	Sample	ND	ND
HC28	1	5/26/04	MUQCDS-S-15512	Blind replicate	ND	ND
HC28	3	5/26/04	MUHC28B-S-17113	Sample	ND	ND
HC28	3	5/26/04	MUQCDS-S-15513	Blind replicate	ND	ND
HC30	1	5/26/04	MUHC30T-S-17116	Sample	ND	ND
HC30	1	5/26/04	MUHC30T-S-17116DUP	Duplicate analysis	ND	ND
HC32	1	5/26/04	MUHC32T-S-17120	Sample	3.6	ND
HC32	1	5/26/04	MUHC32T-S-17120DUP	Duplicate analysis	3.69	ND
HC35	1	5/26/04	MUHC35T-S-17126	Sample	2.87	ND
HC35	1	5/26/04	MUQCDS-S-15660	Blind replicate	0.3	ND
HC35	3	5/26/04	MUHC35B-S-17127	Sample	ND	ND
HC35	3	5/26/04	MUQCDS-S-15661	Blind replicate	ND	ND

TABLE S2.8 (Cont.)

Location	Depth (ft BGL)	Sample Date	Sample	Concentration (µg/kg)		
				Carbon Tetrachloride	Chloroform	
HC49	1	5/27/04	MUHC49T-S-17154	Sample	0.64	ND
HC49	1	5/27/04	MUQCDU-S-15583	Blind replicate	0.72	ND
HC49	3	5/27/04	MUHC49B-S-17155	Sample	0.66	ND
HC49	3	5/27/04	MUHC49B-S-17155DUP	Duplicate analysis	0.57	ND
HC49	3	5/27/04	MUQCDU-S-15584	Blind replicate	0.58	ND
HC57	1	6/30/04	MUHC57-S-17181	Sample	0.8	ND
HC57	1	6/30/04	MUHC57-S-17181DUP	Duplicate analysis	0.8	ND
Q C	1	5/27/04	MUQCBG-S-15585	Sample	ND	ND
Q C	1	5/27/04	MUQCBG-S-15585DUP	Duplicate analysis	ND	ND

<sup>a</sup> ND, contaminant not detected at reporting levels of 0.2 µg/kg for carbon tetrachloride and 0.75 µg/kg for chloroform.

TABLE S2.9 Results of organic analyses on quality control samples collected to monitor analyses of soil samples with the purge-and-trap method at the AGEM Laboratory.

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	R P D <sup>b</sup>	Concentration (µg/kg)	R P D <sup>b</sup>
<b><i>SDG 04-5-28, analysis date March 28, 2004</i></b>							
20-µg/kg standard	116	111	116	21.4	7	23.71	18.5
Methanol blank	102	89	94				
MUQCDU-S-15513	104	88	95				
MUHC19T-S-17094	106	92	98				
MUHC18T-S-17092	106	99	101				
MUHC24T-S-17104	101	95	99				
MUHC41B-S-17139	108	94	97				
MUHC38T-S-17132	100	92	96				
MUHC41T-S-17138	110	95	100				
MUHC21B-S-17099	106	99	103				
MUHC34T-S-17124	112	110	110				
MUQCDU-S-15512	111	112	111				
MUQCDU-S-15512DUP	109	99	101				
MUHC28T-S-17112	112	103	107				
MUHC20T-S-17096	108	101	104				
MUHC24B-S-17105	120	103	110				
MUHC40B-S-17137	116	97	102				
MUHC27T-S-17110	131 <sup>c</sup>	100	111	Reanalyzed in SDG 04-6-1.			
<b><i>SDG 04-6-1, analysis date June 1, 2004</i></b>							
20-µg/kg standard	100	100	100	19.73	1.4	20.87	4.3
Methanol blank	100	100	100				
MUHC27T-S-17110	106	100	101				
MUQCDU-S-15511	93	100	97				
MUQCDU-S-15509	97	100	99				
MUHC25B-S-17107	85	92	89				
MUHC26B-S-17109	81	82	83				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-1, analysis date June 1, 2004 (Cont.)</i>							
MUHC49T-S-17154	77 <sup>c</sup>	83	82	Reanalyzed in SDG 04-6-8.			
MUHC25T-S-17106	79 <sup>c</sup>	77 <sup>c</sup>	79 <sup>c</sup>	Reanalyzed in SDG 04-6-3.			
MUHC25T-S-17106DUP	81	83	83				
MUHC44T-S-17144	92	81	89				
MUHC45B-S-17147	90	82	86				
MUHC49B-S-17155	81	85	85				
MUHC51B-S-15664	78 <sup>c</sup>	80	80	Reanalyzed in SDG 04-6-2.			
MUHC45T-S-17146	78 <sup>c</sup>	79 <sup>c</sup>	80	Reanalyzed in SDG 04-6-2.			
MUHC47B-S-17151	77 <sup>c</sup>	80	79 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUHC46T-S-17148	73 <sup>c</sup>	79 <sup>c</sup>	78 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUHC44B-S-17145	74 <sup>c</sup>	78 <sup>c</sup>	78 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUHC42B-S-17141	71 <sup>c</sup>	75 <sup>c</sup>	72 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUHC48B-S-17153	74 <sup>c</sup>	77 <sup>c</sup>	77 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUQCBG-S-15585	84	77 <sup>c</sup>	82 <sup>c</sup>	Reanalyzed in SDG 04-6-2.			
MUHC43T-S-17142	78 <sup>c</sup>	76 <sup>c</sup>	80	Reanalyzed in SDG 04-6-2.			
<i>SDG 04-6-2, analysis date June 2, 2004</i>							
20-µg/kg standard	100	100	100	17.98	10.1	20.12	0.6
Methanol blank	100	100	100				
MUQCTB-S-15662	103	100	102				
MUHC43B-S-17143	110	113	109				
MUHC47T-S-17150	110	114	111				
MUHC50B-S-17157	110	110	109				
MUQCBG-S-15585	105	108	104				
MUHC51T-S-15663	105	106	105				
MUHC50T-S-17156	105	107	105				
MUHC50T-S-17156DUP	117	107	111				
Methanol blank	107	103	102				
MUHC48T-S-17152	92	94	93				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-2, analysis date June 2, 2004 (Cont.)</i>							
MUHC46B-S-17149	104	107	104				
MUQCDU-S-15583	96	102	97				
MUHC19B-S-17095	103	108	105				
MUHC29T-S-17114	103	109	106				
MUHC51B-S-15664	112	110	108				
MUHC45T-S-17146	86	95	90				
MUHC47B-S-17151	105	110	108				
MUHC46T-S-17148	104	105	103				
MUHC44B-S-17145	108	108	107				
MUHC42B-S-17141	99	102	102				
MUHC48B-S-17153	96	99	97				
MUQCDU-S-15584	96	98	96				
MUHC43T-S-17142	92	98	96				
<i>SDG 04-6-3, analysis date June 3, 2004</i>							
20-µg/kg standard	100	100	100	16.03	19.8	18.29	8.6
Methanol blank	110	115	111				
MUHC49T-S-17154	119	123 <sup>c</sup>	117	Reanalyzed in SDG 04-6-8.			
MUHC25T-S-17106	100	113	103				
MUHC18B-S-17093	109	114	110				
MUHC22T-S-17100	103	107	106				
MUQCDU-S-15508	95	108	102				
MUHC26T-S-17108	103	116	109				
MUHC22B-S-17101	99	107	102				
MUHC22B-S-17101DUP	104	105	101				
Methanol blank 2	91	91	92				
MUHC30T-S-17116	98	103	103				
MUHC21T-S-17098	86	87	88				
MUHC28B-S-17113	96	87	93				
MUHC20B-S-17097	91	87	88				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-3, analysis date June 3, 2004 (Cont.)</i>							
MUHC39T-S-17134	88	92	91				
MUHC23B-S-17103	84	85	86				
MUOCTB-S-15514	94	89	94				
MUHC29B-S-17115	86	90	90				
MUHC27B-S-17111	97	91	93				
MUHC34B-S-17125	99	95	96				
MUHC23T-S-17102	105	105	104				
Methanol blank 3	99	95	97				
MUHC40T-S-17136	101	90	93				
MUQCUDU-S-15510	87	84	87				
<i>SDG 04-6-8, analysis date June 8, 2004</i>							
20-µg/kg standard	100	100	100	20.66	3.3	19.66	1.7
Methanol blank	107	108	107				
MUHC49T-S-17154	106	108	106				
MUHC39B-S-17135	116	115	114				
MUHC03T-S-17062	106	111	107				
MUHC07B-S-17071	105	107	104				
MUHC09T-S-17074	102	97	98				
MUHC09T-S-17074DUP	112	99	104				
<i>SDG 04-6-10, analysis date June 10, 2004</i>							
20-µg/kg standard	100	100	100	17.85	11.4	16.89	16.8
Methanol blank	100	100	100				
MUHC09B-S-17075	106	105	109				
MUHC05T-S-17066	104	103	108				
MUHC08B-S-17073	91	98	95				
MUHC04T-S-17064	81	90	87				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-10, analysis date June 10, 2004 (Cont.)</i>							
MUHC06B-S-17069	88	96	96				
MUHC10T-S-17076	93	92	94				
MUHC10T-S-17076DUP	84	83	86				
MUHC05B-S-17067	53 <sup>c</sup>	57 <sup>c</sup>	58 <sup>c</sup>	Reanalyzed in SDG 04-6-11.			
MUHC01B-S-17059	41 <sup>c</sup>	46 <sup>c</sup>	45 <sup>c</sup>	Reanalyzed in SDG 04-6-11.			
MUHC07T-S-17070	72 <sup>c</sup>	74 <sup>c</sup>	74 <sup>c</sup>	Reanalyzed in SDG 04-6-11.			
MUHC12T-S-17080	52 <sup>c</sup>	52 <sup>c</sup>	52 <sup>c</sup>	Reanalyzed in SDG 04-6-11.			
MUHC02B-S-17061	92	90	92				
MUHC01T-S-17058	103	101	103				
MUHC04B-S-17065	103	97	100				
MUHC30B-S-17117	51 <sup>c</sup>	59 <sup>c</sup>	56 <sup>c</sup>	Reanalyzed in SDG 04-6-11.			
MU-S-15587	87	91	87				
<i>SDG 04-6-11, analysis date June 11, 2004</i>							
20-µg/kg standard	100	100	100	18.24	9.2	18.47	7.9
Methanol blank	100	100	100				
MUHC05B-S-17067	130 <sup>c</sup>	114	119	Accepted.			
MUHC01B-S-17059	110	111	104				
MUHC07T-S-17070	100	102	96				
MUHC12T-S-17080	95	100	93				
MUHC30B-S-17117	100	105	95				
MUHC38B-S-17133	97	100	96				
MUHC36B-S-17129	102	101	97				
MUHC36B-S-17129DUP	98	99	94				
MUHC37B-S-17131	98	100	96				
MUHC36T-S-17128	114	115	112				
MUHC33B-S-17123	110	104	103				
MUHC31B-S-17119	97	102	95				
MUHC31T-S-17118	97	102	95				
MUHC32T-S-17120	98	96	93				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-11, analysis date June 11, 2004 (Cont.)</i>							
MUHC37T-S-17130	99	100	95				
MUHC33T-S-17122	98	102	94				
MUHC32B-S-17121	102	100	96				
MUHC35B-S-17127	100	98	95				
MUQCDCU-S-15661	94	98	90				
MUQCDCU-S-15661DUP	110	105	104				
<i>SDG 04-6-14, analysis date June 14, 2004</i>							
20-µg/kg standard	100	100	100	20.8	3.9	21.07	5.2
Methanol blank	119	113	116				
MUHC35T-S-17126	114	109	110				
MUQCDCU-S-15660	102	111	103				
MUHC13T-S-17082	101	111	105				
MUHC15T-S-17086	102	115	109				
MUHC16T-S-17088	95	106	98				
MUHC03B-S-17063	92	102	98				
MUHC03B-S-17063DUP	83	98	90				
MUHC12B-S-17081	84	108	94				
MUHC11B-S-17079	87	99	94				
MUHC17B-S-17091	91	109	100				
MUHC11T-S-17078	82	104	92				
MUHC14B-S-17085	96	116	107				
<i>SDG 04-6-15, analysis date June 15, 2004</i>							
20-µg/kg standard	102	117	110	20.09	0.4	22.76	12.9
Methanol blank	117	111	116				
MUHC15B-S-17087	115	112	112				
MUHC13B-S-17083	99	109	102				
MUHC16B-S-17089	118	125 <sup>C</sup>	119	Reanalyzed in SDG 04-6-17.			

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-15, analysis date June 15, 2004 (Cont.)</i>							
MUHC08T-S-17072	107	113	113				
MUHC14T-S-17084	100	104	105				
MUHC06T-S-17068	95	104	101				
MUHC02T-S-17060	93	111	105				
MUHC02T-S-17060DUP	94	108	104				
MUHC17T-S-17090	79 <sup>c</sup>	90	85	Reanalyzed in SDG 04-6-17.			
MUHC10B-S-17077	85	97	90				
MUHC42T-S-17140	90	101	95				
<i>SDG 04-6-17, analysis date June 17, 2004</i>							
20-µg/kg standard	95	103	91	19.94	0.3	17.69	12.2
Methanol blank	100	100	100				
MUHC16B-S-17089	107	102	105				
MUHC17T-S-17090	94	92	93				
MUHC17T-S-17090DUP	87	87	88				
<i>SDG 04-6-30, analysis date June 30, 2004</i>							
20-µg/kg standard	117	102	113	23.47	15.9	23.25	15
Methanol blank	100	100	100				
MUSB85-S-17227	101	100	100				
MUSB85-S-17215	95	97	96				
MUSB85-S-17228	91	100	96				
MUSB85-S-17217	85	92	87				
MUSB85-S-17212	92	94	92				
MUSB85-S-17223	93	96	95				
MUSB85-S-17234	101	101	101				
MUSB85-S-17220	93	95	94				
MUSB85-S-17226	95	97	95				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-6-30, analysis date June 30, 2004</i>							
MUSB85-S-17226DUP	98	99	99				
Methanol blank	100	97	94				
MUQCDU-S-15502	114	108	110				
MUSB85-S-17230	103	107	102				
MUSB85-S-17209	101	105	102				
MUSB85-S-17232	103	101	100				
MUSB85-S-17211	101	101	98				
MUSB85-S-17218	104	101	101				
MUSB85-S-17208	102	96	98				
MUSB85-S-17208DUP	95	91	92				
Methanol blank	101	95	99				
MUSB85-S-17221	98	95	95				
<i>SDG 04-7-1, analysis date July 1, 2004</i>							
20-µg/kg standard	81	80	80	18.43	8.1	17.68	12.1
Methanol blank	100	100	100				
MUSB85-S-17229	97	101	100				
MUSB85-S-17231	99	105	101				
MUSB85-S-17225	106	104	105				
MUQCDU-S-15524	104	100	100				
Methanol blank	90	98	91				
MUSB85-S-17216	98	102	100				
MUQCDU-S-11299	96	81	88				
MUSB85-S-17222	89	96	93				
MUSB85-S-17210	99	103	102				
MUSB85-S-17210DUP	95	100	97				
MUSB85-S-17219	96	99	96				
MUSB85-S-17236	94	96	95				
MUQCDU-S-15524DUP	94	98	95				
MUSB85-S-17233	98	99	99				
MUSB85-S-17224	92	94	94				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-7-1, analysis date July 1, 2004 (Cont.)</i>							
MUQCDU-S-11299DUP	92	95	94				
MUSB85-S-17235	95	98	96				
MUSB85-S-17235DUP	101	109	105				
MUSB85-S-17214	112	118	120				
<i>SDG 04-7-2, analysis date July 2, 2004</i>							
20-µg/kg standard	100	100	100	19.09	4.7	17.42	13.8
Methanol blank	100	100	100				
MUSB85-S-17213	94	101	97				
MUQCTB-S-15586	101	109	109				
MUSB86-S-17169	109	116	113				
MUSB86-S-17164	113	105	109				
MUSB86-S-17163	99	99	99				
MUSB86-S-17167	100	100	101				
MUSB86-S-17255	113	106	109				
MUSB86-S-17244	102	100	102				
Methanol blank	106	99	102				
MUSB86-S-17245	100	99	102				
MUSB86-S-17166	106	105	108				
MUSB85-S-17239	100	97	98				
MUSB86-S-17250	109	104	107				
MUSB85-S-17237	102	101	102				
MUSB86-S-17247	93	94	95				
MUSB86-S-17247DUP	100	99	101				
MUSB85-S-17238	108	104	105				
MUSB85-S-17240	99	99	98				
MUQCDU-S-15587	0 <sup>c</sup>	0 <sup>c</sup>	0 <sup>c</sup>	Reanalyzed in SDG 04-7-6.			
MUSB86-S-17253	104	94	100				
MUSB86-S-17161	97	97	96				
MUSB86-S-17171	105	100	106				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-7-2, analysis date July 2, 2004 (Cont.)</i>							
Methanol blank	114	98	109				
MUSB86-S-17172	90	91	93				
MUQCDU-S-15593	106	102	107				
MUSB86-S-17249	107	104	109				
MUSB86-S-17257	103	102	104				
<i>SDG 04-7-6, analysis date July 6, 2004</i>							
20-µg/kg standard	95	105	85	19.11	4.5	19.36	3.3
Methanol blank	100	100	100				
MUQCDU-S-15587	105	105	105				
MUSB86-S-17256	97	100	99				
MUSB86-S-17248	95	95	94				
MUSB86-S-17254	94	103	97				
MUSB86-S-17252	94	98	94				
MUSB86-S-17158	91	92	89				
MUSB86-S-17165	91	90	87				
MUSB86-S-17165DUP	91	93	90				
Methanol blank	91	91	88				
MUSB86-S-17243	91	92	90				
MUSB86-S-17242	89	88	86				
MUSB86-S-17170	89	88	86				
MUSB86-S-17160	89	92	90				
MUSB86-S-17162	84	90	86				

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-7-7, analysis date July 7, 2004</i>							
20-µg/kg standard	110	116	99	18.61	7.2	19.23	3.9
Methanol blank	100	100	100				
MUSB86-S-17159	105	103	102				
MUSB86-S-17251	110	108	108				
MUQCDU-S-15588	109	109	107				
MUSB86-S-17168	107	105	104				
MUSB86-S-17246	105	108	105				
MUHC57-S-17184	108	109	108				
MUHC52-S-17189	105	100	99				
MUHC52-S-17189DUP	108	105	105				
Methanol blank	104	97	98				
MUHC53-S-17191	105	103	102				
MUHC57-S-17183	106	107	103				
MUHC57-S-17181	106	108	105				
MUHC57-S-17194	102	104	103				
MUHC57-S-17185	106	108	103				
<i>SDG 04-7-8, analysis date July 8, 2004</i>							
20-µg/kg standard	92	102	93	16.71	17.9	17.62	12.6
Methanol blank	100	100	100				
MUHC57-S-17186	98	91	91				
MUHC57-S-17192	93	89	89				
MUQCDU-S-17197	90	94	94				
MUHC57-S-17187	98	100	98				
MUHC56-S-17179	94	95	96				
MUHC57-S-17193	97	96	94				
MUHC56-S-17180	100	102	101				
MUHC56-S-17180DUP	114	101	108				
MUHC55-S-15591	13 <sup>c</sup>	109	227 <sup>c</sup>	Accepted on the basis of the result for sample at lower depth and headspace analysis result.			

TABLE S2.9 (Cont.)

Sample	Recovery of Surrogate Compounds <sup>a</sup> (%)			Measured Values for Calibration Check Standards			
	Fluorobenzene	1,2-Dichloro- benzene-d <sub>4</sub>	4-Bromo- fluorobenzene	Carbon Tetrachloride		Chloroform	
				Concentration (µg/kg)	RPD <sup>b</sup>	Concentration (µg/kg)	RPD <sup>b</sup>
<i>SDG 04-7-9, analysis date July 9, 2004</i>							
20-µg/kg standard	100	111	96	17.62	12.6	18.3	8.9
Methanol blank	106	106	107				
MUHC53-S-17190	96	98	100				
MUQCDU-S-17196	109	111	113				
MUHC54-S-15589	104	115	113				
MUSB86-S-17176	102	107	106				
MUHC57-S-17182	93	104	102				
MUHC57-S-17195	100	107	107				
MUHC55-S-15592	94	98	95				
MUSB86-S-17174	100	109	109				
Methanol blank	94	94	93				
MUSB86-S-17173	92	92	92				
MUSB86-S-17175	92	99	97				
MUQCTB-S-15688	78 <sup>c</sup>	75 <sup>c</sup>	74 <sup>c</sup>	Not reported.			
MUQCTB-S-15688DUP	89	84	87	Reported as primary analysis.			
MUQCTB-S-15685	89	84	88				
Methanol blank	107	104	104				
MUHC54-S-15590	105	106	106				
MUHC52-S-17188	97	104	100				

<sup>a</sup> Quality control limit for recovery of surrogate compounds: 80–120%.

<sup>b</sup> Quality control limit for RPD for calibration check standards: ±20%.

<sup>c</sup> Surrogate recovery outside quality control limit.

TABLE S2.10 Results for carbon tetrachloride and chloroform in dual analyses of soil samples with the purge-and-trap method at the AGEM Laboratory.

Location	Depth (ft BGL)	Sample Date	Sample	Concentration (µg/kg)		
				Carbon Tetrachloride	Chloroform	
HC02	1	5/25/04	MUHC02T-S-17060	Sample	ND <sup>a</sup>	ND
			MUHC02T-S-17060DUP	Duplicate analysis	ND	ND
HC03	3	5/25/04	MUHC03B-S-17063	Sample	ND	ND
			MUHC03B-S-17063DUP	Duplicate analysis	ND	ND
HC09	1	5/25/04	MUHC09T-S-17074	Sample	ND	ND
			MUHC09T-S-17074DUP	Duplicate analysis	ND	ND
HC10	1	5/25/04	MUHC10T-S-17076	Sample	ND	ND
			MUHC10T-S-17076DUP	Duplicate analysis	ND	ND
HC17	1	5/25/04	MUHC17T-S-17090	Sample	ND	ND
			MUHC17T-S-17090DUP	Duplicate analysis	ND	ND
HC22	3	5/26/04	MUHC22B-S-17101	Sample	ND	ND
			MUHC22B-S-17101DUP	Duplicate analysis	ND	ND
HC25	1	5/26/04	MUHC25T-S-17106	Sample	ND	ND
			MUHC25T-S-17106DUP	Duplicate analysis	ND	ND
			MUQCDU-S-15508	Blind replicate	ND	ND
HC25	3	5/26/04	MUHC25B-S-17107	Sample	ND	ND
			MUQCDU-S-15509	Blind replicate	ND	ND
HC27	1	5/26/04	MUHC27T-S-17110	Sample	ND	ND
			MUQCDU-S-15510	Blind replicate	ND	ND
HC27	3	5/26/04	MUHC27B-S-17111	Sample	ND	ND
			MUQCDU-S-15511	Blind replicate	ND	ND
HC28	1	5/26/04	MUHC28T-S-17112	Sample	ND	ND
			MUQCDU-S-15512	Blind replicate	ND	ND
			MUQCDU-S-15512DUP	Duplicate analysis	ND	ND
HC28	3	5/26/04	MUHC28B-S-17113	Sample	ND	ND
			MUQCDU-S-15513	Blind replicate	ND	ND
HC35	1	5/26/04	MUHC35T-S-17126	Sample	ND	ND
			MUQCDU-S-15660	Blind replicate	ND	ND
HC35	3	5/26/04	MUHC35B-S-17127	Sample	ND	ND
			MUQCDU-S-15661	Blind replicate	ND	ND
			MUQCDU-S-15661DUP	Duplicate analysis	ND	ND
HC36	3	5/26/04	MUHC36B-S-17129	Sample	ND	ND
			MUHC36B-S-17129DUP	Duplicate analysis	ND	ND
HC49	1	5/27/04	MUHC49T-S-17154	Sample	ND	ND
			MUQCDU-S-15583	Blind replicate	ND	ND
HC49	3	5/27/04	MUHC49B-S-17155	Sample	ND	ND
			MUQCDU-S-15584	Blind replicate	ND	ND

TABLE S2.10 (Cont.)

Location	Depth (ft BGL)	Sample Date	Sample	Concentration (µg/kg)		
				Carbon Tetrachloride	Chloroform	
HC50	1	5/27/04	MUHC50T-S-17156	Sample	ND	ND
			MUHC50T-S-17156DUP	Duplicate analysis	ND	ND
HC52	3	6/30/04	MUHC52-S-17189	Sample	ND	ND
			MUHC52-S-17189DUP	Duplicate analysis	ND	ND
HC56	3	6/30/04	MUHC56-S-17180	Sample	ND	ND
			MUHC56-S-17180DUP	Duplicate analysis	ND	ND
HC57	17	6/30/04	MUHC57-S-17193	Sample	ND	ND
			MUQCDU-S-17197	Blind replicate	ND	ND
HC57	21	6/30/04	MUHC57-S-17195	Sample	ND	ND
			MUQCDU-S-17196	Blind replicate	ND	ND
SB85	3	6/28/04	MUSB85-S-17208	Sample	ND	ND
			MUSB85-S-17208DUP	Duplicate analysis	ND	ND
SB85	7	6/28/04	MUSB85-S-17210	Sample	ND	ND
			MUSB85-S-17210DUP	Duplicate analysis	ND	ND
SB85	19	6/28/04	MUSB85-S-17216	Sample	ND	ND
			MUQCDU-S-11299	Blind replicate	ND	ND
			MUQCDU-S-11299DUP	Duplicate analysis	ND	ND
SB85	39	6/28/04	MUSB85-S-17226	Sample	ND	ND
			MUSB85-S-17226DUP	Duplicate analysis	ND	ND
			MUQCDU-S-15502	Blind replicate	ND	ND
SB85	57	6/28/04	MUSB85-S-17235	Sample	8 6	ND
			MUSB85-S-17235DUP	Duplicate analysis	8 2	ND
SB85	59	6/28/04	MUSB85-S-17236	Sample	ND	ND
			MUQCDU-S-15524	Blind replicate	ND	ND
			MUQCDU-S-15524DUP	Duplicate analysis	ND	ND
SB86	13	6/29/04	MUSB86-S-17247	Sample	ND	ND
			MUSB86-S-17247DUP	Duplicate analysis	ND	ND
SB86	23	6/29/04	MUSB86-S-17252	Sample	ND	ND
			MUQCDU-S-15587	Blind replicate	ND	ND
SB86	49	6/29/04	MUSB86-S-17165	Sample	10	ND
			MUSB86-S-17165DUP	Duplicate analysis	11	ND
SB86	55	6/29/04	MUSB86-S-17168	Sample	12	ND
			MUQCDU-S-15588	Blind replicate	14	ND
SB86	63	6/29/04	MUSB86-S-17172	Sample	ND	ND
			MUQCDU-S-15593	Blind replicate	ND	ND

<sup>a</sup> ND, contaminant not detected at the method quantitation limit of 10 µg/kg.

TABLE S2.11 Recovery of system-monitoring compounds in verification organic analyses of soil samples with EPA Method 8260B at Severn-Trent Laboratory.

Sample	Analysis Date	Sample Delivery Group	Recovery <sup>a</sup> (%)			
			Toluene-d <sub>8</sub>	1,2-Dichloro-ethane-d <sub>4</sub>	Bromofluoro-benzene	1,2-Dichloro-benzene-d <sub>4</sub>
MUHC26B-S-17109	6/11/04	100636	97	114	96	105
MUHC24B-S-17105	6/11/04	100636	99	111	98	105
MUHC45B-S-17147	6/11/04	100636	98	109	101	105
MUHC22T-S-17100	6/11/04	100636	100	104	102	106
MUHC12B-S-17081	6/11/04	100636	97	105	103	107
MUHC26T-S-17108	6/11/04	100636	98	110	101	104
MUHC17B-S-17091	6/11/04	100636	100	111	105	110
MU-S-MEOHBLANK	6/11/04	100636	99	110	100	104
MUHC48T-S-17152	6/11/04	100636	98	115	96	104
MUHC48T-S-17152MS	6/11/04	100636	99	108	102	104
MUHC48T-S-17152MSD	6/11/04	100636	99	106	102	105
LDYD LCS	6/11/04	100636	98	106	96	103
LDYD LCSD	6/11/04	100636	98	119	103	104
VBLKU1	6/11/04	100636	100	111	101	109
MUSB85-S-17233	7/9/04	101183	107	102	113	110
MUSB85-S-17231	7/9/04	101183	105	105	114	111
MUSB85-S-17226	7/9/04	101183	107	103	114	110
MUSB86-S-17250	7/9/04	101183	107	104	111	107
MUSB85-S-17222	7/9/04	101183	108	100	112	110
MUSB86-S-17249	7/9/04	101183	106	106	114	111
MU-S-MEOHBLANK2	7/9/04	101183	108	102	112	104
LECA LCS	7/9/04	101183	106	99	112	109
LECA LCSD	7/9/04	101183	107	102	111	109
VBLKB8	7/9/04	101183	108	106	117	113
MEOH LCS	7/9/04	101183	106	128	112	105

<sup>a</sup> Quality control limits for recovery are as follows:

Analyte	QC Limits (%)
Toluene-d <sub>8</sub>	81–117
1,2-Dichloroethane-d <sub>4</sub>	80–120
Bromofluorobenzene	74–121
1,2-Dichlorobenzene-d <sub>4</sub>	80–120

TABLE S2.12 Recovery and relative percent difference values for spike/spike duplicate organic analyses of soil samples at Severn-Trent Laboratory.

Compound	Concentration (µg/kg)				Recovery (%)			Difference (%)	
	Sample	Spike Added	Spike Analysis	Duplicate Analysis	Spike Analysis	Duplicate Analysis	QC Limits	RPD	QC Limit
<i>Spike/spike duplicate analysis of MUHC48T-S-17152 in SDG 100636</i>									
Chloroform	0	170	170	170	100	100	74–106	0	40
Carbon tetrachloride	5.7	170	180	170	102	97	62–106	5	40
<i>Spike/spike duplicate analysis of LDYD LCS in SDG 100636</i>									
Chloroform	0	10	10	10	100	100	74–106	0	40
Carbon tetrachloride	0	10	10	9.4	100	94	62–106	6	40
<i>Spike/spike duplicate analysis of LECA LCS in SDG 101183</i>									
Chloroform	0	10	9.2	10	92	100	74–106	8	40
Carbon tetrachloride	0	10	9.5	10	95	100	62–106	5	40

TABLE S2.13 Carbon tetrachloride and chloroform concentrations in soil samples selected for verification organic analysis during the targeted investigation at Murdock, Nebraska.

Location	Sample	Depth (ft BGL)	Sample Date	Carbon Tetrachloride			Chloroform			1,1,1-Trichloroethane		
				Concentration (µg/kg)		RPD (%)	Concentration (µg/kg)		RPD (%)	Concentration (µg/kg)		RPD (%)
				AGEM <sup>a</sup>	STL <sup>b</sup>		AGEM <sup>a</sup>	STL <sup>b</sup>		AGEM <sup>a</sup>	STL <sup>b</sup>	
HC12	MUHC12B-S-17081	3	5/25/04	ND <sup>c</sup>	ND	–	ND	ND	–	ND	ND	–
HC17	MUHC17B-S-17091	3	5/25/04	ND	ND	–	ND	ND	–	ND	ND	–
HC22	MUHC22T-S-17100	1	5/26/04	ND	ND	–	ND	ND	–	ND	ND	–
HC24	MUHC24B-S-17105	3	5/26/04	ND	ND	–	ND	ND	–	ND	ND	–
HC26	MUHC26T-S-17108	1	5/26/04	ND	ND	–	ND	ND	–	ND	ND	–
HC26	MUHC26B-S-17109	3	5/26/04	ND	ND	–	ND	ND	–	ND	ND	–
HC45	MUHC45B-S-17147	3	5/27/04	ND	ND	–	ND	ND	–	ND	ND	–
HC48	MUHC48T-S-17152	1	5/27/04	ND	5.7 J <sup>d</sup>	–	ND	ND	–	ND	ND	–
SB85	MUSB85-S-17222	31	6/28/04	303	330	8.5	ND	4.3 J	–	Trace <sup>e</sup>	7.5 J	–
SB85	MUSB85-S-17226	39	6/28/04	ND	ND	–	ND	ND	–	ND	ND	–
SB85	MUSB85-S-17231	49	6/28/04	18	23	24.3	ND	ND	–	ND	9.1 J	–
SB85	MUSB85-S-17233	53	6/28/04	154	190	20.9	ND	2.2 J	–	Trace <sup>e</sup>	8.9 J	–
SB86	MUSB86-S-17249	17	6/29/04	ND	ND	–	ND	ND	–	ND	3.2 J	–
SB86	MUSB86-S-17250	19	6/29/04	ND	ND	–	ND	ND	–	ND	ND	–

<sup>a</sup> Sample preparation and analysis at the AGEM Laboratory with EPA Methods 5030B and 8260B.

<sup>b</sup> Sample preparation and analysis at Severn-Trent Laboratory with EPA Methods 5030B and 8260B.

<sup>c</sup> N D , not detected at the method quantitation limit of 10 µg/kg.

<sup>d</sup> J, estimated concentration below the method quantitation limit of 10 µg/kg.

<sup>e</sup> Compound was present at a level below the quantitation limit.

TABLE S2.14 Quality control results for organic analyses of air samples collected during the 2004 targeted investigation at Murdock, Nebraska.

Chemical	Spike Added (ppbv)	Quality Control Sample		Quality Control Sample Duplicate		Relative Percent Difference <sup>b</sup> (%)
		Concentration (ppbv)	Recovery <sup>a</sup> (%)	Concentration (ppbv)	Recovery <sup>a</sup> (%)	
<i>Quality control sample J1LCS in SDG 101664</i>						
Dichlorodifluoromethane	10	8	80	8	80	0
Chloromethane	10	9	90	9	90	0
Vinyl chloride	10	9.6	96	9.6	96	0
Bromomethane	10	9.5	95	9.4	94	1
Chloroethane	10	9.7	97	9.8	98	1
Trichlorofluoromethane	10	8.7	87	8.9	89	2
Freon TF	10	9.1	91	9.2	92	1
1,1-Dichloroethene	10	9.3	93	9.5	95	2
Methylene chloride	10	8.8	88	9.1	91	3
1,1-Dichloroethane	10	9.4	94	9.6	96	2
<i>cis</i> -1,2-Dichloroethene	10	9.5	95	9.8	98	3
Chloroform	10	9	90	9.3	93	3
1,1,1-Trichloroethane	10	9.8	98	9.3	93	5
Carbon tetrachloride	10	9.8	98	9.5	95	3
Benzene	10	11	110	10	100	10
1,2-Dichloroethane	10	9.5	95	9.3	93	2
Trichloroethene	10	10	100	9.8	98	2
1,2-Dichloropropane	10	11	110	10	100	10
<i>cis</i> -1,3-Dichloropropene	10	10	100	10	100	0
Toluene	10	10	100	9.7	97	3
<i>trans</i> -1,3-Dichloropropene	10	10	100	9.8	98	2
1,1,2-Trichloroethane	10	10	100	9.7	97	3
Tetrachloroethene	10	11	110	9.7	97	12
Chlorobenzene	10	10	100	9.5	95	5
Ethylbenzene	10	10	100	9.3	93	7
Xylene ( <i>m, p</i> )	20	21	105	19	95	10
Styrene	10	11	110	9.7	97	12
Xylene ( <i>o</i> )	10	10	100	9.6	96	4
1,1,2,2-Tetrachloroethane	10	12	120	11	110	9
1,3-Dichlorobenzene	10	11	110	10	100	10
1,4-Dichlorobenzene	10	11	110	10	100	10
1,2-Dichlorobenzene	10	12	120	11	110	9
1,2,4-Trichlorobenzene	10	14	140 <sup>c</sup>	13	130	7
Hexachlorobutadiene	10	14	140 <sup>c</sup>	13	130	7
1,3,5-Trimethylbenzene	10	9.3	93	9	90	3
1,2,4-Trimethylbenzene	10	10	100	9.7	97	3
1,2-Dichlorotetrafluoroethane	10	8.5	85	8.6	86	1
1,2-Dibromoethane	10	10	100	9.7	97	3
1,3-Butadiene	10	9.7	97	10	100	3
Carbon disulfide	10	9.3	93	9.4	94	1
Acetone	10	10	100	12	120	18
Isopropyl alcohol	10	9.7	97	10	100	3
Methyl tert-butyl ether	10	9.2	92	9.5	95	3
Cyclohexane	10	11	110	10	100	10
Dibromochloromethane	10	10	100	9.8	98	2
Methyl ethyl ketone	10	9.4	94	9.9	99	5
1,4-Dioxane	10	12	120	11	110	9
Methyl isobutyl ketone	10	11	110	10	100	10
Methyl butyl ketone	10	10	100	10	100	0
Bromoform	10	11	110	10	100	10
Bromodichloromethane	10	10	100	9.8	98	2

TABLE S2.14 (Cont.)

Chemical	Spike Added (ppbv)	Quality Control Sample		Quality Control Sample Duplicate		Relative Percent Difference <sup>b</sup> (%)
		Concentration (ppbv)	Recovery <sup>a</sup> (%)	Concentration (ppbv)	Recovery <sup>a</sup> (%)	
<i>Quality control sample J1LCS in SDG 101664 (Cont.)</i>						
<i>trans</i> -1,2-Dichloroethene	10	9.1	91	9.4	94	3
4-Ethyltoluene	10	11	110	9.9	99	10
3-Chloropropene	10	9.4	94	9.9	99	5
2,2,4-Trimethylpentane	10	11	110	10	100	10
Bromoethene	10	9.6	96	9.6	96	0
2-Chlorotoluene	10	10	100	9.4	94	6
<i>n</i> -Hexane	10	9.9	99	10	100	1
Tetrahydrofuran	10	11	110	11	110	0
<i>n</i> -Heptane	10	11	110	10	100	10
1,2-Dichloroethene (total)	20	19	95	19	95	0
Xylene (total)	30	32	107	30	100	7
<i>tert</i> -Butyl alcohol	10	8.9	89	10	100	12
<i>Quality control sample J6LCS in SDG 101664</i>						
Dichlorodifluoromethane	10	7.9	79	8.3	83	5
Chloromethane	10	7.7	77	8.2	82	6
Vinyl chloride	10	8.2	82	8.6	86	5
Bromomethane	10	8.2	82	8.7	87	6
Chloroethane	10	8.8	88	9.1	91	3
Trichlorofluoromethane	10	8.1	81	8.6	86	6
Freon TF	10	8.5	85	8.7	87	2
1,1-Dichloroethene	10	8.3	83	8.7	87	5
Methylene chloride	10	8.1	81	8.3	83	2
1,1-Dichloroethane	10	9	90	9.2	92	2
<i>cis</i> -1,2-Dichloroethene	10	8.8	88	8.8	88	0
Chloroform	10	8.8	88	8.8	88	0
1,1,1-Trichloroethane	10	8.7	87	9	90	3
Carbon tetrachloride	10	9	90	9.3	93	3
Benzene	10	9.8	98	9.8	98	0
1,2-Dichloroethane	10	9	90	9.3	93	3
Trichloroethene	10	9	90	9.2	92	2
1,2-Dichloropropane	10	10	100	10	100	0
<i>cis</i> -1,3-Dichloropropene	10	9.8	98	10	100	2
Toluene	10	9.1	91	9.3	93	2
<i>trans</i> -1,3-Dichloropropene	10	9.7	97	10	100	3
1,1,2-Trichloroethane	10	9.3	93	9.5	95	2
Tetrachloroethene	10	10	100	10	100	0
Chlorobenzene	10	9.6	96	9.8	98	2
Ethylbenzene	10	9	90	9.2	92	2
Xylene ( <i>m, p</i> )	20	19	95	19	95	0
Styrene	10	9.6	96	9.8	98	2
Xylene ( <i>o</i> )	10	9.4	94	9.7	97	3
1,1,2,2-Tetrachloroethane	10	10	100	11	110	10
1,3-Dichlorobenzene	10	11	110	11	110	0
1,4-Dichlorobenzene	10	10	100	11	110	10
1,2-Dichlorobenzene	10	11	110	12	120	9
1,2,4-Trichlorobenzene	10	14	140 <sup>c</sup>	14	140 <sup>c</sup>	0
Hexachlorobutadiene	10	13	130	13	130	0
1,3,5-Trimethylbenzene	10	11	110	9	90	20
1,2,4-Trimethylbenzene	10	9.4	94	9.8	98	4
1,2-Dichlorotetrafluoroethane	10	8.2	82	8.5	85	4

TABLE S2.14 (Cont.)

Chemical	Spike Added (ppbv)	Quality Control Sample		Quality Control Sample Duplicate		Relative Percent Difference <sup>b</sup> (%)
		Concentration (ppbv)	Recovery <sup>a</sup> (%)	Concentration (ppbv)	Recovery <sup>a</sup> (%)	
<i>Quality control sample J6LCS in SDG 101664 (Cont.)</i>						
1,2-Dibromoethane	10	9.3	93	9.7	97	4
1,3-Butadiene	10	8.4	84	8.8	88	5
Carbon disulfide	10	8.6	86	8.9	89	3
Acetone	10	9.3	93	9.6	96	3
Isopropyl alcohol	10	12	120	12	120	0
Methyl <i>tert</i> -butyl ether	10	8.9	89	9	90	1
Cyclohexane	10	9.6	96	9.6	96	0
Dibromochloromethane	10	9.5	95	9.8	98	3
Methyl ethyl ketone	10	8.7	87	8.7	87	0
1,4-Dioxane	10	9.4	94	9.8	98	4
Methyl isobutyl ketone	10	9.8	98	10	100	2
Methyl butyl ketone	10	9.2	92	9.3	93	1
Bromoform	10	10	100	10	100	0
Bromodichloromethane	10	9.2	92	9.5	95	3
<i>trans</i> -1,2-Dichloroethene	10	8.9	89	9.2	92	3
4-Ethyltoluene	10	8.4	84	10	100	17
3-Chloropropene	10	8.7	87	8.8	88	1
2,2,4-Trimethylpentane	10	9.9	99	10	100	1
Bromoethene	10	8.6	86	9.1	91	6
2-Chlorotoluene	10	9.3	93	9.7	97	4
<i>n</i> -Hexane	10	9.1	91	9.2	92	1
Tetrahydrofuran	10	9.8	98	9.7	97	1
<i>n</i> -Heptane	10	9.2	92	9.2	92	0
1,2-Dichloroethene (total)	20	18	90	18	90	0
Xylene (total)	30	28	93	29	97	4
<i>tert</i> -Butyl alcohol	10	8.6	86	8.9	89	3

<sup>a</sup> Quality control limits for recovery = 70–130%.

<sup>b</sup> Quality control limits for relative percent difference = 40%.

<sup>c</sup> Result outside quality control range.