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E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program



United States Department of Energy

RCRA Corrective Measures Implementation (CMI) Workplan

for the

Lawrence Berkeley National Laboratory
CA-EPA ID No: CA4890008986
ENVIRONMENTAL RESTORATION PROGRAM

November 2005

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*A Joint Effort of
Environment, Health and Safety Division and
Earth Sciences Division*
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- Attachment 2. Corrective Measure Implementation (CMI) Workplan for Soil Excavation, Building 7 Sump of the Old Town Groundwater Solvent Plume Source Area for the Lawrence Berkeley National Laboratory Environmental Restoration Program, dated November 2005.
- Attachment 3. Monitoring Protocols for Monitored Natural Attenuation and Enhanced Bioremediation for the Lawrence Berkeley National Laboratory Environmental Restoration Program, dated November 2005.
- Attachment 4. Regulatory Agency Comments and Berkeley Lab Responses on the RCRA Corrective Measures Implementation (CMI) Workplan dated November 2005.

LIST OF ABBREVIATIONS

AOC	Area of Concern
Berkeley Lab	Lawrence Berkeley National Laboratory
Cal-EPA	California Environmental Protection Agency
CAP	Corrective Action Program
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COC	Chemical of Concern
CVOCs	Chlorinated Volatile Organic Compounds
DCA	Dichloroethane
DCE	Dichloroethene
DOE	U.S. Department of Energy
DTSC	Cal-EPA Department of Toxic Substances Control
EBMUD	East Bay Municipal Utility District
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ERP	Environmental Restoration Program
FY	Fiscal Year (October 1 through September 30)
GAC	Granular Activated Carbon
gpd	gallons per day
HHRA	Human Health Risk Assessment
HI	Hazard Index
HRC	Hydrogen Release Compounds
HWHF	Hazardous Waste Handling Facility
ICMs	Interim Corrective Measures
ILCR	Incremental Lifetime Cancer Risk
MCL	Maximum Contaminant Level
MCS	Media Cleanup Standard
MNA	Monitored natural Attenuation
PCB	Polychlorinated Biphenyl
PCE	tetrachloroethene
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
SVE	Soil Vapor Extraction
SWMU	Solid Waste Management Unit
SWRCB	State Water Resources Control Board
TCA	Trichloroethane
TCE	Trichloroethene
TI	Technical Impracticability
TSCA	Toxic Substances Control Act
UC	University of California
UCL	Upper Confidence Limit
USEPA	U. S. Environmental Protection Agency
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
Water Board	Regional Water Quality Control Board

SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) Hazardous Waste Handling Facility (HWHF) operates under a Resource Conservation and Recovery Act (RCRA) Hazardous Waste Facility Permit. The Permit requires that Berkeley Lab investigate and address historic releases of hazardous waste and hazardous constituents that may have occurred at the HWHF and at Solid Waste Management Units (SWMUs) throughout Berkeley Lab as part of the RCRA Corrective Action Process (CAP). The CAP consists of the investigation, characterization, and cleanup of releases of hazardous waste or hazardous waste constituents.

The principal components of the CAP are:

- 1) RCRA Facility Assessment (RFA)
- 2) RCRA Facility Investigation (RFI)
- 3) Interim Corrective Measures (ICMs)
- 4) Corrective Measures Study (CMS)
- 5) Corrective Measures Implementation (CMI).

Berkeley Lab is currently beginning Corrective Measures Implementation (CMI), the final phase of the CAP. The purpose of the CMI phase is to design, construct, operate, maintain, and monitor the corrective measures (cleanup activities) recommended by Berkeley Lab in the Corrective Measures Study (CMS) Report (Berkeley Lab, 2005a) and approved by the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC). Implementation of these activities is needed to reduce or eliminate the potentially adverse effects to human health or the environment caused by historic releases of chemicals to soil and groundwater at Berkeley Lab. This CMI workplan provides a detailed description of the design and construction of the approved corrective measures.

1.2 BACKGROUND

The DTSC is the regulatory agency responsible for enforcing the provisions of Berkeley Lab's Hazardous Waste Facility Permit, including the activities required under the RCRA CAP. Berkeley Lab's Environmental Restoration Program (ERP) is responsible for carrying out those activities.

On February 10, 2005, Berkeley Lab submitted its revised Draft Corrective Measures Study Report to the DTSC (Berkeley Lab, 2005a). The CMS Report provides recommendations for the specific corrective measures that should be implemented to eliminate or reduce potential risks to human health from contaminants in the soil and/or groundwater at Berkeley Lab and protect the potential beneficial uses of the groundwater. It also provides the media specific concentrations (Media Cleanup Standards [MCSs]) that the measures should achieve in order to be considered complete.

The DTSC, in consultation with the Regional Water Quality Control Board (Water Board) and the City of Berkeley Toxics Management Division reviewed the Draft CMS Report and determined that it was technically complete (DTSC, 2005a). In addition, DTSC evaluated the corrective measures proposed for Berkeley Lab in the Draft CMS Report and prepared a Statement of Basis indicating its concurrence with the proposed measures (DTSC, 2005b). On May 26, 2005, DTSC conducted a public meeting and hearing on the proposed Berkeley Lab cleanup measures and held a 45-day public comment period that ended on June 8, 2005. On August 31, 2005, DTSC responded to the public comments and issued its "Notice of Determination for Approval of a Corrective Measures Study (CMS) Report that would allow the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL) to implement corrective measures at the facility" (DTSC, 2005c). On August 31, 2005, DTSC also informed Berkeley Lab of its final decision to approve the Corrective Measures Study Report including the proposed remedies, and requested that Berkeley Lab submit a Corrective Measures Implementation Workplan to DTSC (DTSC, 2005d). This CMI Workplan is being submitted to DTSC in response to that request.

SECTION 2

CORRECTIVE MEASURES REQUIREMENTS

2.1 CORRECTIVE ACTION OBJECTIVES

Corrective Action Objectives were developed in the CMS Report to address both potential risk to human health and compliance with regulatory policy. Potential risks to human health were estimated based on an industrial/institutional land use scenario, which is consistent with the current and potential future land use at Berkeley Lab. The regulatory policy addressed was the protection of beneficial uses of groundwater.

Potential Risk to Human Health

The primary Corrective Action Objective is to reduce the concentrations of chemicals of concern (COCs) in soil and groundwater to levels where the theoretical Incremental Lifetime Cancer Risks (ILCRs) to workers at Berkeley Lab are less than, or at the lowest reasonably achievable level within, the United States Environmental Protection Agency (USEPA) target range for risk managers and Hazard Indices (HIs) are less than 1. Although an ILCR anywhere within the target range for risk managers (between 10^{-4} and 10^{-6}) is considered by the USEPA to be safe and protective of public health, the lowest reasonably achievable level within the target range was selected as the risk-based Corrective Action Objective.

Regulatory Policy

Groundwater is not used for drinking water or other beneficial uses at Berkeley Lab and is not used for drinking water downgradient in the City of Berkeley or at the University of California (UC) Berkeley. However, unless otherwise designated by the Water Board, all groundwaters are considered suitable, or potentially suitable, for municipal or domestic water supply. Exceptions to this policy are specified in State Water Resources Control Board (SWRCB) Resolution 88-63 "Sources Policy". Resolution 88-63 defines potential sources of drinking water to include all groundwater, with limited exceptions for areas of high TDS ($>3,000$

mg/L), low yield (<200 gallons per day [gpd]), or naturally high contaminant levels that cannot reasonably be treated for domestic use.

Under the Water Board's Water Quality Control Plan (Basin Plan), cleanup levels for groundwaters with a beneficial use of municipal and domestic supply are set no higher than Maximum Contaminant Levels (MCLs) or secondary MCLs. Therefore, to address regulatory policy the following secondary Corrective Action Objectives were developed:

- Protecting and/or restoring groundwater quality to levels that are protective of beneficial uses.
- Controlling the migration of contaminated groundwater so that COCs do not migrate to groundwater in adjacent uncontaminated areas or to surface water.
- Controlling the migration of contaminated groundwater so that COCs above risk-based levels do not migrate to groundwater in adjacent areas where concentrations are below risk-based levels.

2.2 CHEMICALS OF CONCERN

The Human Health Risk Assessment (HHRA) identified chlorinated volatile organic compounds (CVOCs) in soil and groundwater and polychlorinated biphenyls (PCBs) in soil as the COCs at Berkeley Lab. However, subsequent to completion of the HHRA, Berkeley Lab conducted Interim Corrective Measures (ICMs) (excavation of PCB-contaminated soil) that resulted in reduction of PCB concentrations to levels that are less than the Toxic Substances Control Act (TSCA) (40 Code of Federal Regulations [CFR] Parts 750 and 761) self-implementing cleanup level for soil in high-occupancy areas of 1 mg/kg. This level is considered to be acceptable by the USEPA for unrestricted land use. Therefore, no additional corrective action is required for PCBs, and CVOCs in soil and groundwater are the only remaining COCs at Berkeley Lab.

2.3 MEDIA CLEANUP STANDARDS

Media Cleanup Standards (MCSs) are media- and COC-specific concentrations that a corrective measure must achieve in order to meet the corrective action objectives and be considered complete. The MCS approved by the DTSC for PCB-contaminated soil is 1 mg/kg, the TSCA self-

implementing cleanup level for PCBs in soil in high occupancy areas. As described in the preceding paragraph, no additional corrective action is required for PCBs since the corrective action objective has been achieved.

For CVOCs, MCSs were developed to address both risk-based and regulatory-based Corrective Action Objectives. Cleanup to risk-based MCSs is the short-term goal for areas of Berkeley Lab where groundwater is not considered a potential drinking water source (i.e., does not meet SWRCB well yield criteria of at least 200 gallons per day). Two sets of risk-based MCSs were developed: 1) target risk-based MCSs and 2) upper-limit risk-based MCSs. The target risk-based MCSs are based on theoretical ILCRs of 10^{-6} (the lower bound of the risk management range) and non-cancer HIs of 1. Upper limit risk-based MCSs were also developed that represent the upper bound of the USEPA risk management range (i.e., a theoretical ILCR of 10^{-4}) and non-cancer HI of 1.0. The upper-limit risk-based MCSs are considered by the USEPA to be in the range that is safe and protective of public health and will be used to assess compliance with corrective measure objectives at locations where target risk-based MCSs cannot reasonably be achieved.

Where groundwater meets the SWRCB well yield criteria, cleanup to regulatory-based MCSs is the goal. MCSs for CVOCs in groundwater in those areas were set at MCLs for drinking water. MCSs for CVOCs in soil in those areas were set either at a level that would not potentially result in groundwater concentrations exceeding MCLs (regulatory-based MCS) or the target risk-based soil MCS, whichever was more conservative. The overall long-term goal for all groundwater at Berkeley Lab is the reduction of COC concentrations to MCLs.

The target risk-based MCSs and regulatory-based MCSs for COCs in soil and groundwater are listed in Table 1.

Table 1. Media Cleanup Standards (MCSs) for Groundwater and Soil

	Groundwater		Soil	
	Target Risk-Based Groundwater MCS (µg/L)	Regulatory-Based Groundwater MCS (MCL) (µg/L)	Target Risk-Based Soil MCS (mg/kg)	Regulatory-Based Soil MCS ^(a) (mg/kg)
Applicability	Well yield is < 200 gpd	Well yield ≥ 200 gpd	Soil overlying areas where well yield is < 200 gpd	Soil overlying areas where well yield ≥ 200 gpd
COC				
benzene	175	1	0.1	0.044
carbon tetrachloride	27	0.5	0.05	0.05*
chloroform	1,206	100	0.28	0.28*
1,1-dichloroethane (DCA)	3,663	5	1.3	0.2
1,2-dichloroethane (DCA)	1,030	0.5	0.23	0.0045
1,1-dichloroethene (DCE)	28,873	6	8	1.0
cis-1,2- dichloroethene (DCE)	98,405	6	38	0.19
trans-1,2- dichloroethene (DCE)	94,405	10	50	0.67
1,2-dichloropropane	1,071	5	NA	NA
methylene chloride	10,381	5	1.8	0.077
1,1,1-trichloroethane (TCA)	1,570,783	200	690	7.8
1,1,2-Trichloroethane (TCA)	1,905	5	NA	NA
tetrachloroethene (PCE)	343	5	0.45	0.45*
trichloroethene (TCE)	1,594	5	2.3	0.46
vinyl chloride	12	0.5	0.0035	0.0035*

(a) The lesser of the risk-based or regulatory based MCS.

* indicates MCS is risk based; all other MCSs for soil in areas where well yield is ≥ 200 gpd are regulatory based.

NA: MCS is not applicable. Chemical is not a soil COC.

A compliance level of non-detect was set for surface water and for areas of groundwater that are not currently contaminated but could potentially be impacted by migration of COCs. This addresses the SWRCB non-degradation policy (Resolution 68-16) under the Porter-Cologne Water Quality Control Act.

2.4 COMPLIANCE WITH MEDIA CLEANUP STANDARDS

Soil

Excavation and offsite disposal is the corrective measure approved for the cleanup of soil. Compliance with soil MCSs will be demonstrated by analyzing pre-excavation soil samples that are collected to determine the required extent of excavation. Additional confirmation samples may be collected from the walls or floors of excavations if the pre-excavation sampling locations are not adequate to delineate the magnitude and extent of contamination.

To demonstrate that remedial objectives have been attained, either the maximum detected concentrations or representative chemical concentrations to which human receptors may be exposed (exposure point concentrations [EPCs]) will be compared to the MCSs. In accordance with USEPA guidance (USEPA, 1989), the EPCs will be set for soil at the 95-percent upper confidence limit (UCL) on the arithmetic mean of the sample concentrations, unless the sample size is less than eight ($N < 8$) or the percentage of non-detect values is greater than 80%. In those cases where there are insufficient soil data to calculate a reliable UCL, the maximum concentration will be used.

Groundwater

Compliance with groundwater MCSs will be demonstrated throughout the area of groundwater contamination. Locations for demonstrating compliance will consist of wells in the existing groundwater-monitoring network. These wells are located in the area where groundwater MCSs are exceeded, and also downgradient from those areas to monitor for downgradient plume migration. When the concentrations of COCs in all compliance wells at a groundwater unit averaged over four consecutive quarters of monitoring are less than MCSs, the corrective measure will be considered complete for that unit. Groundwater monitoring at Berkeley Lab is currently based on a schedule (Berkeley Lab, 2005b) that was approved by the RWQCB in 2005 (Water Board, 2005). It is expected that the number of wells required for compliance monitoring and the required frequency of monitoring will decrease over time as groundwater remediation progresses and the area where MCSs are exceeded becomes smaller. Any revision of the groundwater monitoring schedule must be approved by the Water Board prior to implementation.

Technical impracticability (TI) for contaminated groundwater refers to a situation where achieving groundwater cleanup levels associated with final cleanup goals is not practicable from an engineering perspective. It is likely that MCSs, particularly the regulatory-based MCSs (i.e., MCLs), will not be achievable at all groundwater units. Whether MCSs will be attained at a groundwater unit cannot be determined until sufficient data have been collected to determine contaminant reduction rates resulting from the implemented corrective measures, and how those rates change over time. The effectiveness of the implemented remedial technologies in achieving the required MCSs will therefore be evaluated in 2011 after five years of operation, or when sufficient data have been collected to support a Determination of TI. A Determination of TI requires approval of the DTSC.

2.5 TECHNOLOGY DESCRIPTION

Soil Units

The technology approved for cleanup of soil units is excavation and offsite disposal of contaminated soil at an authorized facility.

Groundwater Units

The primary technologies approved for cleanup of groundwater units are in situ soil flushing and monitored natural attenuation (MNA). Construction of all of the required in situ soil flushing systems was completed prior to submittal of this workplan as part of pilot tests or ICMs conducted during the CMS. The approved corrective measures consist of adoption and continued operation of these systems. MNA is the approved measure in those areas where hydrochemical data indicate that natural processes (e.g., biodegradation) could be effective in reducing contaminant concentrations to the required cleanup levels. No additional construction is required for MNA. The corrective measure consists of a long-term groundwater monitoring program.

Secondary technologies that will be implemented for groundwater include injection of Hydrogen Release Compound[®] (HRC[®]) and possibly in situ chemical oxidation (ISCO) in the Building 71B lobe source area. HRC has been injected into the subsurface in several areas of the site to enhance the natural degradation processes (enhanced bioremediation). The method has been effective in reducing contaminant concentrations in groundwater at some of the locations where it

has been tested, including the Building 71B lobe source area. If the application of HRC is effective in meeting the corrective measures objectives for the Building 71B lobe source area, ISCO, a component of the corrective measure approved for this area, will not be required.

Technology Description

In Situ Soil Flushing

In situ soil flushing consists of the concurrent injection of clean water into, and extraction of contaminated water from, the subsurface. A schematic diagram of the in situ soil flushing process is shown on Figure 1. The purpose of soil flushing is to promote flow of contaminated groundwater towards extraction point(s) and to increase the rate that residual soil contaminants desorb into the flowing groundwater. Trenches and wells are used to inject treated water into the subsurface. The injected water is captured by drains, trenches, and wells; extracted; and treated on-site using granular activated carbon (GAC) canisters to reduce volatile organic compound (VOC) concentrations to non-detectable level. The treated water is then either reinjected to flush contaminants from the subsurface or, if the water is not needed for flushing, discharged to the sanitary sewer under a permit issued by the East Bay Municipal Utility District (EBMUD).

In Situ Chemical Oxidation (ISCO)

In situ chemical oxidation (ISCO) relies on direct destruction of CVOCs by hydroxyl radicals, which are powerful oxidants formed from reactions between hydrogen peroxide (H_2O_2) and native catalysts such as ferrous iron (Fe^{2+}). Field implementation of ISCO involves the following elements:

- Installation of a series of injection well-points to the target treatment zone
- Injection of acid to condition the treatment zone. Citric acid was utilized for pilot testing; however, if it is not sufficiently reactive, sulphuric acid may be utilized. Also, an iron sulfate solution may be injected to ensure the presence of sufficient ferrous iron to catalyze the reaction.
- Injection of hydrogen peroxide (H_2O_2) solution under controlled injection pressures and flow rates to various depth intervals.

Monitored Natural Attenuation (MNA)

The term “monitored natural attenuation” or MNA refers to “the reliance on natural attenuation processes within the context of a carefully controlled and monitored site cleanup approach to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods” (USEPA, 1999). The “natural attenuation processes” include a variety of physical, chemical, or biological processes that, under favorable conditions, reduce the mass, toxicity, mobility, volume, or concentration of contaminants. These processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants.

Natural attenuation processes can reduce the potential risk posed by site contaminants in three ways:

- 1) Transformation of contaminant(s) to a less toxic form through destructive processes such as biodegradation or abiotic transformations;
- 2) Reduction of contaminant concentrations whereby potential exposure levels are reduced; and
- 3) Reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

The use of MNA at a site does not preclude the use of “active” remediation or the application of biological activity enhancers, such as HRC. Typically, MNA is used in conjunction with active remediation measures. For example, active remedial measures are applied in areas with high concentrations of contaminants (such as the Building 51/64 Groundwater Solvent Plume source area) while MNA is used for lower concentration areas (such as the downgradient Building 51/64 plume area); or MNA can be used as a follow up to active remedial measures, such as is proposed for the Building 51L Groundwater Solvent Plume.

The USEPA provides the following eight specific objectives for the performance-monitoring program of an MNA remedy (USEPA, 1999):

- 1) Demonstrate that natural attenuation is occurring according to expectations;
- 2) Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes;

- 3) Identify any potentially toxic and/or mobile transformation products;
- 4) Verify that the plume(s) is not expanding downgradient, laterally or vertically;
- 5) Verify no unacceptable impact to downgradient receptors;
- 6) Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy;
- 7) Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors; and
- 8) Verify attainment of remediation objectives.

MNA will include a groundwater monitoring program designed to verify that the corrective measures objectives can be achieved, monitor the long-term behavior of the plumes, ensure that COCs are not migrating downgradient from the plume area, and document when MCSs have been attained. The general site procedures for implementing MNA, which include the specific analytes that will be monitored and the monitoring frequency, are described in Attachment 3 (Monitoring Protocols for Monitored Natural Attenuation and Enhanced Bioremediation). Site-specific sampling requirements are provided in the following sections.

Objectives of the monitoring program will be met by measuring CVOC concentrations and hydrochemical parameters (e.g., oxidation-reduction (redox) parameters, dissolved organic carbon, pH) in the groundwater. These data will be used to identify spatial and temporal changes in the areas of groundwater contamination for which MNA is the approved remedy, and to assess whether these changes will meet the corrective measures objectives specified in the CMS Report (Berkeley Lab, 2005a). Spatial and temporal changes of interest include:

- changes in plume boundaries
- changes in the hydrochemical setting indicated by the hydrochemical parameters, especially the oxidation-reduction (redox) parameters (such as dissolved oxygen, nitrate/nitrite, iron (II), sulfate/sulfide, and methane) that may be indicative of changes in biotic or abiotic processes affecting the rate and extent of natural attenuation
- contaminant concentration reductions indicative of progress toward contaminant reduction objectives

Enhanced Biodegradation Using Hydrogen Release Compound[®] (HRC[®])

Hydrogen Release Compound[®] (HRC[®]) injection consists of the controlled release of HRC into the groundwater to enhance natural biodegradation of CVOCs. HRC is a proprietary, environmentally safe, food quality, polylactate ester formulate manufactured by Regensis Bioremediation Products, Inc. for the slow release of lactic acid into groundwater upon hydration. The lactic acid is biotransformed into pyruvic acid and acetic acid releasing hydrogen in both steps. If anaerobic conditions exist, then HRC can provide a source of hydrogen, which is used as an electron donor in the reductive dechlorination process. Anaerobic microbes substitute the hydrogen for chlorine in the chlorinated hydrocarbon molecule, using both the hydrogen and electrons from the HRC. Field implementation of HRC involves the following elements:

- Installation of a series of injection wells to the target treatment zone or construction of a system such as a drainfield.
- Injection of HRC under controlled injection pressures and flow rates. In some cases, HRC is pre-heated to lower its viscosity and facilitate injection
- Assessment of hydrochemical indicators that may be indicative of changes in biotic processes affecting the rate and extent of biodegradation.

The general monitoring procedures for implementing enhanced bioremediation, including the specific analytes that will be monitored and the monitoring frequency, are described in Attachment 3 (Monitoring Protocols for Monitored Natural Attenuation and Enhanced Bioremediation). Site-specific sampling requirements are provided in the following sections.

SECTION 3

CORRECTIVE MEASURES

3.1 SUMMARY OF CORRECTIVE MEASURES

The CMS Report (Berkeley Lab, 2005a) provides recommendations for the corrective measures that should be required in the four areas of soil contamination and eleven areas of groundwater contamination that the HHRA determined posed an unacceptable potential threat to human health and/or to potential beneficial uses of groundwater. The specific corrective measures that DTSC has approved for implementation in these 15 areas and the current status of those measures are summarized in Table 2. Details of the approved corrective measures are provided in the following sections.

No additional corrective measures are required at two of the soil units and four of the groundwater units included in the CMS. Cleanups of two of the soil units (Building 88 Hydraulic Gate Unit and Building 75 Former Hazardous Waste handling and Storage Facility) were completed as ICMs. PCB-contaminated soil at the two units was excavated and confirmatory samples were taken. The post-excavation samples confirm that the two units were cleaned up to the required MCS. No corrective measures are required at four of the groundwater units, since chemical concentrations are below the risk-based MCSs and groundwater characteristics do not meet criteria of SWRCB Resolution 88-63 – Sources of Drinking Water Policy (well yields are less than 200 gpd). These four units are Solvents in Groundwater South of Building 76, Building 77 Area of Groundwater Contamination, Building 75/75A Area of Groundwater Contamination, and Benzene Detected in Wells East of Building 75A. The locations of the remaining two soil units and seven groundwater units where corrective measures are required are shown on Figure 2.

Table 2. Summary of Approved Corrective Measures

Unit	Approved Corrective Measure ⁽¹⁾	Status of Corrective Measures as of November 1, 2005 ⁽²⁾	Media Cleanup Standard (MCS)
Soil Units			
Building 51L Groundwater Plume Source Area	Excavate contaminated soil in the plume source area and dispose of off site.	<i>Excavation not yet implemented.</i>	Target risk-based soil MCSs.
Area of Concern (AOC) 2-5: Building 7 Sump	Excavate contaminated soil in the plume source area and dispose of off site.	<i>Excavation not yet implemented.</i>	Target risk-based soil MCSs.
Building 88 Hydraulic Gate Unit	No further action is required	Contaminated soils were excavated and disposed of at an approved offsite disposal facility. Excavation was completed and confirmatory samples taken of residual soils to confirm cleanup to the TSCA self implementing cleanup level for soil in high occupancy areas of less than 1 ppm (the approved MCS for PCBs).	1 mg/kg PCBs
Building 75 Former Hazardous Waste Handling and Storage Facility	No further action is required.		
Groundwater Units			
AOC 9-13: Building 51/64 Groundwater Solvent Plume	Continue operation of the Building 64 in situ soil flushing system. Continue collecting and treating water from the Building 51 subdrain system. Implement MNA for contaminants in the groundwater plume.	Soil flushing/groundwater capture system construction completed. Subdrain water capture and treatment system construction completed. <i>MNA not yet implemented.</i>	Target risk-based groundwater MCSs for upgradient plume area. Regulatory-based groundwater MCSs (MCLs) for downgradient plume area.
Building 51L Groundwater Solvent Plume	Reconstruct Building 51L storm drain to prevent inflow of contaminated groundwater into storm drain system. Implement MNA for remaining groundwater contaminants.	<i>Reconstruction of stormdrain not yet implemented.</i> <i>MNA not yet implemented.</i>	Target risk-based groundwater MCSs.

Table 2. Summary of Approved Corrective Measures (cont'd.)

Unit	Approved Corrective Measure ⁽¹⁾	Status of Corrective Measures as of November 1, 2005 ⁽²⁾	Media Cleanup Standard (MCS)
Groundwater Units (cont'd.)			
AOC 1-9: Building 71 Groundwater Solvent Plume Building 71B lobe	<p>Continue operation of in situ soil flushing system with addition of HRC.</p> <p>Continue collecting and treating water from the hydraugers (hillside drains) in the hillside beneath Building 46A.</p> <p>Treat VOCs in soil adjacent to the Building 71 foundation with an in situ chemical oxidation process, if HRC is not effective.</p>	<p>In situ soil flushing with HRC injection system construction completed.</p> <p>Hydrauger effluent capture and treatment system construction completed.</p> <p><i>In situ chemical oxidation not implemented and may not be required.</i></p>	<p>Regulatory-based MCSs (MCLs) for groundwater in upgradient plume area.</p> <p>Target risk-based groundwater MCSs for downgradient plume area.</p>
AOC 2-4: Building 7 Lobe of the Old Town Groundwater Solvent Plume	<p>Continue operation of in situ soil flushing system (Building 7 Groundwater Collection Trench) in plume source area downgradient of the former Building 7 sump.</p> <p>Continue operation of in situ soil flushing system in the plume core downgradient of the Building 7 Groundwater Collection Trench).</p> <p>Continue operation of the groundwater collection trenches near the southeast corner and on the west site of Building 58.</p> <p>Continue operation of the dual phase extraction wells on the Building 53/58 slope.</p> <p>Implement MNA for contaminants in the groundwater plume.</p>	<p>All in situ soil flushing/groundwater capture system construction completed.</p> <p><i>MNA not yet implemented.</i></p>	<p>Target risk-based groundwater MCSs for groundwater in source and core areas of plume.</p> <p>Regulatory-based MCSs (MCLs) for downgradient and peripheral areas of plume.</p>

Table 2. Summary of Approved Corrective Measures (cont'd.)

Unit	Approved Corrective Measure ⁽¹⁾	Status of Corrective Measures as of November 1, 2005 ⁽²⁾	Media Cleanup Standard (MCS)
Groundwater Units (cont'd.)			
AOC 10-5: Building 52 Lobe of the Old Town Groundwater Solvent Plume	Continue to collect and treat groundwater intercepted by the subdrain east of Building 46. Continue operation of in situ soil flushing system (injection and extraction wells) near Building 53 and 52.	Groundwater capture and treatment system construction completed. In situ soil flushing system construction completed.	Regulatory-based MCSs (MCLs).
AOC 10-5: Building 25A Lobe of the Old Town Groundwater Solvent Plume	Continue operation of in situ soil flushing system (groundwater infiltration bed and extraction trench) near Buildings 25A and 44A. Continue to collect and treat contaminated groundwater from an electrical utility manhole near Building 6. Implement MNA for contaminants in the groundwater plume.	In situ soil flushing system construction completed. Capture and treatment system construction completed for contaminated water in electrical conduit. <i>MNA not yet implemented.</i>	Regulatory-based MCSs (MCLs).
Support Services Area (Building 69A Area)	Implement MNA for contaminants in the groundwater.	<i>MNA not yet implemented.</i> HRC is being injected to enhance natural degradation.	Target risk-based groundwater MCSs.
Solvents in Groundwater South of Building 76	Continued groundwater monitoring only (chemical concentrations are below risk-based MCSs and groundwater characteristics do not meet criteria of State Water Resources Control Board Resolution 88-63 – Sources of Drinking Water Policy).	None required.	Target risk-based groundwater MCSs.
Building 77 Area of Groundwater Contamination		None required.	Target risk-based groundwater MCSs.
Building 75/75A Area of Groundwater Contamination		None required.	Target risk-based groundwater MCSs.
Benzene Detected in Wells East of building 75A		None required.	Target risk-based groundwater MCSs.

(1) In addition to the actions described in the table, the following measures will be implemented:

- Hydrogen Release Compounds (HRC) will be injected to enhance bioremediation in some areas of groundwater contamination.
- Water in the Building 51A subdrain will continue to be collected and treated to prevent flow of contaminated drain water to surface water.

(2) Column lists activities that have been completed as pilot tests or ICMs. The approved corrective measures consist of adoption and continued operation of these systems. Construction of all required treatment systems has been completed.

3.2 CORRECTIVE MEASURES AT SOIL UNITS

3.2.1 Building 51L Groundwater Solvent Plume Source Area

A unit-specific workplan (Corrective Measures Implementation (CMI) Workplan for Soil Excavation Building 51L Groundwater Solvent plume Source Area) that provides the details of the corrective measure was submitted to the DTSC on September 25, 2005. The workplan is included herein as Attachment 1. As described in that workplan, contaminated soil will be excavated within an area of approximately 1,400 square feet to a depth of 10 to 20 feet and disposed of offsite at an appropriately licensed landfill.

3.2.2 Building 7 Sump –Area of Concern 2-5 (source area of the Building 7 Lobe of the Old Town Groundwater Solvent Plume)

A unit-specific workplan (Corrective Measures Implementation (CMI) Workplan for Soil Excavation Building 7 Sump) that provides the details of the corrective measure is included herein as Attachment 2. As described in that workplan, contaminated soil will be excavated to a maximum depth of approximately 50 feet within an area of approximately 100 square feet and disposed of offsite at an appropriately licensed landfill.

3.3 CORRECTIVE MEASURES AT GROUNDWATER UNITS

3.3.1 Building 51/64 Groundwater Solvent Plume

The corrective measures objectives for the Building 51/64 Groundwater Solvent Plume are as follows:

- 1) Ensure that groundwater COCs at concentrations exceeding regulatory-based MCSs do not migrate into areas where concentrations are less than MCLs.
- 2) Reduce concentrations of groundwater COCs in the source area to levels below target risk-based MCSs.
- 3) Reduce concentrations of groundwater COCs (vinyl chloride) in the downgradient core area to levels below the target risk-based MCS.
- 4) Reduce concentrations of groundwater COCs in the downgradient area where well yields exceed 200 gpd to levels below regulatory-based MCSs.
- 5) Ensure that groundwater COCs do not migrate to surface water through the storm drain system.

In situ soil flushing is the corrective measure approved for meeting objective (2). MNA is the corrective measure approved for meeting objectives (1), (3), and (4), in combination with in situ soil flushing/groundwater capture in the source zone to help maintain concentrations of COCs in the downgradient groundwater to levels that are conducive for MNA. Collection and treatment of groundwater from the Building 51 subdrain system is the corrective measure approved for meeting objective (5). In addition, downgradient wells and wells near the downgradient edge of the plume will be monitored to document continued plume stability in accordance with requirements of the Water Board. Details of the corrective measures are provided below.

The areas where target risk-based or regulatory-based MCSs are the applicable cleanup levels for the Building 51/64 plume are shown on Figure 3. Risk-based MCSs are applicable to groundwater in the plume source and core areas while regulatory-based MCSs are applicable to the downgradient areas.

Maximum concentrations of groundwater COCs detected above MCLs during the fourth quarter of fiscal year 2004 (FY04) in the plume source and core area are shown in Table 3a in comparison to target risk-based MCSs (the required cleanup level). Tetrachloroethene (PCE), 1,1-dichloroethane (DCA), and vinyl chloride exceed the required cleanup level in the source and core areas. Maximum concentrations of groundwater COCs detected above MCLs during the fourth quarter of FY04 in the downgradient area are shown in Table 3b in comparison to MCLs (the required regulatory-based cleanup level) and the target risk-based MCSs. Seven CVOCs exceed the required MCS in the downgradient area. In addition, vinyl chloride exceeds the target risk-based values.

Table 3a. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 51/64 Groundwater Solvent Plume Source and Core Area

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	759	1,594
PCE	510	343
carbon tetrachloride	16	27
cis-1,2-DCE	96	98,405
1,1-DCE	1,680	28,873
methylene chloride	8.4	10,381
1,1-DCA	7,550	3,663
1,2-DCA	63	1,030
vinyl chloride	249	12
1,1,2-TCA	12	1,905

Note: Boldface type indicates that the concentration exceeds the required MCS.

Table 3b. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 51/64 Groundwater Solvent Plume Downgradient Area

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Regulatory-Based Groundwater MCS (MCL) (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	130	5	1,594
PCE	11	5	343
cis-1,2-DCE	455	6	98,405
trans-1,2-DCE	42	10	94,405
1,1-DCE	31	6	28,873
1,1-DCA	21	5	3,663
vinyl chloride	24	0.5	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

In Situ Soil Flushing and Groundwater Capture in the Source Area

The CMS Report recommended that the in situ soil flushing pilot test in operation during 2004 be continued as the corrective measure for the Building 51/64 plume source area. It also recommended that an additional groundwater collection trench be installed along the south side of Building 64 as an enhancement to the system. The purpose of the additional trench is to control the downgradient migration of contaminated groundwater from the source area. Construction of

the new collection trench was completed as an ICM in September 2005 and no additional construction is required for this measure.

The configuration of the Building 51/64 Groundwater Solvent Plume soil flushing system is shown on Figure 4. The system consists of an injection trench inside Building 64, and two groundwater collection trenches and a gravel-filled excavation outside the building from which contaminated groundwater is extracted and treated. Groundwater from three wells (SB64-98-8, SB64-99-5, and SB64-00-1) inside the building and one well (SB64-05-4) outside the southwest corner of the building is also currently extracted and treated. The extracted groundwater is treated to non-detectable levels of VOCs at the Building 64 Treatment System. The treated groundwater is currently recirculated to the injection trench, but would be disposed of in the sanitary sewer in accordance with Berkeley Lab's EBMUD Wastewater Discharge Permit, if it were not needed for flushing. The new collection trench outside the south side of Building 64 and SB64-05-5 are also used to control the downgradient migration of contaminated water from the source area.

The injection trench is approximately 17-feet long, 3.5-feet wide, and 11- to 12-feet deep. The bottom of the trench excavation was covered with a high-density polyethylene (HDPE) liner. Approximately 2 feet of gravel (drain rock) was placed on top of the HDPE liner and a 4-inch diameter perforated pipe was embedded in the gravel to distribute the water. The trench was backfilled with low-strength concrete to within approximately 0.5 feet of the surface and overlain with a layer of reinforced concrete.

The gravel-filled excavation is approximately 15 feet long, 10 feet wide, and 8 to 18 feet deep. The excavation was created in August 2000 when highly contaminated soil that constituted the major source of the Building 51/64 plume was removed as an ICM. Groundwater extraction well EW64-00-1 was installed in the deepest (northeast) end of the excavation, and the trench was backfilled with gravel and resurfaced with concrete.

The groundwater collection trench on the northeast side of Building 64 is approximately 34-feet long, 2-feet wide, and 25- (southeast end) to 36-feet (northwest end) deep. Groundwater extraction well EW64-03-1 was installed in the deepest (northwest) end of the trench, and the trench was backfilled with gravel to approximately 5 feet below the surface. The trench was

backfilled to approximately 6 inches below the surface with low-strength concrete, which was overlain by a layer of reinforced concrete.

The groundwater collection trench on the southeast side of Building 64 is approximately 48-feet long, 2-feet wide, and 28-feet deep. A 31-foot deep groundwater extraction well (EW64-05-1) was installed at the east end of the trench and the trench was backfilled with gravel to a depth of 3 feet. The top of the trench was backfilled with lean concrete, which was overlain by a concrete slab.

The Building 64 Treatment System consists of two GAC canisters: a 1,000-pound GAC primary canister and a 55-gallon secondary GAC drum used as a backup in the event of breakthrough of contaminants from the primary canister.

Figure 5 shows concentration trends for total CVOCs detected in groundwater samples collected from four wells in the Building 51/64 Groundwater Solvent Plume source area. Since in situ soil flushing was started in October 2003, there has been a significant decrease in CVOC concentrations in the source area.

Monitored Natural Attenuation in the Downgradient Area

Available hydrochemical data indicate that natural attenuation processes are degrading contaminants in the area downgradient (west) of Building 64. Evidence for this conclusion consists of the results of a site-wide evaluation, conducted in 1997, of hydrochemical parameters indicative of the potential for natural degradation of CVOCs, and a more focused study of the Building 51/64 plume area conducted in 2003. Both studies concluded that the potential for biodegradation within the plume was high based largely on the presence of biodegradation daughter products; increases in proportions of daughter products downgradient from the source area; identification within the plume of bacteria capable of degrading chlorinated solvents; isotopic analysis of parent and daughter products showing that biodegradation was occurring and vinyl chloride was being converted to ethane; and pH, moisture, organic carbon content, and culturable bacteria densities sufficient to support natural biodegradation. Therefore, MNA will be used as the remediation method for this part of the plume.

No additional construction is required to implement MNA for the Building 51/64 Groundwater Solvent Plume downgradient area. The general site procedures for conducting monitoring in support of MNA, including the specific analytes that will be monitored and the monitoring frequency, are described in Attachment 3. Site-specific sampling requirements are provided in Table 4.

Table 4. Requirements for Monitored Natural Attenuation – Building 51/64 Groundwater Solvent Plume

Well Number	Location	Sampling Frequency	
		Hydrochemical Indicator Parameters ⁽¹⁾	VOCs (EPA Method 8260)
MW71-95-9 ⁽²⁾	Upgradient	Semiannually for one year and then annually	Not required
MW51-96-16	Plume Core	Semiannually for one year and then annually	Semi-annually
MW51-96-17	Plume Core	Semiannually for one year and then annually	Annually
MW51-97-13	Downgradient Plume Core	Semiannually for one year and then annually	Annually
MW51-97-12	Crossgradient	Semiannually for one year and then annually	Semi-annually
MW51-97-15	Downgradient	not required	Semi-annually
MWP-1	Downgradient	not required	Quarterly

(1) The required parameters and analytical methods are provided in Attachment 3.

(2) Also used as upgradient well for Building 71B lobe

MNA will continue until CVOC concentrations are less than MCLs or until a technical impracticability finding is reached (if regulatory-based MCSs cannot be reasonably achieved), in accordance with provisions specified in the CMS Report.

Sump Effluent Treatment in the Building 51 Motor Generator Room Basement

The Building 51 Motor Generator Room Basement discharge sump collects water from the Building 51 subdrain system. The effluent from the subdrain is captured and treated to non-detectable levels of VOCs to prevent the migration of the contaminated subdrain water to surface water. The treatment system consists of two in-line 1,000-pound GAC canisters. The treated

effluent is discharged to the sanitary sewer in accordance with Berkeley Lab's Wastewater Discharge Permit. No additional construction is required for this measure. The water will continue to be treated as long as it has detectable concentrations of COCs.

3.3.2 Building 51L Groundwater Solvent Plume

The corrective measures objectives for the Building 51L Groundwater Solvent Plume and Source Area are as follows:

- 1) Ensure that groundwater COCs do not migrate to surface water through the storm drain system.
- 2) Ensure that groundwater COCs at concentrations exceeding regulatory-based MCSs do not migrate into areas where concentrations are less than MCLs.
- 3) Reduce concentrations of groundwater COCs below target risk-based MCSs.
- 4) Reduce COC concentrations of soil COCs below target risk-based MCSs.
- 5) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.

Lining or rerouting the stormdrain line so that it does not traverse contaminated groundwater is the corrective measure approved to meet objective (1). Excavation and offsite disposal of contaminated soils from saturated and unsaturated zone (See Section 3.2.1) will meet objectives (2) and (5); and downgradient wells will be monitored to document continued plume stability in accordance with requirements of the Water Board. Soil excavation and offsite disposal of the contaminated soil is also the corrective measure approved for meeting objectives (3) and (4). Details of the corrective measures are provided below.

Maximum concentrations of groundwater COCs detected in the Building 51L Groundwater Solvent Plume above MCLs during the fourth quarter of FY04 are shown in Table 5 in comparison to target risk-based MCSs (the required cleanup level). Vinyl chloride is the only COC that exceeds the target risk-based MCS.

Table 5. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 51L Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	541	1,594
PCE	28	343
cis-1,2-DCE	1,360	98,405
trans-1,2-DCE	645	94,405
1,1-DCE	36	28,873
1,1-DCA	126	3,663
vinyl chloride	1,350	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

Rerouting Stormdrain Line

Currently, groundwater extraction wells are operated to lower the water table adjacent to the existing 24-inch stormdrain and catch basin that is located within the plume area. This action prevents contaminated groundwater from entering the stormdrain from where it would discharge to North Fork Strawberry Creek. The catch basin and the portion of the stormdrain line that currently crosses the solvent plume area will be relocated, so that if groundwater extraction is terminated they will not be a potential migration pathway for contaminants. After this modification is completed, groundwater extraction will be terminated.

Soil Excavation with Offsite Disposal

Excavation requirements for contaminated soil in the Building 51L Groundwater Solvent Plume Source Area are summarized in Section 3.2.1. Details of the corrective measure are provided in Attachment 1.

The planned excavation geometry will result in preservation of a sufficient number of existing groundwater monitoring wells to evaluate residual groundwater concentrations. However, if the excavation is expanded so that additional wells are destroyed, replacement wells will be installed (if necessary) in locations suitable for monitoring residual groundwater COC concentrations.

It is anticipated that post-excavation residual COC concentrations in groundwater will be less than the required MCSs (target risk-based levels). However, if groundwater COC concentrations still exceed MCSs, then MNA will be implemented to achieve the required cleanup levels. Conditions favorable for natural degradation are present within the Building 51L Groundwater Solvent Plume area based on the available hydrochemical data (Berkeley Lab, 2005a). The effectiveness of MNA, if implemented, would be assessed through a monitoring program that would be conducted by collecting groundwater samples from existing groundwater monitoring wells. No additional construction is required for this measure; however, as noted above, if the excavation is expanded, replacement monitoring wells may be required.

General procedures for implementing MNA are described in Attachment 3. The specific wells to be included in the program would be specified only after it was determined that MNA was required. MNA would continue until CVOC concentrations are less than the risk-based MCSs, or until a technical impracticability finding is reached (if risk-based MCSs cannot be reasonably achieved), in accordance with provisions specified in the CMS Report.

3.3.3 Building 71B Lobe of the Building 71 Groundwater Solvent Plume

The corrective measures objectives for the Building 71B lobe of the Building 71 Groundwater Solvent Plume are as follows:

- 1) Ensure that groundwater COCs above detectable concentrations do not migrate to surface water.
- 2) Ensure that groundwater COCs at concentrations exceeding regulatory-based MCSs (MCLs) do not migrate into areas where concentrations are less than MCLs.
- 3) Reduce concentrations of groundwater COCs in the source area below regulatory-based MCSs.
- 4) Reduce concentrations of soil COCs below regulatory-based MCSs and target risk-based MCSs.
- 5) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.

Continued capture of contaminated hydrauger effluent is the corrective measure approved for achieving objective (1). A combination of excavation with offsite disposal (corrective measure completed), in situ soil flushing, and in situ chemical oxidation (for unsaturated zone soils only) in the source zone is the approved corrective measure for meeting objectives (3) and

(4). Enhanced bioremediation using HRC, which has been tested in the source area, has been effective in reducing COC concentrations in the groundwater. HRC is currently proposed as a replacement measure for chemical oxidation, which appears to have limited effectiveness in this area based on pilot test results. The measures approved for meeting objectives (3) and (4) will also help meet objective (2). No action is needed to meet objective (5) since the plume is not migrating; however, downgradient wells will be monitored to document continued plume stability in accordance with requirements of the Water Board. Details of the corrective measures are provided below.

The excavation of contaminated source area soil recommended in the CMS Report was completed as an ICM, and no additional excavation is planned. The residual soil contamination that exceeded MCSs was located in a relatively small area that was inaccessible to excavation due to the risk of compromising the integrity of the Building 71B foundation piers.

Maximum residual (post ICM) concentrations of COCs detected in the soil in the Building 71B lobe source area are listed in Table 6 in comparison to regulatory-based MCSs (the required cleanup level). Residual concentrations of PCE, cis-1,2-dichloroethene (DCE), and methylene chloride exceed the required MCS. PCE also exceeds the target risk-based MCS. Figure 6 shows the location of the ICM soil excavations in the Building 71B lobe source area and where residual concentrations of CVOCs in the soil exceed MCSs.

Table 6. Maximum Residual Concentrations of COCs in Soil in the Building 71B Lobe of the Building 71 Groundwater Solvent Plume Source Area

COC	Maximum Concentration (mg/kg)	Regulatory-Based Soil MCS (mg/kg)
PCE	37	0.45
TCE	0.46	0.46
cis-1,2-DCE	0.45	0.19
trans-1,2-DCE	0.039	0.67
methylene chloride	0.24	0.077

Note: Boldface type indicates that the concentration exceeds the required MCS.

Maximum concentrations of groundwater COCs detected in the Building 71B lobe above MCLs during the fourth quarter of FY04 are shown in Table 7 in comparison to MCLs (the

required regulatory-based cleanup level) and target risk-based MCSs. Trichloroethene (TCE), PCE, cis-1,2-DCE, and vinyl chloride exceed the required MCS. PCE and vinyl chloride also exceed the target risk-based values.

Table 7. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 71B Lobe of the Building 71 Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Regulatory-Based Groundwater MCS (MCL) (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	862	5	1,594
PCE	2,930	5	343
cis-1,2-DCE	204	6	98,405
vinyl chloride	50	0.5	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

In Situ Soil Flushing with HRC in the Source Area

In September 2004, a soil flushing system was installed in the Building 71B lobe source area. The installation consisted of backfilling of the ICM excavation on the east side of the source area with gravel to create a drainfield, conversion of well SB71B-04-1 to a groundwater extraction well, and construction of a GAC treatment system to treat extracted groundwater. Extracted groundwater is treated to non-detectable levels of VOCs, and then discharged to the drainfield where it flushes residual contamination from the source area. The Building 71B treatment system consists of a 1,000-pound GAC canister with an in-line 55-gallon GAC drum as backup. The configuration of the soil flushing system is shown on Figure 7.

Since December 2004, HRC has been periodically added to the injected water to expedite the in-situ biodegradation process. Approximately 2-3 lbs of HRC is mixed with 40 gallons of treated groundwater in an aboveground bioreactor (two 55-gallon drums), heated to approximately 100°F for one to two days using an electric drum heater, and then discharged to the drainfield. The purpose of heating is to accelerate the consumption of dissolved oxygen by aerobic bacteria so that the mixture becomes anaerobic (i.e., dissolved oxygen drops below 0.5 mg/L). The anaerobic condition of the mixture promotes the growth of indigenous anaerobic bacteria that can degrade chlorinated solvents. Shortly after HRC was first introduced into the drainfield, dissolved oxygen concentrations in the groundwater dropped from approximately 2 to

3 mg/L (aerobic) to less than 0.1 mg/L (anaerobic), creating conditions favorable to reductive dechlorination. Reducing conditions have been maintained by injecting approximately 120-200 gallons of the heated dilute HRC mixture into the drainfield each week.

The addition of HRC has been effective in reducing concentrations of CVOCs in the groundwater. Trends in the concentrations of total CVOCs detected in three source area wells (MW71B-99-3R, SB71B-03-1, and SB71B-03-2) are shown on Figure 8. The concentration of total CVOCs (primarily PCE) has declined significantly in all three wells since the start of HRC injection, indicating that biodegradation of the CVOCs is occurring. The effectiveness of HRC is also supported by results from the extraction well (SB71B-04-1) (Figure 9). Since HRC injection was started, the total CVOC concentration detected in the well has dropped significantly, with the percentage of PCE decreasing from approximately 60 to 15 percent of the total mass. Concurrently, biodegradation byproducts (including cis-1,2-DCE and vinyl chloride) have increased from 10 to 45 percent of the total mass.

Injection of treated groundwater in the source area has resulted in an increase in the groundwater level to within a few feet of the surface, thereby allowing the flushing of the former vadose zone soils in the source area. The addition of HRC to the injected water should accelerate the cleanup of the residual shallow soil contamination that exceeds MCSs adjacent to the foundation piers beneath Building 71B.

No additional construction is required for this measure. Soil flushing enhanced with HRC injection will continue until CVOC concentrations in groundwater are less than regulatory-risk based MCSs (MCLs) or if a technical impracticability finding is reached (if regulatory-based based MCSs cannot be reasonably achieved), in accordance with provisions specified in the CMS Report. Soil samples will be collected in the source area to determine whether the soil MCSs have been achieved. If soil concentrations still exceed MCSs, then in situ chemical oxidation will be considered as an alternative. Chemical oxidation reagents would be injected into borings drilled adjacent to the piers to achieve the required MCSs.

The general site procedures for conducting monitoring in support of enhanced biodegradation, including the specific analytes that will be monitored and the monitoring

frequency, are described in the Attachment 3. Site-specific sampling requirements are provided in Table 8.

Table 8. Monitoring Requirements for Enhanced Biodegradation – Building 71B Lobe

Well Number	Location	Sampling Frequency	
		Hydrochemical Indicator Parameters ⁽¹⁾	VOCs (EPA Method 8260)
MW71-95-9 ⁽²⁾	Upgradient	Semiannually for one year and then annually	Not required
MW71B-99-3R	Plume Core	Semiannually for one year and then annually	Quarterly
SB71B-04-1	Downgradient Plume Core	not required	Quarterly
MW90-5	Downgradient	not required	Semi-annually

(1) The required parameters and analytical methods are provided in Attachment 3.

(2) Also used as upgradient well for Building 51/64 lobe

Hydrauger Effluent Capture and Treatment

Effluent from several hydraugers used to dewater the slopes for slope stability purposes has been collected, treated to non-detectable levels of VOCs, and then discharged to the sanitary sewer. Capture and treatment of effluent from these hydraugers (51-01-01, 51-01-02, 51-01-03, 51-01-03A, and 51-01-04) will continue until CVOC concentrations are below levels of detection. Concentrations of CVOCs have been decreasing in the effluent, with the concentration of all CVOCs below MCLs during the third quarter of FY05. The hydrauger effluent is currently piped to the Building 51 Firetrail Treatment System, which consists of two in-line 1,000-pound GAC canisters. Treated water is disposed of in the sanitary sewer in accordance with Berkeley Lab’s Wastewater Discharge Permit. If needed, the treated effluent will be used for injection as part of the Building 51/64 plume soil flushing corrective measures described in Section 3.2.1. No additional construction is required for this measure.

3.3.4 Building 7 Lobe of the Building 7 Groundwater Solvent Plume

The corrective measures objectives for the Building 7 lobe of the Old Town Groundwater Solvent Plume are as follows:

- 1) Reduce concentrations of groundwater COCs within the source and the core areas below target risk-based MCSs.
- 2) Ensure that groundwater COCs at concentrations exceeding target risk-based MCSs do not migrate into areas that are below target risk-based MCSs.
- 3) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.
- 4) Reduce concentrations of groundwater COCs below regulatory-based MCSs in peripheral areas of the plume where well yields exceed 200 gallons per day.

In situ soil flushing with groundwater extraction in combination with excavation of the highly contaminated soil in the source area (as described in Section 3.1.1) is the approved corrective measure for meeting remediation objective (1). Continued operation of the existing groundwater extraction trenches (which are part of the in situ soil flushing system) is the approved corrective measure for meeting remediation objectives (2) and (3). MNA is the approved corrective measure for meeting remediation objective (4). Details of the corrective measures are provided below.

Figure 10 shows the areas where target risk-based or regulatory-based MCSs (MCLs) are the applicable cleanup levels. Maximum concentrations of groundwater COCs detected above MCLs during the fourth quarter of FY04 in the plume source and core area are shown in Table 9a in comparison to the target risk-based MCSs (the required cleanup level). TCE, PCE, and carbon tetrachloride exceed the required cleanup level in the source and core areas.

Maximum concentrations of groundwater COCs detected above MCLs during the fourth quarter of FY04 in the plume periphery areas are shown in Table 9b in comparison to MCLs (the required regulatory-based cleanup level) and target risk-based MCSs. All six CVOCs listed in Table 9b exceed the required MCS. TCE, PCE, and carbon tetrachloride also exceed the target risk-based values.

Table 9a. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Source and Core Areas of the Building 7 Lobe of the Old Town Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	34,600	1,594
PCE	78,900	343
carbon tetrachloride	2,400	27
cis-1,2-DCE	156	98,405
1,1-DCE	31	28,873
1,1-DCA	17	3,663
vinyl chloride	1.4	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

Table 9b. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Periphery Area Downgradient of the Building 7 Lobe of the Old Town Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Regulatory-Based MCS (MCL) (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	105	5	1,594
PCE	122	5	343
cis-1,2-DCE	16.4	6	98,405
1,1-DCE	110	5	28,873
1,1-DCA	28	5	3,663
vinyl chloride	1.9	0.5	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

In Situ Soil Flushing in the Source and Core Areas

The in situ soil flushing and groundwater capture system was completed in several stages as part of ICMs conducted from 1996 to 2004. No additional construction is required for this

measure. The configuration of the system is shown on Figure 11. The principal components of the system (from east to west) are described below.

- 1) *Former Building 7 Sump Injection Excavation:* In August 1995, highly contaminated soil was excavated to a depth of 17 feet (approximate top of saturated zone) from an area approximately 10-feet long by 7-feet wide around the former Building 7 Sump location north of Building 7. Leaks and/or overflows of CVOCs (primarily PCE) from the sump to the underlying soil were the source of the Building 7 lobe contamination. The excavation was drilled out using 3-foot diameter solid stem augers and was backfilled with gravel. Two PVC casings with screened intervals from 5 to 10 feet bgs were installed within the excavation to allow the injection of water for in situ soil flushing.
- 2) *Building 7 Groundwater Collection Trench.* In 1996, the Building 7 Groundwater Collection Trench was installed approximately 15 feet northwest of (downgradient from) the former Building 7 sump location to control the migration of contaminated groundwater downgradient from the source area. The trench, which is 40-feet long by 2-feet wide, was constructed along an arc that intercepts contaminated water flowing from the former sump area. The trench increases from a depth of approximately 55 feet at the southern end to 60 feet at the northern end. Four PVC well casings were installed in the trench to extract groundwater, and the trench was filled with coarse gravel. Starting in April 1997, groundwater extracted from the trench was treated to non-detectable levels of VOCs and then reinjected into the Building 7 Sump Injection Excavation, to flush contaminants from the subsurface. In June 1997, automatic pumping controls were installed in three of the extraction wells. The extracted groundwater is piped to the Building 7 Treatment System, which consists of two in-line 1,000-pound GAC canisters. Recirculation of the treated groundwater was halted in 2000 for the duration of a thermally enhanced soil vapor extraction pilot test. In addition to controlling the migration of contaminated groundwater from the source area, the collection trench currently captures reinjected groundwater flowing eastward from the Building 7 Injection Well System.
- 3) *Building 7 Injection Well System:* In 2002, six 24-inch diameter borings (*IW7-02-1, through IW7-02-6*) were drilled in line to a maximum depth of approximately 56 feet, downgradient from the Building 7 Groundwater Collection Trench. Six-inch-diameter PVC screens were installed in five of the borings and 4-inch-diameter PVC screen was installed in the sixth boring. The annuli of the holes were backfilled with gravel. In 2003, three groundwater extraction wells (*EW7-03-1, EW7-03-2, and EW7-03-3*) were installed approximately 30 to 40 feet downgradient (west) of the injection trench. The wells were drilled into the top of the low permeability Orinda Formation. The treated water that is injected into the well system either flows westward where it is captured by the three extraction wells or eastward where it is captured by the Building 7 Groundwater Collection Trench.
- 4) *Building 53/58 Slope Groundwater Collection Trench and Soil Vapor Extraction System:* In 1998, eight dual phase (groundwater and soil vapor) extraction wells were installed

at the downgradient edge of the Building 7 lobe core area. The wells are 35 to 40 feet deep and run in a north-south line on 4-foot centers. PVC casing was installed in each boring, with the bottom 20 feet screened, and the annuli of the borings were backfilled with gravel. Groundwater extraction pumps with automatic switches were installed in these wells. The extracted groundwater is pumped to the Building 7 Treatment System. A soil vapor extraction (SVE) treatment system was constructed adjacent to the well locations in 1999. The SVE treatment system consists of two 1000-pound GAC canisters in series.

- 5) *Building 58 East Groundwater Collection Trench*: In 2002, the Building 58-East Groundwater Collection Trench was installed at the southeast corner of Building 58 to control the downgradient migration of the core of the Building 7 lobe. The trench is approximately 13 feet in length and ranges from 29 to 31 feet in depth. An 8-inch extraction well was installed in the deepest part of the trench, and the trench was filled with gravel. An automatic pumping system extracts groundwater from the trench and pumps it to the Building 7 system for treatment.
- 6) *Building 58 West Groundwater Collection Trench*: In 1998, a groundwater collection trench was installed west of Building 58 at the edge of the Building 7 lobe to control downgradient migration. The trench is approximately 40 feet long and 20 feet deep. Two 6-inch pipes in the trench extract groundwater, which is piped to the Building 51 Firetrail Treatment System.
- 7) *Building 58 West Subdrain*: Water is pumped from a concrete sump that was installed adjacent to an abandoned corrugated metal pipe subdrain west of Building 58. The contaminated effluent from the subdrain flows into the sump from which it is pumped to the Building 51 Fire Trail Treatment System. The purpose of the system is to prevent migration of contaminated water to surface water via the drain system.

In situ flushing has been effective in reducing CVOC concentrations in the Building 7 lobe groundwater. Concentrations of CVOCs detected in groundwater samples collected from wells monitoring the plume source and core areas have decreased significantly since in situ soil flushing was initiated. The decreases are illustrated on Figure 12 and Figure 13. Figure 12 shows trends in the concentrations of total CVOCs detected in upgradient core area monitoring wells MW7B-95-24, MW7-95-22, and MW7-95-23. Figure 13 shows trends in concentrations of total CVOCs detected in groundwater extraction wells EW7-03-1, EW7-03-2, and EW7-03-3. The concentration of total CVOCs detected in EW7-03-3 declined from approximately 37,000 µg/L in September 2003 to about 1,700 µg/L in September 2005.

All or part of the Former Building 7 Sump Injection Excavation may be destroyed during excavation of the source area soil (described in Section 3.1.1), precluding its continued use for

injection and source area flushing. The need for continued flushing in the source area will be determined after the corrective measure (excavation) at the Former Building 7 Sump location has been completed. Further injection will not be required if residual groundwater concentrations in the source area are below target risk-based MCSs; otherwise, in situ soil flushing will be resumed. In that case, the injection excavation will be repaired or replaced, or new injection wells will be constructed.

Monitored Natural Attenuation in the Periphery Areas

Available hydrochemical data indicate that natural attenuation processes are degrading contaminants throughout the periphery area of the Building 7 lobe. Evidence for this conclusion is based primarily on increases in the proportions of dissolved PCE degradation products (e.g., TCE and cis-1,2-DCE) relative to PCE (the parent product) with distance downgradient from the source area. More direct evidence for this conclusion for the lobe area downgradient (west) of Building 58 consists of the results of a site-wide evaluation of hydrochemical parameters indicative of the potential for natural degradation of CVOCs that was conducted in 1997. The data indicated that the dissolved oxygen concentration in this area was low, a condition favorable to reductive dechlorination processes.

Groundwater CVOC concentrations in the crossgradient plume periphery area near Building 53 (Figure 10) were controlled primarily by the migration of high concentrations of CVOCs from the adjacent Building 7 lobe core area, and are currently affected by in situ soil flushing activities within both the Building 7 lobe and the Building 52 lobe (Section 3.2.5). These impacts obscure the effects of any natural attenuation processes, so MNA is not currently an appropriate remedy for this area. After the corrective measure (excavation) has been completed in the source area and soil flushing has reduced CVOC concentrations in the adjacent lobes, MNA will be implemented in the periphery area near Building 53 if MCSs have not been achieved.

No additional construction is required to implement MNA for the Building 7 lobe of the Old Town Groundwater Solvent Plume periphery area. The general site procedures for implementing MNA, which include the specific analytes that will be monitored, and the monitoring frequency, are described in Attachment 3. Site-specific sampling requirements for the downgradient periphery area are provided in Table 10. MNA requirements for the Building

53 crossgradient lobe area will not be specified until the effects of soil flushing and the additional source area excavation on the magnitude and extent of groundwater contamination have been determined.

Table 10. Requirements for Monitored Natural Attenuation - Building 7 Lobe of the Old Town Groundwater Solvent Plume, Downgradient Area

Well Number	Location	Sampling Frequency	
		Hydrochemical Indicator Parameters ⁽¹⁾	VOCs (EPA Method 8260)
MW 58A-94-14	Downgradient Periphery	Semiannually for one year and then annually	Semiannual
MW58-93-3	Crossgradient Periphery	Semiannually for one year and then annually	Semiannual
MW51-94-15	Downgradient	not required	Annually
MW51-96-3	Downgradient	not required	Annually
SB58-98-6	Downgradient	not required	Annually

(1) The required parameters and analytical methods are provided in Attachment 3.

3.3.5 Building 52 Lobe of the Old Town Groundwater Solvent Plume

The corrective measures objectives for the Building 52 lobe of the Old Town Groundwater Solvent Plume are as follows:

- 1) Ensure that groundwater COCs at detectable concentrations do not migrate to surface water.
- 2) Ensure that groundwater COCs at concentrations exceeding regulatory-based MCSs do not migrate into areas where concentrations are less than MCSs.
- 3) Reduce concentrations of groundwater COCs to levels below regulatory-based MCSs.
- 4) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.

Groundwater capture at the Building 46 Subdrain is the approved corrective measure for meeting objectives (1), (2), and (4). In situ soil flushing combined with groundwater extraction is the approved corrective measure for meeting objective (3), with a possible transition to MNA and/or enhanced bioremediation after COC concentrations have been reduced by soil flushing. Details of the corrective measures are provided below.

Maximum concentrations of groundwater COCs detected in the Building 52 lobe above MCLs during the fourth quarter of FY04 are shown in Table 11 in comparison to MCLs (the required regulatory-based cleanup level) and the target risk-based MCSs. TCE, PCE, cis-1,2-DCE, and carbon tetrachloride exceed the required MCS. Concentrations of all CVOCs are well below target risk-based values.

Table 11. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 52 Lobe of the Old Town Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Regulatory-Based Groundwater MCS (MCL) (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	47	5	1,594
PCE	28	5	343
carbon tetrachloride	5.6	0.5	27
cis-1,2-DCE	17	6	98,405

Note: Boldface type indicates that the concentration exceeds the required MCS.

Migration Control at the Building 46 Subdrain

The downgradient migration of the Building 52 lobe is controlled by a subdrain located east of Building 46A (Building 46 subdrain). The subdrain was installed in the early 1950s to collect subsurface water draining from the hillside as part of landslide mitigation measures. The subdrain increases from 4 feet deep at the southern end to approximately 11 feet deep at the northern end. The contaminated groundwater that is extracted from the subdrain is cleaned to non-detectable levels of VOCs at the Building 46 Treatment System and is then recirculated to injection wells in the source area of the Building 52 lobe. The treatment system consists of two in-line 1,000-pound GAC canisters. Treating the water captured by the subdrain prevents the migration of groundwater COCs to surface water. If the treated water is not needed for flushing, it will be discharged to the sanitary sewer under a permit issued by EBMUD. No additional construction is required for this measure.

In Situ Soil Flushing

The configuration of the Building 52 lobe soil flushing system, including the location of the Building 46 Subdrain is shown on Figure 11. No additional construction is required for this measure. The in situ soil flushing system includes five injection wells (IW5-04-1, IW5-04-2, SB52A-98-1, IW27-04-1, and IW7C-04-1). The injected water is captured by four extraction wells (MW52A-98-8B, MW52-95-2B, EW53-04-2, and EW7C-04-2) or further downgradient at the lobe margin by the Building 46 Subdrain. Groundwater extracted from three of the wells is treated to non-detectable levels of VOCs at the Building 53 Treatment System. The system consists of a 1,000-pound GAC canister with an in-line 55-gallon GAC drum as backup. Groundwater extracted from the fourth well is treated to non-detectable levels of VOCs at the Building 7 system. The groundwater treated by the Building 53 and Building 46 systems is recirculated to the injection wells for continued flushing.

In situ soil flushing has resulted in significant reductions in the concentrations of CVOCs detected in the Building 52 lobe groundwater. Trends in concentrations of total CVOCs detected in groundwater in the Building 52 lobe area are shown on Figure 14 for source area wells MW52-95-2B, MW52-98-9, and MW52-98-8B and on Figure 15 for downgradient monitoring wells MW91-8, MW53-93-9, and MW27-92-20. As of September 2005, the concentrations of CVOCs in five wells in the source area were all below MCLs. The concentrations of total CVOCs detected in downgradient wells MW91-8 and MW53-93-9 have declined from several hundred µg/L to approximately 50 µg/L or less.

Operation of the soil flushing system will continue until groundwater CVOC concentrations are either 1) reduced to MCLs and can be maintained at that level without flushing or 2) reduced to levels above MCLs and no further significant declines in concentration are observed. If condition 2 is the case, implementation of MNA and/or enhanced bioremediation will be considered; however, based on the available data, this scenario seems unlikely.

Monitored Natural Attenuation and Enhanced Bioremediation

MNA and/or enhanced bioremediation may be implemented if either 1) no further significant declines in concentrations are observed and MCSs have not been attained or 2)

groundwater CVOC concentrations rebound to levels above MCLs and restoring flushing will not be an effective measure for permanently achieving MCSs.

Observed ratios of parent compounds to degradation products within the Building 52 lobe indicate that natural degradation occurs during downgradient migration of the contaminated groundwater. However, results of the 1997 site-wide evaluation of hydrochemical parameters indicated that dissolved oxygen concentrations in the groundwater near source area well MW52-95-2B were not conducive to natural degradation processes. Injection of HRC into the groundwater can potentially reduce dissolved oxygen concentrations providing conditions that are more favorable for biodegradation. In addition, HRC can enhance the natural degradation processes. Therefore if soil flushing is not effective in achieving MCSs, MNA and/or enhanced bioremediation may be implemented as a supplemental measure.

No additional construction is required for MNA. Some minor construction may be required for the heating and injection of HRC (as described in Section 3.2.3 for the Building 71B lobe of the Building 71 Groundwater Solvent Plume). Construction of HRC injection points would also likely be required.

3.3.6 Building 25A Lobe of the Old Town Groundwater Solvent Plume

The corrective measures objectives for the Building 25A lobe of the Old Town Groundwater Solvent Plume are as follows:

- 1) Ensure that groundwater COCs at concentrations exceeding regulatory-based MCSs (MCLs) do not migrate into areas where concentrations are less than MCSs.
- 2) Reduce concentrations of groundwater COCs below regulatory-based MCSs (MCLs).
- 3) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.

In situ soil flushing combined with groundwater extraction is the approved corrective measure for meeting objective (2), with a possible transition to MNA and/or enhanced bioremediation after COC concentrations have been reduced by soil flushing. Limited action is needed to meet objective (1) and objective (3) since the plume is generally stable. Continued extraction and treatment of groundwater from the electric utility manhole east of Building 6 will prevent the migration of contaminated groundwater through the underground electrical conduits

to the Building 37 area. Corrective measures approved for the Building 7 lobe address the migration of contaminated groundwater into the area where the Building 7 lobe and the Building 25A lobe coalesce. Wells at the downgradient edge and wells downgradient from the Building 25A lobe will be monitored to document continued plume stability in accordance with requirements of the Water Board. Details of the corrective measures are provided below.

Maximum concentrations of groundwater COCs detected in the Building 25A lobe of the Old Town Groundwater Solvent Plume above MCLs during the fourth quarter of FY04 are shown in Table 12 in comparison to MCLs (the required regulatory-based cleanup level) and the target risk-based MCSs. TCE, PCE, carbon tetrachloride, and 1,1-DCE exceed the required MCS. Concentrations of all CVOCs are well below target risk-based values.

Table 12. Maximum Concentrations of COCs Exceeding MCLs during the Fourth Quarter of FY04 in the Building 25A Lobe of the Old Town Groundwater Solvent Plume

COC	Maximum Concentration Fourth Quarter FY04 (µg/L)	Regulatory-Based Groundwater MCS (MCL) (µg/L)	Target Risk-Based Groundwater MCS (µg/L)
TCE	241	5	1,594
PCE	8.5	5	343
Carbon tetrachloride	1.4	0.5	27
1,1-DCE	79	6	28,873

Note: Boldface type indicates that the concentration exceeds the required MCS.

In Situ Soil Flushing

The configuration of the Building 25A lobe soil flushing system is shown on Figure 11. No additional construction is required for this measure. A groundwater collection trench located south of Building 44 controls the migration of contaminated groundwater from the Building 25A lobe source area on the west side of Building 25A. The trench is approximately 40-foot long by 40-foot deep and is backfilled with gravel. Contaminated groundwater is extracted from an 8-inch diameter well that was installed in the trench and from groundwater monitoring well MW25A-98-3 north of Building 25A. The extracted groundwater is treated to non-detectable levels of VOCs at the Building 25A Treatment System and then recirculated into a shallow gravel-filled infiltration bed located upgradient of the trench to flush contaminants from the

subsurface. The treatment system consists of a 1,000-pound GAC canister with an in-line 55-gallon GAC drum as backup.

Trends in concentrations of total CVOCs detected in groundwater samples collected from groundwater monitoring wells MW25A-98-1, MW25A-98-3, and MW25A-98-7, which are located near the plume source area, are shown on Figure 16. Prior to the start of soil flushing in 2002, the concentrations of total VOCs detected in these three wells ranged from approximately 200 to 400 µg/L. Concentrations have subsequently declined in all three wells to approximately 50 µg/L or less, indicating that soil flushing has been effective.

Operation of the soil flushing system will continue until groundwater CVOC concentrations are either 1) reduced to MCLs and can be maintained at that level without flushing or 2) reduced to levels above MCLs and no further significant declines in concentration are observed. If condition 2 is the case, implementation of MNA and/or enhanced bioremediation will be considered.

Monitored Natural Attenuation and Enhanced Bioremediation

MNA and/or enhanced bioremediation may be implemented if either 1) no further significant declines in concentrations are observed and MCSs have not been attained or 2) groundwater CVOC concentrations rebound to levels above MCLs and restoring flushing will not be an effective measure for permanently achieving MCSs.

Observed ratios of parent compounds to degradation products downgradient from the source area at Building 25A indicate that natural degradation occurs during downgradient migration of the contaminated groundwater. However, results of the 1997 site-wide evaluation of hydrochemical parameters indicated that dissolved oxygen concentrations in the groundwater near source area well MW25-95-15 were not conducive to natural degradation processes. Injection of HRC into the groundwater can potentially reduce dissolved oxygen concentrations, providing conditions that are more favorable for biodegradation. In addition, HRC can enhance the natural degradation processes. Therefore if soil flushing is not effective in achieving MCSs, MNA and/or enhanced bioremediation may be implemented as a supplemental measure.

No additional construction is required for MNA. Some minor construction may be required for the heating and injection of HRC (as described in Section 3.2.3 for the Building 71B lobe of the Building 71 Groundwater Solvent Plume). Construction of HRC injection points might also be required.

Extraction of Groundwater from Utility Manhole East of Building 6

Contaminated groundwater that is present in an electrical utility manhole east of Building 6 is pumped from the manhole to the Building 37 Treatment System. This measure prevents the migration of contaminated groundwater through electrical conduits to the Building 37 area. The system consists of two 55-gallon GAC drums in parallel, with an in-line 55-gallon GAC drum as backup. The treated water is used in the Building 37 cooling tower.

3.3.7 Building 69A Area of Groundwater Contamination

The corrective measures objectives for the Building 69A Area of Groundwater Contamination are as follows. MNA is the approved corrective measure for meeting these objectives.

- 1) Reduce concentrations of groundwater COCs (vinyl chloride) below target risk-based MCSs.
- 2) Ensure that groundwater COCs do not migrate into adjacent uncontaminated areas.

Maximum concentrations of groundwater COCs detected in the Building 69A Area of Groundwater Contamination above MCLs during the fourth quarter of FY04 are shown in Table 13 in comparison to target risk-based MCSs (the required cleanup level). Vinyl chloride exceeds the required MCS.

Table 13. Maximum Concentrations of COCs Exceeding MCLs in FY04 in the Building 69A Area of Groundwater Contamination

COC	Maximum Concentration Detected in Groundwater in FY04 (µg/L)	Target Risk-Based Groundwater Media Cleanup Standard (µg/L)
cis-1,2-DCE	13	98,405
vinyl chloride	44	12

Note: Boldface type indicates that the concentration exceeds the required MCS.

Monitored Natural Attenuation and Enhanced Bioremediation Status

Available chemical and geochemical data indicate that biodegradation of groundwater contaminants by reductive dechlorination is occurring in the Building 69A Area of Groundwater Contamination. The chemical data that support this conclusion are the relatively high concentrations (almost the entire contaminant mass) of cis-1,2-DCE and/or vinyl chloride detected in groundwater samples collected from wells in the Building 69A area. Cis-1,2-DCE and vinyl chloride are degradation products of PCE and/or TCE. Concentration trends for CVOCs (cis-1,2-DCE, PCE, and vinyl chloride) detected in groundwater samples collected from the three wells that monitor the groundwater contamination (MW69-97-8, SB69A-99-1, SB69A-00-1) are shown on Figure 17. The locations of the wells are shown on Figure 18.

The hydrochemical data that indicate that biodegradation is occurring include the low levels of dissolved oxygen measured in the groundwater near Building 69A and the hydrochemical analysis of samples collected in June 2005 from SB69A-99-1. The June 2005 results show that the chemistry of the groundwater is consistent with the effects of biodegradation. The observed effects include low concentrations of dissolved oxygen, nitrate, and sulfate and a high concentration of ferrous iron (Table 14). In addition, the high concentrations of dissolved CO₂ and methane detected provide evidence for methanogenesis, a condition favoring reductive dechlorination of chlorinated solvents.

Table 14. Concentrations of Hydrochemical Indicator Parameters (mg/L) Detected in SB69A-99-1 in June 2005.

	Dissolved Oxygen	Nitrate	Ferrous Iron	Sulfate	Dissolved CO₂	Methane
Optimum Value for Reductive Dechlorination	<0.5	<1.0	>1.0	<20	>2 x Background	>0.5
Measured Site Value	0.18	<0.44	5.3	16	500	5.6

Additional support for biodegradation is provided by the detection of aromatic hydrocarbons in the groundwater. These fuel hydrocarbons are a potential carbon source for indigenous microorganisms. The rate of biodegradation can be limited by a number of factors including the availability of carbon and hydrogen, which are used by bacteria as a food source or

as a substitute for chlorine in the reductive dechlorination process. Therefore, to expedite the cleanup process at this site, HRC has been injected into the source area since August 2005, in an attempt to enhance the biodegradation of the groundwater contaminants. After being filtered through a 55-gallon GAC drum, approximately 45 gallons of drinking water is mixed with 2 to 4 pounds of HRC. The mixture is heated for two to four days and then injected into a 4-inch diameter well (SB69A-05-1) that was installed in the backfill at a former waste oil tank location in the source area. The HRC is injected into the permeable backfill to accelerate the delivery of the HRC to the subsurface. Approximately 90 gallons of HRC mixture is injected per week. The injection area is shown on Figure 18.

Monitored Natural Attenuation and Enhanced Bioremediation Implementation

No additional construction is required to implement MNA for the Building 69A Area of Groundwater Contamination. The general site procedures for conducting monitoring in support of MNA, including the specific analytes that will be monitored and the monitoring frequency, are described in Attachment 3. Site-specific sampling requirements are provided in Table 15.

Table 15. Requirements for Monitored Natural Attenuation – Building 69A Area of Groundwater Contamination

Well Number	Location	Sampling Frequency	
		Geochemical Indicator Parameters ⁽¹⁾	VOCs (EPA Method 8260)
SB69A-00-1	Upgradient Plume Core	Annually (rainy season)	Annually (rainy season)
SB69A-99-1	Plume Core	Semiannually for one year and then annually	Semi-annually
MW69-97-8	Downgradient Plume Core	Semiannually for one year and then annually	Semi-annually
MW69A-92-22	Crossgradient	not required	Semi-annually
SB77-02-1	Downgradient	not required	Semi-annually

(1) The required parameters and analytical methods are provided in Attachment 3.

MNA will continue until CVOC concentrations are less than target-risk based MCSs, or until a technical impracticability finding is reached (if target risk-based MCSs cannot be reasonably achieved), in accordance with provisions specified in the CMS Report.

SECTION 4

REFERENCES

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Figure 17. Time Variations in the Concentrations of VOCs Detected in Groundwater Samples Collected in the Building 69A Area of Groundwater Contamination.

Figure 18. Applicable MCSs for the Building 69A Area of Groundwater Contamination.

 MW25-95-5	Groundwater monitoring well
 MW90-6	Properly destroyed monitoring well
T  SB76-97-3	Temporary groundwater sampling point
T  SB64-98-16	Properly destroyed sampling point
	Groundwater extraction well
	Groundwater injection well
	Slope stability well
	Slope indicator well
	Shallow soil sampling location
	Soil boring
	Spring
	Topographic contour line (elevation in ft above mean sea level)
	LBNL site boundary
	Surface structure (e.g. buildings, etc.)
	Granular activated carbon treatment system
	Groundwater collection trench

NOTES:
All other symbols used are explained on the figures.

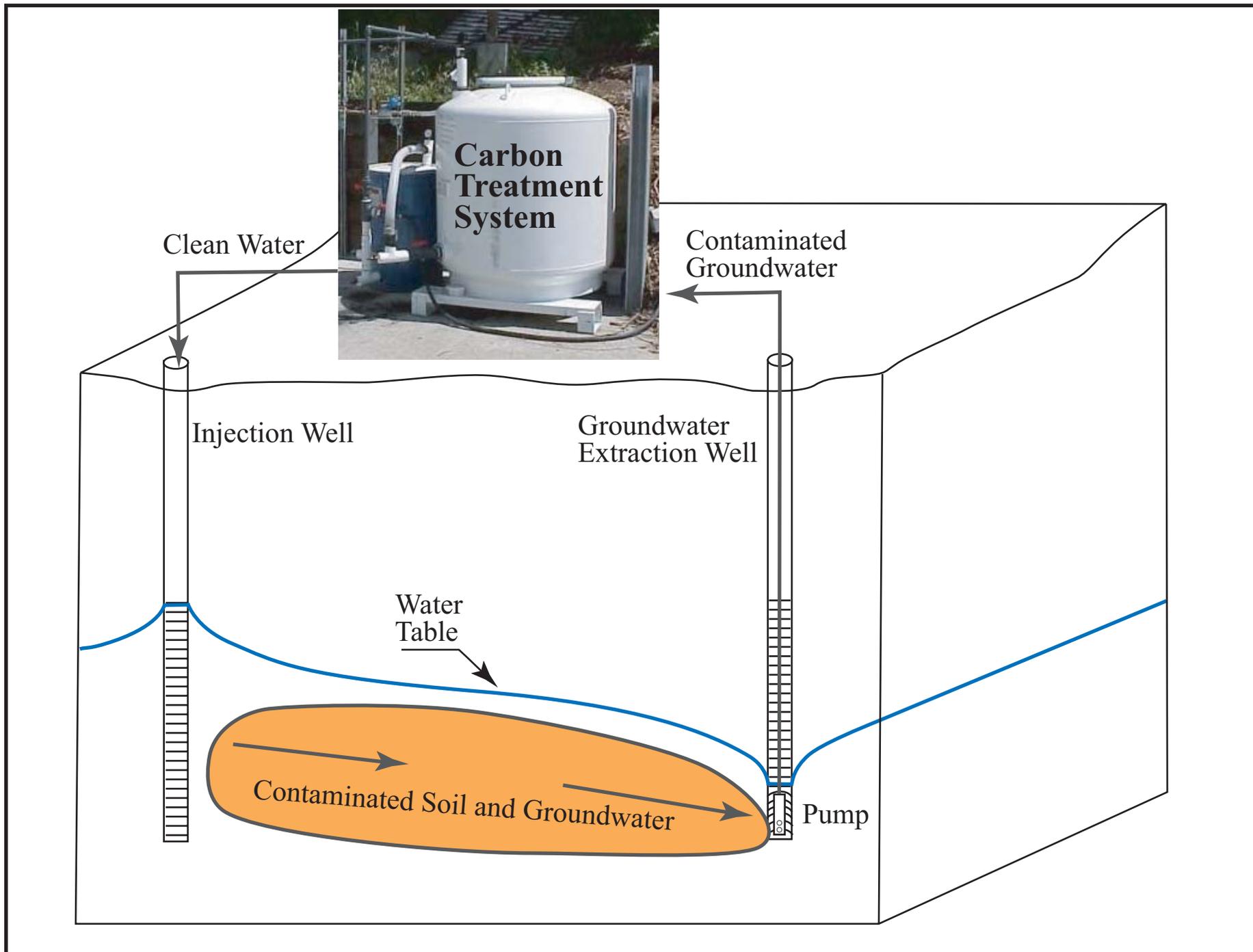


Figure 1. Schematic Diagram of Soil Flushing System

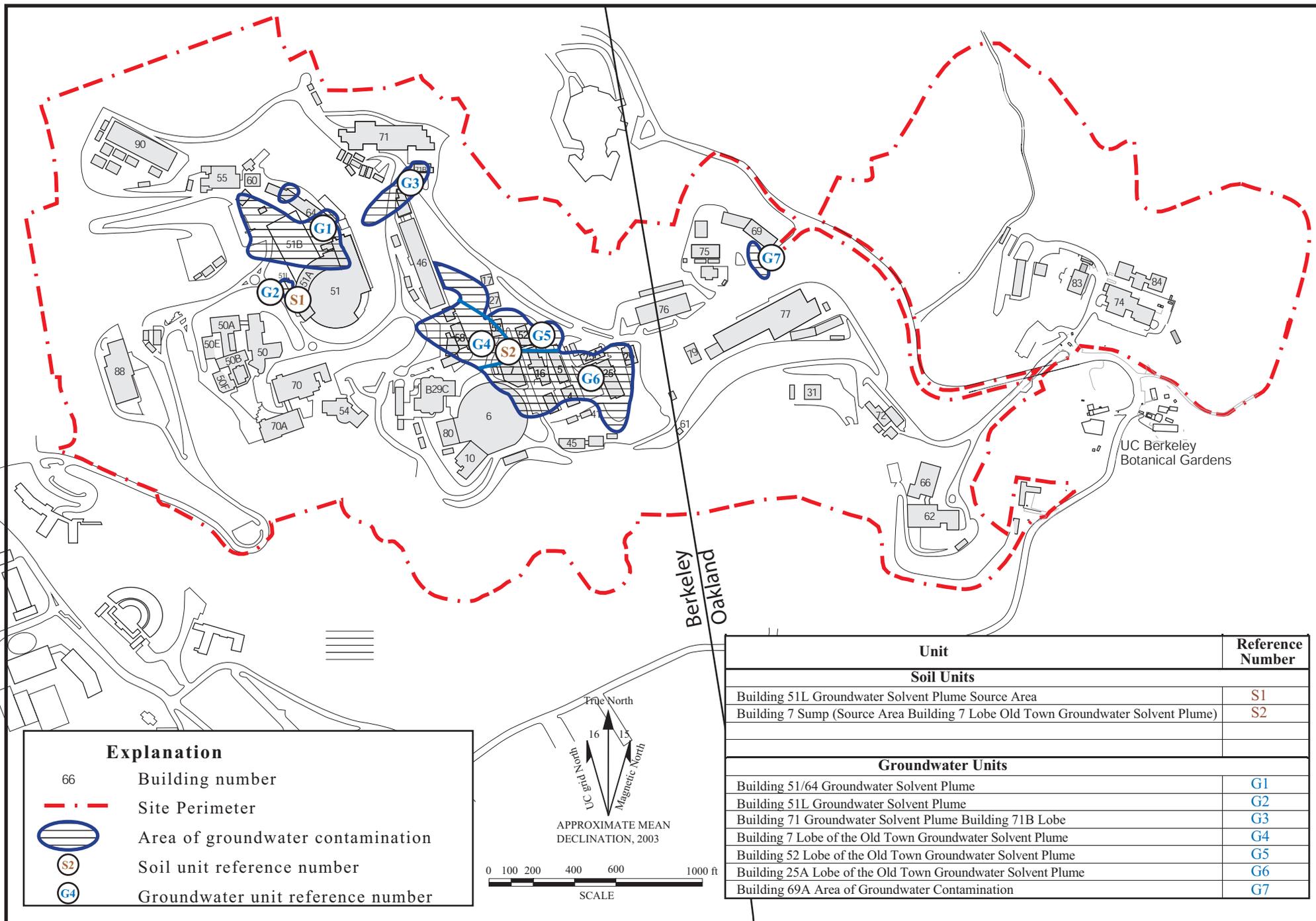


Figure 2. Locations of Soil and Groundwater Units Requiring Corrective Measures.

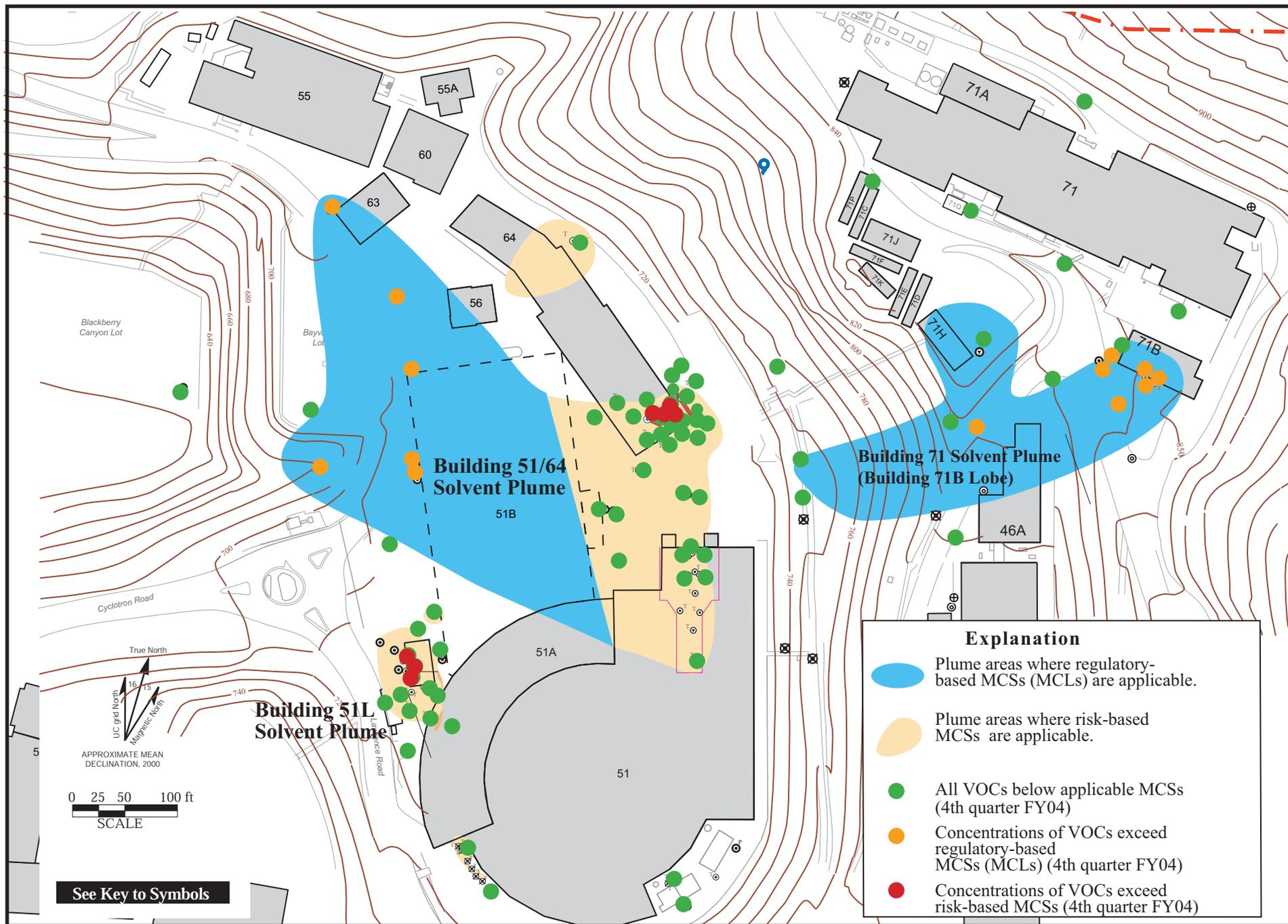


Figure 3. Applicable MCSs for the Building 51/64 Groundwater Solvent Plume, the Building 51L Groundwater Solvent Plume, and the Building 71B Lobe of the Building 71 Groundwater Solvent Plume.

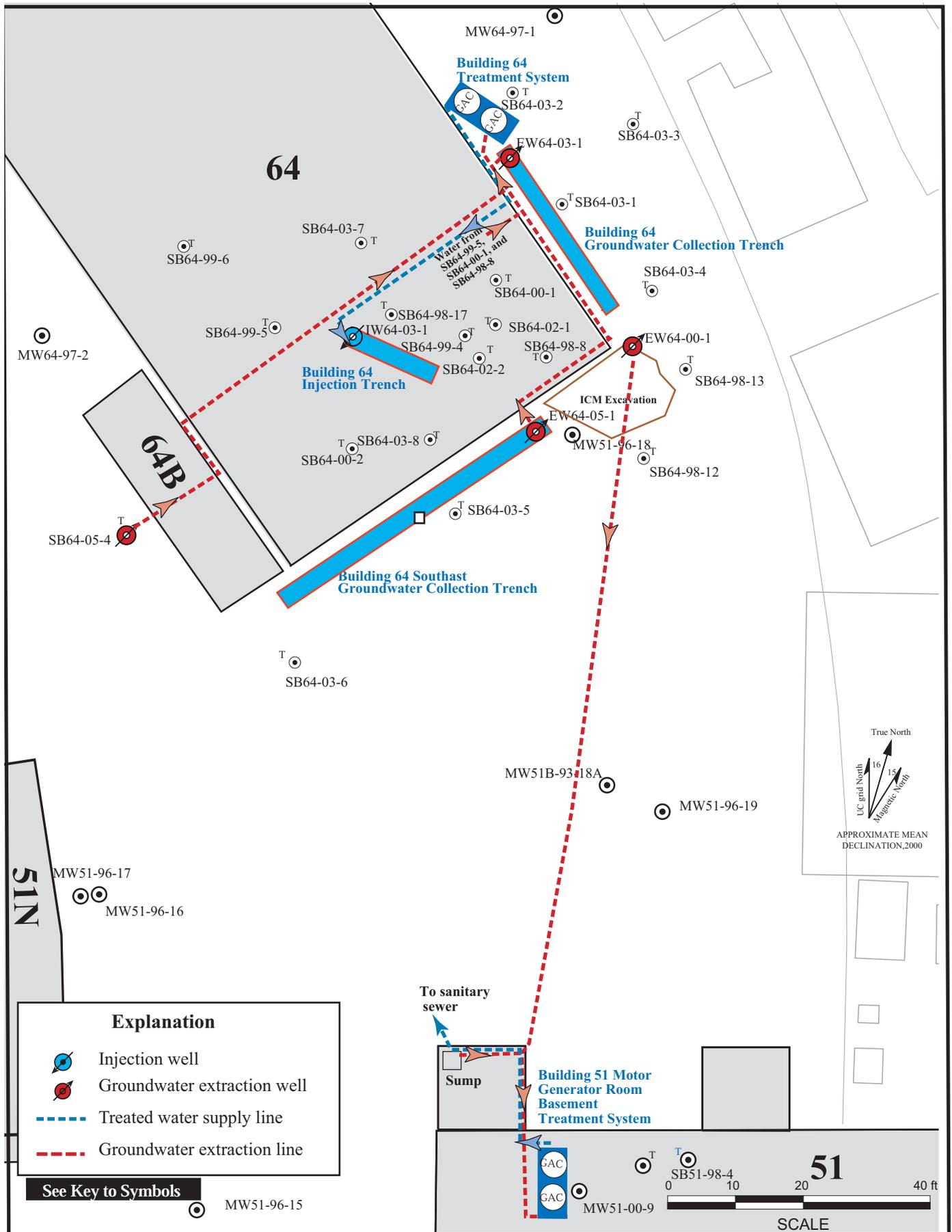


Figure 4. Soil Flushing System, Building 51/64 Groundwater Solvent Plume Source Area.

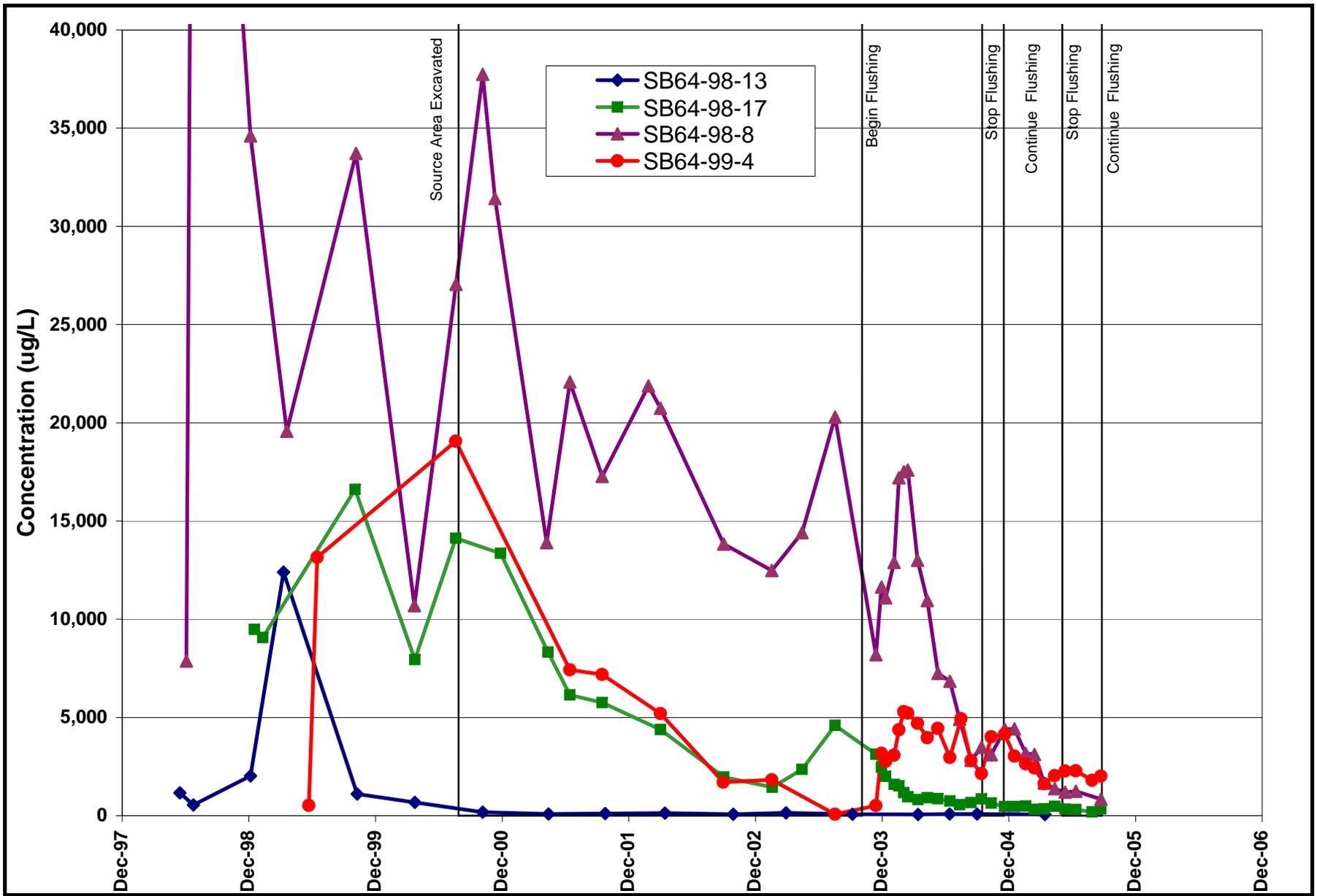


Figure 5. Time Variation in the Concentrations of Total VOCs Detected Groundwater Samples Collected in the Building 51/64 Groundwater Solvent Plume Source Area.

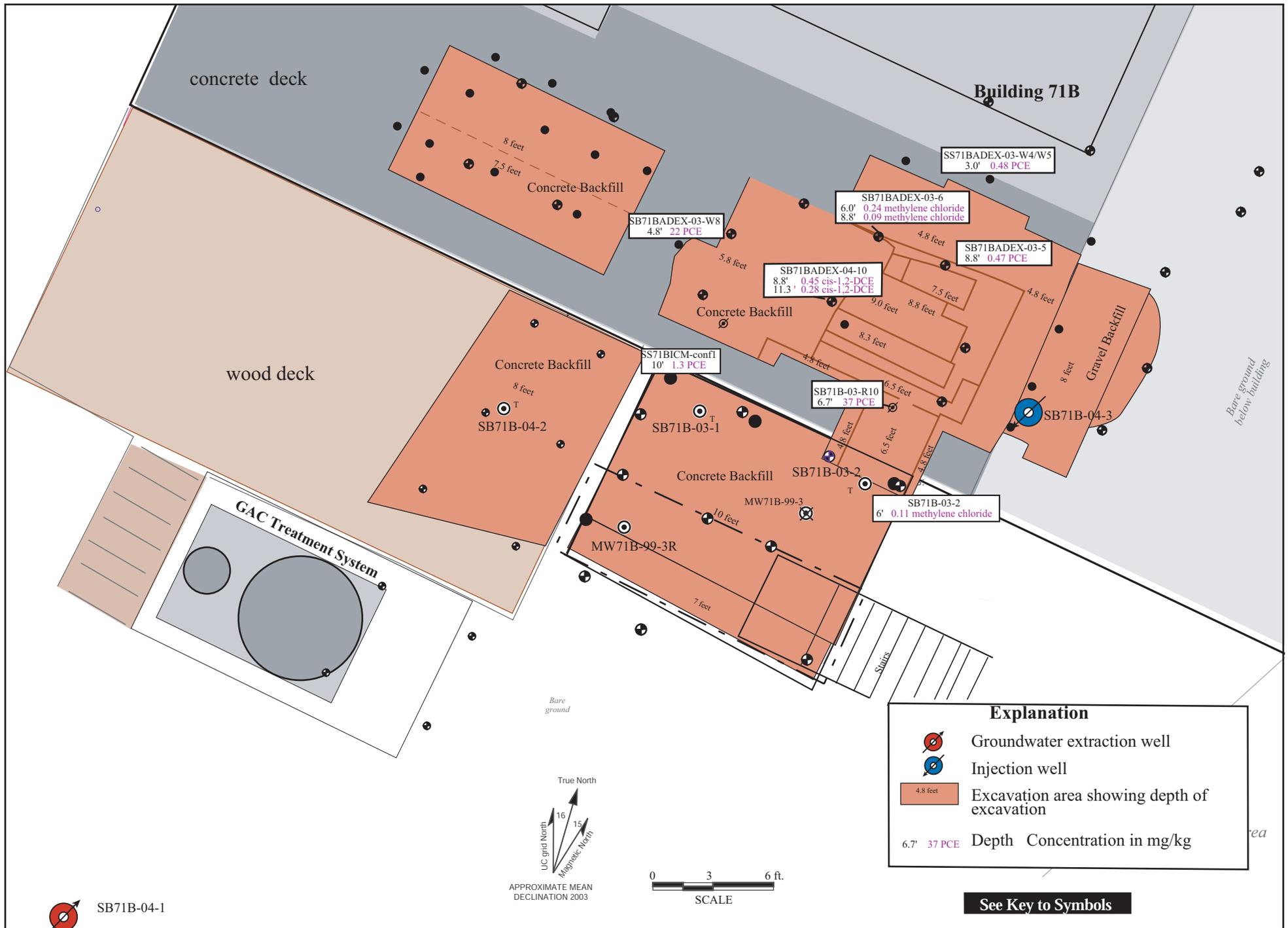


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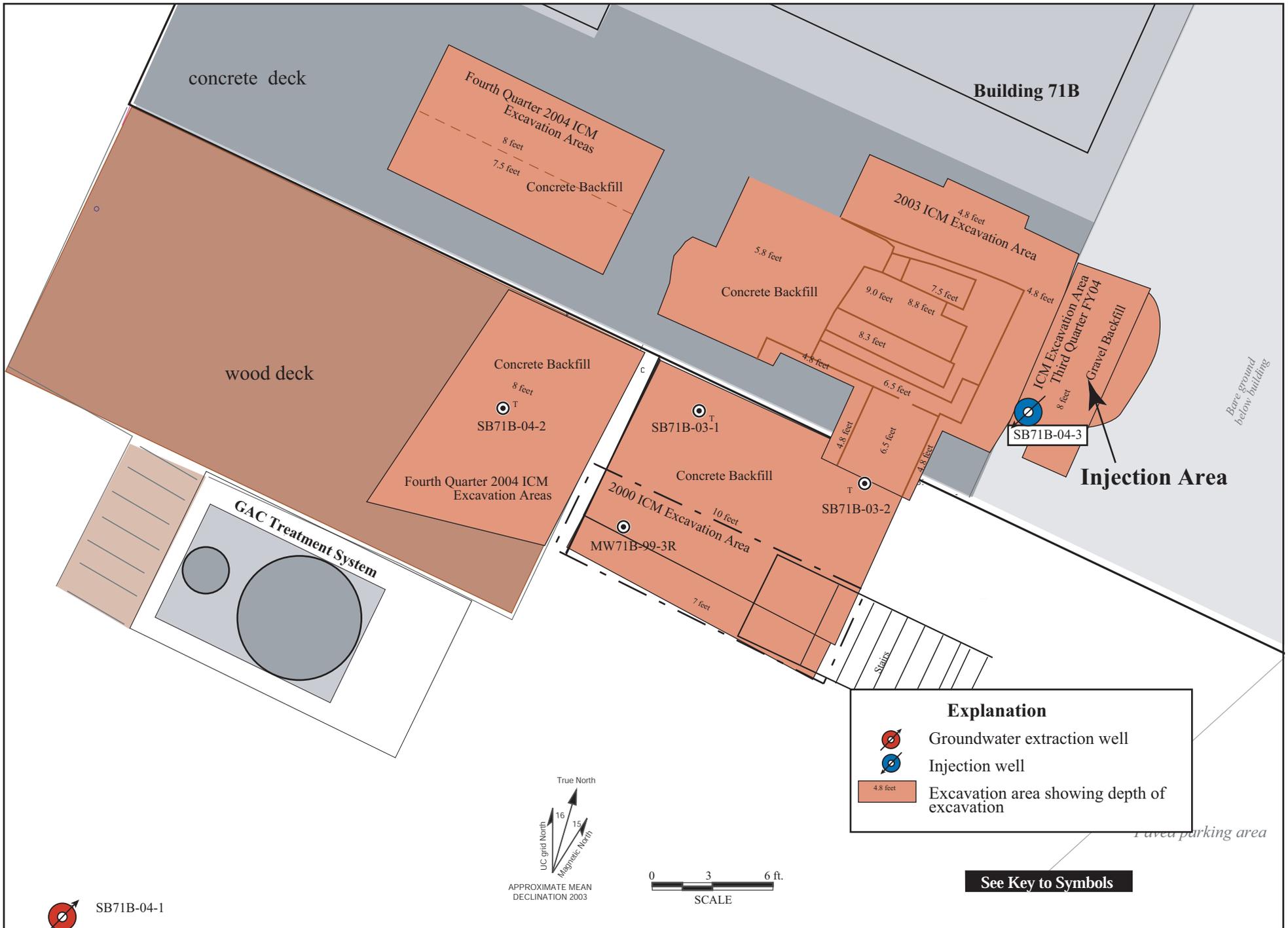


Figure 7. Soil Flushing System, Building 71B Lobe of the Building 71 Groundwater Solvent Plume Source Area.

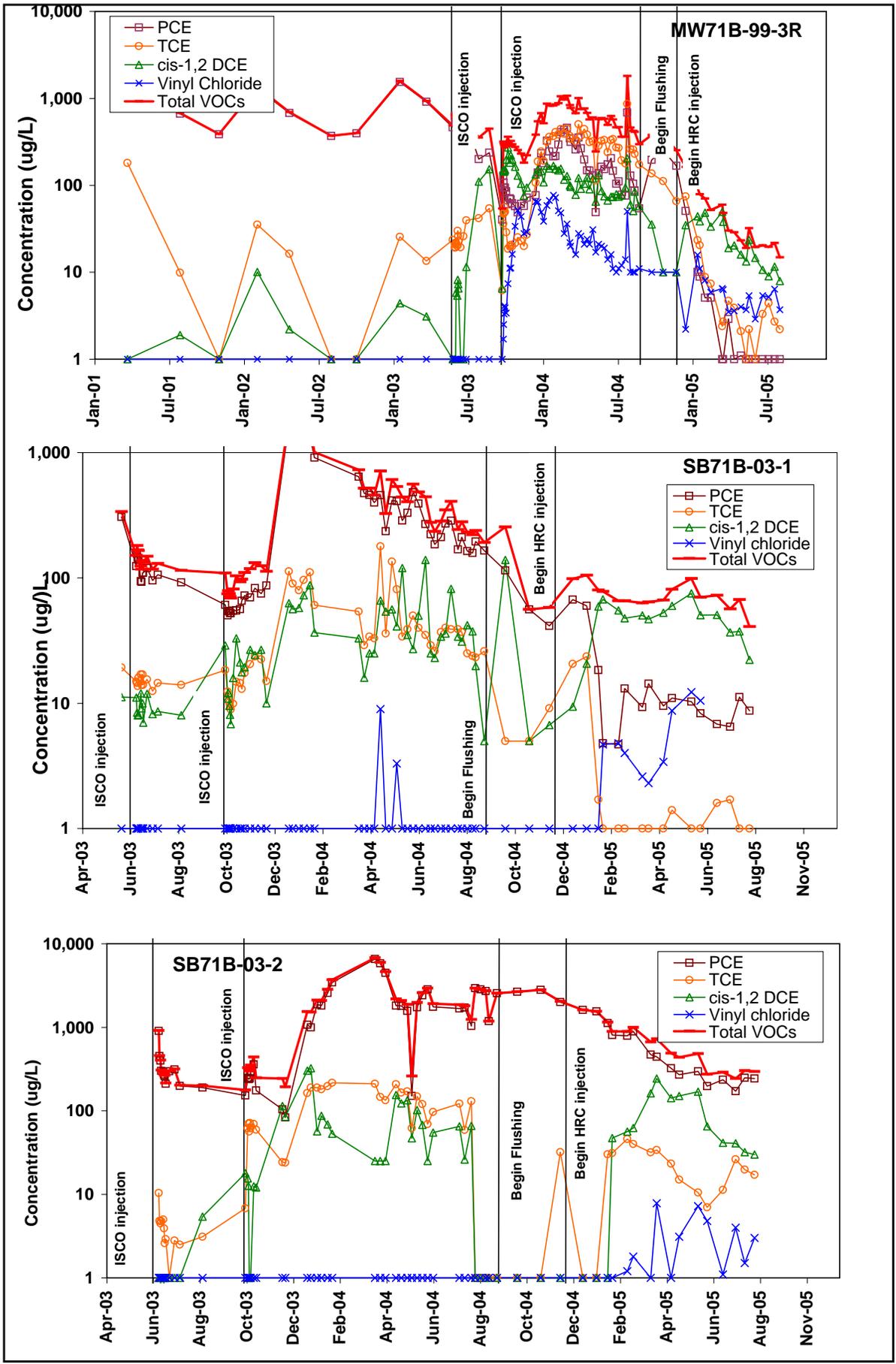


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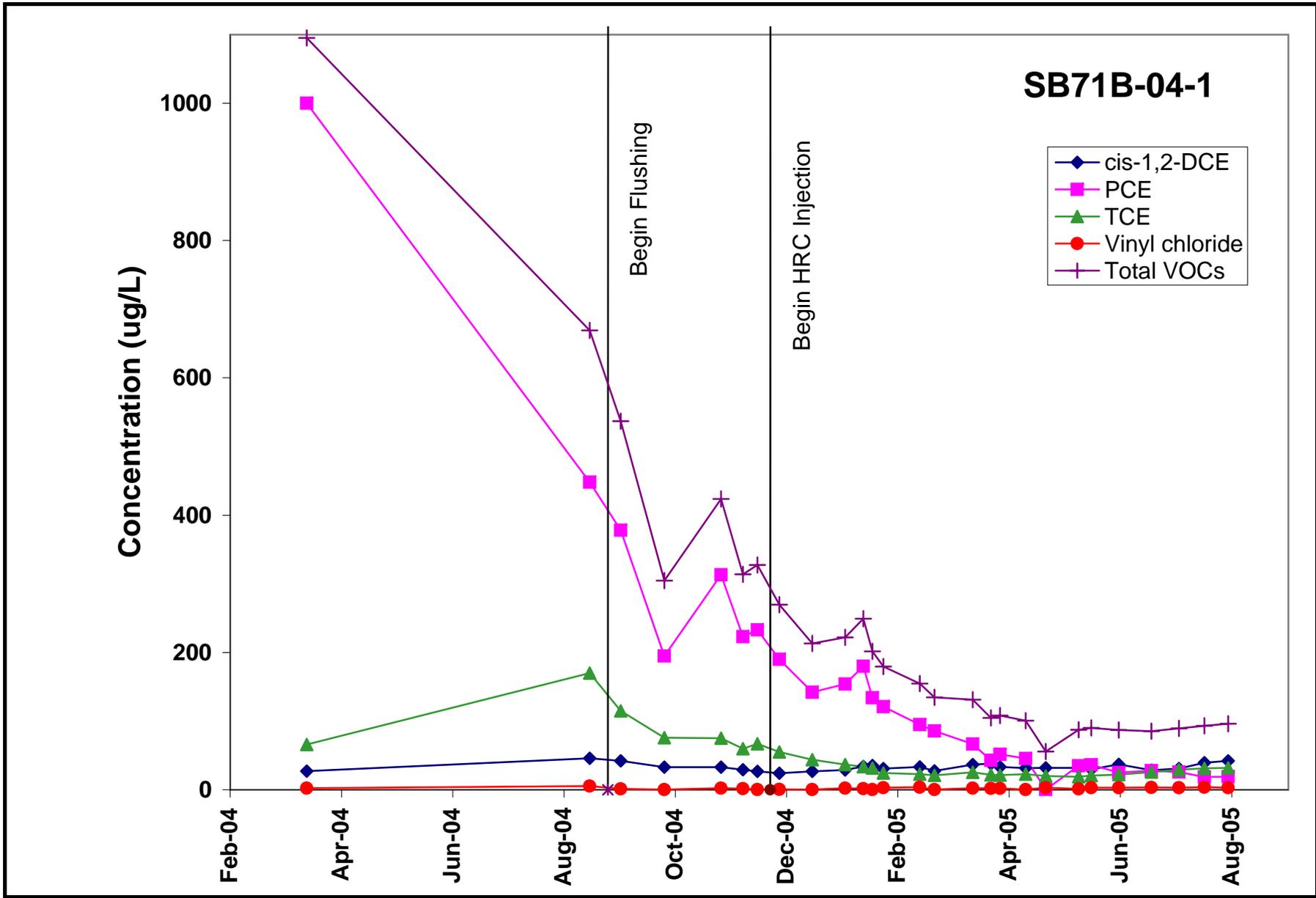


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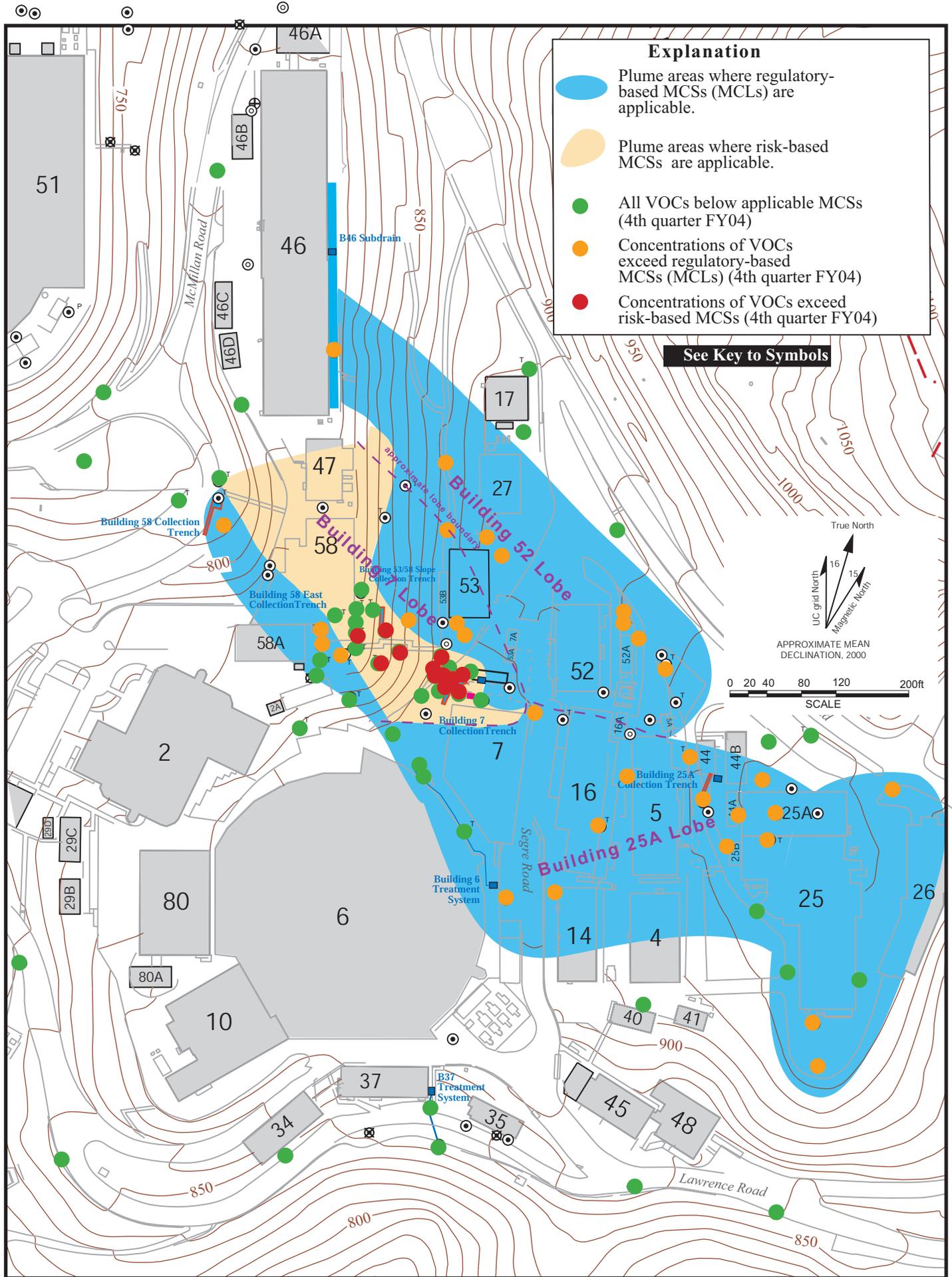


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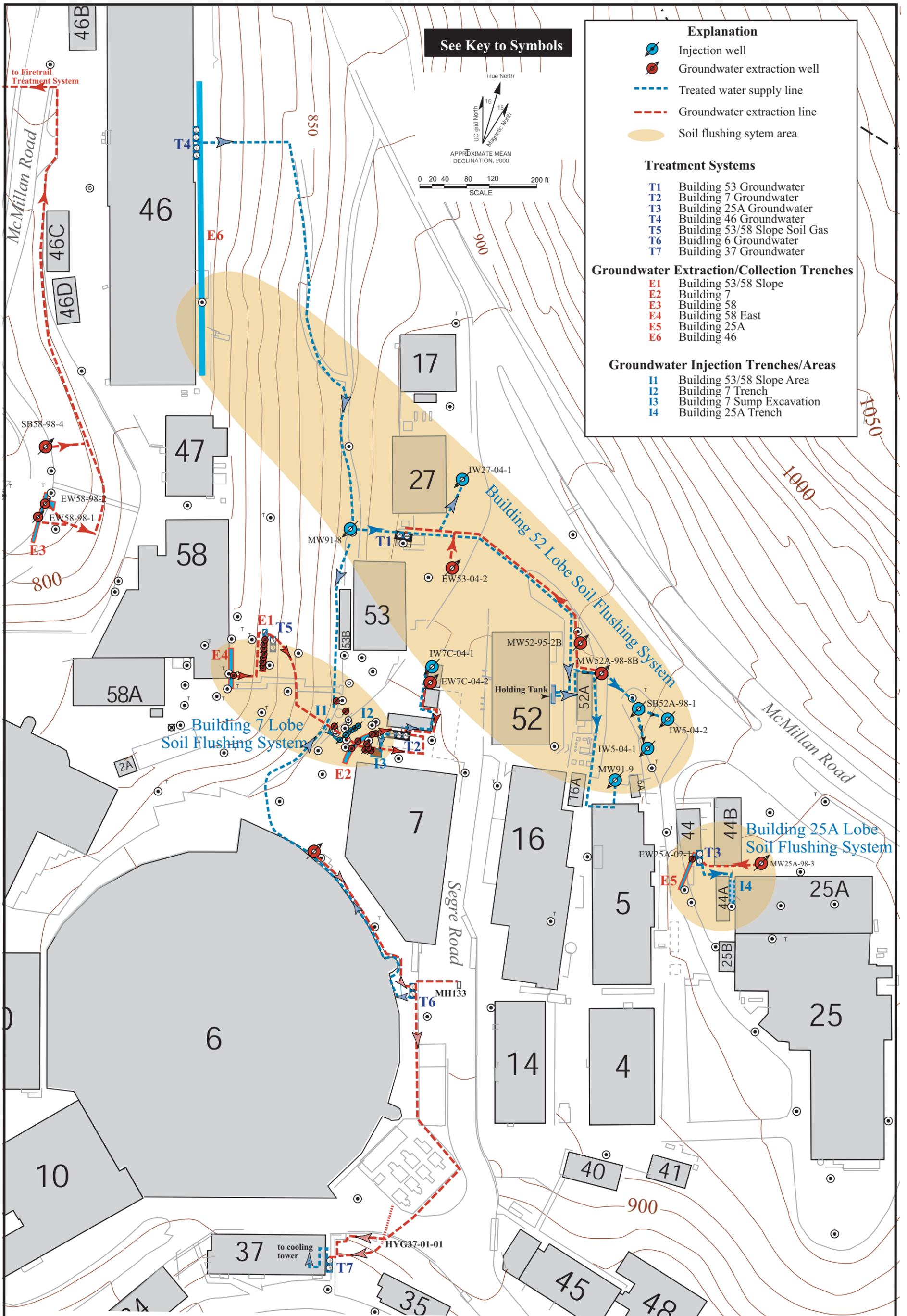


Figure 11. Soil Flushing and Groundwater Migration Control Systems, Old Town Groundwater Solvent Plume.

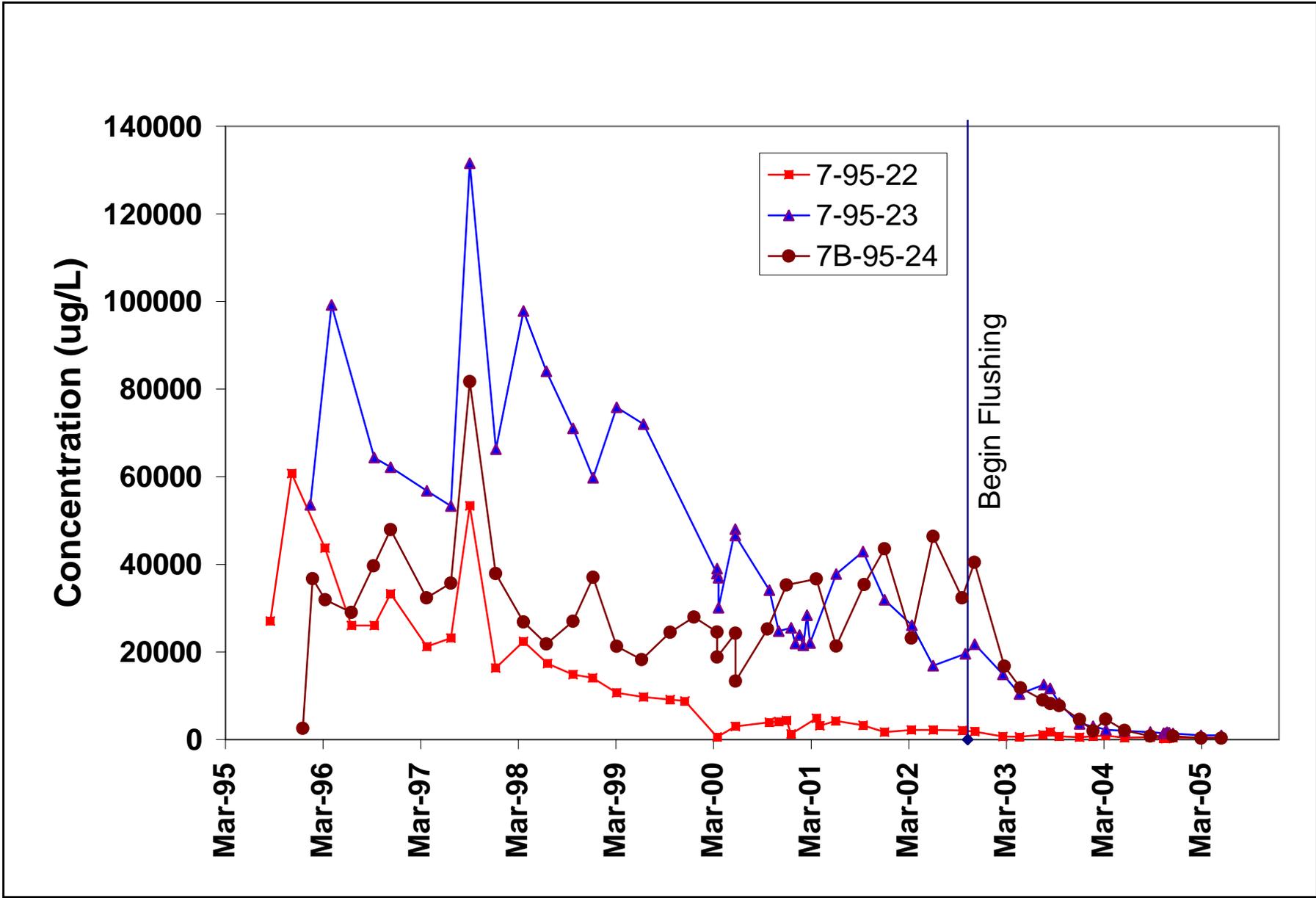


Figure 12. Time Variation in the Concentrations of Total VOCs Detected in Groundwater Samples Collected in the Building 7 Lobe of the Old Town Groundwater Solvent Plume Upgradient Core Area.

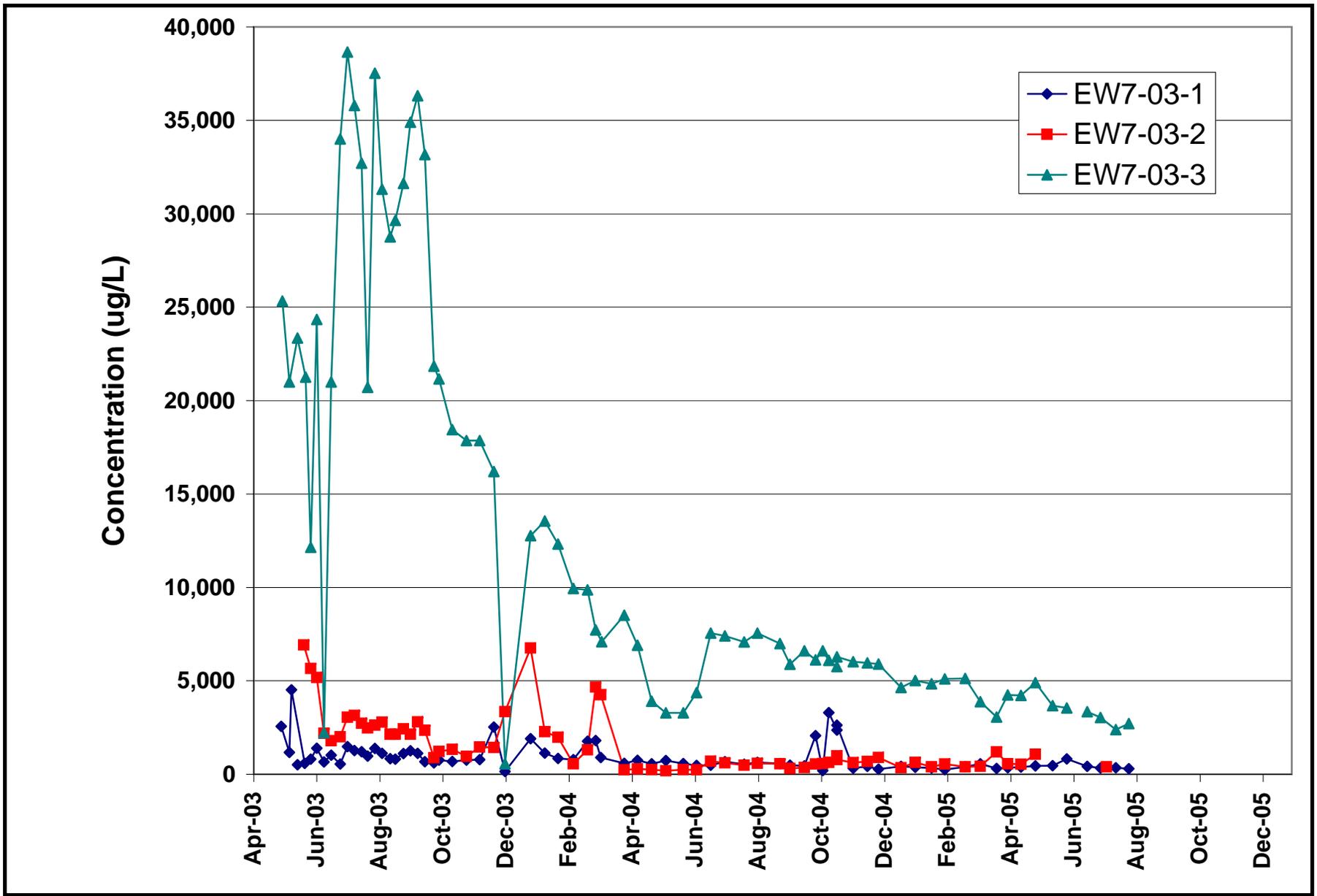


Figure 13. Time Variation in the Concentrations of Total VOCs Detected in Groundwater Samples Collected in the Building 7 Lobe of the Old Town Groundwater Solvent Plume Core Area.

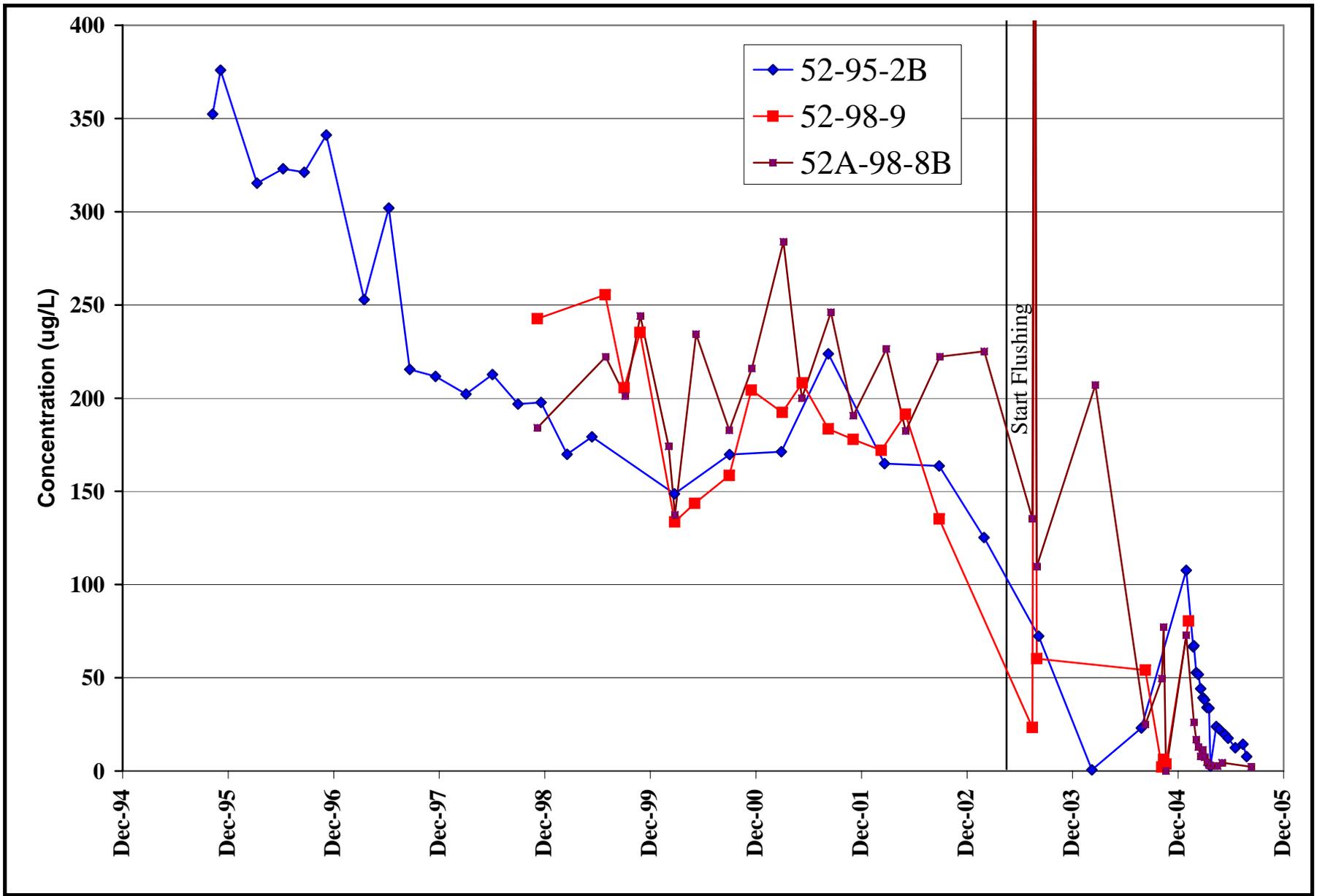


Figure 14. Time Variation in the Concentrations of Total VOCs Detected in Groundwater Samples Collected in the Building 52 Lobe of the Old Town Groundwater Solvent Plume Source Area.

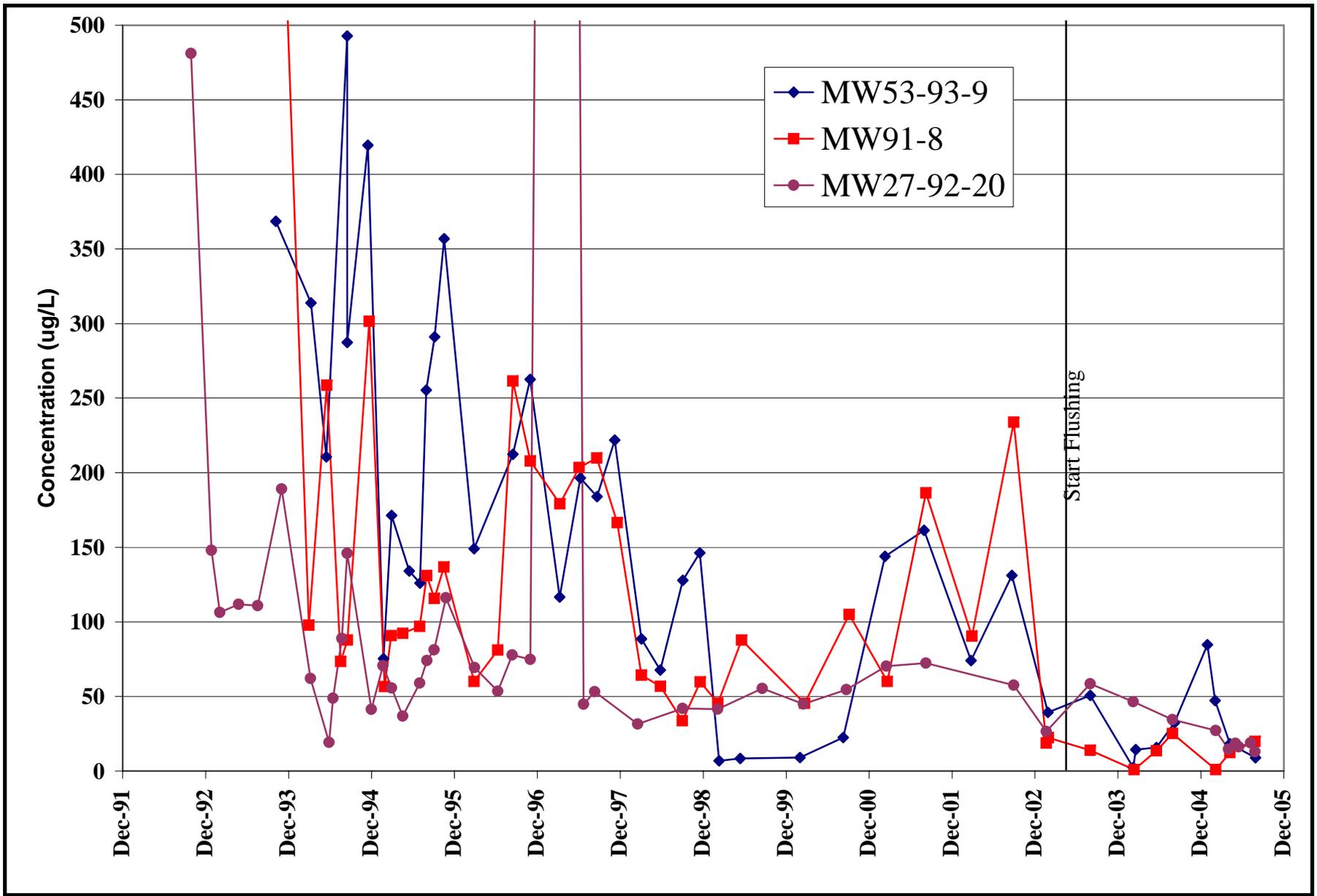


Figure 15. Time Variation in the Concentrations of Total VOCs Detected in Groundwater Samples Collected in the Building 52 Lobe of the Old Town Groundwater Solvent Plume Downgradient Area.

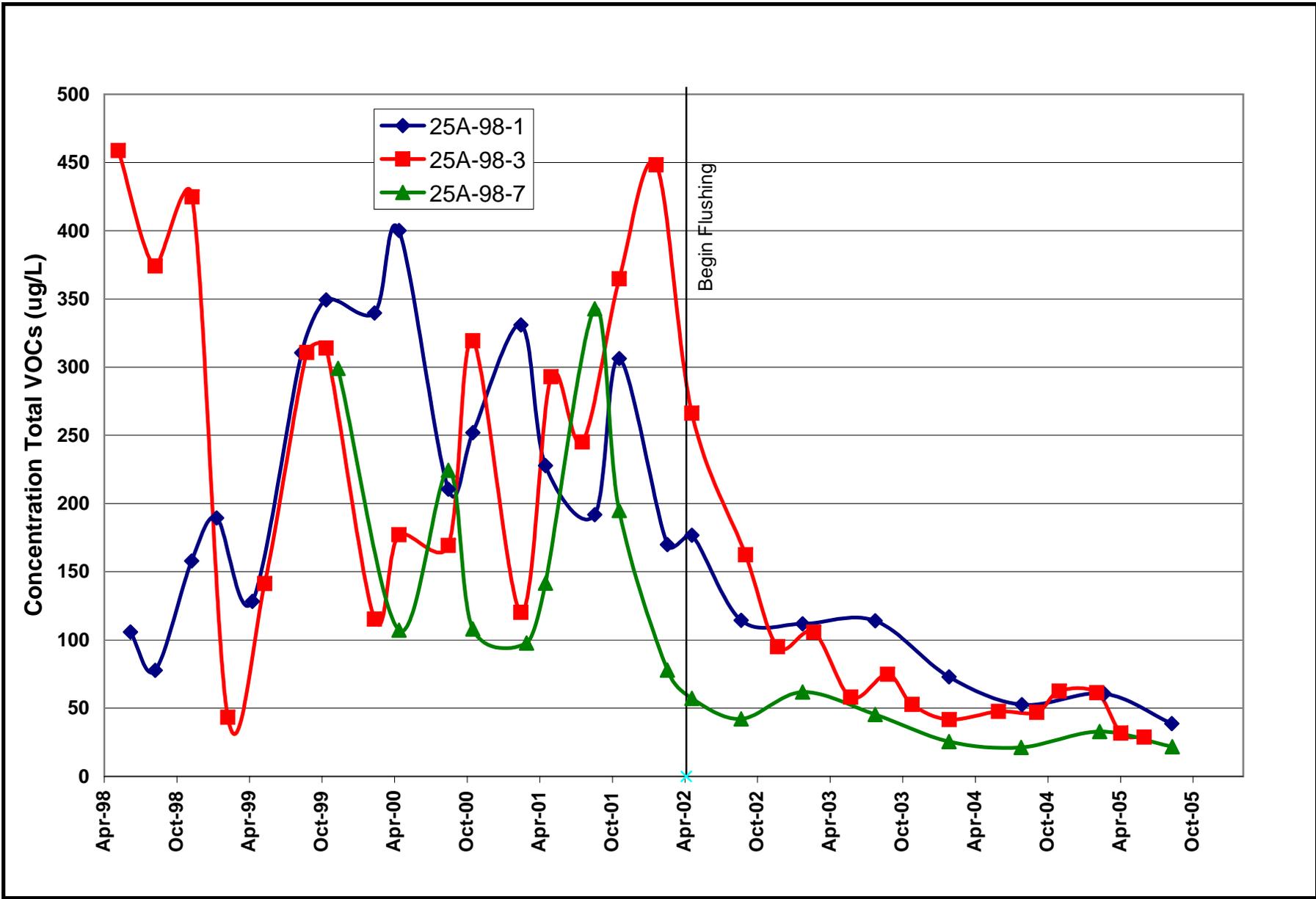


Figure 16. Time Variation in the Concentrations of Total VOCs Detected in Groundwater Samples Collected in the Building 25A Lobe of the Old Town Groundwater Solvent Plume Source Area.

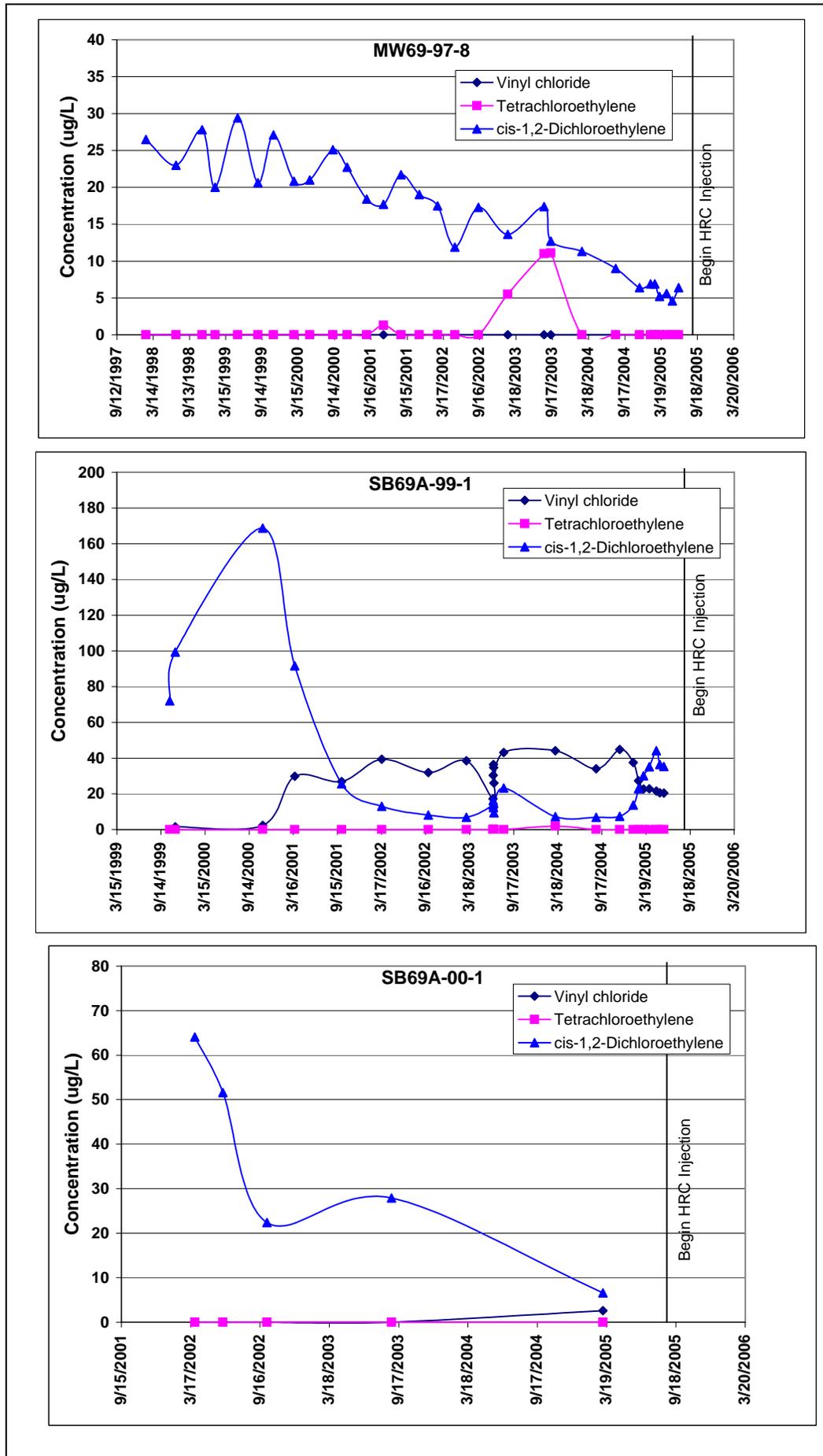


Figure 17. Time Variations in the Concentrations of VOCs Detected in Groundwater Samples Collected in the Building 69A Area of Groundwater Contamination.

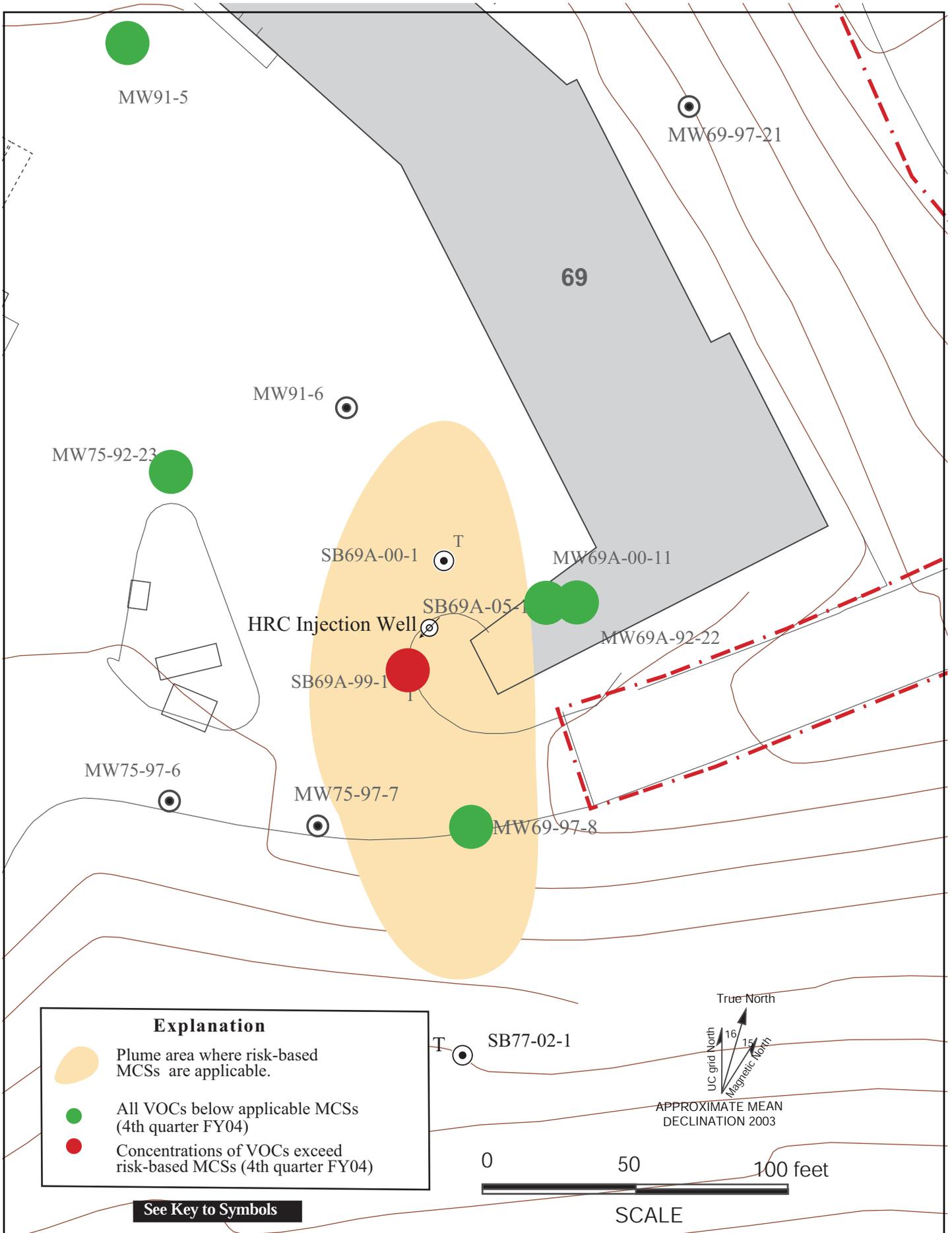
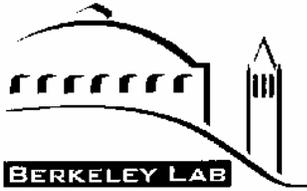


Figure 18. Applicable MCSs for the Building 69A Area of Groundwater Contamination.

Attachment 1

Corrective Measure Implementation (CMI) Workplan for Soil Excavation,
Building 51L Groundwater Solvent Plume Source Area for the Lawrence Berkeley
National Laboratory Environmental Restoration Program, dated September 2005.



E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program



United States Department of Energy

**CORRECTIVE MEASURES IMPLEMENTATION (CMI)
WORKPLAN
for
SOIL EXCAVATION**

**BUILDING 51L GROUNDWATER SOLVENT PLUME
SOURCE AREA**

for the
Lawrence Berkeley National Laboratory
Environmental Restoration Program

September 2005

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for the
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*A Joint Effort of
Environment, Health and Safety Division and
Earth Sciences Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720*

September 2005

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LIST OF ABBREVIATIONS

Berkeley Lab	Ernest Orlando Lawrence Berkeley National Laboratory
bgs	below ground surface
Cal-EPA	California Environmental Protection Agency
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COC	Chemical of Concern
CVOC	Chlorinated Volatile Organic Compound
DCA	Dichloroethane
DCE	Dichloroethene
DOE	Department of Energy
DTSC	Cal/EPA Department of Toxic Substances Control
ERP	Environmental Restoration Program
gpd	gallons per day
HI	Hazard index
HHRA	Human Health Risk Assessment
HSPP	Health and Safety Program Plan
ICM	Interim Corrective Measure
MCL	Maximum Contaminant Level
ILCR	Incremental Lifetime Cancer Risk
LBNL	Ernest Orlando Lawrence Berkeley National Laboratory
MCS	Media Cleanup Standard
mg/kg	milligrams per kilogram
PCE	Tetrachloroethene
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
SOP	Standard Operating Procedure
TCE	Trichloroethene
USEPA	United States Environmental Protection Agency
Water Board	Regional Water Quality Control Board
WRCB	State Water Resources Control Board
WSP	Worksite Safety Plan

SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) submitted its revised Draft Corrective Measures Study (CMS) Report to the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC) on February 10, 2005 (Berkeley Lab, 2005). The CMS Report provides recommendations for the specific corrective measures that can eliminate or reduce potential risks to human health from contaminants in the soil and/or groundwater at Berkeley Lab. It also provides the media specific concentrations (Media Cleanup Standards [MCSs]) that the measures must achieve in order to be considered complete.

The DTSC, in consultation with the Regional Water Quality Control Board (Water Board) and the City of Berkeley/Toxics Management Division reviewed the Draft CMS Report and determined that it was technically complete (DTSC, 2005a). In addition, DTSC evaluated the corrective measures proposed for Berkeley Lab in the Draft CMS Report and prepared a Statement of Basis indicating its concurrence with the proposed measures (DTSC, 2005b). On May 26, 2005, DTSC conducted a public meeting and hearing on the proposed Berkeley Lab cleanup measures and held a 45-day public comment period that ended on June 8, 2005. On August 31, 2005, DTSC responded to the public comments and issued its “Notice of Determination for Approval of a Corrective Measures Study (CMS) Report that would allow the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL) to implement corrective measures at the facility (DTSC, 2005c). On August 31, 2005, DTSC also informed Berkeley Lab of its final decision to approve the Corrective Measures Study Report including the proposed remedies and requested that Berkeley Lab submit the Corrective Measures Implementation (CMI) Workplan to DTSC by October 24, 2005 (DTSC, 2005d).

This workplan provides the details of the corrective measure proposed for the source area of the Building 51L Groundwater Solvent Plume. Soil containing chlorinated volatile organic

compounds (CVOCs) is present in the plume source area at concentrations above the MCSs specified for the unit in the CMS Report. The applicable MCSs are based on potential risks to human health. The corrective measure proposed for this area is excavation and offsite disposal of contaminated soil. Groundwater in the source area also contains CVOCs at concentrations above the risk-based MCSs. Excavating the highly contaminated source area soil should help reduce concentrations of CVOCs in the groundwater in the source area below risk-based levels.

1.2 BACKGROUND

A machine/maintenance shop was located in the Building 51L area prior to the 1970's, before Building 51L was constructed. At various times, solvent drum racks were reportedly located where Building 51L was later built, along the adjacent wall of Building 51A, and along a former retaining wall located approximately 20 feet west of Building 51L. Building 51L was constructed in the early 1980's as a computer support facility for Bevatron operations and was demolished in March 2004 as part of the Bevatron decommissioning process. The former location of Building 51L is shown on Figure 1.

Solvent-contaminated soil and groundwater (Building 51L Groundwater Solvent Plume) underlie the area where Building 51L was located. The principal contaminants are CVOCs that were used as cleaning solvents, or were derived from degradation of cleaning solvents. Soil and groundwater sampling indicate that solvent spills in the area where Building 51L was later constructed were the primary source for the contamination.

SECTION 2

GEOLOGY AND HYDROGEOLOGY

2.1 GEOLOGY

A detailed site map of the Building 51L area, including the locations of soil borings, groundwater monitoring wells, temporary groundwater sampling points, and underground utility lines is shown on Figure 2. Building 51L was constructed on artificial fill comprised of gravelly clay and sandy or clayey silt that lies within a former hillside swale (Figure 3). The thickness of the fill increases from approximately 10 to 20 feet at the retaining wall west of Building 51L to 30 feet near the northeast wall of the building. The fill southwest of Building 51L includes a sand layer that extends from approximately 2 to 5.5 feet below ground surface (bgs), and may have been a migration pathway for contaminants. The artificial fill overlies residual soil/colluvium consisting primarily of silty clay with some gravel, which ranges from approximately 5 to 20 feet thick. Underlying the soil/colluvium is shale and siltstone of the Great Valley Group. The three geologic units (fill, soil/colluvium, and bedrock) beneath the site act as distinct hydrogeologic units. The geology of the site is depicted on geologic cross sections A-A' (Figure 4), B-B' (Figure 5), C-C' (Figure 6), and D-D' (Figure 7). The locations of the cross sections are shown on Figure 2. A map showing structure contours of the top of the soil/colluvium and depicting the horizontal extent of the sand layer is provided on Figure 8.

2.2 HYDROGEOLOGY

Groundwater is currently being extracted from two wells south of the former location of Building 51L as an Interim Corrective Measure (ICM) to lower the water table below the storm drain. The purpose of this ICM is to prevent contaminated groundwater from entering the storm drain system and migrating to surface water. Groundwater extraction has resulted in drawdown of the water table to depths as great as 20 to 35 feet bgs near the extraction wells. In the absence of groundwater extraction, the water table would be approximately 15 feet bgs in this area. A recent

water level elevation contour map of the Building 51L area is shown on Figure 9. As shown on the figure, the regional gradient slopes downwards to the north, indicating that groundwater flows generally northward near Building 51L.

Based on the performance of the extraction wells, the long-term sustainable yield from the Great Valley Group bedrock in this area is less than 200 gallons per day (gpd). Groundwater yields measured in wells screened in the fill overlying the bedrock are also less than 200 gpd.

SECTION 3

MAGNITUDE AND EXTENT OF CONTAMINATION

3.1 GROUNDWATER

The Building 51L Groundwater Solvent Plume covers a relatively small area approximately 100 feet long by 70 feet wide centered under the southwest corner of former Building 51L (Figure 10). The plume contains primarily trichloroethene (TCE), tetrachloroethene (PCE), and degradation products such as cis-1,2-dichloroethene (DCE), trans-1,2-DCE, vinyl chloride, and 1,1-dichloroethane (DCA), which are all present at concentrations above Maximum Contaminant Levels (MCLs) for drinking water.

Groundwater contaminants have generally not been detected in wells screened in bedrock, indicating that the vertical extent of groundwater contamination is limited to the upper 20 to 25 feet in the overlying fill and colluvium. This is interpreted to result from the presence of a relatively low permeability colluvium/clay layer beneath the fill, which impedes downward migration of contaminants.

3.2 SOIL

Concentrations of CVOCs detected in soil samples collected in the Building 51L Groundwater Solvent Plume area are provided in Appendix A. PCE, TCE, and cis-1,2-DCE are the primary contaminants that have been detected in soil. Concentrations of PCE, TCE, and cis-1,2-DCE detected are shown on cross sections B-B' (Figure 11), C-C' (Figure 12), and D-D' (Figure 13). Also indicated on the cross sections is the contact between the fill and the underlying colluvium/clay. The maximum concentrations of PCE (21 mg/kg) and TCE (24 mg/kg) were detected under Building 51L, at depths of approximately 6.5 to 12 feet (Figure 12). The contamination is restricted primarily to the fill (Figure 11, 12, and 13).

SECTION 4

PROPOSED CORRECTIVE MEASURE

4.1 RATIONALE

The Human Health Risk Assessment (HHRA) completed by Berkeley Lab in 2003 (Berkeley Lab, 2003) estimated the potential risks from chemicals of concern (COCs) in soil and groundwater at the site by calculating theoretical incremental lifetime cancer risks (ILCRs) and non-cancer hazard indices (HIs), assuming an industrial/institutional land use scenario. This scenario is consistent with the current and potential future land use at Berkeley Lab. The theoretical ILCRs were compared to the United States Environmental Protection Agency (USEPA) target cancer risk range of 10^{-4} to 10^{-6} , which is considered by the agency to be safe and protective of public health. Exposure to chemicals with an HI less than 1.0 is considered unlikely to result in adverse non-cancer health effects over a lifetime of exposure.

The HHRA estimated the potential risks from COCs in the soil in the source area of the Building 51L Groundwater Solvent Plume. For current indoor workers, intrusive construction workers, and landscape maintenance workers the theoretical ILCR is less than 10^{-6} and the non-cancer HIs is less than 1 for all soil pathways. The estimated risk to current indoor workers was derived from air monitoring data collected inside former Building 51L. Risks to potential future indoor workers, which were estimated using modeling data, predicted that the theoretical ILCR would be greater than 10^{-6} and the non-cancer HI would be greater than 1 for soil pathways. Since the estimated risks exceed the threshold risk values, the Building 51L Groundwater Solvent Plume Source Area was included in the CMS Report (Berkeley Lab, 2005).

The CMS Report provides recommendations for the specific corrective measures that will be implemented to eliminate or reduce potential risks to human health from contaminants in the soil and/or groundwater at Berkeley Lab. The corrective measure proposed for the Building 51L Groundwater Solvent Plume Source Area is excavation and offsite disposal of contaminated soil.

4.2 MEDIA CLEANUP STANDARDS AND PROPOSED CLEANUP LEVELS

The CMS Report (Berkeley Lab, 2005) specifies the MCSs that corrective measures must achieve in order to be considered complete. The MCSs were developed for an institutional/industrial land use scenario. Two types of MCSs were developed, the first to address risk-based objectives and the second to address regulatory requirements for areas that constitute potential drinking water sources. Target risk-based MCSs were set for each contaminant at the concentration that would theoretically result in an ILCR of 10^{-6} or a non-cancer HI of 1. Regulatory-based MCSs are applicable to locations at Berkeley Lab where groundwater is considered a potential source of drinking water under policies of the State Water Resources Control Board (WRCB). As specified in the CMS Report, risk-based MCSs are the applicable cleanup criteria for the Building 51L Groundwater Solvent Plume Source Area.

Table 1 lists maximum concentrations of CVOCs detected in the soil in the source area of the Building 51L plume in comparison to the target risk-based MCSs for institutional land use. The only CVOCs that exceed MCSs are PCE, TCE, and vinyl chloride. However, as discussed in the CMS Report, the detection frequency of vinyl chloride was less than 1% so the inclusion of this chemical is considered to be a statistical artifact, and does not represent a risk to human health.

Table 1. Maximum Concentrations of CVOCs Detected in Soil in the Building 51L Groundwater Solvent Plume Source Area and Media Cleanup Standards

Chemical	Maximum Concentration Detected (mg/kg)	Target Risk-Based MCS for Institutional Land Use (mg/kg)
PCE	21	0.45
TCE	24	2.3
1,1,1-TCA	0.019	690
1,1-DCA	0.8	1.3
1,1-DCE	0.074	7.9
benzene	0.0053	0.1
cis-1,2-DCE	3.1	38
trans-1,2-DCE	0.45	50
vinyl chloride ^(a)	0.012	0.0035

Note: boldface numbers indicate that the maximum concentration detected exceeds the MCS.

^(a) See Section 4.2 for discussion.

4.3 CORRECTIVE MEASURE IMPLEMENTATION

A total of 348 soil samples have been collected from 81 locations in the Building 51L plume source area. No post-excavation confirmation sampling will be collected since a sufficient number of samples have been collected to accurately delineate the extent of excavation that will be required to achieve the MCSs for the unit. Soil sampling locations and the proposed lateral extent of excavation are shown on Figure 14.

The estimated extent and depth of excavation are shown on Figure 15. The depth of excavation is also shown on the cross sections (Figure 11, Figure 12, and Figure 13). It is anticipated that the excavation will be completed using conventional excavation techniques. The excavation shoring method currently being considered is the installation of a soldier beam/lagging shoring system. Holes would be drilled to install soldier (I) beams, and lagging (wood planks) placed between the beams as the excavation is advanced. The excavation method may be modified pending discussions with excavation contractors. Dewatering of the excavation will be conducted if necessary, and any groundwater extracted from the excavation will be treated at the Building 51L Treatment System. A drainage system will be constructed at the base of the excavation to allow extraction and treatment of contaminated groundwater. The excavation will be backfilled in accordance with requirements of the Berkeley Lab Facilities Department.

SECTION 5

GENERAL PROCEDURES

All work will be performed in accordance with requirements of the Berkeley Lab Environmental Restoration Program (ERP) Quality Assurance Program Plan (QAPP) (Berkeley Lab, 1994a), Berkeley Lab ERP Standard Operating Procedures (SOPs) (Berkeley Lab, 1994b), and the Berkeley Lab ERP Health and Safety Program Plan (HSPP) (Berkeley Lab, 2004). In accordance with the HSPP, a Worksite Safety Plan (WSP) will be completed prior to the initiation of any intrusive site work. The WSP will contain a description of the potential contaminants, required personnel protective equipment, site hazards, and monitoring requirements.

SECTION 6

CHEMICAL AND WASTE MANAGEMENT

Excavated soils and all potentially contaminated materials will be temporarily stored in covered storage bins, or temporarily stockpiled at the surface and covered with continuous heavy-duty plastic sheeting until loaded into covered bins for offsite disposal. Any stockpiled soil will be managed in a way that will not cause sediment in storm water runoff. The landfill selected for soil disposal will be based on the landfill's acceptance criteria and the estimated disposal costs. If approved of by the landfill, pre-excavation sampling results will be used to document compliance with the landfill's acceptance criteria; otherwise, samples will be collected from the excavated soil.

SECTION 7

PRELIMINARY SCHEDULE

The following is a preliminary schedule for the activities proposed in this Workplan. The schedule is tentative and may be revised.

September 9, 2005	Submit Workplan to DOE.
September 26, 2005	Submit Workplan to DTSC.
October 4, 2005	Begin Excavation.

SECTION 8

REFERENCES

- Berkeley Lab (1994a). Lawrence Berkeley National Laboratory Quality Assurance Program Plan for the Environmental Restoration Program. Lawrence Berkeley National Laboratory, Berkeley, California. July 1994.
- Berkeley Lab (1994b). Standard Operating Procedure for Lawrence Berkeley National Laboratory Environmental Restoration Program. Lawrence Berkeley National Laboratory, Berkeley, California.
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- DTSC, 2005b. Statement of Basis Proposed RCRA Remedy Selection for Soil and Groundwater at Ernest Orlando Lawrence Berkeley National Laboratory 1 Cyclotron Road Berkeley, California, EPA ID No. CA489008986. April 2005.
- DTSC, 2005c. Notice of Determination Approval of a Corrective Measures Study (CMS) Report that would allow the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL) to implement corrective measures at the facility. Department of Toxic Substances Control Standardized Permits and Corrective Action. State Clearinghouse Number 2005042160. August 31, 2005.

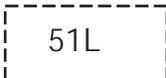
DTSC, 2005d. Approval of Final Corrective Measures Study Report and Remedy Selection Lawrence Berkeley National Laboratory 1 Cyclotron Road Berkeley, California, EPA ID No. CA489008986. Letter from Mohinder Sandhu (DTSC) Chief Standardized Permitting and Corrective Action Branch to Iraj Javandel (Berkeley Lab). August 31, 2005.

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- Figure 13. Cross Section D-D' Showing Concentrations of PCE, TCE, and cis-1,2-DCE Detected in Soil (mg/kg) and Extent of Soil at Concentrations Above MCS for Institutional Land Use.
- Figure 14. Extent of Soil Contamination Above Risk-Based Media Cleanup Standard for Institutional Land Use.
- Figure 15. Approximate Depth of Excavation.

	MW51L-01-1A	Groundwater monitoring well
	SB51L-03-2	Temporary groundwater sampling point
	SB51L-01-24	Properly destroyed sampling point
	EW	Groundwater extraction well
		Soil boring
		Cross section
		Surface structure (e.g. buildings, etc.)
		Removed building

NOTE:
All other symbols used are explained on the figures.

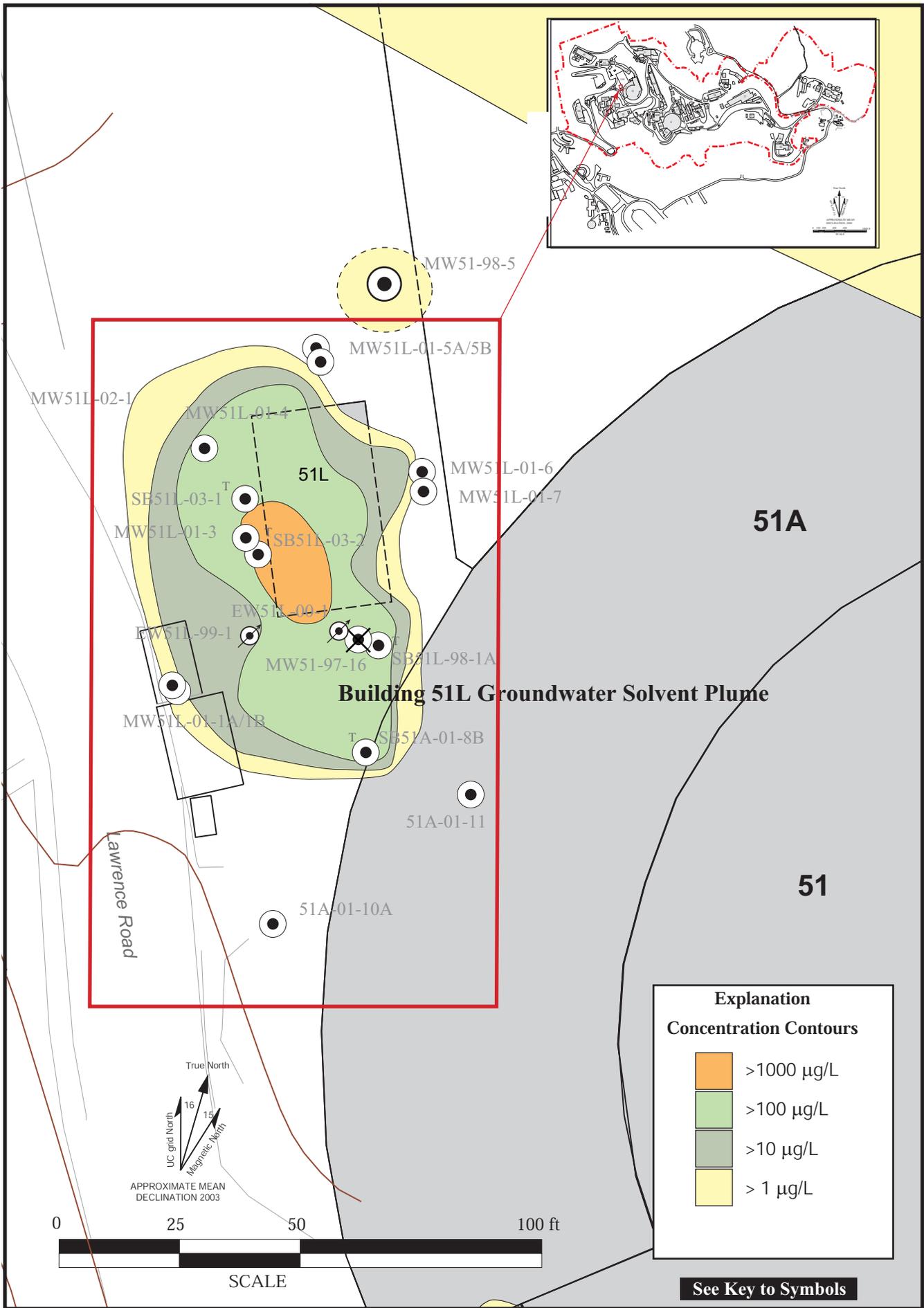


Figure 1. Location of Building 51L Groundwater Solvent Plume Showing Total Halogenated Hydrocarbons in Groundwater (µg/L).

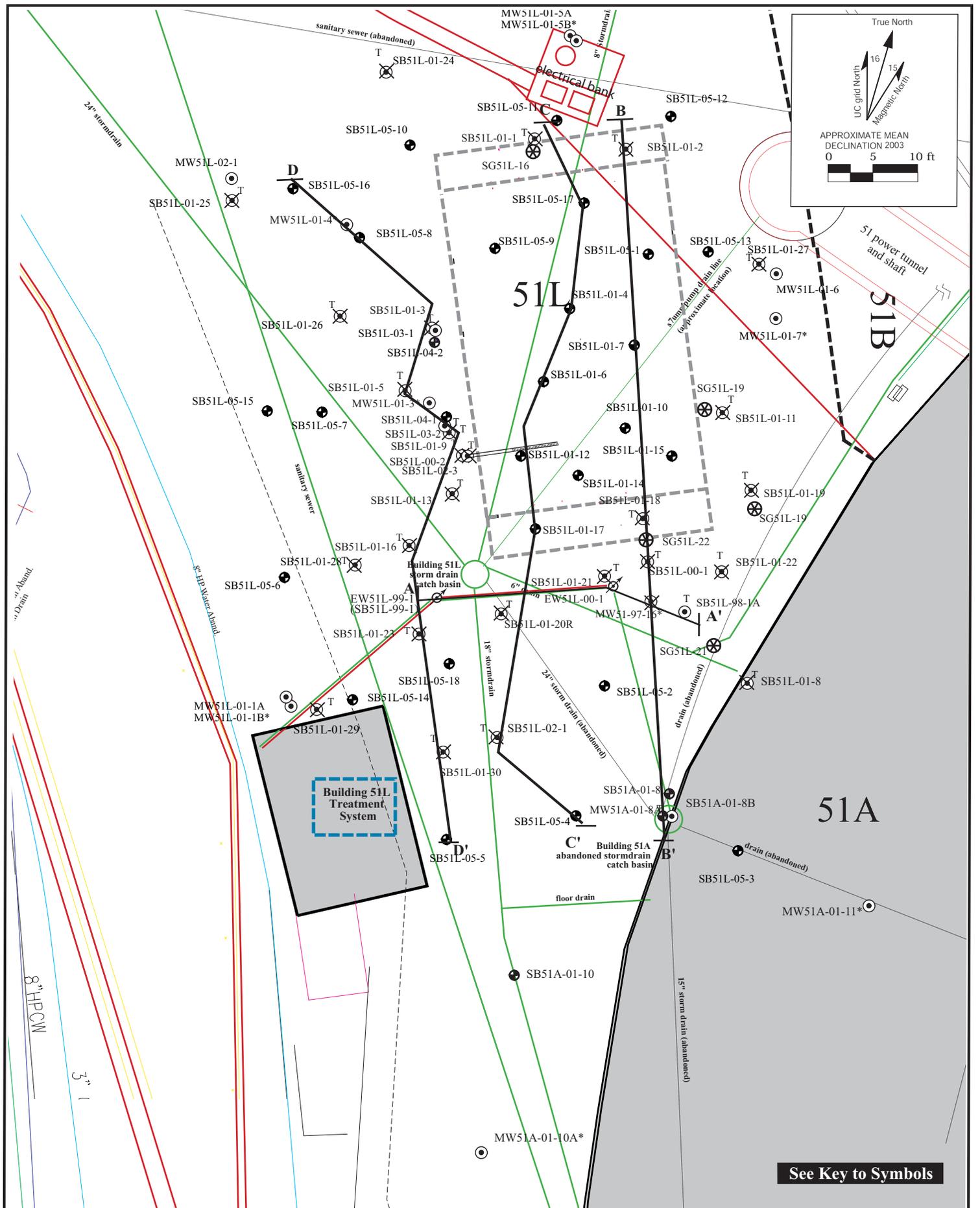


Figure 2. Detailed Site Map Building 51L Area.

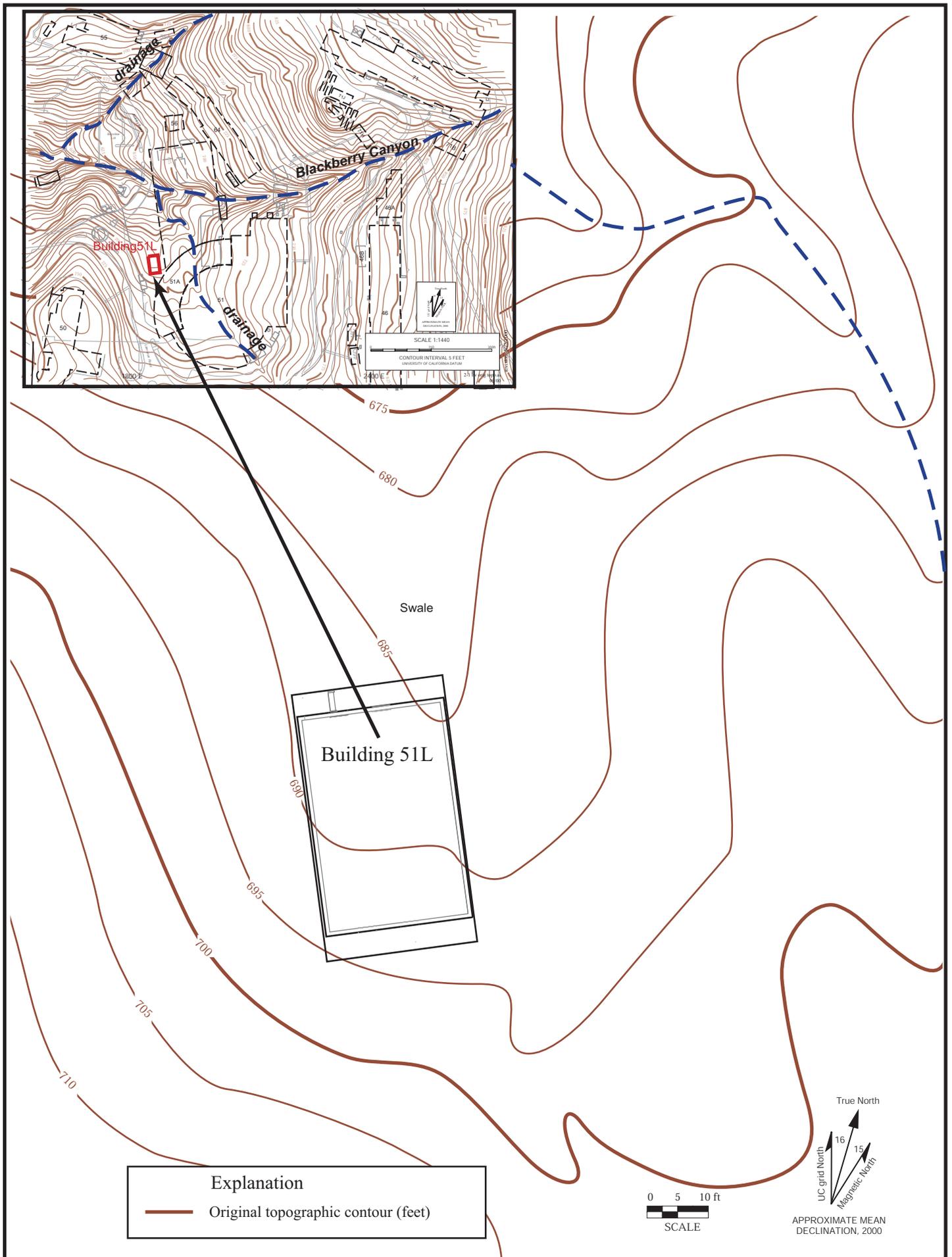


Figure 3. Original Topography Building 51L Area.

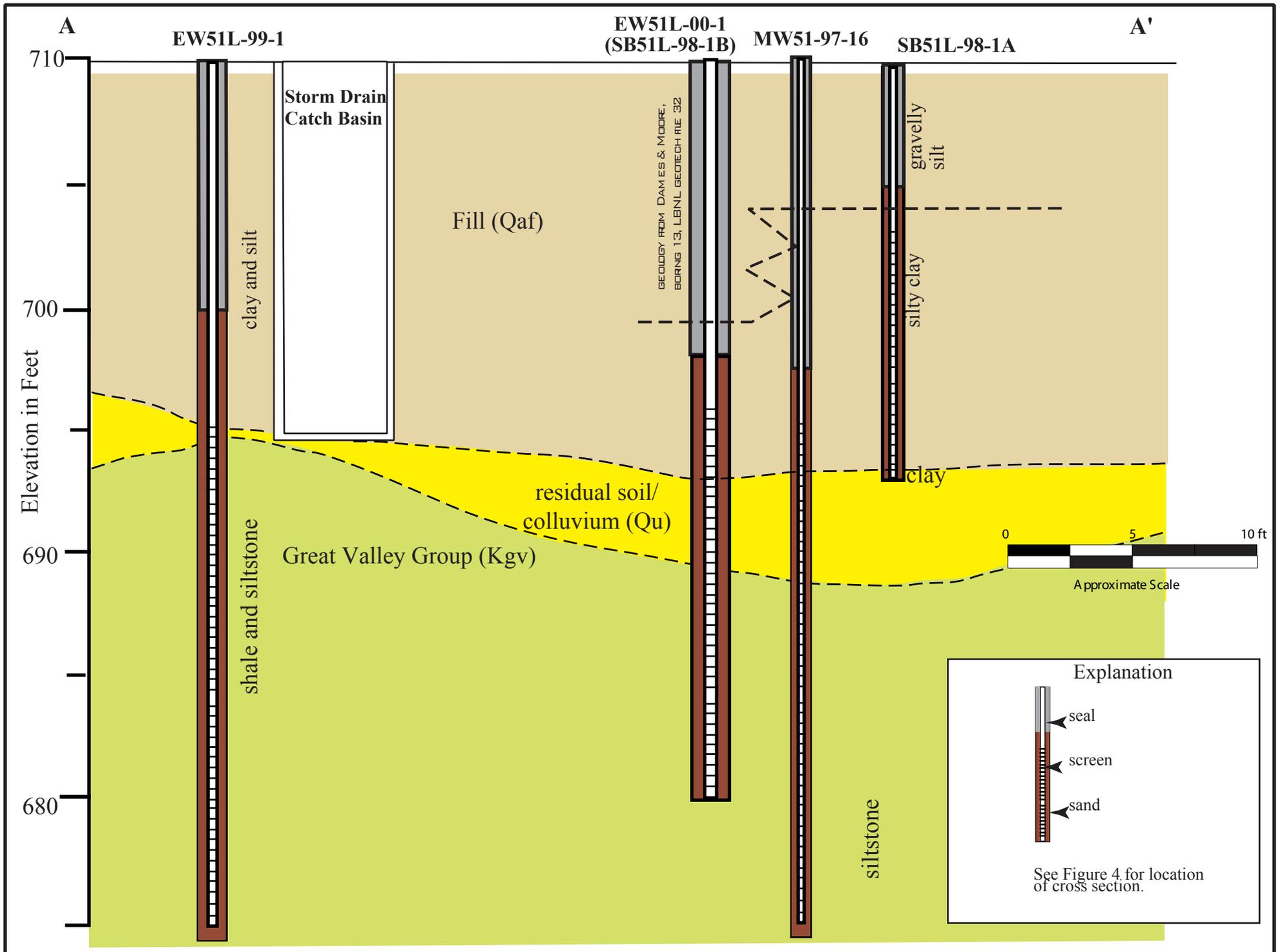


Figure 4 Geologic Cross Section A-A' Building 51L Area.

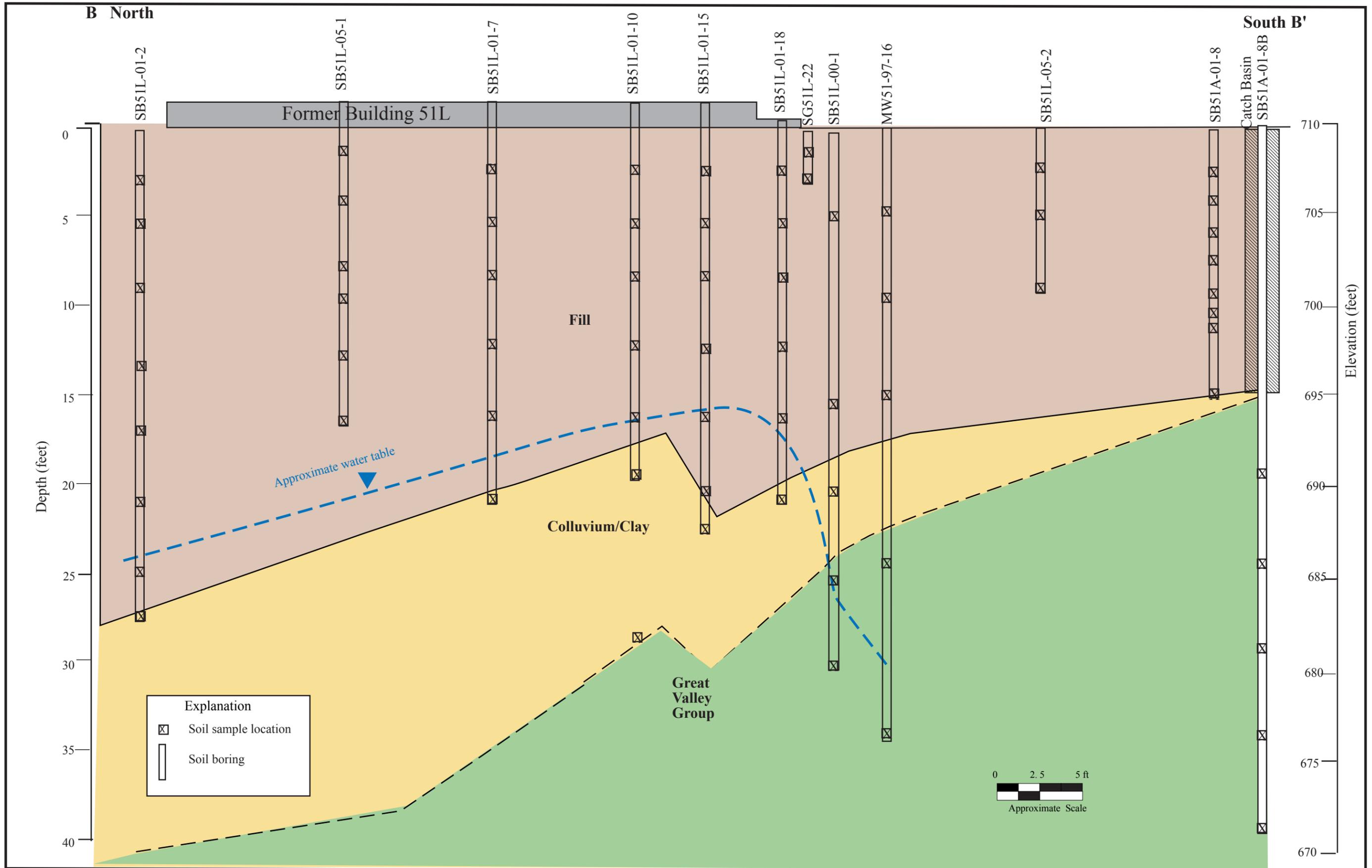


Figure 5. Geologic Cross Section B-B'.

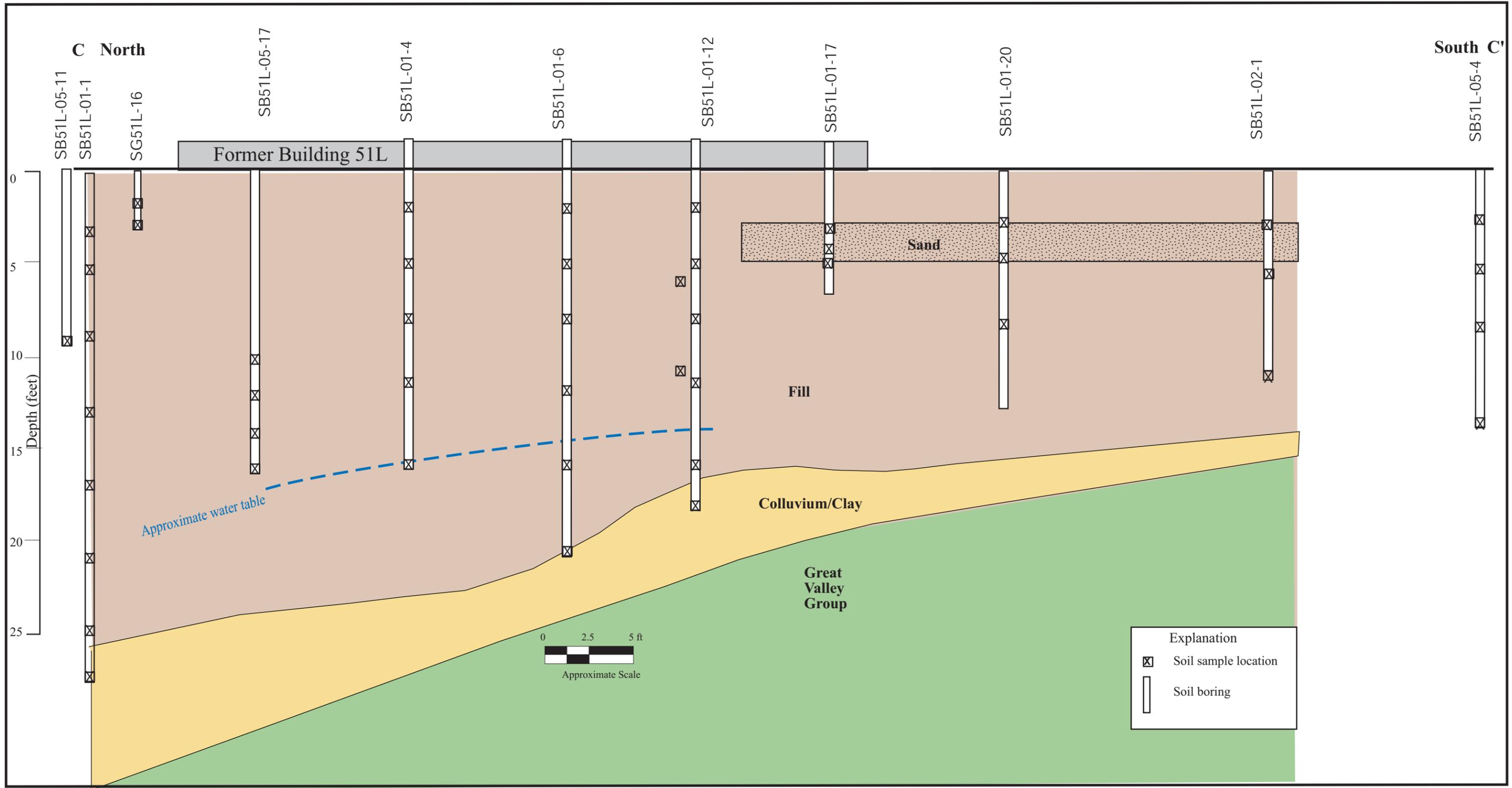


Figure 6. Geologic Cross Section C-C.

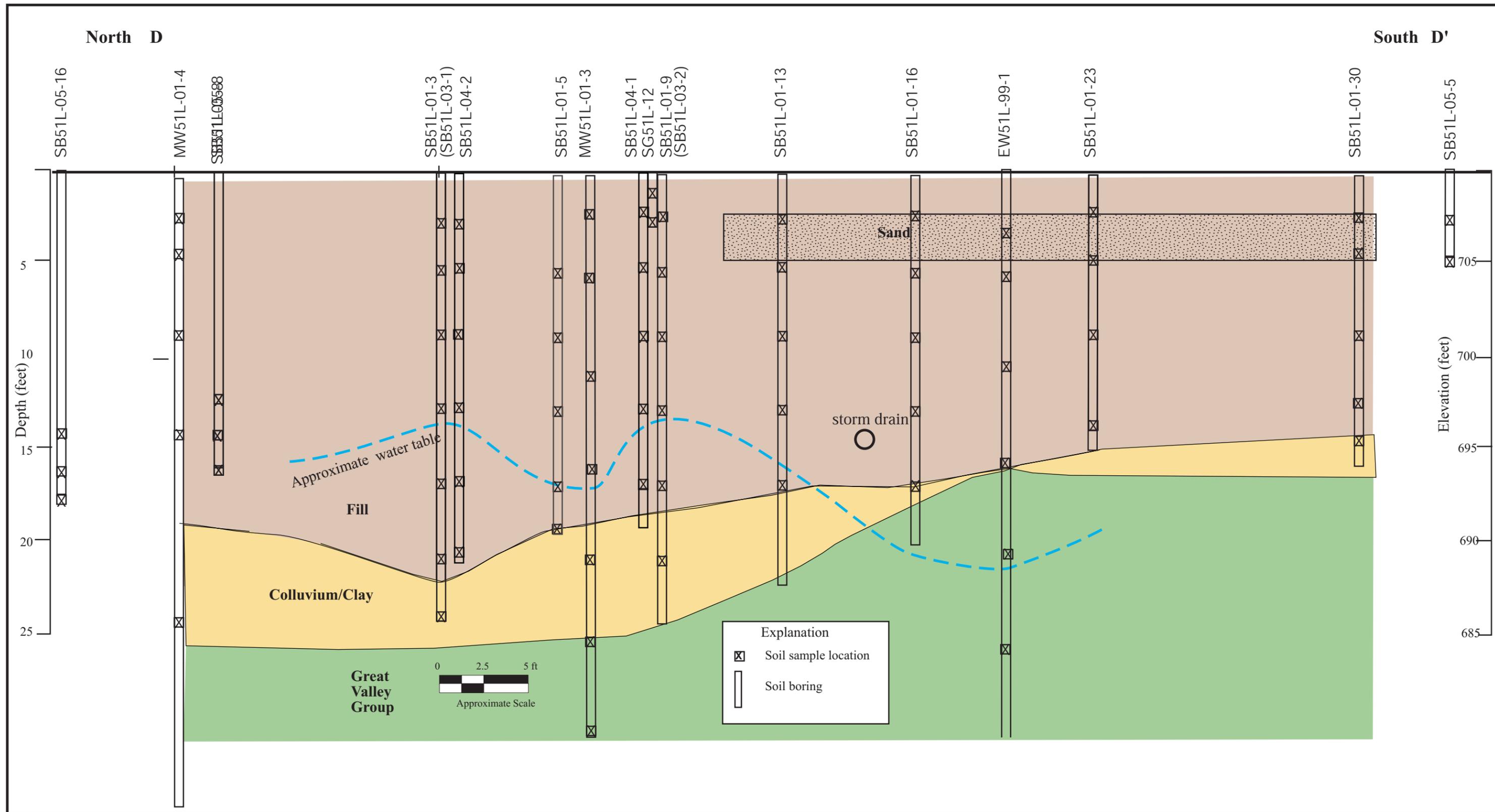


Figure 7. Geologic Cross Section D-D' .

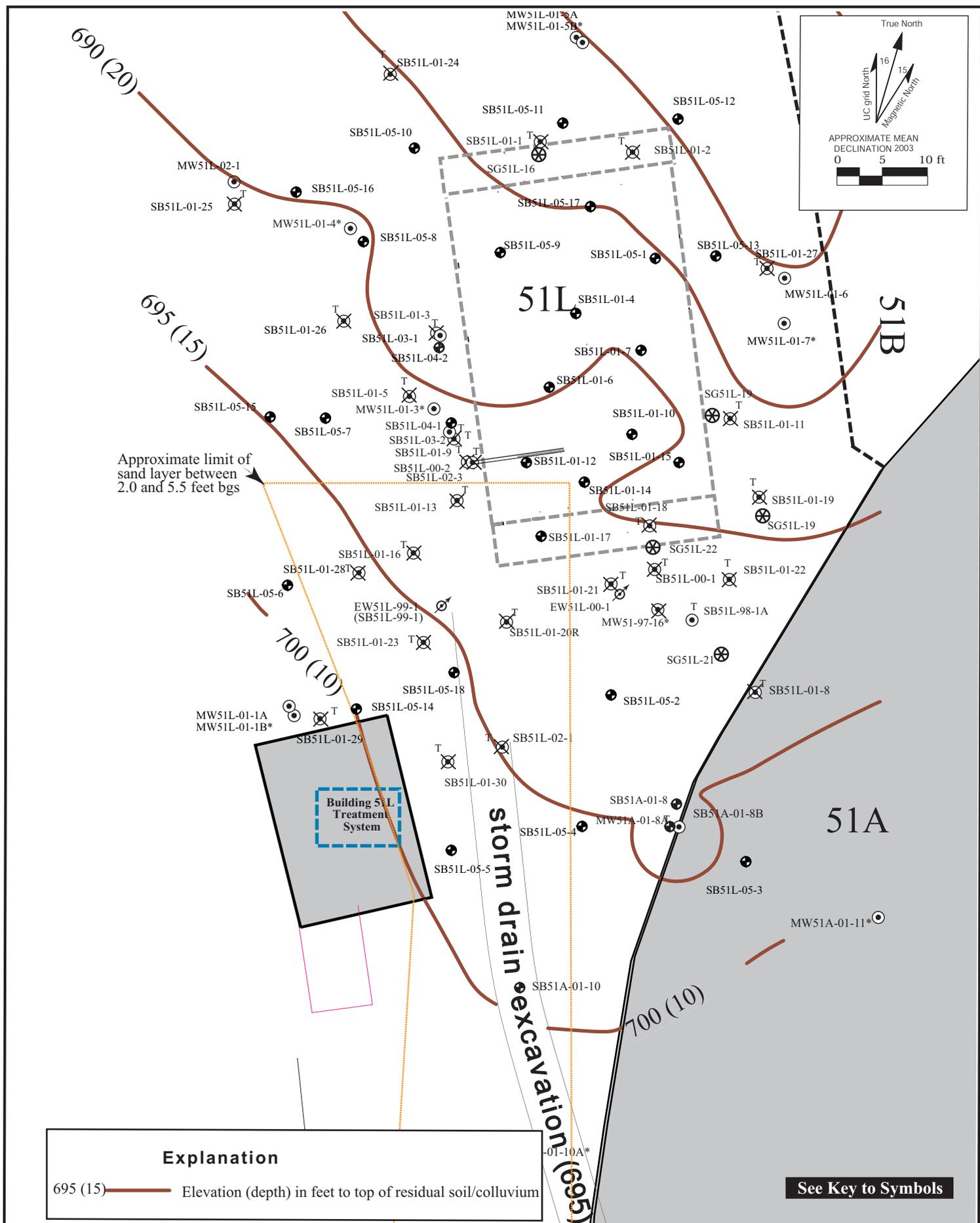


Figure 8. Structural Contour Map of the Top of Residual Soil/Colluvium (Qu).

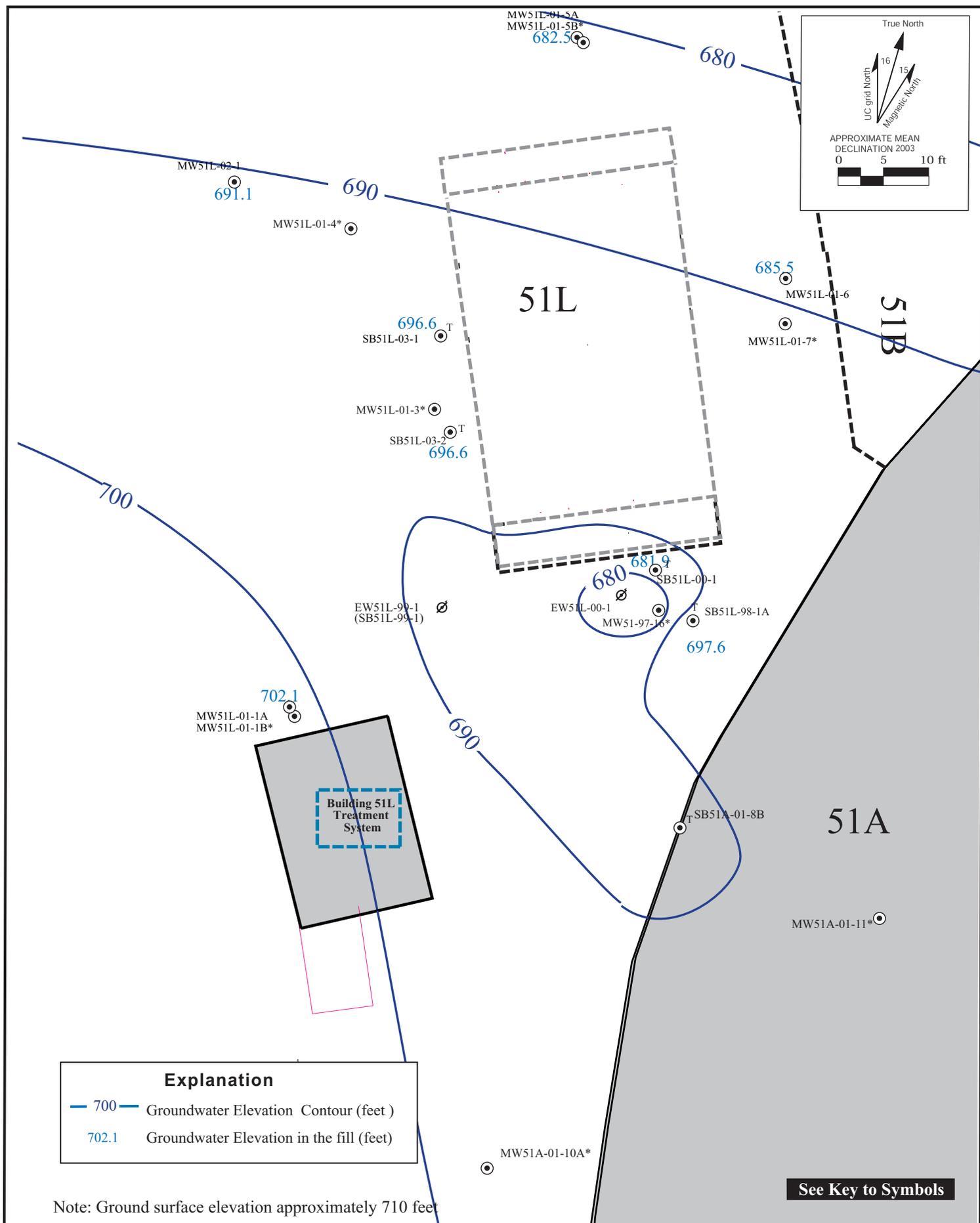


Figure 9 Water Level Elevation Map, Building 51L Area, February 2005.

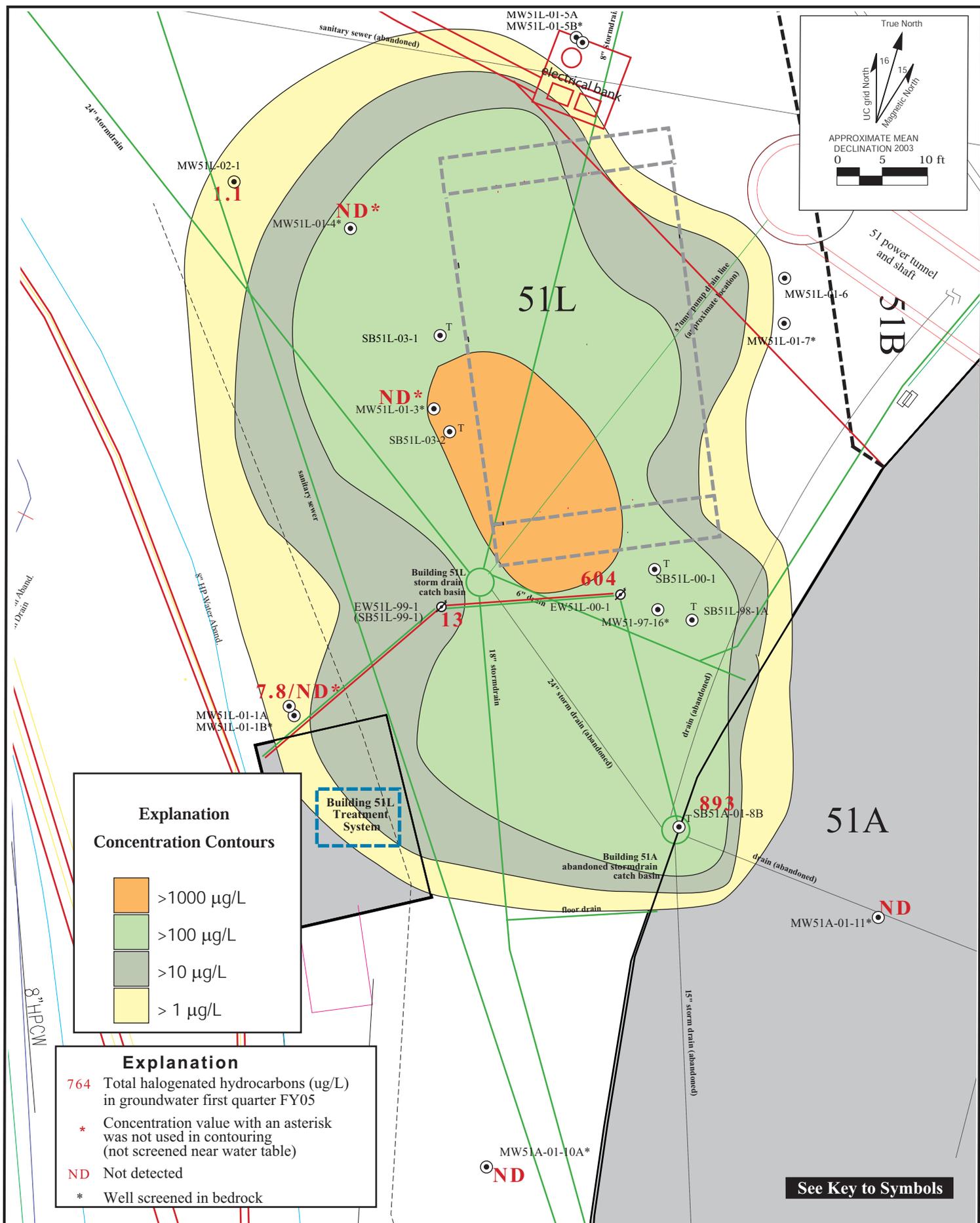


Figure 10. Isoconcentration Contour Map, Total Halogenated Hydrocarbons in Groundwater in Fill, Building 51L Solvent Plume, First Quarter FY05.

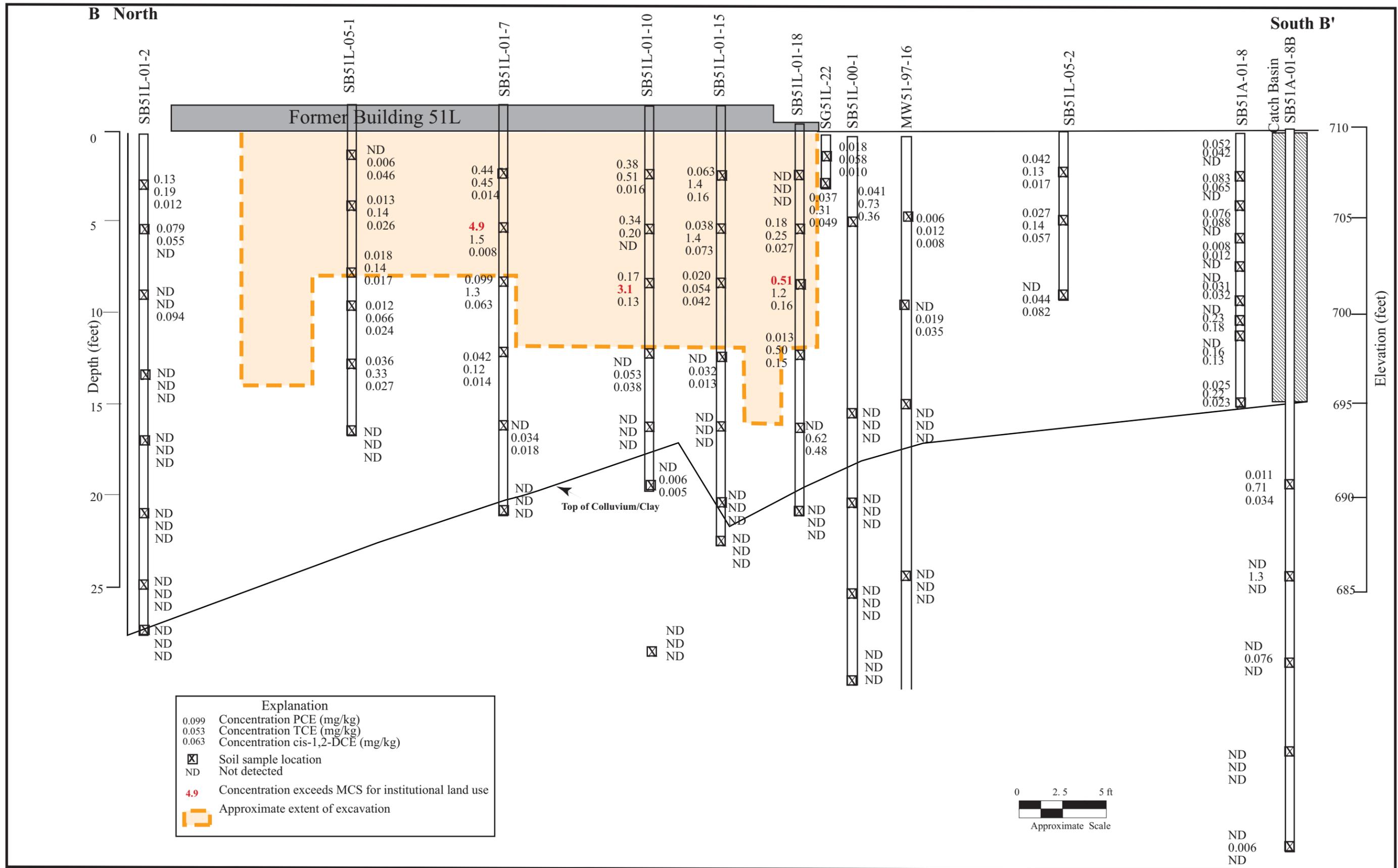


Figure 11. Cross section B-B' Showing Concentrations of PCE, TCE and cis-1,2-DCE Detected in Soil (mg/kg) and Extent of Soil at Concentrations Above MCS for Institutional Land Use.

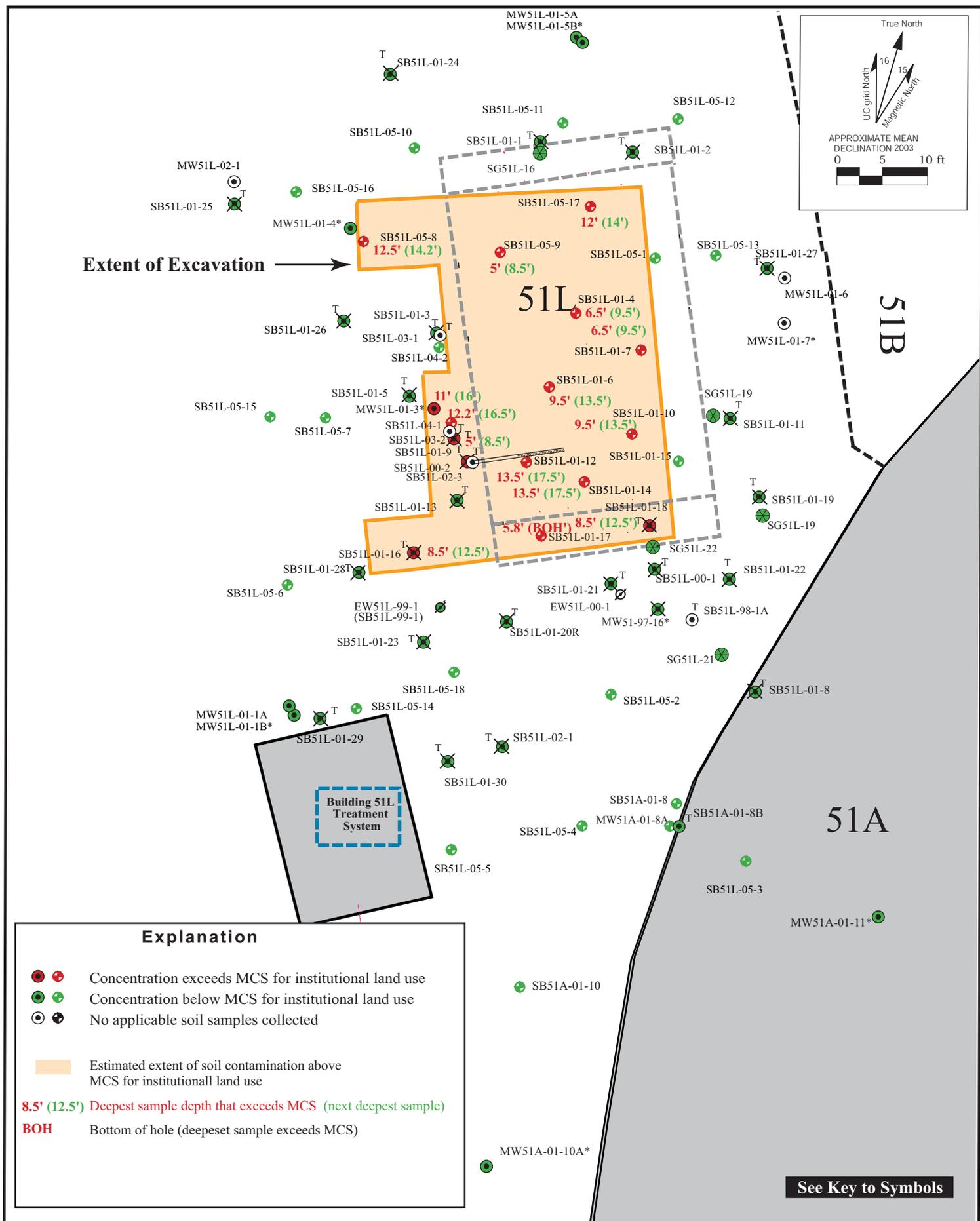


Figure 14. Extent of Soil Contamination Above Risk-Based Media Cleanup Standard for Institutional Land Use.

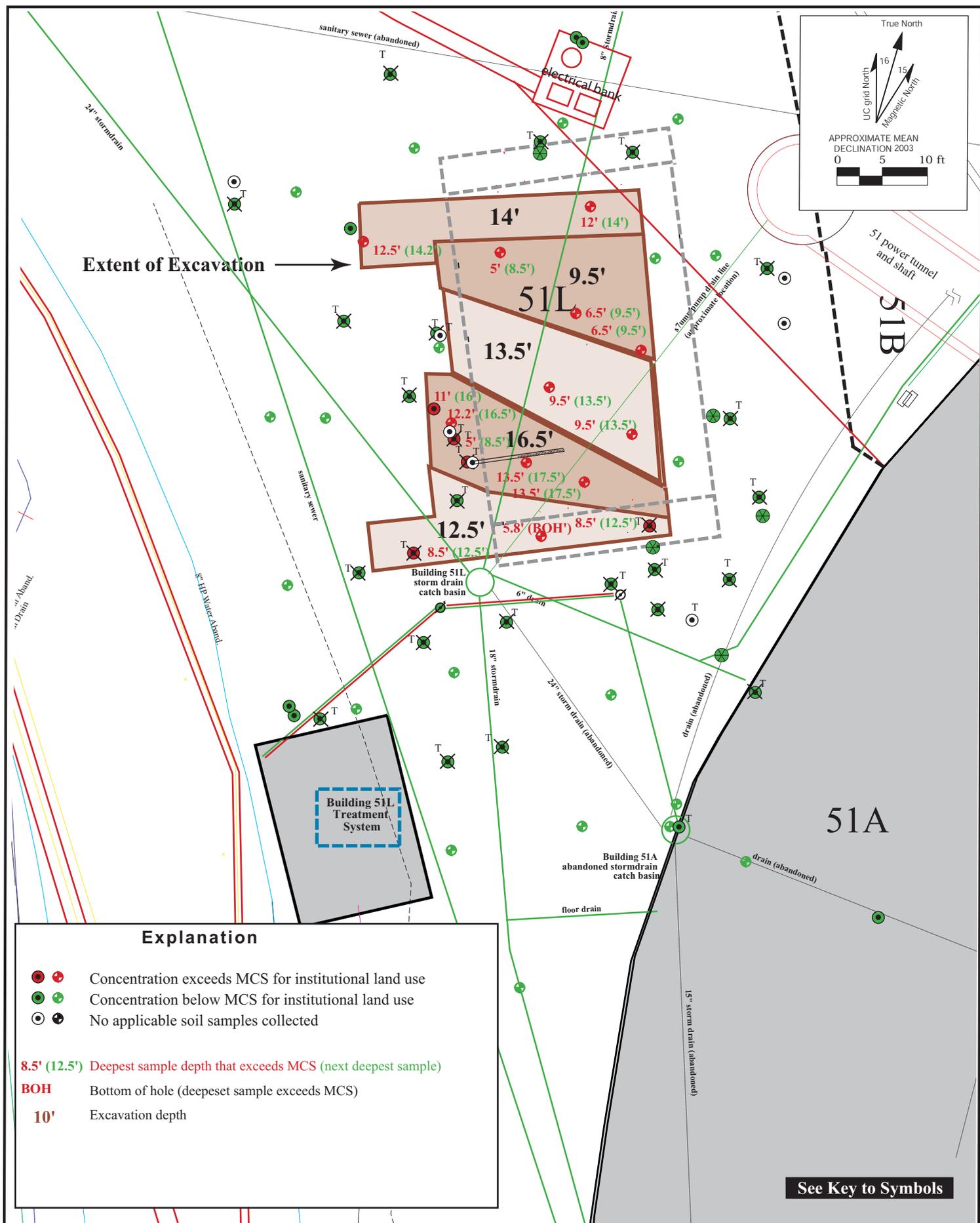


Figure 15. Approximate Depth of Excavation.

Appendix A

Soil Sampling Results from Building 51L Area, Organic Compounds

Appendix A
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690	
Location	Sample ID	Depth	Date	Lab								
MW51-97-16	BS-MW51-97-16-4.2	4.2	Sep-97	BC	<0.005	<0.005	0.0083	<0.005	0.0058	0.012	<0.005	
	BS-MW51-97-16-8.8	8.8			<0.005	<0.005	0.035	<0.005	<0.005	0.019	<0.005	
	BS-MW51-97-16-14	14			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51-97-16-23.7	23.7			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51-97-16-34	34			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
MW51A-01-8A	BS-MW51A-01-8A-17.5	17.5	Sep-01	BC	<0.005	<0.005	<0.005	<0.005	0.041	0.33	<0.005	Hexachlorobutadiene = 0.043
MW51A-01-10A	BS-MW51A-01-10A-2.8	2.8	Oct-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51A-01-10A-7.8	7.8			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51A-01-10A-17.7	17.7			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51A-01-10A-27.5	27.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
MW51A-01-11	BS-MW51A-01-11-2.7	2.7	Sep-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	0.050	<0.005	
	BS-MW51A-01-11-4.2	4.2			<0.005	<0.005	<0.005	<0.005	<0.005	0.018	<0.005	
	BS-MW51A-01-11-9.7	9.7			<0.005	<0.005	0.012	<0.005	<0.005	0.025	<0.005	
	BS-MW51A-01-11-19.9	19.9			<0.005	<0.005	<0.005	<0.005	<0.005	0.0072	<0.005	
	BS-MW51A-01-11-29.9	29.9			<0.005	<0.005	<0.005	<0.005	<0.005	0.0088	<0.005	
	BS-MW51A-01-11-39.8	39.8			<0.005	<0.005	<0.005	<0.005	<0.005	0.0064	<0.005	
MW51L-01-1	BS-MW51L-01-1-2.7	2.7	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005	
	BS-MW51L-01-1-4.1	4.1			<0.005	<0.005	<0.005	<0.005	<0.005	0.0086	<0.005	
	BS-MW51L-01-1-9	9			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-1-14.2	14.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-1-23.5	23.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
					<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
MW51L-01-3	BS-MW51L-01-3-2.5	2.5	Dec-01	BC	0.0064	<0.005	0.031	<0.005	0.021	0.16	<0.005	
	BS-MW51L-01-3-5.7	5.7			0.18	0.07	3.1	0.18	0.02	5	<0.005	
	BS-MW51L-01-3-11	11			0.011	0.0057	0.3	0.06	0.46	1.4	<0.005	
	BS-MW51L-01-3-16	16			0.04	0.0079	0.36	0.16	<0.005	<0.005	<0.005	
	BS-MW51L-01-3-20.8	20.8			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-3-25.4	25.4			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-3-30.2	30.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-3-40	40			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-3-50	50			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
					<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
MW51L-01-4	BS-MW51L-01-4-2.4	2.4	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-4-4.1	4.1			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-4-8.6	8.6			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-4-14	14			0.016	0.011	0.16	0.14	0.070	2.2	<0.005	
	BS-MW51L-01-4-24.5	24.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-4-33.8	33.8			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-4-43.7	43.7			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
					<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected	
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690		
Location	Sample ID	Depth	Date	Lab									
MW51L-01-5	BS-MW51L-01-5-4.5	4.5	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-MW51L-01-5-10	10			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-5-20	20	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-MW51L-01-5-30	30			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-5-40	40			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-5-50	50			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-5-59.5	59.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
MW51L-01-7	BS-MW51L-01-7-35.5	35.5	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-MW51L-01-7-43	43			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-7-53	53			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-MW51L-01-7-62.5	62.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
MW51L-02-1	BS-MW51L-02-1-24.8	24.8	Jan-02	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-MW51L-02-1-29.3				<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51A-01-8 (Properly destroyed)	BS-MW51A-01-8-2.3	2.3	Aug-01	BC	<0.005	<0.005	<0.005	<0.005	0.052	0.042	<0.005		
	BS-MW51A-01-8-3.7	3.7			<0.005	<0.005	<0.005	<0.005	0.083	0.065	<0.005		
	BS-MW51A-01-8-5.5	5.5			<0.005	<0.005	<0.005	<0.005	0.076	0.088	<0.005		
	BS-MW51A-01-8-6.8	6.8			<0.005	<0.005	<0.005	<0.005	0.0078	0.012	<0.005		
	BS-MW51A-01-8-8.9	8.9			<0.005	<0.005	0.032	0.0069	<0.005	0.031	<0.005		
	BS-MW51A-01-8-9.7	9.7			<0.005	<0.005	0.18	0.040	<0.005	0.23	<0.005		
	BS-MW51A-01-8-11	11			<0.005	<0.005	0.13	0.025	<0.005	0.16	<0.005		
	BS-MW51A-01-8-14.6	14.6			<0.005	<0.005	0.023	<0.005	0.025	0.22	<0.005		
SB51A-01-8B	BS-SB51A-01-8B-19.5	19.5	Jun-02	BC	<0.005	<0.005	0.034	<0.005	0.011	0.71	<0.005		
	BS-SB51A-01-8B-24.5	24.5			<0.005	<0.005	<0.005	<0.005	<0.005	1.3	<0.005		
	BS-SB51A-01-8B-29.5	29.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.076	<0.005		
	BS-SB51A-01-8B-34.5	34.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51A-01-8B-39.5	39.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.0058	<0.005		
SB51A-01-10	BS-MW51A-01-10-2.9	2.9	Aug-01	BC	<0.005	<0.005	<0.005	<0.005	0.010	0.0097	<0.005		
	BS-MW51A-01-10-4.5	4.5			<0.005	<0.005	<0.005	<0.005	0.015	0.035	<0.005		
	BS-MW51A-01-10-9	9			<0.005	<0.005	<0.005	<0.005	<0.005	0.015	<0.005		
SB51L-99-1	BS-SB51L-99-1-3.2	3.2	Oct-99	BC	<0.005	<0.005	<0.005	<0.005	0.012	<0.005	<0.005		
	BS-SB51L-99-1-6	6			<0.01	<0.01	0.043	<0.01	0.31	0.25	<0.01		
	BS-SB51L-99-1-10.5	10.5			<0.005	<0.005	0.028	<0.005	0.11	0.42	<0.005		
	BS-SB51L-99-1-15.4	15.4			<0.005	<0.005	0.015	<0.005	<0.005	0.0051	<0.005		
	BS-SB51L-99-1-20.5	20.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005		
	BS-SB51L-99-1-25.5	25.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-99-1-30.1	30.1			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-99-1-34.6	34.6			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected	
Target Risk Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690		
Location	Sample ID	Depth	Date	Lab									
SB51L-00-1	BS-SB51L-00-1-9.5	9.5	Sep-00	BC	0.019	<0.005	0.36	0.077	0.041	0.73	<0.005		
	BS-SB51L-00-1-15	15			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-00-1-20.4	20.4			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-00-1-25	25	Sep-00	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-00-1-29.5	29.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-00-2	BS-SB51L-00-2-2.7	2.7	Sep-00	BC	<0.005	<0.005	0.012	<0.005	0.018	0.25	<0.005		
	BS-SB51L-00-2-3.6	3.6			<0.005	<0.005	0.025	0.0057	1.4	1.1	<0.005		
	BS-SB51L-00-2-5.6	5.6			<0.005	<0.005	0.049	0.0053	1.3	1.3	<0.005		
	BS-SB51L-00-2-8.5	8.5			<0.005	<0.005	0.058	0.0092	21	24	<0.005		
SB51L-00-2	BS-SB51L-00-2-14	14	Sep-00	BC	<0.03	<0.03	0.075	<0.03	0.42	10	<0.03		
	BS-SB51L-00-2-18.5	18.5			0.0099	<0.005	0.051	0.029	<0.005	0.0065	<0.005		
	BS-SB51L-00-2-24.5	24.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-00-2-29.2	29.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-00-2-34.5	34.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	Ethylbenzene=0.0076	
SB51L-01-1	BS-SB51L-01-1-3	3	May-01	BC	0.013	<0.005	0.018	<0.005	0.026	0.28	0.019		
	BS-SB51L-01-1-5	5			<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005		
	BS-SB51L-01-1-8.5	8.5			<0.005	<0.005	0.018	<0.005	0.056	0.30	0.0069		
	BS-SB51L-01-1-12.7	12.7			<0.005	<0.005	0.0073	<0.005	<0.005	0.0097	<0.005		
	BS-SB51L-01-1-16.5	16.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-1-20.5	20.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-1-24.5	24.5			<0.005	<0.005	0.0095	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-1-27.3	27.3			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-2	BS-SB51L-01-2-2.5	2.5	May-01	BC	<0.005	<0.005	0.012	<0.005	0.13	0.19	<0.005		
	BS-SB51L-01-2-5	5			<0.005	<0.005	<0.005	<0.005	0.079	0.055	<0.005		
	BS-SB51L-01-2-8.5	8.5			<0.005	<0.005	0.094	0.018	<0.005	<0.005	<0.005		
	BS-SB51L-01-2-13.2	13.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-2-16.5	16.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-2-20.5	20.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-2-24.5	24.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-2-27.2	27.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
SB51L-01-3	BS-SB51L-01-3-2.3	2.3	May-01	CLS	<0.005	<0.005	<0.005	0.032	0.023	0.023	<0.005		
	BS-SB51L-01-3-5	5			0.1	0.029	0.17	0.036	<0.005	0.55	<0.005		
	BS-SB51L-01-3-8.5	8.5			0.087	0.016	0.11	0.032	0.015	0.79	<0.005		
	BS-SB51L-01-3-12.5	12.5			0.012	0.0066	0.066	0.012	0.34	0.34	<0.005		
	BS-SB51L-01-3-16.5	16.5			0.016	<0.005	0.040	0.017	0.005	0.49	<0.005		
	BS-SB51L-01-3-20.5	20.5			0.12	0.036	0.37	0.087	0.021	0.83	<0.005	vinyl chloride=0.0056	
SB51L-01-4	BS-SB51L-01-4-3.5	3.5	May-01	BC	<0.005	<0.005	0.015	<0.005	0.0051	0.083	<0.005		
	BS-SB51L-01-4-6.5	6.5			<0.005	<0.005	0.078	0.0079	2.1	1.8	<0.005		
	BS-SB51L-01-4-9.5	9.5			<0.005	<0.005	<0.005	<0.005	0.0075	0.058	<0.005		
	BS-SB51L-01-4-13.5	13.5			<0.005	<0.005	0.014	<0.005	0.037	0.094	<0.005		
	BS-SB51L-01-4-17.5	17.5			0.0098	<0.005	0.022	0.0087	0.030	0.21	<0.005		

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690	
Location	Sample ID	Depth	Date	Lab								
SB51L-01-5	BS-SB51L-01-5-5	5	May-01	CLS	0.1	0.05	0.43	0.0066	<0.005	0.019	<0.005	
	BS-SB51L-01-5-8.6	8.6			<0.005	<0.005	0.024	0.0072	<0.005	0.16	<0.005	p- & m-xylenes=0.0053
	BS-SB51L-01-5-12.5	12.5			0.023	0.0057	0.19	0.036	<0.005	0.83	<0.005	
	BS-SB51L-01-5-16.5	16.5			0.018	0.0059	0.12	0.064	<0.005	0.47	<0.005	
SB51L-01-6	BS-SB51L-01-6-18.8	18.8	May-01	BC	<0.005	<0.005	0.020	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-6-3.5	3.5			0.0061	<0.005	0.040	0.028	0.13	0.51	<0.005	
	BS-SB51L-01-6-6.5	6.5			<0.005	<0.005	0.012	<0.005	0.22	0.10	<0.005	
	BS-SB51L-01-6-9.5	9.5			<0.005	<0.005	0.054	0.0052	1.9	0.97	<0.005	
	BS-SB51L-01-6-13.5	13.5			0.013	<0.005	0.035	0.039	0.052	0.69	<0.005	
	BS-SB51L-01-6-17.5	17.5			0.026	<0.005	0.036	0.026	<0.005	0.063	<0.005	
SB51L-01-7	BS-SB51L-01-6-22.7	22.7	May-01	BC	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-7-3.5	3.5			<0.005	<0.005	0.014	<0.005	0.44	0.45	<0.005	
	BS-SB51L-01-7-6.5	6.5			<0.005	0.0084	0.0084	<0.005	4.9	1.5	<0.005	
	BS-SB51L-01-7-9.5	9.5			0.012	0.0076	0.063	0.12	0.099	1.3	<0.005	
	BS-SB51L-01-7-13.5	13.5			<0.005	<0.005	0.014	0.010	0.042	0.12	<0.005	
	BS-SB51L-01-7-17.5	17.5			0.016	<0.005	0.018	0.016	<0.005	0.034	<0.005	
SB51L-01-8	BS-SB51L-01-7-22.1	22.1	May-01	CLS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-8-2	2			<0.005	<0.005	<0.005	<0.005	0.0076	0.005	<0.005	
	BS-SB51L-01-8-5	5			<0.005	<0.005	<0.005	<0.005	0.011	0.0089	<0.005	
	BS-SB51L-01-8-8.5	8.5			<0.005	<0.005	0.006	<0.005	0.021	0.023	<0.005	
	BS-SB51L-01-8-12.5	12.5			<0.005	<0.005	0.018	0.007	<0.005	0.018	<0.005	
	BS-SB51L-01-8-16.5	16.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.0062	<0.005	
SB51L-01-9	BS-SB51L-01-8-18.3	18.3	May-01	CLS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-9-2	2			0.009	<0.005	0.041	<0.005	0.19	0.59	<0.005	
	BS-SB51L-01-9-5	5			0.044	0.0087	0.55	0.034	0.25	3.6	<0.005	
	BS-SB51L-01-9-8.5	8.5			0.0054	<0.005	0.18	0.0073	0.29	0.73	<0.005	
	BS-SB51L-01-9-12.5	12.5			<0.005	<0.005	0.028	<0.005	0.18	0.51	<0.005	p- & m-xylenes=0.0052
	BS-SB51L-01-9-16.5	16.5			<0.005	<0.005	0.012	<0.005	0.009	0.24	<0.005	
SB51L-01-10	BS-SB51L-01-9-20.5	20.5	May-01	BC	<0.005	<0.005	0.1	0.044	<0.005	0.029	<0.005	toluene=0.0059 1,2,4-Trimethylbenzene=0.0064 p- & m-xylenes=0.0097
	BS-SB51L-01-10-3.5	3.5			0.0066	<0.005	0.016	<0.005	0.38	0.51	<0.005	
	BS-SB51L-01-10-6.5	6.5			<0.005	<0.005	<0.005	<0.005	0.34	0.20	<0.005	
	BS-SB51L-01-10-9.5	9.5			0.021	0.025	0.13	0.029	0.17	3.1	<0.005	
	BS-SB51L-01-10-13.5	13.5			0.016	<0.005	0.038	0.048	<0.005	0.053	<0.005	
	BS-SB51L-01-10-17.5	17.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-11	BS-SB51L-01-10-20.6	20.6	May-01	BC	0.0054	<0.005	0.0052	<0.005	<0.005	0.0056	<0.005	
	BS-SB51L-01-11-2	2			0.048	0.035	<0.005	<0.005	<0.005	<0.005	<0.005	Naphthalene=0.0077
	BS-SB51L-01-11-5	5			0.024	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-11-8	8			0.088	0.074	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-11-12	12			0.014	0.0064	0.012	0.0075	<0.005	0.048	<0.005	
	BS-SB51L-01-11-16	16			0.023	0.0095	0.005	<0.005	<0.005	0.039	<0.005	
	BS-SB51L-01-11-20	20			<0.005	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	
BS-SB51L-01-11-23.3	23.3	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690	
Location	Sample ID	Depth	Date	Lab								
SB51L-01-12	BS-SB51L-01-12-3.5	3.5	May-01	BC	<0.005	<0.005	0.0059	<0.005	2.0	0.45	<0.005	
	BS-SB51L-01-12-6.7	6.7			<0.005	<0.005	0.099	<0.005	2.3	0.96	<0.005	
	BS-SB51L-01-12-9.5	9.5			<0.005	<0.005	0.049	<0.005	5.0	1.3	<0.005	
	BS-SB51L-01-12-13.5	13.5			0.0057	0.0064	0.12	0.019	1.1	3.1	<0.005	
	BS-SB51L-01-12-17.5	17.5			0.80	0.029	0.40	0.45	0.0076	1.0	<0.005	
	BS-SB51L-01-12-19.2	19.2			0.092	0.026	0.52	0.45	<0.005	0.0052	<0.005	Vinyl Chloride=0.012
SB51L-01-13	BS-SB51L-01-13-2	2	May-01	CLS	<0.005	<0.005	<0.005	<0.005	0.023	0.0097	<0.005	
	BS-SB51L-01-13-5	5			<0.005	<0.005	<0.005	<0.005	0.037	0.018	<0.005	
	BS-SB51L-01-13-8.5	8.5			<0.005	<0.005	0.18	0.0081	0.2	0.4	<0.005	
	BS-SB51L-01-13-12.5	12.5			<0.005	<0.005	0.037	0.0068	0.026	0.52	<0.005	
	BS-SB51L-01-13-16.6	16.6			<0.005	<0.005	0.24	0.059	<0.005	<0.005	<0.005	
SB51L-01-14	BS-SB51L-01-14-4	4	May-01	BC	<0.005	<0.005	<0.005	<0.005	0.072	0.021	<0.005	
	BS-SB51L-01-14-6.4	6.4			<0.005	<0.005	0.014	<0.005	0.19	0.076	<0.005	
	BS-SB51L-01-14-9.5	9.5			<0.005	<0.005	0.12	<0.005	1.6	0.86	<0.005	
	BS-SB51L-01-14-13.5	13.5			<0.005	<0.005	0.066	0.0056	0.66	0.90	<0.005	
	BS-SB51L-01-14-17.5	17.5			0.096	0.027	0.40	0.33	<0.005	<0.005	<0.005	
	BS-SB51L-01-14-23.1	23.1			<0.005	<0.005	0.057	0.034	<0.005	<0.005	<0.005	
SB51L-01-15	BS-SB51L-01-15-3.5	3.5	May-01	BC	0.085	0.026	0.16	0.028	0.063	1.4	<0.005	
	BS-SB51L-01-15-6.5	6.5			0.038	0.0082	0.073	0.020	0.038	1.4	<0.005	
	BS-SB51L-01-15-9.5	9.5			0.013	<0.005	0.042	0.025	0.020	0.054	<0.005	
	BS-SB51L-01-15-13.5	13.5			0.013	<0.005	0.013	0.0067	<0.005	0.032	<0.005	
	BS-SB51L-01-15-17.5	17.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-15-21.5	21.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-16	BS-SB51L-01-15-23.4	23.4			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-16-2	2	May-01	CLS	<0.005	<0.005	<0.005	<0.005	0.054	0.021	<0.005	
	BS-SB51L-01-16-5	5			<0.005	<0.005	0.014	<0.005	0.28	0.23	<0.005	
	BS-SB51L-01-16-8.5	2			0.045	0.0068	0.23	0.0095	0.58	2.6	<0.005	
	BS-SB51L-01-16-12.5	12.5			<0.005	<0.005	0.024	<0.005	0.012	0.23	<0.005	
	BS-SB51L-01-16-16.5	16.5			<0.005	<0.005	0.11	0.011	<0.005	<0.005	<0.005	
SB51L-01-17	BS-SB51L-01-17-3.5	3.5			May-01	BC	<0.005	<0.005	<0.005	<0.005	0.028	0.0059
	BS-SB51L-01-17-5	5	<0.005	<0.005			<0.005	<0.005	0.093	0.022	<0.005	
	BS-SB51L-01-17-5.8	5.8	<0.005	<0.005			0.046	<0.005	2.0	0.48	<0.005	
SB51L-01-18	BS-SB51L-01-18-2.5	2.5	May-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-18-5.5	5.5			<0.005	<0.005	0.027	<0.005	0.18	0.25	<0.005	
	BS-SB51L-01-18-8.5	8.5			0.011	<0.005	0.16	0.023	0.51	1.2	<0.005	
	BS-SB51L-01-18-12.5	12.5	0.012	<0.005	0.15	0.080	0.013	0.50	<0.005			
	BS-SB51L-01-18-16.5	16.5	May-01	BC	0.080	0.026	0.48	0.13	<0.005	0.62	<0.005	
	BS-SB51L-01-18-21.5	21.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Appendix A (cont'd.)
 Soil Sampling Results from Building 51L Area
 Organic Compounds
 (Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690	
Location	Sample ID	Depth	Date	Lab								
SB51L-01-19	BS-SB51L-01-19-2.5	2.5	May-01	BC	0.024	<0.005	0.040	<0.005	0.075	0.41	0.0084	
	BS-SB51L-01-19-5	5			<0.005	<0.005	<0.005	<0.005	<0.005	0.027	<0.005	
	BS-SB51L-01-19-8	8			0.0059	<0.005	0.0076	<0.005	0.0097	0.061	<0.005	
	BS-SB51L-01-19-12.5	12.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-19-16	16			0.0066	<0.005	<0.005	<0.005	<0.005	0.024	<0.005	
	BS-SB51L-01-19-20	20			<0.005	<0.005	<0.005	<0.005	<0.005	0.029	<0.005	
	BS-SB51L-01-19-22.1	22.1			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-20	BS-SB51L-01-20-2	2	May-01	CLS	<0.005	<0.005	<0.005	<0.005	0.032	0.0058	<0.005	
	BS-SB51L-01-20-4.8	4.8			<0.005	<0.005	0.095	<0.005	0.095	0.18	<0.005	
	BS-SB51L-01-20-8.5	8.5			<0.005	<0.005	0.18	<0.005	0.18	0.52	<0.005	
SB51L-01-21	BS-SB51L-01-21-5.5	5.5	May-01	BC	<0.005	<0.005	0.012	<0.005	0.012	0.014	<0.005	
	BS-SB51L-01-21-8.5	8.5			<0.005	<0.005	0.029	<0.005	0.080	0.065	<0.005	
	BS-SB51L-01-21-12.5	12.5			<0.005	<0.005	0.028	<0.005	0.19	0.13	<0.005	
	BS-SB51L-01-21-17	17			0.047	0.0051	0.68	0.12	<0.005	0.0095	<0.005	
SB51L-01-22	BS-SB51L-01-22-2	2	May-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	0.0053	<0.005	
	BS-SB51L-01-22-3.5	3.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.0074	<0.005	
	BS-SB51L-01-22-8	8			<0.005	<0.005	<0.005	<0.005	<0.005	0.014	<0.005	
	BS-SB51L-01-22-12	12			<0.005	<0.005	0.018	<0.005	0.016	0.12	<0.005	
	BS-SB51L-01-22-17	17			<0.005	<0.005	0.019	<0.005	<0.005	0.094	<0.005	
	BS-SB51L-01-22-20.5	20.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-23	BS-SB51L-01-23-1.8	1.8	May-01	BC	<0.005	<0.005	<0.005	<0.005	0.030	0.017	<0.005	
	BS-SB51L-01-23-4.8	4.8			<0.005	<0.005	0.0086	<0.005	0.098	0.066	<0.005	
	BS-SB51L-01-23-8.5	8.5			<0.005	<0.005	0.026	<0.005	0.11	0.16	<0.005	
	BS-SB51L-01-23-13.3	13.3			<0.005	<0.005	0.31	0.076	<0.005	0.018	<0.005	
SB51L-01-24	BS-SB51L-01-24-2	2	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-24-8.5	8.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-24-12	12			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-24-16.5	16.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-24-20.5	20.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-24-24.5	24.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-25	BS-SB51L-01-25-2	2	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-25-5	5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-25-8.5	8.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0067	
	BS-SB51L-01-25-12.5	12.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-25-16.5	16.5			0.028	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-25-18.7	18.7			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SB51L-01-26	BS-SB51L-01-26-2	2	Jul-01	BC	0.022	<0.005	0.0068	0.016	<0.005	<0.005	<0.005	
	BS-SB51L-01-26-5	5			0.021	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected	
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690		
Location	Sample ID	Depth	Date	Lab									
SB51L-01-26	BS-SB51L-01-26-8.5	8.5	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-01-26-12.5	12.5			0.021	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-01-26-16.5	16.5			0.028	0.0098	0.020	0.020	<0.005	0.043	<0.005		
	BS-SB51L-01-26-19.2	19.2			0.030	<0.005	0.090	0.035	<0.005	<0.005	<0.005		
SB51L-01-27	BS-SB51L-01-27-2	2	Jul-01	BC	0.022	<0.005	0.050	0.021	<0.005	0.042	<0.005		
	BS-SB51L-01-27-5	5			<0.005	<0.005	<0.005	<0.005	0.0055	0.007	<0.005		
	BS-SB51L-01-27-8.5	8.5			0.022	<0.005	0.028	0.025	0.016	0.070	<0.005		
	BS-SB51L-01-27-12.5	12.5			0.021	<0.005	0.011	0.018	0.009	0.032	<0.005		
	BS-SB51L-01-27-16.5	16.5			0.020	<0.005	<0.005	0.015	<0.005	0.0057	<0.005		
	BS-SB51L-01-27-20.5	20.5			0.022	<0.005	<0.005	<0.005	<0.005	0.0091	<0.005		
	BS-SB51L-01-27-25	25			<0.005	<0.005	<0.005	0.016	<0.005	<0.005	<0.005		
SB51L-01-28	BS-SB51L-01-28-2	2	Jul-01	BC	0.021	<0.005	0.026	0.020	0.33	1.3	<0.005		
	BS-SB51L-01-28-8.5	8.5			<0.005	<0.005	<0.005	0.015	0.043	0.17	<0.005		
	BS-SB51L-01-28-12.5	12.5			<0.005	<0.005	0.005	0.015	<0.005	<0.005	<0.005		
SB51L-01-29	BS-SB51L-01-29-2	2	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	0.038	0.0081	<0.005	Toluene=0.0055	
	BS-SB51L-01-29-4.5	5			<0.005	<0.005	<0.005	<0.005	0.018	0.015	<0.005		
	BS-SB51L-01-29-8.5	8.5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
SB51L-01-30	BS-SB51L-01-30-2	2	Jul-01	BC	<0.005	<0.005	<0.005	<0.005	0.025	0.010	<0.005		
	BS-SB51L-01-30-5	4.5			<0.005	<0.005	<0.005	<0.005	0.083	0.035	<0.005		
	BS-SB51L-01-30-8.5	8.5			<0.005	<0.005	0.16	0.036	0.082	0.38	<0.005		
	BS-SB51L-01-30-12.5	12.5			<0.005	<0.005	0.12	0.026	0.019	0.068	<0.005		
	BS-SB51L-01-30-14	14			<0.005	<0.005	0.0054	<0.005	<0.005	<0.005	<0.005		
SB51L-02-1	BS-SB51L-02-1-2.6	2.6	Jan-02	BC	<0.005	<0.005	<0.005	<0.005	0.027	0.012	<0.005	Toluene=0.015, Xylenes=0.01	
	BS-SB51L-02-1-5.6	5.6			<0.005	<0.005	0.017	<0.005	0.067	0.26	<0.005	Toluene=0.013, Xylenes=0.01	
	BS-SB51L-02-1-11.6	11.6			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
SB51L-04-1	BS-SB51L-04-1-2	2	Mar-04	BC	<0.005	<0.005	0.027	<0.005	0.0086	0.14	<0.005		
	BS-SB51L-04-1-5	5			0.03	0.014	1.9	0.2	0.0083	0.79	<0.005	Toluene = 0.0094	
	BS-SB51L-04-1-8.9	8.9			<0.005	<0.005	0.1	0.02	0.37	0.67	<0.005		
	BS-SB51L-04-1-12.2	12.2			0.0051	<0.005	0.13	0.018	1.1	1.8	<0.005		
	BS-SB51L-04-1-16.5	16.5			0.038	<0.005	0.34	0.3	0.06	1.3	<0.005		
SB51L-04-2	BS-SB51L-04-2-2.3	2.3	Mar-04	BC	<0.005	<0.005	0.019	0.011	<0.005	0.1	<0.005		
	BS-SB51L-04-2-5	5			<0.005	<0.005	0.012	0.0063	<0.005	0.12	<0.005		
	BS-SB51L-04-2-8.8	8.8			0.017	0.0067	0.051	0.0066	0.025	1.3	<0.005		
	BS-SB51L-04-2-12.5	12.5			0.012	<0.005	0.08	0.0076	0.048	0.65	<0.005		
	BS-SB51L-04-2-16.5	16.5			0.012	0.0069	0.14	0.031	<0.005	1.3	<0.005		
	BS-SB51L-04-2-20.5	20.5			0.062	0.015	0.16	0.06	<0.005	0.25	<0.005		

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
Target Risk_Based MCS for Institutional Land Use					1.3	7.9	38	50	0.45	2.3	690	
Location	Sample ID	Depth	Date	Lab								
51L-05-1	BS-SB51L-05-1-2	2	Jun-05	BC	0.074	<0.005	0.046	<0.005	<0.005	0.0055	<0.005	
	BS-SB51L-05-1-5.3	5.3			<0.005	<0.005	0.026	0.0084	0.013	0.14	<0.005	
	BS-SB51L-05-1-8.5	8.5			<0.005	<0.005	0.017	0.0056	0.018	0.14	<0.005	
	BS-SB51L-05-1-11	11			0.0056	<0.005	0.024	0.011	0.012	0.066	<0.005	
	BS-SB51L-05-1-13.9	13.9			0.018	<0.005	0.027	0.017	0.036	0.33	<0.005	
	BS-SB51L-05-1-17	17			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
51L-05-2	BS-SB51L-05-2-2	2	Jun-05	BC	<0.005	<0.005	0.017	<0.005	0.042	0.13	<0.005	
	BS-SB51L-05-2-5	5			<0.005	<0.005	0.057	0.016	<0.005	0.14	<0.005	
	BS-SB51L-05-2-8.5	8.5			<0.005	<0.005	0.082	0.029	<0.027	0.044	<0.005	
51L-05-3	BS-SB51L-05-3-2	2	Jun-05	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-3-5	5			<0.005	<0.005	<0.005	<0.005	0.013	0.042	<0.005	
	BS-SB51L-05-3-9	9			<0.005	<0.005	0.058	0.027	<0.005	0.15	<0.005	
	BS-SB51L-05-3-12	12			<0.005	<0.005	0.013	<0.005	<0.005	0.02	<0.005	
	BS-SB51L-05-3-17.5	17.5			<0.005	<0.005	0.018	<0.005	<0.005	0.0076	<0.005	
	BS-SB51L-05-3-22.2	22.2			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-3-26	26			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
51L-05-4	BS-SB51L-05-4-2.5	2.5	Jun-05	BC	<0.005	<0.005	0.0067	<0.005	<0.005	0.025	<0.005	
	BS-SB51L-05-4-5	5			<0.005	<0.005	0.012	<0.005	0.012	0.097	<0.005	
	BS-SB51L-05-4-8.5	8.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.03	<0.005	
	BS-SB51L-05-4-13.4	13.4			<0.005	<0.005	0.093	0.0098	<0.005	0.052	<0.005	
51L-05-5	BS-SB51L-05-1-2.5	2.5	Jun-05	BC	<0.005	<0.005	<0.005	<0.005	0.052	0.025	<0.005	
	BS-SB51L-05-1-4.5	4.5			<0.005	<0.005	0.034	<0.005	0.22	0.14	<0.005	
51L-05-6	BS-SB51L-05-6-2	2	Jun-05	BC	<0.005	<0.005	<0.005	<0.005	0.023	<0.005	<0.005	
	BS-SB51L-05-6-5	5			<0.005	<0.005	<0.005	<0.005	0.017	<0.005	<0.005	
	BS-SB51L-05-6-8.5	8.5			<0.005	<0.005	<0.005	<0.005	0.02	0.0051	<0.005	
51L-05-7	BS-SB51L-05-7-2	2	Jun-05	BC	<0.005	<0.005	<0.005	<0.005	0.068	0.1	0.0068	
	BS-SB51L-05-7-5	5			<0.005	<0.005	<0.005	<0.005	0.075	0.2	0.025	
	BS-SB51L-05-7-8.2	8.2			0.017	0.01	<0.005	<0.005	<0.005	0.021	0.021	
	BS-SB51L-05-7-12.5	12.5			0.016	0.012	<0.005	<0.005	0.0057	0.058	0.04	
	BS-SB51L-05-7-16.2	16.2			0.0054	0.0098	0.032	0.0056	<0.005	<0.005	<0.005	
51L-05-8	BS-SB51L-05-8-12.5	12.5	Jun-05	BC	0.11	0.049	0.28	0.13	0.047	2.6	<0.005	
	BS-SB51L-05-8-14.2	14.2			0.014	0.011	0.16	0.14	0.013	0.15	<0.005	
	BS-SB51L-05-8-16.3	16.3			0.013	0.01	0.17	0.19	0.0077	0.27	<0.005	
51L-05-9	BS-SB51L-05-9-2	2	Jun-05	BC	0.038	0.015	0.18	0.097	<0.005	0.19	<0.005	
	BS-SB51L-05-9-5	5			0.027	0.014	0.17	0.051	1.1	3.1	<0.005	
	BS-SB51L-05-9-8.5	8.5			<0.005	<0.005	0.0062	<0.005	0.18	0.13	<0.005	
	BS-SB51L-05-9-12.2	12.2			<0.005	<0.005	0.025	0.0065	0.36	0.55	<0.005	
	BS-SB51L-05-9-18	18			0.0093	<0.005	0.16	0.063	<0.005	0.087	<0.005	
	BS-SB51L-05-9-21	21			0.007	<0.005	0.069	0.027	<0.005	0.065	<0.005	

Appendix A (cont'd.)
Soil Sampling Results from Building 51L Area
Organic Compounds
(Concentration in mg/kg)

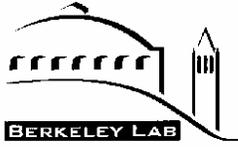
Target Risk_Based MCS for Institutional Land Use					1,1-DCA	1,1-DCE	cis 1,2-DCE	trans 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected	
					1.3	7.9	38	50	0.45	2.3	690		
Location	Sample ID	Depth	Date	Lab									
51L-05-10	BS-SB51L-05-10-2	2	Jul-05	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-05-10-5	5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-10-8	8			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-10-11	11			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-10-14	14			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
	BS-SB51L-05-10-17	17			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
51L-05-11	BS-SB51L-05-11-9	9	Jul-05	BC	<0.005	<0.005	0.083	0.011	0.014	0.14	<0.005		
51L-05-12	BS-SB51L-05-12-2	2	Jul-05	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-05-12-5	5			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-05-12-8	8			<0.005	<0.005	0.0064	<0.005	<0.005	<0.005	<0.005		
51L-05-13	BS-SB51L-05-13-3	3	Jul-05	BC	0.0079	<0.005	0.006	<0.005	0.027	0.33	<0.005		
	BS-SB51L-05-13-8	8			<0.005	<0.005	0.006	<0.005	0.099	0.13	<0.005		
	BS-SB51L-05-13-11	11			<0.005	<0.005	0.036	0.0076	0.011	0.086	<0.005		
	BS-SB51L-05-13-14	14			0.0088	<0.005	0.031	0.011	0.018	0.13	<0.005		
	BS-SB51L-05-13-17	17			0.0057	<0.005	0.025	0.008	0.018	0.12	<0.005		
51L-05-14	BS-SB51L-05-14-8.5	8.5	Jul-05	BC	<0.005	<0.005	<0.005	<0.005	0.016	0.008	<0.005		
51L-05-15	BS-SB51L-05-15-2	2	Jul-05	BC	<0.005	<0.005	<0.005	<0.005	0.0088	<0.005	<0.005		
	BS-SB51L-05-15-5	5			<0.005	<0.005	<0.005	<0.005	0.015	0.0054	<0.005		
	BS-SB51L-05-15-7.5	7.5			<0.005	<0.005	<0.005	<0.005	0.016	0.0061	<0.005		
51L-05-16	BS-SB51L-05-16-14	14	Jul-05	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SB51L-05-16-16	16			<0.005	<0.005	0.019	0.0084	<0.005	0.044	<0.005		
	BS-SB51L-05-16-17.5	17.5			<0.005	<0.005	0.064	0.036	0.0071	0.41	<0.005		
51L-05-17	BS-SB51L-05-17-10	10	Jul-05	BC	<0.005	<0.005	0.023	0.022	<0.005	0.04	<0.005		
	BS-SB51L-05-17-12	12			0.0056	<0.005	0.017	<0.005	0.63	0.3	<0.005	xylenes=0.007	
	BS-SB51L-05-17-14	14			<0.005	<0.005	0.021	0.01	<0.005	0.031	<0.005		
	BS-SB51L-05-17-16	16					0.017	0.0083	0.097	0.097	<0.005		
51L-05-18	BS-SB51L-05-18-10	10	Jul-05	BC	<0.005	<0.005	0.023	<0.005	0.15	0.073	<0.005		
SG51L-12	BS-SG51L-12-1	1	Dec-00	BC	<0.005	<0.005	<0.005	<0.005	<0.005	0.019	<0.005		
	BS-SG51L-12-2.5	2.5			<0.005	<0.005	0.0062	<0.005	0.039	0.11	<0.005		
SG51L-16	BS-SG51L-16-1	1	Dec-00	BC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
	BS-SG51L-16-2.5	2.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.020	<0.005		
SG51L-19	BS-SG51L-19-1	1	Dec-00	BC	<0.005	<0.005	<0.005	<0.005	0.038	0.13	0.017		
	BS-SG51L-19-2.5	2.5			0.0068	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
SG51L-20	BS-SG51L-20-1	1	Dec-00	BC	<0.005	<0.005	<0.005	<0.005	<0.005	0.11	<0.005		
	BS-SG51L-20-2.5	2.5			<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005		
SG51L-21	BS-SG51L-21-1	1	Dec-00	BC	<0.005	<0.005	<0.005	<0.005	0.044	0.044	<0.005		
	BS-SG51L-21-2.5	2.5			<0.005	<0.005	<0.005	<0.005	0.022	0.023	<0.005		
SG51L-22	BS-SG51L-22-1	1	Dec-00	BC	<0.005	<0.005	0.0095	<0.005	0.018	0.058	<0.005		
	BS-SG51L-22-2.5	2.5			<0.005	<0.005	0.049	0.0068	0.037	0.31	<0.005		

BC = Analysis by BC Laboratories
CLS = Analysis by California Laboratory Services

< = Less than reporting limit
Note: boldface concentration exceeds MCS

Attachment 2

Corrective Measure Implementation (CMI) Workplan for Soil Excavation,
Building 7 Sump of the Old Town Groundwater Solvent Plume Source Area for
the Lawrence Berkeley National Laboratory Environmental Restoration Program,
dated November 2005.



E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program



United States Department of Energy

**CORRECTIVE MEASURE IMPLEMENTATION (CMI)
WORKPLAN
for
SOIL EXCAVATION**

**BUILDING 7 SUMP OF THE OLD TOWN
GROUNDWATER SOLVENT PLUME SOURCE AREA**

for the

Lawrence Berkeley National Laboratory

ENVIRONMENTAL RESTORATION PROGRAM

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ENVIRONMENTAL RESTORATION PROGRAM

A Joint Effort of
Environment, Health and Safety Division, and
Earth Sciences Division,
Lawrence Berkeley National Laboratory
University of California
Berkeley, California 94720

November 2005

This work was done at the Lawrence Berkeley National Laboratory operated by the University of California for the U. S. Department of Energy under contract DE-AC02-05CH11231.

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FIGURES

APPENDIX 1. Concentrations of COCs in Soil (mg/kg), AOC 2-5: Former Building 7 Sump.

LIST OF ABBREVIATIONS

AOC	Area of Concern
Berkeley Lab	Lawrence Berkeley national Laboratory
bgs	below ground surface
Cal-EPA	California Environmental Protection Agency
CAP	Corrective Action Process
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CVOC	Chlorinated Volatile Organic Compound
Cal-EPA	California Environmental Protection Agency
COC	Chemical of Concern
CMS	Corrective Measures Study
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous-Phase Liquid
DPE	Dual Phase Extraction
DTSC	Department of Toxic Substances Control
ERP	Environmental Restoration Program
FY	Fiscal Year
GAC	Granular Activated Carbon
HSPP	Health and Safety Program Plan
ICM	Interim Corrective Measure
MCS	Media Cleanup Standard
µg/L	Micrograms per liter (10 ⁻⁶ grams per liter)
PCE	Tetrachloroethene
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SOP	Standard Operating Procedure
SVE	Soil Vapor Extraction
TCA	Trichloroethane
TCE	Trichloroethylene
VOC	Volatile Organic Compound
Water Board	Regional Water Quality Control Board
WSP	Worksite Safety Plan

SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) submitted its Corrective Measures Study (CMS) Report to the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC) on February 10, 2005 (Berkeley Lab, 2005). The CMS Report provides recommendations for the specific corrective measures that will be implemented to eliminate or reduce potential risks to human health from contaminants in the soil and/or groundwater at Berkeley Lab. It also lists media- and chemical-specific concentrations (Media Cleanup Standards [MCSs]) that the measures must achieve in order to be considered complete.

The DTSC, in consultation with the Regional Water Quality Control Board (Water Board) and the City of Berkeley/Toxics Management Division, reviewed the CMS Report and determined that it was technically complete (DTSC, 2005a). In addition, DTSC evaluated the corrective measures proposed for Berkeley Lab in the CMS report and prepared a Statement of Basis indicating its concurrence with the proposed measures (DTSC, 2005b). On August 31, 2005, DTSC issued its Notice of Final Decision on the remedies proposed in the CMS Report, after holding a public hearing and responding to public comments on the proposed measures. The Notice of Final Decision provided approval of the CMS Report effective October 3, 2005 (pending appeal). This approval marked the beginning of the Corrective Measures Implementation (CMI) phase of the Resource Conservation and Recovery Act (RCRA) Corrective Action Process (CAP) at Berkeley Lab. During this phase, the corrective measures proposed in the CMS Report will be applied.

In its Notice of Decision, DTSC requested that Berkeley Lab submit a Corrective Measures Implementation (CMI) Plan to DTSC by October 24, 2005, for the corrective measures proposed for implementation in the CMS Report. This workplan provides the details of the corrective

measure proposed for the source area of the Building 7 lobe of the Old Town Groundwater Solvent Plume. Soil containing chlorinated volatile organic compounds (CVOCs) is present in the source area at concentrations significantly above the MCSs specified for the unit in the CMS Report. There is also evidence that CVOCs are present in the soil as free product (i.e., nonaqueous phase liquid) at some locations in the source area. The corrective measure proposed for this area is excavation and offsite disposal of contaminated soil. The applicable MCSs are based on potential risks to human health. Groundwater in the source area also contains CVOCs at concentrations above risk-based MCSs. Excavating the highly contaminated source area soil should help reduce concentrations of CVOCs in the groundwater in the source area below risk-based levels.

1.2 BACKGROUND

The Old Town Groundwater Solvent Plume is a broad, multi-lobed plume of CVOC-contaminated groundwater, which underlies much of the Old Town area. The distribution of chemicals in the plume indicates that it consists of three coalescing lobes that were originally discrete plumes derived from distinct sources (**Figure 1**). The Building 7 lobe, which contains the highest CVOC concentrations of the three lobes, extends northwestward from the northwest corner of Building 7 to the parking area downslope from Building 58.

Leaks and/or overflows of CVOCs (primarily tetrachloroethene [PCE]) from the Former Building 7 Sump (Area of Concern [AOC 2-5]), an abandoned sump that was located north of Building 7, were the source of the Building 7 lobe. These chemicals were initially released as free product to the soil around the sump and then migrated as dense non-aqueous-phase liquid (DNAPL) into the saturated zone. A sufficient mass of DNAPL remains in the source zone to constitute a continuing source of groundwater contamination. Continuing dissolution of contaminants from the soil and westward to northwestward flow of the groundwater from the sump area has resulted in the development of the Building 7 lobe.

1.3 INTERIM CORRECTIVE MEASURES AND PILOT TESTS

Interim Corrective Measures (ICMs) were implemented during the RCRA Facility investigation (RFI) to remove the source of the Building 7 lobe and to control further migration of

contaminated groundwater (Berkeley Lab 2000). The initial source-zone ICM, which was conducted when the sump was discovered in 1992, consisted of removal and proper disposal of: 1) the concrete slab that covered the sump; 2) the sediment and liquid in the sump; and 3) contaminated soil filling an adjacent concrete ditch. In August 1995, the sump and approximately 70 cubic yards of adjacent highly contaminated soil were removed after the underground utilities in the area were rerouted.

In 1996, a groundwater collection trench (Building 7 Groundwater Collection Trench) was installed immediately downgradient from the former sump location as a source control measure. The location of the trench is shown on **Figure 2**. Contaminated groundwater extracted from the collection trench has been treated and re-injected into the gravel-filled sump excavation during periods of low rainfall to flush subsurface contaminants to the collection trench. Groundwater injection into the gravel-filled ICM excavation was initiated in 1997, using treated groundwater extracted from the Building 7 Groundwater Collection Trench. The infiltrating groundwater has leached downward to the saturated zone and then flowed northwestwards where it has been recaptured by the Building 7 Groundwater Collection Trench. This process was generally continuous from May 1997 through June 2001, at which time recirculation was discontinued to help improve the effectiveness of a thermally enhanced soil vapor extraction (SVE) pilot test. Almost two million gallons of treated water was pumped into the remedial excavation and approximately 50 kg of VOCs were removed from the groundwater during this period, indicating an average removal rate of slightly less than 1 kg/month, which declined asymptotically to very low levels.

In July 2001, a thermally enhanced SVE pilot-test began operation in the area of maximum soil contaminant concentrations immediately west of the sump excavation. The location of the pilot test is shown on **Figure 2**. The system operated primarily during the summer and fall seasons until November 2004, when it was shut down permanently. The test system consisted of three heater wells; two instrument wells to monitor the test; and a central dual phase (groundwater and soil vapor) extraction (DPE) well, later supplemented by three additional DPE wells. Starting in October 2003, the system was enhanced by injection of hot air under pressure. More than 700 kg of CVOCs were removed from the source area during the test, which was terminated in 2004.

Although a large mass of CVOCs was removed from the Building 7 lobe source area, soil samples collected in 2003 to evaluate the performance of the test showed residual soil concentrations that were still significantly above MCSs. In addition, some locations in the source area where CVOC concentrations in pre-test soil samples exceeded MCSs were likely not affected by the pilot test.

SECTION 2

GEOLOGY AND HYDROGEOLOGY

2.1 GEOLOGY

Volcanic and volcaniclastic rocks of the Moraga Formation underlie much of the Old Town area. Most outcrops of the Moraga Formation consist of loosely consolidated, angular blocks composed of andesitic breccia, andesite, siltstone, sandstone, and basalt. These strata are underlain by nonmarine siltstones and fine-grained sandstones of the Orinda Formation. Rocks found along the contact between the Moraga and underlying Orinda Formations in many places comprise a mixture of rock types common to both the Moraga and Orinda Formations, and have therefore been informally named the “Mixed Unit”. The Mixed Unit appears to represent structurally interleaved portions of the Moraga and Orinda Formations. Surficial units (colluvium, alluvium, and artificial fill) are present in some areas, but generally only above the water table.

The upper contact of the Orinda Formation dips northward beneath the Building 7 lobe source zone (**Figure 3**). The upper contact of the Mixed Unit is much more complex (**Figure 4**), forming a “hump” along the south edge of the source zone.

2.2 HYDROGEOLOGY

Groundwater in the Building 7 lobe source area is primarily present in the bedrock units, while the surficial units are above the water table. The Orinda Formation and the Mixed Unit generally have relatively low hydraulic conductivities in comparison to the overlying Moraga Formation volcanic rocks. Groundwater flows generally northwestwards. The primary contaminant migration pathway is within Moraga Formation volcanic rocks and the Mixed Unit. Relatively impermeable fine-grained sedimentary rocks of the Orinda Formation that underlie these units generally impede groundwater flow.

Groundwater is currently being extracted from the Building 7 groundwater collection trench at the west edge of the source area and treated groundwater is being injected into six injection wells located approximately 10 feet west of the collection trench. This has resulted in alteration of the original water table elevation, which has been drawn down to depths as great as 20 to 35 feet below ground surface (bgs) near the extraction trench. In the absence of groundwater extraction, the water table would be approximately 15 to 20 feet bgs in this area.

SECTION 3

MAGNITUDE AND EXTENT OF CONTAMINATION

3.1 GROUNDWATER

Total halogenated VOCs detected in groundwater in the source and core areas of the Building 7 lobe of the Old Town Solvent Plume during the fourth quarter of fiscal year 2004 (July 1 to September 30, 2004) are shown on **Figure 2**. The primary contaminants detected in groundwater in the source area are tetrachloroethene (PCE), trichloroethylene (TCE), and carbon tetrachloride. Immediately prior to the initiation of soil flushing, CVOCs were detected at maximum total concentrations greater than 200,000 µg/L in the source area, and were present at substantially higher concentrations prior to source excavation. These concentrations have been reduced significantly since the start of soil flushing in October 2002. Concentrations of total CVOCs in groundwater samples collected in the source area in the third quarter, FY2005 were approximately 30,000 µg/L in samples collected from a dual phase extraction well in the thermally enhanced SVE pilot test area, but are generally significantly lower (in the range of approximately 200 to 5,000 µg/L in other wells in this area).

Concentrations of total CVOCs in samples collected from multi-level lysimeters in the heater instrument wells remain relatively high at depths of 40 and 45 feet bgs, with the maximum concentration detected at a depth of 40 feet. Lysimeter results from May 2005 are provided in **Table 1**. The very high concentrations measured in these lysimeters are indicative of the presence of DNAPL.

Table 1. Maximum Concentrations of Total CVOCs Detected in Lysimeter Samples Collected from Thermally Enhanced SVE Pilot Test Instrument Wells, May 2005.

Depth	Concentration Total CVOCs (µg/L)	
	HI7-00-1	HI7-00-2
15 feet	2,420	63
20 feet	4,900	
25 feet	4,830	45
30 feet		1,269
35 feet	10,300	
40 feet	111,000	107,200
45 feet	19,498	28,840

3.2 SOIL

Soil analytical results are provided in **Appendix 1**. The locations of the samples and concentrations of total CVOCs detected are shown in plan view on **Figure 5a** (for samples collected prior to 2002) and **Figure 5b** (for samples collected during or after 2003), and in a cross-section view on **Figure 6**.

Pre-Pilot Test Soil Sampling Results

PCE was the primary contaminant detected in soil samples collected near the sump prior to its removal and the excavation of adjacent highly contaminated soil. PCE was detected at a maximum concentration of 14,000 mg/kg at a depth of 2.8 feet, within a few feet of the sump. TCE, 1,1,1-trichloroethane (TCA), cis-1,2-dichloroethene (DCE), and 1,1-DCE were also detected at relatively high concentrations. In 1995, when the sump was removed, the surrounding contaminated soil was excavated to a depth of 17 feet from an area approximately 10 feet long by 7 feet wide (**Figure 5a**). This action resulted in the removal of a large fraction of the highly contaminated vadose zone soil from the site.

Soil samples were collected from numerous locations in the Building 7 lobe source area prior to the start of soil flushing between the backfilled ICM excavation at the former sump location and the Building 7 Groundwater Collection Trench. Additional soil samples were collected from the borings for the heater and heater test instrument wells prior to the start of the

thermally enhanced SVE pilot test. Pre-pilot-test sampling locations and total concentrations of CVOCs detected in soil are shown on **Figure 5a**. As can be seen on the figure, total CVOC (primarily PCE) concentrations exceeding 100 mg/kg were present between approximately 15 and 40 feet bgs in an area extending west from the former sump location, with concentrations of 1,000 mg/kg or greater (3,071 maximum) in three samples collected from HI7-00-1 and one sample collected at the northwest end of the ICM excavation. Contaminant concentrations beneath and immediately downgradient from the former sump location have likely decreased due to: 1) soil flushing between the Building 7 sump ICM excavation and the Building 7 Groundwater Collection Trench; and 2) operation of the thermally enhanced SVE pilot test.

Effects of Soil Flushing and Thermally Enhanced SVE Pilot Test on Contaminant Concentrations

In December 2002, after the pilot test heaters were temporarily turned off, soil samples were collected from four borings (SB7BHTC-02-1 to -4) drilled at locations that were selected to assess whether PCE had condensed at the outside edge of the central heating area (**Figure 5b**). The concentrations of PCE detected in these samples did not conclusively verify or rule out whether PCE had condensed in this area. PCE was detected at a maximum concentration of 720 mg/kg at a depth of approximately 20 feet in SB7BHTC-02-1, the post-heating boring closest to the former sump location. This concentration is also close to reported soil saturation limits for PCE, indicating that free product is probably still present. The maximum concentration detected in the other three borings was approximately 19 mg/kg.

Soil samples were collected from four soil borings in 2003 (SB7-03-1 through -4) to estimate the extent of soil contamination in the area east of the pilot test area (**Figure 5b**). The low concentrations of CVOCs detected in the SB7-03-1, -3 and -4 suggests that elevated concentrations of CVOCs in that area were limited to within approximately 5 feet north and south of the former sump excavation. One of the borings (SB7-03-2) was drilled near the center of the ICM excavation close to the location where PCE had been detected at a concentration of 1,000 mg/kg in a confirmation sample collected from the base of the excavation. The concentration of 0.09 mg/kg PCE detected indicated a significant reduction in CVOC concentrations in soil beneath the central part of the ICM excavation, apparently as a result of

soil flushing. However, as noted above, concentrations of CVOCs in soil at the west edge of the excavation appeared to be unchanged (720 mg/kg total CVOCs maximum), indicating that the effects of soil flushing were localized.

SECTION 4

PROPOSED CORRECTIVE MEASURE

4.1 RATIONALE

The Human Health Risk Assessment (HHRA) completed by Berkeley Lab in 2003 (Berkeley Lab, 2003) estimated the potential risks from chemicals of concern (COCs) in soil and groundwater at the site by calculating theoretical incremental lifetime cancer risks (ILCRs) and non-cancer hazard indices (HIs), assuming an industrial/institutional land use scenario. This scenario is consistent with the current and potential future land use at Berkeley Lab. The theoretical ILCRs were compared to the United States Environmental Protection Agency (USEPA) target cancer risk range of 10^{-4} to 10^{-6} , which is considered by the agency to be safe and protective of public health. Exposure to chemicals with a Hazard Index (HI) below 1.0 is considered unlikely to result in adverse non-cancer health effects over a lifetime of exposure.

The HHRA estimated the potential risks from COCs in the soil at the Former Building 7 Sump location. For current indoor workers in Building 7 and intrusive construction workers, the theoretical ILCR is less than 10^{-6} and the non-cancer HIs is less than 1 for all soil pathways. For landscape maintenance workers, the theoretical ILCR is slightly above 10^{-6} for soil pathways, but the HI is less than 1. For potential future indoor workers, should a new building be constructed at the Former Building 7 Sump location, the HHRA estimated that the theoretical ILCR would be greater than 10^{-4} and the non-cancer HI would be greater than 1 for soil pathways. The risk to potential future indoor workers was based on the potential for inhalation of PCE, carbon tetrachloride, and TCE (for cancer risk) and carbon tetrachloride (for non-cancer hazard) in indoor air. Since the estimated risks exceed the threshold risk values, the Former Building 7 Sump was included in the CMS Report (Berkeley Lab, 2005).

Contaminated soil at the Former Building 7 Sump location is in direct contact with site groundwater, resulting in groundwater contaminant concentrations that also exceed risk-based MCSs. The HHRA indicated that theoretical ILCRs for hypothetical future indoor workers

breathing vapor migrating to indoor air and for intrusive construction workers contacting groundwater exceeded 10^{-6} .

The CMS Report provides recommendations for the specific corrective measures that will be implemented to eliminate or reduce potential risks to human health from contaminants in the soil and/or groundwater at Berkeley Lab. The corrective measure proposed for this area is excavation and offsite disposal of contaminated soil. Excavating the highly contaminated source area soil should also reduce concentrations of CVOCs in the groundwater to below risk-based MCSs.

4.2 MEDIA CLEANUP STANDARDS AND PROPOSED CLEANUP LEVELS

The CMS Report (Berkeley Lab, 2005) specifies the MCSs that corrective measures must achieve in order to be considered complete. The MCSs were developed for an institutional/industrial land use scenario. Two types of MCSs were developed, the first to address risk-based objectives and the second to address regulatory requirements for areas that constitute potential drinking water sources. Target risk-based MCSs were set for each contaminant at the concentration that would theoretically result in an ILCRs of 10^{-6} or a non-cancer HI of 1. Regulatory-based MCSs are only applicable to locations at Berkeley Lab where groundwater is considered a potential source of drinking water under policies of the State Water Resources Control Board (WRCB). As specified in the CMS Report, only risk-based MCSs are applicable to the Building 7 lobe source area.

Table 2 lists maximum concentrations of CVOCs detected in the soil in the source area of the Building 7 lobe in comparison to the target risk-based MCSs. The table does not include sample results from locations that have been previously excavated. The only CVOCs that exceed MCSs are PCE, TCE, carbon tetrachloride, and vinyl chloride. **Figure 7** shows the distribution of contaminants exceeding the target risk-based MCSs.

Table 2. Maximum Concentrations of COCs Detected in Soil at the Former Building 7 Sump Location and Applicable MCSs

COC	Maximum Concentration Detected* (mg/kg)	Target Risk-Based Soil MCS (mg/kg)
PCE	3,071	0.45
TCE	60	2.3
cis-1,2-DCE	0.043	38
1,1,1-TCA	11	690
1,1-DCA	0.024	1.3
1,1-DCE	0.16	8
Benzene	0.0091	0.1
Carbon tetrachloride	10	0.05
Chloroform	0.092	0.28
Vinyl chloride	0.0049	0.0035

*Maximum concentrations noted may have been reduced due to pilot test and ICM operations subsequent to sampling. Note: boldface numbers indicate concentrations above target risk-based MCS.

4.3 CORRECTIVE MEASURE IMPLEMENTATION

Proposed Confirmation Sampling

As described in Section 2, soil flushing and the thermally enhanced SVE pilot test have resulted in the removal of a large mass of contaminants from the Building 7 lobe source area. Therefore, soil samples previously collected within the area affected by flushing or the pilot test may not be representative of current conditions. Current concentrations of CVOCs in the soil are generally expected to be less than the concentrations previously detected, particularly in those areas where samples were collected prior to 2002. However, it is also possible that at some locations volatilization and condensation of contaminants in the vicinity of the heater test area have resulted in increased concentrations.

The minimum and maximum estimated areal extents of soil contamination exceeding target risk-based MCSs, based on previous soil sampling results, are shown on **Figure 7**. The minimum extent shown circumscribes all sampling points where concentrations of one or more CVOCs in soil (primarily PCE) exceeded MCSs. The maximum extent shown circumscribes the sampling points closest to the source area where CVOCs in soil were less than MCSs, with the

exception of the southern extent. The current areal extent of soil contamination exceeding target risk-based MCSs may be smaller than the areas indicated as a result of contaminant mass removal due to ICM and pilot test operations.

The first phase of the corrective measure will consist of collecting confirmation soil samples to delineate more accurately the extent of the area that will require excavation, and to eliminate the need to collect post-excavation confirmation samples. The locations and sampling intervals of soil borings proposed for confirmation sampling are shown on **Figure 7**. It is important to note that ICM and pilot test operation may have reduced the area of the “minimum estimated extent”. If sampling data indicate that chemical concentrations in these borings exceed MCSs, then samples may be collected at additional locations to further delineate the area exceeding MCSs.

All proposed confirmation soil borings will be sampled at approximately 5-foot intervals within the soil sampling intervals shown on **Figure 7**. Sampling depths are listed in **Table 3**. The proposed sampling depths were selected by review of available sampling data and are designed to include the entire thickness of contaminated materials overlying the Orinda Formation. Samples will be analyzed for VOCs using EPA Method 8260.

Table 3. Soil Sampling Requirements

Boring Number	Sample Depth (feet)
Borings for Determining Lateral Extent	
SB7-05-1	25, 30, 35, 40, 45, 50
SB7-05-2	25, 30, 35, 40, 45, 50
SB7-05-3	25, 30, 32, 35, 40, 45
SB7-05-4	10, 15, 20, 25, 30, 35, 40, 45
SB7-05-4A	35, 40, 45
SB7-05-5	5*, 10*, 15*, 18*, 20, 25, 30
SB7-05-6	10*, 15*, 18*, 20, 25, 30
SB7-05-7	10, 15, 20, 25, 30
SB7-05-8	25, 30, 34
SB7-05-9	10, 15, 20, 25, 30, 35, 40, 45
SB7-05-10	20, 25, 30, 35, 40, 46
Borings for Determining Vertical Extent	
SB7-05-11	15, 20, 25, 30, 35, 40, 45
SB7-05-12	30, 35, 40, 45
SB7-05-13	35, 40, 45
SB7-05-13A	32, 37
SB7-05-14	25, 30

*If boring encounters gravel backfill from original ICM excavation, a sample will be collected at 18' below the gravel backfill. If boring does not encounter gravel backfill, samples will be collected at 5' intervals indicated, and the 18' sample will not be collected.

Soil Excavation

The second phase of the ICM will consist of excavation of accessible areas of highly contaminated soil to a maximum depth of approximately 50 feet. The estimated minimum and maximum extent of the area requiring excavation is shown on **Figure 7**. The actual extent of excavation required will be determined based on the results of the proposed soil sampling described above. It is anticipated that excavation will be conducted by drilling large-diameter (approximately 3-feet) auger holes. However, the precise method will be determined after discussions with excavation contractors. The auger holes will be drilled to the depth of the nearest confirmation samples that contain CVOC concentrations less than the target risk-based MCS. Two or three sets of overlapping auger holes will be drilled so that residual material between the holes is removed. After each set of holes is drilled, it will be backfilled in

accordance with requirements of the Berkeley Lab Facilities Department, most likely with cement grout or Durafill™ and allowed to cure before drilling the subsequent overlapping set of holes. **Figure 8** illustrates typical patterns that may be used for overlapping auger holes. Since available sample data indicate that no significant contamination exists in the upper 17 feet of the site, excavated soil from 0 to 17 feet will be segregated from deeper soil, in order to reduce mixing of contaminated soil with relatively uncontaminated soil, thus reducing disposal costs. If excavation is conducted below the former backfilled Building 7 sump excavation, then the gravel backfill from the excavation may be removed (as necessary to advance the augers) and reused for backfilling the new excavation, or stabilized in place by grouting to allow drilling through the backfill. Dewatering of the excavation will be conducted if necessary, and any groundwater extracted from the excavation will be treated at the Building 7 Treatment System.

Sampling data indicate that soil adjacent to the groundwater collection trench in the vicinity of soil boring SB7-96-3 contained CVOCs in excess of MCSs. Confirmation sampling will be conducted to assess whether this condition remains. However, the western boundary of the remedial excavation will be situated sufficiently far east of the groundwater collection trench so that the integrity of the trench will not be compromised by excavation activities or grout intrusion.

SECTION 5

GENERAL PROCEDURES

All work will be performed in accordance with requirements of the ERP Quality Assurance Program Plan (QAPP) (Berkeley Lab, 1994a), Berkeley Lab ERP Standard Operating Procedures (SOPs) (Berkeley Lab, 1994b), and the Berkeley Lab ERP Health and Safety Program Plan (HSPP) (Berkeley Lab, 2004). In accordance with the HSPP, a Worksite Safety Plan (WSP) will be completed prior to the initiation of any intrusive site work. The WSP will contain a description of the potential contaminants, required personnel protective equipment, site hazards, and monitoring requirements.

SECTION 6

PRELIMINARY SCHEDULE

The following is a preliminary schedule for the proposed work discussed in this Workplan. The schedule is tentative and may be revised.

- October 20, 2005 Submit workplan to DOE.
- November 2, 2005 Submit workplan to regulatory agencies.
- December 2005 Start field activities.

SECTION 7

WASTE DISPOSAL

Excavated soils and all potentially contaminated materials will be temporarily stored in covered storage bins, or stockpiled at the surface and covered with continuous heavy-duty plastic sheeting until loaded into covered bins for offsite disposal. Excavated soil will be managed in a way that will not cause sediment in storm water runoff. Less-contaminated soil will be segregated from more-contaminated soil based on field observations and prior sampling results, as discussed in Section 3. The landfill selected for soil disposal will be based on the landfill's acceptance criteria and the estimated disposal costs. If approved of by the landfill, pre-excavation sampling results will be used to document compliance with the landfill's acceptance criteria; otherwise, samples will be collected from the excavated soil. Generally, composite samples will be collected for analysis of Volatile Organic Compounds (VOCs) (by EPA Method 8260) and Title 22 metals (EPA 6000 and 7000 series).

SECTION 8

REFERENCES

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- DTSC, 2005b. Statement of Basis Proposed RCRA Remedy Selection for Soil and Groundwater at Ernest Orlando Lawrence Berkeley National Laboratory 1 Cyclotron Road Berkeley, California, EPA ID No. CA489008986. April 2005.

LIST OF FIGURES

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- Figure 1. Location of Old Town Plume and Building 7 Lobe Source Zone.
- Figure 2. Source Zone and Core Area of Building 7 Lobe.
- Figure 3. Geometry of Top of Orinda Formation in Building 7 Lobe Source Zone.
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- Figure 6. Geologic Cross Section A-A' Showing Soil Sample Results, Building 7 Lobe Source Zone.
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- Figure 8. Schematic Showing Typical Drilling Sequence for Overlapping Borings.

-  Groundwater monitoring well
-  Properly destroyed monitoring well
-  Temporary groundwater sampling point
-  Properly destroyed sampling point
-  Groundwater extraction well
-  Groundwater injection well
-  Dual phase extraction well
-  Slope stability well
-  Slope indicator well
-  Vadose zone monitoring well
-  Shallow soil sampling location
-  Soil boring

 Surface structure
(e.g. buildings, etc.)

NOTES:

All other symbols used are explained on the figures.

Not all symbols may be included on the attached figures for the current reporting period.

Key to Symbols Used on Figures.

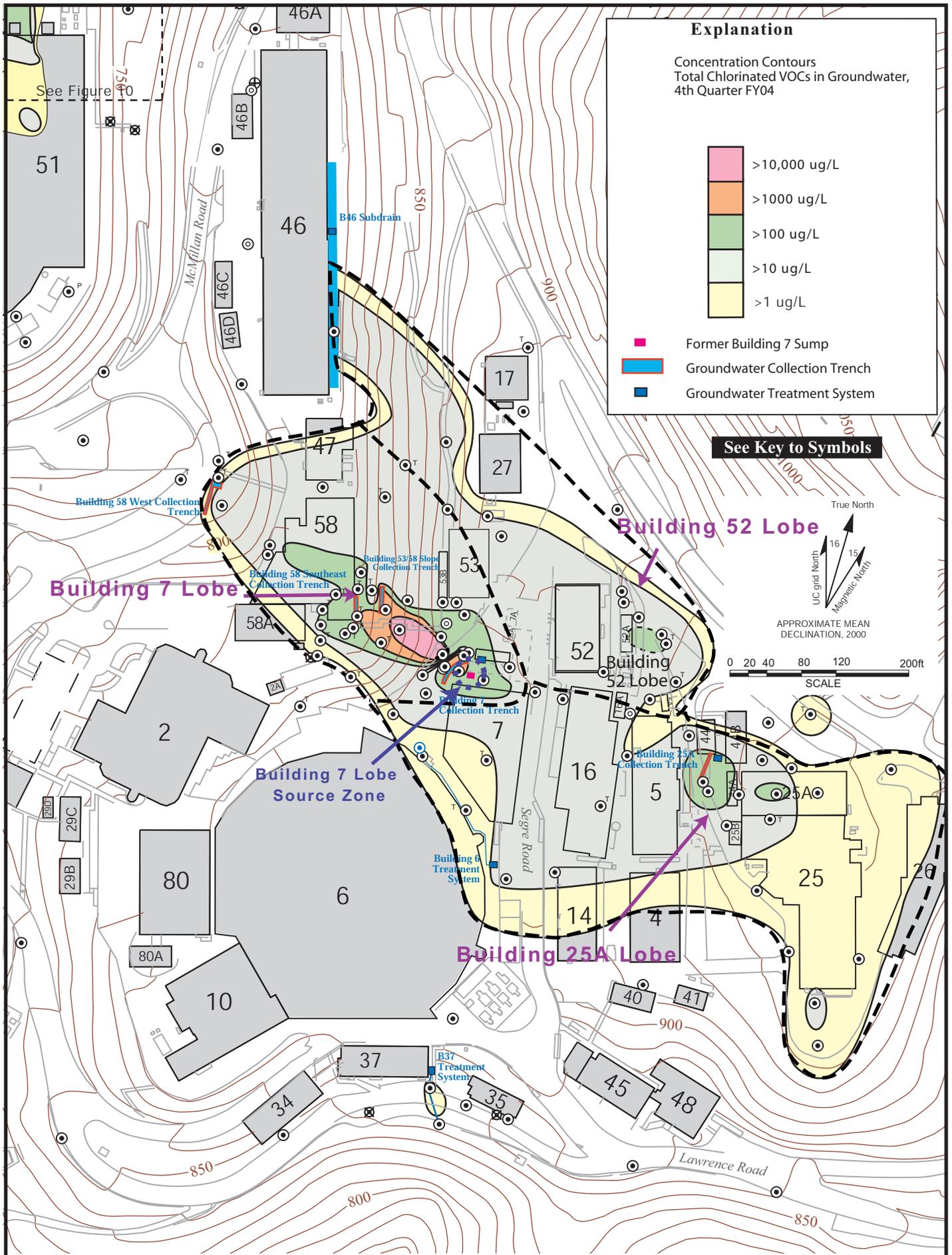


Figure 1. Location of Old Town Plume and Building 7 Lobe Source Zone.

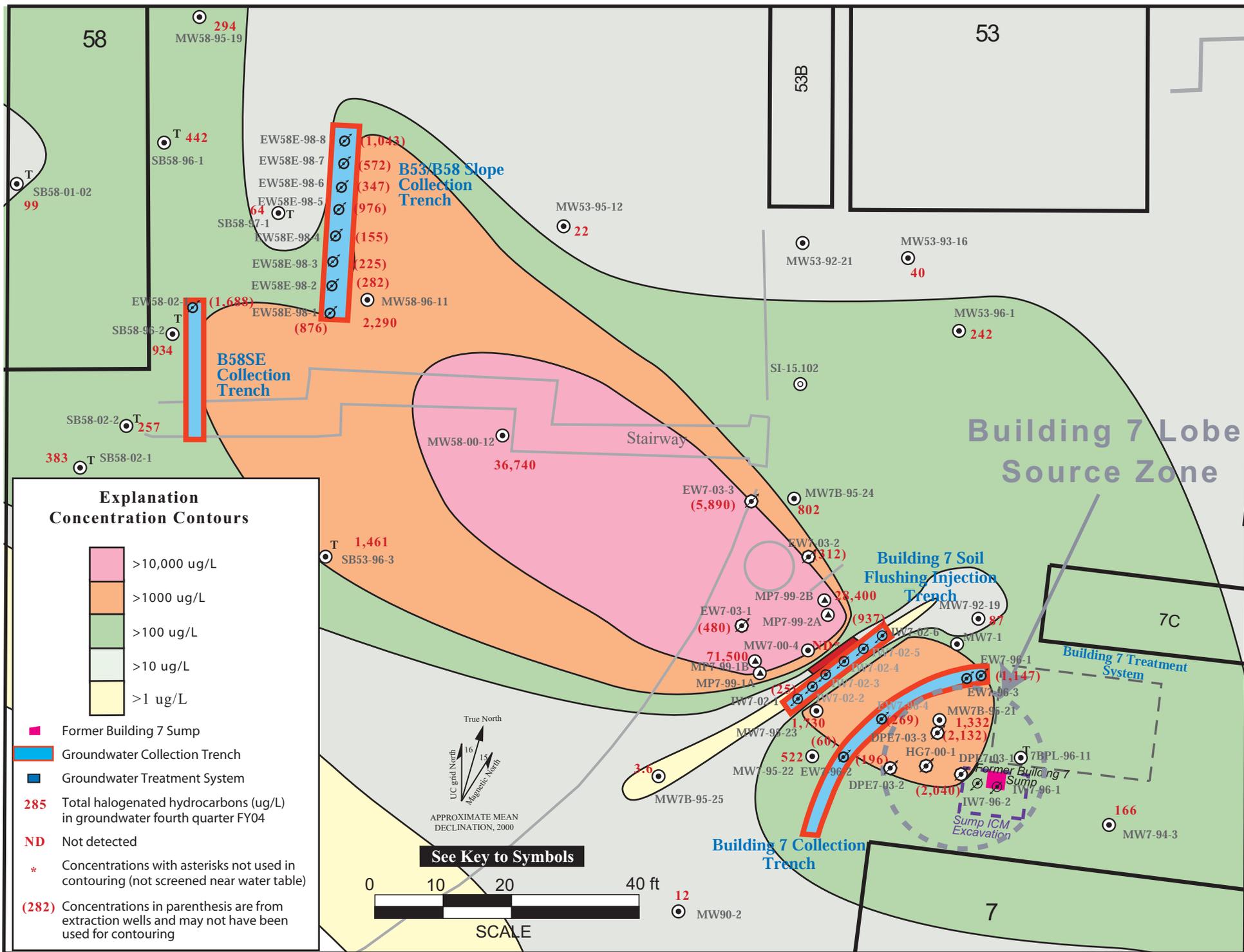


Figure 2. Source Zone and Core Area of Building 7 Lobe.

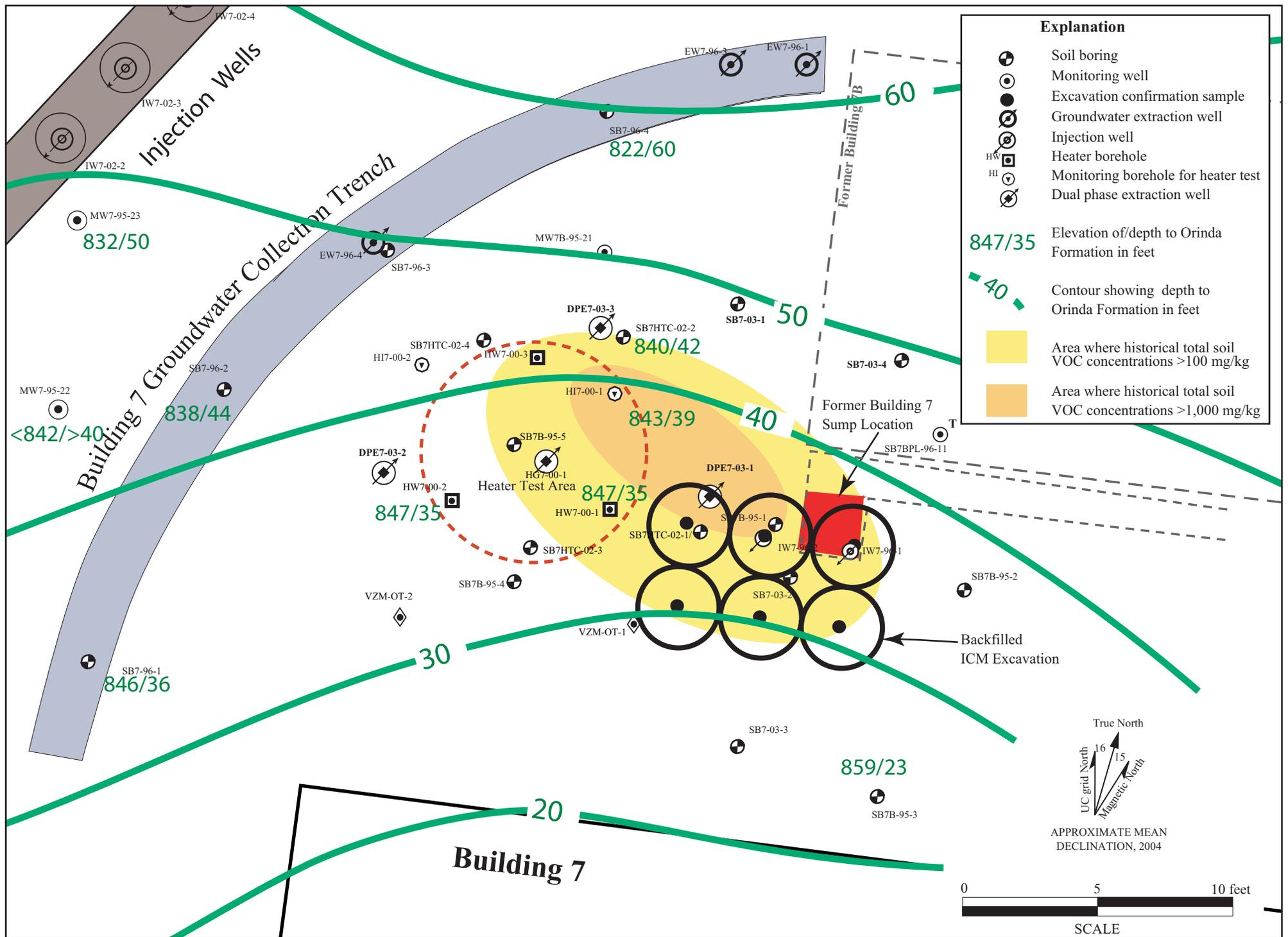
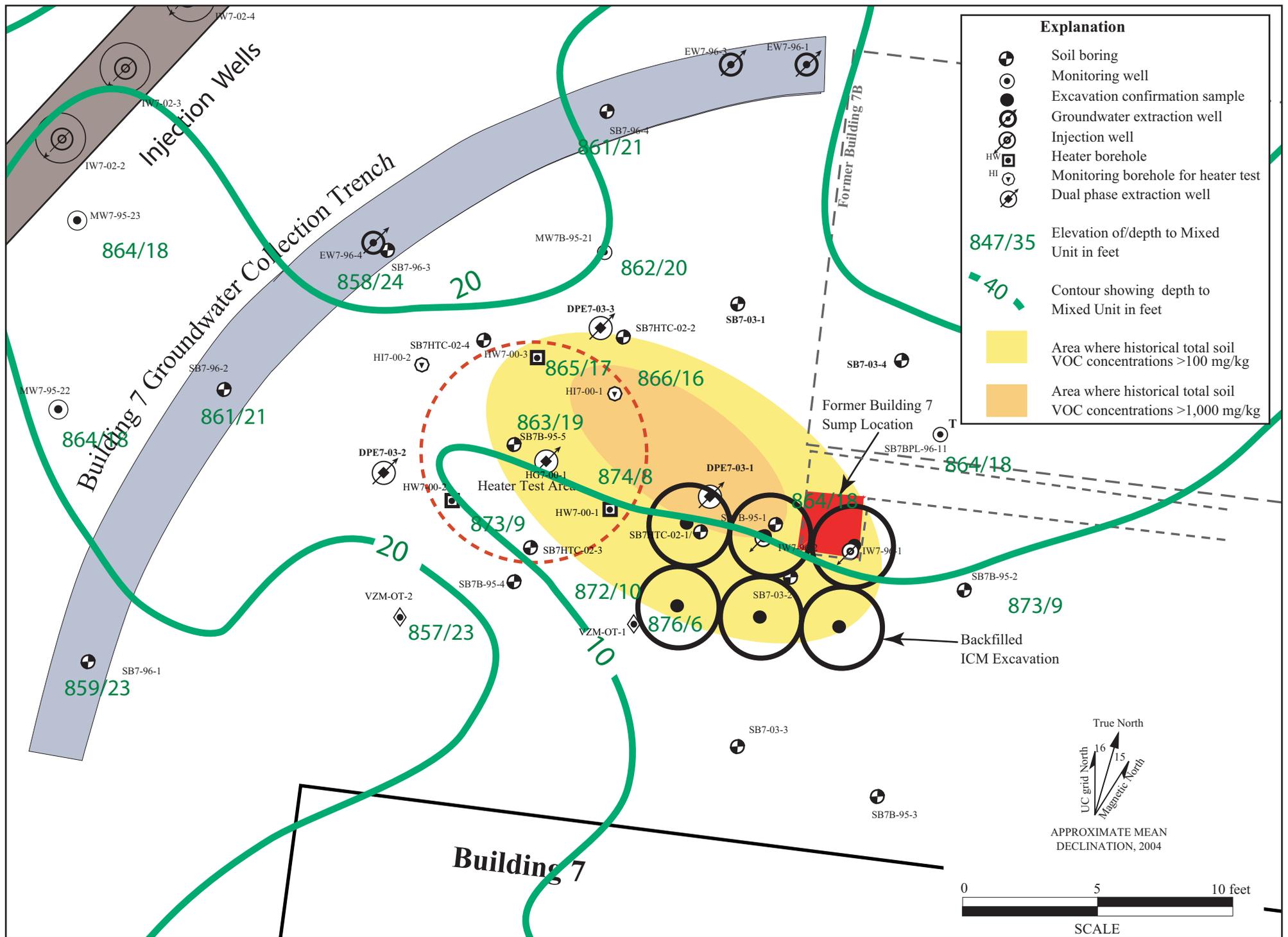


Figure 3. Geometry of Top of Orinda Formation in Building 7 Lobe Source Zone



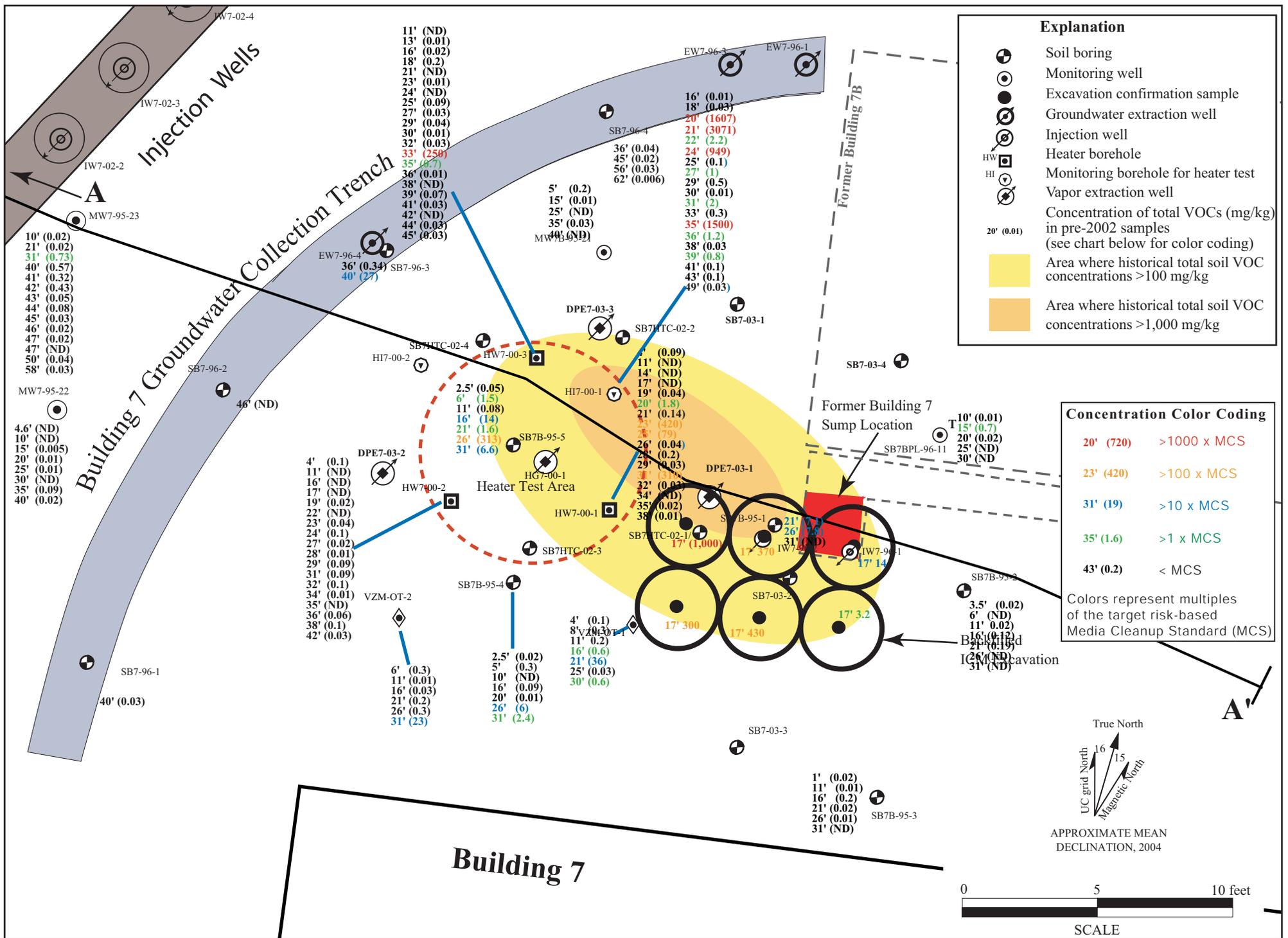


Figure 5a. Concentrations of Total CVOCs Detected in Soil Prior to 2002 (mg/kg), Building 7 Lobe Source Zone.

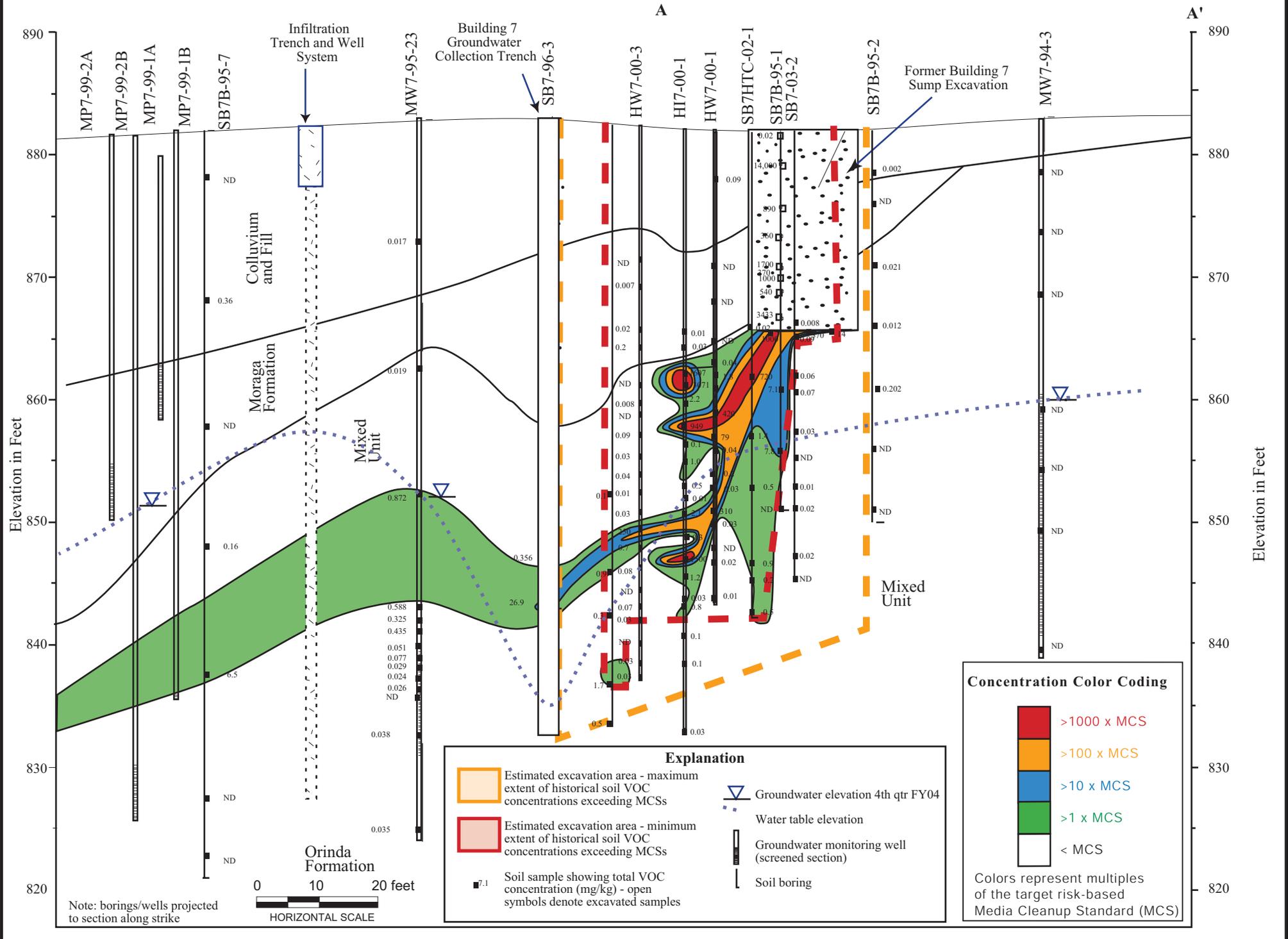


Figure 6. Geologic Cross Section A-A' Showing Soil Sample Results, Building 7 Lobe Source Zone.

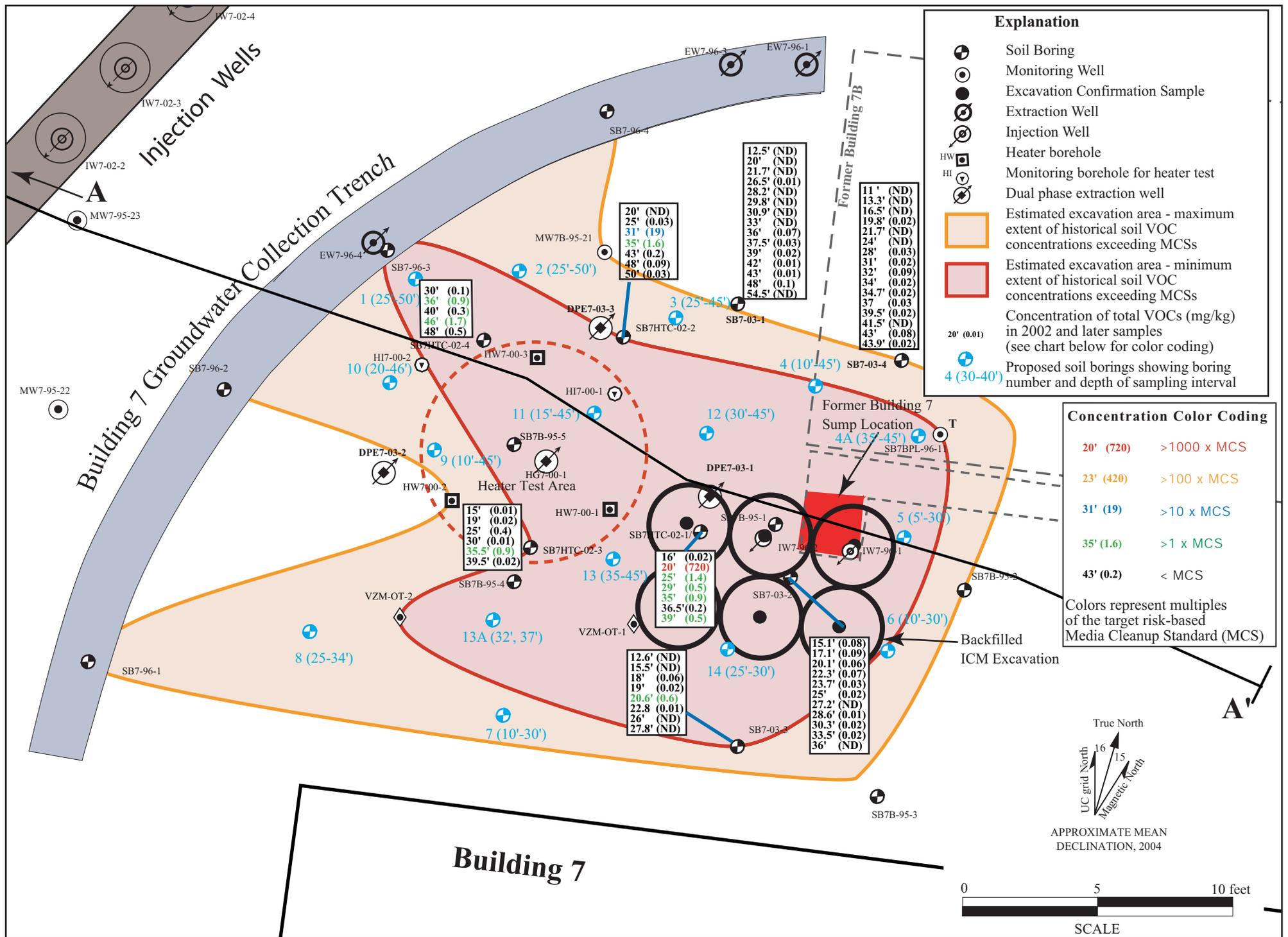
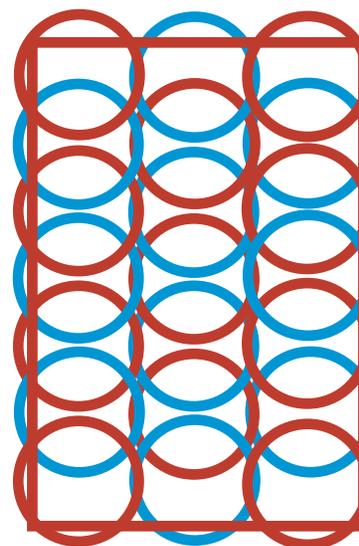
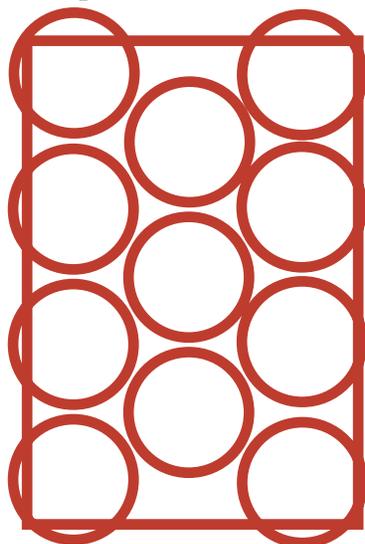


Figure 7. Proposed Soil Boring Locations and Estimated Excavation Area, Building 7 Lobe Source Zone

3,4,5a,5b,7-B7 sump excav.ai

Two boring sets, maximum overlap



Three boring sets, minimum overlap

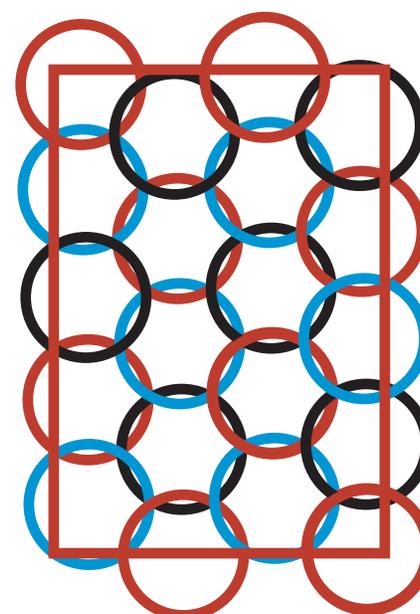
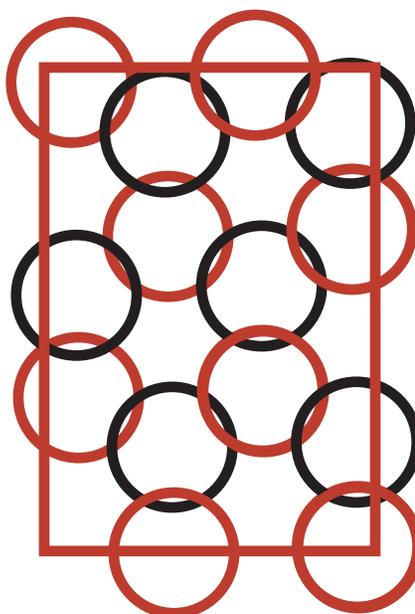
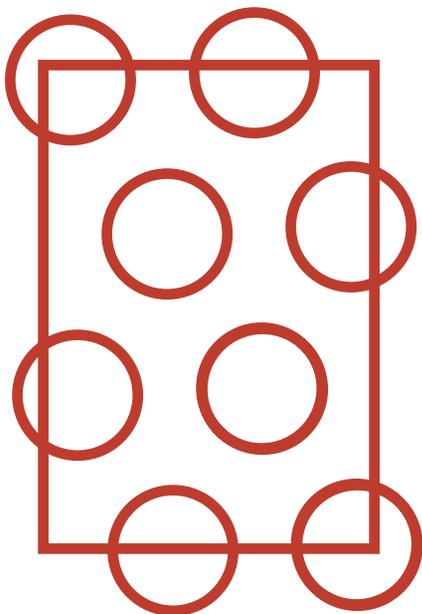


Figure 8. Schematic Showing Typical Drilling Sequences for Overlapping Borings.

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)						
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected		
				43	5.7	2.8	770			
Sample ID	Depth (ft)	Date	Lab							
SS7N-1-0	X 0	Oct-92	C	<0.005	0.11	<0.005	<0.005			
SS7N-2-0	X 0			<0.005	14	<0.005	0.27	Carbon tetrachloride=0.035		
SS7N-3-0	X 0			<0.005	1500	2.1	58	Carbon tetrachloride=7.2 1,1-DCA=1.3 1,1-DCE=0.35 Toluene=0.1		
SS7N-4-0	X 0	Nov-92	LBNL	<0.005	0.0667	0.0004	0.0025	Benzene=0.0001 Ethylbenzene=0.0002 Toluene=0.0007 Xylene=0.0002		
SS7N-5-1	X 1		C	<0.005	3.0	0.012	<0.005			
SS7N-5-2.5	X 2.5			0.024	6.3	0.15	0.22			
SS7N-5-3.5	X 3.5			0.023	8.2	0.88	0.11			
SS7N-6-1	X 1.0			<0.005	0.17	<0.005	<0.005			
SS7N-6-2.5	X 2.5			<0.005	450	0.7	3.4			
SS7N-6-4	X 4.0			0.005	9.6	0.097	0.28			
SS7N-7-1	X 1.0			<0.005	0.13	<0.005	<0.005			
SS7N-7-2.5	X 2.5			<5	5500	1.7	46			
SS7N-8-3	X 3.0			<25	5000	<25	<25			
SS7N-9-3	X 3.0			<0.005	<0.005	<0.005	<0.005			
VZM-OT-1-4	4.0			Dec-92	C	<0.005	0.11	<0.005	<0.005	
VZM-OT-1-7.5	7.5					<0.005	0.29	<0.005	<0.005	
VZM-OT-1-11	11	<0.005				0.15	<0.005	<0.005		
VZM-OT-1-15.5	15.5	<0.005	0.64			0.009	0.0097			
VZM-OT-1-20.5	20.5	<0.035	36			0.3	0.23			
VZM-OT-1-25	25	<0.005	0.031			<0.005	<0.005			
VZM-OT-1-30	30	<0.005	0.56			<0.005	<0.005			
VZM-OT-2-6	6.0	Aug-93	LBNL			<0.001	0.31	0.004	0.003	
VZM-OT-2-10.5	10.5		<0.001	0.006	<0.001	<0.001				
VZM-OT-2-11	11		C							
VZM-OT-2-15.5	15.5		LBNL	<0.001	0.034	<0.001	<0.001			
VZM-OT-2-20.5	20.5		<0.001	0.184	0.004	0.004				
VZM-OT-2-25.5	25.5		<0.001	0.3	0.011	0.009				
VZM-OT-2-30.5	30.5		<0.001	21.8	1.12	0.431				
VZM-OT-2-31	31		C							
MW7-94-3-4.5	4.5	May-94	BC	<0.005	<0.005	<0.005	<0.005			
MW7-94-3-9.5	9.5			<0.005	<0.005	<0.005	<0.005			
MW7-94-3-14.5	14.5			<0.005	<0.005	<0.005	<0.005			
MW7-94-3-24	24			<0.005	<0.005	<0.005	<0.005			
MW7-94-3-28.8	28.8		BC	<0.005	<0.005	<0.005	<0.005			
MW7-94-3-33.7	33.7			<0.005	<0.005	<0.005	<0.005			
MW7-94-3-43.5	43.5			<0.005	<0.005	<0.005	<0.005			
SS-07-94-03-3	3.0	Jun-94	BC							
SS-07-94-03-6	6.0			<0.005	<0.005	<0.005	<0.005			

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
SB7B-95-1-0.5	X 0.5	Jun-95	BC	<0.005	0.021	<0.005	<0.005	
SB7B-95-1-2.8	X 2.8			<400	14,000	<400	<400	
SB7B-95-1-6	X 6.0			<20	890	<20	<20	
SB7B-95-1-8.3	X 8.3			<7	360	<7	<7	
SB7B-95-1-10.8	X 10.8			<30	1700	<30	<30	
SB7B-95-1-12.8	X 12.8			<20	540	<20	<20	
SB7B-95-1-15.3	X 15.3			<10	3400	33	<10	
SB7B-95-1-21	21			<0.10	5.4	1.7	<0.10	
SB7B-95-1-25.8	25.8			<0.1	7.6	0.23	<0.1	
SB7B-95-1-30.8	30.8			<0.005	<0.005	<0.005	<0.005	
SB7B-95-2-3.5	3.5	Jun-95	BC	<0.005	0.02	<0.005	<0.005	
SB7B-95-2-6	6.0			<0.005	<0.005	<0.005	<0.005	
SB7B-95-2-11	11			<0.005	0.021	<0.005	<0.005	
SB7B-95-2-16	16			<0.005	0.012	<0.005	<0.005	
SB7B-95-2-21	21			<0.005	0.19	0.012	<0.005	
SB7B-95-2-26	26			<0.005	<0.005	<0.005	<0.005	
SB7B-95-2-31	31			<0.005	<0.005	<0.005	<0.005	
SB7B-95-3-1.1	1.1	Jun-95	BC	<0.005	0.019	<0.005	<0.005	p-isopropyltoluene=0.007
SB7B-95-3-10.6	10.6			<0.005	0.014	<0.005	<0.005	
SB7B-95-3-16	16			<0.005	0.20	<0.005	<0.005	
SB7B-95-3-20.9	20.9			<0.005	0.017	<0.005	<0.005	
SB7B-95-3-25.7	25.7			<0.005	0.012	<0.005	<0.005	
SB7B-95-3-30.9	30.9			<0.005	<0.005	<0.005	<0.005	
SB7B-95-4-2.5	2.5	Jun-95	BC	<0.005	0.022	0.0051	<0.005	
SB7B-95-4-5	5.0			<0.02	0.29	<0.02	<0.02	
SB7B-95-4-10.1	10.1			<0.005	<0.005	<0.005	<0.005	
SB7B-95-4-15.7	15.7			<0.01	0.094	<0.01	<0.01	
SB7B-95-4-20.3	20.3			<0.005	0.009	<0.005	<0.005	
SB7B-95-4-26	26			<0.005	6.0	0.095	0.059	1,1-DCE=0.006
SB7B-95-4-31	31			<0.01	2.4	<0.01	<0.01	
SB7B-95-5-2.5	2.5	Jun-95	BC	<0.01	0.053	<0.01	<0.01	
SB7B-95-5-5.8	5.8			0.043	1.4	0.13	<0.03	
SB7B-95-5-10.7	10.7			<0.005	0.075	<0.005	<0.005	
SB7B-95-5-15.8	15.8			<0.08	14	0.19	<0.08	
SB7B-95-5-20.5	20.5			<0.06	1.5	0.1	<0.06	
SB7B-95-5-25.7	25.7			<3	310	3.4	<3	
SB7B-95-5-30.6	30.6			<0.06	6.6	0.093	<0.06	
SB7-95-5-0.9	0.9			<0.005	0.13	<0.005	<0.005	
SB7-95-5-5.5	5.5			<0.005	<0.005	<0.005	<0.005	
SB7-95-5-11	11			<0.005	<0.005	<0.005	0.0087	
SB7-95-5-15.6	15.6			<0.005	0.012	<0.005	<0.005	
SB7-95-5-20.9	20.9			<0.005	<0.005	<0.005	<0.005	
SB7-95-5-25.4	25.4			<0.005	<0.005	<0.005	<0.005	
SB7-95-5-31	31			<0.005	<0.005	<0.005	<0.005	

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
SB7-95-6-1.8	1.8	Jun-95	BC	<0.005	0.86	<0.005	<0.005	
SB7-95-6-5.7	5.7			<0.005	<0.005	<0.005	<0.005	
SB7-95-6-10.7	10.7			<0.005	<0.005	<0.005	<0.005	
SB7-95-6-16	16			<0.005	0.0089	<0.005	<0.005	
SB7-95-6-20.7	20.7			<0.005	<0.005	<0.005	<0.005	
SB7-95-6-25	25			<0.005	<0.005	<0.005	<0.005	
SB7-95-6-30	30			<0.005	<0.005	<0.005	<0.005	
SB7-95-7-0.9	0.9	Jun-95	BC	<0.005	0.073	<0.005	<0.005	
SB7-95-7-5.5	5.5			<0.005	<0.005	<0.005	<0.005	
SB7-95-7-10.8	10.8			<0.005	<0.005	<0.005	<0.005	
SB7-95-7-16	16			<0.005	0.0084	<0.005	<0.005	
SB7-95-7-20.7	20.7			<0.005	0.013	<0.005	<0.005	
SB7-95-7-25.8	25.8			<0.005	<0.005	<0.005	<0.005	
SB7-95-7-30.4	30.4			<0.005	<0.005	<0.005	<0.005	
SS7N-95-1-2	X 2	Jul-95	BC	<0.03	0.38	0.039	<0.03	
SS7N-95-1-4	X 4			<1	59	1.6	<1	
SS-B7EXC-CTR-4.8	X 4.8	Aug-95	BC	<1	88	<1	<1	
SS-B7EXC-SE-4.8	X 4.8			<0.005	0.078	<0.005	<0.005	
SS-B7EXC-SW-4.8	X 4.8			<0.05	0.76	<0.05	<0.05	
SS-B7EXC-NE-4.8	X 4.8			<0.005	0.016	<0.005	<0.005	
SS-B7EXC-NW-4.8	X 4.8			<0.3	15	<0.3	<0.3	
SS-B7EXC-W-5	X 5			<0.05	2.0	<0.05	<0.05	
SS-B7EXC-NNE-17	17			<0.3	14	<0.3	<0.3	
SS-B7EXC-N-17	17			<5	370	<5	<5	
SS-B7EXC-NNW-17	17			<20	1000	<20	<20	
SS-B7EXC-SSE-17	17			<0.1	3.2	<0.1	<0.1	
SS-B7EXC-S-17	17			<10	430	<10	<10	
SS-B7EXC-SSW-17	17			<6	300	<6	<6	
BS-MW7-95-22-4.6	4.6			Aug-95	BC	<0.005	<0.005	
BS-MW7-95-22-10.3	10.3	<0.005	<0.005					
BS-MW7-95-22-14.5	14.5	0.0052	<0.005					
BS-MW7-95-22-20.1	20.1	0.013	<0.005					
BS-MW7-95-22-25	25	0.011	<0.005					
BS-MW7-95-22-30.2	30.2	<0.005	<0.005					
BS-MW7-95-22-35.2	35.2	0.055	0.033					
BS-MW7-95-22-40	40	0.022	<0.005					
BS-MW7-95-23-10	10	Dec-95	BC	0.017	<0.005			
BS-MW7-95-23-20.5	20.5			0.019	<0.005			
BS-MW7-95-23-30.7	30.7			0.73	0.13			Carbon Tetrachloride=0.0067 1,1,1,2-PCA=0.0056
BS-MW7-95-23-40	40			0.22	0.35			Carbon Tetrachloride=0.018
BS-MW7-95-23-41	41			0.17	0.15			Carbon Tetrachloride=0.005
BS-MW7-95-23-41.7	41.7			0.31	0.12			Carbon Tetrachloride=0.0053
BS-MW7-95-23-43	43			0.027	0.024			

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
BS-MW7-95-23-44	44	Dec-95	BC	0.049	0.028			
BS-MW7-95-23-44.9	44.9			0.015	0.014			
BS-MW7-95-23-45.6	45.6			0.011	0.013			
BS-MW7-95-23-46.5	46.5			0.0075	0.018			
BS-MW7-95-23-47.2	47.2			<0.005	<0.005			
BS-MW7-95-23-50.3	50.3			0.014	0.024			
BS-MW7-95-23-58	58			0.029	0.0057			
BS-SB7-96-1-40	40	May-96	CLS	<0.009	0.0094	0.018	<0.009	
BS-SB7-96-2-46	46			<0.005	<0.005	<0.005	<0.005	
BS-SB7-96-3-36	36			<0.005	0.34	0.016	<0.005	
BS-SB7-96-3-40	40			<0.05	24	2.7	<0.05	carbon tetrachloride=0.078 chloroform=0.092
BS-SB7-96-4-36	36			<0.005	0.031	0.0083	<0.005	
BS-SB7-96-4-45.4	45.4			<0.005	0.020	<0.005	<0.005	
BS-SB7-96-4-55.6	55.6			<0.005	0.026	<0.005	<0.005	
BS-SB7-96-4-62.2	62.2			<0.005	0.0055	<0.005	<0.005	
BS-HW7-00-1-4	4	Oct-00	BC	<0.005	0.09	<0.005	<0.005	
BS-HW7-00-1-11.1	11.1			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-1-13.7	13.7			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-1-16.9	16.9			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-1-18.8	18.8			<0.005	0.042	<0.005	<0.005	Methyl-t-butylether=0.013
BS-HW7-00-1-19.8	19.8			<0.005	1.8	0.017	<0.005	
BS-HW7-00-1-21.3	21.3			<0.005	0.140	<0.005	<0.005	
BS-HW7-00-1-22.8	22.8			<0.7	420	<0.7	<0.7	
BS-HW7-00-1-24.7	24.7			<0.2	79	<0.2	<0.2	
BS-HW7-00-1-26.1	26.1			<0.005	0.036	<0.005	<0.005	
BS-HW7-00-1-27.5	27.5			<0.005	0.21	<0.005	<0.005	
BS-HW7-00-1-28.9	28.9			<0.005	0.034	<0.005	<0.005	
BS-HW7-00-1-31	31			<7	310	<7	<7	
BS-HW7-00-1-32.4	32.4			<0.005	0.027	<0.005	<0.005	
BS-HW7-00-1-33.9	33.9			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-1-35.2	35.2			<0.005	0.017	<0.005	<0.005	
BS-HW7-00-1-37.7	37.7			<0.005	0.014	<0.005	<0.005	
BS-HW7-00-2-4.1	4.1	Oct-00	BC	<0.005	0.130	<0.005	<0.005	
BS-HW7-00-2-10.7	10.7			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-2-15.6	15.6			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-2-17	17			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-2-18.5	18.5			<0.005	0.018	<0.005	<0.005	
BS-HW7-00-2-21.5	21.5			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-2-23.5	23.5			<0.005	0.043	<0.005	<0.005	
BS-HW7-00-2-24.3	24.3			<0.005	0.14	<0.005	<0.005	
BS-HW7-00-2-26.5	26.5			<0.005	0.018	<0.005	<0.005	
BS-HW7-00-2-27.8	27.8			<0.005	0.008	<0.005	<0.005	
BS-HW7-00-2-29.1	29.1			<0.005	0.093	<0.005	<0.005	

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
PRG				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
BS-HW7-00-2-30.8	30.8	Oct-00	BC	<0.005	0.087	<0.005	<0.005	
BS-HW7-00-2-32.3	32.3			<0.005	0.12	<0.005	<0.005	
BS-HW7-00-2-34	34			<0.005	0.0052	<0.005	<0.005	
BS-HW7-00-2-34.5	34.5			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-2-36.3	36.3			<0.005	0.044	0.017	<0.005	
BS-HW7-00-2-38.1	38.1			<0.005	0.13	0.011	<0.005	
BS-HW7-00-2-42	42			<0.005	0.026	<0.005	<0.005	
BS-HW7-00-3-10.8	10.8	Nov-00	BC	<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-3-13	13			<0.005	0.0072	<0.005	<0.005	
BS-HW7-00-3-16.4	16.4			<0.005	0.016	<0.005	<0.005	
BS-HW7-00-3-18	18			<0.005	0.24	<0.005	<0.005	
BS-HW7-00-3-21.2	21.2			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-3-22.6	22.6			<0.005	0.008	<0.005	<0.005	
BS-HW7-00-3-23.6	23.6			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-3-25.3	25.3			<0.005	0.090	<0.005	<0.005	
BS-HW7-00-3-27.1	27.1			<0.005	0.018	0.013	<0.005	
BS-HW7-00-3-28.6	28.6			<0.005	0.036	<0.005	<0.005	
BS-HW7-00-3-29.9	29.9			<0.005	0.014	<0.005	<0.005	
BS-HW7-00-3-31.7	31.7			<0.005	0.025	<0.005	<0.005	
BS-HW7-00-3-33.1	33.1			<0.005	250	0.120	<0.005	carbon tetrachloride=0.014 1,4-Dichlorobenzene=0.0068 1,1,1,2-PCA=0.012
BS-HW7-00-3-34.6	34.6			<0.005	0.520	0.160	<0.005	1,1,1,2-PCA=0.0064
BS-HW7-00-3-36.2	36.2			<0.005	0.0079	<0.005	<0.005	
BS-HW7-00-3-38	38			<0.005	<0.005	<0.005	<0.005	
BS-HW7-00-3-39.4	39.4			<0.005	0.027	0.042	<0.005	
BS-HW7-00-3-40.7	40.7	<0.005	0.018	0.012	<0.005			
BS-HW7-00-3-42.4	42.4	<0.005	<0.005	<0.005	<0.005			
BS-HW7-00-3-44	44	<0.005	0.030	0.0098	<0.005			
BS-HW7-00-3-45.2	45.2	<0.005	0.025	<0.005	<0.005			
BS-HI7-00-1-16.2	16.2	Nov-00	BC	<0.005	0.014	<0.005	<0.005	
BS-HI7-00-1-17.5	17.5			<0.005	0.031	<0.005	<0.005	
BS-HI7-00-1-19.5	19.5			<0.005	1600	4.2	1.4	carbon tetrachloride=1.2 1,2-Dichlorobenzene=0.058 1,4-Dichlorobenzene=0.072 1,1-DCE=0.066 Ethylbenzene=0.013 1,1,2,2-PCA=0.029 Toluene=0.031 1,2,4-Trimethylbenzene=0.017 1,3,5-Trimethylbenzene=0.006 Total xylenes=0.070

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
PRG				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
BS-HI7-00-1-20.5	20.5	Nov-00	BC	<0.05	3000	60	11	Bromoform=0.12 carbon tetrachloride=10 1,2-Dichlorobenzene=0.30 1,4-Dichlorobenzene=0.38 1,1-DCE=0.16 Ethylbenzene=0.10 1,1,1,2-PCA=2.9 1,1,2,2-PCA=0.17 1,2,4-Trimethylbenzene=0.087 Total xylenes=0.54
BS-HI7-00-1-22.1	22.1			<0.005	1.9	0.30	0.027	carbon tetrachloride=0.009 1,1,2,2-PCA=0.014
BS-HI7-00-1-23.7	23.7			<0.01	910	32	2.0	carbon tetrachloride=3.0 1,1,1,2-PCA=1.5
BS-HI7-00-1-25.3	25.3			<0.005	0.13	0.048	<0.005	
BS-HI7-00-1-26.6	26.6			<0.005	1.0	<0.005	<0.005	1,1,1,2-PCA=0.012
BS-HI7-00-1-28.6	28.6			<0.005	0.33	0.18	<0.005	
BS-HI7-00-1-29.7	29.7			<0.005	0.010	<0.005	<0.005	
BS-HI7-00-1-31	31			<0.005	2.0	0.093	<0.005	1,1,1,2-PCA=0.012
BS-HI7-00-1-32.8	32.8			<0.005	0.28	0.017	<0.005	
BS-HI7-00-1-34.6	34.6			<3	1500	<3	<3	
BS-HI7-00-1-36	36			<0.005	1.2	0.0053	<0.005	Chloromethane=0.0067
BS-HI7-00-1-37.8	37.8			<0.005	0.033	0.0055	<0.005	
BS-HI7-00-1-38.5	38.5			<0.005	0.79	0.028	<0.005	
BS-HI7-00-1-40.8	40.8			<0.005	0.11	0.0074	<0.005	
BS-HI7-00-1-43	43			<0.005	0.13	0.0052	<0.005	
BS-HI7-00-1-48.5	48.5			<0.005	0.025	<0.005	<0.005	
BS-SB7BHTC-02-1-16	16	Dec-02	BC	<0.005	0.024	<0.005	<0.005	
BS-SB7BHTC-02-1-20	20			<0.005	720	0.062	<0.005	n-Butylbenzene=0.0055 1,2-Dichlorobenzene=0.016 1,3-Dichlorobenzene=0.046 1,4-Dichlorobenzene=0.046 Ethylbenzene=0.0055 Hexachlorobutadiene=0.0051 p-Isopropyltoluene=0.0072 Naphthalene=0.0080 1,1,1,2-Tetrachloroethane=0.039 Total Xylenes=0.013
BS-SB7BHTC-02-1-25	25.0			<0.005	1.4	<0.005	<0.005	
BS-SB7BHTC-02-1-29	29.0			<0.005	0.52	0.0057		
BS-SB7BHTC-02-1-35	35.0			<0.005	0.92	<0.005	<0.005	Methyl t-butyl ether=0.017
BS-SB7BHTC-02-1-36.5	36.5			<0.005	0.16	<0.005	<0.005	
BS-SB7BHTC-02-1-39	39.0			<0.05	0.5	<0.05	<0.05	
BS-SB7BHTC-02-2-20.3	20.3			<0.005	<0.005	<0.005	<0.005	
BS-SB7BHTC-02-2-25	25.0			<0.005	0.028	<0.005	<0.005	Methyl t-butyl ether=0.0098
BS-SB7BHTC-02-2-30.8	30.8			<0.005	19	0.041	<0.005	Methyl t-butyl ether=0.0090
BS-SB7BHTC-02-2-35.3	35.3			<0.005	1.4	0.2	<0.005	Carbon tetrachloride=0.0054

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
BS-SB7BHTC-02-2-42.6	42.6	Dec-02	BC	<0.005	0.2	0.011	<0.005	
BS-SB7BHTC-02-2-47.5	47.5			<0.005	0.09	<0.005	<0.005	Methyl t-butyl ether=0.0057
BS-SB7BHTC-02-2-50	50.0			<0.005	0.032	<0.005	<0.005	Methyl t-butyl ether=0.0066
BS-SB7BHTC-02-3-15	15.0			<0.005	0.0084	<0.005	<0.005	Methyl t-butyl ether=0.01
BS-SB7BHTC-02-3-19	19.0			<0.005	0.018	<0.005	<0.005	Methyl t-butyl ether=0.016
BS-SB7BHTC-02-3-24.5	24.5			<0.005	0.4	<0.005	<0.005	Methyl t-butyl ether=0.02
BS-SB7BHTC-02-3-30.5	30.5			<0.005	0.0095	<0.005	<0.005	Methyl t-butyl ether=0.016
BS-SB7BHTC-02-3-35.5	35.5			<0.005	0.91	<0.005	<0.005	Methyl t-butyl ether=0.017
BS-SB7BHTC-02-3-39.5	39.5			<0.005	0.011	0.0064	<0.005	
BS-SB7BHTC-02-4-30.3	30.3			<0.005	0.1	0.016	<0.005	
BS-SB7BHTC-02-4-35.5	35.5			<0.005	0.54	0.33	<0.005	Chloroform=0.0076
BS-SB7BHTC-02-4-40.3	40.3			<0.005	0.11	0.17	<0.005	
BS-SB7BHTC-02-4-45.6	45.6			<0.005	1.5	0.16	<0.005	Chloroform=0.0086
BS-SB7BHTC-02-4-48	48.0			<0.005	0.45	0.03	<0.005	
BS-SB7-03-1-12.5	12.5	Mar-03	BC	<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-20	20			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-21.7	21.7			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-26.5	26.5			<0.005	0.0061	<0.005	<0.005	
BS-SB7-03-1-28.2	28.2			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-29.8	29.8			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-30.9	30.9			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-33	33			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-1-36	36			<0.005	0.066	0.012	<0.005	
BS-SB7-03-1-37.5	37.5			<0.005	0.032	<0.005	<0.005	
BS-SB7-03-1-39	39			<0.005	0.023	<0.005	<0.005	
BS-SB7-03-1-39R	39			<0.005	0.46	0.021	<0.005	
BS-SB7-03-1-42	42			<0.005	0.009	<0.005	<0.005	
BS-SB7-03-1-43	43			<0.005	0.01	<0.005	<0.005	
BS-SB7-03-1-43R	43			<0.005	0.019	<0.005	<0.005	
BS-SB7-03-1-48	48			<0.005	0.096	0.0084	<0.005	
BS-SB7-03-1-54.5	54.5			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-2-15.1	15.1	Mar-03	BC	<0.005	0.0086	<0.005	<0.005	
BS-SB7-03-2-17.1	17.1			<0.005	0.087	<0.005	<0.005	
BS-SB7-03-2-17.1R	17.1			<0.005	0.017	<0.005	<0.005	Benzene = 0.0059
BS-SB7-03-2-20.1	20.1			<0.005	0.063	0.01	<0.005	
BS-SB7-03-2-20.1R	20.1			<0.005	15	0.26	<0.005	Carbon tetrachloride = 0.02 Chloroform = 0.0071
BS-SB7-03-2-22.3	22.3			<0.005	0.072	<0.005	<0.005	
BS-SB7-03-2-23.7	23.7			<0.005	0.028	<0.005	<0.005	
BS-SB7-03-2-25	25			<0.005	0.018	<0.005	<0.005	
BS-SB7-03-2-27.2	27			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-2-28.6	28.6			<0.005	0.0085	<0.005	<0.005	
BS-SB7-03-2-30.3	30.3			<0.005	0.016	<0.005	<0.005	

Appendix 1
Concentrations of COCs in Soil (mg/kg)
AOC 2-5: Former Building 7 Sump

				Volatile Organic Compounds (VOCs)				
				cis 1,2-DCE	PCE	TCE	1,1,1-TCA	Other Compounds Detected
PRG				43	5.7	2.8	770	
Sample ID	Depth (ft)	Date	Lab					
BS-SB7-03-2-33.5	33.5	Mar-03	BC	<0.005	0.016	<0.005	<0.005	
BS-SB7-03-2-36	36			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-3-12.6	12.6	Mar-03	BC	<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-3-15.5	15.5			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-3-18	18			<0.005	0.062	<0.005	<0.005	
BS-SB7-03-3-18R	18			<0.005	0.026	<0.005	<0.005	Benzene = 0.0091
BS-SB7-03-3-19	19			<0.005	0.02	<0.005	<0.005	
BS-SB7-03-3-19R	19			<0.005	0.15	<0.005	<0.005	Benzene = 0.0063
BS-SB7-03-3-20.6	20.6			<0.005	0.6	<0.005	<0.005	
BS-SB7-03-3-20.6R	20.6			<0.005	1.4	<0.005	<0.005	
BS-SB7-03-3-22.8	22.8			<0.005	0.0069	<0.005	<0.005	
BS-SB7-03-3-26	26			<0.005	<0.005	<0.005	<0.005	
BS-SB7-03-3-27.8	27.8	<0.005	<0.005	<0.005	<0.005			

<	= Not detected above reporting limit (reporting limit shown)
	= Not analyzed

BC = Analysis by BC Laboratories
 C = Analysis by Chromolab
 LBNL = Analysis by LBNL
 VOCs analyzed by EPA Method 8240 or 8260

COPCs = Chemicals of Potential Concern
 X = Sample location has been excavated
 Concentrations shown in **bold** are above PRGs for residential soil.

Attachment 3

Monitoring Protocols for Monitored Natural Attenuation and Enhanced
Bioremediation for the Lawrence Berkeley National Laboratory
Environmental Restoration Program, dated November 2005.



E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program



United States Department of Energy

MONITORING PROTOCOLS
for
MONITORED NATURAL ATTENUATION
and
ENHANCED BIOREMEDIATION

for the

Lawrence Berkeley National Laboratory

ENVIRONMENTAL RESTORATION PROGRAM

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LIST OF ABBREVIATIONS

Berkeley Lab	Lawrence Berkeley National Laboratory
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CVOCs	Chlorinated Volatile Organic Compounds
DCA	Dichloroethane
DCE	Dichloroethene
DO	Dissolved Oxygen
ERP	Environmental Restoration Program
HRC	Hydrogen Release Compound
HSPP	Health and Safety Program Plan
µg/L	micrograms per liter
MCL	Maximum Contaminant Level for drinking water
MCS	Media Cleanup Standard
mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
ORP	Oxidation-Reduction Potential
PCE	Tetrachloroethene (perchloroethylene)
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and recovery Act
SOP	Standard Operating Procedure
TCA	Trichloroethane
TCE	Trichloroethene
USEPA	United States Environmental Protection Agency
VFA	Volatile Fatty Acid

SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

Monitored Natural Attenuation (MNA) is the corrective measure approved by the California Environmental Protection Agency Department of Toxic Substances Control (DTSC) for implementation in several areas of groundwater contamination at the Lawrence Berkeley National Laboratory (Berkeley Lab) (Berkeley Lab, 2005). The purpose of this document is to identify the data needs and evaluation methods required to address long-term monitoring requirements for monitored natural attenuation of chlorinated volatile organic compounds (CVOCs) in groundwater at Berkeley Lab. The work will be carried out as part of the Corrective Measures Implementation (CMI) phase of the Resource Conservation and Recovery Act (RCRA) Corrective Action Process (CAP).

MNA has been approved for implementation in the following areas of groundwater contamination at Berkeley Lab.

- Building 51/64 Groundwater Solvent Plume downgradient area
- Building 7 Lobe of the Old Town Groundwater Solvent Plume downgradient area
- Building 25A Lobe of the Old Town Groundwater Solvent Plume downgradient area
- Building 69A Area of Groundwater Contamination.

In addition, MNA may be implemented for the Building 51L Groundwater Solvent Plume and/or the Building 25A Lobe of the Old Town Groundwater Solvent Plume in the event that the primary corrective measures are not effective in meeting corrective measures objectives.

MNA refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The “natural attenuation processes” include a variety of physical, chemical, or biological processes that, under favorable conditions, reduce the mass, toxicity, mobility,

volume, or concentration of contaminants. These processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants.

MNA will consist of a groundwater monitoring program to verify that the corrective measures objectives can be achieved, monitor the long-term behavior of the plume, and document when MCSs have been attained. In addition, groundwater quality will be monitored downgradient from plumes to ensure that chemicals of concern are not migrating downgradient from the plume area. Objectives of the monitoring program will be met by measuring CVOC concentrations and hydrochemical parameters (e.g., oxidation-reduction (redox) parameters, dissolved organic carbon, pH) in the groundwater. These data will be used to identify spatial and temporal changes in the areas of groundwater contamination for which MNA is the approved remedy, and to assess whether these changes will meet the corrective measures objectives specified in the Corrective Measures Study (CMS) Report (Berkeley Lab, 2005). Spatial and temporal changes of interest include:

- Reduction in contaminant concentrations indicating progress toward achieving Media Cleanup Standards (MCSs)
- Changes in plume boundaries
- Geochemical changes that may be indicative of changes in processes affecting the rate and extent of natural attenuation.

This document provides the rationale and overall requirements for monitoring the effectiveness of MNA at Berkeley Lab. Plume-specific requirements for each of the areas of groundwater contamination where MNA is the approved remedy (i.e., the specific wells to be monitored) are provided in the CMI Workplan.

1.2 CONCEPTS OF NATURAL ATTENUATION AND ENHANCED BIODEGRADATION

1.2.1 Natural Attenuation Mechanisms

Natural attenuation mechanisms can be classified as destructive or non-destructive. Non-destructive mechanisms include sorption, dispersion, dilution, and volatilization because they

reduce concentrations, but do not reduce the total mass of contaminants. Destructive mechanisms transform contaminants to a less toxic form through processes such as biodegradation or abiotic transformations. Biodegradation, also referred to as bioremediation, is considered the most prevalent destructive mechanism. Biodegradation is a process in which naturally occurring microorganisms, such as bacteria, break down target substances, such as chlorinated hydrocarbons, generally into less toxic or non-toxic substances.

1.2.2 Biodegradation Processes

Naturally-occurring processes can occur in the subsurface that reduce the mass, toxicity, mobility, volume, or concentration of certain chemicals in soil and groundwater. The natural biodegradation of certain types of organic chemicals can occur when indigenous (naturally-occurring) microorganisms capable of degrading these chemicals are present and when sufficient concentrations of nutrients, electron acceptors, and electron donors are available to these organisms.

Microorganisms obtain energy for growth and activity by mediating (physiologically coupling) oxidation and reduction reactions (redox reactions) and using the chemical energy that is made available by the reactions. Redox reactions involve the transfer of electrons to produce chemical energy. Oxidation is a reaction where electrons are lost (regardless of whether or not oxygen is present), and reduction is a reaction where electrons are gained. Therefore, within a redox reaction, a compound being oxidized is referred to as an electron donor and a compound being reduced is referred to as an electron acceptor (sometimes known as an oxidizing agent). Hence, electron transfer is from the electron donors to electron acceptors.

During biodegradation, carbon typically serves as the primary growth substrate (i.e., “food”) for the microorganisms, and is the electron donor that is oxidized. Either natural organic carbon or anthropogenic (man-made) carbon such as fuel hydrocarbons or certain chlorinated hydrocarbons may serve as carbon sources for biodegradation. Electron acceptors for redox reactions occurring during biodegradation can be elements or compounds occurring in relatively oxidized states such as oxygen, nitrate, manganese IV, ferric iron, sulfate, and carbon dioxide. Under certain conditions, some chlorinated compounds can serve as electron acceptors.

Chlorinated hydrocarbons biodegrade as a result of several processes including: direct oxidation, reductive dechlorination, and cometabolism, discussed below.

Direct Oxidation

In the presence of oxygen bacteria are able to use the carbon found in CVOCs as a primary growth substrate (“food”). In this case, the CVOC is the electron donor, which is oxidized, while one or more electron acceptors is reduced. This is the most common mechanism for the biodegradation of fuel hydrocarbons and some less-oxidized chlorinated hydrocarbons such as vinyl chloride. Under aerobic conditions, dissolved oxygen (DO) in groundwater is the primary electron acceptor. The aerobic oxidation of chlorinated hydrocarbons can ultimately yield carbon dioxide, water, and chloride or other organic by-products such as acetate. In the absence of oxygen, microorganisms in some cases use contaminants as their primary substrate. Under anaerobic conditions, the electron acceptor can be one of the following elements or compounds (listed in decreasing order of energy production [increasing order of reducing conditions]): nitrate, manganese IV, ferric iron, sulfate, and carbon dioxide.

Reductive Dechlorination

The most common anaerobic process by which chlorinated compounds biodegrade is an electron transfer process called reductive dechlorination. In this process, the CVOC is used as an electron acceptor, not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom. This mode of biotransformation requires that a source of carbon (electron donor) be present in order for microbial growth and reductive dechlorination to occur. This mechanism is common for the natural biodegradation of highly-oxidized chlorinated hydrocarbons such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethenes (DCEs), trichloroethanes (TCAs), and dichloroethanes (DCAs). The electron donors (potential carbon sources) can include low molecular weight organic compounds (e.g., lactate, acetate, methanol, glucose, etc.), fuel hydrocarbons, byproducts of fuel degradation (e.g., volatile fatty acids), or naturally occurring organic matter. If the subsurface environment is depleted of electron donors before the chlorinated organic chemicals are removed (reduced), reductive dechlorination will cease. Each successive step in the dechlorination process is theoretically slower than the

preceding step, and therefore at some sites, biodegradation may not proceed to completion and intermediate products (e.g., DCE or vinyl chloride) may accumulate.

Cometabolism

When an organic contaminant is biodegraded via cometabolism, the contaminant is neither an electron acceptor nor an electron donor in the redox reaction. Instead, the degradation of the contaminant is catalyzed by an enzyme cofactor (e.g., catabolic oxygenases such as soluble methane monooxygenase) that is produced by microorganisms for other purposes. These enzyme cofactors catalyze the initial step in the oxidation of their respective primary growth substrate (fuel hydrocarbons or other organic compounds such as methane or phenol) and fortuitously initiate oxidation of a variety of contaminants, including many of the CVOCs. Chlorinated solvents are usually only partially degraded during cometabolism because in some cases the cometabolic degradation of the contaminant may be harmful to the microorganisms responsible for the production of the enzyme or cofactor. Cometabolism has been most commonly identified as a biodegradation mechanism for CVOCs in aerobic environments where oxygen is the primary electron acceptor and a suitable electron donor is present.

1.2.3 Enhanced Biodegradation

In some cases, conditions may be favorable for natural biodegradation processes, but the rate of biodegradation is insufficient, based on an insufficient quantity of constituents that can function as electron donors in the biodegradation process. In such cases, the controlled release of Hydrogen Release Compound[®] (HRC) into the groundwater can be conducted to enhance natural biodegradation of CVOCs. HRC is a proprietary, environmentally safe, food quality, polylactate ester formulate manufactured by Regensis Bioremediation Products, Inc. for the slow release of lactic acid into groundwater upon hydration. The lactic acid is biotransformed into pyruvic acid and acetic acid releasing hydrogen in both steps. If anaerobic conditions exist, then HRC can provide a source of hydrogen, which is used as an electron donor in the reductive dechlorination process. Anaerobic microbes substitute the hydrogen for chlorine in the chlorinated hydrocarbon molecule, using both the hydrogen and electrons from the HRC.

1.3 EVIDENCE OF NATURAL ATTENUATION OR ENHANCED BIODEGRADATION

Natural attenuation and/or enhanced biodegradation is generally evaluated using the following lines of evidence:

- 1) Reduction in contaminant mass.
- 2) Presence and distribution of hydrochemical indicators of natural attenuation.
- 3) Direct microbial evidence.

This workplan provides the requirements for collecting the data required to support only the first two lines of evidence. Laboratory microbial studies were previously completed during the Corrective Measures Study (CMS) for the Building 51/64 Groundwater Solvent Plume, and no additional microbial studies are planned. Collection of microbial evidence is generally only required when field data supporting the first two lines of evidence are insufficient to adequately support natural attenuation.

1.3.1 Reduction in Contaminant Mass

By tracking changes in CVOC concentrations over time, it is possible to show that reductions in contaminant mass are occurring, and/or that the relative proportions of individual CVOCs are consistent with identified degradation pathways. A diagram showing the generalized degradation pathways for CVOCs is shown on Figure 2. In general, reductive dechlorination of chlorinated ethenes occurs by sequential dechlorination from PCE (4 chlorines) to TCE (3 chlorines) to DCE (2 chlorines) to vinyl chloride (1 chlorine) to ethene (no chlorines), and to ethane (also no chlorines).

Chlorinated ethanes can also undergo reductive dechlorination, such as the reduction of TCA to DCA to chloroethane to ethane. However, this pathway can be complicated by nonbiological (abiotic) reactions that can affect TCA and its daughter products. The most common abiotic reactions affecting CVOCs are hydrolysis (a substitution reaction) and dehydrohalogenation (an elimination reaction). Hydrolysis can be responsible for the abiotic conversion of 1,1,1-TCA to acetic acid, and the abiotic degradation of 1,1,1-TCA to 1,1-DCE can be accomplished by dehydrohalogenation. Attributing changes in either the presence or absence of halogenated solvents, or their concentrations, to abiotic processes is usually difficult.

Similar to chlorinated ethenes and ethanes, carbon tetrachloride (4 chlorines) can undergo reductive dechlorination to chloroform (3 chlorines), then to dichloromethane (methylene chloride) (2 chlorines), and then to chloromethane.

1.3.2 Hydrochemical Indicator Parameters

Natural biodegradation of organic chemicals causes predictable changes in groundwater hydrochemistry, which can be measured. As the available electron acceptors are used up, the dominant electron accepting process changes to allow other electron acceptors to be utilized. The depletion of electron acceptors results in a succession of bacterial types adapted to specific electron acceptors and oxidation reduction potential (ORP) regimes. Figure 1 shows these different processes and how they relate to ORP, electron acceptors, and measurable hydrochemical indicator parameters for each of the processes. The reductive potential of the groundwater increases and the ORP of the water decreases as each of the electron acceptors are utilized, which results in a succession of bacterial types adapted to specific redox regimes and electron acceptors. Although measurement of the ORP has been used to identify which electron-accepting processes may be operating or have the capacity to operate at a site, such process identification using ORP measurements is thought to be unreliable because theoretical ORP of groundwater is difficult to accurately measure in the field (Chapelle, 1996). Stronger hydrochemical evidence of biodegradation and the succession of redox reactions is provided by the concentrations of the hydrochemical indicator parameters relative to background levels as shown on Figure 1. These include decreased dissolved oxygen (DO), decreased nitrate, increased ferrous iron (iron II), decreased sulfate, and increased methane.

SECTION 2

NATURAL ATTENUATION AND ENHANCED BIODEGRADATION MONITORING PROGRAM

2.1 SAMPLING REQUIREMENTS

The MNA monitoring program will utilize existing monitoring wells to assess whether hydrochemical conditions remain favorable to biodegradation, to determine whether concentration trends for individual CVOCs are consistent with continued natural attenuation, and to evaluate whether corrective action objectives have been met.

Groundwater samples collected from compliance monitoring wells that will be specified in the Groundwater Monitoring and Management Plan (GMMP) (to be prepared) will be analyzed for the contaminants of concern (CVOCs) to assess their concentration trends. In addition, samples collected from a selected subset of these wells will be analyzed for hydrochemical parameters indicative of the potential for biodegradation. These parameters are: dissolved oxygen (DO); dissolved carbon dioxide (CO₂); nitrate/nitrite (NO₃/NO₂); ferrous iron (Fe²⁺); sulfate/sulfide (SO₄²⁻/H₂S); and, methane (CH₄)/ethane (C₂H₆)/ethene (C₂H₄). Dissolved oxygen, nitrate, ferrous iron, sulfate, and methane are the analytes recommended by the United States Environmental Protection Agency (USEPA) for long-term monitoring in their Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater (Wiedemeier, 1998). Nitrite, sulfide, and carbon dioxide analyses are also proposed. Nitrite and sulfide levels will be used to help assess whether the nitrate to nitrite or sulfate to sulfide reduction process is occurring. Carbon dioxide is an important parameter to measure since it is the final byproduct of every respiration process, except methanogenesis. In addition, the following wellhead parameters will be monitored: pH, temperature, and specific conductance. Where Hydrogen Release Compounds (HRC[®]) are being used to enhance bioremediation, samples will also be analyzed for volatile fatty acids.

The data requirements are also listed in Table 1, which provides information on the ideal use of each parameter in evaluating natural attenuation.

Table 1. Analytical Requirements and Significance

Parameter	Trend in Concentration During Natural Biodegradation	Optimum Range in Concentration	Significance
Laboratory Measurements			
CVOCs	Increase in degradation products		Identify parent and degradation (daughter) products. Certain isomers/degradation products provide direct evidence of biodegradation (e.g., cis-1,2-DCE). Used to help assess reductions in contaminant mass.
Methane (CH ₄) Ethane (C ₂ H ₆), and Ethene (C ₂ H ₄)	Increases	> 0.5 mg/L	After sulfate has been depleted, carbon dioxide can be used as an electron acceptor for anaerobic biodegradation of organic carbon by methanogenesis, resulting in the production of methane.
Volatile Fatty Acids (VFAs) ⁽¹⁾	Increases	> 0.1 mg/L	Indicates that biodegradation through oxidation has occurred. These acids are added as a primary growth substrate, particularly to induce methanogenic conditions such as in Hydrogen Release Compounds (HRC).
Field or Laboratory Measurements			
Nitrate (NO ₃ ⁻)	Decreases	< 1.0 mg/L	After DO has been depleted used as an electron acceptor for anaerobic biodegradation by denitrifying bacteria.
Nitrite (NO ₂ ⁻)	Increases		Produced from nitrate under anaerobic conditions.
Sulfate (SO ₄ ²⁻)	Decreases	< 20 mg/L	After ferrous iron has been depleted used as an electron acceptor for anaerobic biodegradation. Indicator of sulfate reducing bacteria.
Sulfide (H ₂ S)	Increases	> 1 mg/L	May provide evidence of sulphate reduction.
Field Measurements			
Ferrous Iron (Fe ²⁺)	Increases	> 1.0 mg/L	An important trace nutrient for bacterial growth. Indicator of iron reducing bacteria.
Carbon Dioxide (CO ₂)	Increases	> 2 times background	Ultimate byproduct of every respiration process except methanogenesis.
Conductivity			Used to help assess representativeness of sample.
Dissolved Oxygen (DO)	Decreases	< 0.5 mg/L	Indicator of aerobic environments; suppresses the reductive dechlorination pathway at higher concentrations.
		> 1.0 mg/L	Vinyl chloride may be oxidized aerobically.
pH		5 < pH < 9	Measurement of suitability of environment to support a wide range of microbial species. pH is also used to help assess representativeness of sample.
		5 > pH > 9	Outside optimal range for reductive pathway.
Temperature		> 20°C	Biochemical process is accelerated. Used to help assess representativeness of sample.

(1) Analysis for VFAs only in areas where HRC is added to the groundwater to enhance bioremediation.

The analytical methods and collection, preservation, and handling requirements are provided in Table 2. Maximum required quantitation limits are also provided in Table 2.

Table 2. Analytical Methods and Collection, Preservation, and Handling Requirements Groundwater Analytical Protocol (Modified from Wiedemeier *et al.* 1998).

Analysis	Method	Comments	Sample Volume, Container, and Preservation	Maximum Quantification Limit
Laboratory Analysis				
CVOCs	EPA Method SW8260		Collect water samples in two 40 mL VOA vials; cool to 4°C; add hydrochloric acid to pH 2.	Maximum Contaminant Levels for drinking Water (MCL)
Methane (CH ₄), ethane (C ₂ H ₆), and ethene (C ₂ H ₄)	Kampbell <i>et al.</i> , 1989 and 1998 or SW3810 Modified	Method published by researchers at the USEPA. Limited to few commercial labs.	Collect water samples in 50 mL glass serum bottles with gray butyl /Teflon-faced septa and crimp caps; add H ₂ SO ₄ to pH less than 2, cool to 4°C.	1 µg/L
Volatile Fatty Acids	Method SW8015			1-25 mg/L
Laboratory or Field Analysis				
Nitrate (NO ₃ ⁻)	SW9056 (Ion Chromatography) (or other appropriate method, e.g., EPA Method E300.0, E353.2)	48-hr. turnaround time if not preserved with acid.	Collect in 500 mL polyethylene bottles with no headspace, and cool to 4°C. No acid is required for preservation if analyzed within 48 hours. The collected volume will be sufficient for analysis of NO ₃ ⁻ , NO ₂ ⁻ , and SO ₄ ⁻² .	1 mg/L
	Hach [®] Method 8039 (See Appendix B)	Field Method		
Nitrite (NO ₂ ⁻)	SW9056 (Ion Chromatography) (or other appropriate method, e.g., EPA Method E300.0, E353.2)	48-hr. turnaround time if not preserved with acid.	Collect in 500 mL polyethylene bottles with no headspace, and cool to 4°C. No acid is required for preservation if analyzed within 48 hours. The collected volume will be sufficient for analysis of NO ₃ ⁻ , NO ₂ ⁻ , and SO ₄ ⁻² .	0.1 mg/L
	USEPA-approved Hach [®] Method 8507 (See Appendix B)	Field method		

**Table 2. Analytical Methods and Collection, Preservation, and Handling Requirements
Groundwater Analytical Protocol (Modified from Wiedemeier *et al.* 1998) (cont'd.)**

Laboratory or Field Analysis (cont'd.)				
Sulfate (SO ₄ ⁻²)	SW9056 (Ion Chromatography) (or appropriate substitute method, e.g., EPA Method E300.0.)		Collect in 500 mL polyethylene bottles with no headspace, and cool to 4°C. No acid is required for preservation if analyzed within 48 hours. The collected volume will be sufficient for analysis of NO ₃ ⁻ , NO ₂ ⁻ , and SO ₄ ⁻² .	5 mg/L
	Hach® Method 8051 (See Appendix B)	Field Method	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C.	
Sulfide (H ₂ S, HS ⁻)	SW9030 (or appropriate substitute method, e.g., EPA Method E376.1)		Collect 500 ml in a pre-cleaned polyethylene bottle with no headspace; cool to 4°C. Must be preserved with zinc-acetate.	0.5 mg/L
	USEPA-approved Colorimetric Hach® Method 8131 (See Appendix B)	Field Method Filter if turbid	Collect 250 ml in a pre-cleaned polyethylene bottle with no headspace; cool to 4°C. Analyze as soon as possible.	
Field Analysis				
Ferrous Iron (Fe ⁺²)	Colorimetric Hach® Method 8146 (See Appendix B)	Filter if turbid.	Measure on site using a flow-through cell or over-flow cell.	1 mg/L
Carbon Dioxide (CO ₂)	CHEMtrix® Method 4500 or ASTM D513-02	Sodium Hydroxide titrimetric analysis		10 mg/L
Conductivity	E120.1/SW9050, direct reading meter			50 µS/cm ²
Dissolved Oxygen (DO)	E360.1 (direct meter reading) (See Appendix A)			0.2 mg/L
pH	SW9040B (direct meter reading) (See Appendix A)			0.1 standard units
Temperature (°C)	E170.1, Field probe with direct reading meter. (See Appendix A)			

2.2 SAMPLING LOCATIONS AND SCHEDULE

The specific wells that will be used for long-term monitoring of MNA are specified in the overall CMI Workplan. The wells that will be used for performance monitoring and the required frequency of sampling will be specified in a Groundwater Monitoring and Management Plan. Samples for long-term monitoring will be collected semiannually for the first year and annually thereafter. The initial samples will be collected during the summer of 2006. Additional samples will be collected for performance monitoring as required to comply with requirements of the Groundwater Monitoring and Management Plan. These samples will be analyzed for volatile organic compounds (VOCs) only (EPA Method 8260).

2.3 SAMPLING PROTOCOLS

All work will be performed in accordance with the procedures of the Berkeley Lab ERP Quality Assurance Program Plan (QAPP) (Berkeley Lab 1994a), Berkeley Lab ERP Standard Operating Procedures (SOPs) (Berkeley Lab 1994b), and the Berkeley Lab ERP Health and Safety Program Plan (HSPP) (Berkeley Lab 2004).

2.4 WASTE HANDLING

Handling and disposal of purged groundwater from all sampling activities will be done in accordance with the provisions of the Berkeley Lab Standard Operating Procedures (SOPs) (Berkeley Lab, 1994b).

SECTION 3

REFERENCES

- Berkeley Lab, 2004. Health and Safety Program Plan. Lawrence Berkeley National Laboratory, Environmental Restoration Program, Berkeley, California.
- Berkeley Lab, 1994a. Quality Assurance Program Plan. Lawrence Berkeley National Laboratory, Environmental Restoration Program, Berkeley, California.
- Berkeley Lab, 1994b. Standard Operating Procedures. Lawrence Berkeley National Laboratory, Environmental Restoration Program, Berkeley, California.
- Berkeley Lab, 2005. RCRA Corrective Measures Study Report for the Environmental Restoration Program. Lawrence Berkeley National Laboratory, Berkeley, California, February, 2005.
- Chapelle, F.H. (1996). Identifying Redox Conditions that Favor the Natural Attenuation of Chlorinated Ethenes in Contaminated Ground-Water Systems. In: *Proceedings for the Symposium on Natural Attenuation of Chlorinated Organics in Ground Water*, Dallas, Texas, September 11-13, 1996. EPA/540/R-96/509.
- Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, P.E. Haas, R.N. Miller, J.E. Hansen and F.H. Chapelle, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater, EPA/600/R-98/128, USEPA, Office of Research and Development, Washington, DC.

LIST OF FIGURES

Figure 1. Electron-Accepting Processes and Measurable Indicator Parameters of Natural Biodegradation as a Function of Oxidation-Reduction Potential.

Figure 2. Generalized Degradation Pathways of Chlorinated Aliphatic Hydrocarbons (CVOCs).

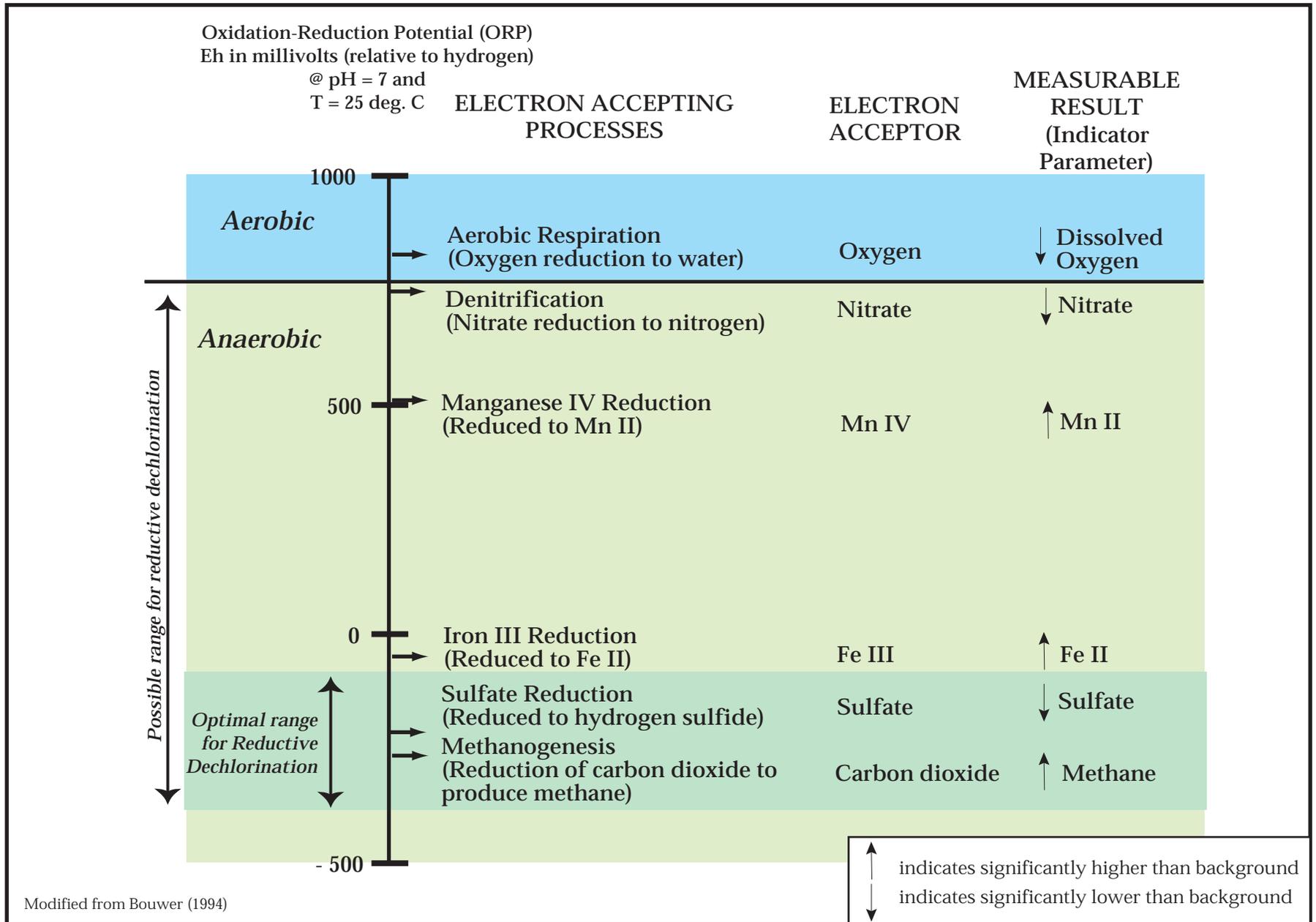


Figure 1. Electron-Accepting Processes and Measurable Indicator Parameters of Natural Biodegradation as a Function of Oxidation-Reduction Potential.

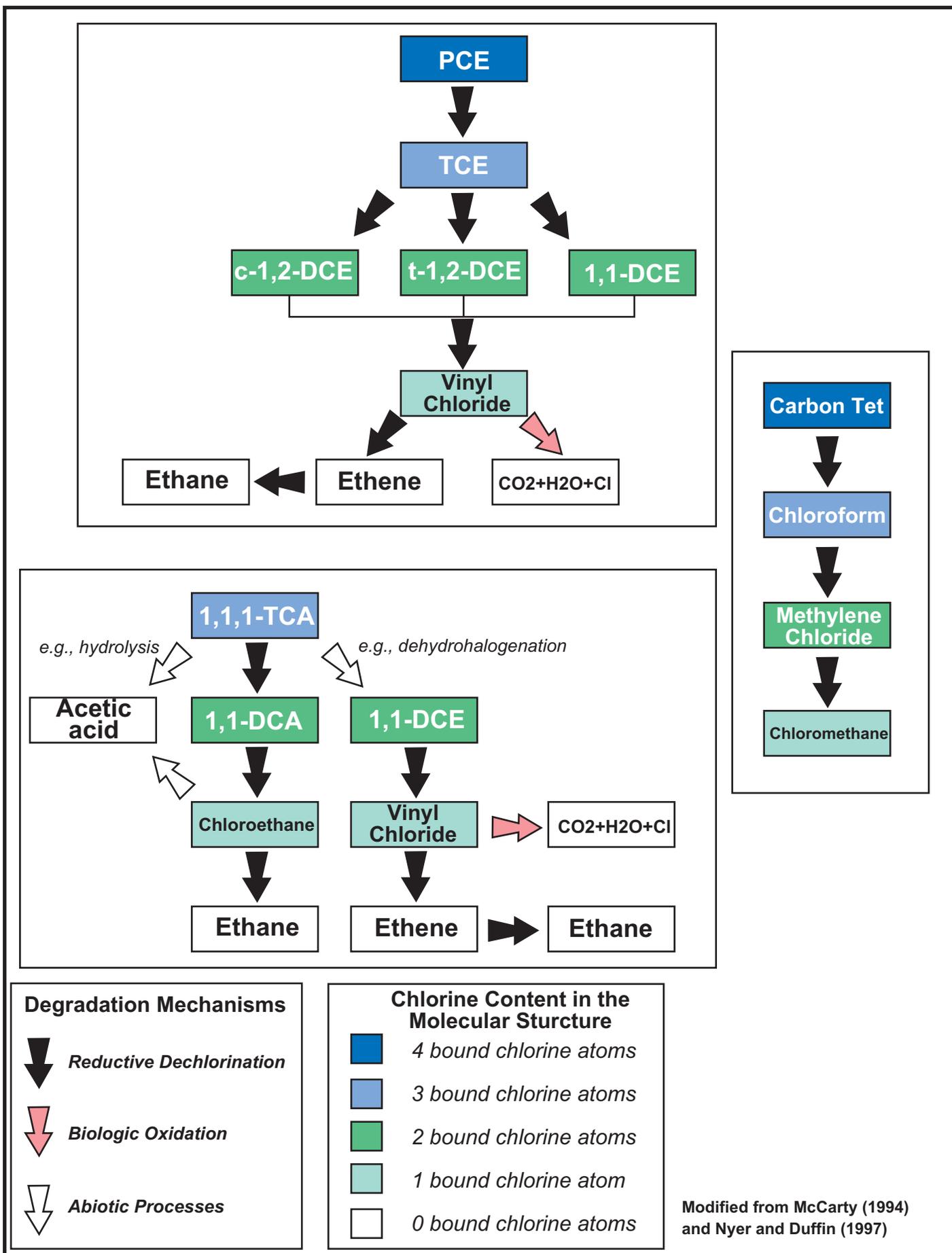


Figure 2. Generalized Degradation Pathways of Chlorinated Aliphatic Hydrocarbons (CAHs). ^{Deg Paths} 6/97

APPENDIX A

Wellhead Measuring and Testing Procedures for Dissolved Oxygen (E360.1), pH (SW9040B), Temperature (E170.1), and Specific Conductance (SW9050A)

seawater and brackish waters may be calculated from dissolved oxygen saturation versus salinity data. Conversion factors for specific inorganic salts may be developed experimentally. Broad variations in the kinds and concentrations of salts in samples can make the use of a membrane probe difficult.

- 4.3 Reactive compounds can interfere with the output or the performance of dissolved oxygen probes.
 - 4.3.1 Reactive gases which pass through the membrane probes may interfere. For example, chlorine will depolarize the cathode and cause a high probe-output. Long-term exposures to chlorine will coat the anode with the chloride of the anode metal and eventually desensitize the probe. Alkaline samples in which free chlorine does not exist will not interfere. Hydrogen sulfide will interfere with membrane probes if the applied potential is greater than the half-wave potential of the sulfide ion. If the applied potential is less than the half-wave potential, an interfering reaction will not occur, but coating of the anode with the sulfide of the anode metal can take place.
 - 4.4 Dissolved oxygen probes are temperature sensitive, and temperature compensation is normally provided by the manufacturer. Membrane probes have a temperature coefficient of 4 to 6 percent/°C dependent upon the membrane employed.
- 5.0 Apparatus
- 5.1 No specific probe or accessory is especially recommended as superior. However, probes which have been evaluated or are in use and found to be reliable are the Weston & Stack DO Analyzer Model 30, the Yellow Springs Instrument (YSI) Model 54, and the Beckman Fieldlab Oxygen Analyzer.
- 6.0 Calibration: Follow manufacturer instructions.
- 7.0 Procedure: Follow manufacturer instructions.
- 8.0 Calculation Follow manufacturer instructions.
- 9.0 Precision and Accuracy: Manufacturer's specification claim 0.1 mg/L repeatability with $\pm 1\%$ accuracy.

Bibliography

- 1. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 450, Method 422F (1975).

METHOD 9040B

pH ELECTROMETRIC MEASUREMENT

1.0 SCOPE AND APPLICATION

1.1 Method 9040 is used to measure the pH of aqueous wastes and those multiphase wastes where the aqueous phase constitutes at least 20% of the total volume of the waste.

1.2 The corrosivity of concentrated acids and bases, or of concentrated acids and bases mixed with inert substances, cannot be measured. The pH measurement requires some water content.

2.0 SUMMARY

2.1 The pH of the sample is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH.

3.0 INTERFERENCES

3.1 The glass electrode, in general, is not subject to solution interferences from color, turbidity, colloidal matter, oxidants, reductants, or moderate (<0.1 molar solution) salinity.

3.2 Sodium error at pH levels >10 can be reduced or eliminated by using a low-sodium-error electrode.

3.3 Coatings of oily material or particulate matter can impair electrode response. These coatings can usually be removed by gentle wiping or detergent washing, followed by rinsing with distilled water. An additional treatment with hydrochloric acid (1:10) may be necessary to remove any remaining film.

3.4 Temperature effects on the electrometric determination of pH arise from two sources. The first is caused by the change in electrode output at various temperatures. This interference should be controlled with instruments having temperature compensation or by calibrating the electrode-instrument system at the temperature of the samples. The second source of temperature effects is the change of pH due to changes in the sample as the temperature changes. This error is sample-dependent and cannot be controlled. It should, therefore, be noted by reporting both the pH and temperature at the time of analysis.

4.0 APPARATUS AND MATERIALS

4.1 pH meter: Laboratory or field model. Many instruments are commercially available with various specifications and optional equipment.

4.2 Glass electrode.

4.3 Reference electrode: A silver-silver chloride or other reference electrode of constant potential may be used.

NOTE: Combination electrodes incorporating both measuring and referenced functions are convenient to use and are available with solid, gel-type filling materials that require minimal maintenance.

4.4 Magnetic stirrer and Teflon-coated stirring bar.

4.5 Thermometer and/or temperature sensor for automatic compensation.

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Primary standard buffer salts are available from the National Institute of Standards and Technology (NIST) and should be used in situations where extreme accuracy is necessary. Preparation of reference solutions from these salts requires some special precautions and handling, such as low-conductivity dilution water, drying ovens, and carbon-dioxide-free purge gas. These solutions should be replaced at least once each month.

5.3 Secondary standard buffers may be prepared from NIST salts or purchased as solutions from commercial vendors. These commercially available solutions have been validated by comparison with NIST standards and are recommended for routine use.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must be collected using a sampling plan that addresses the considerations discussed in Chapter Nine of this manual.

6.2 Samples should be analyzed as soon as possible.

7.0 PROCEDURE

7.1 Calibration:

7.1.1 Because of the wide variety of pH meters and accessories, detailed operating procedures cannot be incorporated into this method. Each analyst must be acquainted with the operation of each system and familiar with all instrument functions. Special attention to care of the electrodes is recommended.

7.1.2 Each instrument/electrode system must be calibrated at a minimum of two points that bracket the expected pH of the samples and are approximately three pH units or more apart. (For corrosivity characterization, the calibration of the pH meter should include a buffer of pH 2

for acidic wastes and a pH 12 buffer for caustic wastes; also, for corrosivity characterization, the sample must be measured at 25±1°C if the pH of the waste is above 12.0.) Various instrument designs may involve use of a dial (to "balance" or "standardize") or a slope adjustment, as outlined in the manufacturer's instructions. Repeat adjustments on successive portions of the two buffer solutions until readings are within 0.05 pH units of the buffer solution value.

7.2 Place the sample or buffer solution in a clean glass beaker using a sufficient volume to cover the sensing elements of the electrodes and to give adequate clearance for the magnetic stirring bar. If field measurements are being made, the electrodes may be immersed directly into the sample stream to an adequate depth and moved in a manner to ensure sufficient sample movement across the electrode-sensing element as indicated by drift-free readings (<0.1 pH).

7.3 If the sample temperature differs by more than 2°C from the buffer solution, the measured pH values must be corrected. Instruments are equipped with automatic or manual compensators that electronically adjust for temperature differences. Refer to manufacturer's instructions.

7.4 Thoroughly rinse and gently wipe the electrodes prior to measuring pH of samples. Immerse the electrodes into the sample beaker or sample stream and gently stir at a constant rate to provide homogeneity and suspension of solids. Note and record sample pH and temperature. Repeat measurement on successive aliquots of sample until values differ by <0.1 pH units. Two or three volume changes are usually sufficient.

8.0 QUALITY CONTROL

8.1 Refer to Chapter One for the appropriate QC protocols.

8.2 Electrodes must be thoroughly rinsed between samples.

9.0 METHOD PERFORMANCE

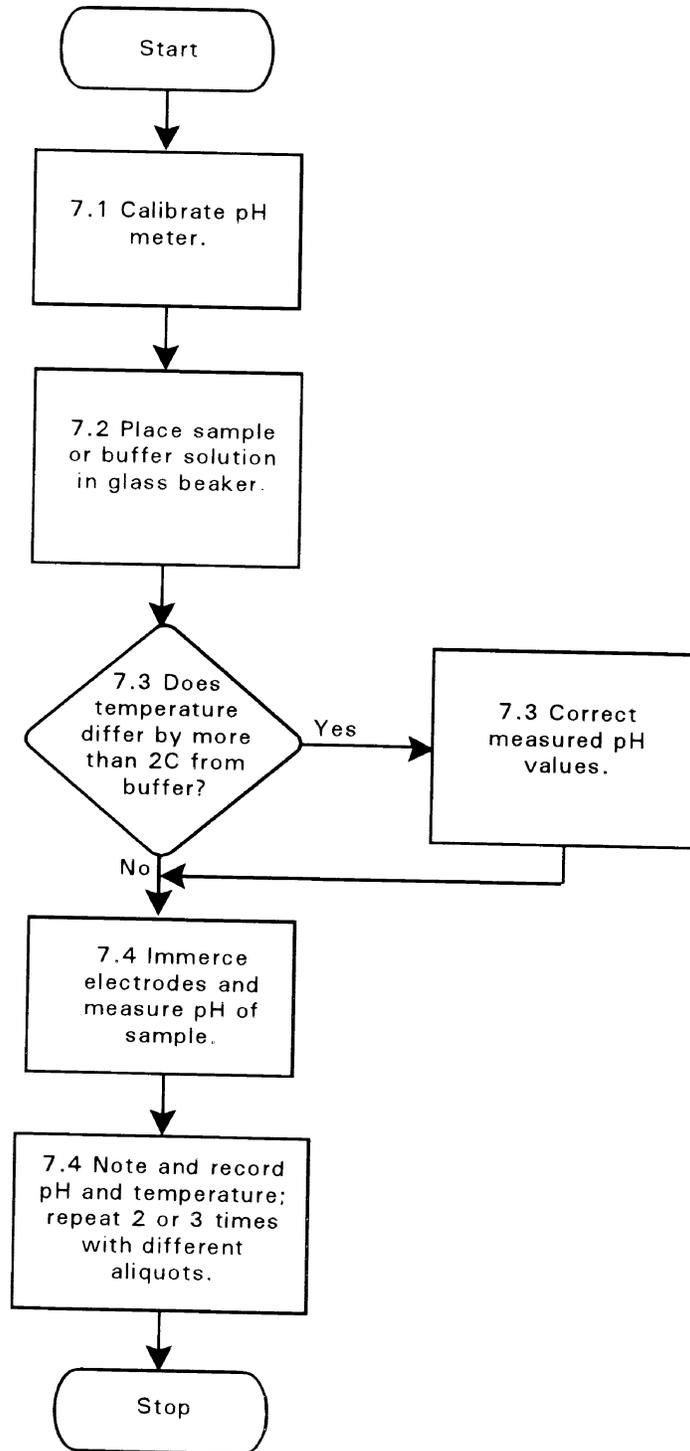
9.1 Forty-four analysts in twenty laboratories analyzed six synthetic water samples containing exact increments of hydrogen-hydroxyl ions, with the following results:

<u>pH Units</u>	<u>Standard Deviation</u> pH Units	<u>Accuracy as</u>	
		<u>Bias</u> %	<u>Bias</u> pH Units
3.5	0.10	-0.29	-0.01
3.5	0.11	-0.00	
7.1	0.20	+1.01	+0.07
7.2	0.18	-0.03	-0.002
8.0	0.13	-0.12	-0.01
8.0	0.12	+0.16	+0.01

10.0 REFERENCES

1. National Bureau of Standards, Standard Reference Material Catalog 1986-87, Special Publication 260.

METHOD 9040B
pH ELECTROMETRIC MEASUREMENT



METHOD #: 170.1 Approved for NPDES (Issued 1974)
TITLE: Temperature (Thermometric)
ANALYTE: Temperature
INSTRUMENTATION: Thermometer
STORET No. 00010

1.0 Scope and Application

1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes.

2.0 Summary of Method

2.1 Temperature measurements may be made with any good grade of mercury-filled or dial type centigrade thermometer, or a thermistor.

3.0 Comments

3.1 Measurement device should be routinely checked against a precision thermometer certified by the National Bureau of Standards.

4.0 Precision and Accuracy

4.1 Precision and accuracy for this method have not been determined.

5.0 Reference

5.1 The procedure to be used for this determination is found in: Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 125, Method 212 (1975).

METHOD 9050A

SPECIFIC CONDUCTANCE

1.0 SCOPE AND APPLICATION

1.1 Method 9050 is used to measure the specific conductance of drinking, ground, surface, and saline waters and domestic and industrial aqueous wastes. Method 9050 is not applicable to solid samples or to organic samples.

2.0 SUMMARY OF METHOD

2.1 The specific conductance of a sample is measured using a self-contained conductivity meter (Wheatstone bridge-type or equivalent).

2.2 Whenever possible, samples are analyzed at 25°C. Unless a temperature correction routine is used by the instrument, samples of different temperatures must be equilibrated to and results reported at 25°C.

3.0 INTERFERENCES

3.1 Platinum electrodes can degrade and cause erratic results. When this happens, as evidenced by erratic results or flaking off of the platinum black, the electrode should be replatinized.

3.2 The specific conductance cell can become coated with oil and other materials. It is essential that the cell be thoroughly rinsed and, if necessary, cleaned between samples.

4.0 APPARATUS AND MATERIALS

4.1 Self-contained conductivity instruments: an instrument consisting of a source of alternating current, a Wheatstone bridge, null indicator, and a conductivity cell or other instrument measuring the ratio of alternating current through the cell to voltage across it. The latter has the advantage of a linear reading of conductivity. Choose an instrument capable of measuring conductivity with an error not exceeding 1% or 1 uS/cm, whichever is greater.

4.2 Platinum-electrode or non-platinum-electrode specific conductance cell.

4.3 Water bath.

4.4 Thermometer: capable of being read to the nearest 0.1°C and covering the range 23°C to 27°C. An electrical thermometer having a small thermistor sensing element is convenient because of its rapid response.

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical

Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Conductivity water: Pass distilled water through a mixed-bed deionizer and discard first 1,000 mL. Conductivity should be less than 1 uS/cm.

5.3 Standard potassium chloride (0.0100 M): Dissolve 0.7456 g anhydrous KCl in conductivity water and make up to 1,000 mL at 25°C. This solution will have a specific conductance of 1,413 uS/cm at 25°C.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must be collected using a sampling plan that addresses the considerations discussed in Chapter Nine of this manual.

6.2 All sample containers must be prewashed and thoroughly rinsed. Both plastic and glass containers are suitable.

6.3 Aqueous samples should be stored at 4°C and analyzed within 28 days.

7.0 PROCEDURE

7.1 Determination of cell constant: Rinse conductivity cell with at least three portions of 0.01 N KCl solution. Adjust temperature of a fourth portion to $25.0 \pm 0.1^\circ\text{C}$. Measure resistance of this portion and note temperature. Compute cell constant, C:

$$C = (0.001413)(R_{\text{KCl}})^{-1} + 0.0191 (t - 25)$$

where:

R_{KCl} = measured resistance, ohms; and

t = observed temperature, °C.

7.2 Conductivity measurement: Rinse cell with one or more portions of sample. Adjust temperature of a final portion to $25.0 \pm 0.1^\circ\text{C}$. Measure sample resistance or conductivity and note temperature.

7.3 Calculation: The temperature coefficient of most waters is only approximately the same as that of standard KCl solution; the more the temperature of measurement deviates from 25.0°C, the greater the uncertainty in applying the temperature correction. Report all conductivities at 25.0°C.

7.3.1 When sample resistance is measured, conductivity at 25°C is:

$$K = \frac{(1,000,000)(C)}{R_m[1 + 0.0191(t - 25)]}$$

where:

K = conductivity, uS/cm;
C = cell constant, cm-L;
R_m = measured resistance of sample, ohms; and
t = temperature of measurement.

7.3.2 When sample conductivity is measured, conductivity at 25°C is:

$$K = \frac{(K_m)(1,000,000)(C)}{1 + 0.0191(t - 25)}$$

where:

K_m = measured conductivity, uS at t°C, and other units are defined as above.

NOTE: If conductivity readout is in uS/cm, delete the factor 1,000,000 in the numerator.

NOTE: In the International System of Units (SI) the reciprocal of the ohm is the siemens (S) and conductivity is reported as millisiemens per meter (mS/m); 1 mS/m = 10 µmhos/cm and 1 µS/cm = 1 µmho/cm. To report results in SI units of mS/m divide µmhos/cm by 10.

8.0 QUALITY CONTROL

- 8.1 Refer to Chapter One for specific quality control procedures.
- 8.2 Analyze an independently prepared check standard to verify calibration.
- 8.3 Analyze one duplicate sample for every 10 samples.

9.0 METHOD PERFORMANCE

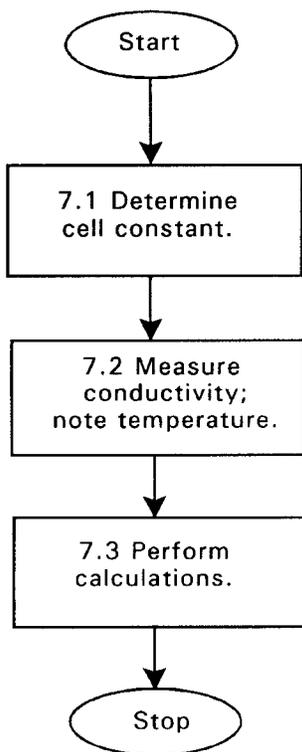
9.1 Three synthetic samples were tested with the following results:

Conduc- tivity uS/cm	No. of Results	Relative Standard Deviation %	Relative Error %
147.0	117	8.6	9.4
303.0	120	7.8	1.9
228.0	120	8.4	3.0

10.0 REFERENCES

1. Standard Methods for the Examination of Water and Wastewater, 16th ed. (1985), Method 205.

METHOD 9050A
SPECIFIC CONDUCTANCE



APPENDIX B

Field Analytical Procedures for Hach® Methods 8039 (Nitrate),
8146 (Ferrous Iron II), 8051 (Sulfate), and 8131 (Sulfide)

Method 8039

Cadmium Reduction Method

Powder Pillows or AccuVac® Ampuls

HR (0.3 to 30.0 mg/L NO₃⁻-N)

Scope and Application: For water, wastewater, and seawater.



Tips and Techniques

- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- A deposit of unoxidized metal will remain after the NitraVer® 5 dissolves. The deposit will not affect results.
- This method is technique-sensitive. Shaking time and technique influence color development. For most accurate results, make successive tests on a 10-mg/L Nitrate Nitrogen Standard solution. Adjust shaking time and technique to obtain the correct result.
- Wipe the outside of sample cells before each insertion into the instrument cell holder. Use a damp towel followed by a dry one to remove fingerprints or other marks.
- Rinse the sample cell immediately after use to remove all cadmium particles. Prepared samples will contain cadmium and must be disposed of according to Federal, State and local hazardous waste regulations. For information on pollution prevention and waste management, refer to *Section 5* on page 59.



Powder Pillows

Method 8039



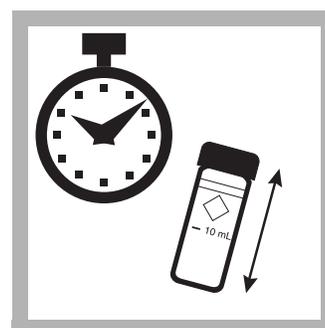
1. Touch **Hach Programs**.
Select program **355 N, Nitrate HR**.
Touch **Start**.



2. Fill a round sample cell with 10 mL of sample.

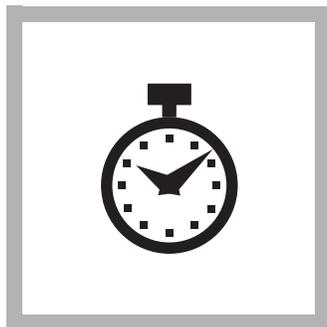


3. Add the contents of one NitraVer 5 Nitrate Reagent Powder Pillow. Cap (this is the prepared sample).



4. Touch the timer icon. Touch **OK**.
A one-minute reaction period will begin. Shake the cell vigorously until the timer beeps.

Nitrate



5. When the timer beeps, touch the timer icon. Touch **OK**.

A five-minute reaction period will begin.

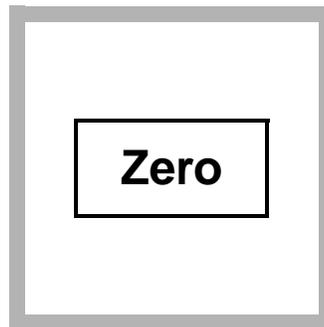
An amber color will develop if nitrate is present.



6. When the timer beeps, fill a second round sample cell with 10 mL of sample (this is the blank).



7. Wipe the blank and place it into the cell holder.



8. Touch **Zero**.
The display will show:

0.0 mg/L NO₃⁻-N



9. Within one minute after the timer beeps, wipe the prepared sample and place it into the cell holder.

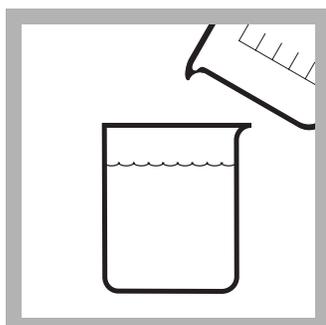
Results will appear in mg/L NO₃⁻-N.

AccuVac[®] Ampul

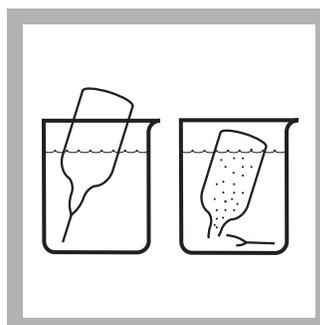
Method 8039



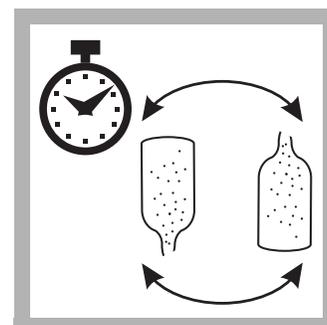
1. Touch **Hach Programs**.
Select program
361 N, Nitrate HR AV.
Touch **Start**.



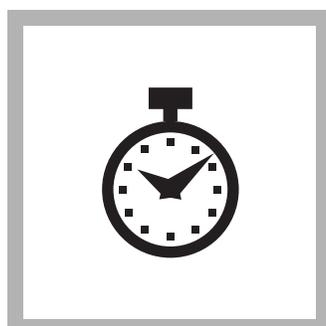
2. Collect at least 40 mL of sample in a 50-mL beaker.



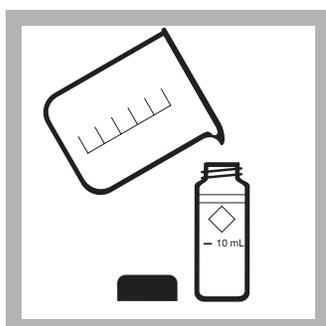
3. Fill a NitraVer 5 Nitrate AccuVac[®] Ampul with sample. Keep the tip immersed while the ampule fills completely. Place a stopper over the ampule tip.



4. Touch the timer icon. Touch **OK**.
A one-minute reaction period will begin. Invert the ampule 48–52 times a minute until the timer beeps.



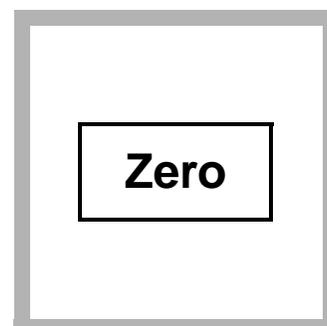
5. When the timer beeps, touch the timer icon. Touch **OK**.
A five-minute reaction period will begin.
An amber color will develop if nitrate is present.



6. When the timer beeps, fill a round sample cell with 10 mL of sample (this is the blank).



7. Wipe the blank and place it into the cell holder.



8. Touch **Zero**.
The display will show:
0.0 mg/L NO₃⁻-N

Nitrate



9. Within one minute after the timer beeps, wipe the ampule and place into the cell holder.

Results will appear in mg/L NO_3^- -N.

Interferences

Interfering Substance	Interference Levels and Treatments
Chloride	Chloride concentrations above 100 mg/L will cause low results. The test may be used at high chloride concentrations (seawater) but a calibration must be done using standards spiked to the same chloride concentration.
Ferric iron	Interferes at all levels
Nitrite	Interferes at all levels Compensate for nitrite interference as follows: a) Before performing <i>step 3</i> , add 30-g/L Bromine Water (Cat. No. 2211-20) dropwise to the sample until a yellow color remains. b) Add one drop of 30-g/L Phenol Solution (Cat. No. 2112-20) to destroy the color. Proceed with <i>step 3</i> . Report the results as total nitrate and nitrite.
pH	Highly buffered samples or extreme sample pH may exceed the buffering capacity of the reagents and require sample pretreatment.
Strong oxidizing and reducing substances	Interfere at all levels

Sample Collection, Storage, and Preservation

More reliable results are obtained when samples are analyzed as soon as possible after collection. If prompt analysis is impossible, store samples in clean plastic or glass bottles for up to 24 hours at 4 °C. To preserve samples for longer periods, add 2 mL of Concentrated Sulfuric Acid (H_2SO_4) (Cat. No. 979-49) per liter and store at 4 °C.

Before analysis, warm the sample to room temperature and adjust the pH to 7 with 5.0 N Sodium Hydroxide Standard Solution (Cat. No. 2450-53). Do not use mercury compounds as preservatives. Correct the test result for volume additions by dividing the total volume (acid + base + sample) by the original sample volume and multiplying the test result by this factor.

Accuracy Check

Standard Additions Method (Sample Spike)

1. After reading test results, leave the sample cell (unspiked sample) in the instrument. Verify the chemical form.
2. Touch **Options**. Touch **Standard Additions**. A summary of the standard additions procedure will appear.
3. Touch **OK** to accept the default values for standard concentration, sample volume, and spike volumes. Touch **Edit** to change these values. After values are accepted, the unspiked sample reading will appear in the top row. See *Standard Additions* in the instrument manual for more information.
4. Snap the neck off a Nitrate Nitrogen Voluette® Ampule Standard, 500-mg/L NO_3^- -N.
5. Prepare three sample spikes. Fill three mixing cylinders (Cat. No. 1896-40) with 25 mL of sample. Use the TenSette® Pipet to add 0.1 mL, 0.2 mL, and 0.3 mL of standard, respectively, to each sample and mix thoroughly.
6. Analyze each sample spike as described in the procedure above, starting with the 0.1 mL sample spike. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.

Note: For AccuVac ampules, fill three mixing cylinders (Cat. No. 1896-41) with 50 mL of sample and spike with 0.2 mL, 0.4 mL, and 0.6 mL of standard. Transfer 40 mL from each of the three mixing cylinders to three 50-mL beakers (Cat. No. 500-41H). Analyze each standard addition sample as described in the procedure above. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.

7. After completing the sequence, touch **Graph** to view the best-fit line through the standard additions data points, accounting for matrix interferences. Touch **View: Fit**, then select **Ideal Line** and touch **OK** to view the relationship between the sample spikes and the “Ideal Line” of 100% recovery.

See *Section 3.2.2 Standard Additions* on page 26 for more information.

Standard Solution Method

1. To test accuracy, use a 10.0-mg/L Nitrate Nitrogen Standard Solution in place of the sample and perform the procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 10.0-mg/L Nitrate Nitrogen Standard Solution, touch **Options** on the current program menu. Touch **Standard Adjust**.
3. Touch **On**. Touch **Adjust** to accept the displayed concentration (the value depends on the selected chemical forms). If an alternate concentration is used, touch the number in the box to enter the actual concentration, then touch **OK**. Touch **Adjust**.

See *Section 3.2.4 Adjusting the Standard Curve* on page 29 for more information.

Nitrate

Method Performance

Precision

Standard: 10 mg/L NO₃⁻-N

Program	95% Confidence Limits of Distribution
355	8.0–12.0 mg/L NO ₃ ⁻ -N
361	9.2–10.8 mg/L NO ₃ ⁻ -N

See *Section 3.4.3 Precision* on page 33 for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Portion of Curve	ΔAbs	ΔConcentration (Program 355)	ΔConcentration (Program 361)
0 ppm	0.010	0.3 mg/L NO ₃ ⁻ -N	0.5 mg/L NO ₃ ⁻ -N
10 ppm	0.010	0.6 mg/L NO ₃ ⁻ -N	0.7 mg/L NO ₃ ⁻ -N
30 ppm	0.010	1.0 mg/L NO ₃ ⁻ -N	0.8 mg/L NO ₃ ⁻ -N

See *Section 3.4.5 Sensitivity* on page 34 for more information.

Summary of Method

Cadmium metal reduces nitrates in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. The salt couples with gentisic acid to form an amber colored solution. Test results are measured at 500 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
NitraVer [®] 5 Nitrate Reagent Powder Pillows (for 10-mL sample).....	1 pillow.....	100/pkg.....	21061-69
<i>or</i>			
NitraVer [®] 5 Nitrate Reagent AccuVac [®] Ampul.....	1 ampul.....	25/pkg.....	25110-25

Required Apparatus

Sample cell, 10-mL, w/cap.....	2.....	each.....	24276-06
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Required Standards

Nitrate Nitrogen Standard Solution, 10.0-mg/L NO ₃ ⁻ -N.....	500 mL.....	307-49
Nitrate Nitrogen Standard Solution, 2-mL PourRite [®] Ampule, 500-mg/L NO ₃ ⁻ -N.....	20/pkg.....	14260-20
Wastewater Influent Standard, Mixed Parameter, for NH ₃ -N, NO ₃ -N, PO ₄ , COD, SO ₄ , TOC.....	500 mL.....	28331-49
Water, deionized.....	4 liters.....	272-56



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HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

Method 8146

1, 10 Phenanthroline Method*

Powder Pillows or AccuVac® Ampuls

(0.02 to 3.00 mg/L)

Scope and Application: For water, wastewater, and seawater

* Adapted from *Standard Methods for the Examination of Water and Wastewater*, 15th ed. 201 (1980)



Tips and Techniques

- Analyze samples as soon as possible to prevent air oxidation of ferrous iron to ferric iron, which is not determined.
- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- If ferrous iron is present, an orange color will form after adding the reagent.

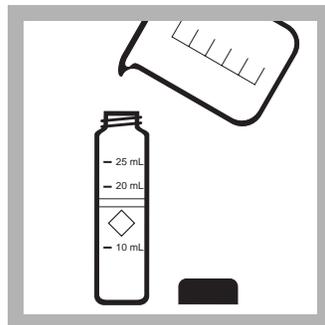


Powder Pillows

Method 8146



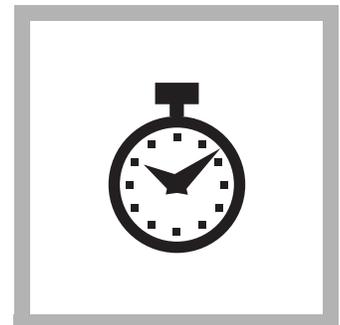
- Touch **Hach Programs**.
Select program **255 Iron, Ferrous**.
Touch **Start**.



- Fill a clean, round sample cell with 25 mL of sample.

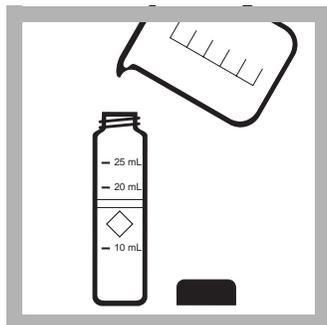


- Add the contents of one Ferrous Iron Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.

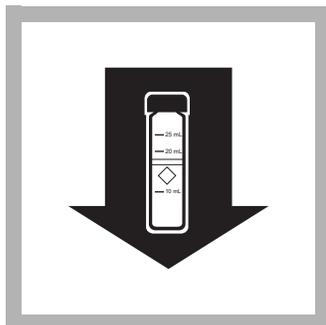


- Touch the timer icon. Touch **OK**.
A three-minute reaction period will begin.

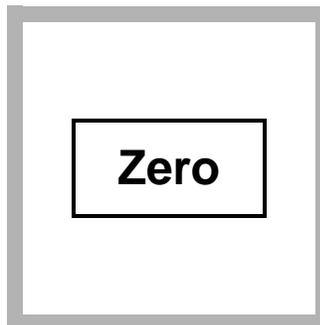
Iron, Ferrous



5. Fill a second round sample cell with 25 mL of sample (the blank).

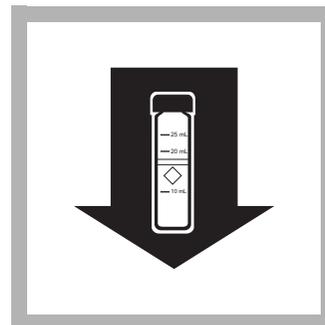


6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.
The display will show:

0.00 mg/L Fe²⁺



8. Place the prepared sample into the cell holder.

Results will appear in mg/L Fe²⁺.

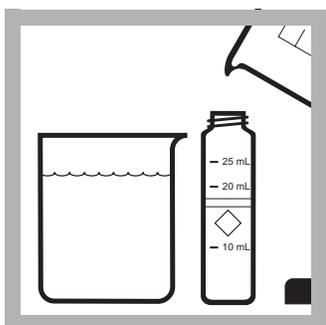


AccuVac Ampul

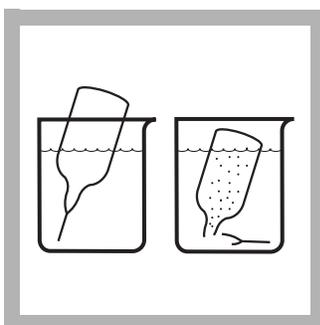
Method 8146



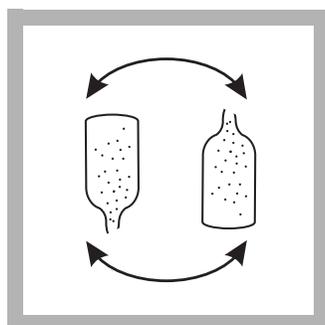
1. Touch
Hach Programs.
Select program
257 Iron, Ferrous AV.
Touch **Start**.



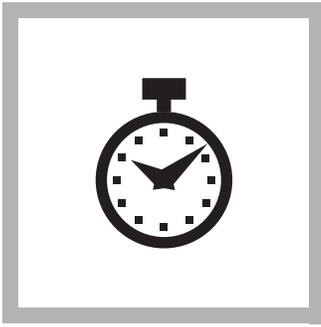
2. Fill a sample cell with 25 mL of sample (the blank). Collect at least 40 mL of sample in a 50-mL beaker.



3. Fill a Ferrous Iron AccuVac® Ampul with sample. Keep the tip immersed while the ampul fills completely.



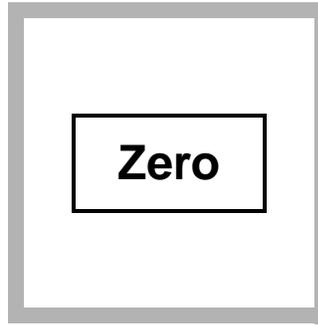
4. Quickly invert the ampul several times to mix. Wipe off any liquid or fingerprints.



5. Touch the timer icon. Touch **OK**. A three-minute reaction period will begin.



6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**. The display will show:
0.00 mg/L Fe²⁺



8. Place the AccuVac Ampul into the cell holder. Results will appear in mg/L Fe²⁺.

Sample Collection, Storage and Preservation

Collect samples in plastic or glass bottles. Analyze samples as soon as possible after collection.

Accuracy Check

Standard Solution Method

1. Prepare a ferrous iron stock solution (100-mg/L Fe²⁺) by dissolving 0.7022 grams of Ferrous Ammonium Sulfate, hexahydrate, in deionized water. Dilute to one liter in a Class A volumetric flask. In a 100-mL Class A volumetric flask, dilute 1.00 mL of this solution to 100 mL with deionized water to make a 1.0-mg/L standard solution. Prepare this solution immediately before use. Perform the iron procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 1.0-mg/L Fe²⁺ Standard Solution, touch **Options** on the current program menu. Touch **Standard Adjust**.
3. Touch **On**. Touch **Adjust** to accept the displayed concentration. If an alternate concentration is used, touch the number in the box to enter the actual concentration, then touch **OK**. Touch **Adjust**.

See *Section 3.2.4 Adjusting the Standard Curve* on page 49 for more information.

Method Performance

Precision

Standard: 1.000 mg/L Fe

Program	95% Confidence Limits of Distribution
255	0.989–1.011 mg/L Fe
257	0.977–1.023 mg/L Fe

See *Section 3.4.3 Precision* on page 53 for more information, or if the standard concentration did not fall within the specified range.

Iron, Ferrous

Sensitivity

Program	Portion of Curve	Δ Abs	Δ Concentration
255	Entire range	0.010	mg/L Fe
257	Entire range	0.010	0.023 mg/L Fe

See Section 3.4.5 Sensitivity on page 54 for more information.

Summary of Method

The 1,10 phenanthroline indicator in the Ferrous Iron Reagent reacts with ferrous iron in the sample to form an orange color in proportion to the iron concentration. Ferric iron does not react. The ferric iron (Fe^{3+}) concentration can be determined by subtracting the ferrous iron concentration from the results of a total iron test. Test results are measured at 510 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
Ferrous Iron Reagent AccuVac® Ampuls.....	1 ampul.....	25/pkg.....	25140-25
<i>or</i>			
Ferrous Iron Reagent Powder Pillows.....	1 pillow.....	100/pkg.....	1037-69

Required Apparatus

Beaker, 50-mL.....	1.....	each.....	500-41H
Sample Cells, 10-20-25 mL, w/cap.....	2.....	6/pkg.....	24019-06

Required Standards

Ferrous Ammonium Sulfate, hexahydrate, ACS.....	113 g.....	11256-14
Water, deionized.....	4 liters.....	272-56



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HACH COMPANY
WORLD HEADQUARTERS
Telephone: (970) 669-3050
FAX: (970) 669-2932

★Method 8051

SulfaVer 4 Method*

Powder Pillows or AccuVac® Ampuls

(2 to 70 mg/L)

Scope and Application: For water, wastewater, and seawater; USEPA accepted for reporting wastewater analyses

* Adapted from *Standard Methods for the Examination of Water and Wastewater*. Procedure is equivalent to USEPA method 375.4 for wastewater.



Tips and Techniques

- You must adjust the standard curve for each new lot of reagent. See *Standard Solutions* following these steps.
- For best results, perform a new calibration for each lot of reagent. See *Calibration Standard Preparation* following these steps.
- For more accurate results, determine a reagent blank value for each new lot of reagent. Follow the procedure using deionized water in place of the sample. Subtract the reagent blank value from the final results or perform a reagent blank adjust. See the instrument manual for more information on *Running a Reagent Blank*.
- Filter highly colored or turbid samples using filter paper (Cat. No. 1894-57) and a funnel (Cat. No. 1083-67). Use this sample in *step 5*.
- After adding reagent to the sample, a white turbidity will form if sulfate is present.
- Undissolved powder that has settled does not affect accuracy.
- SulfaVer® 4 contains barium chloride. The final solution will contain barium chloride (D005) at a concentration regulated as a hazardous waste by the Federal RCRA. See *Section 5* for more information on proper disposal of these materials.

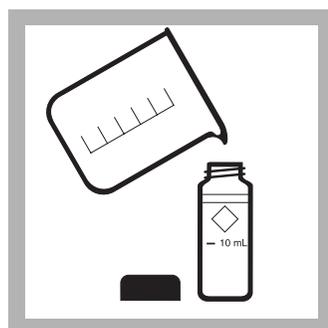


Powder Pillows

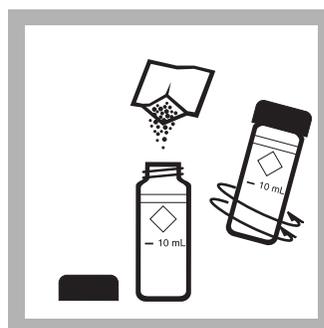
Method 8051



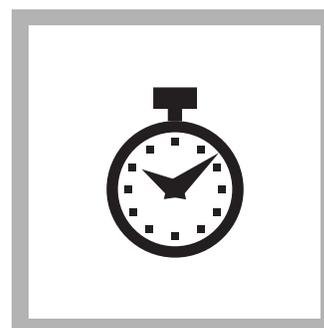
1. Touch **Hach Programs**.
Select program **680 Sulfate**.
Touch **Start**.



2. Fill a clean sample cell with 10 mL of sample.



3. Add the contents of one SulfaVer 4 Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.



4. Touch the timer icon. Touch **OK**.
A five-minute reaction period will begin. Do not disturb the cell during this time.

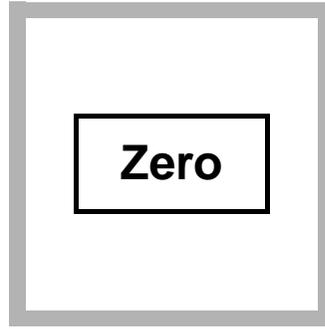
Sulfate



5. Fill a second sample cell with 10 mL of sample (the blank).



6. When the timer beeps, place the blank into the cell holder.



7. Touch **Zero**.
The display will show:
0 mg/L SO₄²⁻

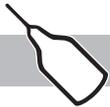


8. Within five minutes after the timer beeps, place the prepared sample into the cell holder.

Results will appear in mg/L SO₄²⁻.



9. Clean the sample cells with soap and a brush.

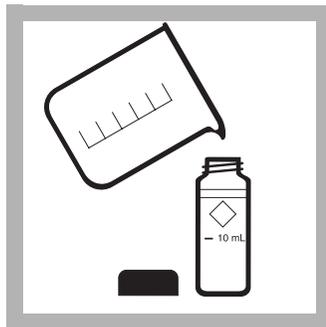


AccuVac Ampul

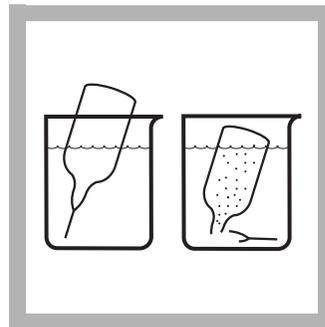
Method 8051



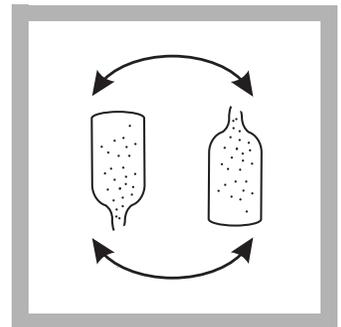
1. Touch
Hach Programs.
Select program
685 Sulfate AV.
Touch **Start**.



2. Fill a clean sample cell with 10 mL of sample (the blank). Collect at least 40 mL of sample in a 50-mL beaker.



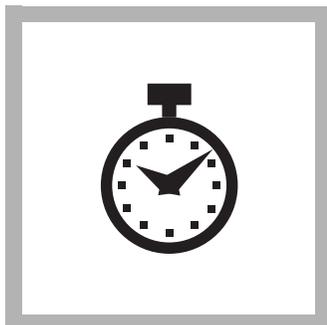
3. Fill a SulfaVer 4 Sulfate AccuVac Ampul with sample. Keep the tip immersed until the ampul fills completely.



4. Quickly invert the ampul several times to mix.



5. Wipe off any liquid or fingerprints from the blank and the ampule.

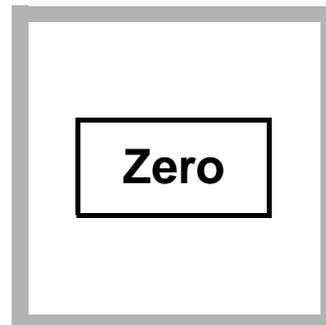


6. Touch the timer icon. Touch **OK**.

A five-minute reaction period will begin. Do not disturb the cell during this time.



7. When the timer beeps, place the blank into the cell holder.



8. Touch **Zero**.

The display will show:

0 mg/L SO₄²⁻



9. Within five minutes after the timer beeps, place the ampule into the cell holder.

Results will appear in mg/L SO₄²⁻.

Interferences

Interfering Substance	Interference Levels and Treatments
Calcium	Greater than 20,000 mg/L as CaCO ₃
Chloride	Greater than 40,000 mg/L as Cl
Magnesium	Greater than 10,000 mg/L as CaCO ₃
Silica	Greater than 500 mg/L as SiO ₂

Sample Collection, Storage, and Preservation

Collect samples in clean plastic or glass bottles. Samples may be stored up to 7 days by cooling to 4 °C (39 °F) or lower. Warm to room temperature before analysis.

Accuracy Check

Standard Additions Method (Sample Spike)

1. After reading test results, leave the sample cell (unspiked sample) in the instrument.
2. Touch **Options**. Touch **Standard Additions**. A summary of the standard additions procedure will appear.
3. Touch **OK** to accept the default values for standard concentration, sample volume, and spike volumes. Touch **Edit** to change these values. After values are accepted, the unspiked sample reading will appear in the top row. See *Standard Additions* in the instrument manual for more information.
4. Snap the neck off a Sulfate 2-mL Ampule Standard, 1000-mg/L sulfate.
5. Prepare three sample spikes. Fill three mixing cylinders (Cat. No. 1896-40) with 25 mL of sample. Use the TenSette Pipet to add 0.1 mL, 0.2 mL, and 0.3 mL of standard, respectively, to each sample and mix thoroughly.
6. Transfer 10 mL of each sample spike to a clean sample cell and analyze each sample spike as described in the procedure above, starting with the 0.1 mL sample spike. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.

Note: For AccuVac Ampuls, fill three Mixing Cylinders (Cat. No. 1896-41) with 50 mL of sample and spike with 0.2 mL, 0.4 mL, and 0.6 mL of standard. Transfer 40 mL from each of the three mixing cylinders to three 50-mL Beakers (Cat. No. 500-41). Analyze each standard addition sample as described in the procedure above. Accept each standard additions reading by touching **Read**. Each addition should reflect approximately 100% recovery.

7. After completing the sequence, touch **Graph** to view the best-fit line through the standard additions data points, accounting for matrix interferences. Touch **View: Fit**, then select **Ideal Line** and touch **OK** to view the relationship between the sample spikes and the "Ideal Line" of 100% recovery.

See *Section 3.2.2 Standard Additions* on page 46 for more information.

Standard Solutions

Prepare a 70-mg/L sulfate standard solution as follows:

1. Using Class A glassware, Pipet 7 mL of Sulfate Standard Solution, 1000-mg/L, into a 100-mL volumetric flask. Dilute to the mark with deionized water. Prepare this solution daily. Perform the SulfaVer procedure as described above.
2. To adjust the calibration curve using the reading obtained with the 70-mg/L standard solution, touch **Options** on the current program menu. Touch **Standard Adjust**.
3. Touch **On**. Touch **OK** to accept the displayed concentration. If an alternate concentration is used, touch **Adjust** and then enter the actual concentration. Touch **OK**.

See *Section 3.2.4 Adjusting the Standard Curve* on page 49 for more information.

Calibration Standard Preparation

To perform a sulfate calibration using the SulfaVer method, use Class A glassware to prepare calibration standards containing 10, 20, 30, 40, 50, 60 and 70 mg/L SO_4^{2-} as follows:

1. Into seven different 100-mL Class A volumetric flasks, pipet 1, 2, 3, 4, 5, 6, and 7 mL of the 1000-mg/L Sulfate Standard Solution.
2. Dilute to the mark with deionized water. Mix thoroughly.
3. Using the SulfaVer method and the calibration procedure described in the User-Entered Programs section of the spectrophotometer *Instrument Manual*, generate a calibration curve from the calibration standards prepared above.

Method Performance

Precision

Standard: 30 mg/L SO_4^{2-}

Program	95% Confidence Limits of Distribution
680	27–33 mg/L SO_4^{2-}
685	18–43 mg/L SO_4^{2-}

See *Section 3.4.3 Precision* on page 53 for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Program	Δ Abs	Δ Concentration
680	0.010	1 mg/L SO_4^{2-}
685	0.010	2 mg/L SO_4^{2-}

See *Section 3.4.5 Sensitivity* on page 54 for more information.

Summary of Method

Sulfate ions in the sample react with barium in the SulfaVer 4 and form a precipitate of barium sulfate. The amount of turbidity formed is proportional to the sulfate concentration. The SulfaVer 4 also contains a stabilizing agent to hold the precipitate in suspension. Test results are measured at 450 nm.

Required Reagents

Description	Quantity Required per test	Unit	Cat. No.
SulfaVer [®] 4 Reagent Powder Pillows	1	100/pkg.....	21067-69
<i>or</i>			
SulfaVer [®] 4 Sulfate Reagent AccuVac Ampuls	1	25/pkg.....	25090-25

Required Apparatus

Beaker, 50-mL.....	1	each.....	500-41
Sample cells, 10-mL, w/cap.....	2	6/pkg.....	24276-06

Required Standards

Sulfate Standard Solution, 1000-mg/L.....	500 mL.....	21757-49
Sulfate Standard Solution, 1000-mg/L, 2-mL Ampules	20/pkg.....	21757-20
Water, deionized	4 liters	272-56



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★Method 8131

Methylene Blue Method*

(5 to 800 µg/L)

Scope and Application: For testing total sulfides, H₂S, HS⁻, and certain metal sulfides in groundwater, wastewater brines, and seawater; USEPA Approved for reporting wastewater analysis**

* Adapted from *Standard Methods for the Examination of Water and Wastewater*.

** Procedure is equivalent to USEPA method 376.2 and Standard Method 4500-S²⁻- D for wastewater.



Tips and Techniques

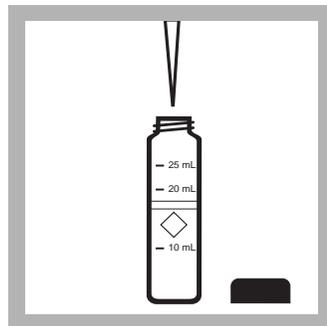
- Analyze samples immediately. Do not preserve for later analysis.
- Avoid excessive agitation of samples to minimize sulfide loss.
- Some sulfide loss may occur if dilution is necessary.
- Wipe the outside of sample cells before each insertion into the instrument cell holder. Use a damp towel followed by a dry one to remove fingerprints or other marks.
- Sulfide 2 reagent contains potassium dichromate. The final solution will contain hexavalent chromium (D007) at a concentration regulated as a hazardous waste by Federal RCRA. Please see *Section 5* for further information on proper disposal of these materials.



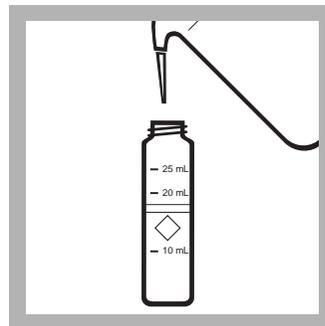
Method 8131



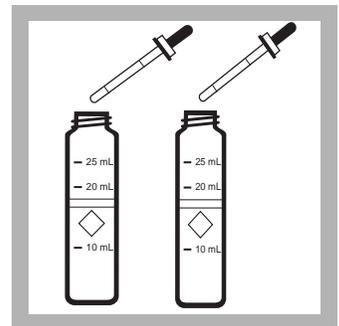
1. Touch **Hach Programs.**
Select program **690 Sulfide.**
Touch **OK.**



2. Avoiding excess agitation of the sample, use a pipet add 25 mL of sample to a sample cell (the prepared sample).

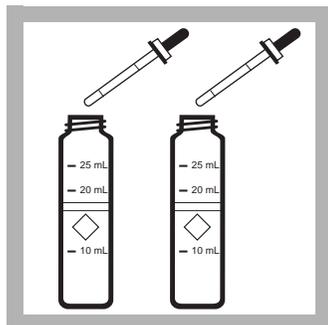


3. Measure 25 mL of deionized water into a second sample cell (the blank).



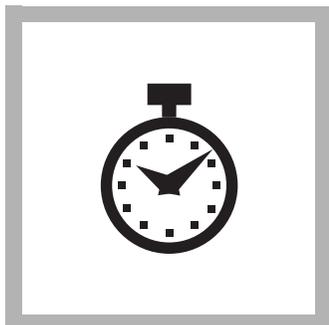
4. Use the calibrated 1-mL dropper to add 1.0 mL of Sulfide 1 Reagent to each cell. Swirl to mix.

Sulfide



5. Use the calibrated 1-mL dropper to add 1.0 mL of Sulfide 2 Reagent to each cell. Cap the cell and immediately invert to mix.

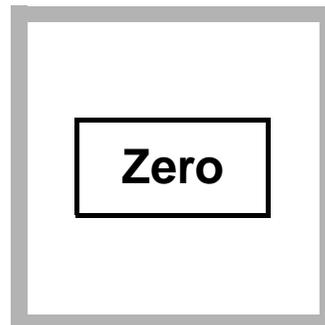
A pink color will develop, then the solution will turn blue if sulfide is present.



6. Touch the timer icon. Touch **OK**. A five-minute reaction period will begin.



7. When the timer beeps, wipe the blank and place it into the cell holder.



8. Touch **Zero**. The display will show:
0 $\mu\text{g/L S}^{2-}$



9. Wipe the prepared sample and place it into the cell holder.

Results will appear in $\mu\text{g/L S}^{2-}$.

Determining Soluble Sulfides

Determine soluble sulfides by centrifuging the sample in completely filled, capped tubes and analyzing the supernatant. Insoluble sulfides are then estimated by subtracting the soluble sulfide concentration from the total sulfide result.

Interferences

Interfering Substance	Interference Levels and Treatments
Strong reducing substances (sulfite, thiosulfate and hydrosulfite)	Interfere by reducing the blue color or preventing its development
Sulfide, high levels	High concentrations of sulfide may inhibit full color development and require sample dilution. Some sulfide loss may occur when the sample is diluted.
Turbidity	For turbid samples, prepare a sulfide-free blank as follows. Use it in place of the deionized water blank in the procedure. <ol style="list-style-type: none"> 1. Measure 25 mL of sample into a 50-mL Erlenmeyer flask. 2. Add Bromine Water (Cat. No. 2211-20) dropwise with constant swirling until a permanent yellow color just appears. 3. Add Phenol Solution (Cat. No. 2112-20) dropwise until the yellow color just disappears. Use this solution to replace the deionized water in <i>step 3</i> of the procedure.

Sample Collection, Storage, and Preservation

Collect samples in clean plastic or glass bottles. Fill completely and cap tightly. Avoid excessive agitation or prolonged exposure to air. Analyze samples immediately.

Method Performance

Precision

Standard: 275 µg/L S²⁻

Program	95% Confidence Limits of Distribution
690	256–294 µg/L S ²⁻

See *Section 3.4.3 Precision* on page 53 for more information, or if the standard concentration did not fall within the specified range.

Sensitivity

Portion of Curve	ΔAbs	ΔConcentration
Entire range	0.010	5 µg/L S ²⁻

See *Section 3.4.5 Sensitivity* on page 54 for more information.

Summary of Method

Hydrogen sulfide and acid-soluble metal sulfides react with N,N-dimethyl-p-phenylenediamine sulfate to form methylene blue. The intensity of the blue color is proportional to the sulfide concentration. High sulfide levels in oil field waters may be determined after proper dilution. Test results are measured at 665 nm.

Sulfide

Required Reagents

Description	Quantity required per test	Unit	Cat. No.
Sulfide Reagent Set (100 tests)			22445-00
Includes:			
(2) Sulfide 1 Reagent	2 mL	100 mL MDB.....	1816-32
(2) Sulfide 2 Reagent	2 mL	100 mL MDB.....	1817-32
Water, deionized	25 mL	4 liters	272-56

Required Apparatus

Pipet, volumetric, Class A, 25-mL.....	1	each.....	14515-40
Pipet Filler, safety bulb	1	each.....	14651-00
Sample Cells, 10-20-25 mL, w/cap.....	2	6/pkg.....	24019-06



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Attachment 4

**Regulatory Agency Comments and Berkeley Lab Responses
on the RCRA Corrective Measures Implementation (CMI)
Workplan, dated November 2005**



Department of Toxic Substances Control

Alan C. Lloyd, Ph.D.
Agency Secretary
Cal/EPA

Maureen F. Gorsen, Director
700 Heinz Avenue, Suite 200
Berkeley, California 94710-2721



Arnold Schwarzenegger
Governor

February 15, 2006

Iraj Javandel
Environmental Health & Safety Division
Lawrence Berkeley National Laboratory
One Cyclotron Road, MS 90-1140
Berkeley, California 94710

COMMENTS ON CORRECTIVE MEASURES IMPLEMENTATION WORKPLAN,
LAWRENCE BERKELEY NATIONAL LABORATORY, BERKELEY, EPA ID
CA4890008986

Dear Mr. Javandel,

The Department of Toxic Substances Control (DTSC) and the San Francisco Bay Regional Water Quality Control Board (RWQCB) have reviewed the *RCRA Corrective Measures Implementation (CMI) Workplan* dated November 10, 2005.

Enclosed is a letter from the RWQCB with their comments dated January 4, 2006. These comments were discussed at the monthly meeting with regulators on February 9, 2006 at DTSC's office.

Also enclosed is a memorandum from DTSC's Geology, Permitting and Corrective Action Branch with comments on the CMI Workplan.

DTSC provided electronic copies of the CMI Workplan to the City of Berkeley Toxics Management Program and the Community Environmental Advisory Commission (CEAC) in mid-November 2005. DTSC requested comments by the December 31, 2005. DTSC again requested comments and extended the time period to January 31, 2006. DTSC has not received comments from either the City of Berkeley Toxics Management Program nor CEAC.

Iraj Javandel
February 15, 2006
Page 2 of 2

Please provide a response to DTSC's and the RWQCB's comments as an addendum that can be inserted into the CMI Workplan. Please provide this response by March 6, 2006.

Sincerely,



Salvatore Ciriello
Supervising Hazardous Substances Engineer
Standardized Permitting and Corrective Action Branch

Enclosures

cc: George Leyva
San Francisco Regional Water Quality Control Board
1515 Clay Street
Oakland, CA 94612

Nabil Al-Hadithy
Toxics Management Program
City of Berkeley
2118 Milvia Street
Berkeley, CA 94704

Hemant Patel
U.S. Department of Energy
Oakland Operations Office
1301 Clay Street
Oakland, CA 94612

Buck King
Northern California Geology, Permitting and Corrective Action Branch
DTSC
700 Heinz Avenue
Berkeley, CA 94710

DTSC Comments

February 10, 2006



Department of Toxic Substances Control



Alan C. Lloyd, Ph. D.
Agency Secretary
Cal/EPA

Maureen F. Gorsen, Director
700 Heinz Avenue, Suite 200
Berkeley, California 94710-2721

Arnold Schwarzenegger
Governor

MEMORANDUM

TO: Waqar Ahmad
Hazardous Substance Engineer
Standardized Permitting and Corrective Action Branch
Berkeley Regional Office

FROM: Buck King, PG, CHG *Buck King*
Engineering Geologist
Geology, Permitting and Corrective Action Branch, Northern California
Geological Services Unit, Berkeley Regional Office

CONCUR: Brian Lewis, CEG, CHG *Bk for*
Engineering Geologist Supervisor I
Geology, Permitting and Corrective Action Branch, Northern California
Geological Services Unit, Sacramento Regional Office

DATE: February 10, 2006

SUBJECT: Review of RCRA Corrective Measures Implementation Workplan for
the Lawrence Berkeley National Laboratory, Berkeley, Alameda
County, California
Project No. 22120/200178-48/39-HWMP

DOCUMENT REVIEWED

RCRA Corrective Measures Implementation (CMI) for the Lawrence Berkeley National Laboratory (CMI Work Plan). Prepared by Lawrence Berkeley National Laboratory and dated November 2005.

INTRODUCTION

The Northern California Geological Services Unit (GSU) of the Department of Toxic Substances Control (DTSC) has completed our review of the CMI Work Plan dated November, 2005. If you have any questions, please contact Buck King at (510) 540-3955 or Brian Lewis at (916) 255-6532.

Waqar Ahmad
February 10, 2006
Page 2 of 2

Per your request, the GSU reviewed the CMI Work Plan and the three attachments consisting of: 1) *Corrective Measures Implementation Workplan for Soil Excavation, Building 51L Groundwater Solvent Plume Source Area for the Lawrence Berkeley National Laboratory Environmental Restoration Program* dated September 2005 (Attachment 1), 2) *Corrective Measures Implementation Workplan for Soil Excavation, Building 7 Sump of the Old Town Groundwater Solvent Plume Source Area for the Lawrence Berkeley National Laboratory Environmental Restoration Program* dated November 2005 (Attachment 2), and 3) *Monitoring Protocols for Monitored Natural Attenuation and Enhanced Bioremediation for the Lawrence Berkeley National Laboratory Environmental Restoration Program* dated November 2005 (Attachment 3).

The GSU participated in a Regulatory Project Manager (RPM) meeting conducted on February 9, 2006 which included a discussion of the issue of post-excavation confirmation soil sampling. The GSU recommended that confirmation soil sampling be conducted as part of Building 51L soil excavation because it is a standard element of soil removal actions and it was technically possible to implement. All parties at the meeting agreed to include confirmation soil sampling during Building 51L soil excavation.

The issue of post-excavation confirmation soil sampling during Building 7 soil excavation was discussed at the RPM meeting. All parties at the meeting agreed that confirmation soil sampling during Building 7 soil excavation was not feasible due to the sequenced soil boring and boring grouting soil excavation process required for soil excavation at the location.

RECOMENDATIONS

The GSU concurs with the proposed corrective measures described in CMI Work Plan with the addition of post-excavation confirmation soil sampling during Building 51L soil removal action. The GSU recommends that the CMI Work Plan be implemented.

LBLN Responses to DTSC Comments

February 28, 2006

Responses to Comments from *Buck King*, DTSC Geology, Permitting and Corrective Action Branch, Northern California Geological Services Unit (GSU), dated February 10, 2006 to Waqar Ahmad, DTSC Standardized Permits and Corrective Action Branch.

Subject: Review of RCRA Corrective Measures Implementation Workplan for the Lawrence Berkeley National Laboratory, Berkeley, Alameda California, Project No. 22120/200178-48/39-HWMP

Item	DTSC Comment	Berkeley Lab Response
<i>Recommendations</i>	The GSU concurs with the proposed corrective measures described in CMI Work Plan with the addition of post-excavation confirmation soil sampling during Building 51L soil removal action. The GSU recommends that the CMI Work Plan be implemented.	Berkeley Lab will conduct post-excavation confirmation soil sampling during the Building 51L soil removal action in accordance with the requirements of the agreement reached at the February 9, 2006 Remedial Project Managers (RPM) meeting. The details of the sampling are provided in Berkeley Lab's Response to Regional Water Quality Control Board Comment 1 on the RCRA Corrective Measures Implementation Workplan dated January 4, 2006.

Water Board Comments

January 4, 2006



California Regional Water Quality Control Board

San Francisco Bay Region



Alan C. Lloyd, Ph.D.
Agency Secretary

1515 Clay Street, Suite 1400, Oakland, California 94612
(510) 622-2300 • Fax (510) 622-2460
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Arnold Schwarzenegger
Governor

January 4, 2006
File No. 2199.9026(GVL)

Waqar Ahmad
Hazardous Substances Engineer
Department of Toxic Substances Control
700 Heinz Ave, Suite 200
Berkeley, CA 94710
wahmad@dtsc.ca.gov

SUBJECT: Water Board Comments Regarding - *RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory*

Dear Mr. Ahmad:

We reviewed the *RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory*, dated November 10, 2005. We concur with the recommendation allowing pollutants at concentrations specified in the Target Risk-Based Media Cleanup Standards (MCS), Table 1, of the report. Table 1 describes maximum contamination allowed for the site and was included in the Corrective Measures Implementation Study, previously approved.

Our concurrence is based on the understanding that groundwater monitoring will continue to verify that the residual contamination is not migrating, not degrading adjacent water resources, and is reducing in concentration. As stated in the work plan, the long-term goal for all groundwater at Berkeley Lab is the reduction of pollutant concentrations to MCLs (drinking water standards). Therefore, monitoring should continue until the concentrations in the groundwater attain the MCLs.

The primary method of remediation proposed in the work plan is to first excavate contaminated soil to comply with the MCS concentrations. Secondly, reduction of the concentrations of the residual contamination will consist of remedial action methods, which chemically decompose the contaminants and enhance the natural decomposition processes.

Comments

1. The work plan proposes to demonstrate compliance with the MCS by analyzing pre-excavation soil samples but specifies that post-excavation samples may or might not be taken depending on whether or not the site was adequately characterized prior to excavation. We recommend that analysis of post-excavation samples be mandatory to verify that the proposed standards were met.
2. Groundwater monitoring is proposed to evaluate the residual contamination for proper decomposition parameters to verify that the pollutant plume is shrinking. In addition,

down-gradient monitoring of the plume will ensure that the contaminants are not migrating into uncontaminated areas. Groundwater monitoring will be implemented pursuant to a Groundwater Monitoring Management Plan (GMMP), not yet prepared. We expect the GMMP be prepared before completion of the CMI work.

3. Contrary to the CMI work plan, samples for long-term monitoring should be collected quarterly during the insitu treatment of the residual contamination and then continued on a quarterly basis for the first six quarters after active remediation activities have ceased. If the contamination consistently declines after active remediation is ceased, then the sampling interval can be increased to semi-annually for two years followed by annual sampling events, verifying that the plume is continuing to decline. If the plume is not degrading as predicted, additional active remediation may be needed.

Thank you for this opportunity to comment on the report. If you have any questions, please contact me at (510) 622-2379 or via e-mail glevva@waterboards.ca.gov.

Sincerely,



George Leyva, EG
Case Manager

cc:

Hemet Patel
US Dept. of Energy
Oakland Operations Office
1301 Clay Street, Suite 700N
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Iraj Javandel
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Lawrence Berkeley National Lab
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Nabil Al-Hadithy
Toxics Management Office
City of Berkeley
1900 Addison Street
Berkeley, Calif. 94704

Pamela Sihvola,
Committee to Minimize Toxic Waste
P.O. Box 9646
Berkeley, Calif. 94709

LBLN Responses to Water Board Comments

February 28, 2006

**Responses to Comments from *George Leyva*, California Regional Water Quality Control Board San Francisco Bay Region dated January 4, 2006, File No 2199.9026(GVL) to Waqar Ahmad, Department of Toxic Substances Control
Subject: Water Board Comments Regarding RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory**

Item	RWQCB Comment	LBNL Response
<i>General Comments</i>	<p>1) Our concurrence is based on the understanding that groundwater monitoring will continue to verify that the residual contamination is not migrating, not degrading adjacent water resources, and is reducing in concentration. As stated in the work plan, the long-term goal for all groundwater at Berkeley lab is the reduction of pollutant concentrations to MCLs (drinking water standards). Therefore, monitoring should continue until the concentrations in the groundwater attain MCLs.</p>	<p><i>Agree.</i> Lawrence Berkeley National Laboratory (Berkeley Lab) groundwater monitoring requirements are specified in the <i>Proposal for Revised Groundwater Monitoring Schedule for the Lawrence Berkeley National Laboratory Environmental Restoration Program</i> (May 2005), which was approved by the Regional Water Quality Control Board (Water Board) on August 1, 2005. Groundwater monitoring requirements specified in that document are designed to:</p> <ul style="list-style-type: none"> • Monitor contaminant concentrations and indicator parameters to assess the performance of corrective measures in areas where Media Cleanup Standards (MCSs) are exceeded. • Monitor contaminant concentrations to assess downgradient plume migration. • Monitor contaminant concentrations to ensure that plumes do not migrate past the site perimeter. <p>The May 2005 monitoring schedule also specifies monitoring requirements to comply with State Water Resources Control Board (SWRCB) policies. Therefore in areas where MCSs have been achieved but groundwater concentrations still exceed MCLs, groundwater monitoring will continue unless alternative requirements are approved by the Water Board.</p> <p>Any revisions to the approved groundwater monitoring schedule will require approval by the Water Board.</p>

Responses to Comments from *George Leyva*, California Regional Water Quality Control Board San Francisco Bay Region dated January 4, 2006, File No 2199.9026(GVL) to Waqar Ahmad, Department of Toxic Substances Control
Subject: Water Board Comments Regarding RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory *(continued)*

Item	RWQCB Comment	LBNL Response
<i>General Comments (cont'd.)</i>	2) The primary method of remediation proposed in the work plan is to first excavate contaminated soil to comply with the MCS concentrations. Secondly, reduction of the concentrations of residual contamination will consist of remedial action methods, which chemically decompose the contaminants and enhance the natural decomposition processes.	The primary cleanup methods proposed for groundwater consist of combinations of: i) excavation with offsite disposal of contaminated soil in the source area; ii) soil flushing with groundwater extraction; iii) monitored natural attenuation (MNA); and iv) enhanced bioremediation.

Responses to Comments from *George Leyva*, California Regional Water Quality Control Board San Francisco Bay Region dated January 4, 2006, File No 2199.9026(GVL) to Waqar Ahmad, Department of Toxic Substances Control
Subject: Water Board Comments Regarding RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory *(continued)*

Item	RWQCB Comment	LBNL Response
<i>Comment 1</i>	<p>The work plan proposes to demonstrate compliance with MCSs by analyzing pre-excavation soil samples but specifies that post-excavation samples may or might not be taken depending on whether the site was adequately characterized prior to excavation. We recommend that analysis of post-excavation samples be mandatory to verify that the proposed standards were met.</p>	<p>Berkeley Lab believes the numerous pre-excavation soil samples it has collected specifically to delineate the extent of soil contamination above MCSs are more than adequate for determining the required depth and extent of excavation. However, pursuant to the agreement reached at the February 9, 2006 Remedial Project Managers (RPM) meeting, the following soil sampling will be conducted to confirm compliance with MCSs. Representatives from the Water Board, Department of Toxic Substances Control (DTSC), City of Berkeley, Department of Energy, and Berkeley Lab participated in the decision.</p> <p><u>Building 51L Groundwater Plume Source Area:</u> Ten post-excavation confirmation soil samples will be collected. Three of the samples will be collected from the floor and seven from the walls of the excavation. The wall samples will be located approximately 1/3 of the way down from the ground surface to the excavation floor, spaced at intervals of approximately 15 to 20 feet. Each sample will be collected at a depth of approximately 6 to 12 inches beneath the floor or into the walls of the excavation.</p> <p><u>Building 7 Lobe Source Area:</u> No post-excavation confirmation samples will be collected. The excavation will be completed to a depth of approximately 45 feet using large-diameter solid-stem augers, and therefore the walls of the excavation will not be accessible for collecting post-excavation samples. Samples collected from the bottom of the borings would be of questionable validity since there would likely be loose material (slough) at the bottom of the boring and it would not be feasible to collect a sample of in-place soil.</p>

Responses to Comments from *George Leyva*, California Regional Water Quality Control Board San Francisco Bay Region dated January 4, 2006, File No 2199.9026(GVL) to Waqar Ahmad, Department of Toxic Substances Control
Subject: Water Board Comments Regarding RCRA Corrective Measures Implementation (CMI) Work Plan for Lawrence Berkeley National Laboratory *(continued)*

Item	RWQCB Comment	LBNL Response
<i>Comment 2</i>	Groundwater monitoring is proposed to evaluate the residual contamination for proper decomposition parameters to verify that the pollutant plume is shrinking. In addition, down-gradient monitoring of the plume will ensure that the contaminants are not migrating into uncontaminated areas. Groundwater monitoring will be implemented pursuant to a Groundwater Monitoring Management Plan (GMMP), not yet prepared. We expect the GMMP be prepared before completion of the CMI work.	<i>Agree.</i> See Response to General Comment 1. In addition, as specified in the Corrective Measures Study (CMS) Report, Berkeley Lab will prepare a Groundwater Monitoring and Management Plan (GMMP). The GMMP will be submitted to the regulatory agencies before completion of the Corrective Measures Implementation (CMI) work and is tentatively scheduled to be submitted in March 2006.
<i>Comment 3</i>	Contrary to the CMI work plan, samples for long-term monitoring should be collected quarterly during the insitu treatment of the residual contamination and then continued on a quarterly basis for the first six quarters after active remediation activities have ceased. If the contamination consistently declines after active remediation is ceased, then the sampling interval can be increased to semi-annually for two years followed by annual sampling events, verifying that the plume is continuing to decline. If the plume is not degrading as predicted, additional active remediation may be needed.	The CMI Workplan only provides the schedule of groundwater sampling associated with those locations where Monitored Natural Attenuation (MNA) is the approved corrective measure. The sampling specified in the CMI Workplan for those locations is designed primarily to evaluate the presence and distribution of the hydrochemical indicators of natural attenuation, to assess whether conditions remain favorable for biodegradation. Berkeley Lab considers the frequency of sampling for those parameters, semiannually for one year and then annually to be sufficient. The requirements for monitoring contaminants in the groundwater at Berkeley Lab are provided in the Proposal for Revised Groundwater Monitoring Schedule for the Lawrence Berkeley National Laboratory Environmental Restoration Program (May 2005). (See response to General Comment 1). The Water Board's comment regarding the frequency of long-term monitoring will be considered when proposing revisions to the currently approved sampling schedule specified in that document.