FINAL
2005 SOURCE MIGRATION INVESTIGATION REPORT
Velsicol Chemical / Pine River Site, OU1

St. Louis, Michigan

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Executive Summary

This report summarizes the results of the Source Migration Investigation (SMI) conducted by the United States Environmental Protection Agency (USEPA) on the former main plant site (Operable Unit 1—OU1) at the Velsicol Chemical/Pine River Site in St. Louis, Michigan. The primary fieldwork for this investigation commenced in September 2004, and concluded in July 2005. A minor field effort related to additional groundwater gradient evaluation is scheduled to be conducted in the spring of 2006 and an addendum to this report will subsequently be produced.

The intent of the SMI is to supplement the data obtained in the draft Remedial Investigation (RI) conducted by the Michigan Department of Environmental Quality (MDEQ). Data gaps were identified through the use of the data quality objective (DQO) process and a field investigation was developed specifically to address these data gaps. The Final Joint Sampling and Analysis Plan/Quality Assurance Project Plan (JSAP) issued in July 2004 described the DQO process and established the sampling techniques and procedures that were used during the investigation.

The DQO planning process identified four data categories that required additional evaluation:

- Dense nonaqueous phase liquid (NAPL) extent in the Shallow Unit and sand seams
- Hydraulic potential between the Intermediate and Lower Units
- Hydraulic relationships within the Lower Unit
- Nature and extent of groundwater contamination in the Intermediate and Lower Units

Additionally, eight principal study questions were developed:

1. *Are there remnant source areas within the interior of the Main Plant Site, and if so, to what extent?*
2. *How far do the sand seams and NAPL within the sand seams extend in areas beneath the river and its northern shore?*
3. *What are the depth, thickness, and grain size distribution of the sand seams along the downgradient site margin, and under the river and its northern shore in the north and northeast directions?*
4. *What is the groundwater flow direction in the Intermediate Unit (sand seams)?*
5. *What are the distributions of vertical gradients between the Intermediate and Lower Units, and between the D and D2 zones of the Lower Unit, and how do they vary seasonally?*
6. *Are Monitored Natural Attenuation processes active in the Lower Unit and is MNA a feasible option for the Lower Unit?*
7. *What is the extent of potential offsite groundwater contamination in the sand seams and Lower Unit in the west, north, and northeast directions?*
8. *To what extent is each city well geologically and hydraulically isolated from potential site contaminants, and how does this relate to the usage of each for municipal water supply?*

The field investigation included the following:

- **Passive soil gas (PSG) survey**—226 total PSG locations installed and analyzed for volatile organic compounds (VOCs)
- **Shallow Unit PSG follow-up soil borings** (based on the results of the PSG survey)—29 total borings advanced, and soil and groundwater samples collected and analyzed for VOCs, semi-volatile organic compounds (SVOCs), total dichlorodiphenyltrichloroethane (DDT)/hexabromobenzene (HBB)/polybrominated biphenyls (PBB), and metals
- **Historical focus sampling**—9 test trenches excavated on OU1 with soil samples collected and analyzed for VOCs, SVOCs, total DDT/HBB/PBB, and metals
- **Test pits advanced in the dewatered portion of the Pine River** (Operable Unit 2—OU2)—8 test pits advanced in Cell 6 and 6 test pits advanced in Cell 7 with 4 soil samples collected and analyzed for VOCs, SVOCs, total DDT/HBB/PBB, and metals
- **Downgradient site margin soil borings**—8 total borings advanced with sand seam soil samples collected for grain size analyses and groundwater grab samples collected and analyzed for VOCs, SVOCs, total DDT/HBB/PBB, and metals
- **Intermediate Unit monitoring wells**—9 total installed
- **D zone monitoring wells**—2 total installed
- **D2 zone monitoring wells**—2 total installed
- **City well study**—Groundwater samples from all 6 city wells analyzed for VOCs, SVOCs, total DDT/HBB/PBB, metals, and pCBSA
- **Offsite west groundwater study**—Groundwater samples from 15 private residential wells analyzed for VOCs, SVOCs, total DDT/HBB/PBB, metals, and pCBSA
- **Groundwater monitoring and sampling**—Samples collected from new and existing Intermediate Unit monitoring wells and new D and D2 zone Lower Unit monitoring wells and analyzed for VOCs, SVOCs, total DDT/HBB/PBB, metals, and pCBSA; water levels measured from all Intermediate Unit monitoring wells and from "clustered" Intermediate Unit, D zone, and D2 zone monitoring wells
- **Monitored Natural Attenuation (MNA) evaluation**—Groundwater samples collected from new and existing Lower Unit monitoring wells and analyzed for natural attenuation parameters

Data obtained during the SMI were evaluated and incorporated with information obtained during previous investigation activities at the site. Answers to the principal study questions are summarized as follows:

1. *Are there remnant source areas within the interior of the Main Plant Site, and if so, to what extent?*

   Two main areas were identified that appear to be acting as remnant source areas based on PSG results, confirmatory borings, observations during OU2 remedial activities, and

observations during previous MDEQ investigations. A few much smaller, isolated areas had elevated PSG signatures, but confirmatory borings and previous MDEQ investigation activities indicate these areas have elevated soil contaminant concentrations, but do not show evidence of remnant source material.

2. *How far do the sand seams and NAPL within the sand seams extend in areas beneath the river and its northern shore?*

   It appears that the Intermediate Unit sand seams under the river along the northern margin of the site extend approximately 700 feet to the north from the Main Plant Site shoreline. On the north side of the river, the sand seams appear to pinch out to the west and thin to the east, although they may extend further to the northeast. NAPL was not observed in the sand seams on the north side of the river but was observed in some of the Cell 6 test pits, which indicates that NAPL is present in the sand seams beneath the river.

3. *What are the depth, thickness, and grain size distribution of the sand seams along the downgradient site margin, and under the river and its northern shore in the north and northeast directions?*

   Along the downgradient site margin, data indicate a relatively high degree of vertical interconnectedness among the sandy intervals within the till which, in part, explains the degree to which the till has been impacted by NAPL and dissolved contaminants. The particle size analysis results indicate that the sand seams along the downgradient site margin are generally composed of a silty sand material with an average of 10 percent gravel, 70 percent sand, and 20 percent fines. Gravel percentages range between 0 and 27 percent.

   The Intermediate Unit sand seams under the river and its northern shore to the north and northeast range from about 679 to 706 feet above msl and were not present immediately north of the site across the river. The pattern of Intermediate Unit sand seam occurrences under the river and the northern shore indicate that sand seams are generally more common under the Main Plant Site. The natural sand and gravel channel observed in the Hot Spot Cell was not observed in Cell 7 test pits. The particle size analysis results for sand seam material in these areas were similar to the results obtained from sand seams along the downgradient site margin.

4. *What is the groundwater flow direction in the Intermediate Unit (sand seams)?*

   Groundwater flow direction in the Intermediate Unit is predominantly to the south and southeast under the majority of the site and was generally consistent between May 2005 and July 2005, although some influence due to the dewatering of Cell 7 was noted.

5. *What are the distributions of vertical gradients between the Intermediate and Lower Units, and between the D and D2 zones of the Lower Unit, and how do they vary seasonally?*

   I/D vertical gradients were uniformly downward across the site, and were consistent during the spring and summer of 2005. The D/D2 vertical gradients were both up and down, and some seasonal variation was observed. Further evaluation of season variation

is pending. Results of this evaluation will be presented in a vertical gradient technical memorandum supplement to this report.

6. *Are Monitored Natural Attenuation processes active in the Lower Unit and is MNA a feasible option for the Lower Unit?*

   Anaerobic conditions appear to be present in the Lower Unit, indicating natural biodegradation rates may be too low to achieve desired reductions of key contaminants, such as benzene and chlorobenzene, within desired timeframes through naturally occurring biodegradation processes alone, and abiotic decay rates are expected to be equally unfavorable.

7. *What is the extent of potential offsite groundwater contamination in the sand seams and Lower Unit in the west, north, and northeast directions?*

   Results from the SMI and results obtained previously by MDEQ indicate that despite the presence of NAPL in the river bed and in sand seams beneath the river bed, groundwater contamination in the Intermediate Unit sand seams and the Lower Unit does not extend very far beyond the site boundaries in the west, north, and northeast directions. pCBSA results from city well samples do indicate potential contaminant migration pathways exist to the northeast of the site.

8. *To what extent is each city well geologically and hydraulically isolated from potential site contaminants, and how does this relate to the usage of each for municipal water supply?*

   The results obtained during the SMI indicate that pCBSA was detected in three of the six city wells at concentrations up to 180 µg/L. No VOCs, SVOCs, or total DDT/HBB/PBB were detected in the city wells. Although the presence of pCBSA in the city wells indicates the potential for other site constituents (e.g., DDT, chlorobenzene, or benzene) to migrate to the city wells, the occurrence of pCBSA at a given location does not necessarily imply that other site constituents will migrate to that location because of the nonconservative behavior of the other site constituents that retards advection of these compounds. The pCBSA data do indicate that continued monitoring of the city wells and select sentry wells for site contaminants is warranted.

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Acronyms and Abbreviations

bgs	below ground surface
COCs	constituents of concern
cm/s	centimeters per second
DBCP	1,2-dibromo-3-chloropropane
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense nonaqueous phase liquid
DQO	data quality objectives
DO	dissolved oxygen
USEPA	U.S. Environmental Protection Agency
EVS	Environmental Visualization System
FID	flame ionization detector
FS	feasibility study
HBB	hexabromobenzene
HSA	hollow stem auger
IDW	investigation-derived waste
JSAP	Joint Sampling and Analysis Plan/Quality Assurance Project Plan
lb/day	pounds per day
MCC	Michigan Chemical Corporation
MDEQ	Michigan Department of Environmental Quality
mm	millimeters
MNA	monitored natural attenuation
msl	mean sea level
NAPL	nonaqueous phase liquid
OSHA	Occupational Safety and Health Administration
OU	operable unit
PAHs	polyaromatic hydrocarbons
pCBSA	parachlorobenzene sulfonic acid
PBB	polybrominated biphenyls
PID	photoionization detector
PPE	personal protective equipment
ppm	parts per million
PSG	passive soil gas
RA	remedial action
RI	remedial investigation

ROD	record of decision
SOPs	standard operating procedures
SVOCs	semivolatile organic compounds
TICs	tentatively identified compounds
TRIS	tris(2,3-dibromopropyl)phosphate
µg/kg	micrograms per kilograms
µg/L	micrograms per liter
yd^3	cubic yard
VOCs	volatile organic compounds

SECTION 1

Introduction

The Velsicol Chemical/Pine River Site is located in St. Louis, Michigan and includes the approximately 52-acre land parcel commonly referred to as the "main plant site" once occupied by a chemical processing plant and designated as Operable Unit 1 (OU1), and approximately 32 acres of contaminated sediments in the Pine River and Mill Pond designated as Operable Unit 2 (OU2). Figure 1-1 shows the site overview, including structures built during recent remedial activities in OU2. The site is in a predominantly residential area with houses on the river banks. A recreational park borders the river's northern bank across from the Velsicol Chemical Company property. The Pine River flows along the site's western and northern sides into Mill Pond, where a hydroelectric dam is situated approximately ¼ mile east of the site.

OU1 was used for industrial operations since the mid-1800s until the plant was closed in 1977. These operations included a lumber mill, oil refinery, salt processing plant, and chemical manufacturing plant. Michigan Chemical Corporation (MCC) purchased the site in 1935 and operated a chemical manufacturing business until the plant was closed in 1977. In 1965, Velsicol Chemical Corporation gained controlling interest in MCC. MCC extracted brine from many wells in the St. Louis area to obtain basic minerals, and by 1945, nine liquid and eight granular forms of bromide, magnesium oxide, and dichlorodiphenyltrichloroethane (DDT) were in production. Full-time research began in 1940.

TABLE 1-1
MCC 1957 Waste Survey

Waste Constituent	Average lb/day Discharged to Pine River
Chloride	128,339
DDT	25.9
Copper	371
Ammonia	440
Oil	137.5
Sulfuric Acid	27,493

Additional products manufactured included soil and grain fumigants such as methyl bromide, rare earth (radioactive) oxides, fire retardants consisting of tris(2,3-dibromopropyl) phosphate (TRIS). The 1962 MCC Annual Report listed 76 chemical and rare earth element products (Pine River Superfund Citizen Task Force, 2003). By the early 1970s, hexabromobenzene (HBB) and polybrominated biphenyls (PBB) were being manufactured.

According to a 1957 waste survey performed by MCC over a 4-day period (MCC, 1957), wastes were discharged from eight locations to the Pine River. The average pounds per day (lb/day) of waste constituents discharged to the Pine River were as shown in Table 1-1. The eight sources of waste discharged to the Pine River are as follows:

- Rare Earths Waste Line
- DDT Waste Line
- Magnesia Plant Line
- Salt Plant Waste Line

- Catch Basin, Northern Side of DDT Plant
- Truck Wash and Brine Storage Area Waste Line
- Brine Separation Tank Waste Sludge
- Byproduct Hydrochloric Acid Wasted to Pine River

It is suspected that some of the waste lines were "flumes" or trenches with wooden planks covering them, with likely leakage to the ground below the waste line. Several flumes, sewer lines, and discharge lines are shown on the 1950 MCC Site Structures and Plant Layout (Figure 1-2). The plant layout was discovered in the St. Louis Historical Society files (MCC, 1950), incorporated into the project database, and has formed part of the basis of the sampling plan approach described in the *Joint Sampling and Analysis Plan/Quality Assurance Project Plan* (JSAP, U.S. Environmental Protection Agency [USEPA], July 2004).

Remediation activities on OU1 occurred in the early 1980s following shutdown of the plant. The buildings on OU1 were demolished, and the site was graded and covered with a 3-foot-thick low-permeability cap using clean imported fill (in some areas, the cap is only about 18 inches thick). Materials from the former burn pit area (located on the golf course property northwest of the main plant site) were transported to and disposed on OU1 before placement of the cap during closure activities in the early 1980s. A bentonite slurry wall was constructed around the entire perimeter of the site and keyed into the underlying glacial till. A second smaller slurry wall was built around an area of oil-contaminated soil on the southeastern boundary of OU1 (referred to as the "oil containment slurry wall"). The slurry walls are shown in Figure 1-1. Also, a series of connected perforated clay tile groundwater collection lines were constructed across the site as a means of removing groundwater that accumulated within the former main plant site.

The OU2 area of concern that is currently being addressed under the 1999 Record of Decision (ROD) extends from the westernmost wall of Cells 5 and 6 on the west to the St. Louis Municipal Hydroelectric Dam (dam) in Mill Pond on the east. The dam generates hydroelectric power during periods of high water levels. OU2 includes an estimated 650,000 cubic yards (yd^3) of DDT-contaminated sediments in the Pine River and Mill Pond. Contaminated sediment removal from OU2 has nearly been completed; only removal of infrastructure from the Pine River's southern side remains for the 2006 construction season. During ongoing sediment remediation, it has been determined that in some areas, sand seams within the glacial till underlying the Pine River contain dense nonaqueous phase liquid (DNAPL or NAPL). There are at least two distinct types of DNAPL: one containing primarily DDT and chlorobenzene (Hot Spot Cell DNAPL) and a second containing primarily brominated and other halogenated organic compounds (Area 3 DNAPL).

Two municipal water supply wells are located on the City of St. Louis power plant property (City Wells #1 and #4). Two municipal water wells (City Wells #6 and #7) are located within 3,000 feet east and northeast of the site. Two municipal water wells (City Wells #5 and #8) are located approximately 3,000 feet southeast and 6,000 feet south to southeast of the site, respectively (Figure 1-3). Groundwater in the area is also used for private water supply primarily through the use of residential water wells. Residential water well usage is discussed in more detail in Section 2.

1.1 Site Hydrogeology

Appendix B of the JSAP describes the site's physical characteristics (including topography and hydrology, geology, hydrogeology, and contaminant and risk characteristics). The units that form the conceptual hydrostratigraphic site model are summarized below and are depicted on regional cross-sections on Figures 1-4 (cross-section location map), 1-5, and 1-6.

The Shallow Unit consists of the saturated parts of the fill and alluvium, and is unconfined and typically about 11 feet thick, depending on the water table level. Although it does not meet its original design specifications, the low permeability cap at the surface of OU1 does act to decrease infiltration to the Shallow Unit. The slurry wall, despite the existence of breaches documented previously, acts both to impound groundwater in the Shallow Unit at the downgradient boundary by up to 5.5 feet above the water levels outside and to restrict flow onto the site at the upgradient boundary. Previous data show the groundwater flow pattern is radial from the interior of the main plant site toward the Pine River with the exception of the northeast corner and the southern boundary of the southeast corner. In the northeast corner, flow is away from or parallel to the Pine River, with flow to the south and east of the main plant site. Groundwater monitoring wells at the site with the "S" suffix in their names are screened in this unit.

Till Aquitard. The till acts as an aquitard between the Shallow and Lower Units. Its composition is 52-percent fines with a median grain size of 0.08 millimeter(s) (mm) (Weston, 2003). The till has a hydraulic conductivity range between 1.00×10^{-7} and 1.55×10^{-5} centimeters per second (cm/s) with a geometric mean of 1.05×10^{-6} cm/s (Weston, 2003).

The Intermediate Unit consists of sand seams at various elevations within the till aquitard (although "sand seams" are described within the glacial till throughout this document, it should be noted that these seams can also contain varying amounts of gravel). The thickness of the sand seams is highly variable, but has not been observed to be more than 5 feet thick. The unit may also include sand seams that are interconnected at multiple levels within the till. The presence of the Intermediate Unit and its effect as a preferential pathway for groundwater flow greatly diminishes the till's effectiveness as an aquitard between the Shallow and Lower Units (see below). The Intermediate Unit is unconfined, or in some locations locally confined ("semi-confined") and appears to be in direct hydraulic communication with the overlying Shallow Unit. Downward hydraulic head differentials between the Shallow and Intermediate Units and Intermediate and Deep Units of up to 5.22 and 12.2 feet (respectively) have been previously reported (Weston, 2003). Groundwater monitoring wells at the site with the "I" suffix in their names are screened in this unit.

The Lower Unit is a leaky confined aquifer (or possibly a series of confined aquifers) and is subdivided into two water-bearing zones under the current conceptual hydrostratigraphic model of the site:

- D Zone—Consists of the advance outwash immediately underlying the Wisconsonian Till and ranges up to 10 feet thick, but is typically about 2 to 4 feet thick, and is not present in some locations. The D zone is under confined conditions with an average potentiometric level of 703.3 feet above mean sea level (msl).

- D2 Zone—Consists of the 21 to 39 feet of the deeper strata immediately underlying the advance outwash layer at the top of the unit (D zone) that are finer grained and more gradational. The D2 zone is under confined conditions with a typical potentiometric level of 703.3 feet above msl, which is similar to that of the D zone and suggests hydraulic communication.

The D and D2 zones appear to be separated at some locations by silt and clay lenses but the thickness and extent of such lenses and, therefore, their effect as potential aquitards is unclear; the two zones may be in direct hydraulic communication. Slightly upward apparent vertical gradients between the D and D2 zones with hydraulic differentials between 0.1 and 2.86 feet have been previously reported (Weston, 2003).

The presence of aquitards within the deeper strata of this unit that would further stratify the water-bearing zones within the Lower Unit is suggested by the apparent presence of tills from earlier (Illinoisan and Kansan) glaciations and supported by an apparent lack of hydraulic response in site monitoring wells to pumping in City Wells #1 and #4 (Weston, 2003), which are constructed with intakes in the deeper (Kansan) advance outwash. City Well# 7, the intake of which appears to be located within the D2 zone, does appear to induce a hydraulic response in some D zone site monitoring wells when pumped.

Figures 1-7, 1-8A, and 1-8B show a cross-section that brings together the current understanding of the site's hydrostratigraphic model and DNAPL extent based on subsurface exploration and field observations from both OU1 and OU2 activities.

1.2 Contaminants of Concern

The tentative contaminants of concern (COCs) lists for soil and groundwater presented in MDEQ's draft Remedial Investigation (RI) (Weston, 2003) and Feasibility Study (FS) are not finalized at the time of this report, and may be subject to review and revision. For the purposes of this report, COCs are considered to include volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total DDT, specialty chemicals (including HBB, PBB, TRIS) and inorganics (including metals, arsenic, and cyanide). Total DDT includes the ortho-para and para-para isomers of DDT, dichlorodiphenyldichloroethane (DDD), and dichlorodiphenyldichloroethylene (DDE).

Subsequent to the JSAP and prior to the start of field work for this investigation, an evaluation of the Area 3 DNAPL was conducted to determine if additional COCs should be included based on the composition of that NAPL. The memorandum describing that evaluation is included as Appendix A, Area 3 NAPL Characterization Documentation. Based on that evaluation, tentatively identified compounds (TICs) were identified. Based on availability of analytical standards, two compounds (1,2-dibromo-3-chloropropane [DBCP] and 1-chlorohexane) were included in the VOC analysis.

1.3 Project Description

The intent of this investigation was to supplement the data obtained in the RI by gaining an understanding of the distribution of DNAPL at the site, extent of DNAPL mobility in the site's subsurface, and the extent of groundwater contamination resulting from DNAPL migration.

Further understanding of DNAPL distribution and mobility and related groundwater contamination was necessary to fully develop and evaluate remedial alternatives for the site. The investigation is organized into four data categories that emerged from the data quality objective (DQO) planning process:

- DNAPL extent in the Shallow Unit and sand seams
- Hydraulic potential between the Intermediate and Lower Units
- Hydraulic relationships within the Lower Unit
- Nature and extent of groundwater contamination in the Lower and Intermediate Units

Section 2 describes the field methodologies used in this investigation. Section 3 contains the investigation results. Section 4 discusses the results in the context of the eight principal study questions identified during the DQO process as identified in the JSAP and reports the conclusions of this investigation.

SECTION 2

Field Methods

The sampling and analysis plan for the source migration investigation is documented in the JSAP. Table A-4 of the JSAP presented a summary of the existing data, additional data needed, and the sampling approach used to address identified data gaps. The elements of the sampling approaches summarized in JSAP Table A-4 and the field methods for each are described below.

2.1 Interior Distribution and Historical Focus Sampling

Interior distribution and historical focus soil and groundwater sampling locations were conducted for the Shallow Unit. The term "interior distribution" refers to randomly distributed samples to assess the broad distribution of potential remnant source areas (for example, DNAPL) within reasonably anticipated homogenous areas of the Main Plant Site based on past industrial operations. The term "historical focus" refers to samples targeted at smaller specific locations that show a larger potential for remnant sources based upon specific knowledge of previous buildings, tanks, and utilities. Please refer to Section A6.2.1 of the JSAP for a description of the sampling methodology for activities described in this section.

2.1.1 Interior Distribution Sampling

To achieve a statistically significant assessment of the potential for residual source areas (for example, areas with DNAPL), the site's interior was subdivided into five areas of investigation based on past chemical production and waste disposal activities at the site. These areas, listed below, are depicted in Figure 2-1:

- Bromides and Fine Chemicals Area
- Waste Drum Storage Area
- Disposal Lagoon Area
- Northwest Pond Area
- Railroad Spur Area

Passive Soil Gas Survey

A passive soil gas (PSG) screening survey was conducted in each area. The PSG methodology was pilot tested at the Bromides and Fine Chemicals Area (near the WMW-21 cluster) and the Waste Drum Disposal Area (near the WMW-19 cluster) prior to full-scale application. Forty-three Gore-Sorber screening modules were deployed into 2-inch diameter holes to a depth of not less than 4 feet below ground surface (bgs). The holes were installed with a Geoprobe truck-mounted rig. The modules were removed 14 days later and sent to Gore to be analyzed for VOCs. The results of the pilot test confirmed the ability of the PSG methodology to detect contaminants at the site. Therefore, the full-scale PSG survey (183 locations) was conducted using the same methodology. These locations are shown on Figure 2-1.

Follow-up Soil and Groundwater Sampling

After PSG results were obtained from Gore, follow-up soil and groundwater sampling was performed in the Shallow Unit. The locations selected for follow-up sampling were generally those that exhibited elevated PSG signatures, although some locations were selected where few VOCs were detected during the PSG screening survey for comparison purposes.

To complete follow-up soil and groundwater sampling, 29 soil borings were installed (SBS01–SBS29) using a combination of CME 95, CME 750, and CME 55 hollow stem auger (HSA) drilling rigs. Split spoon samples were collected continuously from the ground surface to the top of the glacial till. Samples from each borehole were logged and screened for contamination visually, by a combination of photo ionization detector (PID) and flame ionization detector (FID), and with hydrophobic dye for NAPL detection. Boring logs are included in Appendix B. Soil samples were collected from each boring from the interval with the highest PID/FID readings. In the absence of elevated PID/FID readings, the soil sample was collected from the interval directly above the till. This sampling methodology sometimes resulted in the collection of saturated soil samples which was necessary because any residual DNAPL that may have been present in a borehole would most likely be present on top of the till, and the primary goal was to target sampling from zones that were the most likely to be contaminated with DNAPL. One groundwater grab sample was collected from each borehole with a temporary well using low flow sampling methodology in accordance with standard operating procedures (SOPs) in the JSAP.

Although PSG samples are only capable of detecting VOCs, soil and groundwater samples collected from borings located based on the results of the PSG were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, and metals because (1) it is known based on historical sampling at the site that all these types of compounds are present on the site; (2) the cost of obtaining the samples had already been expended.

During groundwater sample collection, field parameters were measured including water quality parameters (temperature, dissolved oxygen, pH, oxidation/reduction potential, and specific conductance). Upon completion of groundwater sampling, each boring was abandoned by backfilling with hydrated bentonite chips to the surface.

While conducting the Shallow Unit follow-up soil and groundwater sampling, two areas on the site were determined to be potentially contaminated with DBCP in concentrations up to 12 milligrams per kilograms (mg/kg) in soil and 72 milligrams per liter (mg/L) in water. The Occupational Safety and Hazard Association (OSHA) permissible exposure limit (PEL) for DBCP is 1 part per billion (ppb) in air. To limit potential exposure to DBCP, control areas were established (Figure 2-2). The DBCP Control Zone was based on standard airborne chemical exposure modeling to derive a concentration limit for soil and groundwater above which exposures to DBCP above 50 times the OSHA PEL would be expected to occur. Areas of the site that exceeded this limit for either soil or groundwater were demarcated as the DBCP Control Zone. The airborne chemical exposure modeling incorporated the maximum concentration of DBCP observed in site soil and groundwater, fraction organic carbon in soil, organic carbon partitioning coefficient, physical chemistry parameters specific to DBCP (water solubility, molecular weight, vapor pressure, and Henry's Law Constant), and the OSHA PEL. All activities within the control areas that

could lead to exposure including hollow stem auger drilling, groundwater sampling, and water level measurements were performed under increased health and safety requirements. The additional requirements included air monitoring, personal air sampling, engineering controls, and additional investigation-derived waste (IDW) management as described in the *CH2M HILL Health and Safety Plan, Velsicol Chemical/Pine River Site*, March 2005.

Additional Health and Safety updates were made based on air sampling conducted by CH2M HILL during operations at the Velsicol Chemical Site in the fall of 2004 (prior to commencing work in the site interior). Two types of air sampling were conducted and will be discussed in more detail below: (1) tank headspace vapor sampling and (2) personal diffusion badge sampling. The results of these samples were reported by e-mail on March 2, 2005 and are included in Appendix A.

Tank Headspace Vapor Sampling

Tank headspace vapor sampling was conducted on August 1, 2004 during transfer of total fluids from manhole MH-3 into the MH-3 holding tank. This sampling consisted of VOC vapor sampling with a SUMMA canister, reactive bromine cartridge sampling, and real-time monitoring of organic vapors with a multiRAE device equipped with an 11.7 eV PID and a chlorine industrial hygiene probe with 100 percent cross-sensitivity for bromine. All equipment was set up in the tank headspace and operating prior to starting the actual total fluids transfer. The actual transfer operation took 23 minutes to complete. Total fluids were pumped to the holding tank at an estimated rate of 10 gallons per minute. The highest reading noted on the PID was 4.9 parts per million (ppm) (background was 0.6 ppm). The highest reading on the chlorine probe was 1.3 ppm (background was 0.3 ppm).

Personal Diffusion Badge Sampling

Air sampling badges were worn by site personnel for activities conducted on September 15 and 16, and November 2, 2004. The samples in September were taken while staff were observing the advancement of test pits and test trenches. NAPL was observed during this activity. Air sampling badge constituents analyzed were benzene, methylene chloride, and 1,2-dichloroethane. These were chosen because among the compounds known to be present at the site at that time, they have the lowest exposure limits. The benzene and methylene chloride exposures were tested, in part, to comply with OSHA regulations for assessing exposure. The methylene chloride standard, in particular, requires air sampling if methylene chloride is present and there is any potential for exposure, regardless of duration or days of potential exposure.

2.1.2 Historical Focus Sampling

In addition to the interior distribution coverage achieved with the PSG grid and follow-up sampling, historical focus sampling was conducted by targeting previously unexplored locations based on historical facilities, utilities, and structures as shown on the 1950 MCC Site Structures and Plant Layout drawing (Figure 1-2).

To complete historical focus sampling, nine test trenches were excavated in the Shallow Unit. Locations of these excavations are depicted as TT2004-01 through TT2004-09 in Figure 2-3. They ranged from 10 to 85 feet in length (with most between 70 and 75 feet), 4 to 10 feet in width, and 9 to 20 feet deep. Observations from each of the test trenches were logged and

soil was screened for contamination visually, by a combination of PID and FID, and with hydrophobic dye for NAPL detection. Test trench logs are included in Appendix C. Soil samples were obtained from eight of the nine test trenches where contamination was suspected based on the screening methods. The samples were analyzed for VOCs, SVOCs, total DDT, HBB, and PBB. Upon completion of the excavation, the test trenches were backfilled with the excavated material. Compaction was conducted using a vibrating plate excavator attachment.

2.2 Cell #6 and #7 Explorations

Test pits were advanced in Cells #6 and #7 as sediment removal for the 2004 OU2 Remedial Action (RA) progressed and permitted access to the exposed glacial till surface.

The primary purpose of these explorations was to delineate sand seams and DNAPL extent beneath the Pine River north and northeast of the site. The technical memorandum *2004 OU2 Test Pits, Velsicol Chemical Site,* prepared in October 2004 by CH2M HILL for the EPA, details the methodologies used, field observations, and analytical results from these explorations. The memorandum is included as Appendix D. Note that a statement is made in the memorandum in Appendix D that data from the OU2 Test Pits will be incorporated into cross-sections in this SMI Report. Revised cross-sections have not been developed for this report because EVS visualization software is being used to develop a 3-dimensional model of the geology and presence of contaminants. Data from the OU2 Test Pits have been incorporated into these models.

2.3 Downgradient Site Margin Soil Borings

Eight soil borings (SBI-01 through SBI-08) were advanced to the bottom of the till to supplement existing data points along the downgradient site margin. Boring locations are depicted in Figure 2-3. The borings were completed using a combination of CME 95 and CME 750 HSA drilling rigs. Continuous split spoon sampling was performed through the Shallow Unit until the glacial till was reached, and continuous 5-foot core sampling was performed using a CME continuous core barrel from this point until the termination of each borehole. Cores from each borehole were logged and screened for contamination using a PID. Boring logs are included in Appendix B. Samples were obtained from sand seams for grain-size distribution analysis where the seams were thick enough to collect sufficient volume for analysis. One groundwater grab sample was obtained from the Intermediate Unit at each location where this unit was sufficiently thick to yield groundwater using low-flow sampling methodology in accordance with SOPs in the JSAP. Groundwater samples were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, and metals. During sample collection, field parameters were measured including water quality parameters.

All eight borings were double cased to minimize cross contamination between the Shallow, Intermediate, and Lower Units. A third casing was added to SBI-03 and SBI-07 to isolate significant sand seams that were encountered within the glacial till at an additional (lower) elevation. Upon completion, each boring (with the exception of SBI-05) was abandoned by grouting from total depth to the surface with bentonite-cement grout using a tremie pipe in accordance with SOPs in the JSAP. The isolation casings were left in place.

SBI-05 was converted to a monitoring well (MW-34I) when groundwater grab samples results obtained under expedited turnaround times indicated that SBI-05 was optimally situated to monitor the edge of the contaminant plume located near the MW-19 cluster. A second borehole was advanced approximately 10 feet west of MW-34I to continue logging the geology down to the Lower Unit in the SBI-05 area. This boring was also completed as a monitoring well (MW-34D) (see also Section 2.5 below).

2.4 Intermediate Unit Monitoring Wells

Nine monitoring wells (MW-16I, MW-21I, MW-22I, MW23I, MW-27I, MW-30I, MW-31I, MW-34I, and MW-35I) were installed in the Intermediate Unit per the JSAP. Intermediate Unit monitoring wells were constructed in upper elevation sand seams within the glacial till that were 1 foot or greater in thickness and yielded water. These wells were intended to be comparable to the existing I-series monitoring wells installed during the MDEQ's RI activities. Most new Intermediate Unit wells were coupled with existing Lower Unit monitoring wells to provide complete well clusters at these locations. Intermediate Unit monitoring well locations are shown in Figure 2-3.

Boreholes for the Intermediate Unit monitoring wells were advanced similarly to the downgradient soil borings. The borings were completed using a combination of CME 95 and CME 750 HSA drilling rigs. Continuous split spoon sampling was performed through the Shallow Unit until the glacial till was reached, and continuous 5-foot core sampling was performed from this point until the borehole was terminated approximately 1 foot below the Intermediate Unit. Each core sample was logged and screened for contamination visually and by using a PID. Boring logs and well completion diagrams are included in Appendix B. Samples of the sand seam from the screened interval were obtained for grain-size distribution analysis to provide additional characterization of the sand seam lithology.

All nine monitoring wells were installed using double casing drilling methods to minimize cross contamination between the Shallow and Intermediate Units. The Intermediate Unit monitoring wells were constructed of 2-inch Type 316 stainless steel with 0.010-inch continuous wire-wrapped screens. Each well was developed according to the SOPs in the JSAP.

Two additional monitoring wells were intended for locations north of Pine River in the Prospect Street right-of-way (SBI-09 and SBI-10); however, upper elevation sand seams were not encountered at these locations (refer again to Figure 2-3). The borings were terminated at 52.5 and 49.0 feet bgs, respectively. These boreholes were advanced similarly to the downgradient site margin soil borings. The borings were completed using a combination of CME 95 and CME 750 HSA drilling rigs. Continuous split spoon sampling was performed through the Shallow Unit until the glacial till was reached, and continuous 5-foot core sampling was performed from this point until the borehole terminated. Each core sample was logged and screened for contamination by PID. Boring logs are included in Appendix B.

Upon completion, each boring was abandoned by grouting from total depth to the surface with bentonite-cement grout using a tremie pipe in accordance with the SOPs in the JSAP. The isolation casing was left in place.

2.5 D Zone Monitoring Wells

Two monitoring wells (MW-31DA and MW-34D) were installed in the D zone of the Lower Unit. To be comparable with the existing D zone monitoring wells, new D zone monitoring wells were constructed within the top 5 feet of the Lower Unit and used similarly sized screened intervals as the existing D zone monitoring wells. MW-31DA was installed along with MW-31I adjacent to existing wells WMW-31S and WMW-31D[1] southeast of the site. MW-34D was installed along with MW-34I near the existing Shallow Unit monitoring well GMW-07 to monitor the edge of the contaminant plume near the MW-19 cluster. D zone monitoring well locations are shown on Figure 2-3.

Boreholes for wells installed in the D zone of the Lower Unit were advanced similarly to the downgradient site margin soil borings using a combination of CME 95 and CME 750 HSA drilling rigs. Boring logs and well completion diagrams are included in Appendix B. One groundwater grab sample was obtained from the Intermediate Unit at each location where this unit was sufficiently thick to yield groundwater using low flow sampling methodology in accordance with SOPs in the JSAP. Groundwater grab samples were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, and metals. During sample collection, field parameters were measured including water quality parameters.

The D zone monitoring wells utilized multiple isolation casings to minimize cross contamination between the Shallow, Intermediate, and Lower Units. The D zone monitoring wells were constructed similarly to the Intermediate Unit monitoring wells with 2-inch Type 316 stainless steel and 0.010-inch continuous wire-wrapped screens. Each well was developed according to the SOP in the JSAP.

2.6 D2 Zone Monitoring Wells

Two monitoring wells (MW-16D2A and MW-17D2) were installed in the D2 zone of the Lower Unit. To be comparable to existing D2 zone monitoring wells, new D2 zone monitoring wells were constructed within the top 15 feet of the Lower Unit and used similarly sized screened intervals as the existing D2 zone monitoring wells. D2 zone monitoring well locations are shown in Figure 2-3.

D2 zone monitoring wells were coupled with existing D zone monitoring wells for the purpose of obtaining water level data suitable for use in evaluating vertical gradients between the D and D2 zones within the Lower Unit.

Boreholes for the D2 zone of the Lower Unit wells were advanced similarly to the downgradient site margin soil borings. Continuous split spoon sampling was performed through the Shallow Unit until the glacial till was reached, and continuous 5-foot core sampling was performed from this point until the borehole terminated approximately 15 to 20 feet into the Lower Unit. Each core sample was logged and screened for contamination by PID. Boring logs and well completion diagrams are included in Appendix B. One groundwater grab sample was obtained from the Intermediate Unit at each location where

[1] Based on observations made during the advancement of MW-31D2, it appears that the existing WMW-31D may be installed in a unit more correlative with the D2 zone. Therefore, the plan for MW-31D was modified, and this monitoring well was completed in the D zone and identified as MW-31D.

this unit was sufficiently thick to yield groundwater using low flow sampling methodology in accordance with SOPs in the JSAP. Groundwater grab samples were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, and metals. During sample collection, field parameters were measured including water quality parameters. The D2 zone monitoring wells utilized multiple isolation casings to minimize cross contamination between the Shallow, Intermediate, and Lower Units. The D2 zone monitoring wells were constructed similarly to the Intermediate Unit monitoring wells of 2-inch Type 316 stainless steel with 0.010-inch continuous wire-wrapped screens. Each well was developed according to the SOP in the JSAP.

2.7 City Well Study

As a result of discussions with USEPA personnel from the National Risk Management Laboratory in Ada, Oklahoma, p-chlorobenzenesulfonic acid (pCBSA) was added to the analyte list for the groundwater receptor vulnerability assessment components (these include the City Well Study to evaluate the city wells as potential public water supply receptors and the Offsite West Groundwater Survey to evaluate residential wells as potential private water supply receptors [see Section 2.8 below]). pCBSA is a byproduct of DDT manufacture with chemical properties that make it particularly useful as an indicator of the groundwater fate and transport of other DDT-related chemicals of concern (for example, benzene and chlorobenzene). pCBSA is becoming more widely included in characterizations of DDT sites; however, because this approach is innovative, relatively little data is available on pCBSA as a site contaminant. Technical memoranda summarizing the current knowledge on the properties and uses of pCBSA are included in Appendix E.

The existing city well logs were examined and the information obtained from these is incorporated into the conceptual site model. Groundwater samples were obtained from City Wells #1, 4, 5, 6, 7, and 8. Samples were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, metals, and pCBSA. During sample collection, field parameters were measured including water quality parameters. Please refer to Figure 1-3 for the locations of the city wells.

2.8 Offsite West Groundwater Survey

A survey of 341 residences in the area was conducted that yielded 18 residential wells. Samples were obtained from 15 of these residential wells (three residents declined participation in the sampling program). One groundwater sample was collected from each of the participating residences. The sample was collected after purging a minimum of 20 gallons from the faucet closest to the well that did not run through a filter or softener. Residential samples were analyzed for VOCs, SVOCs, total DDT, HBB, PBB, metals, and pCBSA. The locations of the wells from which samples were obtained are shown on Figure 2-4.

2.9 Groundwater Monitoring and Sampling

2.9.1 Intermediate and Lower Units

One round of groundwater samples was obtained from new and existing Intermediate Unit monitoring wells and the new Lower Unit monitoring wells including those recently

replaced by the MDEQ (WMW-19DR, WMW-21DR, and WMW–21D2R) to support the evaluation of potential offsite migration of contaminants from identified DNAPL source areas to the north and northeast. One groundwater sample was collected from each of the monitoring wells using low flow sampling procedures and analyzed for VOCs, SVOCs, total DDT, HBB, PBB, metals, and pCBSA. During sample collection, field parameters were measured including water quality parameters.

In addition to sample collection, two rounds of water level measurements were obtained from the Intermediate Unit wells to determine groundwater flow characteristics within the Intermediate Unit. An additional two rounds of water level measurements were obtained from the Intermediate Unit, D zone, and D2 zone monitoring wells to determine the vertical gradient between the Intermediate and Lower Units and the D and D2 zones of the Lower Unit.

2.9.2 Monitored Natural Attenuation Evaluation

One round of groundwater samples was obtained from each new and existing Lower Unit monitoring well using low flow sampling procedures. During sample collection, field parameters were measured including water quality parameters and ferric iron. Samples were analyzed for natural attenuation indicator parameters. These indicator parameters include dissolved iron and manganese, bromide, alkalinity, carbon dioxide, chloride, methane, ethane, ethene, nitrate, nitrite, total organic carbon, and sulfate.

SECTION 3

Results

The *Quality Control Summary Report* (Appendix F) presents the results of the evaluation of analytical data by CH2M HILL from soil and groundwater samples collected at the Velsicol Chemical Site. The remainder of the soil and groundwater samples was evaluated by the USEPA subcontractor, ESAT. *EPA National Functional Guidelines* were used by both companies as guidance for data validation procedures.

3.1 Passive Soil Gas Survey

The passive soil gas results are summarized in the *Gore-Sorber Surveys Final Report*, which is included in Appendix G. Figure 3-1 shows total chlorinated alkenes and indicates that the highest mass is located within the Waste Drum Storage Area with concentrations decreasing radially. There is another small pocket of high concentrations within the Bromides and Fine Chemicals Area. The sum mass of undecane, tridecane, pentadecane, ethylbenzene, and total xylenes appear highest in the center of the Waste Drum Storage Area (Figure 3-2). There is another pocket of elevated mass of these compounds located within the south-central portion of the Railroad Spur Area. Figure 3-3 indicates that the highest mass of Area 3 NAPL constituents (including 1,1-dichloroethane; 1,1,1-trichloroethane, 1,2-dichloroethane, chloroform, carbon tetrachloride, cis-1,2-dichloropropane, and 1,2-dibromo-3-chloropropane) is located in the Waste Drum Storage Area. Figure 3-4 depicts low levels of total target VOC detections throughout the site with the greatest mass occurring within the Waste Drum Storage Area, with other small areas of elevated mass located in the south-central part of the Railroad Spur Area and on the southwest site margin in the Disposal Lagoon Area. Figure 3-5 shows benzene mass only and indicates the largest detection is in the Waste Drum Storage Area, with other high detections on the western edge of the Disposal Lagoon Area, within the Bromides and Fine Chemicals Area, and in two separate locations within the Railroad Spur Area.

3.2 Shallow Unit Passive Soil Gas Follow-up Soil Borings

Twenty-nine Shallow Unit soil borings were installed to follow-up the passive soil gas survey (refer to Figure 2-1 for boring locations). This section presents field observations and sample results for these borings.

3.2.1 Field Observations

The low permeability cap over the site ranged in thickness from 3.5 to 8 feet. The underlying Shallow Unit soils were composed of predominately sand and fill materials. Exceptions to this observation occur in the southern portion of the site within the Lagoon Disposal Area. Soils in this area are composed primarily of silt. The glacial till surface was generally found to be approximately 15 feet bgs; however, the depth ranged from 13 to 33 feet bgs. The

glacial till surface was shallowest in the southern portion of the site where the surface elevation increases.

Residual NAPL was observed through the use of hydrophobic indicator spray in three locations near the MW-21 cluster (SBS-03, SBS-04, and SBS-05) and one near the MW-19 (SBS-14) cluster. Elevated PID and FID readings were observed in 19 locations throughout the site. The highest readings were observed in locations near the MW-19 cluster.

3.2.2 Volatile Organic Compounds

Soil and groundwater grab samples were collected while completing the Shallow Unit follow-up borings and analyzed for VOCs, SVOCs, metals, total DDT, HBB, and PBB. Analytical results for soil samples are included in Table 3-1, and results for groundwater samples are included in Table 3-2. Figures depicting concentrations of selected VOCs for soil and groundwater are included as Figures 3-6 and 3-7, respectively. The VOCs depicted on the figures were chosen based on the total numbers of detections for that media. DBCP was also included on the figures due to its potential impact on health and safety as described under Section 2.1.1 above.

VOCs were detected in all soil samples collected. The six most frequently detected constituents and their concentration ranges in micrograms per kilogram (µg/kg) are listed below:

Acetone	9–1,390 µg/kg	Benzene	3.9–9,420 µg/kg
Chlorobenzene	0.53–391,000 µg/kg	Methyl Ethyl Ketone	2.4–72.9 µg/kg
Methylcyclohexane	0.44–193,000 µg/kg	Trichloroethylene	2.2–80,700 µg/kg

DBCP was detected in a total of five samples at concentrations ranging between 8.5 and 87,500 µg/kg. Samples from SBS-14 (located in the Waste Drum Storage Area) and SBS-23 (located in the Bromides and Fine Chemicals Area) had the most individual detections of VOCs in soil (21 each).

VOCs were detected in all groundwater grab samples collected in the Shallow Unit. The six most frequently detected compounds and their concentration ranges in micrograms per liter (µg/L) are listed below:

1,1-Dichloroethane	0.51–39.4 µg/L	1,2-Dichloroethylene	1.3–293 µg/L
Benzene	0.21–12,500 µg/L	Chlorobenzene	0.9–569 µg/L
Toluene	0.18–4,800 µg/L	Trichloroethylene	0.99–12,400 µg/L

DBCP was detected in a total of eight samples at concentrations ranging between 1.5 and 7,290 µg/L. Vinyl chloride was also detected in several of shallow groundwater samples in concentrations ranging from 0.7 µg/L (estimated) to 212 µg/L (SBS-15). Samples from SBS-07 and SBS-10 (both located in the Bromides and Fine Chemicals Area) had the most individual detections of VOCs (22). The highest chlorinated VOC concentrations were detected in a sample from SBS-28 (also located in the Bromides and Fine Chemicals Area).

3.2.3 Semivolatile Organic Compounds

SVOCs were detected in 22 of the 33 Shallow Unit soil samples. The most commonly detected constituents were the following three polyaromatic hydrocarbons (PAHs), detected in 45 percent of samples:

Chrysene	43.4–92,500 µg/kg	Phenantherene	51.8–180,000 µg/kg
Pyrene	42.8–200,000 µg/kg		

A sample from SBS-04 (10–12 feet) had the highest number of individual SVOC detections (20) as well as the highest detected concentrations. Another sample from SBS-04 (12–14 feet) was the next highest in both categories (19 SVOC detections). SBS-04 is located in the Bromides and Fine Chemicals Area.

SVOCs were detected in low estimated concentrations in 9 of 29 groundwater samples collected from the Shallow Unit. Of the eight compounds detected, only the following four were detected in multiple samples:

2-Methylnaphthalene	7.5–10.8 µg/L	Acetophenone	0.75–1.6 µg/L
Naphthalene	3.1–6.6 µg/L	Phenol	3.3–25.3 µg/L

Of these compounds, phenol was detected in the most samples (five). The highest concentration of phenol was detected in a sample from SBS-28.

3.2.4 Total DDT/PBB/HBB

These compounds were detected in 29 of 32 Shallow Unit soil samples in concentrations ranging as follows:

Hexabromobenzene	1.3–67,000 µg/kg	Hexabromobiphenyl	1.2–90,000 µg/kg
O,P'-DDD	2.1–380,000 µg/kg	O,P'-DDE	1.4–94,000 µg/kg
O,P'-DDT	2.1–170,000 µg/kg	P,P'-DDD	8.5–110,000 µg/kg
P,P'-DDE	1.8–140,000 µg/kg		
P,P'-DDT	2.1–3,000,000 µg/kg (31,000 is next highest value)		

The highest number of constituents and the highest concentrations are located (in decreasing order) at SBS-25, SBS-14, SBS-16, SBS-20, SBS–13, and SBS–18. These locations, with the exception of SBS-20, are located beneath the Waste Drum Storage and Disposal Lagoon Areas. SBS-20 is located within the oil containment slurry wall.

These compounds were detected in 16 of 29 Shallow Unit groundwater grab samples. The most commonly detected compounds and their concentration ranges are as follows:

O,P'-DDD	0.03–36 µg/kg	O,P'-DDT	0.19–9.7 µg/kg
P,P'-DDD	0.061–42 µg/kg	P,P'-DDE	0.034–12 µg/kg
P,P'-DDT	0.076–40 µg/kg		

The most detections as well as the highest concentrations were detected in a sample from SBS-14.

3.2.5 Metals

Metals were detected at low concentrations in all soil samples collected from the Shallow Unit PSG Follow-up Borings. In the groundwater grab samples from these borings, the highest individual dissolved metals concentrations vary by location; that is, there was not one location where all metals detected are at the highest values, nor did any one location have the highest number of detections. Metals were detected in all groundwater samples collected from the Shallow Unit. Mercury and selenium were detected in concentrations of 0.025 to 1.04 µg/L and 2.95 to 158 µg/L, respectively. The highest concentration of mercury was detected in a sample from SBS-28, while the highest concentration of selenium was detected in a sample from SBS-21.

3.3 Main Plant Site Test Trenches

Analytical results for samples collected from the main plant site test trenches are shown in Table 3-3. Field observations and results from these analyses are presented in this section.

3.3.1 Field Observations

As with the follow-up soil borings, the Shallow Unit soils observed during excavation activities were composed of sand and fill materials. Test Trench TT2004-04, excavated in the northwest corner of the site near the former magnesium oxide kiln (refer to Figure 1-2), was found to contain a significant percentage of magnesium oxide in the fill material.

NAPL was observed trickling from a sand and gravel seam approximately 8 feet bgs in Test Trench TT2004-05, located approximately 100 feet southeast of Test Trench TT2004-04. Chemical odors were observed in eight of the nine excavations. The exception was Test Trench TT2004-02, which was abandoned shortly after excavation began when the groundwater collection tile was encountered. Elevated FID readings were observed in three locations (Test Trenches TT2004-03, TT2004-04, and TT2004-07) ranging from 80 ppm to 650 ppm. The highest readings were observed in Test Trench TT2004-07.

3.3.2 Analytical Results

Volatile Organic Compounds

A number of VOCs were detected at estimated quantities in soil samples collected from the test trenches. Those detected in greater than 50 percent of the samples include trichloroethylene, toluene, and chlorobenzene. Their concentration ranges were 0.44 to 66.8 µg/kg, 1.3 to 110 µg/kg, and 0.8 to 3,890 µg/kg, respectively. In addition, benzene was detected in all samples in concentrations ranging from 4.8 to 1,920 µg/kg. The highest concentration of benzene was detected in the sample from Test Trench 2004-03. Also notable, 1,2-dibromo-3-chloropropane was detected at 12,100 µg/kg in one sample from Test Trench TT2004-07.

Semivolatile Organic Compounds

PAHs were detected in all soil samples collected from the test trenches. Compounds detected in greater than 50 percent of the samples and their concentration ranges are as follows:

2-Methanaphthalene	63–320 µg/kg	Bezno(a)anthracene	45.2–2,590 µg/kg
Chrysene	43.8–3,340 µg/kg	Flourene	38.6–6,170 µg/kg
Naphthalene	75.4–1,680 µg/kg	Phenanthrene	56.2–3,870 µg/kg
Pyrene	39.3–5,650 µg/kg		

The highest concentrations and most individual SVOCs were detected in samples collected from Test Trench TT2004-06. Pyrene, the most commonly detected SVOC, was detected at 5,650 µg/kg in Test Trench 2004-06.

Total DDT/PBB/HBB

These compounds were detected in 14 of the 15 samples collected (no detections were reported for one sample from Test Trench 2004-07). As with the SVOCs, the highest concentrations were detected in samples collected from Test Trench 2004-06. Individual constituent ranges are as follows:

Hexabromobenzene	6.5–11,000 µg/kg	Hexabromobiphenyl	1.4–290,000 µg/kg
O,P'-DDD	1.4–110,000 µg/kg	O,P'-DDE	11–16,000 µg/kg
O,P'-DDT	4.1–21,000 µg/kg	P,P'-DDD	4.1–320,000 µg/kg
P,P'-DDE	3.6–100,000 µg/kg	P,P'-DDT	1.6–500,000 µg/kg

3.4 Cell #6 and #7 Explorations

The test pit activities found sand seams within the glacial till in Cell #6 from 680 to 689 feet above msl that ranged from less than 0.5 to 2 feet in thickness as well as many sand seams less than 0.5 feet thick within the upper 8 feet of the excavations (692 to 700 feet above msl). Some of the layers and seams appear to intersect with the glacial till surface. In Cell #7, only one test pit (C7TP-1) located closest to the Cell #6/7 wall was observed to have a sand and gravel seam (8 inches thick). Only one observation of NAPL was made in any sand seam (C6TP-3). However, many of the smaller layers appeared to have trace amounts of NAPL present.

Analytical results from the four samples collected showed traces of 1,2-dichloroethane, benzene, and methylene chloride in C6TP-3, while C7TP-1 and C7TP-4 have small detections of diethylphthalate. Mercury was detected in low estimated concentrations in C6TP-3, C7TP-1, and C7TP-4. No pesticides were detected in any of the samples. The technical memorandum, *2004 OU2 Test Pits, Velsicol Chemical Site,* prepared in October 2004 by CH2M HILL for the USEPA, details the methodologies used, field observations, and analytical results for these explorations. The memorandum is included as Appendix D.

3.5 Downgradient Site Margin Soil Borings

As described in Section 2, eight soil borings were installed along the downgradient site margin (refer to Figure 2-3). When a significant sand seam was encountered, a temporary monitoring well was installed to screen the seam, and a groundwater grab sample was collected. Analytical results for these samples are included in Table 3-4. Where sufficient soil volume could be obtained, a soil sample was collected for grain size analysis. This section

presents field observations made during these activities, grain size distribution, and temporary monitoring wells that were installed.

3.5.1 Field Observations

The low permeability cap was between 5 and 6 feet in depth in SBI-01 through SBI-08. The underlying Shallow Unit consists of predominately sand and fill materials. This is consistent with previous observations. The depth from ground surface to the top of the glacial till along the site margin ranges from approximately 8.5 to 18 feet indicating an increase in the thickness of the Shallow Unit from southwest to northeast. Sand seams within the glacial till ranged in thickness from one inch to as much as 4 feet and were observed in all borings. The Lower Unit was composed of interbedded silty sand and silt layers. The elevation of the Lower Unit sloped downward along the site margin from 668.4 feet above msl in SBI-08 to 659.6 feet above msl in SBI-01. The Lower Unit was not observed in SBI-03, which was terminated at 645.9 feet above msl.

Elevated PID readings and NAPL odors were observed in SBI-01 and SBI-02 in the Shallow Unit only. There were no other readings above background or odors observed.

3.5.2 Grain Size Distributions

Samples obtained from sand seams encountered while installing the downgradient site margin soil borings were analyzed for grain size distribution (additionally, samples for grain size distribution were also collected from Intermediate Unit sands during the advancement of MW-16I, MW-23I, and MW-31I). As Table 3-5 indicates, both the Intermediate and Lower Unit sands are predominately silty sands. The one exception occurs in the SBI-03 location at 51.5 to 54 feet bgs, which was found to be silty gravel.

TABLE 3-5
Particle Size Analysis Summary Table

Location	Depth (feet bgs)	Unit	Gravel (%)	Sand (%)	Fines (%)	USCS
SBI-1	39–42	Intermediate	25.3	60	14.7	SM
SBI-2	45–50	Intermediate	6.6	62.5	30.9	SM
SBI-3	33–35	Intermediate	0	89.4	10.6	SP-SM
SBI-3	51.5–54	Intermediate	56	37	8.4	GP-GM
SBI-4	24–28	Intermediate	2.2	58.9	38.9	SM
SBI-4	67–72	Lower	5.3	55.7	39	SM
SBI-5 (MW-34I)	26–27	Intermediate	3.8	73.3	22.9	SM
SBI-5	29–34	Intermediate	26.8	60.1	13.1	SM
SBI-6	60–66	Lower	9.4	59.2	31.4	SM
SBI-7	40–45	Intermediate	11.4	69.8	18.8	SM
MW-16I	33.75–34.75	Intermediate	3.1	70.1	26.8	SM
MW-23I	42–45	Intermediate	7.8	81.5	10.7	SW-SM
MW-31I	30–32	Intermediate	8.4	86.4	5.2	SP-SM

3.5.3 Temporary Monitoring Wells

A temporary monitoring well was installed in each Intermediate Unit sand seam. Two temporary wells were installed in both SBI-07 and SBI-03 because two Intermediate Unit sand seams were encountered. SBI-08 did not receive a temporary well because sand seams greater than 1 foot were not observed. Thus, a total of nine Intermediate Unit temporary monitoring wells were installed. A temporary well was also installed within the top 5 feet of the Lower Unit in each boring for a total of five. The Lower Unit was not encountered in SBI-03 and groundwater was not encountered in SBI-01 and SBI-02. Groundwater grab samples were collected from each of the temporary wells with the exception of SBI-06, which did not recharge. Groundwater grab sample detections are included on Figures 3-8 through 3-13 along with groundwater results from samples collected from permanent monitoring wells.

3.6 Groundwater Monitoring Wells

3.6.1 Analytical Results

Groundwater from both the Intermediate and Lower Units was sampled in May 2005 for VOCs, SVOCs, metals, pesticides, and pCBSA. A subset of all site wells was sampled; those sample results are presented in this section. Figures depicting concentrations of VOCs, select metals, and pCBSA, first for the Intermediate and then for the Lower Unit, are included as Figures 3-8 through 3-13. Complete analytical results are included in Table 3-6.

Volatile Organic Compounds

VOCs were not detected in any of the Intermediate Unit wells sampled that are located north of the Pine River, nor were any detected in WMW-17I, MW-21I, MW-30I, or MW-31I (Figure 3-8). The highest number of individual VOC constituents, and most of the highest Intermediate Unit VOC concentrations, were detected at WMW-19I (beneath the Drum Storage Area). The benzene concentration at WMW-19I (8,960 µg/L) was detected at a value of more than three orders of magnitude higher than anywhere else in the Intermediate Unit. Other chlorinated constituents were also detected at WMW-19I, including the only detections in the Intermediate Unit of trichloroethylene and chlorobenzene, as well as 1,1-dichloroethane (1,1-DCA) (147 µg/L) and 1,2-dichloropropane (1,2-DCP) (136 µg/L). WMW-29I also has detections of 1,1-DCA (17.1 µg/L) and 1,1-DCP (1,150 µg/L), along with acetone and benzene. WMW-29I is situated just south of the Bromides and Fine Chemicals Area.

Fewer VOCs were detected at the groundwater grab sample locations than at permanent groundwater monitoring well locations in the Intermediate Unit. Also, fewer individual VOCs were detected in the Lower Unit (Figure 3-11) than in the Intermediate Unit (Figure 3-8).

Metals

Concentrations of metals detected in the Intermediate and Lower Units are shown in Figures 3-9 and 3-12, respectively, and are discussed below.

Because the presence of VOCs may, under some conditions, mobilize metallic constituents, a comparison was made by unit (Intermediate or Lower) between the occurrence of VOC concentrations at a given well and the metals concentrations at the same well.

Metals were detected at all Intermediate Unit locations that were sampled. WMW-27I, MW-16I, MW-35I, MW-17I, WMW-31I, MW-30I, SBI-01, SBI-02, SB-03 (51.3 to 56.3 µg/L), SBI-04, and SBI-07 (39.5 to 44.5 µg/L) all had metals concentrations but no VOC detections. Four individual metals were detected most often in these wells, ranging in concentration as follows:

Arsenic	2.2–40.2 µg/L
Barium	20–29,000 µg/L (13,700 µg/L is next highest value)
Beryllium	0.30–41.6 µg/L
Chromium	1.32–59.5 µg/L

In addition, cyanide concentrations ranged from an estimated 4.02 µg/L to an estimated 76.32 µg/L.

The highest individual dissolved metals concentrations in the Intermediate Unit vary by location (that is, there is not one well location where all metals detected are at the highest values). WMW-17I and SBI-07 had the highest number of individual metals detected (seven each). A similar approach was used for the Lower Unit wells that were sampled. However, fewer Lower Unit wells were sampled for metals concentrations, so patterns are fairly difficult to discern (Figure 3-12).

Metals were detected in all Lower Unit wells that were sampled. Of the wells in which no VOCs were detected (MW-34D and WMW-30D), only barium was detected at both locations. The detected Lower Unit barium concentrations are within a similar concentration range to those indicated for the Intermediate Unit. In addition to barium, arsenic (detected at 1.36 to 20.8 µg/L) and beryllium (detected at 5.4 to 20.4 µg/L) were most commonly detected in the Lower Unit wells.

Semivolatile Organic Compounds

SVOCs were not detected in any of the 12 Intermediate Unit wells sampled. Groundwater grab samples collected from temporary wells SBI-02 (45 feet to 50 feet) and MW-17D2 (30 feet) had detections of di-n-octylphthalate (estimated concentration of 3.6 µg/L) and bis(2-ethylhexyl)phthalate (79.8 µg/L), respectively.

Only one SVOC was detected in the eight Lower Unit wells that were sampled (Figure 3-14). Caprolactam was detected in WMW-30D at an estimated concentration of 2.1 µg/L.

Total DDT

These compounds were not detected in any of the 12 intermediate wells sampled. The only detections were P,P'-DDT in Intermediate Unit groundwater grab samples at SBI-05 from a depth of 26 feet and SBI-02 from a depth of 45 to 50 feet at estimated concentrations of 0.06 µg/L and 0.059 µg/L, respectively.

Total DDT compounds were detected in three out of thirteen locations sampled in the Lower Unit. O,P–DDD was the only one of these compounds detected at multiple locations, WMW-19DR (estimated at 0.014 µg/L) and WMW-30D (estimated at 0.016 µg/L). Two

additional compounds were also detected at WMW-30D: P,P'-DDD (estimated at 0.021 µg/L) and P,P'-DDE (estimated at 0.009 µg/L).

p-Chlorobenzenesulfonic Acid (pCBSA)

The detection of this compound is depicted for the Intermediate and Lower Units on Figures 3-10 and 3-13, respectively. The groundwater grab samples were not analyzed for this compound. The highest concentration of the compound in the Intermediate Unit was detected near the eastern edge of the site, at location MW-30I (two samples collected, 360,000 and 290,000 µg/L). The groundwater elevation contour maps drawn for the Intermediate Unit (Figures 3-14 and 3-15) indicate this location is downgradient of the Bromides and Fine Chemicals Area and the Pine River. The pCBSA concentrations decrease farther west into the site, with the exception of location WMW-19I on the westernmost edge (8,100 µg/L), located directly beneath the Drum Storage Area.

The city of St. Louis municipal wells are included on Figure 3-13. This figure indicates the highest concentration was detected near the eastern edge of the site at location WMW-22D (west of the MW-30 cluster). Concentrations again decrease toward the remainder of the site in the west, with the exception of the WMW-19 well nest where concentrations ranged from 520 µg/L in WMW-19DR to 1,800 µg/L in WMW-19D2.

3.6.2 Intermediate Unit Groundwater Flow

Groundwater flow maps generated are based on groundwater elevations calculated from the depth-to-water measurements collected in May 2005 and July 2005. These maps are presented as Figures 3-14 and 3-15, respectively. As the figures indicate, groundwater in the Intermediate Unit flows offsite radially from MW-21I.

Dewatering activities in the northern portion of the river significantly lowered the groundwater elevation in the MW35I in July 2005 (Figure 3-15) as compared to static conditions in May 2005 (Figure 3-14). This indicates a hydraulic connection between this well and the river.

3.6.3 Vertical Gradients

Vertical gradients between the Intermediate and Lower Units and the D and D2 zones of the Lower Unit were calculated based on groundwater and screen mid-point elevations. Figures depicting the gradients are presented as Figures 3-16 through 3-19.

Figures 3-16 and 3-17 indicate a downward gradient between the Intermediate and Lower Units. However, within the Lower Unit, between the D and D2 zones, the vertical gradient direction appears to change with location. Vertical gradients calculated from measurements taken in May 2005 indicate the gradient reverses from a downward gradient in the southeast portion of the site to a slightly upward gradient in the north and northwest (near the Pine River) with the greatest upward magnitude occurring north of the river at the MW-16 well cluster (Figure 3-18). In July 2005, a slightly upward gradient is observed onsite and north of the river, while that south of the site has an increased downward gradient (when compared to May 2005) (Figure 3-19). The gradient between the two zones in the MW-17 well cluster appears to fluctuate between slightly downward and slightly upward. A groundwater elevation contour map of the Lower Unit is included as Figure 3-20.

3.6.4 Monitored Natural Attenuation Evaluation

Results of the samples collected for natural attenuation parameters are included in Table 3-7. A discussion is included in Section 4.

3.7 Groundwater—City Wells

There were no VOCs, SVOCs, or pesticides detected in the city wells that were sampled. Complete analytical results are included in Table 3-8. The compound pCBSA was detected in City Wells #1, 4, and 7 (Figure 3-13) in concentrations ranging from 7 µg/L to 180 µg/L.

3.8 Groundwater—Residential Wells

The pCBSA, pesticides, VOCs, and SVOCs were sampled at residential water wells situated adjacent to the site (refer to Figure 2-4) but were not detected with the following exceptions:

Well Name	Compound	Concentration
05CB10-14	Chloromethane	0.48 µg/L (estimated)
05CB10-01	Chloromethane	0.42 µg/L (estimated)
05CB10-05	Chloromethane	0.35 µg/L (estimated)
05CB10-10	Chloromethane	0.45 µg/L (estimated)

Chloromethane is not detected onsite and is commonly a remnant of water well disinfection processes. Complete analytical results are included in Table 3-9.

SECTION 4

Discussion and Conclusions

The DQO process documented in the JSAP identified thirteen DQOs in four data categories. These DQOs were condensed into nine problem statements that guided the development of the scope of work for the JSAP. The nine problem statements were in turn focused into eight principal study questions (PSQs). These eight PSQs are the data gaps that this investigation was designed to address. The eight PSQs are discussed in more detail below in the context of the findings from this investigation.

4.1 Principal Study Question #1

Are there remnant source areas within the interior of the Main Plant Site, and if so, to what extent?

The passive soil gas results, confirmatory borings, observations from sediment removal activities in OU2, and observations from MDEQ Phase II OU1 RI monitoring wells indicate two remnant source areas (SA-1 and SA-2, Figure 4-1). These two areas show evidence of either free-phase or residual NAPL and significantly elevated soil and groundwater contaminant concentrations. Test Trench 2004-05, where NAPL was observed, is also situated within the apex of SA-1.

SA-1 includes locations where NAPL has been observed seeping from the riverbank in the Hot Spot Cell and Area 3 as identified during the OU1 remedial action and extends southwesterly into the site interior forming a "V" pattern to include an area with elevated DBCP concentrations in soil and groundwater and possibly free-phase NAPL near the apex of the "V" pattern.

SA-2 includes areas focused around the MW-19 cluster that is located in the Drum Storage Area. During drilling of MW-19DR, residual phase NAPL was observed in the Shallow Unit, and the area shows strongly elevated PSG signals. During the 2002 NAPL Investigation (CH2M HILL, 2003), elevated concentrations of benzene (up to 1,140 µg/kg in CBR-37) and chlorobenzene (up to 20,400 µg/kg in CBR-26) were observed in sediment samples obtained from the western part of SA-2. Also, a strongly elevated total DDT concentration (3,303 mg/kg) was observed in a soil sample from 12 to 14 feet bgs in SBS-25, which was a confirmatory boring for PSG sample DL01.

In addition, the PSG results show elevated signals of benzene and Area 3 constituents at PSG samples WD02, WD03, WD07, and WD08 which are located in an area where the limits of SA-1 and SA-2 are close to each other.

Two other areas of elevated PSG signals appear in the southeast and southwest corners of the site. One of these areas (the southeast area) is located near the slurry wall for oil contamination. However, based on confirmatory borings and draft MDEQ Phase II RI sampling results, these areas appear to be the result of elevated soil contaminant concentrations and do not show evidence of remnant source material.

4.2 Principal Study Question #2

How far do the sand seams and NAPL within the sand seams extend in areas beneath the river and its northern shore?

Intermediate Unit sand seams were absent from borings SBI-09 and SBI-10 advanced in Prospect Street on the north side of the Pine River. Also, the Intermediate Unit sand seams were absent at the MW-28 cluster (to the northwest approaching the golf course). Thin stringers of sand (not more than 1-inch thick at about 691 feet above msl in MW-28D, and of lesser thickness in SBI-09 and SBI-10) were observed in these explorations. However, these do not appear to be significant pathways for NAPL migration based on the extreme thinness and absence of field screening indications of contamination.

Intermediate Unit sand seams had been previously observed at about 718 feet above msl (0.3 foot thick), about 703 to 704 feet above msl, and about 686 to 688 feet above msl in MW-27D which is approximately 500 feet northwest of the Main Plant Site shoreline (Draft RI Report, Weston Solutions, October 2003). NAPL was not present in these sand seams, and there were no field screening indications of contamination. For this investigation, MW-27I was installed in a sand seam at approximately 704.5 to 706.5 feet above msl correlative with the middle sand seam in MW-27D. A sand seam was also present at about 711 to 712 feet above msl in MW-27I roughly correlative with the upper sand seam in MW-27D; however, this sand seam did not yield water. The Intermediate Unit sand seams at this location appear to be under unconfined conditions and hydraulically connected to the river (this will be discussed in more detail below). NAPL was not present in these sand seams, and there were no field screening indications of contamination. Monitoring well sampling results are discussed in more detail in Section 4.7.

An Intermediate Unit sand seam was present at about 691 to 694 feet above msl in MW-16D2A which is approximately 400 feet northeast of the Main Plant Site shoreline. Also, a 4.6-inch stringer of sand was observed at about 710 feet above msl in this exploration. NAPL was not present in these sand seams, and no field screening indications of contamination were observed. MW-16I was completed in this sand seam. Monitoring well sampling results are discussed in more detail in Section 4.7.

An Intermediate Unit sand seam was present at about 695 to 696 feet above msl in MW-35I which is approximately 680 feet northeast of the Main Plant Site shoreline and approximately 460 feet east of MW-16D2A. NAPL was not present in this sand seam, and no field screening indications of contamination were observed. MW-35I was completed in this sand seam. Monitoring well sampling results are discussed in more detail in Section 4.7.

The test pits excavated in Cells #6 and #7 of the OU2 Phase 2 remediation area are described in a technical memorandum dated October 29, 2004 (Appendix D). Sand seams were present within the till in Cell #6 from 680 to 699 feet above msl and ranged from less than 0.5 to 2 feet in thickness. Many very thin sand stringers were observed within the upper 8 feet of the excavation in C6TP-1, C6TP-3, C6TP-4, C6TP-7, and C6TP-8. The sand seams were fewer and thinner in Cell #7 than in Cell #6. In Cell #7, only C7TP-1 was observed to have a sand and gravel layer, which was approximately 8 inches thick. No other test pit in Cell #7 exhibited evidence of a sand or gravel seam.

The C6TP-6 and C6TP-7 test pits revealed sand seams about 1.5 feet thick sloping upward from around 690 feet above msl to intersect the top surface of the till at around 699 feet above msl. This is significant because sand seams that intersect the top of the till in this area of the river are potential routes of migration for NAPL and contaminated river water to migrate into the Intermediate Unit, and in part, explain the degree to which the till has become impacted by NAPL and dissolved contaminants. Also, these observations suggest that this part of the river acts as a recharge zone for the Intermediate Unit (that is, river water is directly recharging groundwater in the Intermediate Unit at this location). This is further supported by Intermediate Unit groundwater elevation data and groundwater contour maps discussed in Section 4.4.

NAPL was observed in C6TP-1 and C6TP-3. In C6TP-1, NAPL appeared only in the numerous small seams located in the upper 8 feet of the excavation. The larger (approximately 1 foot) sand and gravel seam at approximately 684 feet above msl showed no signs of NAPL. In C6TP-3, NAPL appeared in both the numerous thin stringers located in the top 8 feet of the excavation and in the 4-inch sand and gravel layer located at approximately 685 feet above msl. The amount of NAPL present was trace (not present in pumpable quantity). A sample was collected for analysis from this seam. No NAPL was observed in any of the test pits in Cell #7.

Therefore, it appears that the Intermediate Unit sand seams under the river along the northern margin of the site extend approximately 700 feet to the north from the Main Plant Site shoreline. On the north side of the river, the sand seams appear to pinch out to the west and thin to the east (from approximately 4 feet thick at MW-16D2A to 1 foot at MW-35I) although they may extend further to the northeast beyond the MW-16 cluster. NAPL was not observed in the sand seams on the north side of the river but was observed in some of the Cell #6 test pits. This indicates that NAPL is present in the sand seams beneath the river. The extent of the NAPL in these sand seams is the basis for the northern extent of SA-1 as shown on Figure 4-1.

4.3 Principal Study Question #3

What are the depth, thickness, and grain size distribution of the sand seams along the downgradient site margin, and under the river and its northern shore in the north and northeast directions?

Downgradient Site Margin

The Intermediate Unit sand seams along the downgradient site margin were encountered at elevations between 676 and 707 feet above msl (approximately 56 to 24 feet bgs). Thickness of the sand seams ranges from 0.5 to 4.5 feet with the thinnest occurrence observed at SBI-06 and the thickest at SBI-07. In five of the eight downgradient soil borings (SBI-01, SBI-02, SBI-03, SBI-04 and SBI-07), sand seams occurred at two distinct elevations. The first (upper) sand seams occurred within an interval ranging from about 681 to 707 feet above msl (approximately 51 to 24 feet bgs and the second (lower) sand seams occurred within an interval ranging from about 676 to 691 feet above msl (approximately 56 to 38 feet bgs). In two of the borings (SBI-05 and SBI-06), only one sand seam (at elevations correlative with the upper sand seam) was encountered. In the eighth boring (SBI-08), no distinct sand

seams were observed; however, sand stringers from 1 to 5 inches in thickness occurred within an interval ranging from about 690 to 705 feet above msl (approximately 40 to 25 feet bgs).

The overlap in the depth/elevation ranges of the two sand seam intervals and the wide vertical dispersion of sand stringers in SBI-08 indicates a relatively high degree of vertical interconnectedness among these sandy intervals within the till which, in part, explains the degree to which the till has been impacted by NAPL and dissolved contaminants. Also, a highly interconnected network of sand seams at multiple elevations within the till offers a pathway for contaminated groundwater to migrate downward, driven by the observed downward vertical hydraulic gradients observed between the Intermediate and Lower Unit (see below for further discussion on vertical hydraulic gradients). Also, as noted above, some of these sand seams interconnect directly with the river bottom which provides a direct route of migration to the Intermediate Unit for NAPL and/or dissolved contaminants that have seeped into the river.

The particle size analysis results indicate that the sand seams along the downgradient site margin are generally composed of a silty sand material with an average of 10 percent gravel, 70 percent sand, and 20 percent fines. Gravel percentages as high as 24.3 and 26.8 percent were observed in SBI-01 and SBI-05 (respectively) and no gravel was observed in the sand seam sample from SBI-03 (this material classified as a poorly graded (fine) sand with silt). Also, lower amounts of gravel were observed in the samples of sand seam material from SBI-03 and SBI-04 (2.2 percent and 3.8 percent, respectively). Fines percentages ranged from around 5 to 39 percent. Samples with the greater fines percentages tended to have lower gravel percentages that are typical of well stratified till sands. Particle size analysis laboratory reports are included in Appendix H.

Under the River/Northern Shore to North and Northeast

The Intermediate Unit sand seams under the river and its northern shore to the north and northeast range from about 679 to 706 feet above msl (approximately 49 to 28 feet bgs) and were not present immediately north of the site across the river (SBI-09 and SBI-10). Under the river (Cell #6 and Cell #7), the sand seams range from at least an elevation 680 to 699 feet above msl (due to excavation constraints, exploration depths in the river were between 680 and 700 feet above msl). Also, sand seams were fewer and thinner in Cell #7 than in Cell #6 (only one sand seam of 8 inches thick was observed in Cell #7).

Under the river, the sand seams, where present, ranged from 0.3 to 2 feet thick with the thinnest at C6TP-3 and the thickest at C6TP-6 (both located in Cell #6). Also, very thin sand stringers tended to occur from around 691 to 699 feet above msl. Under the northern shore of the river, the sand seams, where present, ranged from 1 to 2.5 feet thick with the thinnest at MW-35I located on the east side of Penny Park and the thickest at MW-16D2A located on the west side of Penny Park.

The pattern of Intermediate Unit sand seam occurrences under the river and the northern shore indicate that sand seams are more common under the Main Plant Site (except the southwest portion near the M-46 bridge), Hot Spot Cell, Cell #5/Area 3, and Cell #6 than they are under Cell #7 and the northern shore. The natural sand and gravel channel observed in the Hot Spot Cell in 2001 and 2002 was not observed in Cell #7 test pits. The

observations during the excavation of this material indicated that the channel appeared to taper up and pinch out to the northeast near the sheet pile wall. These observations were corroborated by the negative findings in the Cell #7 test pits excavated in the areas where the channel would have extended into the northern portion of the OU2 remedial area. This overall distribution of the Intermediate Unit sand seams may have limited the degree to which NAPL has migrated to the north and the routes of migration currently available to contaminated groundwater.

The particle size analysis results for sand seam material in MW-16I indicates a silty sand material consisting of approximately 3 percent gravel, 70 percent sand, and 27 percent fines. This result is similar to the results obtained from sand seams along the downgradient site margin. Particle size analysis laboratory reports are included in Appendix H.

4.4 Principal Study Question #4

What is the groundwater flow direction in the Intermediate Unit (sand seams)?

Groundwater flow direction in the Intermediate Unit is predominantly to the south and southeast under the majority of the site. There is a radial flow pattern in the northern portion of the site centered around the MW-21 cluster. This results in multiple additional groundwater flow directions in the northern portion, including northwest, north, northeast, and east. This overall groundwater flow pattern was generally consistent between May 2005 (Figure 3-14) and July 2005 (Figure 3-15). The exception to this is the hydraulic influence of dewatering Cell #7 on MW-35I as noted previously in Section 3.6.2.

4.5 Principal Study Question #5

What are the distributions of vertical gradients between the Intermediate and Lower Units, and between the D and D2 zones of the Lower Unit, and how do they vary seasonally?

Vertical hydraulic gradients between the Intermediate and Lower ("I/D") Units are shown on Figures 3-16 and 3-17. I/D vertical gradients were uniformly downward (indicating groundwater flow potential from the Intermediate Unit to the Lower Unit) across the site, and were greatest in an area centered around the MW-21 well cluster. The vertical hydraulic gradient distribution appears to be related to both the sand seam distribution and the groundwater flow pattern observed for the Intermediate Unit, all of which indicates that this area of the site is a recharge zone for the Intermediate Unit, that appears to be hydraulically contiguous with the river and/or the Shallow Unit in this area from which it is receiving recharge. This recharge in turn sustains an increased hydraulic head that influences the relatively strong vertical hydraulic gradients observed in this area of the site. The I/D vertical gradients were consistent during the spring and summer of 2005. Further evaluation of season variation is pending. Results of this evaluation will be presented in a vertical gradient technical memorandum supplement to this report.

Vertical hydraulic gradients between the D and D2 ("D/D2") zones of the Lower Unit are shown on Figures 3-18 and 3-19. The D/D2 vertical gradients were both up and down. Upward vertical gradients were observed at the MW-21, MW-19, and MW-16 well clusters. The upward vertical gradients at the MW-21 and MW-16 well clusters coincide with the

greatest downward I/D vertical gradients. The significance, if any, of this coincidence is not known at this time. That which is more significant is the presence of upward D/D2 vertical gradients at the two well clusters exhibiting the greatest contaminant impact in the Lower Unit. The presence of contaminants in the D zone of the Lower Unit at the MW-19 and MW-21 well clusters may, in part, be due to downward I/D vertical gradients. However, the upward D/D2 vertical gradients inhibit the further downward migration of contaminants to deeper zones of the Lower Unit at these locations. The upward D/D2 vertical gradient at the MW-19 well cluster was consistent during the spring and summer of 2005 (the D/D2 vertical gradient at the MW-21 well cluster could not be determined for the July 2005 monitoring event due to the presence of an MDEQ transducer in the MW-21DR. The D/D2 vertical gradient was consistently downward at the MW-31 well cluster during the spring and summer of 2005. The D/D2 vertical gradient at the MW-17 well cluster changed from downward in the spring to upward in the summer. Further evaluation of season variation is pending. Results of this evaluation will be presented in a vertical gradient technical memorandum supplement to this report.

4.6 Principal Study Question #6

Are Monitored Natural Attenuation processes active in the Lower Unit and is MNA a feasible option for the Lower Unit?

Natural attenuation (NA) can involve a number of interactive processes that may include dilution, adsorption, advection and dispersion, volatilization, geochemical dynamics, and chemical or biological transformation (microbial attenuation).

For chlorinated VOCs, the USEPA Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17 (1999) identifies three lines of evidence that can be used to demonstrate the occurrence of NA:

- Documented loss of primary contaminants at the field scale
- Documented presence and distribution of geochemical and biochemical indicators of NA
- Direct microbiological evidence

Field monitoring of groundwater conditions or laboratory testing is used to evaluate these lines of evidence and to provide data to support an evaluation of the occurrence and significance of NA processes. For this investigation, the first line of evidence is evaluated by examining concentrations of key contaminants at select monitoring wells in the Lower Unit at time intervals. Numbers of detections were used to determine contaminants and monitoring wells on which to focus the evaluation. The second line of evidence is evaluated using field parameter readings for natural attenuation parameters. The last line of evidence, involving microbial analysis, was not investigated. Screening level values were exceeded at two areas within the Lower Unit:

- **Beneath the Drum Storage Area at MW-19D and MW-19D2.** VOC detections at this area include benzene and chlorobenzene at concentrations several orders of magnitude greater in MW-19DR than MW-19D2R. Also, 1,1-dichlorobenzene and cyclohexane were detected in MW-19D at lower concentrations.

- **Beneath the Former Manufacturing Area at MW-21DR and MW-21D2R.** As indicated on Figure 3-11 within the "D" zone, benzene, 1,1-dichloroethane, 1,2-dichloroethane, and 1,2-dichloropropane are all detected at relatively low concentrations. However, screening level values are only exceeded by 1,2-dichloropropane at 18.7 µg/L and 1,2 dichloroethane at 7.9 µg/L (both have an MDEQ residential drinking water standard of 5 µg/L).

Figure 3-11 indicates that there is no well-defined plume in the Lower Unit. "Conventional" or MNA constituent chemistry for the Lower Unit is summarized in Table 3-7. There were no readily apparent correlations between these data and groundwater flow paths in the Lower Unit. The following statements can be made in regard to the overall observations for the MNA constituents:

- Oxidation/Reduction Potential (ORP)—Values were fairly consistent in the Lower Unit wells ranging from -30 to -274 which are indicative of anaerobic conditions (Wiedemeyer, et. al, 1999).
- Dissolved Oxygen—Most Lower Unit concentrations were less than 1 mg/L, suggesting the presence of anaerobic conditions (USEPA, 1998).
- Methane—Concentrations ranged from 7.9 to 1,750 µg/L, indicating that methanogenic conditions exist in portions of the Lower Unit[2]. Methane is produced by the metabolism of a wide range of organic substrates by methanogenic bacteria (USEPA, 1998).
- Ethene—Ethene was detected at estimated concentrations ranging from 1.8 to 2.4 µg/L in MW-19DR and MW-19D2, potentially indicating complete degradation of chlorinated ethenes (USEPA, 1998).
- Nitrate—Some of the nitrate data appear to contradict ORP, dissolved oxygen, and methane data. Nitrate is not usually detected under anaerobic conditions (USEPA, 1998). In the MDEQ Phase II RI data, nitrate ranges from "not detected" to 40 mg/L. The data obtained for this (2005) investigation indicate that nitrate as nitrogen was detected in only three wells at estimated concentrations ranging from 0.0316 to 0.0716 mg/L.
- Sulfate—There are two useful data points for each of MW-19DR and MW-19D2 (November 2002 and May 2005). For MW-19DR, the values were 20.2 and less than 20 mg/L. For MW-19D2, the values were 109 and 133 mg/L. These data indicate that reduction of sulfate in the D zone (possibly by native sulfate-reducing bacteria) is occurring. Since the contaminants have not penetrated to the D2 zone (that is, no additional substrate to stimulate sulfate reduction), sulfate levels remain at their natural levels in the D2 zone. This is also significant to the overall groundwater oxidation potential. Nitrate reduction appears to have depleted nitrate levels all across the site which drives ORP down. ORP will be further driven down in areas where sulfate reduction is active.

[2] The highest methane value was detected in WMW-30D. Subsequently, WMW-30D has been repaired and redeveloped because of leakage into the well casing from surface sources that appeared to include sewage.

Benzene and chlorobenzene concentrations in MW-19D are shown in Table 4-1. The upward trend apparent in the 2005 data is a result of the fact that MW-19D was replaced by MW-19DR between the November 2002 and May 2005 sampling rounds. MW-19DR appears to have been installed in a more contaminated part of the D zone based on boring log indications and groundwater sampling results.

TABLE 4-1
Benzene and Chlorobenzene Concentrations in MW-19D and MW-19DR

Contaminant	RI (8/2002)	RI (11/2002)	SMI (5/2005)
Benzene	520	470	742
Chlorobenzene	360	430	845

All values in μg/L.

MDEQ Phase II RI data and data obtained for this investigation provides some evidence for the natural attenuation of chlorinated VOCs in the Lower Unit. The current mechanisms of natural degradation appear to include anaerobic biodegradation of chlorinated organics through sulfate-reductive processes. However, because MW-19D, MW-21D, and MW-21D2 had to be replaced, a good time series evaluation cannot be made at this time and additional data rounds will be required to ascertain and document loss of primary contaminants at the field scale.

Chlorobenzene and benzene are the main constituents detected at significant concentrations in the Lower Unit. Biodegradation of benzene is known to be most favorable under aerobic conditions. Chlorobenzene, too, will degrade by aerobic pathways similar to benzene. However, given the distribution of anaerobic conditions in the Lower Unit, it appears that natural biodegradation rates may be unfavorably low, and may be too low to achieve desired reductions of key contaminants, such as benzene and chlorobenzene, within desired timeframes through naturally occurring biodegradation processes alone. Abiotic decay rates are expected to be equally unfavorable. Additional contaminant concentration data from future points in time would be required to complete this assessment of decay rates for key contaminants in the Lower Unit and to fully ascertain whether or not a loss of primary contaminants at the field scale is occurring within the Lower Unit, and if the decay rate is sufficient to halt plume migration. These would include the following:

- Quarterly monitoring of select VOCs and MNA parameters including nitrate, sulfate, Iron (II), methane, pH, ORP, conductivity, dissolved oxygen, temperature, and chloride for a 2-year period.
- Reevaluation of MNA performance after 2 years.

4.7 Principal Study Question #7

What is the extent of potential offsite groundwater contamination in the sand seams and Lower Unit in the west, north, and northeast directions?

Groundwater sampling results are discussed for specific locations below.

West

Site organic contaminants were not detected in samples obtained from residential wells located to the west of the site. Well logs could not be obtained as originally planned to determine the completion depths and lithologic unit of completion of the wells sampled. Well logs either did not exist or, for existing well logs, contained insufficient information to correlate the well log to a specific residence. However, the sample data indicate that regardless of completion depth and unit, residential groundwater receptors to the west of the site have not been impacted by site organic contaminants.

North

Sand seams were not present in SBI-09 and SBI-10 (located due north of the Main Plant Site across the river). Thus, the sand seams do not appear to be a viable contaminant migration pathway directly north of the site beyond the northern side of the river.

Groundwater sampling results from MW-27I (located north–northwest of the Main Plant Site across the river) did not show any detections of VOCs, SVOCs, or total DDT/PBB/HBB above reporting limits. Select metals were detected. Barium was detected at 548 µg/L and chromium (total species) was detected at 24.4 µg/L.

Chloromethane and cyanide were detected in samples from MW-27D obtained during the MDEQ Phase II RI (2 and 6.3 µg/L, respectively, both J-qualified). Other groundwater sampling results from MW-27D did not show any detections of SVOCs or total DDT/PBB/ HBB above reporting limits. Select metals were detected. Barium was detected at 71 µg/L.

Northeast

1,1-dichloroethane was detected in samples from MW-16I at 0.59 µg/L (J-qualified). Other groundwater sampling results from MW-16I did not show any detections of SVOCs or total DDT/PBB/ HBB above reporting limits. Select metals were detected. Barium was detected at 1,600 µg/L.

Groundwater sampling results from MW-35I did not show any detections of VOCs, SVOCs, or total DDT/PBB/HBB above reporting limits. Select metals were detected. Barium was detected at 13,700 µg/L (J-qualified).

Six synthetic organic compounds were detected at J-qualified concentrations during the MDEQ Phase II RI at MW-16D (Weston, 2002). These included 4-methyl-2-pentanone (1 µg/L), acetone (6 µg/L), bis(2-ethylhexyl)phthalate (9 µg/L), Endosulfan I (0.004 µg/L), hexabromobenzene (0.019 µg/L), and 2,4'-DDT (0.0036 µg/L).

Acetone and methylcyclohexane were detected at low concentrations of 8.3 and 0.86 (J-qualified) µg/L (respectively) in MW-16D2A. These detections are probably due to sample contamination at the analytical laboratory.

Also of interest is the information obtained during this study on pCBSA distribution. In particular, the differences in pCBSA concentrations in the Intermediate and Lower units at the MW-30 cluster in comparison to the MW-22 cluster. These two clusters are separated by about 1,500 feet (MW-30 being due east of MW-22 which is located on the eastern margin of the site). In the Intermediate Unit, the relatively high concentration of pCBSA in MW-30I (180,000 µg/L) in comparison to the relatively low concentration of pCBSA in MW-22I

(180 µg/L) indicates a concentration gradient from MW-30 to MW-22 (east to west, from offsite to onsite) which disagrees with the direction of groundwater flow in the Intermediate Unit between those two wells which is from west to east. This would imply that either a "slug" of groundwater with very high pCBSA concentrations has completely migrated offsite toward MW-30I via the Intermediate Unit, or that groundwater advection of pCBSA from potential onsite sources near MW-22 easterly toward MW-30 (offsite) is not occurring and there is a potential source of pCBSA in the vicinity of MW-30 that is contributing to the significantly elevated concentrations of pCBSA in the Intermediate Unit at that location.

Conversely, examining the Lower Unit data for these two well clusters reveals a pCBSA concentration gradient in the opposite direction, from MW-22D (onsite, west) to MW-30D (offsite, east) which also disagrees with the direction of groundwater flow in the unit between those two wells which, in contrast to the Intermediate Unit, is from east to west in that area of the Lower Unit. Due to the location of MW-22 in the vicinity of former DDT operations, it is highly probable that MW-22 is located near a pCBSA source. However, this does not explain why the concentration in MW-22D is an order of magnitude higher than MW-22I unless a "slug" of pCBSA contamination has migrated downward to the Lower Unit leaving residual contamination in the Intermediate Unit without significant lateral dispersion in the Intermediate Unit. The lack of apparent lateral dispersion in the Intermediate Unit around MW-22 makes this scenario improbable due to the tendency of till sands to promote lateral dispersion. However, it may be the most probable explanation of the observed data. Alternatively, a conduit (such as a dry well) that conveyed disposal waste directly to the Lower Unit near MW-22 could also explain the vertical distribution of pCBSA. However, there are no known dry wells or other disposal wells in this area of the site. The vertical distribution of pCBSA at the MW-30 cluster could also be explained by a similar scenario of downward vertical migration without significant lateral dispersion. However, in addition to the problem of lateral dispersion described above, this scenario would also require a source of pCBSA at the MW-30 cluster which, based on current site history information, is not known to exist. The vertical concentration gradient within the MW-30 cluster would be compatible with a vertical migration scenario without requiring the movement of a "slug" of contamination, as described above, for the MW-22 cluster.

Summary

These results and results obtained during the MDEQ Phase II RI (Weston, 2002) indicate that despite the presence of NAPL in the river bed and in sand seams beneath the river bed, groundwater contamination in the Intermediate Unit sand seams and the Lower Unit does not extend very far beyond the site boundaries in the west, north, and northeast directions. The results of the risk assessment should determine if the isolated, low level detections of certain analytes (1,1-dichloroethane, chloromethane, cyanide, barium, and chromium) are significant enough to present unacceptable risk to human health and the environment.

The presence of select metals in groundwater samples is not unusual but may require additional evaluation to determine risk contribution and, if necessary, area background concentrations. The detections of barium in MW-16D2A, MW-27I, and MW-35I appear anomalous and may require additional evaluation if they are determined to pose unacceptable risk to human health and the environment.

The Former Burn Area Site is located across the river to the northwest. This site and its relationship to the Velsicol Superfund Site is also the subject of a separate investigation being conducted by the MDEQ. However, samples obtained during the MDEQ Phase II RI from MW-28D which is located between the Velsicol Superfund Site and the Former Burn Area Site (northeast of the Main Plant Site across the river) contained cyanide at 6.2 µg/L (J-qualified) and barium at 86 µg/L. The barium concentration in MW-28D is considerably lower than other offsite monitoring wells that exhibit barium concentrations as high as 2,400 µg/L (MW-16D) (Weston, 2002). Certain onsite Lower Unit monitoring wells also exhibit elevated barium concentrations (MW-17D2, MW-19DR, MW-21D2R and MW-34D). The absence of Intermediate Unit sand seams and of synthetic organic compounds in the Lower Unit at MW-28, and the relatively low barium concentration would argue against contaminant migration via Intermediate or Lower Unit groundwater from either of these sites to the other.

4.8 Principal Study Question #8

To what extent is each city well geologically and hydraulically isolated from potential site contaminants, and how does this relate to the usage of each for municipal water supply?

During antecedent trend monitoring for the MDEQ Phase II RI aquifer test, drawdown was observed in MW-16D. This drawdown correlated with a time when City Well (CW) #7 was pumping. This observation indicates a hydraulic connection between the two wells, and possibly with other wells that were not observed or pumped during the test. CW-6, which is constructed at a similar depth to CW-7, was not observed during the test. CW-4 and CW-5, which were pumped during the test, are completed about 70 feet deeper than CW-7. Pumping at CW-4 and CW-5 showed no hydraulic influence on site monitoring wells (Weston, 2002). Also, VOCs, SVOCs, and total DDT have not been detected in any city wells during either the MDEQ Phase II RI (Weston, 2002) or this investigation.

The city wells can be initially classified into two categories based on depth. "Deep" city wells are screened from approximately 180 to 230 feet bgs. These include CW-1, CW-4, CW-5, and CW-8. "Shallow" city wells are screened from approximately 120 to 140 feet bgs. These include CW-6 and CW-7. Based on well logs, there appears to be at least two (possibly more) aquitard strata occurring between the elevations where contaminants are observed in the Lower Unit on the site and where the deeper city wells are screened. These intervening aquitard strata vary considerably in number, thickness, and elevation from well to well. Even CW-1 and CW-4 which are in the same location show remarkably poor stratigraphic correlation of the units recorded on the well logs. The "deep" wells would be expected to be less vulnerable than the "shallow" wells due to the protection afforded by depth-related dispersion and the retarding influence of the intervening aquitard strata.

To further assess the level of vulnerability of the city wells to offsite migration of contaminants, each city well and site monitoring wells in the Lower and Intermediate Units were analyzed for pCBSA. pCBSA is a byproduct of DDT production. In groundwater, pCBSA behaves as a conservative tracer, meaning that it is highly soluble, poorly retarded by sorption to aquifer matrix, and resists biological or abiotic degradation. These properties make pCBSA highly suitable for assessing the potential pathways of future migration of DDT and related compound (such as chlorobenzene and benzene) groundwater plumes.

An important consideration, though, is that the occurrence of pCBSA at a given location does not necessarily imply that the contaminants of interest (e.g., DDT, chlorobenzene, or benzene) will migrate to that location because of nonconservative behavior that retards advection of those compounds. In the case of DDT, nonconservative behavior is due to its relatively low water solubility; in the case of chlorobenzene and benzene, it is due to matrix sorption, biological or abiotic degradation, dispersion, and other natural attenuation factors. Predictive factors for estimating plume extent or concentrations of DDT or other contaminants of interest based on pCBSA plume extent or concentrations are not currently available. Unlike DDT and several other site contaminants of concern, pCBSA is not known to be highly toxic. Available information on pCBSA characteristics and uses are attached in Technical Memorandums provided in Appendix E.

The pCBSA results indicate that the city wells also can be grouped according to distance from the site. Furthermore, the pCBSA results reveal that distance from the site appears to have a stronger influence on pCBSA concentration (and therefore, potential vulnerability to site contaminants) than does depth. The intervening aquitard layers noted above for the deep city wells appear to be insufficient to preclude the migration over time of pCBSA into the deeper zones screened by some city wells. This could be due to high leakage factors and/or discontinuity among the intervening aquitard strata. Thus, the vulnerability of the city wells to site contaminants can be classified as shown in Table 4-2.

TABLE 4-2
Vulnerability Classification of City Wells

Relative Level of Vulnerability	Distance from Site (Approximate)	Relative Intake Depth	pCBSA Conc. (μg/L)	Wells
Highest	1/4 mile	Deep	81, 180	CW-1[3], CW-4
Higher	1/2 mile	Shallow	32	CW-7
Lower	2/3 mile	Shallow	<1	CW-6
Lowest	7/8 mile	Deep	<1, <1	CW-8[4], CW-5

Based on MDEQ Water Bureau annual pumpage/usage report data from the two most recent years on record (2003 and 2004), CW-5, CW-6, and CW-8 make up the majority of the water supply. In 2004, these wells represented 18, 20, and 37 percent (respectively) of the total water supply (75 percent in aggregate). These percentages were 21, 16, and 20 percent (respectively) for these same three wells in 2003 (57 percent in aggregate). Conversely, CW-1, CW-4, and CW-7 made up 11, 9, and 23 percent of the total water supply in 2003 (43 percent in aggregate), and 8, 2, and 15 percent of the total water supply in 2004 (25 percent in aggregate). These data indicate that the percentage (both individually and in the aggregate) of the total water supply obtained from the wells with the greatest relative risk has been decreasing over the two most recent years on record. While this trend is beneficial from the perspective of avoiding potential site-related contaminant impacts to the wells having the highest relative risk, the continued reliance on an increasing percentage of the total supply from fewer wells may cause undesirable capacity impacts in the future (such as excessive aquifer water level declines or diminished well performance) which should also be

[3] Screening level results obtained in September 2004 indicated a pCBSA concentration of 97 μg/L in CW-1.

[4] Screening level results obtained in September 2004 indicated a pCBSA concentration of 7 μg/L in CW-8.

taken into consideration when evaluating potential response actions relative to the public water supply.

The results obtained from this investigation agree with previous findings relative to non-pCBSA site contaminants (pCBSA having not been analyzed prior to this investigation). However, the pCBSA data indicate that continued monitoring of the city wells and select sentry wells for site contaminants is warranted.

SECTION 5

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Tables

Figures